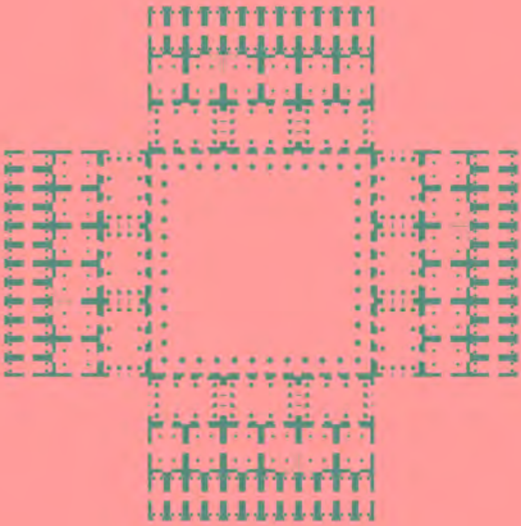
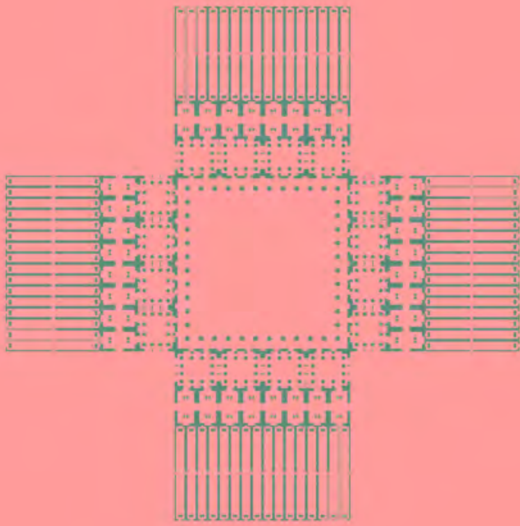
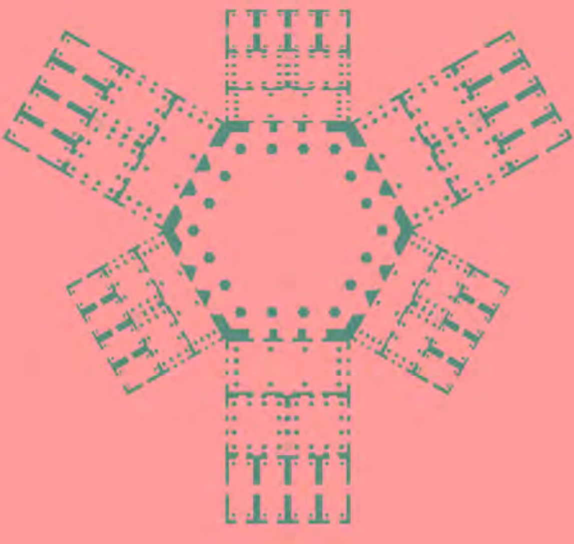


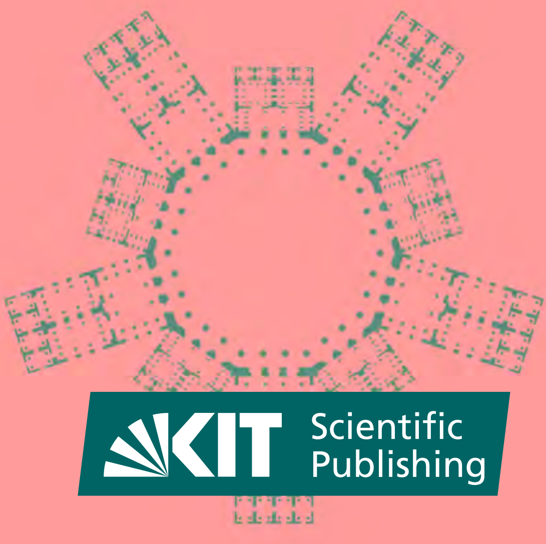


Federico A. Garrido

INNOVATIVE TOOLS & DESIGN STRATEGIES

The Case of Eclectic Architecture in Buenos Aires





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Federico Andrés Garrido

Innovative tools and design strategies

The case of Eclectic Architecture in Buenos Aires

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by
Federico Andrés Garrido

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Innovative tools and design strategies

The case of Eclectic Architecture in Buenos Aires

Vom Fachbereich Architektur/ Raum- und Umweltplanung/ Bauingenieurwesen der Universität Kaiserslautern zur Verleihung des akademischen Grades Doktor-Ingenieur (Dr.-Ing.) genehmigte Dissertation

von

Federico Garrido

- *Preface*

This thesis represents the culmination of years of research and inquiry in the field of architecture that started thanks to a DAAD scholarship. It began by focusing on digital tools and methodologies but it eventually expanded to history and design in general, with the intention to connect Buenos Aires' architecture with Europe using novel tools as an excuse. It is with great pleasure and gratitude that I present this work to the academic community, and I would like to take this opportunity to express my sincere thanks to those who have made this endeavor possible.

First and foremost, I would like to express my heartfelt appreciation to my research director, Apl. Professor Lucas Merx, for his invaluable guidance, support, and expertise throughout the entire process. His vision, dedication, and firm commitment to excellence have been an inspiration to me and have greatly contributed to the success of this project. Proof of this is our continuous collaboration within the research project Rokokorelevanz.

I would also like to extend my sincere gratitude to Professor Joaquin Medina Warmburg, who has graciously collaborated with me throughout the research process and provided insightful comments and feedback that have significantly enhanced the quality of this work. Besides their encouragement and support even before the application stages of my PhD. scholarship, Luc and Joaquin provided me with a fresh and fascinating view of Buenos Aires' architecture that I had completely missed. I've had greatly appreciated their contribution, as well as our collaborative work afterwards.

Finally, I would like to thank my family, Eduardo, Felisa, Agustin, Mariano, Dana, and many friends from Argentina and Germany for their unwavering support and encouragement throughout this journey. Their love and motivation have sustained me through the challenges and difficulties of doctoral study, and I am forever grateful for their presence in my life.

Index

CHAPTER 1

- *Introduction*

Since the advent of digital tools many aspects of our practice had been radically altered; from the representation of the architectural features by drawings, renderings and animations, to the fabrication of building parts and whole structures via 3d printing and robotic manufacturing, along with the documentation of buildings by means of digital photography, 3d scanning and drone footage. It should be fair to state that almost every phase of the design procedure and architectural practice is to some degree, influenced or carried on by a digital tool.

A brief survey of current software packages might be enough to ascertain the amount and variety of digital tools available to each stage of a design process; either for sketching, volume outlining, detailing, rendering, project managing, image editing, utility design, and so on. What is interesting to analyze, is the real influence of these (not so new) breed of tools in our design practice, how do they influence our internalized processes, how do we perceive and analyze architecture and of course, the designs and objects they help to produce.

We will group these procedures, intentions, conditions, circumstances and contingencies under the term 'design strategies. Although the term 'design strategy' has been used on many disciplines such as chemistry, biotechnology and marketing, we will use it to cluster specific design conditions, indicators and variables that will drive and regulate an architectural design process.

At this point we could also define as 'digital design strategies' as the new set of procedures triggered and supported by the intensive and extensive use of digital tools, whether they are for analysis, design, manipulation or manufacturing.

The main purpose of this research to propose a new way to produce architecture supported by digital instruments. It is also manifold; on one hand is to suggest a new outlook on the use of digital tools in architecture, and on the other, to gain knowledge of historical tools, strategies and conditions, now under the light of a contemporary view. This work intends not only to nourish current digital practices by including historical information but also to provide a new outlook on historical references, by establishing analogies in the realm of tectonics, technologies and aesthetics among other aspects.

Another aim of this study is finally to discover new architectural qualities; a new way of looking and producing while commenting on historical and contemporary architecture by analyzing common design conditions, building technologies and design techniques. This research proposes the analysis of historical case studies under a 'digital' point of view and intends to shed light on architectural qualities previously overlooked or even forgotten.

Personal motivations, background.

During my training as an architect in Buenos Aires, I became immediately fascinated by computer tools, at that time mainly used for drafting and rendering, as they were just becoming popular first among students and then in architectural offices. Following relevant practitioners such as Greg Lynn and Hernan Diaz Alonso, at that point we were far more interested in software that was initially developed for sculpting, animation, special effects or photo edition that to architecture-specific tools. I still maintain such biased interest towards non-disciplinary design tools as it holds an important role on this research. The use of non-architectural software such as Mudbox or Maya for sculpting and animating are still a channel for creativity and drive innovation in design processes.

As a student I came in contact with prominent professors and researchers at the FADU UBA[1], from whom I gained knowledge of disciplinary and research topics, many of them still driving my own interests. On this regard, I should mention two main branches of my architectural instruction, as I participated in teaching activities in two advanced courses at the FADU; one directed towards design research and creativity processes[2] and the other, oriented towards a broad and critical understanding of architecture, both influencing and being influenced by culture and history[3]. I collaborated on both chairs as a student assistant and then as an associate researcher, both in undergraduate courses as well as in a postgraduate one[4].

Around the year 2011 I co-founded the UAP research group (Unidad de Arquitectura Paramétrica) under the Centro Poiesis[5], the first of its kind at the University of Buenos Aires, concerned by the intersection of design research, design strategies and digital tools. By organizing postgraduate courses, workshops, conferences and exhibitions, the UAP´s production explored the relationship between the advancement of digital design and manufacturing tools such as parametric tools, generative design, rapid prototyping and 3d printing applied to specific architectural problems such as massive housing projects, planning and experimental building techniques.

Academic motivations.

The motivations to undertake this research are rooted on my academic background in Buenos Aires as well as a brief experience in academic exchanges between the University of Buenos Aires and the Technical University

1 Facultad de Arquitectura, Diseño y Urbanismo, Universidad de Buenos Aires.

2 ‘Investigación proyectual’ (Project Research), undergraduate and graduate chair, Prof. Dr. Arq. Jorge Sarquis.

3 ‘Análisis Critico de la Arquitectura Moderna y Postmoderna’ (Critical Analysis of Modern and Postmodern Architecture) chair Prof. Arq. Jorge S Mele.

4 ´CEIP - Carrera de Especialización en Investigación Proyectual´ (Postgraduate Specialization Course in Project Research) directed by Dr. Arq. Jorge Sarquis at the FADU UBA.

5 ‘Unidad de arquitectura paramétrica - Centro Poiesis FADU UBA’, along Mg Dr Federico Eliaschev and other junior researchers.

of Kaiserslautern.

After my graduation I collaborated as a researcher at the Poiesis Centre for Creativity in Architecture under the direction of Dr. Arch. Jorge Sarquis, where I investigated on the possibilities of digital tools in relationship to design research particularly in relation to housing, parallel to my teaching activities both in graduate and postgraduate courses. I was also awarded with a Research Scholarship grant for a postgraduate Master´s during which I also explored digital design methodologies applied to the problem of urban housing[6].

I came in contact with my current research director, Professor Lucas Merx thanks to a DAAD supported workshop on which I collaborated with the Gropius chair, in charge of Professor Joaquin Medina Warmburg, who later became my co-director. Prof. Medina organized a student exchange that lasted an entire year between the FADU and the Technical University of Kaiserslautern on which I also participated as coordinator, culminating in the organization of a workshop in Germany. During that time, I kept in contact with Prof. Merx and developed a research plan thanks to which I was awarded with a doctoral scholarship by the Deutscher Akademischer Austauschdienst (DAAD). The proposed research aligned both Prof. Merx and my interests regarding the study of the influence of tools and historical references in digital design processes.

The intention on assuming a research task in Germany was two-fold and bi-directional, related to one of the main topics of interest that is, the relationship (in terms of architectural exchanges) between Europe and Argentina. The possibility of undertaking a PhD research in Germany under the direction of Prof. Merx allowed me not only to benefit academically and personally while gaining invaluable insight thanks to the close collaboration with his research group Rokokorelevanz, but also to take advantage of the large academic and technical means available in Europe.

The purpose was on one hand, to gain firsthand knowledge of European architecture (to which we as Argentines are closely connected), and also to experience the European academic environment and resources. On the other hand, I have also considered interesting the possibility of divulgation some interesting and uncommon aspects of Argentinean architecture to a European public, by studying exceptional and remarkable buildings which are often ignored even in our country but nonetheless bear unique architectural value.

An important appeal of the research is also the fact that the case studies selected from Argentina can be defined as non- canonical, or at least, they are considered to be not so relevant in the academic and research areas. Instead of focusing on historically established projects, this research will look into less known examples that do not belong to the ´mainstream´ narrative of 19th Argentinean architecture, but nevertheless, transmit the period´s characteristics, topics of interest, contradictions and also, its uniqueness.

The quest for and assessment of this uniqueness, in terms of architectural quality, is one of the main goals of this research, now with the opportunity of

6 'Proyectos de vivienda para la emergencia social y ambiental generadas con metodologías digitales' (Housing projects for social and environmental emergency created using digital methodologies). 3 year scholarship UBA Grant directed by Prof. Em. Juan M Borthagaray.

identification and improvement via computational tools.

The relationship between Europe and Argentina, with its characteristics, nuances and overall impact are a recurring topic throughout the research. Europe´s political, financial and cultural influence over Argentina was particularly decisive since its independency. The local architectural production was certainly linked to the old continent not only in terms of stylistic influence but also in the field of education, finances and even logistics, as much of the construction between 1880 and 1930 can testify.

Material goods and human resources were exchanged continuously throughout the period, leaving an indelible mark on our cities. We should also state that most of this flow went in one direction: Architects, engineers, builders, artists and handworkers from Europe found in Argentina a vast and receptive market for their skills, not only eager to collect established, disciplinary knowledge but also open to experimentations and investigations, now possible thanks to the booming economy of a novel country.

This research intends to bring to light some exceptional examples of this period, unquestionably products of their time, but simultaneously hybrid, strange and eccentric. They are not usually studied at the history courses in architecture not because their lack of architectural quality but precisely because their quality cannot be precisely defined by the traditional canon that usually defines the period. It is not the purpose of this research to review this established canon for 19th century architecture in Argentina, however, as it was also inherited from and tied to Europe, so were the categories to analyze its production, sometimes indifferent to its unique qualities and characteristics.

This design research intends, through analysis, redesign and experimentation, to review and to value unique examples the period´s architecture in Argentina, its purpose is not to discover anything new but to propose an original insight on buildings that most of the general public, including many architects, overlook.

THESIS

Structure. Introduction.

The purpose of this research is to propose a novel method for producing architecture, based on complexity, hybridity, detail and quality, while exploring contemporary design strategies supported by digital design and fabrication tools. These tools are not meant to be exploited as autonomous devices but informed by architecture's own tools, on this particular case, this research is interested in historical design strategies and construction techniques. This research intends to learn from architectural history by providing a new perspective on historical references, on this instance, 19th century architecture form Europe and Argentina, from a digital standpoint.

The question is why to include digital tools in such a complex task? Digital media are ubiquitous, they have permeated every aspect of our lives and the architecture discipline is no exception to it. Parallel to the first experiments on digital tools, architecture theorists and practitioners[7] have explored their possibilities with great interest and with astonishing results. Ever since their popularization in the mid 90's, due to the massification of personal computing, their role in architecture practice has grown exponentially and casted a great influence on many aspects of our discipline. Since then, areas like architectural education, building techniques, aesthetics, construction technologies, logistics and many more have been permanently and most important, irreversibly influenced.

There is no need to list all the advantages and benefits that the incipient digitalization brought to our practice; they provide many possibilities and features, available much faster and cheaper than ever before. Innovative aesthetical, material and spatial qualities are now possible thanks to the extensive use of digital design and fabrication tools crystallized in the seamless combination of design, manufacturing and logistics. Yet many interesting and relevant architectural features are at times difficult to grasp by digital tools, whether in terms of documentation, manipulation or materialization. Using digital tools as an aid to a design research does not means to be ´digital´ or anything particular, it just means to be contemporary.

This research is interested in remarkable architectural features present in 19th century buildings; some of them absent on many projects, some are simplified or diminished. The topics this study wants to revise are distinct but can be loosely defined as complexity, hybridity, detail and quality. These topics are multi-focused and cut across many other subjects as they unfold in the research structure, ranging from spatial qualities to building materials and logistics. They also slice through history, as they are present and had been explored on many historical references, from which we intend to learn.

Structure. Description.

This research proposes to identify a series of topics of interest in historical case studies from 19th century architecture, analyze them with contemporary design tools and then to produce a series of design experiments by recreating, altering and re-deploying them with the aid of digital instruments.

With the introduction of complex computational design tools (such as Generative and Parametric tools, Building Information Modeling, Organic modeling) and rapid prototyping techniques (3d printing, robotic manufacturing, CNC milling) many of these attributes and topics can be explored under a different light. It is also important to remark, that this research will focus on the impact of procedures and tools on these designs. The abstract nature of contemporary design procedures as well as the apparent capacities and limitations of design software may influence on how architectural qualities are assessed and finally produced. We produce quality through digital tools, hence our interest in the relationship between tools and their production, often

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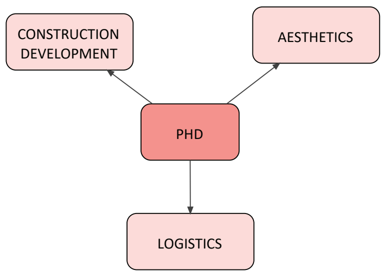
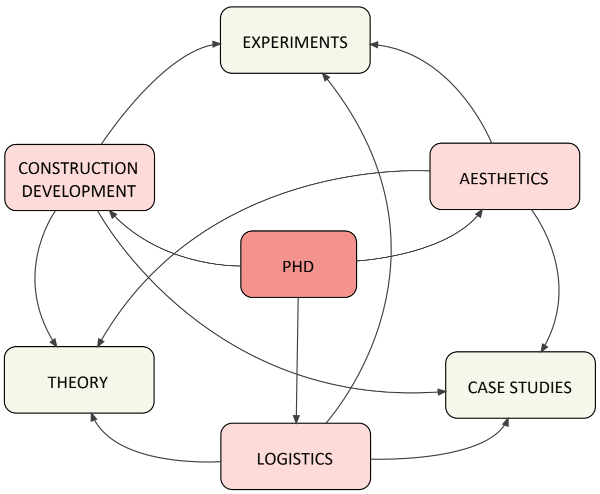
7 Some pioneers in the field of digital tools in architecture include Nicholas Negroponte, Cedric Price and Yona Friedman the 60s and 70s. Later on, during the mid-90s John Frazer, Greg Lynn, Frank Gehry and Lars Spuybroek were part of a second wave of mainstream digital practitioners in architecture, among many, many others.





1-1 Diagram. Research main categories.
1-2 Diagram. Interrelation between categories and subcategories.

neglected.

Nonetheless many researchers and digitally based architects have bypassed this tendency and are currently producing much of the most interesting and relevant projects regarding contemporary digital design. This research intends not only to register such practices but also to recognize similar procedures and features on historical projects, both from Europe and from Argentina that may be useful to illustrate the relevance of these concepts.

The research intends to focus on the tools and strategies, not on the historical processes that influenced them. For this reason, many aspects that are required in a historical research will be overlooked in favor of topics associated to the design strategies and manufacturing techniques that enabled the design and construction such particular projects.

The reason to select 19th century projects is manifold. The first cause is the particular relationship between Argentina and Europe on that period. The relationship was thriving on many aspects, especially in commerce but also on a cultural basis. This relation eventually shaped not only our institutions and our economy but also our buildings, our cities and even large portions of our country. As an Argentinean studying in Europe, it seemed important to me to revise of this relationship and explore its architectural results.

In addition, the proliferation of new technologies such as cast iron, wrought iron, prefabricated terracotta and ceramics as well as a renewed technical stance on the discipline is also interesting as it might find an analogous condition to contemporary practices, now under the influence of the aforementioned computational tools.

19th century architecture in Europe can be interpreted as a seemingly tumultuous and chaotic period when many theories, styles and techniques collided, energetically producing for a world that needed all sorts of buildings, infrastructures, administration and many other construction types and programs that will be addressed on the following chapters. Several debates were held discussing not only which style was more suitable[8] at the time but also the role of the discipline on the verge of several technical and theoretical advances.

This particular situation produced an amazing number of creative and innovative projects, exploring new technologies, typologies, styles and programs. The result of these conditions was an unprecedented degree of freedom and variety, which did not come undisputed, on the contrary, it was fostered. An example of the production under this new set of conditions can be observed in the international exhibitions and the pavilion designs from them. Dozens of countries and companies grouped together to exhibit their cultural and industrial production displayed under remarkable, pioneering and many times, record-breaking structures designed to amaze their visitors.

A goal of this research is to transmit an honest fascination for the architecture of this period, as well as to approach the many questions and

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8 Heinrich Hübsch and Wolfgang Herrmann, In what style should we build? The German debate on architectural style., Texts & documents (Santa Monica, Calif.: Getty Center for the History of Art and the Humanities, 1992), Heinrich Hübsch [et al.]; introduction and translation by Wolfgang Herrmann

uncertainties of this period that are still present on our discipline.

Structure. Categories.

The research is structured in three main categories, each with different procedures and products. Each of them will deal with the topics of interest in a distinct manner as they will read, manipulate and evaluate them according to a different set of criteria. They are all however intertwined and the research will try to illustrate the set of relationships that cross-connect them as every category is present in the other ones similar to a fractal-type structure.

The research is divided into three main categories: Theory, Case Studies and Experiments. They will group several topics and tasks of the study as they organize the relationships between different sorts of information, whether their origin comes from bibliographic resources, photographs, architectural information, drawings or material experiments. Each of these categories corresponds to the three parts of this publication.

The 'Theory' category will group textual information, bibliographical sources and written media regarding the description, analysis and critique of theoretical subjects and topics of interest from the 19th century period. Many of these topics are extensively well covered in bibliographical sources from the period as well as historical studies, and they will be addressed here briefly. As an example, the question of style and the eclectic character are part of the conventional narrative of the 19th century whereas other topics such as the role of engineering, the aesthetical influence of natural sciences or the proliferation of industrial and commercial patents are not often described in detail[9] in architecture books. The research interest will be set on both conventional as well as atypical topics.

It is also essential to state that this is not a historical investigation but a design research; even though that some tools and topics are common to both, their interests, methods and results are significantly different. On these terms, it must be brought to attention that this work will focus on subjects that architectural historians may found not so relevant. Such is the case of Argentinean architecture; some of the issues and case studies that will be described on this work are often overlooked, and their significance occasionally disregarded.

The origin of these topics will also be of a diverse nature; some are present in many bibliographical sources and are an indisputable part of architectural education, while others will arise from a close analysis of the case study references or the formal experiments, the other two main categories.

The 'Case studies' category will collect architectural projects in the form of technical drawings, building details, artist renderings, photographs and models. An important part of these projects will be re-drawn for reasons of analysis,

9 The work of Siegfried Giedion on ´Mechanization takes command´ is essential on some of these topics as well as exemplary on the sort of difficulties that the period´s study may involve. As an example, Giedion names the lack of primary source materials such as commercial catalogs due to the fact that they were deemed unimportant by both industry as well as historical research.

which will be discussed later on. The purpose of this collection is to illustrate the topics described in the 'Theory' chapter but at the same time to induce and present new topics as well. This bi-fold quality, simultaneously illustrative and generative, is one of a great importance for the research since the analysis of case studies produces information of an unquestionably architectural nature.

These historical references were collected from 19th century architecture projects, and the selection responds to diverse criteria, such as their construction technologies or the design strategies employed in them, assuring variety on the collection. There are some case studies that graphically illustrate some of the period's topics of interest, they act as an archetypical explanation of them, where as in some buildings these topics are blurred or hybridized. At the same time, some case studies are harder to analyze and difficult to categorize, but nonetheless possess undeniable architectural quality; these cases are the ones that provide relevant feedback to the Theory chapter and generate new topics of interest.

Another guideline responds to the origin of the project. Originally this research was focused on buildings and projects from Argentina but the selection eventually was broadened to its final state, including European buildings. The close relationship between Europe and Argentina during the 19th century was also visibly depicted in the architectural production.

The details of the selection criteria of the case studies will be explained in the following chapters but the general guiding principles are related to an alternate idea of architectural quality. The research intends to find these values in historical projects, find out how to read them and how and what to learn in order to enhance our current practice from them.

Finally, the last category 'Experiments' aims to group formal, material and compositional experimentations throughout speculative procedures induced by different topics and subjects extracted from the other two categories. A number of digital and analog techniques will be used on this section, both for design, representation and fabrication at the same time by testing a number of innovative tools as well as traditional ones.

These design exercises are rooted on the experimental nature of the research, and are considered a source of architectural knowledge. The experiments are organized in order to illustrate and explore several topics of interest; aesthetical and formal speculations, material explorations and compositional permutations are some of the proposed studies. As explained on the other categories, the 'Experiment´ chapter will feed the 'Theory' and 'Historical References' alternatively, as the results it produces may trigger more topics to be investigated and references to be studied.

Structure. Main topics.

Another structure that spans across the investigation is related to the specific topics of interest. As stated previously, these topics will describe general subjects that the research considers relevant not only on 19th century architecture but in contemporary practices as well. They reflect both Rokokorelevanz and my own interests in architecture, as well as their strengths and challenges. These subjects ultimately operate as guidelines in order to read, analyze and propose new questions for the discipline.

The main topics are 'Construction/ Development', 'Aesthetics' and 'Conditions/ Logistics'. All three include in turn a series of sub topics that will be deployed throughout the three research categories (Theory, Historical References and Experiments). This means the ´Aesthetics´ chapters will also include a 'Theory', covering topics regarding visuality and expression, 'Historical References' will be comprised of case studies in which the visual component is of interest and ´Experiments´ will include design experimentations exploring expressive effects, and so on.

In turn, many subjects are shared between each of the main topics and they are deeply interrelated to each other as their limits become blurred and difficult to clear-cut and separate in order to fit on each category. This is not necessarily undesirable since it is a symptomatic expression of the complex and hybrid characteristics this research is trying to descript.

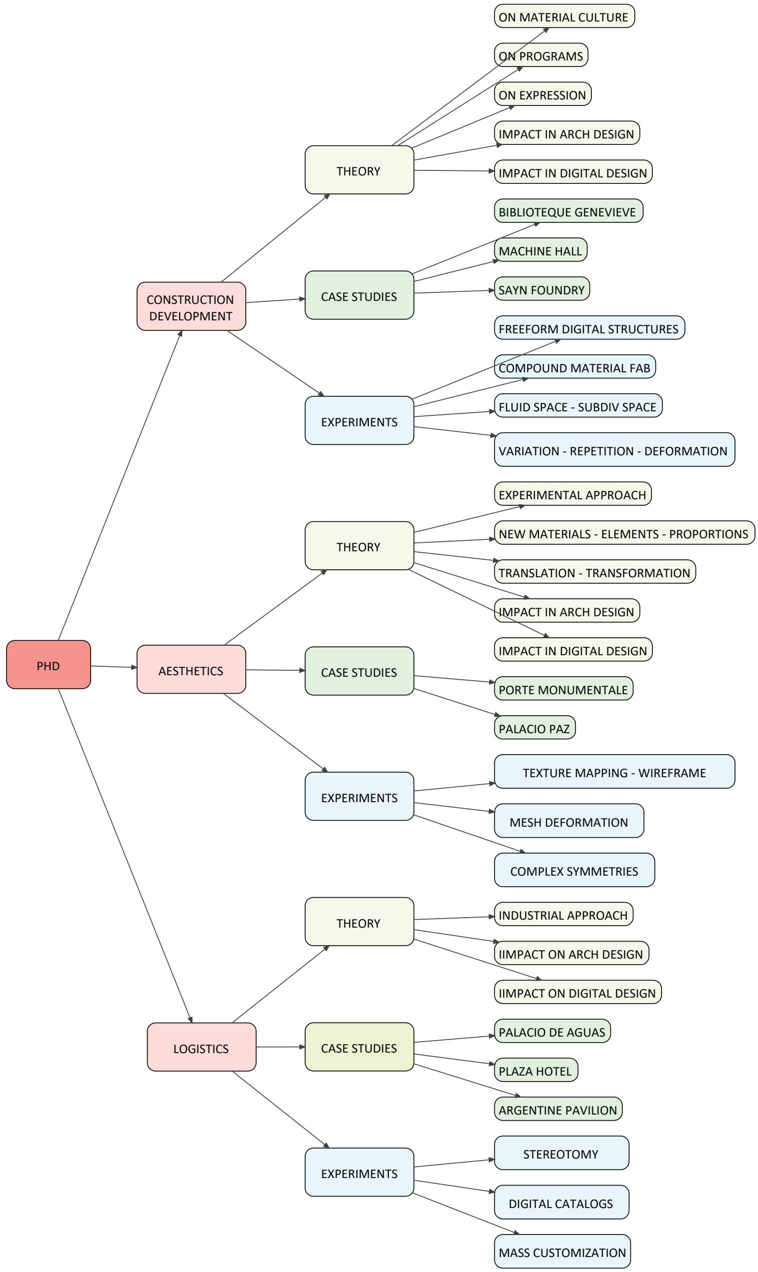
The first topic, 'Construction / Development' covers subjects primarily related to technical advancements in the building activity, the development of new materials, new fabrication techniques and how did they influence designs and design strategies during the 19th century. It will also address the architectural implications of these advancements, as they forged new typologies, proposed new uses and fostered new programs.

Building developments were significant and had a decisive role on 19th century architecture, arguably more than in any previous period in architectural history. The period itself was overwhelmed with all sorts of inventions and an encompassing sense of progress. Although the discipline's attitude towards technical innovations was indecisive, their impact on the production is one of great importance for this research.

The second main topic is 'Aesthetics' and it intends to discuss the subjects relating the expression and visual culture that 19th century architecture projected towards its interior as well as outside to the cultural landscape. The technical advancements of the period clashed with the inherited classical conception of the predominant architecture, yet the apparent conflict spawned a great variety of responses both in favor and against, fostering passionate debates about the role of style in the discipline. This debate was not only academic but took place on the actual cities, projects and buildings, also including administrators, the press and the general public, where each designer laid out their position on every intervention.

The apparent distance between the visual expression and its material composition is an interesting aspect of the period's architecture production, and from a contemporary point of view, it is still a subject of debate. This analogy between 19th century and present architecture cuts through the whole research as it considers that the reaction and overall attitude of the discipline in the verge of breakthrough technical innovations are in some terms equivalent or comparable.

The last topic is 'Conditions / Logistics', covering issues such as the transformation of the building activity into an industry and the organizational changes that it carried out thanks to this process. These transformations were



1-3 Diagram. Branching structure, categories, subcategories and topics.

in some cases imperceptible from an aesthetic or material point of view, and sometimes spawned a whole new set of possibilities for architects and clients as well. The transition towards prefabrication or the transformation of the building site by including machines, and many other innovations were reflected on the projects and fascinated architects and the general public at the same time.

The rapid expansion of commerce and an incipient process of globalization made possible the swift dissemination of architectural ideas, technologies and sometimes, whole buildings, as is the case of many projects selected as case studies. The prospect of designing a project, manufacturing its components and assembling a building in three or more different countries was at that time a certain possibility. Once again, the consequences and traces of these conditions are inspiring for this research as a powerful argument on similar contemporary opportunities.

OBJECTIVES.

In view of the growing and widespread use of digital technologies for the design, representation and production of architecture, it is deemed necessary to frame these new (and not so new) set of tools into a broader disciplinary field. The particular objective of this research is to structure some of these practices by utilizing design research methodologies, that is, by producing design experiments and exercises, and in particular, ones that are shared with the Rokokorelevanz research interests.

On this matter, the objectives of this research are completely aligned with Rokokorelevanz´s mission: to produce novel and mindful designs by carefully analyzing the relationships between tools (for design, for fabrication, for analysis) and its results, and predominantly, by tapping into the discipline´s own history and resources to achieve it.

The purpose is also to visualize and deploy these set of tools and methods in a coherent manner, from which these set of relationships establish an articulate dialogue between historical tools and digital ones that is not based on mimic or revival but on logical, formal and material processes.

The instrumentality of these experiments is by no means universal and easily transferable, as it relies on the specificities of the subjects and interests surrounding the research, yet the idea is to provide a feasible roadmap on how to include these types of information and variables into a design process.

RESEARCH METHODOLOGY.

Epistemology.

The methodology applied on this research was developed by Alberto Sarquis on his doctoral thesis[10], it has been continuously refined for several years, through graduate and postgraduate courses, research works and publications, and his post-doctoral studies are also devoted to this subject. I came into contact with Dr. Sarquis on the last year of my studies in 2005, first by attending to his course 'Project Research', then by participating as an intern at his research project and also by collaborating in several teaching positions in investigations, graduate and postgraduate courses approximately for 7 years under his direction.

As Sarquis' epistemology is under continuous development at the time of this thesis, I 've decided for this research to use one of the latest versions, ca. 2014, which was used as a base for the Master's Thesis seminar at the 'Project Research Master's Program'[11] on which I collaborated as a research associate on two studio courses.

I chose Sarquis' epistemology mainly for two reasons; firstly, I'm fairly familiar with it, by learning it as a student and using it as a researcher, and secondly, because it interestingly combines a descriptive and an operative character. This means, through a system of categories, variables and indicators it intends to explain diverse architectural theories, practices and styles internally within its own flexible model while at the same time it is operative, as it devises a roadmap for an architectural research with a distinctive goal: to produce architectural knowledge.

Sarquis' epistemological model has been expanding since its conception and its complexity is well beyond the scope of this research. In order to explain this research's methodology, we will describe only the basics of its structure and will develop further its topics as they emerge in the progression of the investigation.

The goal of this model is to produce a 'Project Research' and eventually, create the possibility of architectural knowledge. There are significant differences between a Project Research and an architectural project; the main one being the possibility of identifying and producing architectural knowledge by the first one. On this particular topic, at the time of this writing, there is a very fruitful debate at the FADU UBA[12], and as such, completely exceeds the purposes of this thesis. This research will use Sarquis' epistemology as an operative framework, not only to as a method to organize and arrange information but to orient it as well towards a design research.

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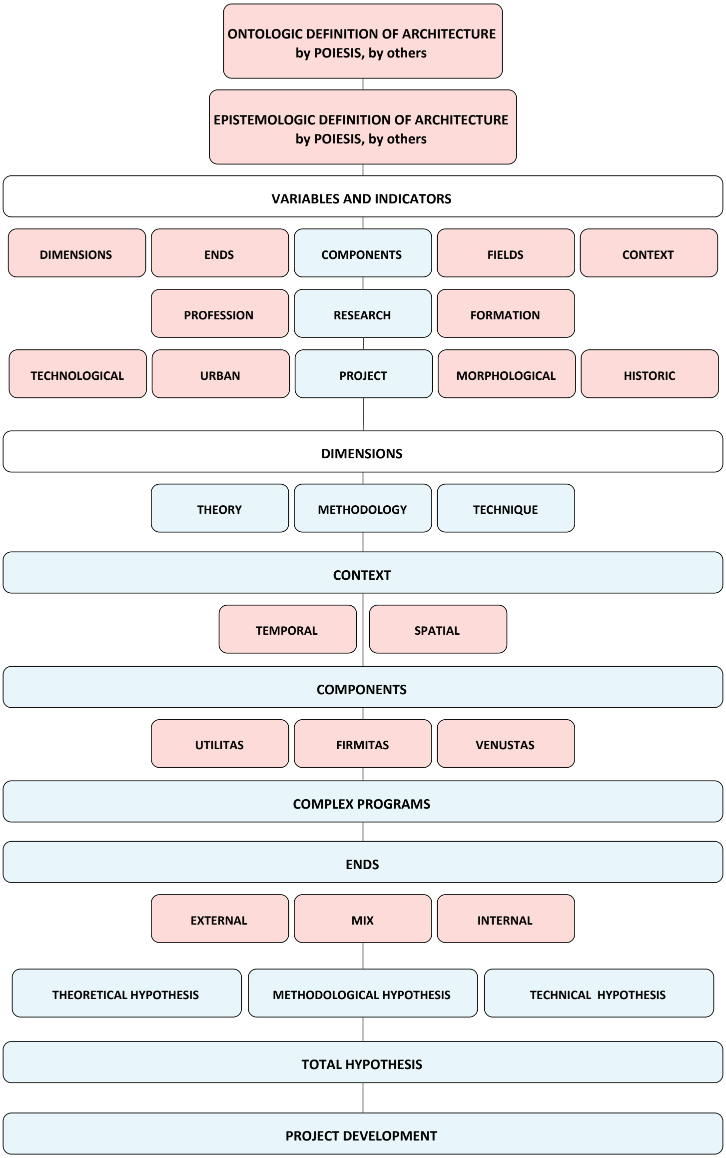
10 Jorge Sarquis, Itinerarios del proyecto: La investigación proyectual como forma de conocimiento en arquitectura (Buenos Aires, Argentina, México D.F.: Nobuko; Juan O'Gorman Librerías, 2003-2004)

11 Maestría en Investigación Proyectual – Dir. Dr Arq J Sarquis

12 The PhD program at the FADU UBA and its board of supervisors Profs. Sarquis, Doberti and others.



1-4 Diagram. ´Project Research´ structure from Sarquis ´Itinerarios de Proyecto´. Research path and relationship between Variables and Indicators.

Analyzing Sarquis´ epistemology, we could start defining its basic organization. The epistemological model is based on a branching structure consisting of Variables and their Indicators, describing disciplinary aspects ranging from theoretical assumptions to a detailed definition of Context, information about the program and the user, among many others. The first and main category or 'Variable' is called 'Dimensions' (Dimensiones) and depicts the diverse levels of knowledge of Architecture, or in other words, a possible definition of Architecture. Sarquis says:

'..from its Greek origins, through all the controversy over its validity and legitimacy. But it slides and mixes itself with the Theory of Architecture, which in our epistemic position is intertwined with the Methodology and Technique of Architecture and leads to some confusion; especially when describe the Methodology of Architecture, which is the Architecture Configuration Procedure (PCA) and will be the developed as the second indicator of the design Path, either Composition or project.'[13]

The 'Dimensions' variable is described as the first and more important one (a ´Mater´ Variable, according to Sarquis) as it postulates the main concepts and definitions about architecture. The Indicators (Indicadores) branching from this Variable are three: ´Theory´ (Teoría), ´Methodology´ (Methodología) and ´Technique´ (Técnica). ´Theory´ will describe the conception of architecture under which we operate, ´Methodology´ depicts on how this conception is applied in an architectural process and finally, ´Technique´ explains the specific tools and devices used in the design process.

In turn, each of these Indicators has their own Indicators, in a fractal-type structure: ´Theory´ has a ´Theory´, ´Methodology´ and ´Technique´, ´Methodology´ also has all three of them and ´Technique´ has them as well. This is rather important as the complex structure becomes useful in order to describe more detailed aspects of the research, for example when we talk about 'Digital tools. We can use the indicator ´Technique´ to approach them, but when we discuss specific Parametric tools, we argue in terms of ´Technique´ of the ´Technique´, or when we describe Generative concepts on digital tools we consider ´Theory´ of the ´Technique´.

We will use the first Variable, 'Dimensions' in order to describe the research methodology and how it will engage the main topics of interest, research tools and experiments.

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13 Sarquis, Jorge – Seminario de actualización de proyecto –july 2015. Translation by the author.

THEORY. METHODOLOGY. TECHNIQUE.

Theory.

Simply put, ´Theory´ must explain which definition of Architecture we subscribe to, namely, in which type of Architecture we are interest in, or which type of projects do we want to produce. The research is interested in a certain type of quality in Architecture, and it considers that much of that characteristic is lost in contemporary practices, thus, the problem of quality will be certainly present on this Variable.

The Indicator 'Theory' describes the role of architectural theory in our temporal and spatial Context. Although Sarquis warns about the impossibility of detaching it from Methodology and Technique, it is necessary to isolate this Indicator momentarily it in order to continue analyzing the other Variables:

'It is not possible to think about the Purposes (Fines) of Architecture without setting beforehand the basic questions of what is the –non-disciplinary- architectural thinking today interested in them, and how to warn the material that gives concrete expression to the Project´s anticipatory technique? . Sarquis explains why it may be necessary to isolate the Theory:

'What we can do, is to 'save it in the act', i.e., at the time of use it to talk about the remaining Variables, where it is not possible to speak, for example, about the Context and its features without thinking about how will we work (Methodology) and how we shall specify it (Technique). It is not possible to think about the Purposes (Fines) without putting the basic questions of what –non-disciplinary- architectural thinking today is still interested in them, and how to notice them on the concrete material expression that anticipatory technique of the Project provides?´[14]

What we call 'quality' can be loosely described as a certain expertise in the use of form, material, space and programs. 'Detail' is the precise perception of such quality, how this quality is manifested, how it is dependent on scale, shape and material. This characterization will be part of the definition of ´Theory´ under which we are intending to operate.

The core of this research is to claim quality and detail as a disciplinary domain: in order to gain complexity and value, Architecture and architectural design strategies must include the appreciation and production of quality and detail. The research intends to use historical references as base material in order to find potentially innovative and original responses to this claim recognizing 19th century architecture as a fundamental period in regard of these topics.

The majority of 19th century architecture resulted from the combination of seemingly outdated classical design strategies (through a mixture of both traditional and new educational institutions) and at the same time, the embracement of new technologies, materials, organizational models, calculus and scientific and historical knowledge in general.

14 Sarquis, Itinerarios del proyecto

The resulting architecture was an unorganized corpus of buildings and theories so complex and diverse yet very dissimilar and hard to classify and categorize. New ideas emerged, the question of architectural styles erupted as many or all of them coexisted simultaneously (ancient, historical, regional, fantastic styles) while at the same time many theorists debated which one was the better, or the most suitable for each use, location or client.

Hybridity is another topic that this research is genuinely interested in. The combination of multiple materials, programs and stylistic characteristics in one building is a defining characteristic of 19th century architecture. Similarly, this work intends to analyze and exploit the hybrid character of the nineteenth century as a possible guide to contemporary practices. Many topics of interest described on the following chapters regarding construction developments, novel material expression and complex logistics contribute to this general idea of a defining architectural hybridity.

METHODOLOGY

According to the Project Research's epistemology, the ´Methodology´ indicator specifies which formal procedure is going to be used in order to carry the research on. Sarquis' describes two main procedures previously defined by Massimo Cacciari[15], accounting for two possible paths ('Caminos de proyecto') on designing in Architecture: a 'Path-to' and a 'Path-from'.

Broadly speaking, the 'Path-to' relies heavily on pre-figuration; the design procedure has a goal, an image to recreate. The objective is rather clear, but the path is not precisely defined. Its opposite concept, the 'Path-from' is built upon process and technique; it must be clearly defined and strictly followed. The result of this procedure is unexpected and it is revealed as a discovery at the end.

This research uses both methodologies on different stages, since the importance of starting points, procedures and objectives varies on each phase and particular experiment. For example, on a first analysis stage a 'Path-to' procedure was carried on, whereas in the experiment phase for the same project the 'Path-from' method was considered more suitable.

The analysis stage (the case studies chapters) consists on selecting and isolating historical references and case study projects from 19th century (both from Europe and Argentina) that fit a certain criteria regarding topics of interest (developed on the 'Theory' chapters). Depending on the building type, topics, scale, material, the whole building or a part can be selected for analysis. Then, a formal analysis must be performed in order to extract geometric information, organizing principles and proportions and also to speculate on the design procedures and formal strategies that made them possible.

At this point the building (or a part of it) must be translated into another digital entity using a specific technique or tool (as described on the ´Techniques´ sub-chapter). This tool needs to be able to 'read' and 'write' the case study, that means, it should provide a method to understand the project or parts or it and at the same time, to produce more of it, the ultimate goal of this work.

´Reading´ a project means for a tool to be able to translate a project´s geometry, guiding lines or proportions into another type of information of an indexical nature. Calibrating these ´indexes´ is a part of a secondary ´writing´ procedure that may be used to unfold and deploy the information embedded in them.

On this case, the Technique is developed as a 'Path-to' device with a specific goal, which is first, to try to recreate the case study project accurately and then, at the same time, to do it with enough flexibility to generate extensive variation from it. At the end of this stage, the product is bi-fold; on one side a formal analysis and on the other, a tool to produce it again and then some more.

The experimental stage (Experiments chapters) aims to produce a series of explorations by taking the results of the previous stage and manipulating them with several digital tools (such as parametric tools, generative algorithms,

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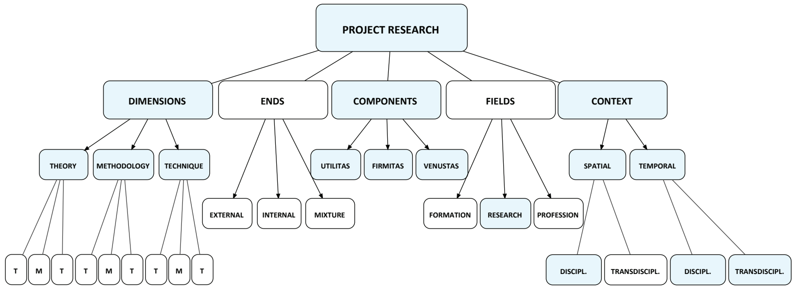
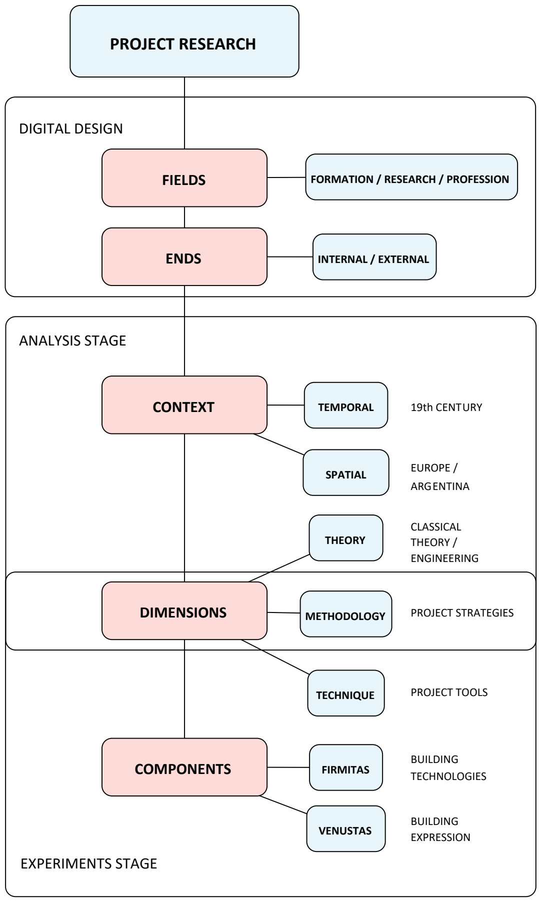
15 Sarquis, Itinerarios del proyecto





1-5 Diagram. ´Project Research´ structure. Variables and indicators used on this research are colored.
1-6 Diagram. Project research Variables and Phd research methodology.

CAD or mesh manipulation among others). The degree of association between case studies and experiments is variable, as each tool is at the same time dependent and independent from its source.

The Path-to methodology demands an over-determination of the formal procedure, and to describe each operation as a continuous process of manipulation, while the result is unexpected and indeterminate. The product of this stage is an object or family of objects, such as floorplans, models, renders or building elements.

Technique.

The last Indicator of the Dimensions Variable is the Technique. It groups the tools and devices employed on the actual procedure of the Project Research. On this case, there is a set of tools in place at the Analysis stage and a different set at the Experiments stage. There is no prior relationship between tools, historical references, topics and procedures; however, the intention of the research is to test the relevance of parametric tools on both analytic and experimental stages.

On this regard, the research presupposed a relationship between some topics (characteristic of the 19th century) and specific digital tools. For example, the extensive use of catalogs from cast iron or terracotta companies can be linked to some parametric tools related to the production of variation and repetition to which catalogs are a natural result. Another case is the façade composition strategies and its relation to contemporary paneling tools available in various design software packages, or the presence of radial symmetry and repetition on central floor plans, a common tool in design software packages.

Context.

Another important variable of Sarquis´ epistemology is Context:
“The Context is a creation of the project author, listening to micro and macro, disciplinary and trans-disciplinary, determined and undetermined aspects, and it can be done by reading and interpreting it acritically form the stereotypes, the devices, culturalized places, or making its critical reading from its own construction as the beginning of the Project Procedure and innovating or renovating its view or its interpretation”[16]

Sarquis originally defined the Context as the location in space and time of the Project Research. As a basic prerequisite of any architectural oeuvre, it positions itself not only on a particular place, site or place (with particular ambient and material characteristics) but also on a temporal realm, embedded on a contemporary discourse, among disciplinary discussions and topics.

Sarquis´ epistemology granted this variable an increased importance over the years, establishing it as one of the most important ones in the research

16 Translation by the author, internal publication. Jorge Sarquis, “Seminario de Actualización en Investigación Proyectual”

process along with greater influence on its outcome. Moreover, the epistemology challenges the idea of a Context as an inherited set of constrains that are uncompromising and inflexible. On the contrary, for Sarquis, the Context is a designed entity; it is constructed, both spatially as historically.

This research taps into this idea as well on two different realms; on one hand it intends to recreate a particular 19th century by selecting and arranging a set of case studies, while at the same time it tries to insert its ´lessons´ into a contemporary debate regarding digital tools. In terms of Sarquis´ structure, the nineteenth century described on this research does not exist, at least as a coherent narrative. It is built, recreated by realigning fragmentary narratives, forgotten projects and ignored buildings.

Components.

The last of Sarquis´ variables relevant to this research is ´Components´, and its indicators are the historical ´Utilitas´, ´Firmitas´ and ´Venustas´. ´Utilitas´ is related to the use, the programs and the actual activities that model a Project Research. Thanks to the growth of cities, economic development and technical inventions like the trains, many new programs were originated during the 19th century, injecting a great deal of inspiration and innovation in the discipline. The analysis of such activities and its reverberance in the architectural form is one of the key concerns of this indicator.

´Firmitas´ defines the scope of the material decisions, their expression and how they will propagate throughout the project. It does not limit itself to the selection and combination of materials but also as the possibilities of experimentation and innovation through its use. The orthodox or alternative use of material and its expressive capacities also belong to this variable. Additionally, it explores the material presence of form, expressing its weight, presence as well as its symbolic and imaginary value. The material innovations of 19th century, the explosion of their use and the speed of their propagation in all areas of life turns this variable to the upmost importance.

´Venustas´ is the last of the Vitruvian triad, concerned with the pleasure that shapes, forms and their images inspire on the users. The variety of new materials and their expressive capabilities along with the multiple sources of inspiration that became available in the period (new forms extracted from nature, fantasy or exotic cultures) make this particular variable relevant. Thanks to several coding processes, these images found their way into the architectural realm, inspiring designers and astonishing the general public.

On a smaller scale when compared to Tzonis´[17] approach to classical architecture, the aim of the research is to understand how 19th century architecture was conceived and how can it be seen as a ´formal system´, in Tzonis own words. In order to construct a coherent system out of the unlimited variety of the 19th century production, Tzonis methodology proves to be useful, analyzing case study buildings as "compositions from a visual, morphological, or stylistic point of view" but also including material or programmatic variables. Tzonis is of course aware about the limitations of a purely formal method of analysis, setting aside meaning, material or social information and warns, right from the start about the misuse of the outcome of such tools.

It may also be relevant to state that these limitations may be related to the actual tools involved in the analysis. On this case, the use of digital tools and generative programs operates as a sift, filtering types of information while ignoring other ones, as any indexing process[18]. For example, on some cases, expressive information such as sculptures or detailed organic forms may be hard to ´see´ or to ´codify´ though a digital process, while mathematical relationships, such as the proportions of a pillar are easily recognizable and translated. Through this process, it is self-evident that the type of information to be registered will be exclusively defined by the ´reading´ or ´indexing´ device.

Different to Tzonis' attitude, this research considers formal analysis not only as a descriptive tool but as a generative one as well, particularly when attempting to understand hybrid, non-canonical case studies such as the ones this research intends to grasp. This way, a formal analysis creates a project that does not exist outside its indexical representation. However, Tzonis is cautious about the reach of his formal analysis method, limiting the role of form in the overall work of architecture among other important variables such as its social relevance and cultural meaning.

On this regard, the author explains the expected reach of an isolated formal approach to architectural analysis of classical buildings:

"The isolation of formal aspects and their independent analysis is necessary, however, if one is interested in understanding classical architecture as a coherent system rather than as a haphazard collection of shapes and details. It offers a deep comprehension of how a building is made, which is different from how it is used, and what impact it has."[19]

Tzonis proposes a rather distant approach in regard to classical architecture, for the fear of ´contaminating´ his analysis not only with imprecise and ambiguous definitions such as metaphors, or ´psychological concepts´ but also risking itself ´of being a mere reflection of our contemporary reactions and thus of producing trivial results´.

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17 Alexander Tzonis and Liane Lefaivre, Classical architecture: The poetics of order /Alexander Tzonis and Liane Lefaivre (Cambridge, Mass., London: MIT Press, 1986)

18 Kipnis, Jeffrey, Performative anxiety, 2G #6 (Barcelona, Ed GG, 2000)

19 Tzonis and Lefaivre, Classical architecture

On this topic, we might differ from Tzonis and his aim towards a depersonalized, ´scientific´ approach, since this research proposes a set of particular tools (digital, parametric, generative). The use of digital tools to understand, recreate and re-write architectural pieces is undoubtedly contemporary and while the experimental part intends to produce its results under ´ideal conditions´, it has no pretention of objectivity in terms of an indisputable truth. The design and utilization of each of these tools is influenced by their author and their results are interpretable as well.

The reasons for this approach towards historical references are mainly three. The first one being that as a ´design research´, the character of this work is of an experimental nature and unlike a historical research it is not bound by its purely scientific nature. The second reason is tied to a particular character, related to one of the primary intentions of this research, that is to effectively comment on 19th century architecture and assess its value to contemporary architectural practices and bring it under the light of present debate.

Finally, the object of study of this research is 19th century architecture, which by several factors is regarded as manifold, complex and hybrid, thus making it particularly difficult to organize and catalog its production under fixed categories. The impressive production of the period, multiple material innovations, building technologies, formal references and even the contrast of the between actual buildings from the beginning of the period in relation to the latter examples, complicates the task of analyzing it since the sheer quantity and variety is significant.

Thanks to the mediation of many architectural styles, building cultures, construction technologies, programs and typologies, it is hard to find an established historical or architectural narrative tied to this period, a strict ´canon´ for its analysis remains opaque. The understanding and analysis of 19th century architecture presented here is therefore fragmentary and incomplete, but is undoubtedly contemporary and as such, ephemeral.

Going back to the methodology, our first step is concurrent with Tzonis´ publication; that is, to consult documents from the periods where the classical canon of architecture was defined and subject their buildings and schemes to analysis. Moreover, the research began by searching for the simplest building available, the minimal spatial unit and then study the geometric and formal rules that shape them. The collaboration with the ´Pavilions´[20] exhibition by Rokokorelevanz provided an excellent excuse to frame the research task and delineate a working methodology and tools to analyze and produce central-floor plan projects[21].

The study of classical treatises from the Renaissance onwards and architecture manuals from 18 and 19th centuries provided a cumulative database of central floor plan buildings to test a first research procedure;

20 Lucas Merx, Holmer Schleyerbach, and Federico Garrido, “Exhibition Pavilions,” http://rokokorelevanz.de/details/exhibition-kerstenscher-pavillon.html

21 Federico Garrido, “Central floorplans and digital strategies,” in Archiving and questioning immateriality, ed. Everardo Reyes García, Pierre Châtel-Innocenti and Khaldoun Zreik (Paris: Europia Productions, 2016)

analyze formal rules, extract and codify the rules to a generative parametric procedure and finally to produce variation, or ´families´ of projects, on this case, central floor plan projects.[22]

Selection Criteria. First Categorization.

After these initial research tasks regarding central floor plans a series of case study projects were selected and subjected to analysis. As previously stated, it is hard to agree on an undisputed cannon of 19th century architecture, there is however a series of buildings that are undoubtedly characteristic of the period. Some of them, like the Galerie des Machines or the Eiffel Tower were reclaimed for example, by the modernist narratives as paradigms of the so-called ´engineering architecture´. Others, such as the Bibliothèque Sainte-Geneviève and the Opera House in Paris are often cited for different reasons such as the exposed metalwork or the particular combination of multiple decorative styles. Train stations, bridges and skyscrapers are also typical typologies of the period, as they were perfected or even invented at that time. It is not the purpose of this research to recreate a definitive cannon for the 19th century architecture but it is sufficient to state that such a partial narrative exists or at least it can be defined with more or less precision.

This research however, intends to focus on the less known, rare, exceptional buildings of the period, both from Europe and Argentina, which are also unmistakably a product of 19th century architecture and yet they are not part of the mainstream narrative of the time.

In order to undertake such task and in view of the vast production of the period, a series of variables were defined, creating a matrix to which several case studies were compared against one another. A first collection of buildings was classified with this tool.

Tzonis tackled the canonic system underlying on the classical buildings by operating in three levels of formal devices: Taxis (partition in elements), Genera (the characterization of elements) and Symmetry (the relations between elements). This methodology, while comprehensive and proscriptive, do not take into account other variables that this research considers relevant to the analysis of the period.

For our purposes, the five main categories to analyze 19th buildings are Order, Formal devices, Technique, Spatial Effects and Programs. The intention is to provide a set of characteristics that are distinctive of the period, some of them overlap with the classical canon (and to Tzonis´ system of analysis) while others are exclusive of the period, such as the articulation of new programs. The idea was to expand Tzonis´ structure, enabling it to register and include less common, hybrid characteristics, while understanding the fact that the larger and more complex this structure becomes, the harder it becomes to effectively use it as an organizing tool.

The idea of this matrix-type analysis was to provide a quantitative

22 Some examples of this procedure can be found under ´Central Floor plan generator´, ´Room generator´ and ´Palace generator´ on the experiment chapters of this research. ´

instrument in order to evaluate and orient the selection process of case study projects. Each category and subcategory operate binarily, that is, each of the projects will either comply or refuse them. Once again, this tool is indicative and sometimes an assessment may fall in a subjective appraisal, but it effectively served as a primary filter for the vast and varied production of the period.

The first main category is Order, and it describes the adequacy of each project to the classical canon of organization defined by Tzonis, that is, to effectively reflect the classical ordering ethics such as symmetry or rhythm. This category encompasses three sub categories: Classical canon, Ornamental order and Parataxis. ´Classical canon´ relates to whether the project reflects classical ordering principles such as symmetry, the relation between elements, modulation, balance, rhythm and repetition. These characteristics will be present strictly on architectural documentation like drawings, plans, sections and facades. In the evaluation of 19th century projects, this parameter is often related to the organization of the floor plans and facades.

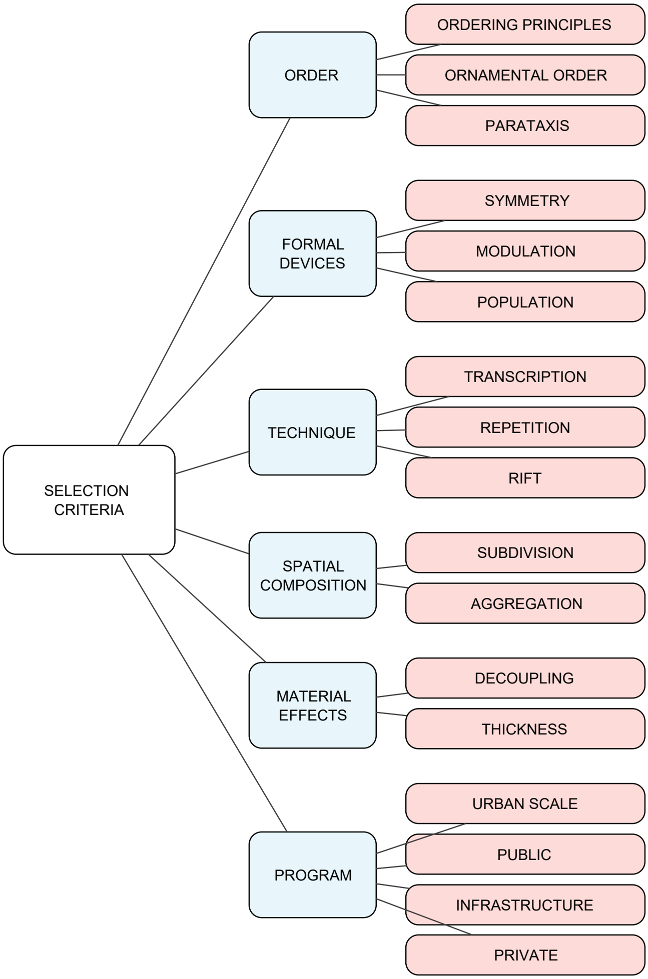
The second subcategory is ´Ornamental Order´, relating to the capacity of ornaments to perform as a visual aid for recognizing ordering principles or patterns, for example, by emphasize regulating grids, symmetrical axis or a particular modulation. This may seem congruent with the previous sub-category, however several 19th projects may be ornamented less rigorously than others or even do completely without them, as the case of utilitarian buildings. For example, the ornamental modulation of the Argentinean pavilion for the Paris International Exhibition reinforces the structural subdivision, tripartition, etc., while the ornamentation in the Porte Monumentale is more linked to the structural elements that compose it.

The third subcategory is Parataxis, and according to Tzonis: “It connotes a kind of taxis, a schema for concatenating formal units. Each unit is part of a linear, consecutive cumulative whole with well-defined upper and lower limits but without specific side terminations.”[23] Parataxis operates as a differentiation in the application of a classical cannon, present thanks to repetition, but also sensitive to anomalies and interpretation errors. Tzonis refers to it as an ´architectural parade´, exemplifying it in row houses and urban environments. It is however an interesting indicative of 19th century architecture, particularly in view of the industrial character of the period´s production, relying on the reiteration and variation of a flexible canon. Several examples on both sides of this category can be cited, like the famous Crescent in London. However, in the late 19th century, the particularities of urban design and large availability of different materials and ornamentation types provided even more possibilities of variation. To name a less known example, the Oppenhoffallee boulevard in Aachen displays an irreverent level of variation within a strict housing arrangement[24].

The second large category group is directly based on Tzonis´ classes; they are Symmetry, Modulation and Population. Symmetry can be defined as

23 Tzonis and Lefaivre, Classical architecture

24 Peter Ruhnau, Das Frankenberger Viertel in Aachen, Landeskonservator Rheinland. Arbeitsheft 11 (Köln: Rheinland-Verlag, 1976)



1-7 Refined selection criteria for the Case Study projects.

the order the relationships between individual elements, it governs how and which architectural elements are chosen and arranged relative to each other and to the whole composition, by means of an ordering pattern[25]. This variable might be present in many administrative or representational buildings but when analyzing utilitarian constructions or pavilions, their organization is often related to technical or material constrains.

The second subcategory is ´Modulation´ and it refers to the capacity of the work to administrate and synchronize the subdivided parts of each element. It is related to Tzonis´ ´Taxis´ category by which the architectural work is divided in parts (usually three) by axis, grids and patterns. Modulation indicates the relationship between these partition procedures and their manifestation in the overall order of the building. A curious case is the Palacio de Aguas Corrientes in Buenos Aires, which is not organized by classical design strategies yet the façade modulation is precise and complex.

The last subcategory is ´Population´ is related to Tzonis´ Genera, which relates to the individual elements that cover or ´populate´ the architectural work, most often the facade or the roofing. As Tzonis defines genera as ´a sort of iconography of construction, as diagrams visualizing the way horizontal loads in a building are transmitted to the ground´, Population deals with elements that may not be iconographic, do not represent weight or display ´tectonics´. On this particular case, ´Population´ is also related to the capacity to identify individual elements on the whole composition, which can be also relate to the fabrication technologies involved in the construction; prefabricated buildings such as international pavilions comply with this variable while more traditional brick and mortar buildings do not[26].

The third group of subcategories ´Technique´ is related to a series of 19th century topics, ´Repetition´, ´Transcription´ and ´Rift´. ´Repetition´ describes the project´s design strategy based on the patterning and multiplication of a motif, element or piece. This variable may be recognized on the floor plan or façade and it is multi-scalar; it can be expressed by the repetition of a building element such as a truss or an ornamental terracotta piece but also as the repetition of building floors on a multi storey building. This variable may be indicative of the industrial techniques used in the production of the building but many projects of the period relevant to this research, for example some mansions in Buenos Aires like the Palacio Paz or the Palacio Anchorena are less likely to comply with it.

´Transcription´ describes whether the project or its parts reflect a process of translation between different building technologies. It articulates both material and aesthetic decisions, as it employs one material to emulate another one, usually of a better ´quality´ or ´tectonic value´. This ´translation´

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25 Tzonis dedicates a whole chapter to Symmetry on his book, governing ‘all kinds of relations between architectural elements’, defining much more than the typical ‘bilateral symmetry’

26 The preference of prefabricated buildings over traditional ones by this parameter is also indicative of a particular property of 19th buildings. This parameter was relevant because it was also related to a ´digital methodology´; the covering of a surface by distinctive elements or ´population´ is a typical procedure on parametric software. It operates by subdividing a surface, generating a regular UV grid and then placing the objects on each cell of the grid. It is also an efficient method for ´panelization´ which deals with flat, more or less regular elements.

process has been present throughout the entire history of the discipline, but the introduction of iron and the industrialization of building elements expanded its reach and its possibilities[27] .

Finally, the subcategory ´Rift´ is related to ´Transcription´ and it illustrates whether the project articulates a distance between the construction technology and its visual expression. It is based on a mimetic conception of architecture but also on the deliberate masking of certain material or visual properties. The case of 19th century architecture is characterized by the inclusion of iron, and the efforts to shape it in order to impersonate wood, stone, ceramics or even vegetation.

The fourth main category is ´Spatial composition´ and it describes two approaches or design strategies in relation to large, complex spaces. The first subcategory is ´Subdivision´, related with the compositing strategy of subdividing space by a series of elements such as structural elements like columns, walls or beams. According to this strategy, a building enclosure would be defined and then it would be divided in order to fit the different parts of the program and uses.

The other subcategory is ´Aggregation´ and it illustrates the strategy of defining independent rooms and spaces and then juxtaposing them in an ordered manner. This particular approach decides to focus first on the parts and then on the overall organization and it does not imply a direct opposition to the Partition strategy. For example, we could mention the spatial design of the Palacio Paz in Buenos Aires; the shape of its rooms, courts and galleries are easily recognizable while its internal organization, though present, comes to a second plane.

It is clear that these two design strategies are not exclusive of the 19th century architectural production; however, it is relevant for they may help to relate each project to a design strategy of a digital nature. For example, BIM packages such as Autodesk Revit include workflows that operate by partition: the designer defines a building envelope and then it is possible to slice the volume with slabs separated in regular distances. On the other hand, custom parametric software can be sketched in order to work by adjoining ´spatial units´ or rooms along an axis or following a pattern[28].

The next group is called ´Material Effects´ and it illustrates the influence of material decisions in the adopted design strategy. The first subcategory is ´Decoupling´ which express material efforts in the façade operating as a separation between inside and outside. Opposite to a luminal conception of the façade, the growing separation between external expression and organization and growing internal requirements. Rem Koolhaas expressed a similar distinction while praising the skyscraper´s facades in New York for their capacity to filter the internal activity from the outer surface representation[29].

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27 Further information on these particular topics will be developed under the Construction and Aesthetics chapters.

28 Some experiments on both design strategies will be addressed on the Experiments chapters.

29 Rem Koolhaas, Delirious New York: A retroactive manifesto for Manhattan / Rem Koolhaas (New York: Oxford University Press, 1978)

			ORDER			FORMAL DEVICES			TECHNIQUE			SPATIAL COMPOSITION		MATERIAL EFFECTS		PROGRAMS			
			CLASSICAL CANNON	ORNAMENTAL ORDER	PARATAXIS	SYMMETRY	MODULATION	POPULATION	TRANSCRIPTION	REPETITION	RIFT	SUBDIVISION	AGGREGATION	DECOUPLING	THICKNESS	URBAN SCALE	PUBLIC PROGRAMS	INFRASTRUCTURE	PRIVATE
			Ordering principles	Ornament as a visual aid for order	Differentiation in the application of a similar cannon	Symmetry and order relations between individual elements	Taxis : Division, tripartition, grid	Genera: Individual elements that populate each part divided by taxis	Translation between building technologies	Expression of industrialized construction	Distance between technologies and visual effects	Composition by cellular partition of space. Division. Single spaces	Composition by porches, vestibules, stairs, rooms, courtyards	Difference between interior and exterior	Wall depth / thickness covering steel structure, infrastructure, facilities, other technologies	Large urban projects	Administrative, cultural, International exhibitions	Water towers, train stations, warehouses	Private program, houses, palaces, companies
BUENOS AIRES	BOYE, O	Palacio de Aguas Corrientes	X	X	X	X	X		X	X	X	X		X	X			X	
	ZUCKER, A	Hotel Plaza			X	X	X		X	X	X	X		X	X		X		
	SORTAIS, L	Palacio Paz	X	X	X	X	X	X	X		X		X		X				X
	MAILLART, N	Palacio de Correo	X	X		X	X		X		X	X	X	X	X	X	X		
	MAILLART, N	Palacio de Justicia	X		X	X	X		X			X	X		X		X		
	MAILLART, N	Colegio Central	X	X		X	X		X		X	X			X		X		
	CHRISTOPHERSEN, .	Palacio Anchorena	X	X		X	X		X	X	X		X	X					X
	SACKMANN, E	Banco Aleman Transatlantico			X	X	X		X		X	X							X
	LeMONNIER, E	Banco Argentino Uruguayo		X	X	X	X		X		X	X		X	X				X
	MEANO, V	Teatro Colon	X	X		X	X	X	X			X			X	X	X		
	MEANO, V	Palacio de Congreso	X	X	X	X	X				X	X	X	X	X	X	X		
	HEYNEMANN	Museo Cs. De La Plata	X	X		X	X						X		X	X	X		
EXHIBITION UNIVERSELLE	DE DION, H	Palais du Champ de Mars	X			X	X	X		X			X				X		
	BALLU, A	Pabellon Argentino	X		X	X	X	X		X		X					X		
	BINET, R	Porte Monumentale			X	X			X	X	X		X				X		
	DUTERT, F	Galerie des Machines						X		X		X					X		
	HENARD, E	Palacio de la Electricidad	X	X	X	X		X		X		X					X		
	DEGLANE, H	Palacio de Champs Elysees	X	X				X		X							X		
VIENA RINGSTRASSE	VON FERSTEL	Universitat Wien	X	X		X	X		X		X	X				X	X		
	VON FERSTEL	Voltivkirche Wien		X		X			X		X	X				X	X		
	VON SCHIMDT	Rathaus	X		X	X	X		X			X			X	X	X		
	SEMPER, G	Naturhistorisches Museum	X		X	X			X		X	X				X	X		
	SEMPER, G	Kunstmuseum	X	X		X	X				X	X		X		X	X		
	SEMPER, G	Semperdepot		X	X		X			X		X		X	X	X		X	
	HANSEN, T	Osterreiches Parlament	X	X		X	X	X	X		X	X	X			X	X		
	SEMPER, G	Neue Burg		`X		X		X	X				X		X	X	X		
	SEMPER, G	Burgtheater	X	X		X	X	X		X		X	X			X	X		
	VON SICARDSBURG	Wiener Staatsoper	X	X		X	X		X		X	X	X		X	X	X		
	HANSEN, T	Musikverein	X			X	X	X					X			X	X		
	HANSEN, T	Borse	X	X		X	X	X		X			X			X	X		
BERLIN	WALLOT	Reichstag	X		X	X	X	X	X		X		X		X	X	X		
	SCHINCKEL	Altes Museum	X	X		X	X	X				X				X	X		
PARIS	GARNIER	Grand Opera	X	X	X	X			X		X	X	X	X		X	X		
BRUSSEL	POELAERT	Palais de Justice		X		X	X	X			X	X	X		X	X			

1-8 First selection matrix for the Case Study Projects.

The subcategory ´Thickness´ relates to the project´s efforts to emulate monumentality, weight and material presence through the addition of ornamental or non-structural elements. With the introduction of iron and steel, the overall thickness of structural members diminished, becoming progressively slender also due to economic constrains[30].

Finally, the last group of categories ´Programs' covers typical programs of the 19th century; some of them inventions while others became more popular. The first subcategory is ´Urban scale´ and it names the projects that belong to a larger urban development, emblematic of the period´s efforts to further expand and organize cities and their public spaces. Hausmann´s plan in Paris, the Ringstrasse in Vienna and even the Avenida de Mayo in Buenos Aires are just some paradigmatic examples of the large urban transformations that took place worldwide.

´Public programs´ group buildings of an administrative, cultural or governmental nature that exploded on this period, due to many factors, such as the crystallization of modern democracies, the ascension of bourgeoisie and the progressive access of the masses to cultural infrastructure such as museums, theaters, opera houses and international exhibitions.

´Infrastructure´ covers buildings and facilities such as train stations, water tanks, warehouses and department stores and finally, the subcategory ´Private´ collects the houses, manors (Palaces in Argentina) and private buildings such as company offices.

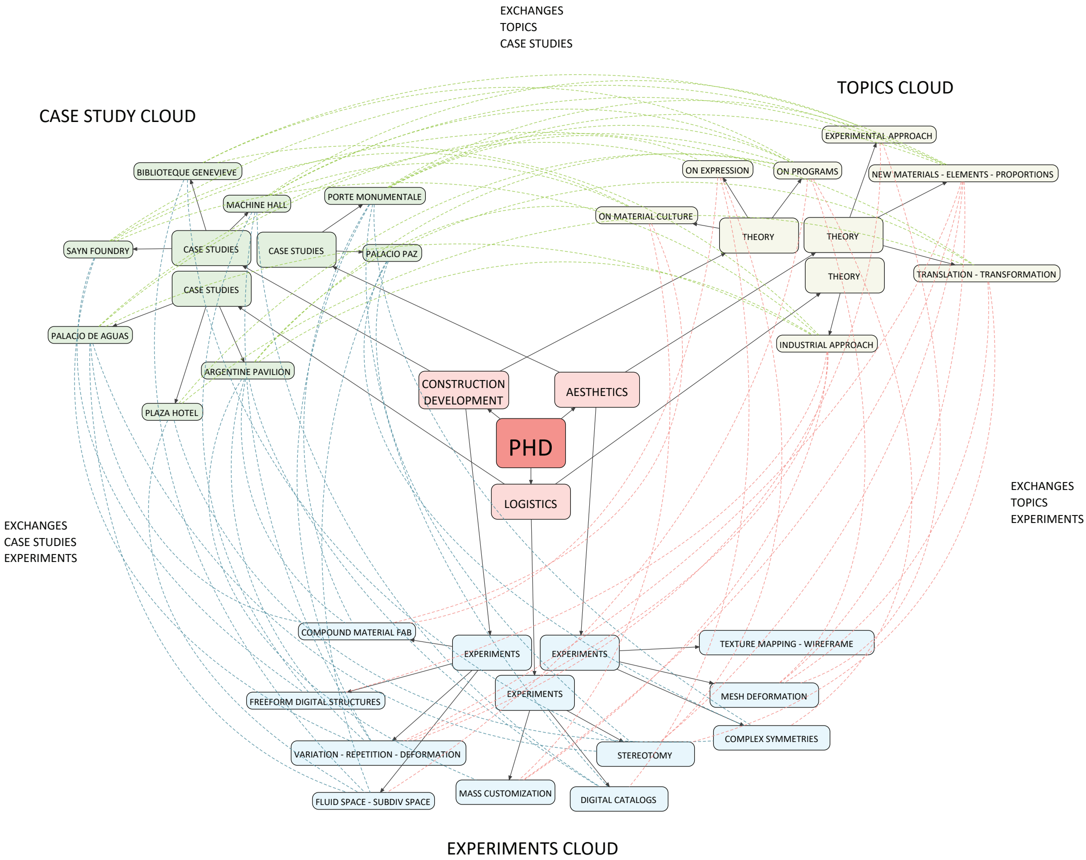
Case studies. Final selection criteria.

Once the topics were reviewed, the selection criteria for the case studies were modified and the final list of projects was narrowed down to ten examples. The main selection criteria that prevailed was to select projects that emphasize the relationship between form and production techniques (or the association between tools and its products in terms of Rokokorelevanz´s research). Another factor that determined the selection criteria was the pursue of projects that were not part of the 19th century mainstream narrative, particularly in Buenos Aires where the architectural production from the period is vast and yet it is often hard to come across with information and publications about several of the most interesting and creative buildings.

With this in mind, a first group of projects from Buenos Aires were selected: the Palacio de Aguas Corrientes, the Plaza Hotel, the Palacio Paz and the Argentinean Pavilion from the International Paris Exhibition (which was moved to Buenos Aires and repurposed in 1893). All the buildings shared ties to Europe whether by their designers, the origin of their construction material, their workforce, and their style. Also, most of them fell and still remain under the radar of Argentinean academic interests, and their diffusion is another objective of this research.

From Europe, the selection is mixed, combining innovative, ground-

30 The covering of these slender parts with terracotta or plaster became a common practice on the period and will be covered in the subsequent chapters.



1-9 Interaction between Categories, Topics and Case Study Projects.

breaking buildings such as the Bibliothèque Sainte-Geneviève or the Galerie des Machines, with less known examples like the Sayner Foundry, the Berliner Börse, the Porte Monumentale and the Palais du Champs de Mars.

The final selection criteria were defined in order to clearly read the relationship between the production techniques and the formal results in each building, emphasizing not just the innovative and sometimes record-breaking applications but also the strange, hybrid results. These eccentric, hard to classify examples like the structure of the Sayner Hütte or the over-decoration of the Palacio de Aguas remain as a core interest of this research, particularly in view of their interpretation and translation through digital tools.

STATE OF THE ART

For the last years a large amount of research has been carried out on the topics of digital tools[31], digital fabrication[32] and their consequences for design procedures[33]. As a member of the UAP, we've done extensive research about the influence of digital tools on design procedures[34]; specifically, how to use parametric tools for the design of housing projects, how to include user information on the process and how to compute material information, among many subjects. These research projects were also performed under Sarquis' 'Project research' epistemology, proving its flexibility and relevance on these kinds of investigations.

Digital techniques in Architecture.

Ever since the introduction of personal computing and design software on the early 90s, architecture practices incorporated them almost immediately, originally in the form of CAD and photo editing software. Design packages were primarily used for architectural representation and it took them roughly a decade to completely replace hand drawing, airbrushing and other techniques. On this subject, Manuel De Landa[35] explained the role of CAD software in design

31 International networks like ACADIA (Association for Computer Aided Design in Architecture), eCAADe (Education and research in Computer Aided Architectural Design in Europe and SIGRADI (Sociedad Iberoamericana de Gráfica Digital) among others, had been steadily promoting good practices and sharing information related to the application of computational technologies in research and education for architecture and design disciplines since at least 3 decades. Their annual conferences and proceedings provide a comprehensive overview on the state of the art regarding computational design topics.

32 International conferences such as Fabricate or RobArch had been showcasing the latest advancements in the area of digitally controlled fabrication, the development of new fabrication tools, techniques and novel materials.

33 On the specificities regarding the influence of digital tools and their influence in design techniques the panorama opens well beyond the scope of this thesis. On specific topics such as housing design we could mention the research group UAP from the Centro Poiesis, the works of Federico Eliaschev and Santiago Miret, and just to name a few.

34 Eliaschev, Federico. "Dispositivos Proyectuales Sensibles." Master Thesis, Facultad de Arquitectura Diseño y Urbanismo, Universidad de Buenos Aires, Miret, Santiago. "Mil edificios: Procesos Maquinicos en Estrategias Proyectuales Complejas." Master thesis, Facultad de Arquitectura Diseño y Urbanismo, Universidad de Buenos Aires and Garrido, Federico. 2012. "Proyectos de vivienda para la emergencia social y ambiental generados con metodologías digitales." UBACyT Research.

35 Manuel de Landa, "Philosophies of Design: The Case of Modelling Software," in Verb (Architecture Boogazine): Processing (2001)

process, their origin in Monge's representation system and their limitations regarding material properties.

The experiments of several architects regarding computational tools originally began by the end of the 60's with the developments in cybernetics and their application in architecture by Nicholas Negroponte, Gordon Pask, Cedric Price, Yona Friedman and many others, including Jorge Sarquis himself (thanks to a research grant in Spain). These investigations however interesting were prior to the computer interfaces we are used to today and the tools they utilized were much too different to ours. Many of the pioneers in cybernetic research were showcased in the famous 'Serendipity' exhibition at the ICA in 1968, exploring the aesthetic possibilities of digital media.

During the 90's Greg Lynn wrote several publications regarding the specificity of design tools of a digital nature and the new opportunities they created for the design disciplines. His book 'Folds, bodies and blobs'[36] compiles many of these articles, communicating the fascination for NURBS (digital Bezier curves), blobs (tridimensional fluid-like entities) and the power of animation tools as design instruments. Lynn advanced on the consideration of computer software from a representational tool to a generative one by exploring the native characteristics of complex digital entities like parametric curves and double curved surfaces.

Neil Leach described the relationship between the capabilities of software and architectonic features, focusing on scripting and tectonics[37]. Leach's approach was relevant because it drew attention to a native function of the computer, that is, the capacity of programming shapes and objects not by defining them explicitly but by coding their behavior, switching the role of the architect from designing to scripting.

This shift is significant for it requires the discipline to adapt itself to another field, though ubiquitous, foreign to it. The need for architects to understand and domain computer language was argued ever since the beginning of cybernetics in the 60s, and it has been claimed by both practitioners and theoreticians such as Greg Lynn[38] and many others[39]. This situation created a new field of exploration for architects, spawning not only new design procedures and applications, but also a new breed of complex shapes and forms.

Patrick Schumacher argued in favor of a 'Parametric' style[40] and has been the first one to consider the investigations on parametric design tools as a research program; with a characteristic set of preoccupations and topics, a method for analyzing and processing them and a distinctive way of evaluation

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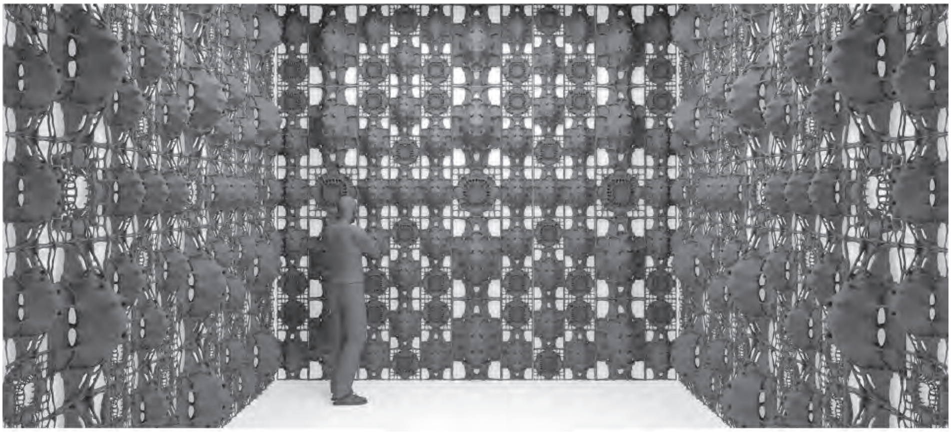
36 Greg Lynn, Folds, bodies & blobs: Collected essays / Greg Lynn, Books-by-architects (Bruxelles: La Lettre vole, 1998)

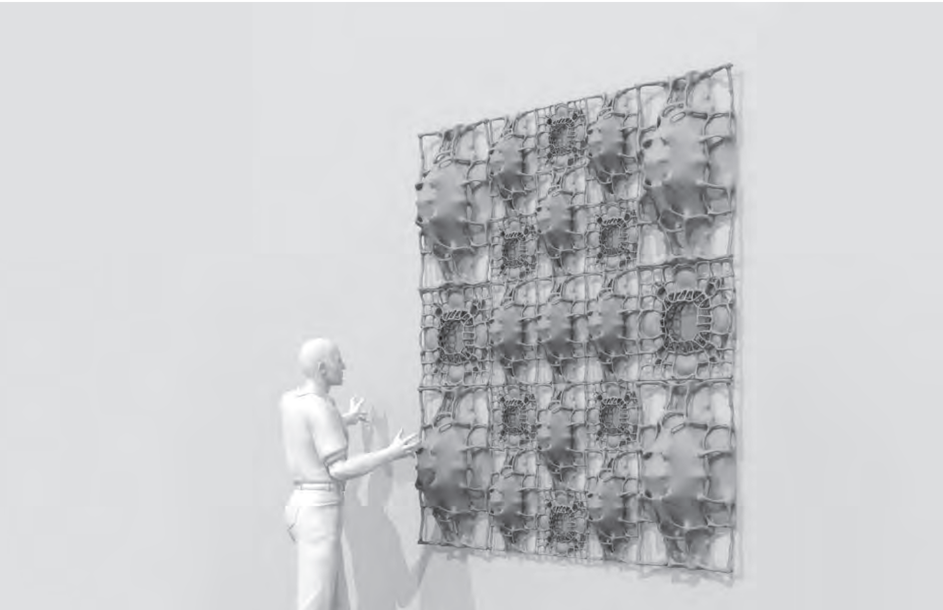
37 Neil Leach, David Turnbull and Chris Williams, Digital tectonics (Chichester: Wiley-Academy, 2004)

38 Greg Lynn, Animate form (New York: Princeton Architectural Press, 1999)

39 Casey Reas, Chandler McWilliams and Jeroen Barendse, Form+code in design, art, and architecture, Design briefs (New York: Princeton Architectural, 2010)

40 Patrick Schumacher, "Parametricism as Style - Parametric Manifesto," http://www.patrikschumacher.com/Texts/Parametricism%20as%20Style.htm





1-10 Stucco.MGX (2008) Instalation by Luc Merx and Gagat international translating Rococo geometric characteristics to a digital medium and then to a physical one.
1-11 The pieces are designed in 3d software and 3d printed in order to enhance its haptic features.

in order to draw valid conclusions. On his extensive writings[41] Schumacher links computational design tools to a shift in the means of production; from a Fordist to a post-Fordist system, thanks to the robotization and digitalization of the production and their overall influence on economy and society.

The thesis of Schumacher is relevant to this research primarily because he successfully linked the notion of architectural style (a 19th century topic of internal debate within the discipline) to a research program, comparable to other disciplines and sciences that produce knowledge. Parallel to this, the notion of style in architecture, specifically parametric architecture, is associated to formal, material and spatial attributes, such as the generation of continuous variation, spatial differentiation and surface continuity as articulation.

More importantly, this 'stylistic' shift is supported by technological advancements: controlled variation, component personalization and small-batch production is now possible and cost-effective thanks to the use of digital fabrication technologies. Production robots, CNC mills, 3d printers and other rapid prototyping technologies are at the core of the current developments in the field of digital design, and Schumacher´s writings embraced them into a coherent discourse.

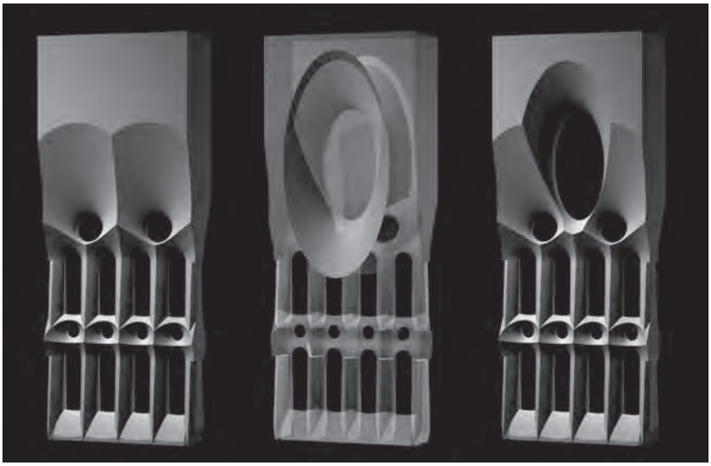
Rokokorelevanz.

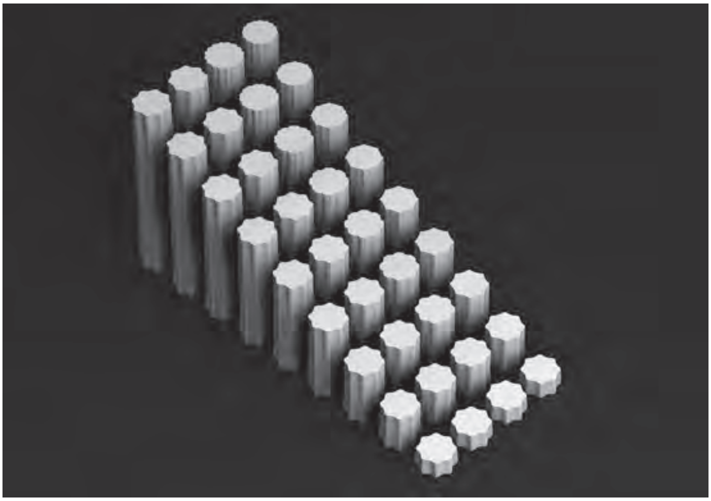
Lucas Merx's research project, Rokokorelevanz is focused on the detailed study of Baroque and Rococo architecture as a source of inspiration for contemporary design. By revisiting tools, buildings, projects, drawings, decorative objects and motifs from the 18th century, Rokokorelevanz gathers insight in order to produce installations, industrial objects, wallpapers, sculptures and artifacts combining both traditional handmade as well as digital techniques.

Distant from a postmodernist attitude of citation and reference, Merx's project is dedicated to a detailed study of production methods, design conditions and contingencies of the German Baroque and 18th century architecture in general. This particular point of view allows him to explore the not so obvious relationships between historical production conditions and cutting-edge design technologies like complex 3d modeling and 3d printing. The study of historical and contemporary production techniques is a relevant attribute for this research, as it attempts to learn from Rokokorelevanz´s methodologies and depart from different architectural periods and different conditions.

Rokokorelevanz produced exhibitions, sculptures and objects as an excuse to think over several topics in contemporary design; the role of detail, quality and the influence of production and manufacturing methods on the design and expression of objects. At the same time, it criticizes current manufacturing technologies and their claim for universal capabilities, by exposing and enhancing their role on the production. The research presents a standpoint against the common assumption that 3d printing can produce anything, any

41 Patrik Schumacher, The autopoiesis of architecture: Volume 1 (Chichester: Wiley, 2011-2012)





1-12 The center nave clerestory of the Sagrada Familia is digitally reconstructed with a sequence of boolean operations.(Mark Burry).
1-13 A digital catalog of column variations at the Sagrada Familia.

shape and form that can be designed on a computer independent of form or material.

Merx's project proposes to take advantage of current manufacturing techniques producing complex objects, impossible to fabricate by traditional means but at the same time related to historical tools and techniques. One of his latest projects ´Profile/Tourneur´ project explores both traditional stucco techniques and digital driven manufacture in order to produce classical column and cornice profiles.

On this regard, Rokokorelevanz production is one of great interest for this research, both in methodology as well as the evaluation of its production; it is not possible to fully appreciate its designs without the intricate relationships between its historical references, aesthetic associations and the influence of production techniques.

Mark Burry.

The case of Mark Burry's research and intervention in Gaudi's Sagrada Familia is perhaps the most interesting and relevant for many reasons; it is an exemplary manifestation of the use of digital tools such as scripting and generative design in order to comprehend, analyze and perform a complex design strategy from a historical reference. Motivated by fascination and enthusiasm, Burry's work can be considered a benchmark of the use of computing and its possibilities first, to understand and then, to enhance a design procedure.

On the case of Gaudi's architecture and the methodologies the devised it was clear that the complexity and variety of his compositional strategies demanded high levels of expertise on the description and manipulation of complex geometries. As an example. he used hyperboloids, paraboloids and ruled surfaces, among many other geometrically generated shapes to populate his designs. Burry's pioneering approach using not only digital tools, but specifically scripting tools as a powerful yet flexible device in order to grasp intricate, multi-step geometrical procedures is a blunt demonstration of their potential.

On the chapter 'Cultural Defense' of the primer 'Scripting Cultures - Architectural design and programming'[42], Burry defines three possible approaches or 'cultures' regarding scripting tools in architecture: the first one 'towards productivity', the second towards 'the answer' and the last one as 'scripting for a voyage of discovery'. He illustrates what we could define as an analogy of Sarquis' Methodology (derived from Cacciari´s 'project paths'), a path which will define the goal of a certain design procedure.

The first 'culture' describes the obvious and immediate application of a computing tool; digitalization allows the possibility of standardization and optimization, a much too desired capacity in every industry, being the building industry a very expensive one and poorly optimized. That being said, productivity is not only a manufacturing goal but might also be a powerful

42 Mark Burry, Scripting cultures: Architectural design and programming / Mark Burry, AD primer series 5 (Chichester: Wiley, 2011)

design guideline. As an example of this approach, the use of genetic algorithms, among other procedures, can produce entire series of variations by defining one object, its defining parameters and an optimization goal.

The second one, oriented towards a known goal ('the answer') is comparable to Cacciari´s 'Path-to', where the computing tool is instrumented in order to analyze and 'understand' a particular form, procedure or design strategy. This methodology implies that the object being analyzed and the tool share the same language. The most interesting aspect of Burry's research is the fact that his understanding of Gaudi's work in purely geometrical terms, steers away from aesthetic or stylistic interpretations and still provides new and refreshing readings.

Performing a critical procedure, one could argue that Gaudi's compositional method was indeed 'computational' (as Burry himself implies), and as such, the translation of this methods into a digital medium is manifest and clearly defined. However, the counterargument could be equally valid; scripting languages deal exclusively on variables, algebraic formulas and algorithms, so when they are overlaid on a particular practice, their response will unavoidable be on the same terms.

Of course, this does not imply that Gaudi's methodology wasn't as complex as Burry's analysis, but since the available information about such procedures is sometimes scarce, there is a creative and innovative quality on the reconstruction efforts. The balance between ´precise´ interpretation and ´creative´ interpretation varies on the several elements that Burry reconstructs, as the material available from Gaudi such as models, plans and notes are incomplete.

The last culture, towards experimentation is according to Mark Burry, the one who he is more focused on. It is also comparable to the 'Path-from' methodology, which is organized from the study and determination of complex design rules and their deployment on a digital medium. This method exploits fundamental characteristics of scripting; the definition of an initial state (simple geometries), the definition of mathematical procedures (Gaudi's methodology on this case) and their application in a digital environment.

Regarding the use of historical references as a mean to develop contemporary design techniques, Burry says:

"It uses an historical project as a means to show that the idea might transcend the technical knowhow, by considering an example of creative play from a world figure who died long before digital design had even been thought of."[43]

What's interesting for this work is that Burry's research overlays a contemporary design concepts over Gaudi's project, extracting its defining characteristics and then developing a particular Theory, a definition of Architecture (according to Sarquis), on this case related to the virtual presence and real absence:

"A combination of digital representation of the design of the building and

43 Burry, Scripting cultures

a range of automated material preparation techniques come together to allow construction to continue at a significantly accelerated pace. Interestingly, the new techniques sponsor a richer appreciation of Gaudi's mind's eye. In seeking to represent a distillation of Gaudi's three-dimensional thinking for constructional or intellectual understanding, we reveal further insights into his unique conceptual abilities. In this final period, we find Gaudí working with an architecture of real absence, and an architecture of virtual presence. This chapter deals with real absence."[44]

And then, reinforcing the contemporaneous character both of the digital tools as for Gaudi's own method, he describes part of the process of reconstruction of the Rose Windows:

"Even if these models were mere paths towards something else unidentifiably intangible for the next iteration, what they reveal in terms of a design language and design process is quite astonishing. Their conceptual implications are contemporary in ways that few commentators have been able to assess." [45]

Another example of these operational reading of Gaudi is the comparison between his manipulation of solids with contemporary Boolean operations, present in every 3d design software as a common tool to manipulate and modify 3d solids.

"Looking at the coursework from the period at the school where Gaudí studied (Barcelona University) we see that descriptive geometry was a significant course component and that Gaudí would have been undertaking exercises in solids description and what were effectively 'Boolean operations'"[46] [47]

There are three types of Boolean operations, Addition, Subtraction and Intersection, determining the possible combination of closed volumes or solids. The continuous Boolean operations of addition, intersection and subtraction is interpreted by Burry as a compositional procedure, that is, taking a base solid, performing a solid subtraction, then another one, then another one, then an intersection, and so on until a complex form is achieved.

This type of procedure, however tedious, can be scripted, that is, translated into a series of commands that eventually can be executed autonomously. The Rose window from the Sagrada Familia is a good example of such procedures; beginning form a basic solid and then removing a sphere for each window division. This ´removal´ process is a Boolean operation, and as it is performed repetitively over time, is deemed perfect for a scripting procedure.

After this first definition, some parameters can be altered in order to explore possible unseen solutions, thus creating a group or a family of solutions, parting from a single origin. It is common to refer to these novel solutions as 'emergences' (borrowing the term from Systems theory) Burry

44 Burry, Scripting cultures

45 Burry, Scripting cultures

46 Burry, Scripting cultures

47See: CFA Leroy, Traité de Géométrie Descriptive, Mallet-Bachelier (Paris), 1844 on the notes section of Burry, Scripting cultures argues however, that there is room in the process for intuition, hand sketching and other methods of authorial input and still end up with unexpected results:

"Through a study of Gaudi's sculptured motifs for the clerestory window, a number of further paradoxes and apparent contradictions will be presented. Firstly, even while being explicit about a compositional strategy through scripting, operationally the strategy may yet afford opportunities for intuitive input, sketching and emergence along the way. Secondly, compositional scripting is looked at for its potential inadvertently or deliberately to spawn the monster (teratoid), however much the designer might be endeavoring to engineer beauty."[48]

Finally, Burry's argument in favor of Gaudi's compositional model is related to freeform design, a popular design technique. Freeform surfaces or 'form-finding' is a contemporary digital design technique consisting in designing a base surface (or mesh) and then applying abstract forces, like gravity, wind or imaginary charges in order to deform it and obtain catenary-like structures. Gaudi's Sagrada Familia hanging model is a common reference of this procedures.[49]. In addition to this form-finding technique, Burry also recognizes yet more contemporary topics in Gaudi's work:

"Beneath, and removed from the stone and gypsum surfaces, are sufficient clues that he was well advanced in his thinking about the elusive intangibility of free-form; an 'intangibility' that, paradoxically, risks being conceptually lost when any free-form architectural composition is physically manifested as a building. Prior to his accidental death in 1926, he demonstrated a complexity and richness that foreshadow contemporary post-computer interest in less compliant form making; ideas that extend well beyond the merely superficial to the hypersuperficial. During these later years he introduced ideas of metamorphosis, morphogenesis and polymorphism into this work."[50]

Finally, Burry recognizes the potential of digital media not only as a tool to produce (or reproduce) technical works, but as a powerful medium to read, understand and communicate architectural ideas, not only contemporary but also historical ones:

"The rewards that scripting brings to the study and implementation of Gaudi's design using the best of digital technology also support the communication of aspects of the design to interested parties with no special knowledge in the area. Such endeavors for an architect as enigmatic as Gaudí are perhaps means and ends that justify themselves. Much of the research findings reported in this and the previous chapter has only become comprehensible in terms of Gaudi's design plan through the efforts to complete the Sagrada Familia church, and inevitably this work has been dragged into the digital arena. But it is inevitable also that the issue of whether it is appropriate to tar an architect such as Antoni Gaudí with the digital brush

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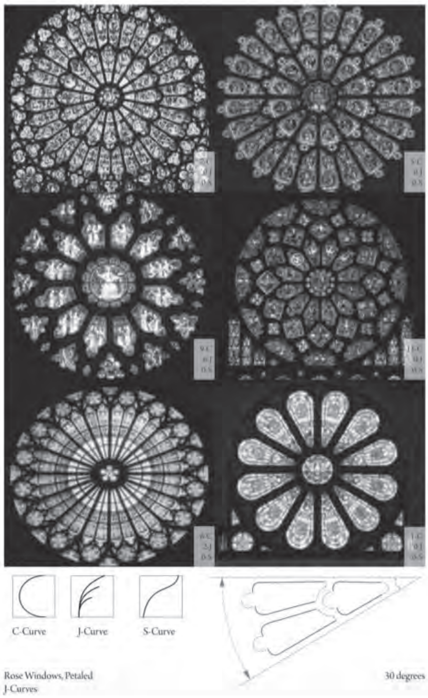
48 Burry, Scripting cultures

49 Although there is no direct mention of them in Burry´s writings, several programs and plug-ins operate on direction. The Rhinoceros plug-ins Karamba and Kangaroo are amongst the most popular ones in design research and form-finding techniques.

50 Burry, Scripting cultures



1-14 Gothic Rose windows curve analysis (Lars Spuybroek).
1-15 S-type patterns in William Morris´ designs (Lars Spuybroek).

will rapidly become less of an issue as society becomes more accepting of the way this medium has infiltrated all aspects of our creative lives."[51] We may finally agree with Burry on this last point; reading Gaudi's work through digital media is not (just) an effort to permeate every architectural resource with a digital varnish but to actually use contemporary and ubiquitous digital tools to read, understand and appreciate historical works. Understanding and appreciation are key concepts that will span over the research; enabling new viewpoints, offering new interpretations is a common goal of Burry´s approach and this one.

Lars Spuybroek.

On the preface of his book "The sympathy of things – Ruskin and the ecology of design"[52] Professor Lars Spuybroek defines two possible ways in order to revitalize a historical figure: the first one is the typical historical research; one must find more details, connect him with his contemporaries, 'make him more historical' according to Spuybroek. The second method is to rip out the reference from its history, isolate him from the common assumptions of the time, 'not creating a ghost version of the original', in other words, make the reference more contemporary and less historical.

Spuybroek goal is to update John Ruskin, or to create a Ruskin and use it in order to improve contemporary conditions. For the author, digital tools should be understood in the terms Ruskin proposed, not in a pre-modern era, but in a pre-renaissance one, the Gothic. Spuybroek even defines a 'Gothic ontology' from which he organizes the book. His aim is to assume Ruskin's concepts from a digital perspective, but at the same time, he warns us about the conversion from history into theory and such transformation, if made uncarefully 'would degrade his position into a mere legitimization of our own'.

This warning is certainly useful in terms of this research and other similar contemporary ones; the use of digital tools is by no means a validation device for a design or historical research, and its utilization does not automatically authenticate its results. The tools are only useful if a precise framework for its use and its results are defined within a disciplinary agenda.

Lars Spuybroek proposes that both Gothic and contemporary digital design share common processual characteristics, through Ruskin's vision. By overcoming modern dichotomies, such as structure-ornament or force-form, he proposes an 'a-modern' point of view that sees both ways, past and present, establishing parallelisms between gothic and digital processes, both considering formal characteristics, the influence of forces and the randomness of material manipulation.

He arguments in favor of 'Variation': in renaissance variation was not possible, only changes in scale, proportions changed, but the element itself

51 Burry, Scripting cultures

52 Lars Spuybroek, Sympathy of things: Ruskin and the ecology of design (Rotterdam, New York NY: V2 Publishing; NAi Publishing; Available in North South and Central America through D.A.P./Distributed Art Publishers Inc, 2011)

did not. On Gothic, the element changed on every scale variation. He calls it 'Configurational variation'. Ruskin argued for two sets of variability, one related to the internal variation of each element, and the other, related with the combination of such elements. This double variation capability is why Spuybroek defines gothic's 'digital' nature; 'the fundamental variability of all figures', separating it both from industrial as of handcraft production:

"The return of variation, more precisely to configurational variation, including a material understanding of it, that I am commending necessarily implies another, more forward-looking Gothic, which probably won't even look Gothic to most of us but nonetheless will show the same rigor, the same changefulness and savageness: an art of digital, configurational variation. Handicraft, while offering variation, cannot provide us with nearly enough continuity; and inversely, industrial casting (prefab) offers continuity but no variation "[53]

Spuybroek takes Ruskin's defining characteristics of the Gothic but he updates and reorders them in order to describe their digital nature; Redundancy, Changefulness, Rigidity, Naturalism, Savageness and Grotesqueness can be used to describe contemporary digital tools.

Variation and changefulness are at the core of digital tools; gothic is full of complex formal operations on a material base. Such operations, like branching, overlapping, merging, splitting, crossings and braiding were present in gothic architecture, but not on classical elements (such as columns, porticos or arches) but on what Spuybroek calls 'non-parts' or 'almost-parts', parts that are neither wall, pillar, column or brick but a mix of them.

This mixed essence of digital gothic, contrary to classical or even modern dichotomies is what both Spuybroek and Ruskin find more interesting and fruitful; ornament-structure, force-form, abstract-material are mixed and hybridized pairs on both versions of the Gothic. Today they are understood as a powerful argument against contemporary design techniques whether classical or modern.

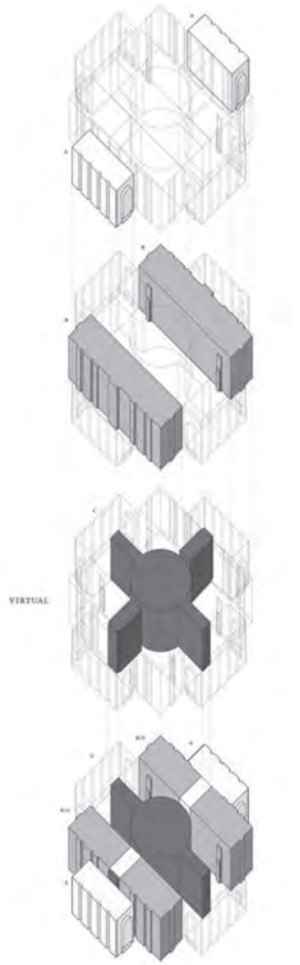
'The sympathy of things' describes an intricate and compelling theory in favor of complexity and hybridization, not only as a critique to contemporary digital design but also as a distinct method to re-observe and re-learn from historical figures and theories. Although Spuybroek's concern is mainly theoretical, the operativity of the concepts he describes is yet to be proved, and while some may have already been tested on academic exercises and research[54], their final evaluation will be significant for this investigation.

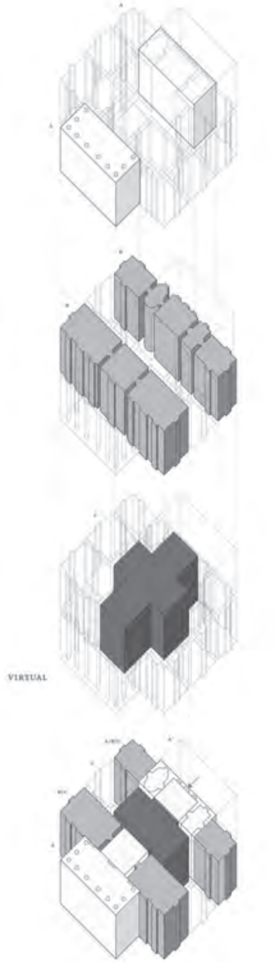
Peter Eisenman – Palladio Virtuel.

Peter Eisenman's book about Palladio's villas is a great example of a contemporary and creative view on architectural history. On his latest book he combines the analysis of historical projects and the concepts of ´space syntax´

53 Spuybroek, Sympathy of things

54 Lars Spuybroek, Research & design: The architecture of variation (London: Thames & Hudson, 2009)





1-16 Villa Rotonda (Palladio). Formal analysis by Peter Eisenman on ´Palladio Virtuel´.
1-17 Villa Foscari (Palladio). Formal analysis by Peter Eisenman on ´Palladio Virtuel´.

and ´close reading´. In a nutshell, the proposal of a spatial syntax intends to find hidden and immaterial architectural relationships, concealed behind geometry and formal relationships:

"The idea of a spatial syntax goes beyond simple function. While there is no architecture without the external surfaces that shelter and enclose, the architectural membrane –that is, the vertical surface- is not just functional, it is also representational. While both horizontal and vertical membranes convey information in one way or another, Rowe has argued that the vertical surface manifests character while the plan is the source of composition. By contrast, it can be argued that the vertical surface records something other than character, as the plan records something other than composition. That "other" is a defining characteristic of architecture: not the literal, material scale or proportion of building parts and spaces, but the latent, immaterial possibility of multiple readings of the same space through topological conditions such as adjacency, overlap, or superposition –all manifestations of architectural relationships as opposed to geometric coordinates."[55]

His argument in favor of such analysis rests on the analogy of what he defines as 'architectural shifts', or moments of intense debate and change in the discipline. Eisenman identifies northern Italy from 1520 to 1575 as a critical moment regarding those shifts and recognizes the significance of that specific period as it shares certain common conditions to his own. His focus on Palladio's heterogeneous space (in contrast to Alberti's homogeneous space) is an argument in favor analogous of a tension between 'ideal' and 'virtual' conditions. Most importantly to this research is the underlying definition of the 'virtual':

"The virtual refers to architectural relationships that are implied by a condition of presence but that exist beyond the literal or the ideal. This could be considered a first definition of the virtual. By identifying moments of tension between ideal and virtual conditions in Palladio's work, the analysis uncovers –or invents- the underlying architectural strategies, inscriptions, and notations in the works."[56]

By combining a distinct mode of graphical notation (architectural elements by letter and color), Eisenman proposes a novel viewpoint on historical case studies, evaluating topological conditions, spatial operations and geometric compositions, that not necessarily are present but implied or suggested. This is what he defines as 'virtual', it is hypothetical, and it exists beyond the literal.

At the same time, Eisenman explains that his reading of Palladio is achieved through the analysis of 19th and 20th literature, with a specific academic context and disciplinary tradition. Eisenman's analysis of Palladio is based on what he calls 'close reading' of his floorplans, but producing at the same time, new information, new drawings and topological diagrams grounded on a dynamic conception of space and geometry. He uses contemporary concepts and tools in order to break down previous 'classical' definitions such

55 Peter Eisenman, "Close Reading on Architecture Exhibition" (Exhibition catalog, Milan,)

56 Peter Eisenman and Matt Roman, Palladio Virtuel (New Haven: Yale University Press, 2015)

as proportion, symmetry and geometrical correspondences in favor of what we could call, topological relationships, focused on adjacency, juxtaposition, location and sameness.

This contemporary interpretation of Palladio's work is justified as a search for hybridities and heterogeneities, in contrast to more 'ideal' readings of part to whole relationships and typological purity.

Eisenman clarifies about the analogy between close reading of Palladio´s floorplans and digital algorithms:

"My Palladio Virtuel book attempts to redirect attention away from the formal components of an architecture typically conceived in static geometric terms towards a supple topology similar to the output of today's digital algorithms. (…) The results are a series of processes engendered by intrinsic, rather extrinsic, movement, which reanimates the idea of close reading of history, now as a dynamic process. It is the critical reassessment of a formal logic, rather than the static formal project itself, that can become a necessary part of our culture of architecture today."[57]

Instead of considering each of the twenty villas as variations of an ideal model, Eisenman's focus is set on finding uniqueness on each project by deploying a set of tools, a 'modeling grammar', registering articulations, relationships and adjacencies far from geometrical reductionisms and simple diagrammatic interpretations.

Finally, it is also important to note that Eisenman's argument is not only centered on Palladio and his projects but on the importance of developing a personal analysis device to interpret historical (as well as contemporary) projects. This device or methodology is what he defines as the 'close reading' of architecture.

Michael Hansmeyer.

Hansmeyer's research is relevant to this investigation mainly for two reasons; the tools and the references it exploits. There are two projects of interest on these two matters; Columns (2011) and Digital Grotesque (2013), both are installations regarding isolated architectural elements and a blunt demonstration of what it can be defined as 'computational architecture'[58].

The methodology applied in the design of these processes is of a pure computational nature; both were not designed using CAD or NURBS design software but rather they were 'scripted', in terms of Neil Leach. Each project was programmed; their final shape is the result of a procedure, a code that acts like a theatrical script determining parts, positions, movements and behaviors. With this method, Hansmeyer could produce extremely detailed objects without the necessity to personally decide and resolve every part. The

57 Eisenman, "Close Reading- Formal analysis on Architecture" Exhibition, Milan 2017.

58 There are several definitions of what ´computational architecture´ or ´computational design´ is, but it could be summarized in a change of paradigm in design techniques, shifting the focus of its interest, tools and expression geometry to logic. Thus, relationships between the design´s elements are no longer formal and static but defined by fluid, infinitely alterative mathematical associations.

result is a series of very meticulous and intricate designs, resulting in complex models with huge amounts of geometrical information. As an example of this complexity, the digital model for the 'Digital Grotesque' project has 2.6 million faces.

This 'hyper-resolution' is a consequence of the generative tool; the author programmed it using a scripting language called JavaScript which iterates and subdivides surfaces adding more and more detail on every step. Surface subdivision is a very powerful procedure on design packages; it operates by dividing a surface, creating four new sub-surfaces thus adding the possibility of more manipulation. Subdivision is a procedure that increasingly divides surfaces over and over again, in an automatic process, adding more detail and intricacy; its potential lies in its capacity of producing detail without too much authorial intervention or control. Subdivision is a natively computational process and as such, it depends exclusively on mathematical formulas and an excellent manifestation of the enhanced capabilities they bring to a design process.

These two projects were manufactured with different tools; the 'Columns' were assembled by stacking laser-cut cardboard sheets and 'Digital Grotesque' was 3d printed in a sand-like material. The perception of detail in them is completely different as the machines have different precision and tolerance levels. The 'Columns' were laser cut on 1mm cardboard, because, according to the author, large 3d printers lacked the precision he needed in order to fabricate a 3m column.

On the other hand, the 'Digital grotesque' installation was 3d printed in parts using Voxel jet printers and then assembled together on site. Its resolution is approximately 1/10th of a millimeter, since the machine works by placing and gluing small sand-like grains and then coated with paint.

The final objects are full of detail as they resemble ancient architectural elements; sculpted columns, artificial and natural grottos. What he defines as 'highly specific local conditions'[59] is the product of a computational process that aggregates detail and articulation at a local level, maintaining continuity and coherence at a larger scale. But those references operate as a guideline in a first stage of design, a first stage that relates the author and its product, prior to the computational procedure. This relationship returns finally when the user or spectator establishes symbolical relationships with the object; it triggers associations, memories, fantasy, curiosity, surprise.

There is an order on Hansmeyer projects, but that order is not of a classical nature nor it is easily distinguishable; one can perceive it, but it is slightly discernible from chaos. The order is there and it is mathematically defined, but our understanding of its complexity associates it to other references, such as a rocaille or a natural formation; in this case analogy and reference is not a generative tool but a byproduct of an algorithm. This is the true potential of Hansmeyer's design techniques; achieving artistic and emotional effects by the means of mathematically organized chaos. These kinds of procedures,

59 Michael Hansmeyer, "Subdivided Columns," http://www.michael-hansmeyer.com/subdivided-columns

1-18 Subdivided Column (2010) by Michael Hansmeyer and Benjamin Dillenburger uses subdivision algorithms to produce a sort of multi-scalar recursion geometry which is assimilated as architectural detail.
1-19 Digital Grotesque II (2017) by Michael Hansmeyer and Benjamin Dillenburger uses similar algorithms to create highly-ornamented architectural elements.

algorithmic and subdivision tools will be explored further in the Experiments chapters.

Benjamin Dillenburger.

Dillenburger's practice 'Numerical Material' is also relevant to this research; in addition to his collaborations with M. Hansmeyer in the 'Digital Grotesque' project his focus on generative digital tools and digital manufacture has also re-defined the role of detail in current practices.

On their paper 'The Resolution of Architecture in the Digital Age'[60] Dillenburger and Hansmeyer argue in favor of a high-resolution detail, recently available to contemporary practices thanks to the combination of computational tools and rapid prototyping techniques. They insert sand-printing techniques into the list of technologies that influenced and shaped Architecture, like cast-iron or concrete, establishing the possibility of a new 'exuberant architecture' as a stylistic byproduct of these technologies.

The paper defines 'resolution' as 'a measure of the spatial density of information inherent in a building'[61] and indirectly suggests a millimetric sand grain as the new architectural element, the smallest building block available. But is there an architectural style derived from the use of powder printers? Dillenburger's practice seems to escape this dilemma by establishing aesthetical and historical associations not in the design procedure but in the appreciation of its results. It is however unclear if these stylistic references guide the generative process on any way.

On his personal website[62] many projects are described by a combination of architectural elements and stylistic analogies. Projects like 'Arabesque wall', 'Grotto' ('Digital Grotesque' with M. Hansmeyer), 'Rocaille' and 'Domes' are examples of a powerful combination of generative tools and analogical thinking. These projects somehow manifest that the potential and freedom that digital design and manufacturing tools bring to the discipline may still require a correlation to architectural history.

RESEARCH PROCEDURES.

Analogy as a procedure.

The procedures and outcomes of this thesis are divided in two types of media; one is textual and the other is of an architectural nature, i.e., drawings,

60 Michael Hansmeyer and Benjamin Dillenburger, "The Resolution of Architecture in the Digital Age," in Global design and local materialization: 15th international conference, CAAD Futures 2013, Shanghai, China, July 3-5, 2013, proceedings, ed. Jianlong Zhang and Chengyu Sun, Communications in computer and information science, 1865-0929 369 (Heidelberg: Springer, 2013)

61 Hansmeyer and Dillenburger, "The Resolution of Architecture in the Digital Age"

62 http://benjamin-dillenburger.com/

floorplans, details, renders, 3d models. This dual character allows describing different aspects of the research either on one distinct medium or through a combination of both.

The combination of both textual and graphical material responds to the necessity of describing, analyzing and presenting diverse types of information. This research is firmly supported by graphical information, much of which is either very difficult or impossible to translate into a textual format. In other words, drawings do not play a supportive role of text but act as a complementary medium and an actual research device; the analysis and production of architectural information is by itself a form of exploration and investigation. Consequently, many conclusions will have this very same characteristics and their expression in a textual format will be incomplete.

At the same time, many design experiments carried out for this research are a 'useful excuse' to bring interesting topics to the table and then to extrapolate and propagate their conclusions to other areas. This analogue character of the experiments is considered an important asset, and it is developed as a consistent procedure throughout the entire research.

There are two interesting projects on which analogy acts as a powerful procedure in order to illustrate, discuss and analyze topics relating the architectural discipline and its relationship to production tools, materials and design strategies. The projects were carried out as collaboration with Rokokorelevanz research project and were developed by a common set of interests for both investigations.

Pavilions.

'Pavilions'[63] was an exhibition at the Kerstenscher Pavilion in Aachen, Germany as part of collaboration with the research project Rokokorelevanz (Prof. Lucas Merx).

The main concern of this project was to study and develop digital design and manufacture tools in relation to specific references from the history of architecture. The project focused on the procedures and disciplinary methods when including historical information regarding processes and strategies in contemporary digital design[64].

The exhibition at the pavilion Kerstenscher was proposed as a brief demonstration of these concerns, trying to illustrate possible approaches to addressing inclusion and manipulation of information from architectural references in digital design processes. As a result, a series of aluminum and plaster models, renderings and drawings were produced.

My role on the collaboration consisted in collecting and redrawing a series of central floorplans, as an example of the deployment of design strategies and their possibilities of geometrical and spatial variation. These floorplans acted

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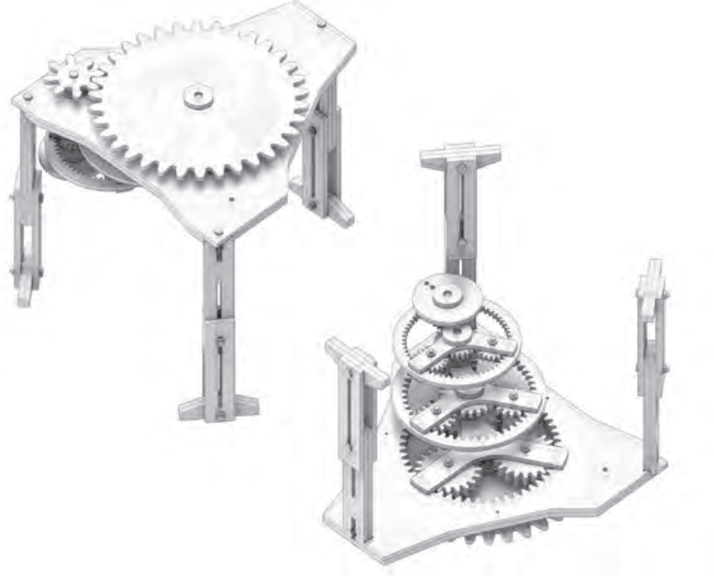
63 Lucas Merx, Holmer Schleyerbach, and Federico Garrido, "Exhibition Pavilions," http://rokokorelevanz.de/details/exhibition-kerstenscher-pavillon.html

64 Federico Garrido, "Central floorplans and digital strategies," in Archiving and questioning immateriality, ed. Everardo Reyes García, Pierre Châtel-Innocenti and Khaldoun Zreik (Paris: Europia Productions, 2016)

1-20 Pavillions Exhibition (2015) by Rokokorelevanz (Luc Merx, Holmer Schleyerbach and Federico Garrido). Photograph by Luc Merx.



1-21 Drawing Machines - Planetary mechanism (2016) by Rokokorelevanz (Luc Merx and Federico Garrido) is a research project combining fascination for mechanical systems and their geometric byproducts.

as an illustration of design strategies applied to simple architectural programs, many of them were pavilions, small chapels or temples.

A part of the collaboration also intended to investigate which geometric, formal and material lessons can be learned in relation to digital tools, resulting in the creation of a digital tool from parametrizing specific geometric information from historical buildings and projects.

Each project, pavilion or building is by itself a manifestation of a series of canonical formal principles embodied in several drawing rules, such as a close attention to symmetry, proportion, detail, compositional axes and guides, among others. The study of these mathematical relationships and its expression in terms of an interdependent parametric model allowed turning its operation not only as an analytical tool but also as a generative one. The product of this generative tool is then a series of digitally generated central floorplans and pavilions.

The Pavilions exhibition was one of the first steps of this research and opened several possibilities by casting new light on the use of historical references in digital processes. It showed the true value of historical references and the importance of their appreciation in terms of detail and variation even in simple, single architectural spaces.

Drawing machines.

Drawing machines is a collaboration project with Prof. Luc Merx aiming to explore the relationship between aesthetics, production processes and geometry. The project consists in the design, manufacture and exhibition of a series of drawing devices, from simple drawing tools to more complex, mechanical machines that produce intricate designs such as helicoids and spirals.

The drawing tools are designed in order to express their function, reduced to its minimal expression and the manufacturing technology used for them. These technologies include lathes, chucks and CNC milling machines and their capabilities and limitations were included in the design process and eventually, the products of the drawing tools. The collection of objects includes pens, pencils, rulers, tools for drawing circles and other elaborate devices capable of producing curves, helicoids and other geometrical repetition shapes.

Some of the tools such as the pen and pencils are lathed in aluminum while others include a combination of technologies. The complex drawing machines were prototyped in laser cut sheet material and are intended to be fabricated in milled aluminum and bronze.

The correlation between a minimal form and a specific function is also expressed in the way each tool works. For example, the circle drawing tool is composed by a pen, a nail and a cord joining both of them. Tool, procedure and product are carefully choreographed on each design. Similarly, the complex machines are composed by articulated arms, planetary gears and rotational axis; their product is equally complex in terms of geometry.

It is also relevant to state the relationship between procedure and product. In the case of the straight lines or circles, the result is easily predicted but in the case of the complex mechanical drawing machines, it is no longer possible.

The complex drawings cannot be ´drawn´ without the machines since they are a result of a complex procedure, they are pure process. One can, however, simulate the inner workings of the machine and preview a potential result, yet every machine produces unique movements and consequentially, unique drawings.

This research project is an excuse to discuss the influence of tools in the discipline; how they influence architectural thought and the results they produce, as they cast their influence over a large amount of the design process, from simple rulers and strings that draw lines and circles, to perspective machines and contemporary design software.

Aesthetics are also a very important topic to this research, not only the shapes and geometries that these machines produce with a varying degree of complexity but also, the appearance of the machines themselves: their shape and formal characteristics should also be an expression of the function they perform. This is not a mere fetishization of machines but an exploration of the relationship between the aesthetics of mechanical devices and the movements and geometries they produce.

These are very relevant topics to this thesis since 19th century was a key moment in history regarding the introduction of machines and the mechanization of many aspects of human life, including of course, buildings. These drawing machines are therefore an analogy of this influence, not only as a direct association between tool and the mechanization of production but also as a way of thinking, and eventually, a way of dealing with design problems.

Analogy as a research strategy.

Analogical thinking is a useful design strategy. Vitruvius[65] and many authors[66] after him compared the dimensions of buildings and columns to the dimensions of the human body. Comparisons between architecture and other disciplines are numerous, as it continuously borrows concepts and models in order to improve its own capacity to communicate and further develop itself.

Here we could define two main uses of this analogical thinking; one oriented to the ‘outside’ of the discipline, such as the communication of complex ideas (for example, the use of metaphors in postmodernism, or the recurrence to the ‘Hokusai wave’ reference in Zaera Polo’s description of Yokohama Terminal Station[67]) and the other, oriented towards the ‘inside’ of the discipline, in order to develop new ideas, taking influence from diverse disciplines from biology and quantum physics to naval engineering.

This research is focused on the second type, but the goal is not to look outside the discipline in order to borrow novel tools and concepts, but to look inside to the history of architecture focusing on similar topics and common

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65 Vitruvius Pollio and Morris Hicky Morgan, The ten books on architecture, Dover books on architecture (New York: Dover, 1960)

66 Leon Battista Alberti, Cosimo Bartoli and Giacomo Leoni, The ten books of architecture: The 1755 Leoni edition (New York: Dover Publications, 1986)

67 Kipnis Jeffrey et al., 2G Issue 16: Foreign Office Architects (Barcelona: Gustavo Gigli, 2001)

conditions in historical and contemporary architecture.

Among many practitioners, the work of Peter Eisenman is a good example of such use of history, particularly on his book 'Palladio Virtuel'[68], previously described. On the preface, he states about the relationship between Palladio's and his own time as a period of dynamic change:

"…this work considers history as a template for the possible multiple interpretations and transformations of any project that are reflections of a dynamic culture."[69]

And particularly the relationship between a research tool, the 'close reading' and its importance on contemporary design.

"The analysis presented here does not go against or refute technology; on the contrary, it shows that technology itself is grounded on history, made more pliable and dynamic by close reading. This work attempts to redirect attention away from the formal components of an architecture typically conceived in static geometric terms toward a supple topology similar to the output of today's digital algorithms."[70]

Eisenman´s analogy between the deployment of his tools and contemporary digital algorithms is a potent tool, not in terms of metaphor or resemblance but as operative ones. The production of flexible topological models is not just aimed at the analysis; Eisenman´s methodology can be also used to produce architecture.

19th century architecture and digital research tools.

This research proposes to read 19th century architecture from a contemporary point of view particularly influenced and motivated by digital tools. This must not be interpreted as a statement in favor or a justification of digital tools but rather as a fresh look on the history of architecture, one that has been studied and analyzed many times and it is relatively closer to us than other periods. The use of digital tools in particular responds to the fact that almost every aspect of our discipline is filtered by their influence, from representational tools for sketching and rendering, to environmental or structural analysis software. More importantly, research tools and resources have been permeated by digital media, spawning whole new areas of knowledge like the case of Digital Humanities[71].

Much of this research is carried through and with the aid of digital tools, from the collection of data, the use of digital repositories and archives, image editing software, CAD packages, CAM software and many more. This is not by itself a statement; it's about being contemporary and carrying out a research with the available tools in the 2010s.

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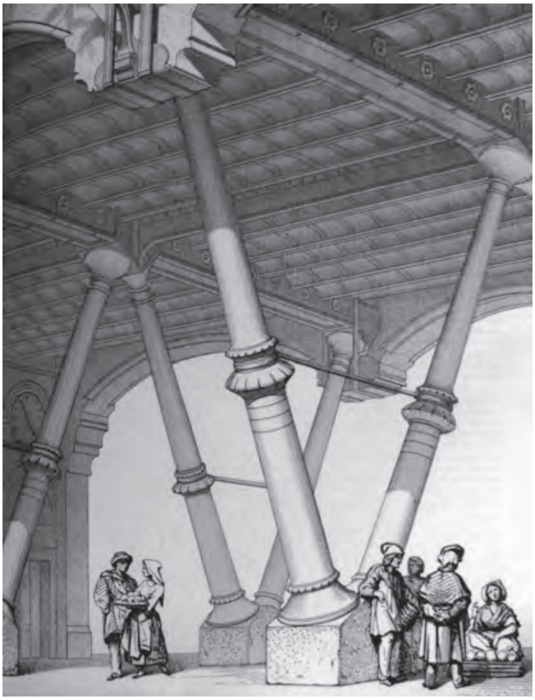
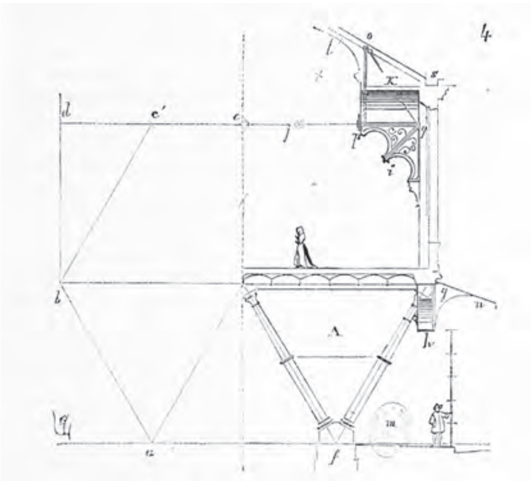
68 Eisenman and Roman, Palladio Virtuel

69 Eisenman and Roman, Palladio Virtuel

70 Eisenman and Roman, Palladio Virtuel

71Digital humanities are a relatively novel academic field focusing on the application of computational tools and methods to traditional humanities disciplines like history, literature and philosophy.





1-22 Market Hall Project (Eugène Emmanuel Viollet-le-Duc) making use of iron in a novel structural typology combined with traditional building techniques.
1-23 Market Hall Project (from 'Entretiens sur l'architecture' Eugène Emmanuel Viollet-le-Duc)

The premise is that there are a number of characteristics, parameters and conditions of 19th century architecture that can be 'uncovered' or 'unveiled' by observing them through a different lens, on this case, a digital one. But again, the intention is not to conduct a historical research but to comment on contemporary architecture and gain further insight on their strengths and opportunities.

The same way that Eisenman compares Palladio's period with his own in general terms of a 'dynamic culture', this research will try to establish a similar relationship between contemporary and 19th century conditions, not only regarding architectural discipline, but also on a broader spectrum, taking into account a series of particular circumstances, ranging from technological advancements to logistical networks between Europe and Argentina. To this end, the investigation suggests a series of analogies between 19th century architecture and todays as a guideline to gain better judgement in current digital design strategies and their possibilities.

Technological analogies.

The technological innovations that occurred during the 19th century might be the most crucial and far-reaching factor that defined and transformed not only architectural discipline but the entire realm of human activities[72].

The consequences of the so-called second industrial revolution[73] regarding the use of new materials, new energy sources, transportation and communication systems were significant for our discipline, radically reshaping it like no other period before it, not just technically but also in aesthetical, economical and in organizational terms.

The invention of new materials and fabrication techniques (like cast iron, wrought iron, steel, aluminum, copper, reinforced concrete) was so impetuous that architecture could barely keep up with them, much less could it adapt to them as a unified discipline. At the same time, it was a period of interesting and unprejudiced speculation which was embodied in optimistic and experimental constructions, as we will discuss later on the case of international pavilions and other innovative structures.

Coming from the highly codified rules of classicism, the use and metabolization of new technologies was a slow and comprehensively discussed. Several theoreticians like Ruskin opposed not only to the use of industrial techniques but also to materials like cast iron[74], while architects like Violet-Le-Duc[75] embraced their use by adopting them effortlessly to his designs. This adoption ranged from a seamless, emulative use to experimental, avant-garde aesthetics.

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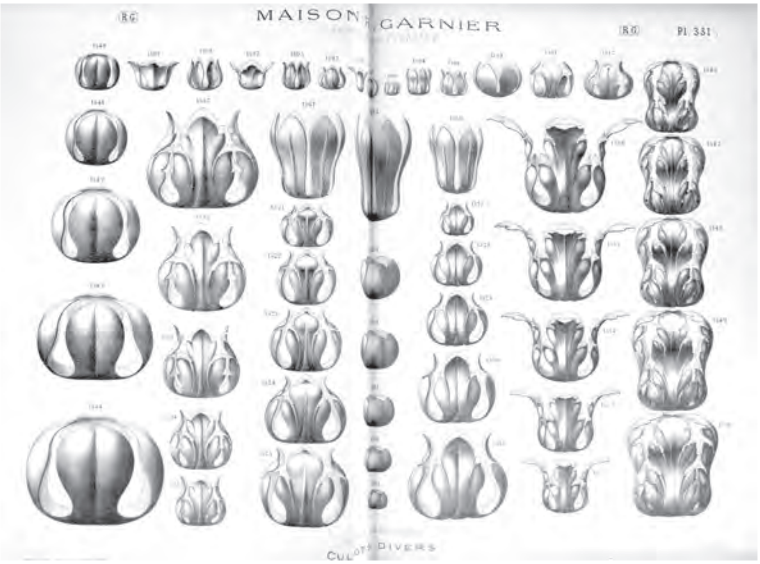
72 See Jürgen Osterhammel, The transformation of the world: A global history of the nineteenth century, America in the world (Princeton: Princeton University Press, 2014)

73 Joel Mokyr and Robert H Strotz, The Second Industrial Revolution, 1870-1914 (1998)

74 John Ruskin, The stones of Venice (New York: United States book company, 1880)

75 Eugène-Emmanuel Viollet-le-Duc, Entretiens sur l'architecture (Farnborough)



1-24 Catalog of iron ornamental pieces organized by shape and size, similar to a morpho-genetic process (Maison Garniere - Cuivrerie et Serrurerie Artistiques)
1-25 Slight variations of ornamental iron pieces, halfway between handmade forms and controlled variation (Maison Garniere - Cuivrerie et Serrurerie Artistiques)

These are just a sample of a large sequence of inventions (and micro-inventions, as Mokyr remarks), but what it is more important for this research is the internal mechanisms that our discipline put in motion in order to understand, process and integrate them to its practice.

Comparable to this particular situation, contemporary practices face similar circumstances; the fast development of rapid manufacturing techniques such as 3d printing or robotic fabrication, showing advances almost at a daily pace, are somehow comparable to 19th century enthusiasm for precast techniques, cast iron, terra cotta, ceramics, and other construction technologies.

Ruskin's rejection of cast iron was founded on the conviction that it could take any form and therefore it had no history nor 'technique' to be referenced to. His argument could be comparable to our reluctance in the use of 3d printed polymers or robotically knitted textiles in favor of more 'stable' or 'strong' materials such as bricks, reinforced concrete or steel, which ironically, were also rejected on their time.

Apart from this initial rejection, there are still more points of comparison when analyzing the role of technologies and their influence on design strategies. Mechanization, that is, the unlimited production of identical elements thanks to casting techniques or complex geometrical patterns thanks to precise tools also changed the role of the architect and his true influence on the design. Other improvements such as indirect methods of control, third-party fabrication, off-site manufacturing, thanks to the precision of technical drawings (resulting from the invention of Gaspar Monge) provided a degree of de-personalization and simultaneously, freedom to design without the limits of materials or the abilities of handworkers.

The same freedom is now available thanks to the large availability of software tools oriented to architects, industrial designers, artists or engineers and seamlessly coordinated with CNC milling machines, 3d printers or multipurpose robotic arms. Several and impressive research has been carried out in the last decade on this topic[76] however their use is still infrequent outside the universities and their integration into everyday construction is still under development.

The analogy between the inclusion of machines both in 19th century and contemporary practices can be very fruitful since the arguments against such inclusion are still comparable; while Ruskin argued against the use of machinery to produce architecture elements such as castings, molds or carving machines mainly because it 'depersonalized' fabrication and the relationship between man and the product of his labor[77], many contemporary practices reject the use of 'machines' (computational tools and fabrication robots) on the base of a loss of the authorial character or the lack of an anchor to architecture´s history [78].

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76 Fabio Gramazio et al., The robotic touch: How robots change architecture / edited by Fabio Gramazio, Matthias Kohler, Jan Willmann; translation into English: Ralf Jaeger, Berlin (Zurich, Switzerland: Park Books, 2014)

77 Ruskin, The stones of Venice

78 Jorge Silvetti, "The Muses Are Not Amused: Pandemonium in the House of Architecture," Harvard design magazine, no. 19 (2003)

The debate regarding the apparent conflict between digital tools and traditional tectonics may seem outdated now but it has been a subject of discussion at the FADU during my formative years, continuing up until this day. Contemplating from the periphery of the global debate, the FADU in general[79] has been fairly cautious on the adoption of digital design tools and digital fabrication techniques, deciding in favor of an idea of local, expressive tectonic[80]. For this matter, the importance of the research carried by the Centro Poiesis, the UAP (Parametric Architecture Unit) and the thesis of their members[81] in the dissemination and amplification of the discussion regarding the digital influence in the discipline.

Most importantly, this research intents to recall the pioneering efforts of many architects and engineers from 19th century in Europe and Argentina that not only embraced the use of new technologies but also exploited them in the most inventive and imaginative ways. The use of cast iron, for example, had no creative restrictions and was employed on every possible element of the buildings; cast iron columns, cast iron panels, utilities, roofs, decoration, furniture and many more, experimentation had no limits. We will discuss the possibilities of cast materials in more depth on the next chapters.

Design analogies.

As a reaction to the technical innovations, many architects and engineers developed novel and original design tools. These design tools or 'strategies' are a possible way or method by which architects incorporate new techniques into their own design process and internalize their results.

These strategies illustrated how the use of certain techniques influenced the designs, their processes and their outcomes. However, many of them were metabolized and 'disguised' in order to fit the aesthetical requirements of 19th century architecture taste. Sometimes they mimicked ancient styles and artifacts, sometimes they invented new ones via hybridization and mixture. This dissension between technical means and expression will be addressed in the forthcoming chapters, under the section 'Aesthetics'.

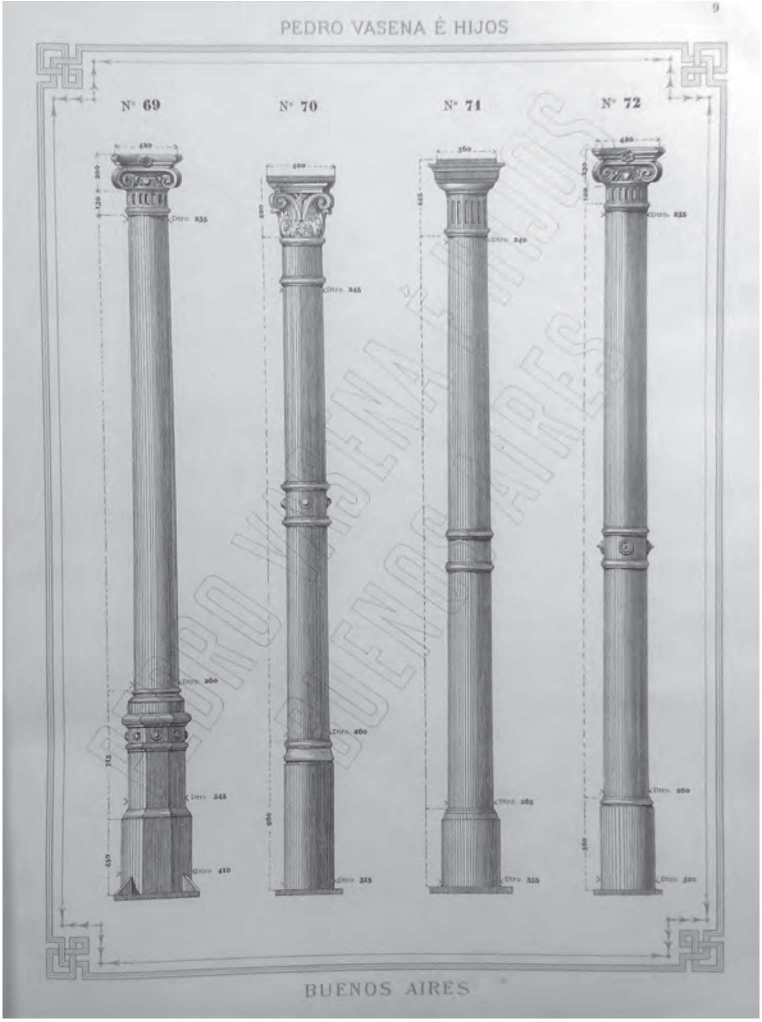
At the same time, this research is interested in tracing analogies between 19th century design tools and contemporary digital strategies. The conversion of the building activity from an artisanal activity (regulated by guilds) and handmade techniques into a proper industry led to a series of changes. These changes were not only organizational but also technical, aesthetical and financial.

Take for example, the composition of a classical façade; the ´classical strategy´ would involve the sequential drafting and architectonic decisions.

79 These are of course, generalizations since the FADU (the architecture faculty of the University of Buenos Aires) is comprised by dozens of chairs, research clusters and institutes with approximately 25.000 students. Yet the statement is founded from a personal experience of attending and teaching for 15 years.

80 Kenneth Frampton, Estudios sobre cultura tectónica: Poéticas de la construcción en la arquitectura de los siglos XIX y XX (Madrid: Akal, 1999)

81 Federico Eliaschev, "Dispositivos Proyectuales Sensibles" (Master Thesis, Centro Poiesis, Facultad de Arquitectura Diseño y Urbanismo, Universidad de Buenos Aires, 2012)



1-26 Cast iron catalogs were available worldwide, as each foundry published their own catalogs, like the Vasena Catalog in Buenos Aires (La Europea, talleres mecánicos : fundición de hierro, acero y bronce; herrería y calderería)

First the regulatory traces should be defined, then the main symmetry axes, then the secondary ones, the openings, rustication, and so on[82]. Construction companies and guilds would interpret these tracings and translate them into building elements. Suddenly, the use of industrialized materials, off-site manufacturing and precast materials added a layer of complexity to this process; for example, the addition of a steel structure that would be afterwards covered with masonry, or the use of precast terracotta panels[83]. These operations would have a distinct influence on the design process; the façade needed to be subdivided and modulated in order to organize the disposition of the precast elements. Cladding elements would need to be adapted to fit multiple positions; such as flat surfaces, corners, indentations, cornices, etc.

These operations, the subdivision of a façade in smaller, manufacturable elements, are similar to contemporary 'Panelization' techniques. Panelization is a digital design strategy consisting in the subdivision of a surface and the following 'population' with elements, for example, tiles in a roof or panels in a façade. Since the popularization of CAD tools and parametric software, there are a several tools and software plug-ins available that perform these types of operations on almost any type of mathematically defined surfaces[84].

Another analogy could be traced between 19th century soft prefabrication or 'mass customization'[85] and modern 'personalization' thanks to digital fabrication. 'Mass customization' describes the capacity of companies and factories to manufacture product lines not just identical to each other (mass production) but including variations amongst them. This allowed to different levels of flexibility in the design of pieces and molds, enabling a sort of ´personalization´ or controlled variation.

As an example, the European iron foundries printed catalogs with hundreds of designs for all sorts of products, building elements such as fences, columns or tiles, door handles, garden statues, pipes and many more. The interesting fact is that those designs were just that, designs, drawings; they were produced on-demand, on time and according to the client's specifications, very similarly to modern 'just in time'[86] manufacturing methodologies thanks to robotic fabrication and precise logistics[87].

Furthermore, current design software allows designing not just finalized

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82 As Carpo states, classical treatises did not include any information regarding the building technologies involved in their fabrication, which was carried out by construction guilds, quarries and other institutions. See Mario Carpo, The alphabet and the algorithm, Writing architecture (Cambridge, Mass., London: MIT Press, 2011)

83 The case of 'Palacio de Aguas Corrientes', will be detailed in the Historical References chapters.

84 Grasshopper and Paneling tools are some of the most popular parametric design plug-ins available to perform 'panelization' operations.

85 'Design by choice – The origins of mass customization in Europe' was an exhibition curated by Axel Sowa and Jules Schoonman in Maastricht in 2015, presenting the relationship between European iron foundries, designers and consumer products in the 19th century by exploring the enormous variety and richness presented in industry catalogs. See also Axel Sowa, ed., Design by choice: The origins of mass customization in Europe = De oorsprong van massaproductie op maat in Europa (Maastricht: Bureau Europa, 2015)

86 Just in time production or JIT is a management philosophy originated in the Toyota factory in Japan a means of meeting consumer demands with minimum delays. See http://www.ifm.eng.cam.ac.uk/research/dstools/jit-just-in-time-manufacturing/

87 Jesse Reiser and Nanako Umemoto, Atlas of novel tectonics, 1st ed. (New York: Princeton Architectural Press, 2006)

elements but ‘parametric’ entities: flexible objects that can be further adjusted and readjusted almost endlessly in the search of new possibilities and variation. This enables the creation not just objects, but ‘families’ of objects, with some common characteristics and some different ones.

Similarly, trade catalogs showed products and their variations, for example, cast iron columns on different sizes, diameters and styles, fences with multiple combinations of elements and sizes, and many more options. The flexibility that enabled such designs and variation is a relevant topic for this research, as it will be explored in the ‘Experiments’ chapters.

Condition analogies.

Apart from the technological conditions, 19th century witnessed a number of political, social and economic transformations that radically altered almost every aspect of life in the western civilization. The consolidation of modern countries and economies, the expansion of trade routes, the rapid growth of railroad networks, the reduction of shipping costs thanks to transportation technologies among other factors, precipitated a process of internationalization in many aspects like migration, finances and production.

The so called ‘first wave of globalization’ around 1870[88] reshaped and benefited Argentina in a great way:

“The countries that participated in it often took off economically, both the exporters of manufactures, people and capital, and the importers. Argentina, Australia, New Zealand, and the United States became among the richest countries in the world by exporting primary commodities white importing people, institutions and capital. All these countries left the world behind.”[89]

There are many buildings in Buenos Aires that can illustrate the extent of these transformations; this early globalization allowed for example, that the Argentinean government could hire a British engineering office to design a water facility, a Norwegian architect to design its façade, a British company to fabricate terracotta tiles and another Belgian company to manufacture the iron structure. Everything would be designed, approved, fabricated in Europe, labeled, shipped and finally assembled in Buenos Aires.

More generally, topics like globalization, outsourcing and prefabrication were defining conditions in 19th century architecture, and along with the unrestricted use of styles prevalent at the time defined a fascinating period.

The combination of these particular conditions in respect to design, fabrication and logistics promoted an unusual degree of freedom in design and fabrication, encouraging architects and engineers to innovate in many situations while assuming a conservative role in others. This research proposes to exploit those very same characteristics in contemporary architecture in order to take advantage of such freedom and explore its latent, uncharted

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88 Paul Collier and David Dollar, Globalization, growth, and poverty: Building an inclusive world economy, A World Bank policy research report (Washington, DC: World Bank; New York, 2002)

89 Collier and Dollar, Globalization, growth, and poverty

possibilities.

HYPOTHESIS.

The main question that this research proposes is: How to produce new architecture by learning from 19th century? What can we learn by asking similar questions that they've asked? Which lessons are available for contemporary digital practices?

1.

The research hypothesizes that there are several unique characteristics of 19th century architecture, especially related to freedom in design, detail and variety that can be unveiled and retrieved by performing what Eisenman calls 'close reading' of architecture, a careful observation process of architectural information, drawings, floorplans, sections and details.

Our contemporary view on historical topics can be an interesting source not only of knowledge but also of genuine inspiration. The idea is not to conduct a historical research and find new resources, but to unveil, to uncover the invisible, the unseen, the 'virtual' on buildings and material which is already available.

We can learn by asking similar questions on different backgrounds, taking an opportunity to comment on contemporary digital practices. The research proposes to 'read' 19th century projects from Europe and Argentina by recognizing innovative in design strategies tied to material and technical innovation.

2.

In terms of the attention of our discipline to the period, the hypothesis of this research is to create a complementary narrative of the late 19th century (1870-1930), by finding hidden, ignored characteristics but nevertheless inventive and original, in projects from Europe and Argentina. Architecture historians such as Siegfried Giedion[90], Henry-Russell Hitchcock[91] and Ulrich Pfammater[92] had written extensively on these topics, establishing compelling narratives connecting 19th century architecture to modernism and in the case of Pfammater, to contemporary production.

The study of these characteristics will be performed in a graphical language, by using architectural information; floor plans, sections, perspective drawings and models as well as an observation of the buildings, in case they

90 S. Giedion, Mechanization takes command: A contribution to anonymous history / Siegfried Giedion; afterword by Stanislaus von Moos, First University of Minnesota Press edition (Minneapolis: University of Minnesota Press, 2013)

91 Henry Russell Hitchcock, Architecture nineteenth and twentieth centuries, The Pelican history of art Z15 (Harmondsworth Middlesex: Penguin Books, 1958)

92 Ulrich Pfammatter, Building the future: Building technology and cultural history from the Industrial Revolution until today (Munich, London: Prestel, 2008)

are available.

Peter Eisenman explains in 'Palladio Virtuel' that the Venetian architect redrew his projects not as they were built but as Palladio wanted them to be known, as yet another act of redesign:

"The reality of Palladio's work therefore exists between the drawings and the buildings themselves, as a virtual Palladio (…)"[93]

The same way this research proposes to revise these projects in this mixed virtual plane, by focusing on specific material, formal or spatial aspects and by making them visible graphically, or virtually present. However, this is not a historical revision of primary or secondary sources, but a creative outlook on the innovative characteristics in historical projects.

3.

Through the deployment of several sets of experiments and their classification, the research speculates on the systematization of technical and methodological procedures inherited from a historical Context. The identification of this Context, the study of its design tools and fabrication processes are considered as information that may be coded into a digital design process that can be modified, transmitted and re-deployed.

4.

The set of experiments proposed on this research may act as initiators to new design investigations, by systematizing not only the production but also the analysis of its products, particularly in relation to disciplinary knowledge and its creative deployment.

Digital design approach.

At the same time, this research intends to cast a new view on design procedures based on digital tools, using historical references from 19th century projects. There are several approaches available when it comes to undertake a design process with digital tools.

My own experience in the subject was oriented initially towards the design of housing projects using parametric techniques[94] under the framework of Centro POIESIS at the University of Buenos Aires and its digital branch 'Unidad de Arquitectura Paramétrica' (UAP), whose members have also made interesting advances on the use of parametric tools and evolutionary algorithms for the design of complex multi-programmatic housing projects. Federico Eliaschev's master and doctoral thesis[95] are pioneering works on this area in the context

93 Eisenman and Roman, Palladio Virtuel

94 Federico Garrido, "Proyectos de vivienda para la emergencia social y ambiental generados con metodologías digitales," (unpublished manuscript, 2012)

95 Federico Eliaschev, Dispositivos Proyectuales Sensibles (Buenos Aires, Argentina: Concentra, 2017)

of Argentina regarding digital architecture. The research done at the UAP was oriented towards the inclusion and interpretation of user and environmental information, including user's dimensions, programmatic and aesthetical needs, scheduled activities, contextual information, light, and many other parameters.

Most of the research done at the UAP regarding combinatorial tools, designing projects that operate by combining different ´ready-made´ pieces or with little variation. In addition, we could mention another approach to digital methodologies regarding structures and the definition of structural elements like roofs or space frames. This can be defined as a 'structural approach' to design, described for example in Oliver Tessmann's doctoral thesis[96] , which is only an example among many other academic works. On this case, the inclusion of the digital tools is oriented towards the optimization of structural shapes when they are set under the influence of forces like gravity or wind. The creative use of these techniques is referred as 'form finding' processes, as the relationship between forces, shapes and restrictions interact in order to achieve a harmonious or 'self-organized' result.

The thesis' approach is different in the sense that it proposes to begin with historical references, not only as an aesthetic or material point of departure but as an organizational framework from which to systematize the rest of the design operations. The list of parameters, that is, the mathematical variables that control each element of the project is then defined by an analysis and interpretation of a case study. For example, when designing a parametric model of a façade, the variables involved in the parametric definition will have to be extracted, initially, from the architectural elements in the reference, like columns, pilasters, windows, niches, and so on. Not only the elements are important but the dimensions, sequences and overall relationships between the elements themselves are also relevant and their analysis and reutilization is at the core of this research.

The definition, dimensions and relationships between architectural elements are the key components of this research; their analysis, parametrization (the translation into mathematical variables) and controlled deployment is a central goal of this work.

96 Oliver Tessmann, Collaborative design procedures for architects and engineers (2008)

PART 1

- *Topics*

The following chapters are organized under a broad category defined as 'Theory', identifying and classifying a number of topics of interest originated in the review of historical case studies from 19th century with the intention to speculate about their influence in contemporary architectural practices supported by digital tools.

As the research focuses on tools and strategies, the topics were selected, analyzed and descripted in terms of their association to design strategies and manufacturing techniques that enabled the conception and materialization of the case study projects presented in Part 2. In some way, this part functions as a guide to 'read' the case studies.

This first part is structured in three main categories: Construction, Aesthetics and Conditions. From the perspective of a Design Research, consisting in text, images and drawings covering the description, analysis and critique of theoretical subjects and topics of interest from the 19th century period relevant to this research.

The partition of topics under the three aforementioned categories is purely organizational, as the research considers them intertwined with each other, and their isolated analysis is covered by specialized literature of the period. The division in Construction, Aesthetics and Conditions serves not only to guide the analysis of case studies from Part 2 but also, in a more subtle way, for the organization the design experiments from Part 3.

For this reason, it is possible to track certain topics through the entire length of this publication, in a non-linear reading. For example, the description of the new geometric possibilities of iron construction are present in the Construction and Aesthetic chapters, but also in the graphical analysis of the Sayn Foundry and on several design experiments using parametric design.

CHAPTER 02

- *Construction*

ON MATERIAL CULTURE.

Advances on iron and glass.

"The first Industrial Revolution - and most technological developments preceding it- had little or no scientific base. It created a chemical industry with no chemistry, an iron industry without metallurgy, power machinery without thermodynamics. Engineering, medical technology, and agriculture until 1850 were pragmatic bodies of applied knowledge in which things were known to work, but rarely was it understood why they worked"[1]

For centuries, architectural elements were made more or less in variations of the same materials: wood, natural stones and fired ceramics. Around the 1st century B.C. the use of lime and structural mortars were introduced by the romans on what historians call the ´Concrete revolution´. Their use allowed the expansion of the empire´s physical presence in the form of all types of infrastructure: temples, aqueducts, baths, theaters, circuses, bridges and all sorts of civil and military buildings.

Eighteen centuries later, another revolution was about to burst, this time from the furnaces of central Europe.

There were three types of iron alloys used in buildings in the 19th century: wrought iron, cast iron and mild steel. The main difference in their composition is the presence of carbon which grants different material characteristics, altering their fabrication process, their resistance capabilities and their potential use in construction.

Wrought iron was produced by hammering red hot iron ore and charcoal, this process simultaneously reduced the content of iron oxide and shaped the mixture for its final use, from bars, swords and utensils. Its use in architecture can be traced to antiquity; Romans used it to hold construction stones together by embedding wrought iron bars in their version of concrete. It was then used in several medieval buildings, such as the Palatine chapel in Aachen, Germany, Saint Peter´s in Rome and Saint Paul's in London. The main use of this material was in the form of bars or chains in order to secure the expansion forces in large masonry domes and linear vaults[2].

Before industrialization, the manufacturing process was made by manual

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1 Joel Mokyr and Robert H Strotz, The Second Industrial Revolution, 1870-1914 (1998)

2 Bill Addis, "The iron revolution.: How iron replaced traditional structural material between 1770 and 1870," in Rinke; Schwartz, Before steel

hammering or by roller mills, limiting the dimensions of the pieces, their resistance properties and their potential use in buildings. The mechanization of production allowed bigger elements and a higher degree of precision, steering their fabrication towards the standardization of production quality. It also enabled the possibility of manufacturing larger parts by joining and riveting different sections, such as I, C, L and H profiles. Thanks to its unprecedented mechanical properties against compression and tensile efforts, wrought iron was ideal for columns, beams and trusses.

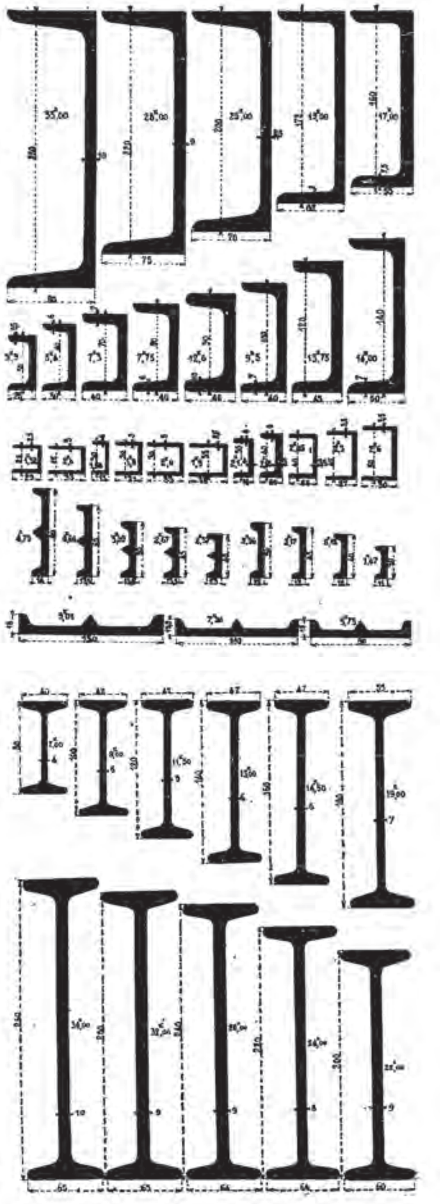
Metal casting was also used before industrialization for the production of monolithic pieces like large bells and cannons. The method of production required a master cast or pattern, made of wood consisting in one or several parts, being able to produce more complex elements than the ones made by hammering or rolling. At the same time, it was possible to cast hollow shapes with relatively thin thickness, thus reducing use of material and weight thus lowering their cost. Thanks to the accumulated practical knowledge through centuries, by the time industrialization techniques extended over Europe, its adoption was swift. It is also important to state that because iron casting was no different than any other metal casting, its production process was not drastically altered by industrialization.

The main appeal of this type of production was the possibility of complex and detailed forms, not only reduced to simple, 'rolled' profiles but now open to more intricate and elaborate designs. The downside was that pouring melt iron in the cast caused a heterogeneous material, full of impurities like slag that compromised the structural qualities of the elements, thus limiting their use in load bearing structures. Unlike wrought iron, cast elements were brittle and had little tensile strength, making them suitable only in columns (submitted to almost pure compression efforts) or ornamental pieces. The problem of brittleness and poor tensile resistance was partially solved by increasing the element´s section, naturally increasing the weight and cost.

Lastly, steel was introduced by developing a fabrication procedure (almost simultaneously by H. Bessemer and W. Kelly) that reduced the amount of carbon in iron ore in a closely controlled process. After that, the Siemens-Martin process improved the procedure and became widely popular until the beginning of the 20th century.

Steel was used the exact same way as wrought iron, but since it was purer and more reliable, the sections were reduced, pieces became smaller and construction began to dematerialize. Curiously, since steel had the same basic properties than wrought iron (in terms of resistance to compressive and tensile forces), its use had no distinctive influence on the design of structural pieces, other than the aforementioned size reduction.

19th century witnessed an explosion in the use of iron in construction, mostly thanks to two main factors: availability and reliability. Important changes in international politics led to a sustained period of peace (thanks to the Napoleonic Wars), commerce, finance and logistics changed entirely the way architecture and building materials were produced and distributed globally.



2-1 Structural personalization. Wrought iron profiles of different sizes and thicknesses available at the end of the 19th century.

As Mario Carpo[3] stated, prefabrication and the dissemination of architectural elements may have begun in gothic quarries, were Medieval builders produced identical elements and the distributed to several sites across Europe. This situation shifted in Renaissance, were printed books, in the form of treatises and manuals spread what Carpo defines as 'predesigned' architectural elements, according to the five orders but with no material 'weight'. Classical elements could be built in marble, stone, wood; the treatises did not provide recommendations or details regarding material.

At the beginning of 19h century, trade routes crossed the globe and the circulation of people, goods and currency was only restricted by short military conflicts[4]. A large variety of iron manufactures in the form of consumer products, architectural ornaments, building materials, utilities and machine parts, among many others was at that time, available at a global scale. Railroads in North America, train stations in India, water facilities in Argentina and bridges in France, are just examples of a proto-globalization process driven by the unique characteristics of iron and efficient logistics.

Iron and steel were homogenized materials, ductile, isotropic and uniform; as a result of a controlled industrial process their use and manipulation were highly codified and their behavior, reliable and trustworthy[5]. Material engineering was established in 19th century as a multidisciplinary source of knowledge; the study of material properties, the tabulation of its attributes and the prediction of its behavior held a key role in their dissemination.

Like every aspect of human life since the Enlightenment, materials went through a process of study and scientification. The science of materials, no longer dependent on local specificities nor the abilities of artisans was a product of experimentation, close observation and repeatability. Its study became a science, white its fabrication became a technology.

Engineers like Claude-Louis Henri Navier and Camille Polonceau were only two examples of a long list of 18th and 19th century scholars who defined the use of iron structures by studying and systematizing material properties, structural behavior and geometry. The result of this process was a series of 'standard' practices, material charts and calculation methods in order to design sound structures. This expertise in the use of materials also marked the clear separation of engineering and architecture disciplines; the first focused on the behavior of materials and structures and the latter on the creation of space and ornamentation.

Manufactured by a standardized process, with standard properties allowed the commercialization of iron and steel pieces worldwide. This global availability and reliability ensured that the roof of a train station in Buenos Aires could be assembled the same way, and would stand loads similarly as one in Bombay or in London. The standardization of parts, practices and calculation methods

3 Mario Carpo, Architecture in the age of printing: Orality, writing, typography, and printed images in the history of architectural theory. Translated by Sarah Benson (Cambridge, Mass., London: MIT Press, 2001)

4 Frederick C. Schneid, Mid-Nineteenth-Century European Wars (Oxford University Press, 2012). https://doi.org/10.1093/obo/9780199791279-0043

5 Manuel De Landa, "Philosophies of Design: The Case of Modelling Software," in Verb (Architecture Boogazine): Processing (2001)

provided a great deal of freedom for the design of light, large-span complex structures, never before available in the history of architecture.

This freedom had a great deal of influence on the design disciplines, as several structural types were developed simultaneously. Polonceau, Town, Vierendeel trusses were just some examples of structural design, and to this day, several elements still bear their names.

Also, different calculation methods were defined (like Cremona, Cullman or Ritter[6]) in order to understand structures and predict their behavior with precision but more importantly, without effort.

The calculation methods divided the structure in small parts and calculated the resistance of each structural member and the relationship with its neighboring elements. It provided the basis for several experimentations in structural types, each one pushing the limits of the material, structural types and the calculation methods themselves.

Experimental structures were developed in order to maximize supported loads, lengths and spans with minimum material. Engineering (and not Architecture) pushed relentlessly towards optimization.

Bridges and train stations were at the top of the list in these experimentations, as the need for large structures was first required by the booming railroad industry. Similarly, the need for large covered spaces was also a requisite for several urban infrastructure pieces (a novelty at that time) such as market halls, theaters and exhibition spaces.

19th century was an outstanding period for structural experimentation not only thanks to the advancements in statics and material engineering, but also thanks to the pioneering efforts and imagination of a new breed of professionals that were suddenly empowered by an unusual degree of freedom.

It should be noted that while such freedom was applied to architectural form, structural types were more or less standardized, as calculation methods tended to simplify their behavior under stress. This way, they were easy to comprehend and their execution was more organized.

To this day, standardization of materials, calculation methods and execution still affects our practices.

Regarding the influence of steel building techniques and calculation in contemporary design, Manuel Delanda[7] explains that homogenized materials like steel are at the core of contemporary CAD design software and the design philosophy behind them. Formal procedures in digital software such as extrusions, revolutions or Boolean operations depend on the capacity of the computers to simulate material states; on the case of CAD programs, the crystal state is the easiest to replicate and as such, the resulting operations are applied to a homogeneous, virtual material.

Moreover, three-dimensional software common modeling tools are directly derived from steel fabrication, like “extrusion” or “revolution” performing similarly as an extruder or a lathe.

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6 Karl-Eugen Kurrer, The History of the Theory of Structures: From Arch Analysis to Computational Mechanics (Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA, 2008). https://doi.org/10.1002/9783433600160

7 De Landa, “Philosophies of Design: The Case of Modelling Software” in Verb (Architecture Boogazine)

Recent design software packages, such as Rhinoceros-Grasshopper or Autodesk Fusion include the possibility of material behavior and the design of complex structures, thanks to new calculation methods such as Finite Element Analysis (FEA).

Innovations in glass.

Simultaneous to the expansion of iron fabrication techniques, several developments in the field of glass took place. Like many other technologies in the 19th century, the impulse on glass fabrication was not fueled by specific breakthroughs but for the broader push of industrialization and numerous small innovations, what Mokyr defines as ´Micro inventions´[8]. After the cancellation of a lucrative tax on glass pieces in Britain (they were taxed by weight, resulting in the fabrication of small pieces) the industry could finally take off in 1845.

Innovations in the manufacturing process like machine polishing (around 1800) and the ´Rolled Plate´ method (1847) made the production of large quantities of flat glass possible. One must have in mind, that a large availability of glass plates was an absolute prerequisite for buildings like the Cristal Palace (1850) and the Munich Glaspalast (1853). Other inventions like an early automatization process and the development of float glass by Henry Bessemer were also significant but too complex and expensive for their time.

Glasshouses took advantage of industrial manufacturing techniques since the beginnings of 19th century. The use of prefabricated architectural elements, curvilinear shapes and complex roofs were introduced by pioneers like John Loudon[9], whose greenhouses and publications influenced garden and glasshouse designers.

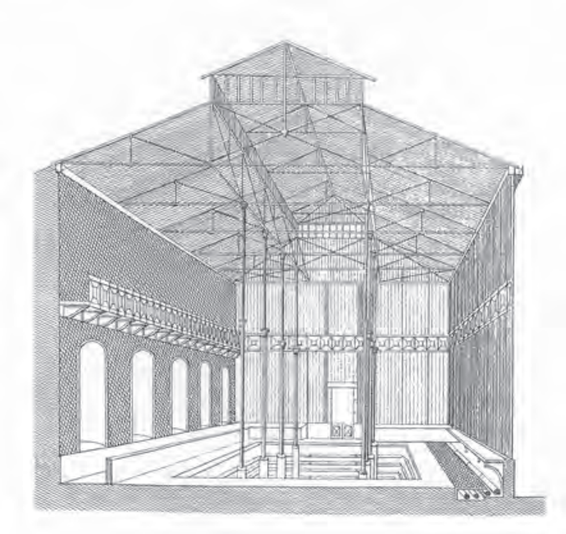
The rationalization and industrialization of architectural elements began in France and expanded to Europe, where its popularization increased rapidly. At the same time, a growing interest in construction technologies and the possibility of new spatial types caused a shift in the use of the glasshouses, from a botanical hothouse for preservation and development, to a more 'cultural event space', as Ulrich Pfammater defines it. Turner's ´Great Palm house´ in Kiew and Paxton's ´Cristal palace´ are examples of this shift where these new typologies made their entrance into the social life.

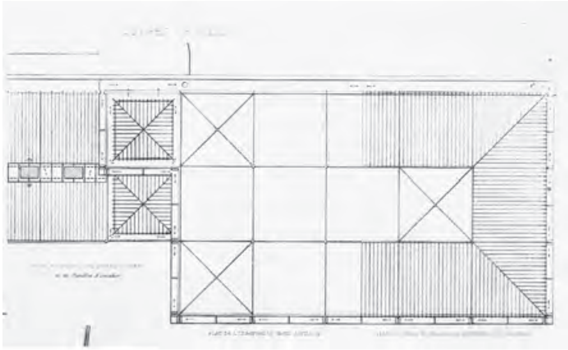
These new trends in glasshouse design were not only reduced to a single architectural program or typology but were rapidly extending to the whole building industry. In fact, the conversion of the building erection process into a proper 'industry' was propelled by the pioneering techniques used in the construction of these two iconic buildings. What was defined as 'new trends' in building techniques was later expanded and further developed into what we know today not only in terms of building technology but also in the fields of

8 Joel Mokyr, Lever of Riches: Technological Creativity and Economic Progress / Joel Mokyr, New ed. (1992)

9 J. C. Loudon, An encyclopedia of gardening; comprising the theory and practice of horticulture, floriculture, arboriculture, and landscape-gardening, including all the latest improvements: A general history of gardening in all countries; and a statistical view of its present state, with suggestions for its future progress in the British Isles., Longman, Hurst, Rees, Orme, Brown, and Green (London, 1825)

2-2 One of the technical enablers of the open space. Glass Roof of the Crystal Palace.
2-3 The building innovative materials and construction technology demanded equally innovative tools for its assembly.





2-4 Formal modulation imposes over structural rationality. Jardin des Plantes by C. R. de Fleury (1836) building organization, logistics and material engineering.

To summarize a short but comprehensive description of these 'new trends' according to Pfammater:

"...in the standardization of building production and assembly thanks to a rational mindset and a grid with regard to space and construction –the key to high speed and low cost; in limiting the number of component parts to just a few, in prefabrication in workshops under controlled conditions (consistent quality), on-site dry assembly (apart from glass puttying) and a uniform design (dimensions, profiles, connections). (...) The industrial mindset was at the same time a construction programme and ultimately determined spatial quality, method, shape, detailed figure creation and the perception of a new type of transparency"[10]

Scheduled construction, just-in-time production and delivery, precise and standardized detailing, industrialization of building sites, large machines like mobile cranes and mobile scaffolding, direct connection to the railways and an overall multidisciplinary approach to construction made these buildings possible and still describe the complexities of our activity.

The backgrounds from glasshouse builders were diverse; gardeners, botanists, inventors, engineers, landscapists and of course, architects. The influx of these disciplines in the design of new structural and spatial types was indeed revitalizing, as well as the attempts of trained architects to align them with their contemporary architectural theories.

An interesting case is Charles Fleury, a disciple of Jean Nicolas-Louis Durand, who built the ´Jardin des Plantes´ in Paris (1833). His pavilion was an example of Durand's composition grammar, based on the use of regular grids, not only on floorplan organization but also three-dimensionally. Although Durand's method was originally devised to be used in stone or masonry, on this example, the spatial and structural modulation finally met industrialized construction and building organization.

Pfammater also notes something interesting about the structure of the glasshouse: there are slender iron columns in the junctions where they are not structurally required, since the truss is already supported on its ends. These columns are however a requisite in the grid organization of the floorplan (according to Durand's method). Pfammater defined this apparent misinterpretation as 'creative misunderstanding'. This operation may be an interesting characteristic of this period where compositional rules encountered new materials and their possibilities. This unconscious or deliberate 'mistakes' will appear often as 'translation errors', and are of a great importance for this research for their creative and expressive potential.

New spatial types.

The rapid expansion of railroad infrastructure overlaid large pieces of manmade structures on top of natural and artificial landscapes; bridges were assembled

10 Ulrich Pfammatter, Building the future: Building technology and cultural history from the Industrial Revolution until today (Munich, London: Prestel, 2008)

in order to connect to previously separated portions of land and train stations were built in order to connect this infrastructure to the existing urban tissue.

Both bridges and train stations were typical constructions of the 19th century, illustrating not only the new capabilities of materials (thanks to innovations in iron, glass, wood, and others) and technical expertise (thanks to the creation of new disciplines, schools, universities and institutions[11]) but also as the illustration of a new conception of distance and time. The world became smaller, and the train stations became the gates of this new world.

Train stations were a great analogy of the clash between technical-driven infrastructural constructions and the stylistic requirements of iconical buildings in 19th century. As Giedion[12] explained, for the first time in history architect and engineer were separated and train stations were a perfect metaphor of this division. The exterior was designed according to the stylistic preference of the architect and the site requirements while the interior, the large halls and platforms were conveniently assembled with technical efficiency and precision by the civil engineers.

Civil engineering departed as a discipline from military engineering (previously in charge of roads, bridges and fortresses), and it was responsible for the design, calculation and construction of roads, bridges, facilities, ports, large halls, stations and many infrastructural elements outside military facilities. These elements enjoyed an explosion in demand and were suddenly required in the expanding cities of the 1800s.

The apparent conflict between architectural Beaux-arts aesthetics and sheer technical solutions of engineering were one of the many causes of the crisis regarding styles in the 19th century. Historians like Giedion explained, much of these technical buildings were 'dressed' in 'historicist' clothes, without any other reason than to mitigate their blunt expression.

The divergence between Beaux-arts and engineering was partially illustrated in train stations. An academic façade and a large shed coexisted with no interface between them. While the historicist front faced the city and its aesthetical requirements, iron and glass structures covered the platforms providing shelter to the constant movement of men and machines.

Train stations and bridges provided a testing ground for new structural types, and despite the few parameters that drove their design (large spans, minimum material use, structural repetition, standardization of pieces and joints) several creative solutions were developed.

Saint Pancras, King´s Cross, Paddington stations in London, Gare du Lyon and Gare du Nord in Paris were just examples of collaborative multidisciplinary work between architecture and engineering. In Argentina, train stations like Estación Constitución (1885) and Estación Retiro (1905) combined references to French academicism, eclecticism, neo-renaissance and Victorian architecture. In the case of Constitución, the use of mansards, attics, domes and sculptures

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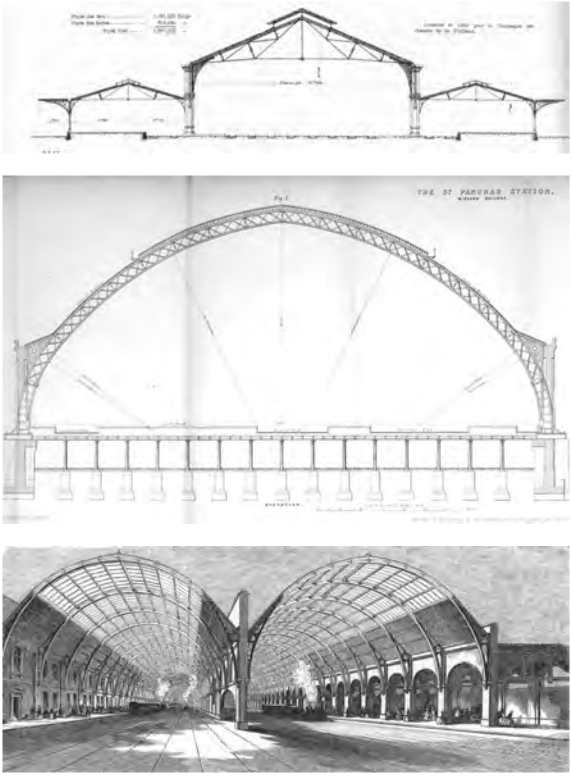
11 Ulrich Pfammatter, The making of the modern architect and engineer: The origins and development of a scientific and industrially oriented education (Basel, Boston: Birkhauser-Publishers for Architecture, 2000)

12 S. Giedion, Space, time and architecture: The growth of a new tradition / Sigfried Giedion, 5th ed., rev. and enl, The Charles Eliot Norton lectures 1938-1939 (Cambridge, Mass., London: Harvard University Press, 2008)



2-5 Large span structures from mid-19th century. Comparison between rail station platforms. Train Gare d´Austerlitz by P.L. Renaud (Paris, 1865) , Saint Pancras Station by W.H. Barlow (London, 1868), Kings Cross Station by L. Cubitt (London, 1852) and the articulation between a central and lateral bodies were directly inspired in French castles like Maisons-Lafitte.

Estación Constitución's 'palatial' aesthetics while covering technical solutions was one of the firsts examples of its kind in Argentina and it would become a common practice for engineering facilities and infrastructural pieces. From then on, utilitarian buildings would become 'Palaces': the 'Palacio de Aguas' (Palace of waters', later described and analyzed in the Historical Reference chapters) was the central water deposit, 'Palacio de Correos' ('Postal palace') and even electrical power plants were ornamented in eclectic clothes, like the Usina Puerto Nuevo.

Another type of typology developed in 19th century was the large exhibition hall. They were inaugurated by the Crystal Palace (Paxton, 1851) and the München Glaspalast (von Voit, 1854). Originated in medieval trade fairs, international exhibitions began due to the proliferation of industrial manufactures and the need of commercial outlets for their production. Nations were then convinced to organize international exhibitions as a showcase for their products in order to expand their markets by presenting themselves, their production and their culture to the rest of the world. All sorts of manufactured goods were exhibited in these halls, from large machines to consumer goods, textiles, artworks and plants and the need for large, covered spaces became a possibility thanks to iron and glass technologies.

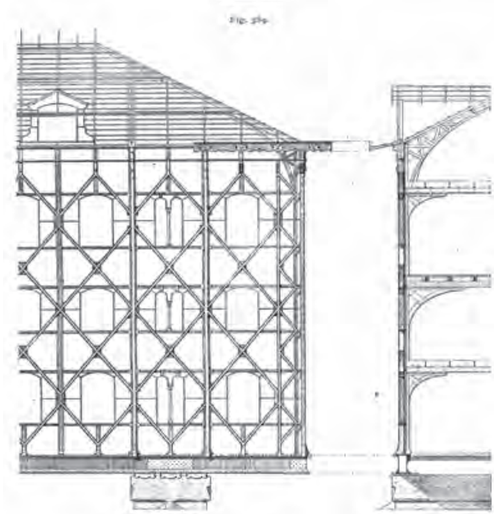
As a spatial type, the Crystal Palace presented a modular configuration extended in three dimensions: it was an open, modular system that could be expanded in any direction and stacked in height just by recombining columns and trusses. More importantly, it presented its audience a large luminous space, a controlled environment where the traditional architectural values like solidity and weight were replaced by lightness and dematerialization.

Similarly, several infrastructural elements were needed in the cities in order to manage their continuous growth and the needs of their population. Water deposits, market halls, public baths, factories, warehouses were just examples of the part-building-part-machine typical in the 19th century. Mechanization and machines became a constituent part of the construction, used to maintain the temperature, regulate humidity, get rid of rain waters and animate water fountains. Even the Crystal Palace had mechanized ventilation systems, used its structure as rain drainage and had steam engine transmissions.

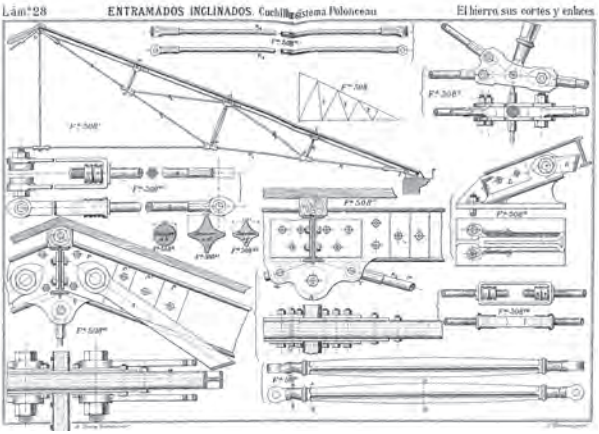
Development of new structural types.

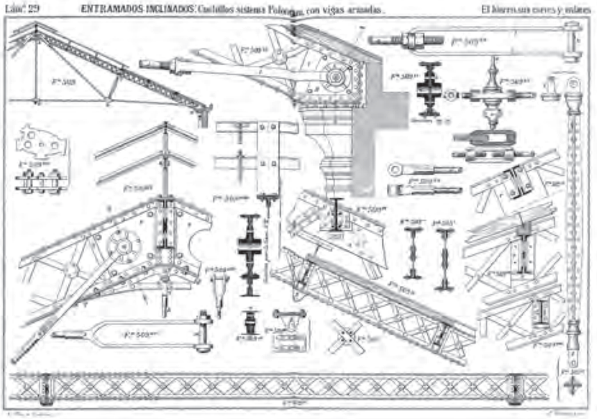
The large availability and reduced cost of iron made it available to the building industry and its use permeated almost every aspect of construction. It replaced wood in roofs, stone and masonry in structures and facades, bronze in decorations and earthenware and lead in water management.

The translation process from wood, masonry and stone to iron architecture was irregular but nevertheless an interesting one. So far, the main quality of material in architecture was to ascertain its own presence, its weight, what Vitruvius defined as Firmitas. Moreover, such Firmitas would include not only the fact of effectively provide support but also, its representation.



2-6 The Menier Chocolate factory by J. Saulnier (Noisel, 1872), one of the first experiments in iron structures, mimicking traditional half-timber work.
2-7 Detail of a wall panel, where the brickwork is used entirely as an ornamental element.





2-8 Structural kit of parts. Piece catalog for Polonceau trusses for sloped roofs.
2-9 Piece catalog and connection details for riveted wrought iron structures.

This representation of support was therefore illustrated in the shape of columns, arches, walls along with their textures, segmentations and rustications. Iron architecture would change radically that notion by altering its very perception; the elements were slender and light, almost fragile in comparison to the classical robustness. This shift in the perception of structural proportions will be discussed in terms of the translation processes between building technologies later in the Aesthetics chapter.

But even more important than lightness, the use iron columns and trusses made possible something far more relevant to our discipline: the separation of structure from walls. This characteristic segregated the structure from other architectural elements, liberating its use, expression and signification.

The Menier chocolate factory by Jules Saulnier (Noisiel, 1871) is considered the first multi-storey iron skeleton structure, while its walls are designed only as infill with no supporting role. As many 19th century buildings, this was a hybrid construction both in material terms (stone pillars, iron structure, brick walls, ceramic decoration in facades, wooden roofs) and in program; part building, part machine, part advertisement and typologically similar to a bridge. It is a great illustration of the period's inventiveness and open-minded approach to construction. The building´s location directly over a power source (a river stream) is a fantastic metaphor for the period´s relationship between building and site; energy resources and transportation infrastructure became the novel commodities of the period.

The final separation of load bearing structure from enclosure would be highly regarded later on by modern architects as the grammatical distinction between building elements reassured yet again by the idea of a clear relationship between (component) form and (structural) function.

The conflict between 'monumentality versus dematerialization', described in Berthold Hub's essay[13], is exemplified in the progressive disintegration of structural elements thanks to the combination of precise multi-part fabrication and assembly and the evolution of structural calculus and graphical statics. What was initially a massive, homogeneous and monumental element like a column or an architrave was then decomposed in a combination of short, slender elements, organized in the form of branches, webs or a sparse fabric. What was massive, became light, what was one, became decomposed. The binomial structure inherited from classical antiquity composed by column and architrave was going to be replaced by a new one, of a different nature, composed of trusses, arches and articulated supports.

The new structural possibilities of iron and its combinations allowed the invention of novel structural elements. Although the first iron structures mimicked timber construction, the development of joint technologies, advanced calculus and the improvement of manufacturing precision made possible a series of increasingly complex structural assemblies like trusses, girders and ribs.

The word 'truss' is originated in the Old French 'trousse', "collection of

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13 Berthold Hub, "Architect versus Engineer: Monumentality versus Dematerialization," in Rinke; Schwartz, Before steel

things bound together"[14]. It represents a structural element, an assembly of linear components behaving as a single object, typically arranged in triangulated shapes.

Town's lattice truss, Allan truss, Bailey Truss, Pratt truss, Lenticular truss and Vierendeel truss are just some examples of the variety of configurations on a single structural type. The Poloceau truss (the product of a thesis by Camille Polonceau), one of the most successful structural design for roof support of the 19th century, began as a translation of wood structures but oriented towards efficiency, by using less material but lacking architectural expression. The conflict between purely artistic expression and purely engineering solutions was a common one in 19th century. Nevertheless Polonceau´s typology was very successful and its use spanned all over Europe. As an example of his influence over the continent, a comparison between the works of Camille Polonceau and Paul Joseph Ardant in Belgian public buildings is addressed in the paper "Polonceau versus Ardant: efficiency versus aesthetics?"[15].

Prior to this conflict some hybrid and interesting solutions were also developed, particularly by iron manufacturers and artisans. They operated without the pre-figurations of design disciplines or mathematical certainties but in close contact with the material, in a trial-and-error basis. The case of the Sayn Foundry by Carl Ludwig Althans (Bendorf, 1828) is particularly attractive; the invention of a structural panel was a mixture between a gothic lattice and a segmented arch. There is no previous model to copy or typology to be inspired from, its expression is utterly inventive as it was not driven by pure aesthetics (the composition is an amalgam of gothic and industrial elements) neither by material efficiency (the construction is full of structural redundancies).

The 19th century exemplified the shift from a highly codified, representational structure to the purely geometric expression and simplification of gravitational forces. A column did not represent solidity anymore but the quickest path of the building´s forces towards the ground. On this regard, some examples made use of the ornamental capabilities of cast iron, like the arches of Bibliothèque Genevieve by Henri Labrouste (Paris, 1861) and alarmed architects as the monumental characteristics of traditional buildings were endangered. The transition to a purely geometrical expression, like the popular Polonceau Truss, accelerated even more this sentiment.

ON EXPRESSION.

Multi-material approach.

On his book 'Architecture in the Age of printing'[16] Mario Carpo establishes a

14 http://www.etymonline.com/index.php?term=truss

15 Michael de Bouw and Ine Wouters, Polonceau versus Ardant: Efficiency versus aesthetics? (2011). https://doi.org/10.2495/STR110271

16 Carpo, Architecture in the age of printing

relationship between the invention of printing technologies and the propagation of architectural ideas through the circulation of treatises during the Renaissance. In his thesis, the briefly addresses a pattern that associates every mayor architectural period to specific material or structural development:

"…the Ancient Greek with trabeation, Roman with the arch, Gothic with stereotomy, right through modernism with reinforced concrete) …"

In relation to the material characteristics of architectural elements in Renaissance treatises, Carpo describes the lack of such information and the consequences of their dissemination across Europe (and eventually America as well):

"The Renaissance orders were not prefabricated. They were predesigned. With few exceptions, Renaissance treatises define architectural "orders" (columns, capitals, lintels, etc.) that are singularly lacking in material weight. What are they made out of? Wood, marble, stone, brick, stucco? How are they made? By whom? With what instruments? At what price? The books don't tell us. Despite the standardized production of tens—sometimes hundreds—of identical architectural components destined for the same building, the concept of economies of scale does not belong to the sixteenth century."[17]

According to Carpo, this lack of information proved to be very effective, since the availability of materials, machines and tools was certainly irregular in Europe. With this in mind, only people and books could be freely distributed and such limitations and freedom left its mark on the period. Prefabrication and 'predesign' took the form of the popularization of the five orders, their proportions and inner geometrical relationships. Naturally, prefabrication and predesigned elements acquired a different meaning and significance thanks to the industrial age:

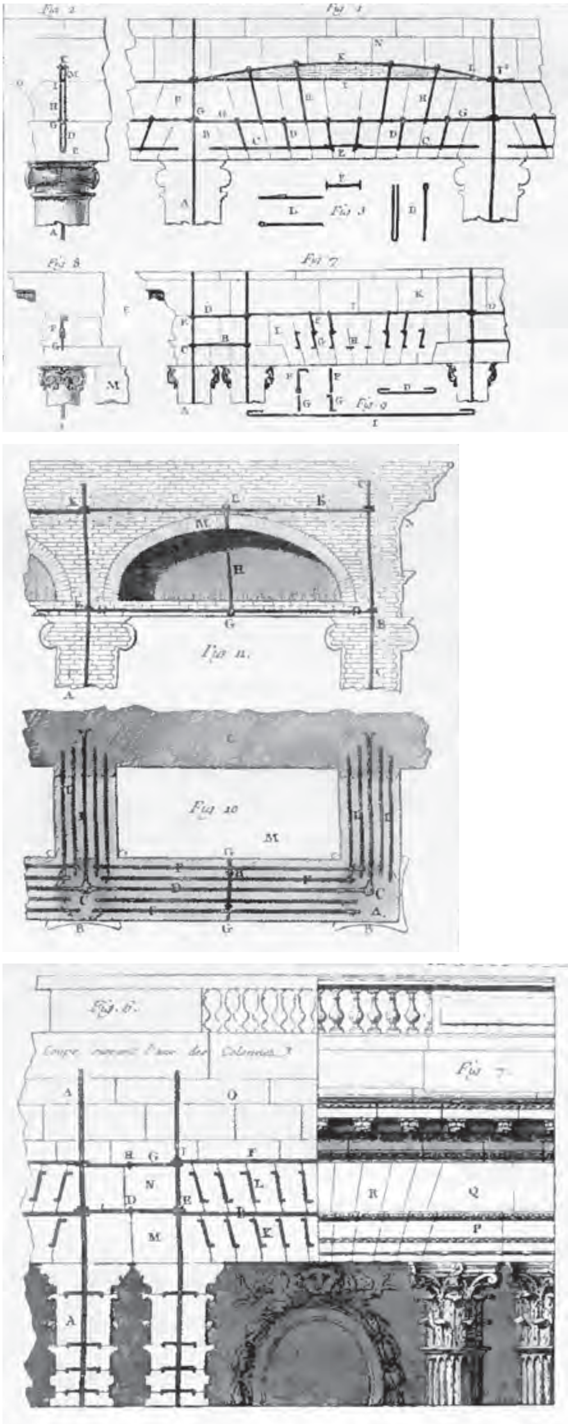
"Logically, a history of the relationship between culture and industry should begin with the industrial revolution: enclosures, the crisis of the guild system, the power loom, coal, steel, and so on. As far as the industrialization of architecture is concerned, the scenario that has been commonly accepted runs the following course: first came the diffusion of new construction materials, then the resistance of traditionalist or reactionary architects in the nineteenth century, and in the end the purifying act of the pioneers of modernism who invented—or liberated—the architectural forms appropriate to the new machine age."[18]

Arguably, the material that shaped 19th century was iron. But, in historical terms, the origins of iron as an architectural material are rooted in a multi-material conception of construction. As Tom Peters explains:

"The material iron found its way into construction as soon as it became available in ancient times, first as nails, bolts and hinges, cramps, ties, and short bars –in other words as subsidiary components. The reason for this was that iron was expensive to produce until the Industrial Revolution, and its quality vary with its impurities, chiefly carbon, and are difficult to control.

17 Carpo, Architecture in the age of printing

18 Carpo, Architecture in the age of printing



2-10 Classicist architecture and its hidden structure. Iron reinforcements on Perrault's Colonnade at the Louvre (Paris, 1667).

So for centuries iron remained a non-structural material that builders used only sparingly to solve difficult connection problems in wood and masonry construction."[19]

By 18th century its production became cheaper and more reliable, and as a result its use became gradually more common, not just as a connection material but as strengthening in masonry for tensile forces. Later on, the industrialization process boosted its use, more thanks to the initiative of inventors and engineers than to architectural practitioners. In fact, the continuous exploration of iron's 'true' form (ultimately irrelevant as a fluid composite could take any shape or form by hammering or casting) led to many creative uses not only in structure, but as ornamentation, cladding or roofing, among many others.

At his point, the lack of a 'massive' quality as a required architectural feature led architectural practitioners to combine iron structures (once more) with more traditional materials such as stone, marble, masonry and wood. There is however a significant difference with pre-industrial use of iron; it was no longer subjugated to a foreign construction logic but this time, the systematized, rationalized, standardized iron structure governed (unnoticeably) the design.

Like many inventions, iron was first tested as a structural material in textile mills. It was used as primary support in textile workshops around 1790 but its use was dangerous because of the limitations of fireproofing at that time. Later on, the developments in ceramics and terracotta fabrication would solve these restrictions and much of the iron structures produced before the exhibition of Paris in 1889 were covered with other materials for protection.

Of course, many great buildings from Europe and Argentina from later periods still made use of this approach to iron construction; the need for ornamental effects and material qualities like polished marble or stone finishes still account for this practice.

An interest example of this approach is present on the Vasena product catalog[20]: the 'Vasena system' for iron cast columns defined a series of hollow column profiles prepared to be filled with refractory (fireproof or fire retardant) material. I was also remarkable, the fact that these profiles include cross section wings in order to align the exterior decoration of the column. The significant quality of the Vasena system lies in the possibility of combining a structural material (cast iron) with interior infill and exterior ornamentation. This embedded multi-material character is yet another example of 19th century's open-minded and creative approach to the relationship between material innovations and architectural styles.

For this research, the importance of this multi-material approach is not only related to the history of architecture but with the future of it. Contemporary developments in fabrication techniques, such as 3d printing (in plastic, ceramics or metal) frequently present the possibility of building or fabricating an entire

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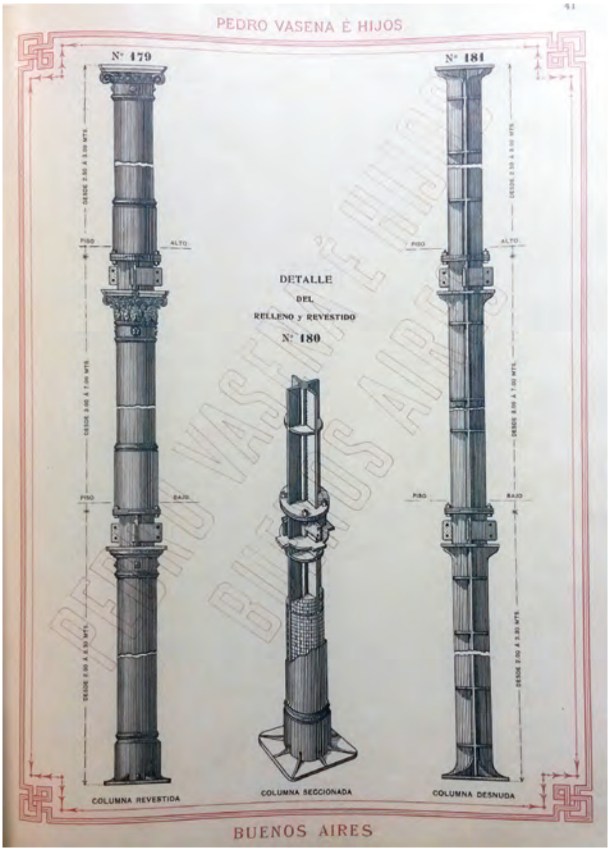
19 Tom Peters, "How the introduction of iron in construction changed and developed thought patters in design," in Rinke; Schwartz, Before steel

20 Santiago Vasena, Primer Catalogo. La utilización del hierro en la arquitectura y la construcción, 1902, Sociedad Central de Arquitectos



2-11 The Vasena Column system from Buenos Aires combined structural elements, ceramic insulation and ornamental cast iron. Extracted from the Vasena Catalog.

building[21] or a bridge[22], just to name a few recent record-breaking examples. This approach to design and fabrication implies that a single material must perform several functions, support, covering, joints, etc.

At first it might sound like an interesting solution: a one-for-all answer to construction problems. However the interest of Architecture in construction techniques relies not just on the technical performance of materials but also on the expressive possibilities that these techniques enable.

Similar to 19th century's iron, contemporary 3d printed polymers can take any form and shape and perform any function in the building. It can be extruded, milled or cast, it is used in facades, roofs, flooring and wall covering, and it can be structural, isolation and cladding.

This formless capability of digitally manufactured material might present itself more as a problem than a solution, particularly in terms of material expression; 3d printers leave no mark or trace of their work, and soon it will be impossible to distinguish its products from, for example natural ones, like stones or marble.

This research suggests that the true power of digital fabrication techniques lies in the possibilities of multi material construction, whether they are used for structural support, enclosure, surface finishing or binding. By combining different techniques, whether are digitally fabricated, industrialized or handmade, many interesting and innovative architectural effects can be achieved, and 19th century architecture is a great example of that type of thinking.

Façade and structure separation.

The Menier chocolate factory could be considered as the starting point of a modern tendency towards the final separation between enclosure and support structure. That separation, though previously technically achievable, was not accomplished until the advent of iron structures and their weightlessness.

Gothic architecture achieved an optimal relationship between load bearing structures, geometry and ornamentation. Lars Spuybroek, analyzing Gothic through John Ruskin's´ writings[23] describes the gothic relationship between ornament and structure as an inversion of their Classical conception. Classical elements rested on their clear partition and identification; a column was divided first on three large sections, then each section was subdivided again in three smaller parts and so on. Spuybroek argues that Gothic composition blurred these divisions and masked their separation, not just in terms of identification but in their function as well.

For example, Gothic tracery acts as a multi-scalar ornament and structure simultaneously, at the same time performing a series of complex formal operations (such as mergings, braidings, splittings, crossings, branchings,

21 http://3dprintcanalhouse.com/construction-technique

22 http://mx3d.com/projects/bridge/

23 Lars Spuybroek, Sympathy of things: Ruskin and the ecology of design (Rotterdam, New York NY: V2 Publishing; NAi Publishing; Available in North South and Central America through D.A.P./Distributed Art Publishers Inc, 2011)

overlappings), blurring the distinction between their component parts.

In fact, Spuybroek states that Gothic should be understood in Ruskin´s non-classical terms, it could be described as a "genetic engineering of architectural language", since the building elements vary and evolve, and are not easily distinguishable from one another, as they can be considered 'non parts' or 'almost-parts'. This superimposition and blurring of elements were then altered once more by the introduction of slender pieces of wrought or cast iron.

Iron parts cannot be smeared or blurred into one another, nor can't they perform multiple functions on a building. The fabrication process of iron was expensive and its price was amortized by the number of elements produced; the more elements manufactured, the lower the price per unit. This meant that each iron piece should be evaluated not as a single entity but as a part of a whole system, a building system in which each piece must play a particular role. This specificity and the type of systemic thinking it eventually required (after all, building technologies were at the time taken over by engineers) predisposed the separation of each project in a series of subsystems; structure, utilities, sewage, heating and envelope, among others. Architects were only required to represent this systemic approach, to express this division and exploit it creatively.

The quest for the separation between support and supported elements in architecture was advocated parallel to the 'multi-material´ approach to construction. On one hand, mass fabricated standardized products organized in complex combinations of iron, masonry, marble and bronze (for example some buildings and columns in Buenos Aires[24]) and on the other, a tendency to detach them from one another in relation to its function (structure, utilities, enclosure).

This may seem contradictory in the beginning, but it could also be understood in terms of the prolongation of classical semantics through novel technical means. The use of iron structures disseminated so quick that architects did not have enough time to properly absorb and understand its characteristics and metabolize them in a coherent disciplinary narrative.

Transparency as a parameter.

Greenhouses were the testing ground for many architectural innovations of 19th century. Iron ribs, modular structures, rain piping and of course, an extensive use of glass. As we mentioned above, the production of glass improved greatly in this period; improvements like the one by Siemens (1851) for example, cut the fuel usage by half, or Robert Chance (1839), who improved glass' surface finish[25]. The true consequence of the period's innovations was, for the first time in history, the crowning of glass as an architecture material.

Glass panels were in high demand in order to cope with the immediate

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24 Le Monnier Eduardo, Banco Argentino Uruguayo (Buenos Aires, 1928)

25 Christian Schittich, Glass construction manual, 2nd, rev. and expanded ed. (Basel: Birkhäuser; London Springer [distributor], 2007)

2-12 Novel materials enabled novel typologies with innovative spatial qualities. Magasin au bon Marche by L.A. Boileau and G. Eiffel (Paris1876) requirements of large covered spaces such as domes, train stations, exhibition spaces and market halls. Buildings like the Halle aux blés in Paris were progressively covered by glass, first the apex (1838) and then the whole dome (1889). Market halls and vast shopping spaces like the Magasins de Bon Marche[26] (Paris, 1876) by Louis Auguste Boileau used large infill glass panels in the façade. Glass-roofed streets were also an interesting example on the use of glass at a large scale.

Glass allowed large public spaces to be filled with light, and along with the use of slender prefabricated iron elements, construction began to dematerialize and consequently, transparency became a desirable architectural feature.

Combined to fabrication techniques, the use of glass was also encouraged by a shift in architectural strategies as well; the progressive separation between wall enclosure and structure allowed the design of thin, glass walls wrapped around iron structures. The load bearing capacity of outer walls was being transferred to slim iron skeletons, thus reducing its function to a mere membrane separating interior from exterior. Facades would no longer be considered (and designed) as perforated solid walls but as light frames with a glass infill.

Glass was the perfect material for this new task and thanks to its recent standardized qualities it fueled architecture's route towards dematerialization. The Crystal Palace is a prime example in order to illustrate the importance (and limitations) of this new material; the glass panes used in the construction (manufactured by Robert Chance's company) governed the entire modulation of the building[27].

A unique size of glass was chosen and the decision reverberated in the entire building. At the time, the largest glass pane available measured 10 by 49 inches (250 by 1220 cm), defining a basic three-dimensional module of 24 feet (7.32m) which was repeated and coordinated also in height. A total of 270.000 glass pieces and 956,000 square feet were used in the building[28], creating a space never seen before, open, transparent and light, allowing natural and atmospheric effects finally take part of architecture. The division of interior from exterior was radically altered.

The combination of glass and iron on such a large scale changed forever the perception of an interior space; a controlled artificial atmosphere enclosed in iron and glass. Iron and glass and iron provided architects the possibility of an enclosure without mass, strength without weight, which earned both enthusiastic admirers and detractors[29].

26 Michael Barry Miller, The Bon Marché: Bourgeois culture and the department store, 1869-1920, 1. Princeton paperback print, Princeton paperbacks (Princeton, NJ: Princeton Univ. Press, 1994)

27 Isobel Armstrong, Victorian glassworlds: Glass culture and the imagination 1830-1880 / Isobel Armstrong (Oxford: Oxford University Press, 2008)

28 Armstrong, Victorian glassworlds

29 John Ruskin, The stones of Venice (New York: United States book company, 1880)

New architectural programmes and activities.

The rapid expansion of industrialization was first associated to cotton mills and foundries, often located in relation to river streams or material and energy sources. It was then after the 1820s that industries settled in the vicinity of cities thanks to many factors, being the most important the decrease of transportation costs (thanks to the train and ports) and the large availability of human resources.

Due to the development of large rail networks, the growth of cities was deemed unstoppable. In 1801 London had 1 million inhabitants, in 1851 they were duplicated, by 1881 they were 4 million and reached 6 million in 1911. Demographic growth exploded in every mayor European city throughout the 19th century; Vienna (from 230 thousand to 1.76 million), Berlin (270 thousand to 1.89 million), Paris (750 thousand to 3.75 million) are just some examples. Due to other factors, Buenos Aires experienced a similar increase but in a different magnitude; at the beginning of 1800s there were just 40.000 inhabitants and by the end of the century, it grew almost to a million and its population doubled again during the next 30 years.

The costs of transportation of materials and energy dropped significantly throughout the century, and so did the cost of relocating factories near the cities; the expansion of railway networks, ports and the large availability of cheap and concentrated labor, and closeness to consumption centers were the most important factors of rapid urban expansion. The 19th century witnessed the intimate and sometimes controversial relationship between industrial progress, economic growth and urban development.

By the end of the century, the use of electricity (Edison, 1879) and internal combustion engines (Benz, 1886) provided even more transportation freedom not just for capitals, materials and merchandise but for citizens and workers. Quick means of transportation created networks that weaved entire cities, first by horses, then by tramways (Siemens, 1879) and finally by buses.

Urban growth and densification were also accompanied by the expansion of cultural institutions; the industrial, commercial and financial bourgeoisie, along with government and military officials promoted the development of ´cultural infrastructure´. An unprecedented emanation of museums, opera houses, ballrooms, libraries, zoos and hotels populated the cities, now turned metropolises.

Most of these programmes were already developed like museums and opera houses; however until that time they were often financed by wealthy citizens or the nobility through the figure of patronage in order to uphold their political or social ambitions. Political and economic changes altered this dynamic by taking these cultural infrastructures away from private patronage towards a publicly supported funding system. The state, mostly through the bourgeois class, decided to support cultural activities, making them available for the citizens and visitors, thus requiring from our discipline not just new technical means but also a new aesthetical sensitivity.

On top of that, the popularization of tourism and the interest in unique cultural attractions fostered a world-wide competition for the public's interest. The international exhibitions summarize this phenomenon; public from all over the world would flood a city to witness fascinating buildings, novel urban programmes and revolutionary inventions.

New infrastructure.

The demographic explosion of 19th century demanded the upgrade of city-scale infrastructure; sanitation services, water supply and wastewater management were on top of the requirements at the beginning of the period. Bridges, ports and railway networks were also infrastructural pieces required on a global scale. By the end of 19th century, gas piping, electric energy supply, telecommunications, public transportation networks and city parks were considered part of the mandatory urban infrastructure. This list could also be enlarged by the so-called 'soft-infrastructure', consisting in healthcare, educational and financial systems, as well as police and emergency services.

Vienna, London and Paris are textbook examples of the importance of infrastructure and its role on the development of urban areas.

Case Study: Vienna.

The case of Vienna is particularly interesting because it combined explosive demographics, a controlled urban expansion, the administration of urban land and the development of new infrastructure. Most importantly for this research, Vienna´s expansion fostered the creation of a significant urban space, the Ringstrasse, with a distinctive architectural footprint, effortlessly combining distinctive styles and typologies.

By 1850 Vienna incorporated the suburban zone within the Linienwall and was divided into urban districts. In 1857 the Emperor Francis Joseph decided to advance towards the obsolete city defenses and to take advantage of top-quality urban land. The whole belt of walls, military fortifications and large empty spaces were included in the city planning as a wide thick ring around the historical city.

The newly conformed city and its recent council took over the infrastructural development and started to reorganize it according to the requirements of a modern metropolis[30]. By 1850 a gas network was used for street lighting, between 1869 and 1875 the Danube River was regulated, its bed excavated and the 'Danube Canal' was built.

In 1873 the drinking water supply was amplified by the construction of the First Vienna Spring Water Main (it is still in use today), drawing water from 120km away, eliminating the need for domestic wells and improving health quality of all citizens, including the suburbs. Later on, Otto Wagner

30 Michaela Pfundner, ed., Wien wird Weltstadt: Die Ringstraße und ihre Zeit (Wien: Metroverlag, 2015)

2-13 Typological variety in the Ringstrasse. The Vienna Parliament, Rathaus and Voltivkirche in background.
2-14 Urban space in front of the Vienna Opera.

was in charge of the design for the metro stations and bridges between 1894 and 1910, defining yet another key piece of crucial urban infrastructure. In the course of 50 years one of the capitals of the world was radically, and successfully reshaped into a metropolis.

The Ringstrasse was born in that period; crossed by boulevards and Strassenbahns, it hosted a series of public and private buildings, showcasing the prominent style of the time: eclectic historicism. The City hall, the Opera House, the Parliament building and the University, among many other magnificent examples, populated this expansion, along with private houses (more like small palaces) for the elite industrialists and bankers. For many years these buildings coexisted with military buildings, parade spaces and exercise courts.

Parallel to this, and in preparation for the world exhibition of 1873, the Ringstrasse congregated much of the hotel infrastructure that would host thousands of visitors. Unfortunately the Weltaustellung Wien was a failure due to an international financial crisis and a cholera epidemic in Vienna. The hotels in the Ringstrasse were empty and bankrupted while cartoons from newspapers mocked their failure.

Once the glacis was entirely dismantled, the Ringstrasse was defined to its current state: an archetypical urban space and infrastructure piece of the 19th century was built. Its buildings were neo-classical, neo-baroque, neo-renaissance and neo-gothic yet the urban space they define as background is completely coherent and organized. The combination of planning, urban regulations and at the same time, stylistic freedom, characterized a unique city, a metropolis that embodied much of the period´s pioneering spirit.

Case Study: Buenos Aires.

Buenos Aires is another example of the development of a metropolis, particularly during the period between1880-1910. Founded in the 16th century, it depended heavily of commercial activity (and contraband) particularly during the 1700's. On 1776 it was proclaimed as the capital of the Rio de la Plata Viceregal in an effort to bring foreign influence and contraband to an end. At the moment of the country's independence in 1810, Buenos Aires was the hegemonic center with 40.000 inhabitants, not undisputed by the inner regions with their own economic and political interests.

After a series of painful internal conflicts, in 1854 the 'Municipalidad' or city government was founded, and many of its problems would begin to solve. Several problems were indeed related to its growth (from 24.000 inhabitants in 1779 to 177.000 in 1869[31]), such as water supply, sanitation and the lack of green spaces.

One of the most important tragic events is the yellow fever epidemic of 1871, taking between 13.500 and 14.500 lives and provoking major changes in the urban landscape. The disease was spread mostly due to the lack of a water

31 Source: INDEC Argentina – National Institute of Statistics and Censuses.

2-15 19th century Greek-roman eclecticism in Buenos Aires. Congress Palace by V. Meano (Buenos Aires, 1895)
2-16 Palatial references were common in administrative buildings. Pizzurno Palace (Argentine Ministry of Education) by C. Altgelt and H. Altgelt (Buenos Aires, 1888)
2-17 Post and Telecomunications Palace by N. Maillart (Buenos Aires, 1889)

supply network, the pollution of water tables, the contamination by the meat industry, and the overcrowding of large parts of the population, the working class, particularly in the south of the city.

After the disastrous event, the government took a series of measures, like the creation of a water supply and sewage network (by the engineer John F. La Trobe Bateman, later responsible for it and the 'Palacio de Aguas') and the acquisition of new lands for a cemetery. Most importantly, the majority of the population that lived in the south part of the city moved to the north, away from the polluted creeks and meat industries. The imbalance of the north and the south part of Buenos Aires is still one of the city's sources of inequality and it is rooted on this tragic incident.

A long process defined Buenos Aires as the permanent capital of the newly founded country, and the federalization process defined its condition to its current metropolitan status. Claudia Shmidt described this process as a passage 'from a provision to a permanence'[32], as the city gained a new status of 'capital, federal and permanent' of Argentina. Shmidt's doctoral thesis describes the details of this passage: the political thrust towards a modern capital, the need for modern infrastructure and government buildings and particularly, the discussions relative to the character and expression of its national institutions.

On this topic and particularly in relation to this research, the title of her book 'Palaces without kings' is descriptive of the overall image that these buildings tried to achieve; the idea of 'palace' as a manifestation not of royalty, concentrated power and splendor, but of a thriving nation, strong national institutions and perhaps also, the overstating of the European roots of a modern democracy.

On the idea of ´palace´ in 19th century architecture, Shmidt states:

"(…) facing the crisis of the classic tradition, the French Académie de Beaux-Arts itself offered, as the most modern alternative, by its ambiguity and adaptability, the idea of palace. But it was not a specific type, nor a determinate style, but a compositional piece that could break the thematic hierarchies that the classical tradition itself had imposed for centuries, on those destinies of which Architecture had to be occupied." [33]

The main water distributor, 'Palacio de Aguas' (Palace of Waters) was built on this purpose, and along with the 'Palacio de Congreso' (Palace of Congress), 'Palacio de Justicia' (Palace of Justice), Palacio Pizzurno (Ministry of education) and 'Palacio de Correos' (Postal Palace), are some examples of the prominence of Architecture on the definition of a national character and expression of its institutions in the fabric of the city.

Shmidt defines the true role of Architecture on this period:

"The period between 1880 and 1890 responds to the lapse during which the capital question intersects (…) the prominence of Architecture as articulator between the city and politics, whose developments, on some cases, extended to the next decade. It is the moment when the palaces without kings were

32 Claudia Shmidt, Palacios sin reyes: Arquitectura pública para la "capital permanente" Buenos Aires, 1880-1890, Colección Historia argentina 12 (Rosario Argentina: Prohistoria Ediciones, 2012)

33 Shmidt, Palacios sin reyes. Translation by Federico Garrido

constituted in the public architecture for the permanent capital." (italics by the original author)[34]

Embedded in a process of metropolitanization, the role of architects, as opposed to the engineers, was to provide a democratic image to the government buildings and also to develop a 'character', another topic of international interest in 19th century. Furthermore, this process was also set away from the stylistic debate of the period, but nevertheless trying to react and adapt to comparable challenges in a different set of circumstances. Under these conditions, Shmidt describes the idea of palace as a convenient typology to explore, a 'symbolic form for the material representation of the government'.

Development of new architectural typologies.

We´ve addressed the new technical possibilities and programmes that came to the attention of our discipline during the 19th century. The natural response was to condense them along with distinctive spatial, material and expressive characteristics into a new breed of building typologies. We will discuss some of the many factors that made them possible and their characteristics.

An important one was the cultural and academic exchanges that took place first in Europe and then expanded worldwide. Thanks to the permanent exchange of professors, students and bibliographical material (in the form of textbooks, manuals and treatises), the Beaux Arts method spread internationally by proposing not only technical knowledge but also a set of universally accepted artistic regulations, which in turn derived in a common architectural language or grammar.

At the same time, due to the constant technical development, the greenhouse typology evolved not only in size but also in style and expression. The greenhouse grew into a hall and eventually the hall turned into a palace. Furthermore, the overall function of these buildings changed over time, from small sheds for exotic plants and private gatherings to large, international exhibition halls; becoming a critical piece of 19th century urban infrastructure.

The economic growth thanks to the mechanization of production and the development of new energy sources required the constant expansion of markets in order to place its production, and at the same time, to supply itself of raw materials. This is how the international division of labor was defined; Europe was the cultural and manufacture core, while the satellite countries supplied resources and markets. England functioned as the financial hub for this system and every transaction was made in British pounds. For this trade circuit to work continuously, a growing interest in trade and novelty in general was maintained at a global scale. International trade fairs and exhibitions were designated for this task.

Originated in the French national exhibitions and medieval trade fairs, the 'Universal Exhibitions' were an important event in 19th century life, not

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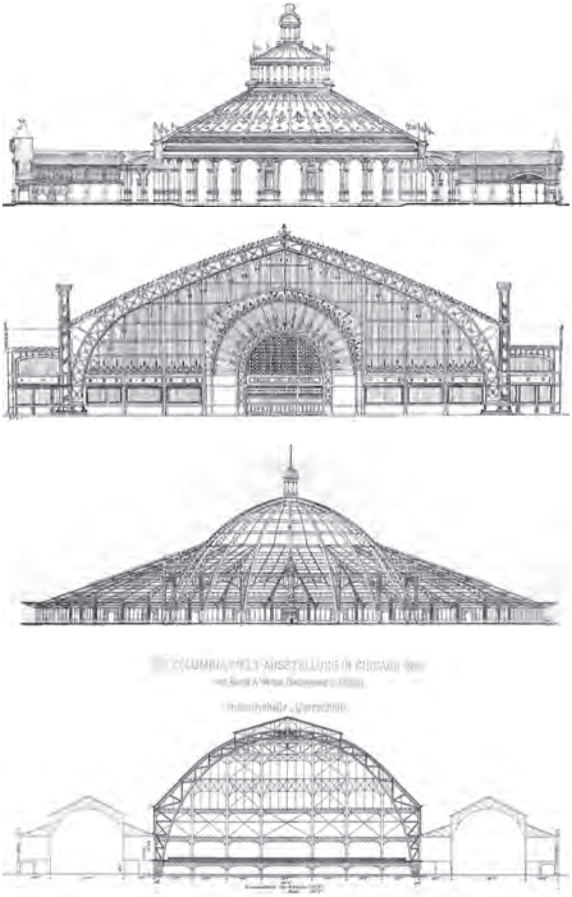
34 Shmidt, Palacios sin reyes. Translation by Federico Garrido



2-18 The international exhibitions fostered a new exhibition hall typology enabled by the use of iron and glass. The Rotunde for the Viena Weltausstellung (Viena, 1873), Galerie des Machines for the Exposition Universelle (Paris, 1889), World´s Columbian Exposition (Chicago, 1893), Palais principal from the Exposition universelle Lyon (Lyon, 1894).

only for the occasion itself but for their impact in everyday life. The hosting cities (London, Paris, Munich, Vienna, among many others) were significantly altered to accommodate the exhibition and its participants, most of the times hundreds of thousands and sometimes even millions. These events pushed the cities to promote major urban changes that included train stations, parks, boulevards and of course, the exhibition building itself.

The aforementioned Crystal Palace in London (in occasion of the ´Great Exhibition of the Works of Industry of all Nations´ in 1851) was the first of many 'Great Exhibition Halls', followed by Munich (the Weltaustellung in 1854), Vienna (1873), Barcelona (Exposición Universal de Barcelona, 1888), Paris (Exposition Universelle, 1889,1900), and Chicago (World's Columbian Exposition, 1893) and Lyon (1894) among others. Each exhibition required large halls, pavilions, parks, pedestrian bridges, parks and tramways, and each of these elements were built with the state-of-the-art building technologies of the time.

Large exhibition halls were a mixture of architecture, utilitarian buildings and infrastructure pieces. Each one was unique and many of them broke world records at their time of construction; they were required to host machines, arts and manufacture exhibitions, public events and even exotic trees and plants from all over the world (just like the greenhouses, their typological ancestors). The general idea for them was to enclose several expositions and activities simultaneously under a same roof, while entertaining and astounding the public.

Classical architectural categories failed to classify such buildings; the Utilitas was too vague and flexible, the light, three-part hinged structure of the Palais des Machines clearly defied the conception of Firmitas, and the overall expression of exhibition halls resisted to be analyzed under the light of Vitruvius´ Venustas. Of course this does not mean that exhibition halls lacked architectural qualities; quite the contrary, their sole erection was enough evidence of the creative and inventive spirit of 19th century, not only reserved to everyday objects but also applied to architecture as for every aspect of human life.

Originally designed for temporary expositions, these large halls were developed in parallel to railways, train stations and sheds. Even though the halls were bigger and more complex by any parameter, they also benefitted from design and engineering lessons thanks to the accumulated experience in rail infrastructure. In addition, the ephemeral character of both construction types was a key attribute on this exchange. On this regard, Pfammatter states:

"The railways were the engine room of developments in construction in general, and specifically exhibition buildings, as here, too, it was the case of planning, producing, transporting and building swiftly. Even the building sites and organization resembled each other – a sign of the beginning. The temporary character of the exhibition structures led to new deliberations with regard to assembly and dismantling – this was the birth of lightweight construction and ephemeral decors."[35]

And then:

"The pavilions for international exhibitions (...) benefited on the one hand from the concepts or railway sheds, while on the other hand they also represented unique contributions to the development of building technology and to a new interpretation of space. For the most part, the players – architects, engineers, builders and entrepreneurs- came from the same schools of thought and 'schools of railway construction'."[36]

The guiding principle in the design of these buildings was utilitarian; the achievement of long spans, large covered areas, easy to fabricate and uncomplicated assembly drove the efforts of designers, both architects and engineers. Aesthetics, the mode of appearance and overall expression of these constructions was somehow secondary to the practical aspect, and of course, yet another cause for the collaboration between architects and engineers, as the technical solutions required for the design, fabrication and erection of these halls were unprecedented.

Several authors like Pfammater[37], Mario Rinke[38] and Tom Peters[39] define a new 'mindset' or 'thought pattern' associated to the rationalization of the building design, fabrication and montage. Standardization, modulation, homogeneity and regularity suddenly became important factors in the design activity. The exhibition buildings (just like any other utilitarian structure like sheds or train stations) required such rational mindset and expressed it spatially and materially. On this topic, Pfammater states:

"(the) Crystal Palace and the Glass Palace illustrate where the new trends are to be found; in the standardization of building production and assembly thanks to a rational mindset and a grid with regard to space and construction –the key to high speed and low cost; in limiting the number of component parts to just a few, in prefabrication in workshops under controlled conditions (consistent quality) and a uniform design (dimensions, profiles, connections). (...) The industrial mindset was at the same time a construction programme and ultimately determined spatial quality, method, shape, detailed figure creation and the perception of a new type of transparency."[40]

Repetition and precise modulation were suddenly presented as spatial qualities: homogenous space (through endless reiteration of a structural unit), the blending of interior and exterior (thanks to glass but also to modern climate and lighting control) and the ultimate dematerialization of the building (thanks to the lightness of iron and steel). These new qualities reshaped architectural strategies by presenting new design solutions to novel spatial problems:

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35 Pfammatter, Building the future

36 Pfammatter, Building the future

37 Pfammatter, Building the future

38 Mario Rinke, "The infinitely shapable structure: Structural iron and the decontextualization of construction," in Rinke; Schwartz, Before steel

39 Tom Peters, "How the introduction of iron in construction changed and developed thought patters in design," in Rinke; Schwartz, Before steel

40 Pfammatter, Building the future

2-19 The modular tectonics of the Crystal Palace (London, 1851)

"The exhibition pavilions did not, first and foremost, represent an architectural achievement but were rather the result of an organizational and construction process: nothing that had previously existed could be imitated; even traditional building work and decision-making process were doomed to failure; everything was new". [41]

IMPACT ON ARCHITECTURAL DESIGN.

This thesis intends to explore how the developments in construction technologies influenced architectural design and in particular, how design strategies were impacted by the use of new tools, materials and construction types. This impact was crystallized in the form of an unprecedented freedom thanks to unique conditions in the history of architecture. Those circumstances were met not only by the advances and large availability of technical means, a theoretical independence and overall autonomy, but also were coupled with the institutionalization and democratization of architectural knowledge (in the form of schools, academies and universities) and the specific requirements of the society which demanded architecture of quality and in quantity across the globe.

Architecture schools in 19th century.

The Ecole Polytechnique[42] embodied the revolutionary ideas inherited from the Enlightenment relating not only to architecture but more importantly, to the architectural education. The military-oriented 'École des ponts et chaussées' (School of bridges and roads) was focused on infrastructure and according to some authors, was disarticulated while some of its members were still supporting ideas from the Ancien Régime.

At the same time, the newly formed government needed technicians with a military organization in order to install and support the revolutionary ideals in the interior of the country. With this task ahead, the architects from the Académie des Beaux-Arts were just unable to fulfill the required double role, both military (revolutionary) and civilian (building designer). Regarding the history of the Académie and the École des Beaus-Arts, Drexler's 'the Architecture of the Ecole des Beaux-Arts'[43] offers a detailed recollection since its funding period, the influence of the Revolution until its influence in 20th century.

The revolutionary government not only needed many new buildings and structures for its functioning and celebration (such as governmental institutions, representational buildings and revolutionary monuments) but also the new

41 Pfammatter, Building the future

42 After the French revolution, the 'Conseil des Batiments Civils' was organized in order to define the buildings that the newly founded republic would require. This council originally organized the École des Travaux Publics for this task, which was later renamed École Polytechnique in 1794.

43 Arthur Drexler and Richard Chafee, The Architecture of the École des beaux-arts (New York, Cambridge Mass.: Museum of Modern Art; distributed by MIT Press, 1977)

republican social life had its own requirements as well. These requirement include hospitals, schools, churches, markets, prisons, large factories, train stations, sea ports, among many others, including the new cultural programmes described before.

Composition.

Design methodologies for architecture were enthusiastically discussed, as Drexler describes: from the use of the word 'distribution' ("to apportion between several") by Boffrand (1745), Blondel (1771) and Quatremere de Quincy (1788), then turned 'disposition' ("to arrange, to put things in certain order") and finally 'composition' ("to form, to make a whole out of several parts")[44]

Finally, the concept 'parti' was deemed more significant and complex: while 'composition' merely arranged elements, the 'parti' was applied to a general layout, as an inspiration, as a guide to define the relative importance of the different elements (parts).

Drexler describes the importance and connection of both ideas:

"(…) composition has to do with the presentation of architectural ideas, but not with the generation of these architectural ideas themselves. These ideas, furthermore, are partis, choices (from prendre parti, to make a choice, take a stand). Being seen as choices, these generative ideas were not taught at the Ecole itself, but a range of theories and convictions was available to the students in the ateliers."[45]

Architectural composition was indeed a proper method designed to present architectural ideas, regardless of their origin, articulation or purpose. This was substantially important in the 19th century, when classical architectural ideas and theories were destabilized, and at the same time architectural education seek universality, standardization and institutionalization:

"It was the institutionalization of the 'battle of the styles and this confidence in the suppleness of a certain method of composition (…)" [46]

And then:

"Thus, "Beaux-Arts" denote not a style but rather a technique, By 1900, however composition had become an end in itself; the liberal preference for compromise had produced an architecture that was, literally, superficial – dealing with surface, avoiding substance" [47]

At the same time, the student's designs (particularly those who were awarded by the Prix de Rome) demonstrated a concern about the relationship between surface and mass, interior and exterior; while the outside was designed in terms of a classical composition of elements and proportions, the interior was organized as a sequence of captivating spaces. On this matter,

44 Drexler and Chafee, The Architecture of the École des beaux-arts

45 Drexler and Chafee, The Architecture of the École des beaux-arts

46 Drexler and Chafee, The Architecture of the École des beaux-arts

47 Drexler and Chafee, The Architecture of the École des beaux-arts

Drexler explains:

"Beaux-Arts composition at the outset was concerned with masses rather than detailing, with those masses as containers of space, and with those spaces as experienced when walked through. A Beaux-Arts building was designed from the inside out."

Parallel to the Beaux-Arts, another school was also dealing with design methodologies for architecture and building engineers: the École Polytechnique. Ulrich Pfammater describes with great detail the evolution of the educational institutions from the Polytechnique to contemporary Technical Universities across Europe on his book 'Making of the modern architect and Engineer'[48]. We do not want to enter the specifics of the École's organization (for that topic, Pfammatter work is comprehensively detailed) but to describe one of its great contributions to architectural theory: the Durand method for composition.

The method of Jean Nicolas Louis Durand.

As previously stated, the industrialization process in general and the French revolutionary government in particular required not only a whole new set of buildings, constructions and structures but also, a new breed of professionals trained in the use of new technologies and also committed with the revolutionary process. Old training institutions would not suffice and a new method to train architects was required.

The Ecole Polytechnique illustrated a shift in the model of architectural education; from the master's atelier model to an institutional curriculum model[49]. Jean Nicolas Louis Durand was a professor of architecture from its foundation until 1830, and his design methodology, which would be the basis of this course, would be influential throughout the 19th and part of the 20th century.

The École des Beaux-Arts did not teach architectural composition, the students became familiarized with it on the ateliers, not on the school. For that reason, Durand expressed with surprise that the topic of composition was not discussed on any text (1817). Some writers like Drexler also note that authors like Louis-Ambroise Dubut also illustrated similar methods and principles, but without clarifying, or describing them in depth.

Durand's method was by itself, a shift in traditional architecture teaching since style was no longer a topic of study but of a simple choice of another nature rather than technical, material or spatial (sometimes it involved a question of character, image or expression). Paradoxically, during the 19th century the question of style was indeed an important topic of architectural discussion.

Durand (but also the Ecole, and at some point, the government) was interested in creating a method, a theory of utility; one in which the function

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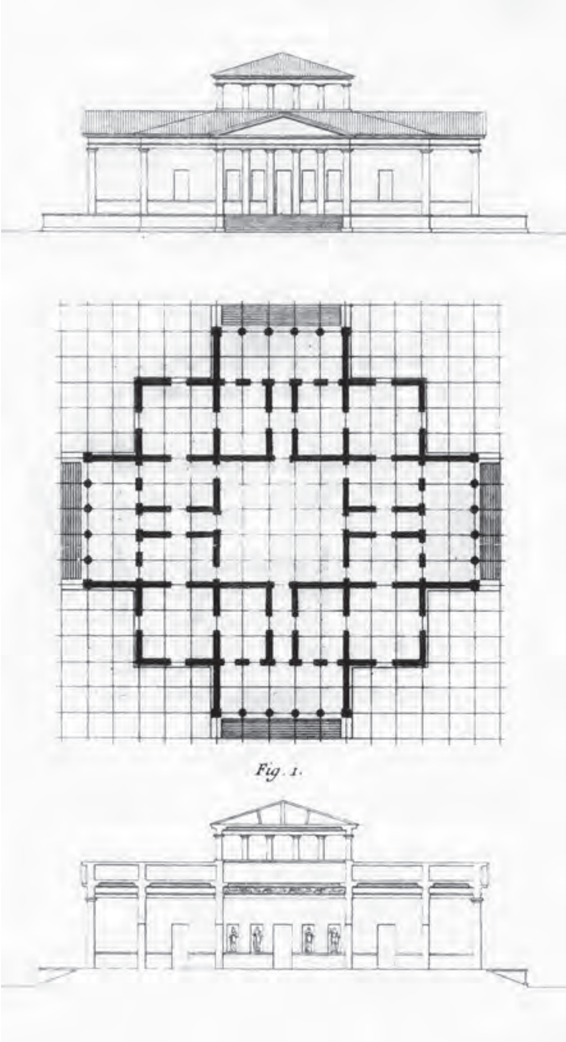
48 Pfammatter, The making of the modern architect and engineer

49 For a detailed description of the curriculum at the Ecole, Pfammatter's 'Making of the Modern architect and engineer' includes the first structure, showing the interrelation between polytechnical fields according to d'Alembert and Diderot's encyclopedic model.



2-20 Compositional strategies and codified modular design by J.N.L. Durand.

and programme of the building would drive the design, spatial relations and compositional efforts. Durand's compositional method would prioritize the function of the building and adjust the structural type and material resolution most suitable to it.

Guided by economy, the simple, ordered, mathematically and geometrically practical structure would equalize structure to composition, and composition to architecture. The classical orders are no more a prerequisite of a good design (in fact, Durand's drawings show no sign of Doric, Ionic or Corinthian capitals, just a geometrical simplification); the real order behind design would not be stylistic but a spatial one.

Durand's project methodology proposed a scientific approach to design (one that would be later retrieved by digital design researchers), configuring a proper 'design procedure', as it divided the design decisions into a series of carefully-planned steps which, executed in order, would configure an architecture project. These decisions would reflect on a project characterized by order, hierarchy and clarity.

The project would be drawn in floor plan and frontal view simultaneously, defining a basic grid on graph paper (millimeter grid), the columns would need to be ordered organizing each room in a modulated spaces. The ordering principle of the project is the grid, the axial lines and not the canonically defined separation between columns; the grid separation defines the main set of proportions. The project is divided in small modules, established by a rational, geometrically coherent structure, aggregated one next to another, delineating the entire building by assembly and combination. That's the architectural meaning of 'composition'; to position one element next to the other[50].

Durand's method was revolutionary but its ´building elements´ were derived from architectural tradition: columns, slabs, roofs, vaults, walls and openings. They were differentiated from the 'building parts', which were the small architectural units that in time, would compose a building. Those 'parts' (the French 'partie'[51]) were among others: stairs, patios, lounges, porches, rooms, which were in turn, delimited by the aforementioned elements.

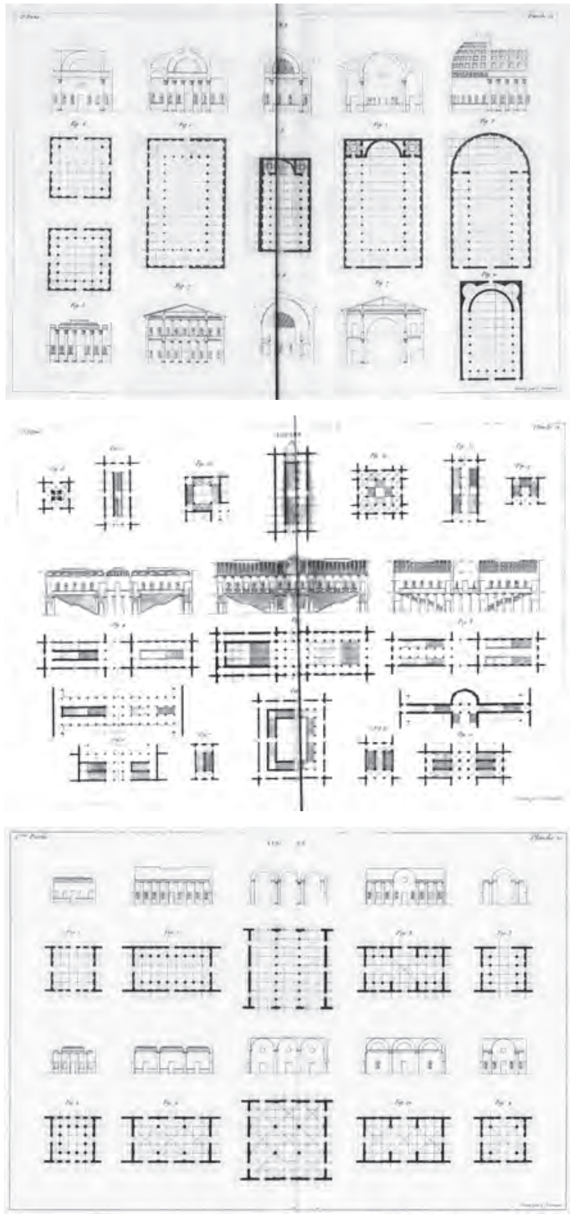
For a detailed description of Durand's method, Pfamatter's book and particularly Leandro Madrazo's paper[52] are an excellent source of information. Authors like Jorge Sarquis have argued against Durand's method as a proper process leading to an architecture project, mostly for lacking the complexity, expressive quality and programmatic significance that Architecture requires. On this matter, Sarquis describes several other methodologies, named 'Architectonical form configurational procedures', one of which is Durand's 'Composition'[53]. It is differentiated from 'Modern Composition' (the updated

50 Jorge Sarquis, Itinerarios del proyecto: La investigación proyectual como forma de conocimiento en arquitectura (Buenos Aires, Argentina, México D.F.: Nobuko; Juan O'Gorman Librerías, 2003-2004)

51 In Argentina, this compositional method was also known loosely as 'parti architecture' (arquitectura de partido) which would also be updated by modern architects and professors.

52 Leandro Madrazo, "Durand and the Science of Architecture," Journal of Architectural Education (1984-) 48, no. 1 (1994), https://doi.org/10.2307/1425306

53 Jorge Sarquis, "No todo proyecto es un proyecto," http://jorgealbertosarquis.blogspot.de/2012/04/no-todo-proyecto-es-unproyecto.html



2-21 Standardization and modularization of architectural elements, spaces and buildings in Durand´s method. Rooms, staircases and vestibule catalogs.

20th century version of Durand's), 'Architectural Experimentation' and finally, the most complex one 'Architecture project'.

By attempting to code architectural knowledge in the form of an architectural methodology, the method becomes objective, and then, it can be divided into small segments, analyzed, transmitted and applied by other actors. Madrazo defines this as the scientification process of architectural design and teaching.

The attempt to systematize and rationalize the process of architectural design responded to two main factors; on one hand the need for a rational approach to design as well as to any other human activity (which of course was aligned with the inherited ideals of Enlightenment and the Revolution) and on the other; the pressure to project and erect numerous buildings required for the new regime. This meant, that the Polytechnique intended to train a number of architects as fast and efficient as possible. Durand's methodology was, on this sense, influenced by the urgent demands of the industrial age and a nascent government.

Other professors like Reynaud would emphasize the role of industrialization in the building design process by truly including an industrial dimension in architectural education. Louis Charles Mary organized another ´Cours d'architecture´ heavily influenced by Durand's and included the description of building materials such as iron and its uses, form masonry reinforcements to independent structural members. He also focused on the connection joints between materials (as a manifestation of the collaboration between engineers and architects) towards the systematization of the entire project. Unlike Durand, Mary's methodology was not inductive as the combination of elements was designed to grow, from simple to complex, from the individual part to the whole, from the element to a system.

Mary's method relied on the complexity and simultaneity of the architectural design and structural design process; it augmented Durand's methodology by proposing a complex problem-solving progression based on several parameters such as the materials, the territory, the climate, culture spatial requirements, and so on.

The methods developed by Durand, Reynaud and Mary among others, illustrate the efforts of 19th century´s approach to knowledge, not just architectural design. As architecture was previously separated from other sciences, Durand's advances towards a scientific mode of understanding the architectural project were clear attempts to bring them together by developing something analogue to a scientific method to understand and produce architecture.

The study of ruins, ancient buildings and monuments, their categorization and the study of their general design principles were at the basis of such method. LeRoy's work on describing Greek ruins[54] and Durand's Recueil[55] are interesting examples of the efforts towards the analysis, measurement and

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54 David Le Roy, The ruins of the most beautiful monuments of Greece, Texts & documents (Los Angeles: Getty, 2004)

55 Jean Nicolas Louis Durand, Recueil et parallèle des édifices en tout genre, anciens et modernes, remarquables par leur beauté, par leur grandeur ou par leur singularité, dessinés sur une même échelle (Meline, Cans et Cie, 1840). https://doi.org/10.3931/e-rara-53442

classification of ancient architecture. In order for this classification method to work, a certain level of abstraction must be achieved; many buildings were simplified or even changed in relation to the originals (sometimes a level of interpretation was also part of the procedure). The idea of 'type' [56] became a useful and a valuable tool in order to manage the different building categories, styles, programmes and structures.

The codification of architectural information was only possible by a methodology in which, a project can be translated into abstract information such as geometry, formal relationships or mathematical 'parameters'. As Madrazo describes, by codifying architectural knowledge by the means of a method, it becomes objective, it can be transmitted and applied by other architects. In other words, it becomes scientific. Thus, Architecture became detached from the natural world; it developed into a system of concepts, abstract ideas and matured into self-sufficiency.

As this thesis will develop later on, the systematization process is key in the contemporary digital practices; parametric, algorithmic and many other digital methodologies require the abstraction and codification of architectural information into a nonrepresentational set of parameters. Spatial, structural, material and geometrical information need to be expressed in such terms, determining a specific type of architectural strategy. On this terms, Durand´s method implied not just a design strategy but a modern definition of architecture altogether, more focused on formal and spatial organizations rather than stylistic discussions.

On style.

On top of technical and theoretical developments, 19th century witnessed an active discussion on the role of stylistic references in architectural design. It is not the purpose of this research to describe in detail the abundant arguments of such debates, but the process of questioning and reassuring the function of historical references had important consequences for the discipline.

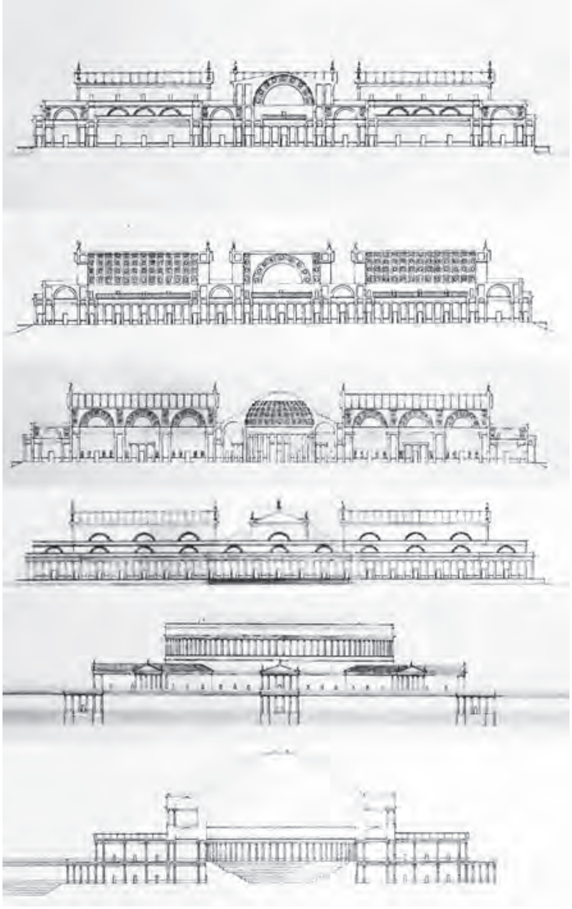
Rooted in the investigations of Johann Winkelmann[57], the historical diversities and characteristics were coupled with social, regional and national differentiations to define what the 19th century would discuss as 'style'. Heinrich Hübsch's publication[58] sparked the debate in order to develop a contemporary style, taking into account climate adjustments and building technologies, elements and comfort. Karl Bötticher[59] also argued in favor of a style according to its own time, influenced by the advances on iron constructions and technical

56 A detailed study on the concept of type can be found in Leandro Madrazo, "The Concept of Type in Architecture: An Inquiry into the Nature of Architectural Form," Swiss Federal Institute of Technology, ETH Zurich, 2018

57 Johann Joachim Winckelmann, History of Ancient Art (New York: F. Ungar Publishers, 1969)

58 Heinrich Hübsch and Wolfgang Herrmann, In what style should we build? The German debate on architectural style., Texts & documents (Santa Monica, Calif.: Getty Center for the History of Art and the Humanities, 1992), Heinrich Hübsch [et al.]; introduction and translation by Wolfgang Herrmann

59 Karl Bötticher, Das Prinzip der hellenischen und germanischen Bauweise hinsichtlich der Übertragung in die Bauweise unserer Tage (Berlin: Ernst, 1906)



2-22 Variation in facade compositions by Durand's method.

developments, while comparing the role of iron structures with the performance of gothic building techniques. Gottfried Semper[60] further developed the idea of architectural style, by taking into account technical processes of creation, the genesis, conditions and circumstances of each process.

Related to the discussion of architectural styles and the development of digital tools, Patrik Schumacher wrote a series of articles relating not only the contemporary function of style[61] as a research program. He also proposed 'parametric' techniques and tools as a contemporary equivalent of style, aligned with the concepts inherited from 19th century[62] but now guided by a unified theoretical system, what the calls an 'architectural autopoiesis'[63].

IMPACT ON DIGITAL DESIGN.

Durand and combinatory parametrics.

Durand's quest for a scientific method for design in architecture was a successful attempt that would foster a whole new area of research in design methodologies, particularly through the developments in computational techniques. The 'scientification' process initiated by Durand´s method required to extract abstract information in order to process it; in his case, through a combinatorial matrix in a structured grid with hierarchical axes. The abstraction of architectural information was achieved thanks to simple geometric entities, which in turn generated architectural elements and then architectural 'parts'. The conscious combination of parts, or 'composition' required a correspondence between architectural form (or its proxy, a geometrical entity) and a particular architectonic program; it purposely ignored architectural styles, details and other features that could not be translated (or reduced) to an abstract entity.

This concurrence of geometry and program (or human activities), would be again resumed by architects and researchers in early computational tools during the 1970's. The case of Yona Friedman's 'Flatwriter'[64] is significant on this matter. Friedman's conceptual project was based on software that generated housing projects by associating different building parts according to the preferences of each inhabitant. Every relationship between the parts (each individual housing unit) and the whole (a large housing project) was created

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60 Gottfried Semper, Style: Style in the technical and tectonic arts, or, practical aesthetics / Gottfried Semper; introduction by Harry Francis Mallgrave; translation by Harry Francis Mallgrave and Michael Robinson, Texts & documents (Los Angeles, Calif.: Getty Research Institute, 2004)

61 Patrik Schumacher, "Style as Research Programme," in DRL ten: A design research compendium / conceived and implemented by Tom Verebes (publication coordinator); Theodore Spyropoulos (exhibition coordinator); Yusuke Obuchi and Patrik Schumacher (pavilion coordinators), ed. Tom Verebes, AADRL documents 2 (London: AA Publications, 2008)

62 Patrik Schumacher, "Parametricism as Style - Parametric Manifesto," http://www.patrikschumacher.com/Texts/Parametricism%20as%20Style.htm

63 Patrik Schumacher, The autopoiesis of architecture: Volume 2 (Chichester: Wiley, 2011-2012)

64 Yona Friedman, "The Flatwriter: Choice by computer," Progressive Architecture 52 (1971)

from geometric and algorithmic affiliations as the association between each unit and its neighbors was expressed through a series of combinatory rules.

Like Durand's method, the Flatwriter proposed an algorithmic approach to a complex design project, but instead of relying on regulatory primary and secondary axes, symmetry and a dominant regular framework to inscribe it. Friedman's composition was organized through a grid, but it was built upon the local relationships between each housing unit, presenting a different type of organization, un-hierarchical and de-stratified.

Another interesting case is the Urban 5 project by Nicholas Negroponte[65]. It operated similarly from a geometrical point of view, but the regulation of the relationships between each housing unit was defined by questionnaires and interviews to the future users. Although Negroponte's goal was to effectively replace the figure of the architect (Durand's method wanted to produce architects faster and more efficiently), his research[66] intended to produce projects autonomously and freely, and it later derived in the development of artificial intelligence.

The 'Generator' by Cedric Price[67] proposed yet another computational method to produce architectural designs, and devised a way to elude the linearity of design decisions by injecting (every certain number of cycles or in a determinate lapse). This sort of 'surprise factor' worked as an indeterminacy inducting device, avoiding mechanistic and foreseeable solutions., which are a natural product of a scientific procedure. Particularly, in the case of Price's project, every time the system came to a determinate stability threshold in its formal configuration, a module would reorganize and redesign the set by combining a random variable to the generative rules.

Price´s project came into contact with a disciplinary problem that the previous ´method´ architects have not foreseen: by turning the architectural design process into a scientific procedure, its results would eventually start to look like one another, losing the specificity that a good architectural project requires.

Price´s random-inducing machine would partially solve this matter, although one has to have in mind that every solution proposed by this uncertainty would also be included in the design procedure.

The control of overdetermination and the administration of randomness will be a constant in digital design procedures.

A similar approach was taken by Federico Eliaschev's master and doctoral thesis[68] [69] by defining a housing unit, composing several rooms according to the activities of a family unit. An apartment would be integrated by private

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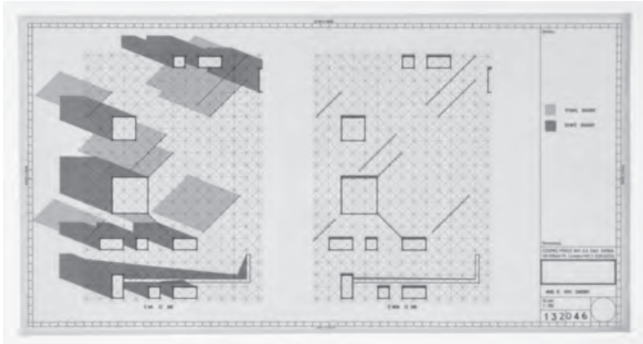
65 Nicholas Negroponte, Soft architecture machines (Cambridge, Mass., London: M.I.T. Press, 1975)

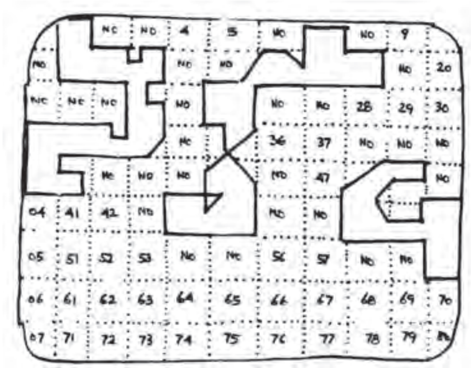
66 Nicholas Negroponte, "Toward a Theory of Architecture Machines," Journal of Architectural Education 23, no. 2 (1969)

67 Cedric Price, "The Continuing Relevance of Generator," in Cedric Price. Opera., ed. Samantha Hardingham (Chichester: Wiley-Academy, 2003)

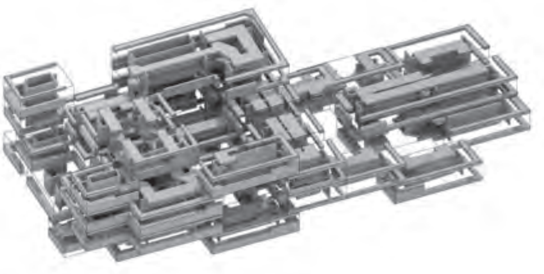
68 Federico Eliaschev, "Dispositivos Proyectuales Sensibles" (Master Thesis, Centro Poiesis, Facultad de Arquitectura Diseño y Urbanismo, Universidad de Buenos Aires, 2012)

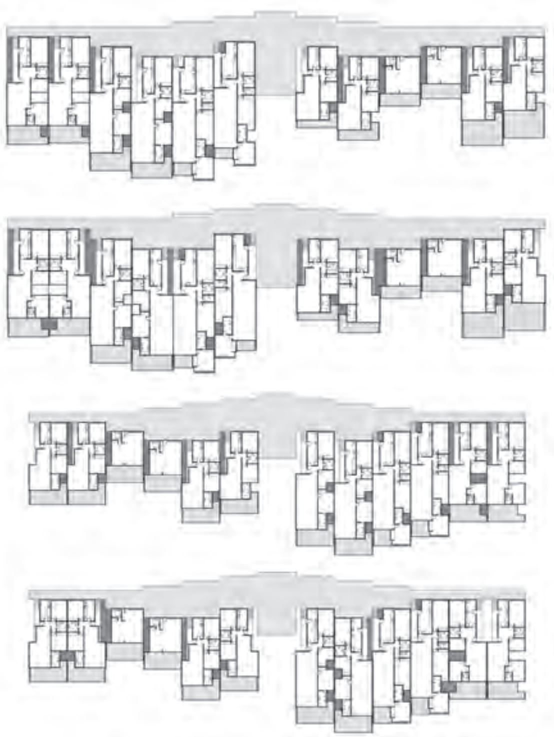
69 Federico Eliaschev, Dispositivos Proyectuales Sensibles (Buenos Aires, Argentina: Concentra, 2017)





2-23 Shadow studies in architectural compositions using digital tools during early computation experiments. The Generator Project by Cedric Price (1977)
2-24 Combinatorial design example in building design. The Flatwriter by Yona Friedman (1967)





2-24 Combinatorial parametrics in housing projects. Master thesis by Federico Eliaschev (2017)
2-25 Mil Edificios (Thousand Buildings) by Santiago Miret (2017)
2-26 Master Thesis project by Federico Garrido (2012)

rooms, shared spaces and services according to the number and type of family members.

The system would sequentially compose a multi-storey housing complex by joining several housing units next to another. Unlike Durand's, Eliaschev's composition strategy is guided not by geometrical constrains and systems of order but by affinities between the activities on each unit (i.e. bathrooms next to rooms, kitchens next to entrances) and by empathy levels between each family unit (i.e. young couples next to students, nuclear families close to elders).

A postgraduate Master´s research project by the author of this thesis[70] is also based on these design experiments, using the capacities of digital design tools in order to compose complex projects by combining single architectural units guided by a series of rules and parameters.

At the Poiesis Center we also did extensive research on these tools and their ability to produce usable architectural information. This process implied taking user information (types of family, familiar affiliations, daily activities, preferred aesthetics, desires, etc.) and then transforming it into architectural information (spatial, morphological, tectonic) by procedures that are not necessarily digitized or mediated by a computer.

As a member of the UAP[71] and as a part of the master thesis, the author of this research has organized and dictated several workshops using similar composition techniques. Some of them are Parametrics in 2010, Vivienda Masiva (Massive housing) in 2010 at the FADU-UBA and 'Agregaciones Intensivas' (Intensive aggregations) in 2012 at the SCA (Central Society of Architects). They proposed to explore different digital solutions in relation to the controlled combination of habitable units in order to generate large housing complexes, or in terms of Durand, combining architectural parts in one harmonic, organized composition.

Both this research and Eliaschev's thesis were also influenced by the Barcode Housing System[72] by Leandro Madrazo, a scholar of Durand and author of several texts about his compositional method who successfully applied a similar approach to housing projects.

The correlation between a 'classic' compositional methodology and its updated version through digital tools will be addressed in future chapters, particularly on a series of experiments regarding the complex addition of architectural spaces, rooms and elements. This particular technique is denominated as 'Parametrization model by combination of geometries' in Eliaschev's Master thesis[73]:

"It is the case of previously parametrized or explicit shapes, whose

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70 Federico Garrido, "Proyectos de vivienda para la emergencia social y ambiental generados con metodologías digitales," (unpublished manuscript, 2012)

71 UAP - Parametric Architecture Unit, a research cluster interested in the use of digital generative tools in housing projects. F. Eliaschev, F. Garrido,S. Miret, F. Menichetti are the founding and most active members .

72 Leandro Madrazo et al., "Barcode housing system: Integrating floor plan layout generation processes within an open and collaborative system to design and build customized housing," T. Tidafi and T. Dorta (eds) Joining Languages, Cultures and Visions: CAADFutures 2009, PUM, 2009, pp. 656- 670, 2009

73 Eliaschev, "Dispositivos Proyectuales Sensibles"

combination is parametrized in order to generate more complex systems. They are systems that combine architectural pieces ranging from little architectonic elements, to habitable sub-units, like bathing spaces, places for sleeping, etc. or complete Habitable Units. The mode of combination is given by some sort of algorithm of a more complex kind."

And then:

"In this case it could be said that this represents a Parametrization of a first order which determines the position and relations of a series of pre-designed pieces. But in turn these pieces can be internally parametrized, representing a Parametrization of a second order." (Uppercases by the original author)

De Landa and virtual materials.

During the 19th century, the development of materials like steel and the machines to mold and modify them produced a series of consequences that can be traced not only to design strategies and methods but also to the operation and conception behind contemporary design software.

On his text "Philosophies of design – The case of modeling software"[74] Manuel De Landa explores two possible design approaches to a design process by considering it as material problem. One would be 'conceptual or cerebral', on which the designer imposes his ideas into a 'homogeneous, obedient and receptive' matter, while the other process requires the designer to understand and take into account material properties, heterogeneities and particularities.

According to De Landa:

"(…) several historical processes have conspired to impose the wrong philosophy of design. For example, the nineteenth century process of routinizing labor, of transferring skills from the human worker to the machine (the process which came to be known as Taylorism) and the task of homogenizing metallic behavior went hand in hand."

The process of mechanization of production required a homogeneous and receptive material, one who would not require the machine to notice small differences, heterogeneities and particular properties. This material can be exemplified by steel:

"Manufacturing processes can be broken down into many separate stages, each requiring a minimum of skill or intelligence... At a higher mental level, the design process becomes a good deal easier and more foolproof by the use of a ductile, isotropic, and practically uniform material with which there is already a great deal of accumulated experience."[75]

While De Landa argues for the second design procedure (machinic, non-conceptual), he argues that traditional CAD software operates on a similar 'conceptual' approach as the first one. He exemplifies this by the fact that the generation of tridimensional objects is produced without any influence of the material or its qualities. De Landa explains that there is however a material conception embedded on CAD packages, one corresponding to a crystal state of matter:

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74 DeLanda, "Philosophies of Design: The Case of Modelling Software" in Verb (Architecture Boogazine)

75 DeLanda, "Philosophies of Design: The Case of Modelling Software" in Verb (Architecture Boogazine)

"Most early forms of solid modeling involved a simple "material", rigid polygons, and allowed only a few operations for the creation of basic shapes, such as taking a line representing the profile of a simple, symmetric shape [a wine glass or a bottle] and spinning it around to generate a three-dimensional form. these are "surfaces of revolution", so called because they are generated by spinning or revolving a line. Another simple operation, called "extrusion", begins with a surface or a cross-section and generates a three-dimensional shape by displacing it or scaling it, while at the same time providing new side surfaces to complete the solid form. In both cases only a very small repertoire of shapes may be created. This reduced variety may be increased somewhat by including "Boolean operations", which allow the designer to combine several forms generated by revolution or extrusion."

Extrusion and revolution are common operations in 3d modeling software and they are excellent examples of a direct relationship between a production technique, a design procedure and the object it produces. On this particular topic, the author and the director of this research (Prof. Dipl. Ing. Lucas Merx) collaborated in an exhibition[76] exploring the possibilities of such operations in the design of pavilions, exploring the complex possibilities of applying simple design procedures, such as metal turning and extrusion.

Although De Landa's position in favor of a more complex assessment of material information in the use of modeling software, the analysis of what he defines as 'conceptual' approach to design and its subsequent influence on the use of traditional 3d software is still relevant, and a proof on how 19th century ideas and material conceptions influence are silently present on everyday digital tools.

76 Lucas Merx, Holmer Schleyerbach, and Federico Garrido, "Exhibition Pavillons," http://rokokorelevanz.de/details/exhibition-kerstenscher-pavillon.html

CHAPTER 3

- *Aesthetics*

EXPERIMENTAL APPROACH TO DESIGN

Experimentation with iron.

"The new structural treatments of load and support demanded new aesthetic reactions. In the past people had grown to expect the basis of the equilibrium between load and support in a building to be visible at a glance, to lie open to inspection. But with the introduction of new methods of iron construction it became more and more difficult to differentiate between load and support: a new poised equilibrium of all the parts of a structure began to appear."[1]

The use of iron can be traced back to the Greeks and Romans. Although they lacked precise tools and proper means of fabrication, they could merely produce a weak alloy, rendering bronze as a more suitable material. According to Antoine Picon in his text 'The first steps of construction in iron'[2], one of the earliest adoptions of iron in architecture was the fabrication of reinforcements in the Louvre Colonnade by Claude Perrault (1665-1680). Although these reinforcements were not visible, they expanded the dimensions of the Colonnade in order to gain a monumental character by exceeding those they referenced on the first place. Monumentality was impossible to achieve without iron.

Picon's report on the first adoptions of iron is also symptomatic of its use throughout the 19th century. As Gideon explains on the use of new building techniques:

"Advances in building technique seem to have brought with them only the practical problems involved in using new methods to produce old effects."

Antoine Picon describes a similar question, directly related to the use of iron in order to achieve technical performances impossible to attain formally without the aid of bigger or even complementary structures:

"(…) the use of iron nonetheless poses a formidable problem insofar as it leads to a dissociation of the architectural form from the techniques that enable its construction."[3]

The implementation of iron reinforcements in order to produce audacious structures also challenged classic Vitruvian conceptions regarding the Firmitas:

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1 S. Giedion, Space, time and architecture: The growth of a new tradition / Sigfried Giedion, 5th ed., rev. and enl, The Charles Eliot Norton lectures 1938-1939 (Cambridge, Mass., London: Harvard University Press, 2008)

2 Antoine Picon, "The first steps of construction in iron.: Problems posed by the introduction of a new construction material," in Rinke; Schwartz, Before steel

3 Antoine Picon, "The first steps of construction in iron.: Problems posed by the introduction of a new construction material," in Rinke; Schwartz, Before steel

buildings should not only remain structurally sound and stable, but also they should represent such soundness and stability. This implied a problem for iron architecture.

A perception of the clear path of the gravitational forces as they travel through materials was the implicit accord between a building and its user; tectonic stability is the acknowledgement of this relationship. Iron would disrupt this perception and thus, shake the entire design framework that associated this perception of solidity within a system of geometrically organized proportions.

The use of cast iron parts in construction and in architecture in particular required a precise degree of material knowledge (both chemical and physical), however the manufacturing process was still under development at the beginning of the 19th century and it did not produce a completely homogenous material throughout Europe. Added to the theoretical concerns, this reason made the architects uneasy in face of the possibilities of iron and the development of its own aesthetic expression. This also paved the way for engineers to take a leading role in the formal and structural experimentations with iron. Often collaborating with architects, the result of this partnership would lead to the development of new conception of structure, its materialization and its relationship with architectural space.

The experimentation regarding structural elements could be exemplified with the early iron skeleton buildings. According to Giedion, the first 'true skeleton type' was the Menier Chocolate Works by Jules Saulnier (Noisel, 1871), whose structure is supported entirely by an iron skeleton, visible on the façade and filled in-between with brick and ceramics.

The building's façade-structure is entirely planar, without projections or balconies, undecorated and flat. The outer walls functioned as thin curtains, preceding the contemporary character of facades. Giedion claims that this factory provided a precedent for the iron frames that were later a required condition to the development of the American skyscraper, as he defined Saulnier's factory as "essentially, an iron frame clothed in masonry"[4].

L.S. Buffington[5] and W. Le Baron Jenney[6] would later develop further the idea of an iron skeleton covered with masonry clothes, which, along with other independent inventions like the electric elevator would produce the skyscraper, an entirely modern building typology.

Aside from its structural use, cast iron and more important yet, the appeal of cast iron would permeate more and more aspects of everyday life in the 19th century. Giedion summarizes it:

"(iron) was a new and fascinated material which could not be employed too much. Its unexplored possibilities quickened everybody's imagination. It was such an attitude that led John Wilkinson to want a cast-iron mausoleum,

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4 Giedion, Space, time and architecture

5 According to Giedion, Pennsylvanian architect Leroy Buffington would claim the invention of the skyscraper in 1880, by taking inspiration form Violet LeDuc's Lectures on Architecture.

6 William Le Baron Jenney's 'Home Insurance Company' is considered the first built skyscraper, planned and executed with modern principles and construction technologies.

and even a cast-iron coffin."[7]

The iron foundries printed catalogs (sometimes several volumes) showcasing all sorts of products; construction elements like columns, roof tiles or rain gutters, sculptures, decoration pieces like vases, plaques, garden furniture, and many, many more. Unlike in building structures, design experimentation did not exceed the period's taste for historical references; cast iron was a cheap and affordable material ('iron is the bronze of the poor') to bring consumer products to the masses, but always referencing historical pieces.

Experimentation in international exhibitions. The Hall and the Pavilion.

"The exhibitions also fostered a spirit of rivalry, a desire to equal or improve upon the last exhibition. Thus risks were taken in many departments, not least of all in architecture. Such a spirit of rivalry, together with the efficiency it promoted, is visible in the Crystal Palace world exhibition of 1851."[8]

The great exhibitions were established in parallel to the explosion of modern industry, the 'inventor' mindset and the search for new processes and machines. They were truly hubs for the exhibition, distinction and competition between the different branches of the industries and arts. It also accelerated the development of the industries, by fostering the exchange of knowledge, experiences and also, the search for new markets and business opportunities.

As Giedion explains, the international exhibitions symbolized much more than trade fairs:

"The industrial exhibition embodied a synthesis of the as yet unformulated aims of the nineteenth century. It foretold the transformation that was to be effected in man as well as in industry, in human feelings as well as in human surroundings. The exhibitions were a part of the march of industry and were bound up in its destiny."[9]

Architecture was present in international exhibitions in two forms, embodied in two distinct typologies: the hall and the pavilion. Similarly to every aspect of the exhibitions, experimentation was carried on both of them with a different character; while on exhibition halls the search for greater spans and efficient building methods drove their design, the national pavilions explored the expressive possibilities of new materials and technologies as well as the inspiration from foreign cultures[10].

The exhibitions, understood as the international showcase for technological advancements provided also the opportunity to thrill and inspire the visitors by presenting them to unseen architectural spaces and effects. At the same

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7 Giedion, Space, time and architecture

8 Giedion, Space, time and architecture

9 Giedion, Space, time and architecture

10 In his book On "Zwischen Glaspalast und Palais des Illusions" Erich Schild details several of these experiments while describing their formulation from purely functional structures to ceremonial and expressive ones. See Erich Schild, Zwischen Glaspalast und Palais des Illusions: Form und Konstruktion im 19. Jahrhundert, 2. Aufl., Bauwelt-Fundamente 20 (Braunschweig: Vieweg, 1983)

3-1 One of the two examples of construction, disassembly and re-assembly. Chilean Pavilion at the Exposition Universelle by H. Picq (Paris, 1889)
3-2 One of the largest pavilions at the Exposition universelle de Paris. Argentinean Pavilion at the Exposition Universelle by A. Ballu (Paris, 1889)

time, it was a splendid opportunity to combine technique and emotional effects by attempting record-breaking structures, larger covered areas, longer spans between supports, taller towers, and so on.

The Galerie des Machines and the Eiffel tower (both erected in the Champ de Mars) are textbook examples of this record-breaking, bold mentality; in order to show technical and material superiority the world industry leaders proposed these structures that progressively distanced themselves from traditional architectures but also from familiar typologies as well. Duterte's Galerie was a blunt industrial facility, it had no ornamentation or reference to architectural orders but also, it challenged the contemporary architectural grammar itself. The Galerie´s space presented no separation between support and supported elements, no columns, no walls or roof, everything was synthesized in a grandiose structure.

Javier Cimadevila[11] analyzed the underlying geometry of the hall and argues that unlike the Eiffel tower, the defining arch of the Galerie is deviated from the optimal structural shape, thus demonstrating some sort of compromise between sheer structural needs and stylistic decisions. The result, however, is distant from a purely architectural or stylistic solution, prioritizing an industrial expression.

On the contrary, the pavilions (local and national ones) did explore other architectural effects by making use of all means available like novel materials, paintings, light effects (first natural, later electricity), mirrors and even water and vegetation. Unlike the large exhibition halls, there were no particular technical requirements (i.e. restrictions in size or spanning between supports) or programmatic prerequisites that conditioned their materialization: architectural experimentation was on these cases the driving force.

Such freedom and availability of technical solutions produced a variety of experiments consisting in the creative exploit of a few variables: simplicity of construction, ease of montage and rationality in design (i.e. industrialized parts, standardization, repeatability). It is also necessary to state that these pavilions were not cheap at all, as they required a considerable investment, particularly in the case of the ones commissioned by developing countries. The case of the pavilions of Argentina and Chile (Paris, 1889) is symptomatic of the required effort placed on these constructions; they were both disassembled and transported to their sponsoring countries where they functioned for several decades as museums. The topics related with these particular solutions will be further developed on the 'Conditions' chapter.

Formal experimentation however did not run parallel to engineering developments, especially in their aesthetical appraisal. Pavilions like the "Palais de l'Electricité" (by Henard and Paulin) or the "Château d'Eau" (Paris, 1900) illustrated how the technical advancements like electricity, wireless telegraphy, steam dynamos and x-rays would reshape the world by showcasing technological wonders, yet their housing was clothed in Louis XIV facades.

Practically every building from these exhibitions was built in an iron

11 Javier Estévez Cimadevila and Isaac López César, "La Galería de las Máquinas de 1889. Reflexiones histórico-estructurales," VLC arquitectura. Research Journal 2, no. 2 (2015), https://doi.org/10.4995/vlc.2015.3598

structure but profusely covered with masonry and stucco. This presented yet another predicament for the visitor, since the straightforward perception of the relationship between load and support that the large halls offered (in didactical manner) was completely disguised by the historical wrapping of the smaller pavilions.

This seemingly contradictive attitude towards technique and expression did not necessarily imply an abuse or misuse of the building technologies but yet another example of the period´s open-minded approach to technical developments, coupled with the unprecedented degree of both practical and artistic freedom.

NEW MATERIALS, NEW ELEMENTS, NEW PROPORTIONS.

New materials vs style, engineer vs architectural aesthetics.

19th century witnessed the progressive separation between architects and engineers; their schools and academies were disengaged as their roles in the building process were clearly differentiated. Such division remains today but its origin is rooted in contrasting (and sometimes uncompromising) conceptions of what a building should be, an attitude towards materials, how to construct space and how to organize construction procedures. All of these concepts and questions were embedded in the 19th century discussion.

On Berthold Hub's 'Architect versus Engineer'[12], the author contrasts the two conflicting points of view supported on the text 'Ingenieuräesthetik' by Joseph Lux from 1910. According to Lux, the divergence lies on the conception of the building itself and its aesthetical perception; on one hand, the architects and their quest for material presence and on the other, the engineers, and their pursuit for efficiency. These two conflicting tendencies can be defined by its material outset but also as an aesthetical assessment: the perception of material presence and soundness was understood at that time as 'monumentality', which was also tied with another fervent 19th discussion regarding character[13]. This position also relied on a historical discourse; in order to continue the classical building tradition inherited by Greeks, Romans, Renaissance, etc. the Vitruvian Firmitas needed to be sustained: buildings should not only 'be' supported but also 'express' such support through a sound material presence.

Engineer aesthetics also advocated for the correct expression of support, but instead of relying on historically recognized forms, the expression of materials depended on precise calculations, experimentation and efficiency.

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12 Berthold Hub, "Architect versus Engineer: Monumentality versus Dematerialization," in Rinke; Schwartz, Before steel

13 Several definitions of the architectural character are contrasted by Quatremere de Quincy, mainly focused on the building´s strength, originality and its expressive qualities. Taken from the compilation directed by Jorge Sarquis see Antoine Chrysostome Quatremère de Quincy, Diccionario de arquitectura: Voces teóricas, Serie Textos Teóricos (Buenos Aires: Nobuko, 2007)

3-3 Water Castle and the Palace of Electricity by M. Paulin and M.E. Henard at the Universal and International Exhibition of Paris (Paris, 1900)
3-4 Facade of the Palace of Electricity by M. Paulin and M.E. Henard at the Universal and International Exhibition of Paris (Paris, 1900)

For them, structures should represent the lines of force, how the gravity and weight travelled from each point of the building to the next one until they reached the ground. Engineers associated this traverse of forces with clear, slender elements, which also represented the lines of force and aimed to manufacture them with the least possible amount of material. In other words, the quest of iron architecture was to express itself as the interplay of forces seeking equilibrium. Open and complex networks of slender elements that represented the movement of forces instead of sheer weight, their material presence was indeed the search of immateriality.

Lux praised industrial halls, train stations and bridges as great examples of engineering and actual architecture precisely because their authors have not been influenced by architects, focusing solely on the technical aspect of construction, arguably, a sheer iron structure with no other spatial, programmatic or expressive purpose than material and technical efficiency. For Lux, this drive towards efficiency was enough to create and develop a style on its own.

Hub clarifies nonetheless, that although Lux's point of view was shared by many architects and critics such as Violet-le-Duc or August Choisy, he was disputed by German architects who did not share the belief that iron buildings were indeed the future of architecture. They criticized that the preponderant role of structure and the material characteristics of it, that its line-like, diagrammatic elements of lattice construction lacked of proper expression of mass, of weight, of monumentality.

Architects like Gottfried Semper and Richard Streiter also warned about the lack of 'tectonic' expression on the use of iron, as the dimensions of it may be meager to the human eye. Streiter[14] argued that the network of thin weightless elements, dimensionally invariable, organized in complex arrangements were just too complex to produce a sentiment at first glance, at least for a technically uneducated public.

On the same text, references to Otto Wagner and Walter Gropius also reinforced the difference between a mathematically calculated formal arrangement (like the one needed in iron architecture) and a 'tectonically' conceived one, relying more on the harmonious relationship between parts and of course, a simple but instinctively perception of weight and forces. Perception is then a key component in the evaluation of iron architecture; the use of new materials, technical suitability and structural soundness did not guarantee that the building was indeed a work of architecture; an aesthetic demand must be fulfilled and mathematical thought and engineering efficiency were just not enough to achieve it.

Peter Behrens also argued in favor of monumentality. Understood in terms of the consistency and uniformity of architectural form, monumentality could not be achieved through a myriad of discrete elements as in iron structures. Under this definition, wall continuity, surface articulation and unity of form were deemed necessary for architectural quality.

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14 Richard Streiter, Architektonische Zeitfragen eine Sammlung und Sichtung verschiedener Anschauungen; mit besonderer Beziehung auf Professor Otto Wagners Schrift "Moderne Architektur" (Berlin: Cosmos, 1898)

Ruskin criticized iron structures not for the lack of monumentality but for the physical manifestation of a perceptive deceit. Pevsner summarizes Ruskin's thoughts as well as many other 19th century theorists[15]; he valued honesty in art and he understood it as "a statement of certain facts, in the clearest possible way". On his book 'The seven Lamps of Architecture', Ruskin opposes his contemporary architecture production in favor of Gothic craft and identified three 'deceits', regarding the relationship between material, surface and ornamentation.

The first deceit was structural: the increasing use of iron and the simultaneous persistence on classical references motivated a tendency to hide the real (iron) structure behind layers of masonry, stone and stucco. In other words, the concealment of the load bearing elements was against Ruskin's notion of 'material honesty'.

The second deceit was superficial: the utilization of industrial coatings, like paintings or cast materials like cast iron, terra cotta or ceramics in order to represent other materials was deemed untruthful. Devices and effects like the 'Trompe-l'oeil' (fooling the eye), 'faux bois et marbre' (fake wood and fake marble) were imperfect means to produce profound architectural effects like texture, shadow and depth, achieved only by a masterful use of traditional materials like stone, marble or masonry.

The last one is an operative deceit: the use of cast materials or machine-made ornaments was condemned by Ruskin not because of the material or applied style by itself but for the lack of human intervention. For Ruskin, the contribution of human hand in the production of architecture was valuable, as he feared that the widespread use of machines would contribute not only to the loss of architectural quality but to social decline as well.

Unlike stone or masonry, which were developed for hundreds of years, iron did not have a history or building culture of its own. For this reason, Ruskin did not consider iron architecture as proper architecture, not until a new set of laws and principles derived from metallic construction were developed.

However, architects like Eugene Violet-le-Duc saw unique aesthetical opportunities in the use of iron. Like Ruskin, he admired gothic architecture and its structural drive; new materials like iron were more suitable to be applied in Gothic style, than for example, Roman or Greek.

The slender, structurally efficient elements of the Gothic, like columns or traceries could be easily translated into cast iron as Violet-le-Duc's formal experiments[16] illustrate, by graciously combining masonry and stone vaulting with iron columns and beams. The contrast of thick stone compression vaults with slender iron tensile structures was unseen at the time, and the illustration of a true experimental spirit regarding technique, materials and architectural styles.

Violet-le-Duc's rational mindset defined each architectonic element's shape and material not according to a semantic prefiguration but in relation

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15 Pevsner Nikolaus, Some architectural writers of the 19th century (Oxford: Clarendon, 1972)

16 Eugène-Emmanuel Viollet-le-Duc, Entretiens sur l'architecture (Farnborough)

to its function on the buildings' structure. This evidences the sort of logical approach to construction (which was comparable to engineering) that intended to produce architectural effects through a rational use of materials. Entretiens and the Dictionnaire exemplify Viollet-le-Duc´s concerns about the relationship between architectural form, material expression and architectural character.

The expression of such effects through the use of iron is a topic of interest for this research. The case of Labrouste's 'Bibliothèque de Saint Genevieve' is a compelling example of pioneering use of a new material, simultaneously exploiting its load bearing capacity, formal meaning and expressive quality. The library's skeletal structure even alarmed Semper, who questioned its material presence: being too thin and too light, it motivated a sense of immateriality which was deemed unsuitable for serious architecture at the time.

Labrouste's structural proposal was also interesting due to the fact that the design of the iron arches was derived from the rational repetition of an artistic motive; its origin is unknown and whether or not such design or if its soundness was somehow secured. The design and its repetition reconstruct in some way a diagram of a flat triangulated truss, thus securing the transfer of forces and its structural function.

What is relevant about it is that the 'artistic' design of the iron structure precedes the perception of the sheer structural expression and the affirmation of the architect's role, frontally assuming an experimental character in regard to new materials and their architectonical expression. Years after the Bibliothèque Genevieve, the structure of the Bibliothèque Nationale (Labrouste, 1868) was significantly different: its iron arches, even though they were decorated, were undoubtedly based on a cross-braced typology. The two libraries illustrate how structural expressionism triumphed over pure artistic drive.

Trusses, cross-braced structures, and other engineered structural typologies would soon become standardized thanks to the contributions of engineers like Polonceau, Town, Vierendeel, Cremona, Cullman and Ritter, among many others. A proven method for calculation, design and execution, in addition to a reliable and uniform isotropic material like iron soon provided a standard procedure to deal with complex metallic structures.

The downside was to surrender control to the engineers and specialists; the expression of the structure was no longer a matter of aesthetic discussion among architects but to other factors such as material and economic efficiency, ease of calculation and formal simplification, far away from stylistic decisions.

Labrouste's attitude towards structural design was symptomatic of a distinctive way of dealing with new materials, new structural typologies and above all, how to seamlessly introduce them into a contemporary project conception rooted in history. His alleged design methodology on the Bibliothèque Genevieve's arches: first design, then structural verification, was gradually discarded by another approach. Structural design and its expression are no longer a matter of decision by the architects but for the consultants and specialists.

3-5 Shaping a shapeless material. Roof structure variations in iron for the Sainte-Geneviève Library by H. Labrouste (Paris, 1850).

Industrialized classical elements: a new set of proportions.

The building for the Great Exhibition in Hyde Park not only presented iron as the new architectural material to the grand public but also prompted and encouraged a young generation of architects in its use. The Crystal Palace captivated builders, architects, engineers and designers by its structural and expressive qualities, along with the ease of design, fabrication and montage thanks to its modular composition. One important question previously mentioned, was about solving the aesthetic problem associated with its application; more specifically, how to combine it with other materials, and more importantly, how to deal with the specific dimensions, scale and proportions of its design.

Architects like Semper were fascinated by the building and the possibilities it promoted, while detractors like Ruskin seriously questioned the use of iron, describing its use as a 'deceit'. We've already described the problem of the lack of 'monumentality' and the 'immaterial' qualities of the iron elements, but the widespread and the variety of the use of iron soon prompted a whole series of new questions once its use was popularized. The problem of the design of structural elements and their proportions was one of them.

According to Ruskin, the main problem of the use of iron was paradoxically, its strength. Vitruvius' Firmitas establishes a particular relationship between the strength, the load bearing capacity of structural elements such as columns or architraves and their size. Firmitas did not just meant that the building and its elements should stand by itself but that it should also express solidity. The task of expressing such solidity could be accomplished in many ways, but one of the main characteristics to achieve such effect is by carefully designing the dimensions and proportions in size. Other means to accomplish it can be a change in the material, the design of the element´s texture, the design of the sections, etc. This was a proven methodology to deal with the expression of weight and strength originated by Egyptian, Greek and Roman architecture that spanned throughout several periods up until the beginning of the 19th century.

The specific problem with iron was that its load-bearing capacity is far greater than any material known at the time and, as a consequence of it, the structural elements required much smaller dimensions. This was one of the fundamental problems in its adoption by classical-educated architects; for Ruskin the dilemma of iron is that it fundamentally disrupted the correlation between solidity and the perception of such solidity.

The perception of architectural proportions was indeed a question of user's education; there are several reports and descriptions by visitors of the Crystal Palace portraying with astonishment due to the ethereal and luminous quality of the exhibition building. The general audiences, unaccustomed to the material qualities and dimensions of the cast iron pieces were simply flabbergasted by the contrast with the heavy-looking, massive columns and material presence of traditional, classical or neoclassical buildings.

With the exception of a few examples, the iron revolution's impact on architecture was perceptible by a sudden shift in the proportions of building elements and parts. The case of columns is of course the most discernible, but beams, trusses and girders were altered as well. We've already reviewed Ruskin's position on the subject and it is also interesting to note that some architects like Charles Driver attempted to synthesize Ruskin's critical stand with the contemporary engineer approach[17].

As an example of these new set of proportions for architectural elements, we can evoke the case of iron foundry catalogs. One of the most famous foundries from Great Britain, the Saracen Foundry issued several catalogs, showcasing varied products, ranging from rain gutters, fences, garden furniture and of course, structural elements such as columns, girders and trusses for assembly.

As a case study, the Saracen Foundry Catalogue by Walter McFarlane includes such elements, and in the section XX describes a series of columns for 'Architectural, Engineering and general constructions'[18]. The catalog is illustrated in detail and includes the column's capital and pedestal sections, along with a frontal view of them.

The Saracen Foundry offered complete columns, pilasters, capitals and pedestals. They were offered in several sizes, ranging from under 7 feet high up until more than 10 feet, in several architectural styles, with flat or striated shafts, Solomonic and other possible combinations. The capitals are also of a varied sort, being the Corinthian the most repeated ones, some byzantine and others of a more geometric design.

The first part of the catalog is dedicated to columns under 7 feet (roughly 2,13 meters), they are mostly used in verandas or galleries. Their proportions are too slender for a classical canon, thus appearing a bit eccentric even when they are covered with classical ornamentation. For this reason, these types of columns are often segmented, or sometimes composed with several styles; the top two-thirds are on one style, for example, Solomonic, the lower third or pedestal is striated. There are however some examples of whole columns with a single ornamental style, but their proportions make them difficult to perceive harmonically.

There is another set of these columns that are divided in halves, usually with a ring or series of rings as an articulations between them. Coordinating slender proportions and classical ornamentation is one reason for this division in halves or thirds, but there was also an economical and production motivation for them. Slender, hollow elements were sometimes hard and expensive to cast, hence the justification for dividing them in two or three smaller parts. The underlying problem of this decision was however that the assembly of parts undercut the piece's structural integrity, diminishing its strength. This was not, of course an important inconvenience, given the limited structural requirements of these pieces.

While the height increased, the proportions of the columns resembled the

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17 The paper by Paul Dobraszczyk describes the critical use of cast iron elements by Driver, as well as the careful design of its elements and their proportions. Particularly, it recalls the use of cast iron columns, but similar in size and proportions as a masonry or stone one, hence acknowledging the role of dimensions and perceptive quality of cast iron products at the time. See Paul Dobraszczyk, "Historicizing Iron: Charles Driver and the Abbey Mills Pumping Station (1865-68)," 49 (2006), http://www.jstor.org/stable/40033824

18 Walter MacFarlane & Co Ltd, Illustrated catalogue of Macfarlane's castings. Vol 2. imprint Glasgow Walter Macfarlane & Co

3-6 Classic architectural proportions altered. Cast iron column catalog from the Saracen Foundry Catalog (MacFarlane´s Castings) ones from the classical cannon; for columns 10 feet or higher, the Saracen Foundry offered Corinthian and Composite varieties, as well as composite columns with ornamental flowers, combinations of smooth and fluted shafts, among other types. There was also the possibility to select pilasters or half-columns in a wide variety of styles and decorations; from classical Corinthian, to Gothic branched ones, as well as rectangular or flat pilasters.

Finally, the foundry offered an interesting variety of capitals and pedestals in both full and half diameters. As usual, the assortment included several architectural styles, levels of detail and sizes. On these last set of items lies the critical advantage of cast iron prefabrication techniques; when the combinations were no longer defined by the architectural canons or the taste of the foundry but by the requirements and desires of the designer and clients.

Open structural systems. The Vasena column.

Each foundry had its own variety of items and selection of architectural elements, but most of them concurred on the classical and eclectic taste from the mid-19th century in Europe. The Vasena Foundry from Buenos Aires showed however an interesting improvement regarding the stylized cast iron columns; on top of the regular variety of styles, it developed a patented 'system' of columns, the 'Vasena System'[19].

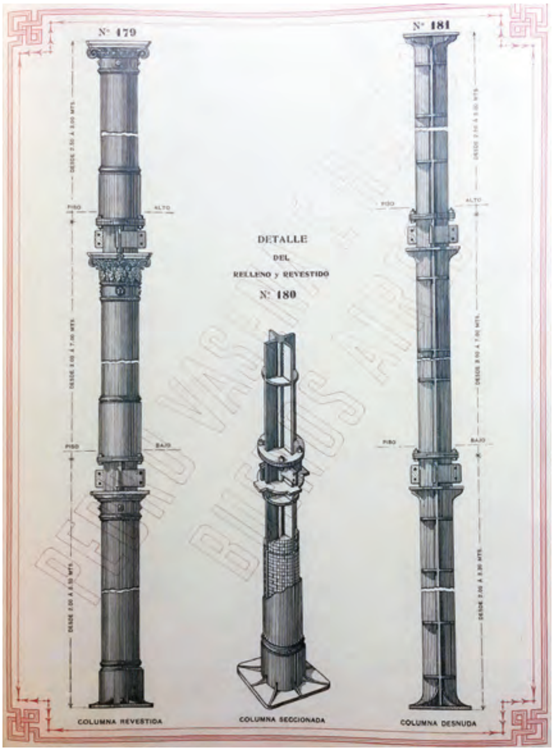
The proprietary system not only provided a variety of diameter profiles and lengths (from 1,75m to 7m), but also standard connections to beams and girders. The relationship between the column´s parameters and strengths, resistance and safety coefficients are detailed and tabulated as well. However the best feature of this system was that the columns were prepared, and purposely designed to be filled and covered with refractive material.

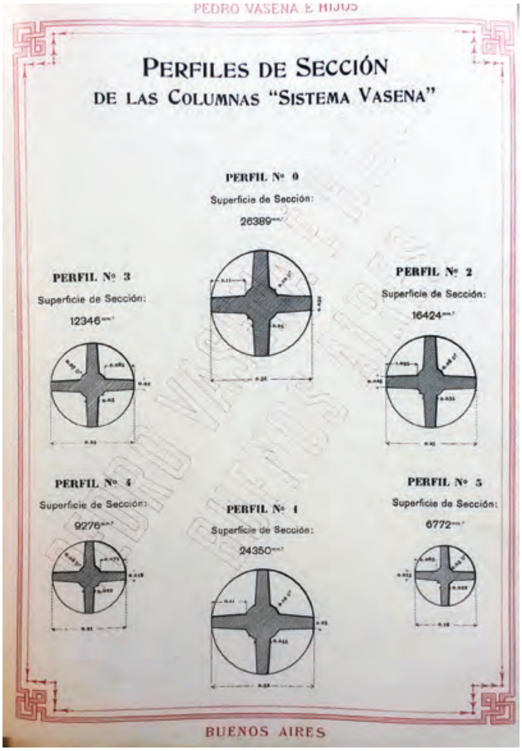
Thus, the Vasena iron column was intended as a support structure for a practical and stylistic function; a truly open system that could be theoretically adapted to fulfill several and varied purposes, multiplying the combinatory possibilities by altering lengths, diameters, quantities and types of fireproof material and of course, architectural ornamentation.

The Vasena structural system could be understood as a complex parametric element, dependent not only on geometrical constraints, but on other functional and aesthetic variables; dimensions, structural integrity, strength, fire resistance, ornamentation: they could all be altered within a single, coherent and encompassing system.

The freedom arisen from these economical, stylistic and production conditions is one of the topic of interest of this research and a true source of architectural variety and value. The implications of such freedom echoed in every aspect of the architectural practice as well as on several corners of the world. Foundry catalogs were a successful method of communication between companies and its clients, (sometimes even surpassing architects and engineers) and their use and distribution were widespread up until the mid-

19 Santiago Vasena, Primer Catalogo. La utilización del hierro en la arquitectura y la construcción, 1902, Sociedad Central de Arquitectos





3-7 Multimaterial configurations; ornament, structure, iron and ceramics on the Vasena Column system.
3-8 Sections of the Vasena Column system. Extract from the Vasena Catalog.

20th century.

Industrial catalogs are predominantly interesting for this research for many reasons; one being the catalogs an illustration of the relationship between the design of prefabricated pieces, their fabrication and their use by construction professionals.

Catalogs such as the Saracen Foundry from Glasgow or the Vasena Foundry in Buenos Aires included detailed drawings and etchings of detailed cast iron elements, but these elements were not stockpiled or waiting to be picked up on a warehouse. These catalogs included drawings as a guide for clients and architects to discuss and select the construction materials, they showed finished designs but not fabricated products; those were manufactured only on request by the client. We will discuss more on the selection, purchase and fabrication of elements on the subsequent chapters.

Cast iron structural elements, a new set of shapes.

Before cast and wrought iron elements completely replaced timber structures a buffer period of experimentation reshaped traditional structural elements, thanks to the manufacturing, formal and structural possibilities of the new material. As previously stated, the first uses of iron in construction were associated with the reinforcement of masonry walls, columns and arches, but as the fabrication techniques improved in technical (and therefore financial) terms by the end of the 18th century, the use of the new material steadily increased its role in constructions and architecture.

The immediate application of iron structures happened on industrial constructions such as warehouses and mills. On those typologies fireproof protection was a crucial factor due to the manipulation of hazardous materials; the mix of flammable materials such as cotton, silk, oil and other chemicals and a timber structure was indeed a dangerous combination[20]. Cast iron elements and a modular construction techniques were one of the first successful applications of this new material, but iron alone was not enough to ensure a secure fireproof structure. The use of cast and wrought iron was indeed more expensive than timber construction but the insurance costs of such buildings would drop, making it financially suitable over time[21].

Inventors-engineers like William Strutt developed interesting systems of construction combining cast and wrought iron, masonry and timber (true multi-material constructs!) for the Derby Mill and the Milford Warehouse, the first ever two fireproof buildings. He used solid cast iron columns tied to each other with wrought iron connectors linking them with tie wrought iron rods and timber beams. Each beam supported brick arches that carried the weight of each floor; every element but the cast iron columns and tie rods were fire proofed with materials such as plaster, sand and wrought iron sheets covering

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20 It was also used in theaters for the same reason: large collections of dresses, costumes, decorations and sceneries were prone to fire accidents.

21 For a brief description of the progression in fireproof construction, see Bill Addis, "The iron revolution.: How iron replaced traditional structural material between 1770 and 1870," in Rinke; Schwartz, Before steel

the arches from below.

Strutt's system made use of iron's structural capabilities depending on each fabrication technique; cast iron elements were very resistant to compression but brittle when subjected to traction efforts, hence the use of solid cast iron in columns (whose main effort is compressive) and wrought iron in the slender tie rods (exclusively supporting traction forces). The resting element to be replaced by iron would be the timber beam, but the complexity of its structural behavior made its 'efficient' design much too intricate.

Addis' text names on this regard, the works of Charles Bage in Castle Foregate Mill in Shrewsbury, having designed and fabricated a wrought iron beam according to its structural efforts, thick at the bottom (where the traction is greater) and deeper at the mid span (where the bending moment is greater). The Foregate Mill columns were equally innovative; their cross-type solid section was thickened at the mid height, where the bending efforts (according to the buckling theory) were greater, creating a particular profile.

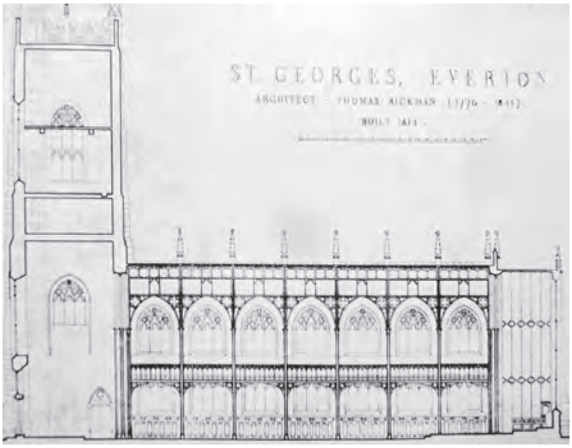
These first attempts to scientifically design efficient structures were noteworthy at their time and a prerequisite to modern and contemporary approach to structural design. The rational approach to the design of structural elements based on the actual efforts of each component was consequential from two separate developments; first the progressive understanding of structural behavior and second, a shift on the design of iron elements.

Regarding the first cause, the capability of observing, analyzing and predicting the performance of a structural member up until the point of failure led engineers and fabricators to design and test new shapes, sections and profiles in order to minimize the use of material, reduce weight and decrease costs. The subsequent development was derived from the use of iron; as an infinite shapeable material through casting, hammering or welding encouraged such experimentation, no longer tied to the inherited shapes from the classical antiquity or the limitations of natural sources such as trees or stones.

Parallel to this rational approach to structural design was a more formal, classical and perhaps naive attitude towards the design and fabrication of iron elements. Of course this does not mean that the design of such components was completely irrational or dependent on aesthetical factors alone, but the use of geometrical motives, patterns and expressionist shapes was greatly present.

On top of aforementioned case studies such as the St. Genevieve Library by Labrouste, several architects, engineers and builders experimented with cast iron shapes that occupied prominent structural roles in the buildings, such as trusses, beams, girders and columns. On this regard, we could mention a couple of interesting examples are the St George's Church in Everton and St Michael's Church in Aigburth, both designed by architect Thomas Rickman and built by John Cragg, who owned the Mersey Iron Foundry.

Both 'Iron Churches' became notorious for being two of the first buildings to include cast iron on their construction (around 1813-1815) not only in their structure but in many other places, as Cragg looked for new ways to include iron in every possible situation. Although the churches were built on brick, they included many cast iron components such as the parapets, battlements



3-9 Interior view of one of the iron churches St. Georges Everton by T. Rickman and built by J. Cragg (iron master)
3-10 Section of St. Georges Everton by T. Rickman and built by J. Cragg (iron master)

and pinnacles and also the roofs were of slate slabs in a cast iron framework.

The interesting aspect of the churches for this research is not the use of new materials by itself but the aesthetics of such elements, consisting in gothic motives and tracery. Completely different from the rational design of trusses such as the Polonceau variant or a geometrical-expressive approach such as the one by Labrouste, the 'iron churches' offered a direct translation of Gothic designs to cast iron elements. The flattened elements hollowed by decorative figures gave the structure a lightweight expression; the trusses were dematerialized almost to its linear elements, impossibly thin for their constitution. The later addition of tie rods in St. George disturbed the original appearance, creating a complex web-like composition.

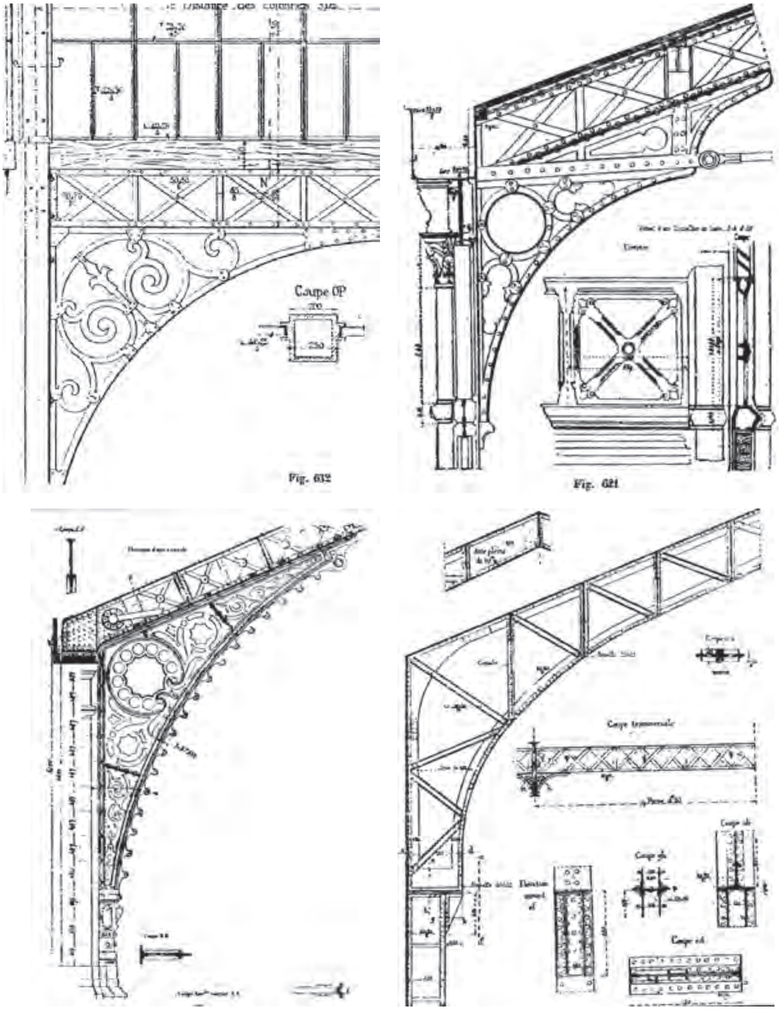
The sheer geometrical and expressive approach to design and particularly, the design of structural elements in the early 19th century are of great interest for this research. The quantity and quality of material experimentation in view of an entirely new material were higher than ever before, resulting in interesting designs, exercises and experiments: true design research combining aesthetical prerequisites, structural requirements and financial demands.

Iron trusses. The standardization of structural elements.

The design and production of standardized truss elements in wood was mainly based on two structural typologies; the King post and Queen post roof types, along with some variations. With the introduction of iron, these two typologies were gradually updated and their elements replaced by cast and wrought iron, depending on the type of stress that each part endured. The first uses would involve replacing compression elements by T shaped cast iron pieces and the tensile ones by wrought iron bars. The use of this new material and the reshaping of structural elements were often accomplished by precisely detailed drawings, however due the experimental state of their use, standardization was accomplished in terms of general design but not in shapes or forms. Eventually rolled I, C and T beams would replace cast iron elements as fabrication techniques and design confidence increased over time.

Experimentation in structural design took two diverging paths, the first one being an 'artistic-experimental' approach, on which thanks to the characteristics of iron (mainly stress resistance and plasticity) were exploited in order to achieve new shapes and geometries previously unobtainable with wood or stone. The second path was a 'geometric-optimized' approach, pursued by architects and engineers alike, aiming at optimizing the amount of material used in the structures, relying on mathematical calculations and statics. Both of these approaches were highly experimental and equally bold; the mathematics of statics and calculations were developed much later that many of the structural experiments and as such, a number of iron structures collapsed due to a number of reasons such as fires, miscalculations or other unforeseen events.

The separation between these approaches is merely descriptive, as the accelerated pace of new experiments, processes and developments helped to create a fertile ground for material innovation. It is however unclear, on many



3-11 Between geometrical ornamentation and structural rationality. Multiple possibilities in structural connections between columns and joists.

cases, the design methodologies or strategies that spawned these projects or what was the precise influence or impact of these two approaches on structural design.

These two approaches intend to clarify what was more significant or relevant in the structural design process: the quest for artistic expression and ornamental effects, or on the other hand, the search for geometrical clarity and formal purity. This separation was not at all clarified or even expressed back in the 19th century; Henry Labrouste himself is an interesting example of both these tendencies. On his two famous libraries he made use of both strategies; on Saint Genevieve (1843-1850) he used a decorated cast iron arch with curve motives while on the Bibliothèque Nationale (1858-1868) he designed cross braced arches with riveted wrought iron pieces.

But thanks to the Polonceau´s innovations, the 'geometrical-optimized' approach eventually prevailed. Developed alongside the King post, the Polonceau truss was only possible thanks to a precise knowledge of material behavior, not only the identification of compression and tensile members but also a careful way to tie them together. The Polonceau truss provided a consistent method for calculation, a lightweight construction and a geometrical framework to compose trusses for all sorts of spans. In other words, it provided a reliable and repeatable system for solving structures in an elegant and cost-effective manner.

It is also interesting to add that in between these two approaches, a number of formal experimentations in relation to the design of arched structures took place. Thanks to the plastic qualities of iron a wide variety of forms, form organic, artistic or curvilinear shapes (like the Bibliothèque Genevieve) to more geometrically refined -although not statically efficient- a diverse range of solutions were possible. The first example of this trend is of course the Iron Bridge at Coalbrookdale by Pritchard and Darby (1777-1779), where 'decorative' rings were placed between the ribs. Similar rings appeared in several roof structures, like cotton mills or warehouses, and the resource of filling with decorative rings would be recursive throughout the 19th century in many examples, for instance in Saint Pancras Station, filling the planar gap between the structural arch and the roof near right on top of the supports.

Thanks the accumulated experience on truss design, calculation and construction gathered by 1840's, truss design in France and Britain converged around Polonceau and its variants. Many of these variants relied on graphical statics calculation but the overall design, material behavior and interplay of forces remained fairly similar.

Prefabrication, mass fabrication and mass customization.

Thanks to the improvement of furnace technologies by the mid-19th century, high quality cast and wrought iron (and later on, steel) was produced on a reliable, controllable process all across the world. On Europe, many of these enterprises were established around the area of Liege and Maastricht, near the trilateral border between Belgium, the Netherlands and Germany.

Casting techniques combined with the relative ease of iron to take almost any form was significantly uncomplicated in relation to other materials such as wood, stone or other precious metals. For this reason, countless household objects were replaced by the newest, durable and aesthetically pleasing cast iron objects. Mass production of these objects also carried a significant benefit; industrialized fabrication reduced the costs drastically, making the manufactured goods accessible even to a larger market.

But unlike precious metals, cast iron was not supposed to provide luxurious items; iron was widely available and while manufacturing techniques improved, its affordable price rendered its items accessible to all social classes, worldwide. "Iron is the bronze of the poor" summarized the perception of cast iron products by mid-19th century: not only industrial parts and pieces, but entire household collections were fabricated with this material. Along domestic decoration, urban infrastructure pieces like sewers, rain grids and lighting were also manufactured with this technique; entire cities were re-furnished throughout the century with cast and wrought iron pieces. This new material permeated every aspect of urban life in the century, to the extent that even bijouterie and delicate jewelry pieces were cast in iron.

An important factor of the expansion of iron were the foundries themselves: not only they were responsible for the production of raw material, its process and the research it involved, but as explained earlier, they were also often in charge of the designs of the objects they provided as well as the commercial solutions for them.

Trade catalogs were a crucial part of the iron industry; they showcased the products of each foundry by providing artistic imagery of each product, along with descriptions and possible uses. When describing industrial and mechanical pieces they also included technical drawings, dimensional and material information.

But what is more interesting for the purposes of this research is the fact that these catalogs did not describe products that each foundry produced; they illustrated the products they could produce, meaning, they depicted a range of industrial, practical and decorative products within the reach of each foundry according to their technical and (often) artistic capabilities. This is a key factor of 19th century industrial production regarding iron, ceramics or terracotta: there was no large warehouse where all the products were stocked. Instead, products were designed and produced by request, fabricated and delivered on time. However, during the period, the production of the foundries and their catalogues shifted from the personalized, customizable designs to homogeneous, unvarying objects. Later on, 'Taylorism' and 'Fordism' theories characterized and crystallized this trend further on.

Trade catalogs existed since the establishment of manufacturing industries in need not only to allocate their products but also to educate their customers. They would often portray the latest design and artistic trends in order to gain the public's attention as well as to stimulate their curiosity and satisfy their hunger for new products. The first catalogues were directed to architects and builders but later on, as their market grew, they eventually expanded to the general public.

Prof. Axel Sowa organized an exhibition in Maastricht called 'Design by Choice - The origins of Mass-Customization in Europe'[22] exploring the relationship between the use of trade catalogs in 19th century and their influence on design, taste and the relationships between mass production and mass customization.

On the exhibition's catalog, Sowa's text 'Building the trade catalog' explains the original role of these publications:

'The catalogue fulfills the role of an agent. It is a magazine of potentially manufacturable items, which are produced on specific patterns.' And later on: 'Borrowing the idea of a more or less ordered storage area, trade catalogues were seen as storehouses of product information. They contained collections of visual material, organized to a specific ordering system.'

Sowa also establishes similarities between the layout of the trade catalogs and scientific, natural and technical publications based on sources like Diderot and D'Alembert's Encyclopedia. Like scientific and natural publications, trade catalogs required a method for ordering graphical information and collections of images and the catalog plates provided a distinct system of organization. Sowa states:

'Eighteenth-century scholarly investigations into the world of species, artifacts and technical procedures were encyclopaedic in a literal sense, since their aim was to embrace the entire circle of knowledge. In the early nineteenth century, encyclopaedic methods of classification and graphic registration migrated into the branches of architecture and archaeology.'[23]

This particular way of organizing graphic material was also aimed at a broader public; it allowed both professionals and laymen to compare formal characteristics such as details or scale or technical ones, such as resistance, dimension or price. Simultaneously, these publications provided yet another argument for clients in order to discuss ornamental details with the architects and builders by presenting a large array of alternatives, organized by element type, structural capabilities, size, and function in a didactical manner. The client would then use catalogs as both formal references and negotiation tools.

Sowa states on this regard:

'While in the case of building construction it is still the architect who determine the edifice's structure and composition, trade catalogues enable the architect's clients to negotiate formal aspects of visible parts, such as balustrades, staircases or canopies. Therefore, the catalogue offensively occupies a territory that previously belonged to professionally trained architects. The industry, which hired craftsmen to employ them as modelers, became an important stakeholder in the process of form finding'[24]

More on the empowering role of catalogs in the hands of clients:

'Trade catalogues empowered customers to make their own choices. By choosing specific patterns, customers took part in the process of designing and making. To allow this co-determination, trade catalogues were successfully

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22 Axel Sowa, ed., Design by choice: The origins of mass customization in Europe. De oorsprong van massaproductie op maat in Europa (Maastricht: Bureau Europa, 2015)

23 Sowa, Design by choice

24 Sowa, Design by choice

3-12 Cast iron catalogs. Vases inspired in´Modeles anciennes´ and allowing further modifications by the clients from the catalogue by Maison R. Garnier ´Cuivrerie et serrurerie artistiques´.

established as media, reaching far beyond the confined circles of learned experts, such as architects and engineers. Not corresponding to any aesthetic doctrine, they initiated direct feedback from clients. The success of specific models could be easily measured by the amount of incoming orders.'[25]

We will later discuss some specific examples regarding this rational and organizational method and a possible relationship with the contemporary design theory, particularly under the light of present-day production systems, as the crossing point of industry 4.0, flexible accumulation and post-Fordist models.

Case study. The terra cotta industry manufacture procedure.

The case of iron foundries was not isolated from other branches of industrial production and manufacturing. Every aspect of industrial fabrication was modified or restructured, from extraction industries like mining, metals or fossils, to forest industries and livestock farming. Sigfried Giedion described a comprehensive and critical review of these changes and their repercussions on culture and design on his book "Mechanization takes command".

Regarding the building industry, among the traditional materials that drew on the use of these production techniques and commercial tools such as trade catalogs and flexible production methods was the terra cotta industry.

An example of the complex and flexible practices that were common in 19th century can be examined in the book 'Architectural terra cotta, standard construction' by the National Terracotta Society from the United States.[26] Even though this publication dates from 1914[27], it illustrates many aspects that were typical in the 19th century industries regarding stylistic, technical and commercial parameters that defined the terra cotta industry.

The publication belongs to the National Terracotta Association, and states in its foreword:

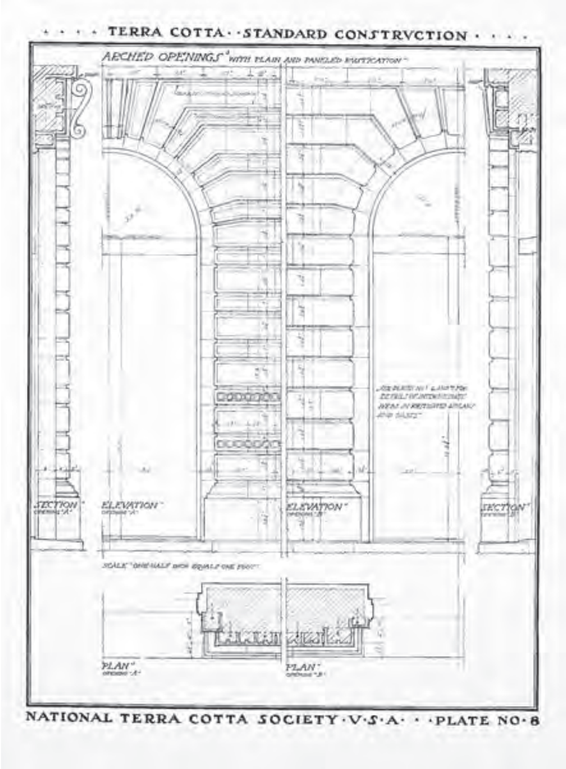
"The purpose of this book, prepared through the co-operation of nearly all the manufacturers of Architectural Terra Cotta in the United States, is to facilitate the use of this material; to save time, trouble and expense to all concerned by disseminating accurate and dependable information on proper methods of jointing and construction."

The book itself is not a trade catalogue since it does not belong to a single manufacturer but to an association gathering many manufacturers across the United States. It does not sell specific pieces but serves as a primer on technical information regarding sizes, supports and connections between pieces, among other items. However it does function as a catalogue in terms of providing reference images regarding stylistic and constructive solutions to a number of architectural solicitations; one can decide to build and decorate a

25 Sowa, Design by choice

26 National terra cotta society, Terra cotta: Standard construction, Rev. ed. (New York N.Y.: National terra cotta society, 1927)

27 The reviewed catalogue was edited later in 1927.



3-13 Terra cotta construction examples imitating classical tectonics. The publications not only showcased the innovative possibilities of industrialized terra cotta but also educated architects in the use of novel materials. From a publication by the National Terra Cotta Society.

portico with classical style, with neo-Norman arches or even with neo-Gothic structure. Although the book's foreword does state that it is 'intended to be a book of artistic aspirations', the wide range of stylistic solutions depicted on its pages does operate as a persuasive pamphlet of the creative and expressive potential of architectural terracotta.

The capacity of terracotta to emulate different 'historical' materials such as stones, stuccos or ceramics turned it into a reliable material to emulate ancient styles according to the contemporary taste. It is also remarkable that another reason for the adequacy and popularity of terracotta was the fact that it was associated with steel construction; because of the material poor structural capabilities, its primary use is for cladding and fire proofing, and it was deemed as a perfect complement to the iron construction types. For this reason, the foreword states that '(…) where the important rules of jointing and construction are observed, well made Architectural Terra Cotta is the ideal building material of the Twentieth Century'.

Apart from general and technical considerations about the terracotta pieces, the manual provides a detailed description of a typical design and fabrication process, describing each step of the manufacture procedure from the initial drawings to the final erection of the pieces. This synopsis of the terra cotta manufacture process is important for this research as an indicative of the type of flexible design and fabrication procedures on other industries of 19th century such as cast iron. The fact that they all relied on a labor-intensive processes, large variety of products, mass production and a reliable logistic chain for distribution was common to many of the industries that thrived on that period.

Naturally, the reason for this interest is the influence of these procedures on the design capabilities of architects, the constraints and freedom it imposed on their oeuvre, and eventually, how these practices shaped the style of an entire period.

Under the title 'Terra Cotta - A brief synopsis of the manufacture of Terra Cotta' the book describes 12 steps explaining the manufacturing process parting from the initial design of the pieces. We could divide the entire process in three large groups, the first relative to the design and adjusting of the pieces, the second one containing the fabrication steps and the last one depicting the logistics, meaning the shipping and mounting of each piece.

The drawing stage begins when the original drawings of the pieces and steel framing designed by the architect, engineer or builder are sent to the manufacturer. These drawings must be adjusted by the manufacturer in order to regulate joints and construction detailing, as well as to compensate for material shrinkage. The new set of shop drawings must be then submitted to the architect for approval, prior to the manufacturing of models and molds.

The next stage consists in the production of models and plaster molds, from which the terra cotta pieces will be later casted. These 'original' pieces must be decorated according to the architect's drawings and descriptions regarding ornamental styles, artistic period and other factors, applied in clay on top of the plaster ones.

The decorated pieces must be approved again by the original designer (the book recommends the use of photographs or a personal visit) for examination and approval at the factory. The use of soft clay allows further corrections, improvements and modifications.

Once the pieces are approved a series of negative molds are casted in plaster, in which the terra cotta will later be casted by pressing. The pressing of clay is an entirely manual process, on this stage each piece is pressed against the plaster mold by hand, assuring that the minimum thickness of 1 inch is secured, following the contour of the mold. When the clay is dry, it is removed from the plaster molds and carefully retouched for details. The terra cotta pieces are then placed on controlled industrial driers in order to evaporate moisture. After an optional step of coloring or glazing for decoration or protection, the pieces are fired in a kiln. The options for coloring and glazing are limitless; the development of pigments and ceramic powders allowed the architects a great deal of freedom in the design of ornamental pieces.

Later on, once the pieces are naturally cooled, they proceed to the fitting department, where each piece is identified and numbered according to their position on the façade on the drawings. In case the firing process altered the dimensions of the pieces outside the predefined parameters, the joints and edges are squared by cutting or grinding.

Finally the pieces are packed for shipping in a specific order, to fit the assembly of the façade. This is an interesting feature of terra cotta building pieces; the shipping organization is in direct relationship with the building process; each piece is numbered according to its place in the façade but also to its specific location on the building process.

This brief description of the terra cotta manufacture process indicates the intimate relationship between design, material and technical constraints, logistics and design freedom in 19th century. Later architectural ideas claiming for a clearer separation between structure and cladding, and the everlasting search for "truth" in architectural construction and its expression deemed Terra cotta as an unsuitable material for the new epoch. Solutions like reinforced concrete and naked steel structures were more unambiguous in the expression of the novel architectural ideas regarding material honesty.

Protoparametrization. Pre-Fordist industry.

It is not easy to define 19th industry and production system in comparison with other management theories like Taylorism or Fordism, nor is the purpose of this research to elaborate on such contrasts. It is possible however, on a basic level, to trace some relationships between these production systems and their contemporary architectural styles.

Closer to our time, Patrick Schumacher[28] established an interesting parallelism between post-Fordist production models and contemporary design techniques and processes, linking the use of complex design algorithms, robotic technologies, flexible production methods and other factors into a novel

28 Patrik Schumacher and Rogner Christian, "After Ford," in Stalking Detroit, ed. Georgia Daskalakis, Charles Waldheim and Jason Young (Barcelona: Actar, 2001)

architectural paradigm beyond modernism or postmodernism. Schumacher would later on define an important concept for contemporary design theory and this research: 'Parametricism', or 'Parametric architecture' as a new research program and architectural style of the 21st century. We will later discuss this concept in relationship with present-day design tools, design theory and fabrication techniques.

As discussed before, thanks to moldable materials like iron or ceramics, 19th century's industry proved to be flexible enough to design, produce and deliver products characterized by a vast diversity and variety. A great deal of this 'flexibility' in terms of production was possible thanks to the increment of mechanization, not only in quantity but also in quality; faster, more powerful and more precise machines were used for milling, sanding, cutting and polishing. But also, and equally important, the workers were subject to poor labor conditions on the factories and workshops; in order to keep up with the increasing demand, large amounts of unskilled workers were incorporated into production.

Mechanization of production implied that a production process was separated into smaller, simpler tasks that could be produced repetitively in time. Coupled with a homogenous, isotropic material (like iron, for example) it ensured that all pieces were fabricated with the same quality. Mechanization also presupposed that manual, physical and material knowledge, which was embedded in the hands the skilled worker was transferred to a machine as a part of a manufacturing process[29].

A great deal of 19th century industry's variety was possible thanks to the large number of unskilled workers that were included into manufacturing processes. Long working hours, low wages and practically no benefits ensured that the labor cost remained marginal in the final price of a manufactured piece. Iron casting or the terra cotta industry required considerable amounts of handwork regarding finishing, corrections, polishing and mountings, among others; to remain cost effective in such handwork should remain cheap and easily accessible.

A large number of protests, demonstrations and strikes demanding a change of such conditions took place in several countries. An important protest took place in the Vasena Workshops (a steel foundry) in Argentina, which later sparked a major tragedy, named 'The Tragic Week', which led up to 800 killed. An interesting paper on the historical and archeological assessment of the Talleres Vasena was published online by the Centro de Arqueología Urbana at the FADU-UBA[30]

Once again, it is not the purpose of this research to detail these conditions, but the evolution of management and production systems like

29 There are several authors that challenge this established narrative regarding the relationship between mechanization, industrialization and capitalism, particularly discussing the contrast between mass production and flexible manufacturing. See Charles Sabel and Jonathan Zeitlin, "Historical alternatives to mass production: Politics, markets and technology in nineteenth-century industrialization," Past and Present 108, no. 1 (1985), https://doi.org/10.1093/past/108.1.133

30 Daniel Schávelzon and Ana Igareta, "La destrucción de la modernidad: Arqueología de los Talleres Vasena y la Semana Trágica en Buenos Aires," Patrimonio Cultural: la gestión, el arte, la arqueología y las ciencias exactas aplicadas, 2013, http://www.iaa.fadu.uba.ar/cau/?p=4147

Taylorism and later on, Fordism would change this landscape irreversibly. Further mechanization and specialization, cost efficiency, energy and material economy, production standardization and extreme rationalization ultimately replaced these manufacturing methods. This shift had of course an impact on architecture and design; flexibility and mass personalization were replaced by serialization, mass production and rationalization. Naturally, manufacturing methods and their organization influenced architectural expression on a great scale.

Protoparametrization. Open construction systems.

The growing number of products offered by foundries and the possibilities of endless variation also developed construction systems by associating different building elements and not just isolated parts. These product 'families' ranged from ornamental parts such as balustrades or railings to entire structural systems with columns, beams and trusses. For example, the catalog of MacFarlane's Castings from the Saracen Foundry[31] included systems for railings, stairs, spiral stairs, and brackets. One could, theoretically, build a 20 meter spiral staircase, just by piling up each of the stair step segments, or change the style of a neo-renaissance column by using a Corinthian capitol, which were also interchangeable. The open-system mentality permeated almost all of their products.

The design using a catalog of structural parts relied on standardized measurements, standardized joints and connections; in other words, standard, rationalized solutions. This confidence on a consistent system of products also gave the architects and designers yet another degree of freedom and expanded their field of structural experimentation.

Readymade constructions were also available ranging from small kiosks to large industrial sheds, which were built by combining several products from other sections of their catalog. On this regard, MacFarlane designed and sold several designs of complete greenhouses, gazebos and kiosks[32]. As another example, the French foundry Follereu from Nevers[33] apart from the typical railings, fences and gates, offered greenhouses, trusses and even bridges.

MacFarlane's castings also presented an interesting design exercise; on a two page display, it portrayed a building's façade, maybe an office or an apartment building with a shop on the ground floor and 3 top floors (pages 624, 625). The first drawing just shows the building's main characteristics, some simple lines, windows and some cornices. The next page shows the same building but covered with the foundry's products; it is perceived as an entire new project. The shop on the ground floor is decorated with slender ornamental columns, the shop windows are also decorated, the entrance gate

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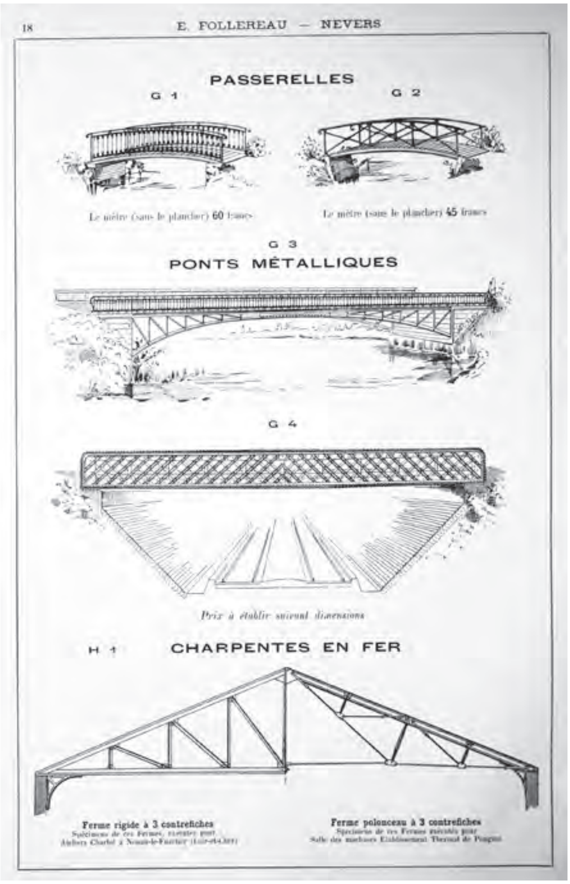
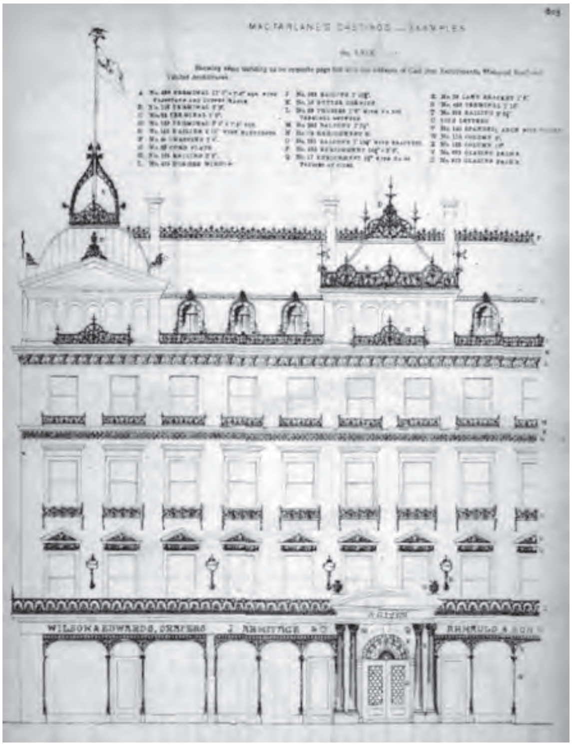
31 Walter MacFarlane & Co Ltd, Illustrated catalogue of Macfarlane's castings. Vol 1. imprint Glasgow Walter Macfarlane & Co

32 Walter MacFarlane & Co Ltd, Illustrated catalogue of Macfarlane's castings. Vol 2. imprint Glasgow Walter Macfarlane & Co

33 E. Follereau, Catalogue general constructions metalliques, serrurerie d'art.



3-14 Ready made infrastructure. Catalogue of various iron products: pasarels, bridges and iron framework.



3-15 Ornamentation opportunities now possible thanks to cast iron products from Macfarlane's Castings.

is flanked by two pairs of columns, a curved pediment. The rest of the floors are also decorated with cast iron parapets on top of the cornices, pointed pediments over the windows, ornamental railings, flag poles and lamps, among others. And that's just one of the seemingly infinite combinations available from the catalogue's drawings.

This powerful set of illustrations depicted the true potential of the iron industry; it provided the means to characterize and individualize common constructions into a more complex, intricately ornamented architecture. Theoretical concerns like style, composition, harmony or architectural character were put aside in favor of an individual solution, granted by technical means. The large variety of ornamental choices available thanks to a booming industry that nourished from ornamental styles belonging to all previous historical periods brought an unprecedented level of liberty (and autonomy) to architects and engineers.

TRANSLATION AND TRANSFORMATION.

Style, material and translation.

Aligned with several authors like Semper who focused on a material approach to analyze Architecture and its historical styles, Bannister Fletcher published in 1897 an essay called 'The influence of material on Architecture'[34]. From the introduction, Fletcher defines his guiding criteria through which he will examine different historical periods and their corresponding styles, ranging from the Egyptians to his contemporary 'modern' steel architecture. The book establishes a rather direct correspondence between architectural styles and the influence of materials. On this regard, Fletcher clarifies::

"Style is created by the discoveries of experience or genius out of the qualities of the materials employed. Successive periods have had their distinctive materials, of which they seem to have exhausted the possibilities, and their resulting methods of treatment are the basis of what is afterwards classified as "style". Changes of style are forced on by the use of new materials, to which at first the old forms are applied. After a period the old forces of tradition and prejudice are laid aside, and the new forces of utility, reason and cost draw attention to the innate qualities of the newer materials, which, finding expression, develop to a greater or less degree of perfection a new style."[35]

The author argues that architecture is 'an affair of material', from which its 'true use or needs' would mold the style, dependent on the characteristics and qualities of each material and their particular relationship with its own use and history. Therefore he argues that Egyptian architecture derives from mud and its translation in stone and granite, while the Greek one is developed from wood constructions and its transformation in stone and marble, and so on.

Translation between materials is a key concept here; a civilization acquires

34 Banister Fletcher, The influence of material on architecture (London: B. T. Batsford, 1897)

35 Fletcher, The influence of material on architecture

a certain skill and experience with building materials easily available like mud, clay or wood, then the next step in order to create lasting buildings (or architecture?) is to find suitable, long lasting materials like stone, marble or granite. However this new material is often hard to manipulate, and familiar forms are frequently used in them; this means traditional material knowledge was not forgotten or discarded, but decoded and reinterpreted into a new entity.

Of course this theoretical view was disputed, particularly for classical architecture, for example by Violet-le-Duc. He elucidated that Greek architecture was an original stone building technique, but also from a building technology point of view; by addressing constructive problems in the supposed translation from wood to stone.[36]

Similarly, Roman architecture also translated Greek elements through their own constructive system: for example the solid stone or marble columns were also built in roman buildings and monuments with brick, mortar and then covered with marble pieces. Additionally, they also used large pieces of iron embedded on the concrete mixture hidden behind stone elements, allowing the achievement of greater spans and simultaneously altering the classical proportions inherited from the Helens.

Translation processes often worked in two distinct manners. The first could be defined as a 'technical mimicry' in which elements were decoded from one material by its function, one by one, to a new material. The organization of the entablature or the frieze is an example of these procedures and Fletcher also cites the example of the Greek Guttae deriving from wooden construction pegs as well. This is supported by the fact that the constructive complexity in terms of interlocking pieces, for example at the entablature, friezes and architraves demonstrate that it is precisely that constructive intricacy is the one being translated and not just its formal characteristics.

The other possible translation operation could be defined as 'formal transcription' and can be interpreted as blunter or less mediated by technical attention, by decoding just the formal characteristics from one material assembly into another. For example, the Egyptian columns of the 18th dynasty resemble the bundles of reeds from Egyptian sculptures; the agglomeration of single elements into a bigger ensemble was directly translated into stone, but then the dimensions and proportions are straightforwardly altered. Stone has its own structural dimensions and material tolerances, and in order to achieve an expressive image the original forms need to be distorted; hence the new 'expression' explicitly relates to the new material.

A similar operation can be inferred for example in Roman Corinthian columns; the outer shape is a direct imitation of their Greek counterparts while the inside filling consists in brick and mortar and sometimes iron reinforcements. The outer shape is mimicked by marble pieces that imitate the shafts and their divisions but without any structural load.

36 According to Flecther, Violet-Le-Duc refuted the idea of direct translation between wood and stone with some practical arguments, for example, by explaining that the fluting of the trigliphs was difficult to perform due to the grain of the wood, or the geometrical correspondence between the Doric entablature in both materials.

However some 19th century writers like Semper[37] question the 'translation' processes particularly from classical architecture; according to him, Architecture did not evolve from the structural frame (Laugier's 'primitive hut') but from the 'in-between' surfaces, that is, the dressing of the frame.

As Semper argues that technical arts precede Architecture, it is the covering of the structure, initially woven, the element which defines the space. His critique to the 'translation' processes lies in the fact that while Greek temples derive from wooden hut, they are originated in a structural symbolism; classical Architecture is born from the emancipation of form from material.

From masonry to iron: 19th century.

19th century brought to the foreground two main issues in both architectural history and theory regarding construction technologies; on one hand, the possibility of a scientific study of architectural techniques throughout the ages, styles and periods thanks to a systematic and methodical research and findings in the field of archaeology and on the other, the possibility of retrieving and recreating such techniques and their expression thanks to the use of new materials and technologies.

On this regard, Fletcher states his skepticism:

'Endeavoring at the beginning of the century to reproduce the forms of classical art, without taking any trouble to analyze and develop their principles, architecture has been incessantly hastening to its decay. Is has become Neo-Greek, Neo-Gothic, Neo-Roman, Neo-Renaissance, Neo-Romanesque (…) In fact, its various phases present a grotesque medley of styles, fashions, and epochs. Construction has become the art of successful deception.'[38]

What Fletcher calls 'deception' might as well be interpreted as a partial translation process, that is, the recreation of formal and expressive features without taking into account other parameters, such as material characteristics or the expression of its formation processes. The 'superficial study of architecture' is the one factor to blame in Fletcher's argument, as the disregard of a true and profound revision of construction means would be the main cause for the period´s crisis in terms of identity.

As many contemporary colleagues, Fletcher argues in favor of an expression defined by the means of construction, but then again, having in mind that iron is the periods material of choice, which is its own structural function and how to extract beauty from it?

'In Architecture, materials must indicate their functions by the form we give them, and these should conform to their nature. This, of course, has been more or less easy for past styles, working in natural materials having no very great contrasting qualities, but it is very difficult for us who have to make use of materials which possess different and even opposite qualities, to which must

37 For a summarized description of Semper's ideas in the context of 19th century see Pevsner Nikolaus, Some architectural writers of the 19th century

38 Fletcher, The influence of material on architecture

be given the appearance befitting these opposite qualities.'[39]

The balance by which elements expressed materiality and how they were actually fabricated became conflictive in 19th century; Fletcher's argument runs clearly and lineally from Assyrian, Egyptian, Greeks and Romans throughout Renaissance but conflicted with the progress of the building industry and the influence of engineering practices in architecture. Few theorists like Violet-le-Duc effectively understood the true role of iron and steel in architecture besides its prominent structural capacity by rethinking its function through the looking glass of Gothic architecture and the value of craft in our discipline.

Cast iron slowly introduced new elements in the construction industry: panels, grills, fences but also, it gradually replaced elements previously manufactured in other materials such as roof tiles. To mention another example, the stone acroters were soon to be casted in several foundries and became widely available. Classical cornice parts like antefixes and anthemions previously manufactured in stone, marble or casted in ceramics, became patterns and were fabricated in cast iron or pressed zinc, their low price assured its popularity and their use can be even traced for example, to temporary train stations in Argentina. The same way that Greek and other ancient cultures used antefixes to cover the hollow end of the roof tiles, industrialized roofs used similar zinc pieces to cover rain gutters and to hide other constructive joints. While their scale and thickness diminished (they were even set upside down, opposite to its classical origins) these elements preserved their initial function, that is, to shield us for unpleasant constructive details.

Other types of pieces were used for example, in ceilings, where panels made of tin were pressed using different cast iron patterns. These tin ceiling panels were very popular in the United States where they replaced traditional plasterwork since they were quicker, cleaner, and sometimes even cheaper to produce, in addition to their fireproof qualities.

The separation between an inner, structural, technical, rational form and an outer expressive, ornamental form that characterized 19th century construction technologies also enabled the combination of multiple functions in one construction element.

As cities expanded and population grew, constructions of all sorts faced the need to comply with several building requirements, like fireproofing or thermal isolation. Some companies like the Roebling Construction Company published an exhaustive catalogue[40] of fireproof systems and elements also offering 'classical' ornamentation components in plaster or papier-mâché designed to cover beams and ceilings. Companies like these fulfilled the desire for a practical and economical construction system while simultaneously presenting a historical expression.

Joseph Kendall Freitag published a comprehensive study of fireproofing buildings[41] comparing materials, shapes and systems from different buildings.

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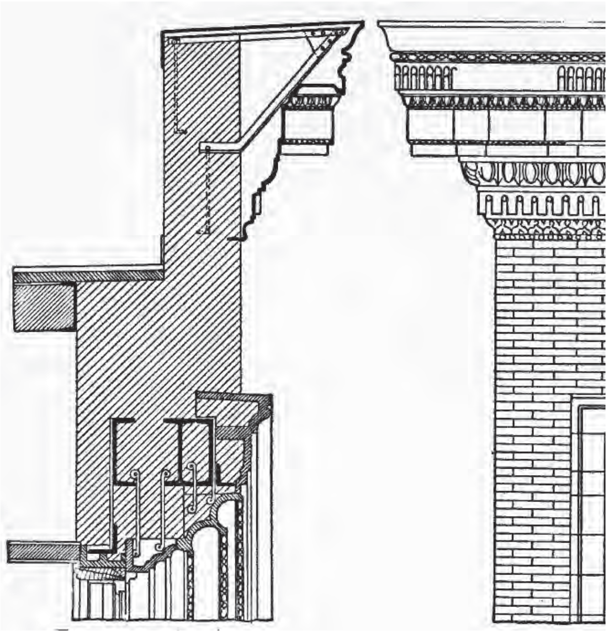
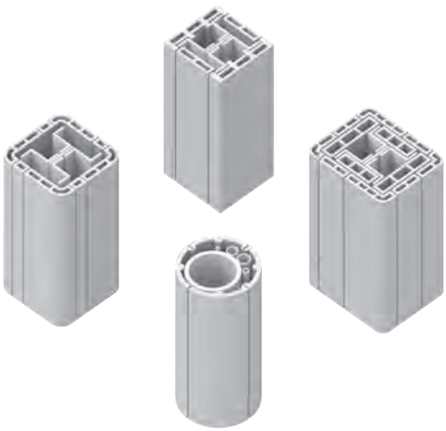
39 Fletcher, The influence of material on architecture

40 Roebling Construction Company, The Roebling System of Fire Proof Construction (New York: Roebling Construction Company, 1905)

41 J. K. Freitag, The fireproofing of steel buildings (New York: Wiley, 1899)





3-16 Copper, Zinc, iron, masonry and terracotta combined in a 19th century facade. Multimaterial cornices from The Cable Building (New York,1894).
3-17 Ceramic covering on steel columns. Based on the publication of Freitag J - The fireproofing of steel buildings. Render by the author.

The book's chapters cover topics such as fireproofing methods, corrosion prevention, column and girder protection, concrete and composite floorings, among other topics. However it also serves as a descriptive archive of the multiple combinations of steel structures and their protective 'outer shell' in ceramics, terra cotta or concrete available by the end or 19th century.

As an example of the variety that Freitag surveys, on the page 17 there is a column-terra cotta composition that resembles the Vasena system from Argentina, along with multiple combinations with tube columns, I and double T profiles for columns, girders, ceilings and floors. It is also notable that the book is primarily focus on technical information and barely describes ornamented or 'classical' elements, except on the last chapters when some cornices or ceilings from case study buildings are described.

The use of classical elements, their patterning and the subsequent industrial fabrication not only created several variations of ancient motives but also, by affecting them by the scale, tolerances and characteristics of other materials such as terra cotta, cast iron or pressed galvanized zinc also generated a new set of shapes and eventually, new uses for them.

It is also interesting that these translation procedures triggered not only 'aesthetical' solutions but also technical ones, like fireproofing and insulation. On this topic, Tom Peters describes such processes as well as some examples:

'The process of translation takes time and an associative leap that shifts the thinker's focus from one object or method to another. This leap is typical of technological thought, and the time lag in the process of translation is characteristic of technology transfer from one culture to another.'[42]

Peters also cites the examples of John van Osdel who 'claimed' to discover the fireproofing characteristics of clay cladding elements protecting iron structures after the great Chicago fire of 1871, and then, how the brittleness of clay products failed on the San Francisco earthquake and fire of 1906. Peters finally states:

'Translating limiting criteria is even more difficult than translating potential advantages. Aside from the leap in thinking, it requires the technological translator to postulate hypothetical extreme situations.'[43]

From building to assembling.

When cast iron elements became available to builders, the first step was to cast elements similar to timber structures, with which they were fairly familiarized. As a fireproofing technique, timber structures from cotton mills were replaced by cast iron members[44] but the characteristics of iron (brittleness, weakness in tension) demanded a different approach than pure 'translation', particularly in relation to joints and connections. As previously discussed, Bage's design of structural elements was carried on without any previous indication or experience

42 Tom F. Peters, Building the nineteenth century (Cambridge, Mass., London: MIT Press, 1996)

43 Peters, Building the nineteenth century

44 Charles Bage being the pioneer on his own mill in Schrewsbury by 1796.

to refer to. It was based on traditional design and material knowledge, such as the theory of buckling of columns, which was derived from other material practices related, once again, to stone or timber.

Translation became a difficult design procedure to follow and building became a more complex task as iron components were impossible to fabricate or modify on site like other materials such as wood or stone. Cast and wrought iron elements were fabricated on specialized shops, foundries and factories, so a different design approach was needed. We will later discuss this particular mindset under the section 'Kit of parts approach', but in regard to the relationship between translation processes, it was clear that the use of prefabricated iron parts found no resemblance in other historical building techniques.

This way, the focus of fabrication shifted from unique pieces to standardized elements with standard connections. This trend was set in motion with the construction of bridges, where a set of standard pieces were fabricated and then combined to assemble a final form. As Peters state in regard to Thomas Wilson's Wear Bridge at Sunderland (1796), the bridge's design was a combination of standardized parts instead of a general design broken into smaller parts. What Peter's define as a 'bottom-up design process'[45] can be summarized on how the focus on design shifted from buildings or building parts to the design of construction systems, where the final design of a building was an indirect byproduct of a specific combination of standardized elements and joints.

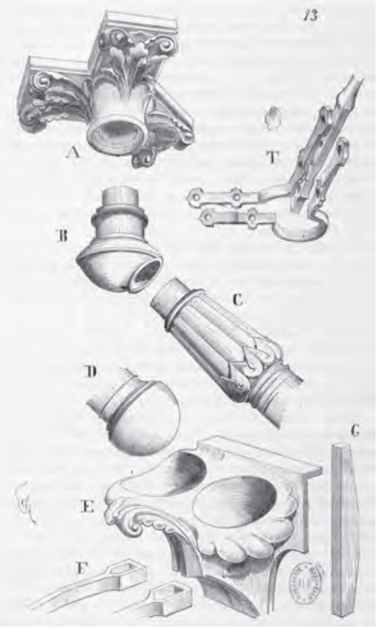
The impact of this mindset on the design of structural elements was certain: standard shapes and profiles like C, I, T, L and their combinations became available in all sorts of sizes, thicknesses and lengths. Extrusion techniques provided constant, reliable profiles with prismatic shapes suitable for many building parts and solicitations. Wrought iron and later, steel accentuated this trend due to the fact that they were able to sustain compressive and tensile forces consistently.

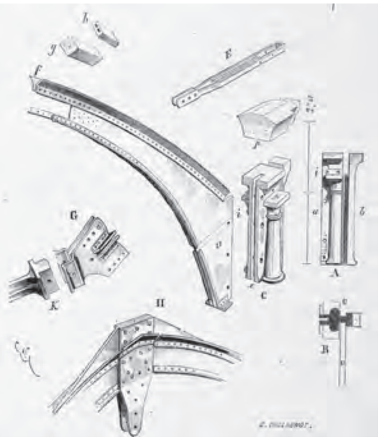
In regard to light construction techniques and aesthetics, Viollet-le-Duc provided an interesting approach; primarily by his interest in gothic construction and specifically, how medieval master builders materialized slender, bone-like structures. Combined with the attention on iron as a new building material, Viollet-le-Duc hypothesized on how medieval builders would effectively use it if it was available on their time. For this, he used a particular example on his lecture XII[46] (figures 1, 2 and 3) on how to support a projecting gallery with different construction methods. On the first figure, the drawing shows the 'medieval method' for the support on stone corbels, while the second shows the same structure but with iron struts. The third drawing depicts a 'novel method of resisting the thrust of Vaulting', using diagonal struts and complex bolted iron connections replacing the typical gothic flying buttresses.

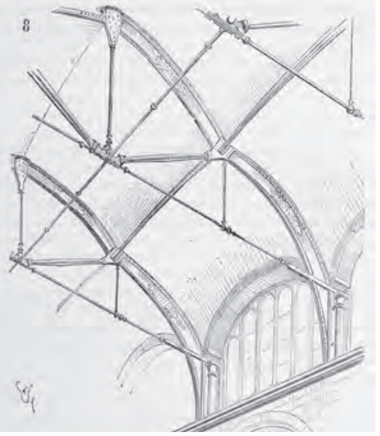
Tom Peters states on this exemplary use of 'translation', while describing Viollet-le-Duc's thinking process:

45 Peters, Building the nineteenth century

46 Eugène-Emmanuel Viollet-le-Duc, Lectures on architecture (New York: Dover; London Constable, 1987)







3-18 Structural kit of parts. Cast iron elements for the polyhedral vaulted hall.
3-19 14-meter-span vaulted roof and cast iron pieces. Extracted from Viollet-le-Duc ´Entretiens sur l'architecture, vol. 2´.

‘(…) when a builder uses a material logically, by which he means economically according to its load bearing capacity and limitations, the result design changes structure and consequently form. He applied historical precedent to iron construction and achieved radically unprecedented solutions –and he demonstrated this in his celebrated proposal for a market hall. By replacing masonry corbelling with iron, he concentrated and reduced the supports beyond what structural tradition could envision and created visionary form.’[47]

And regarding the use of gothic structural types in order to develop new ones based on iron:

‘Viollet-le-Duc’s focus lay on form and space and not on structure and function alone as did the engineers’ focus. He could now vary the geometrical principles of Gothic ribbed vaulting infinitely and design filigree structures that loaded the foundations far less than their predecessors had done.’[48]

Having designed a membrane-like roofing system, entirely in iron, based on the gothic ribbed vaults, Viollet-le-Duc’s approach to translation procedures in 19th century is a brilliant case study on how the enthusiasm for new technologies and a deep understanding of historical construction techniques led to inventive and significant results. While describing the translation process, Peters goes a step further, adding yet another layer of complexity on his design procedures:

‘He practiced the design strategy of translation –that is taking a solution associatively from the human skeleton or masonry construction and rethinking it in iron. That is however only half the process of successful design: he then transformed the result, from ribbed vaulting to folded-plate construction, a membrane structure in iron that was similar to corrugated iron sheeting (…)’[49]

Translation in 19th century´s Argentina.

Translation processes did not occur in Argentina as the ones described previously, since the country’s architectural heritage wasn’t established or even defined on the same terms as the European at that time. On the other hand, a distant region like South America somehow ‘de-territorialized’ aesthetic decisions regarding construction techniques due to the lack of adequate materials, tools and skilled workforce.

Commercial ties to Great Britain were also manifested in the large importations of British iron into the country from the second half of the 19th until the early 20th. One of the vital concerns of the British was the vast rail network superimposed over the country in order to dispatch cereals and cattle from the productive regions right to the capital’s sea port. On this

47 Tom Peters, “How the introduction of iron in construction changed and developed thought patters in design,” in Rinke; Schwartz, Before steel

48 Tom Peters, “How the introduction of iron in construction changed and developed thought patters in design,” in Rinke; Schwartz, Before steel

49 Tom Peters, “How the introduction of iron in construction changed and developed thought patters in design,” in Rinke; Schwartz, Before steel

scheme, British companies provided every aspect of the railway infrastructure; machines, rails, stations, even the workers´ housing. Such strong financial and commercial ties also extended to other aspects of the iron industry, for example, iron foundries in need for new markets to expand their business.

Translation processes took place in Argentina and the South American countries since the time of the colonies; for example the catholic churches and colonial administration buildings such as Councils were adapted to warmer climates and less stable materials like adobe or handmade bricks. The result was an alteration in building´s dimensions, proportions and ornamentations; walls were thicker, vaults were lower.

Architecture in Buenos Aires did not depend too much on wood due to geographical and climatic reasons. Simultaneously, the influence of Spanish and Italian immigrants contributed to the local building culture in the use of brick and stucco. Thus, translation processes such as the ones that took place in Europe did not happen in Argentina except for the fact that the extensive use of brick and mortar replaced stone since colonial times, which, combined with painting evoked different material effects.

IMPACT ON ARCHITECTURAL DESIGN.

Design theory in 19th century architecture schools.

I could be stated that architecture schools in France led the developments not only in the production of design theory and projects but also in the conception of a design pedagogy, from the organization of different schools according to their approach to art, design, construction and architecture, to the organization of an architecture curriculum, courses, and ateliers. The Grand Prix de Rome can be used as a measurement of such developments as well as a showcase of the state of architectural debate. Donald Egbert[50] describes the importance of this competition, the deliberations around it and the ideas it fostered as an excuse to discuss and portray architectural topics, tools and theories from the end of 17th century until the middle of the 20th century.

Egbert illustrates different aspects of Beaux-Arts architectural tradition and influence with different instances of the Grand Prix. The last part of his book is separated 3 chapters, each one analyzing diverse aspects of each prize, as well as their resonance in their contemporary architectural practice. These aspects are 'Theory of design', 'Character' and 'Programs'.

The author places the extraction of French design theories in Italian Renaissance treatises (mostly based on paintings), which in turn were rooted on the classical antiquity, at the time comprised by the writings of Vitruvius. Architectural form depended on beauty of form, which was correlated to fixed, universal and most important, teachable principles of taste. Egbert describes

50 Donald Drew Egbert and David van Zanten, The Beaux-Arts tradition in French architecture (Princeton N.J.: Princeton University Press, 1980)

its role on architectural education:

"The principles of beauty in design were therefore to be based on good taste, which was regarded as good everywhere and for all time, and thus more important than any particularities whether utilitarian requirements, materials, time and place, or the idiosyncratic genius of an architect."[51]

Classical scholarship relied on the universal character of certain abstractions such as symmetry, proportion, harmony, order and rhythm, an such abstractions were crucial to differentiate Art (with a capital A) from art, or common craft. Such universality was also translated to buildings, typologies and programs; the monumental character of significant buildings, palaces or monuments was indeed a manifestation of their everlasting value.

Egbert also details the confrontation between the 'Ancients' and the 'Moderns', regarding the role of the historical references from classical periods, from ancient Greece to Renaissance and Mannerist architecture as a direct reaction against baroque geometries and scientific positivism[52]. The role of classic canons of design is also questioned in its methodology; whether by imitating remarkable case studies from the past or by 'learning' from 'classic examples and authorities in order to combine the "best" features of those selected as in the most "correct" taste.'[53]

Symmetry (in both definitions[54]) and axial composition were the prevalent design devices to achieve geometrical clarity of organization. The correct use of these tools in seemingly complex projects provided a straightforward method not only for the design and production of form but also for its propagation and communication; classical design theory regarded readability and clearness as a significant architectural feature.

Impact on digital design.

Bryony Roberts attempts an interesting contrast between the original ´Querelle´ (between Ancients and Moderns) and contemporary practices using architectural history as a reference[55]. Roberts clarifies the distinction between them not in terms of the antagonism between tradition and progress but as a difference towards the direction the discipline should aim to. The Moderns intended to bring Architecture closer to sciences, relying on empirical experimentation while the Ancients argued in favor of an established, historically validated discipline, based on both humanities and science, that its, to include

51 Egbert and van Zanten, The Beaux-Arts tradition in French architecture

52 On the introduction of Log 31 'The new Ancients' Bryony Roberts offers an interesting update on the 'Querelle' from a contemporary point of view , as contemporary architecture is "facing a similar epistemological divide between empirical experimentation and broader cultural knowledge" . See Bryony Roberts, "Beyond the "Querelle"," in Log 31 - spring/summer 2014 new ancients ([Place of publication not identified]: Anyone Corporation, 2014)

53 Egbert and van Zanten, The Beaux-Arts tradition in French architecture

54The original f definition of symmetry was based on the relationship between the parts and the whole and between themselves, similar to the concept of 'proportion'. A later definition, translated by Perrault was associated to the identification or correspondence between elements of both sides of an axis, closer to our contemporary definition, or bilateral symmetry.

55 Roberts, "Beyond the "Querelle"" in Log 31 - spring/summer 2014 new ancients

both modern and classical scholarship in their professional expertise.

The author perceives a similar ´epistemological divide´ in contemporary architectural debate; one separating empirical experimentation from an extensive, encompassing practices, including a wider cultural field. She defines the ´New Ancients´, operating ´across the empirical realms of material and digital experimentation, but they locate intellectual discovery in dialogue with scholarly histories of techniques and precedents´.

The ´New Ancients´ defined by Roberts could perfectly fit some of this research´s own references, such as Rokokorelevanz project. These new breed of practitioners intend to use history in order to establish a dialogical exchange between methodologies, technologies and aesthetics. As Robert remarks, their quest is not to detach themselves from the original opposition between form generation and innovation but raise architectural experimentation and relation to history to another level:

´(...) they invest in architecture as a cultural and intellectual project with a history of techniques for transforming abstraction into constructions´[56].

The author also clarifies a certain distinction between contemporary relation to history and postmodernism. While the latter was (for the most part) interested in signification and quotation by locating architecture to a condition comparable as a language, new practitioners (and this research as well) intends to establish a sincere fascination with history mediated this time, by technique. This shift in the focus, but also in the tone (from postmodern irony to technical sincerity) does not come without hazards:

´The recent obsession with technique leads some to appropriate historical precedents purely to enhance virtuosity, but the forerunners featured here use technique conceptually to stage parallels between past and present disciplinary predicaments.´[57]

It is also interesting to note that Bryony Roberts distinguishes the ´New Ancients´, that is, practitioners driven by a technical mediation between history and present and ´digital baroque´ architects. This separation is useful in terms that it establishes a certain geometrical refinement in order to establish such mediation with the past; aesthetic appraisal and formal exuberance alone is not sufficient to such critical task. On this topic, the author recognizes a certain ´classical rigor´ in the formal analysis of historical references. Much similar to this research, the search for an invisible order, regulating axes, hidden geometrical rules and ordering principles, is linked to a classical approach to geometrical tools and their contemporary digital counterparts.

The interest in historical tools and techniques is not severed from the study of historical references. Roberts names a new field defined by these interests: ´the emerging phenomenon of experimental preservation´ as a practice that ´manipulates historical structures as fully embedded in material, political and urban conditions.´

This field of ´alternative preservationism´ based on the exploit of digital

56 Roberts, "Beyond the "Querelle"" in Log 31 - spring/summer 2014 new ancients

57 Roberts, "Beyond the "Querelle"" in Log 31 - spring/summer 2014 new ancients

tools is still under development, and its relevance, particularly towards architectural experimentation, is undoubtedly significant. Their relationship to history is not mediated by scientific rigor but rather as an appeal towards the latent possibilities buried in architecture´s past; history is not uncovered and conserved but rather constructed and fictionalized.

Briony explains:

"Both old and new Ancients refuse to align architecture with either individual self-expression or technological positivism. Both see the beauty, success, and intellectual depth of architecture as emerging from a dialogue between techniques of the past and real-world demands of the present."

And finally:

"Absorbing and transforming, they develop a new authorship based not on singular individuality, but rather the ability to alter both past and present by making them inextricable. Past geometric techniques quietly shape contemporary forms, while digital techniques rearrange historic structures from the inside out. The intimacy of old and new plays out in the subtle redirection of architectural form and the rearranging of the architectural mind."[58]

58 Roberts, "Beyond the "Querelle"" in Log 31 - spring/summer 2014 new ancients

CHAPTER 04

- *Conditions*

INDUSTRIAL APPROACH TO ARCHITECTURE.

Industrial takeover of the building activity.

By the end of the 18th century industrial production was fully organized, mostly to provide machines for diverse branches of production, from cotton mills to agricultural equipment. Machines replaced manpower performing repetitive and demanding tasks like punching, cutting or bending, combining moving parts, gears, rods, pulleys, belts, chains and cranks. Wear and tear often required pieces to be repaired or replaced in order to keep functioning. Tom Peters recalls that early on, the 'machine culture' relied on interchangeable parts[1] as a rational step in order to increase productivity by having parts replaced for reparation or improvement.

Standardization was a part of this mentality, that is, under the new industrial paradigm it was easier and cheaper to change a piece than to buy a new machine

(which of course was impossible to do with human workers). More importantly, it was also easier and cheaper to buy a replacement part than to learn the skills and acquire the tools to repair it. Peters explain the influence of this mentality and the takeover of the building activity by the industry in the United States:

'The American light-wood frame, with its standardized members, connectors, and nails, was one consequence of this mentality. The result of this outlook has been that the industrial replication of parts and their assembly into additive, repetitive forms still underlie American building design.'[2]

This did not mean that the entire building activity relied on mechanical means, as the particularities of architecture required a greater dependence on human labor. The mechanization of industrial parts often involved a cycle of design, prototyping, testing and redesign; this way, standardization helped to separate common parts on different machines (and often companies) and improve them independently from one another. The goal was to improve efficiency on every conceivable task, from digging trenches for a canal to bolting rivets on an iron board: efficiency translated into diminishing times and consequently, lowering costs. According to Peters, the case of buildings was different since 'Traditional building methods are not easy to accelerate or change' and '(…) British contractors made it simple for themselves and

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1 Tom F. Peters, Building the nineteenth century (Cambridge, Mass., London: MIT Press, 1996)

2 Peters, Building the nineteenth century

increased their labor force. They put pressure on the workers and treated them as consumable machines.'

But the human feature that machines did change in the building activity was skill, more precisely, the true role of the builder's skill on the construction process. Mechanization made possible to unskilled workers to perform repetitive, simple tasks in order to achieve a single step in a larger, more sophisticated process. The successive accumulation of steps eventually produced a complex object or manufacture. This way, traditional building techniques like stone or wood work where an artisan or a master builder relied on experience and knowledge embedded on their body were replaced by single-purpose machines, operated by single-purpose workers. Mechanization implied transference of human skill to machines within a larger, refined process. Similarly, the construction and building erection was progressively turned into an assembly process.

The 'dehumanization' of the building process was carried out by following several 'efficiency' and 'rationalization' studies[3] for the organization of both the industry and the corporation that managed it. By studying movements of workers, machines and materials these studies proposed strict guidelines in order to regulate every aspect of the building process, or any industrial task. Detailed descriptions of each task, a simple learning process and a system of recompenses at some point replaced the guild system of master and apprentice in the building activity:

'The guilds had had neither the mechanistic nor the mechanical model to build upon, and they didn't have the concepts of progress and rationalization to dehumanize the learning process either'[4]

The industrialization of the building process involved a simultaneous, progressive and methodic standardization of building components, processes and procedures. And while medieval guilds organized the workers assignments according to tradition and rules of good practice regarding both procedures and materials, the industrial effort was oriented almost exclusively to the optimization of time and costs. Construction prefabrication was of course driven by this trend, significantly reducing the role and influence of guilds, often to specific tasks and materials that could not be fully mechanized and mass-produced, for example stonework or stucco detailing. Giedion laments the role of material knowledge under this new paradigm: 'The charm that lay in the proper use of the material was lost in a hopelessly misdirected mass production'[5]

The regulatory role of the guild system lost its purpose on the brink of total mechanization, now that the production of architectural elements and the erection of structures were replaced by mechanical fabrication and precise assembly. Since the necessity of skilled workers declined, their didactic role was also compromised; technical (and sometimes artistic) knowledge was

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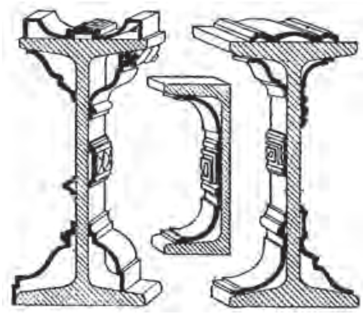
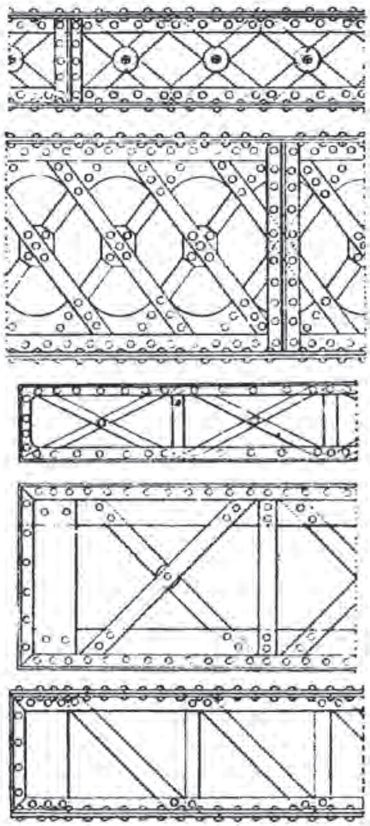
3 Along some of the examples cited by Peters, see Frank Gilbreth, Field System (New York: The Myron C. Clark Publishing Co., 1908) and Frank Gilbreth, Bricklaying System (New York: The Myron C. Clark Publishing Co., 1909)

4 Peters, Building the nineteenth century

5 S. Giedion, Space, time and architecture: The growth of a new tradition / Sigfried Giedion, 5th ed., rev. and enl, The Charles Eliot Norton lectures 1938-1939 (Cambridge, Mass., London: Harvard University Press, 2008)





4-1 Ornament and performance. Cast iron ornamentations over wrought iron beams.
4-2 Different truss combinations from bolted sections extracted from Denfer J.´ Architecture et constructions civiles´

transferred via other means, like the educational system (universities, technical schools, research institutes) and printed media (technical manuals, industrial catalogs), while simultaneously being closely protected by the patent system.

A late but interesting example of this type of media is the publication by J. Denfer 'Charpenterie Metallique – Menuiserie en fer & serrurerie' from 1891[6]. Denfer was a professor at the Ecole Central in Paris and compiled two volumes including a comprehensive description of technical information of iron and its applications in architecture. The publication showcased fabrication information, resistances, and tension values along with a graphical description of standard profile sections with their correspondent technical information. This encyclopedia/manual also described calculation methods for structural solicitations including several charts collecting information about the different solicitations and resistances allowed for each structural member.

The manual included descriptions of connections between members, joints, screws and several types of linkages. Descriptions of composite elements like beams, columns and floor structures were also included, however Denfer did not just include purely technical depictions but also the artistic possibilities behind them. On pages 399 to 401 it showcased some examples on how to cover I or double T beams with 'classical' plates, inserts and details.

The combination of technical information, accurate drawings and the representation of artistic motives applied on structural members is indicative of the century's simultaneous concern for technological and expressive solutions, marked by an eclectic understanding of architectural style. The successive description of case studies showing both cross-braced trusses composed with standard profiles and decorated beams and corbels from several case studies typify this mixed character.

The selection of case studies is also symptomatic of this trend; they show the full spectrum of 19th century's concerns in regard of the role of technical advancements, structural clarity and architectural expression and character. Denfer is concerned mostly on 'infrastructural' buildings, where structure takes a decisive role such as central stations, bridges and factories, but also depicts new architectural programs such as exhibition halls and department stores.

Finally, it's also interesting to note that several parts of this publication are presented as catalogs, that is, as an ordered sequence of elements with common parameters and variations, for example in their dimensions. Several cast and wrought iron profiles are depicted this way, showing common characteristics as thickness and shape, while differentiating in width, height and length. The approach is similar to the trade catalogs where variety and diversity is more important than originality, however on this case, the effect is different since a 'core' shape (double T, I, C profiles) is common to all variations.

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6 J. Denfer, Architecture et Constructions civiles. Charpenterie métallique, menuiserie en fer et serruserie, Encyclopédie des travaux publics (Paris: Gauthier-Villars, 18914)

In order to explain the scope and the relevance of commercial relationships and the exchange of technology and building culture between Europe and the colonies, Lucia Juarez's paper[7] is indicative of the complexities of such interactions, exemplifying the networks between the British empire and Argentina during the second half of the 19th century.

After its independence, the rapid urban development of Argentina due to a demographic growth required en matching effort in the development of infrastructure. Similar to several metropolis typical of 19th century, large urban expansions required roads, railway systems, water provision and disposal, gas and electricity. In addition, the new republic demanded for civic and urban infrastructure; administrative buildings, ports, central stations, warehouses and many other building types. The establishment of Buenos Aires as the country´s capital accentuated this request.

These buildings not only expected a satisfying material resolution but also a symbolic one as well. Rushed by these necessities and the fact that Argentina's industry lacked the maturity and variety of the European's, the majority of these commissions required the participation of foreign nations in the form of investment and materials, as well as the involvement of professionals and workforce.

Naturally, prefabricated materials such as iron, steel and terra cotta were perfect for this sort of enterprise, since they could be designed, manufactured on central economies and then shipped to every corner of the world. Juarez states on this regard:

'Since Britain (…) already dominated the international market for architectural ironwork, the urbanization of Argentina presented a potentially lucrative new market for British manufacturers, as well as the opportunity to develop new forms of prefabricated architectural technology.'[8]

Thanks to a series of financial and political benefits in favor or British investments, their influence on Argentina expanded over time, particularly around the development of the railway system, organized around the distribution of British products inward as well as outward the country.

Juarez emphasizes the role of British iron in the development of Argentina's infrastructure:

'Iron was perhaps the most important material, used for everything from rolling stock to entire bridges and railway stations. Iron was also used in other contexts such as in the development of ports, sewage and water-supply systems (pipes, tanks or even buildings) and other public and private enterprises in which the British were engaged.'[9]

Although by the mid-19th century Argentina had local foundries, the high

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7 Lucia Juarez, "Documenting Scottish Architectural Cast Iron in Argentina," in Function and fantasy: Iron architecture in the long nineteenth century, ed. Paul Dobraszczyk and Peter Sealy (New York: Routledge Taylor & Francis Group, 2016)

8 Juarez, "Documenting Scottish Architectural Cast Iron in Argentina"

9 Juarez, "Documenting Scottish Architectural Cast Iron in Argentina"

cost of materials, machinery and transportation limited their production to small parts or ornamental pieces for architecture and even so, their capacity to compete with European companies was narrowed by the fact that they just couldn't produce iron pieces in similar quantities. Juarez concludes: 'Given this situation, Argentina unsurprisingly imported the majority of its iron products from Scotland and also depended on iron and coal from Britain for its industrial and urban development.'[10]

Imported iron goods not only included standardized pieces like structural elements, profiles and beams but also urban furniture, ornamental pieces for architecture, train stations and of course, entire buildings. Again, the shipping costs (significant on any international trade) were greatly reduced by the fact that merchant ships transporting meat and cereals from Argentina to Europe keenly accepted iron goods as ballast for their return trips.

On this scenario, trade catalogs played a significant role in the dissemination of what Juarez calls a 'truly global aesthetic' by promoting industrialized products on colonies and other participating countries. Also, many European foundries established commercial offices in Buenos Aires in order to conduct and expand their business not only in the country but the South American continent as well.

According to Juarez, the combination of special commercial conditions to European imports particularly in favor of British products, as well as the influx of foreign building professionals, architects, engineers, and skilled workers combined with the inherent qualities of cast iron products generated particular circumstances under which 19th century Eclecticism thrived. An example of this trend is the Italianate style, which Juarez describes as an example of imported style in Argentina:

'As seen across Europe, the Italianate style was inherently flexible, adaptable to many different building types and contexts, providing architects with a wide range of choice in terms of design. The inevitable eclecticism that resulted was ideally suited to cast iron, a material that could, after all, be formed into most any desired shape by means of molds. With the choice of style left to the individual taste, eclecticism spread rapidly. '

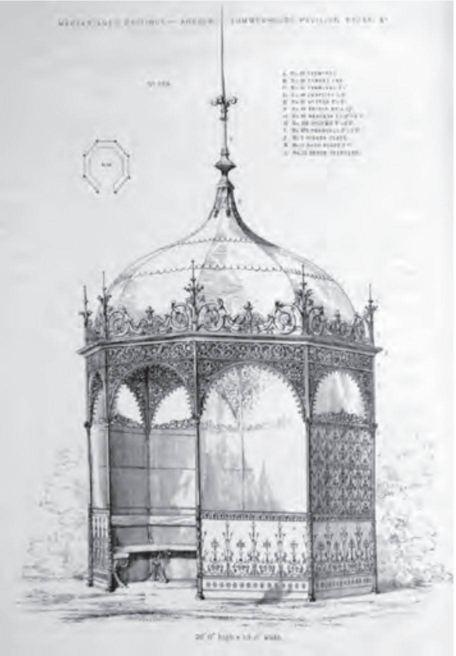
And further on, Juarez also elaborates on the lack of prejudice regarding the use of cast iron instead of more traditional architectural materials:

"Unlike Europeans, who generally found cast iron to be a poor substitute for more conventional building materials, it seems that Argentinian architects (and others in Latin America) freely accepted its use without any of the concerns that had been expressed by such influential figures as Pugin, Ruskin or Viollet-le-Duc" [11]

British companies not only exported iron goods to Argentina, to the eyes of the local public (and consumers) they exported modernity. The reasons why cast iron detractors criticized its use, that is, the mechanized repetition of artistic motifs were exactly the causes of the Argentinean public to embrace

10 Juarez, "Documenting Scottish Architectural Cast Iron in Argentina"

11 Juarez, "Documenting Scottish Architectural Cast Iron in Argentina"



4-3 Ready made kiosks, band stands, winter gardens from the Saracen Foundry catalogue.

it as well. The use of mechanized pieces and ornaments brought them closer to industrialized countries, and despite its critiques, cast iron symbolized that ambition.

British iron was then a synonym of progress, not only in terms of technical innovation, since they provided vital infrastructure that connected and unified the country but also because it brought 'modern' living conditions to the urban population. Aside sanitation and lighting services, Juarez focuses on the park equipment like gazebos, bandstands, kiosks, gates and railings enhancing and characterizing urban parks 'as an important element in the increasing leisure time of the working classes.'[12]

The author cites an example of MacFarlane casting company whose systemic approach to iron castings granted the possibility of providing mass produced elements such as gates or park lamps (included in the company catalogue) combined with individualized elements like the region's symbol.

In the conclusion, Juarez links the use and influence of cast iron in Argentina with the British Empire's commercial domination; the exchange of iron manufactures for raw materials and trade rights was seen at the time as a sign of material progress. This imbalance on the relationship and the intensity of the exchange are recalled by the author as a contributing factor to the establishment of Argentina as an 'informal colony'. Again, there was apparently no contradiction between the economic conditions imposed by Great Britain and the genuine sentiment of progress that iron imports provided. Even so, they became so widespread that the large variety of cast iron products and even the possibility of personalization did not conceal the ubiquity of British products across the continent:

"Cast iron created certain cultural and design uniformity across the British Empire that affected all colonial lands, including Argentina. However, this sense of imperial style provoked little resistance. Instead, it symbolized Argentina's and, especially, its mayor cities' aspirations to be like their more "civilized" counterparts at the European imperial centre."[13]

12 Juarez, "Documenting Scottish Architectural Cast Iron in Argentina"

13 Juarez, "Documenting Scottish Architectural Cast Iron in Argentina"

IMPACT ON DESIGN.

Kit of parts approach.

As previously mentioned, the experimental use of iron, initially in bridges, implied a new approach to design structures. The transition from composing and building to assembling by means of employing a set of standardized pieces and more importantly, standardized connections. Iron manufacturers, being familiar with the use of casting molds (arguably an expensive part of the fabrication process) tried to utilize them as much as possible in order to redeem their cost quickly.

Consequently, designers took notice and harnessed its advantages through novel design strategies.

Tom Peters defines this approach in terms of ´bottom up´ strategies:

'(the bridges) were designed with more modern connections and their builders organized in a new way: as systems. Instead of designing them traditionally by first determining the bridge form and then subdividing it into parts for prefabrication, they used a bottom-up design process, standardizing the members and connections as they went and arranging them into an assembly. Their "kit of parts" determined the final form as much as the form influenced the parts –a form of matrix thinking"[14]

This type of approach is not unfamiliar to contemporary practices; the use of standard components like structural members, windows, doors, panels and several others is a common practice and one can still trace its use to experimental structures, for example the space frames developed from tetrahedral geometry.

As connection technology grew on importance, the act of building transformed into on-site assembly. However, assembling also meant that components arriving from the factory allowed practically no adjustment on the construction site, thus narrowing the flexibility in response to building problems and limiting improvisation.

Thanks to open (but rigid) construction systems protected by copyright patents, a builder could only build what the components and the factory allowed. It also meant that the act of building (as defined historically) was altered, as Peters states:

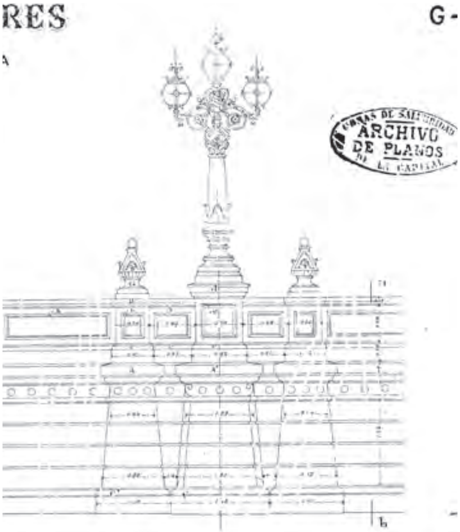
'(…) organizing component hierarchies rather than composing forms'[15] (italics by the original author). And then: '(the construction system) Its characteristics are repetitive prefabrication, standardization, and site assembly rather than site manufacture and manipulation of raw materials'[16]

The significance and attention to standardization and organization was

14 Peters, Building the nineteenth century

15 Peters, Building the nineteenth century

16 Peters, Building the nineteenth century



4-4 Ready made lamppost from the Saracen Foundry (MacFarlane) documented from the Palacio de Aguas Corrientes in Buenos Aires. (Buenos Aires, 1887
4-5 Palacio de Aguas Corrientes (Buenos Aires, 2017)

emphasized due to the effective distance between the factory (England, Scotland, Belgium) and the final destination of the building (Argentina, Chile, South America). The Argentinean Pavilion from the Paris Exhibition or the Palacio de Aguas Corrientes are textbook examples of this approach; being both of them almost entirely manufactured off-site and assembled in Argentina.

This 'kit of parts' approach represented a highlight as a manifestation of the manufacturing techniques of 19th century as it involved an elaborated network of production parameters, material limitations, financial tools and commercial associations. The combination of these determining factors also influenced design strategies in the form of design constrains and guidelines, as the planning stage of the construction took a significant role like never before.

This design and production mentality is still valid as a contemporary paradigm, updated by complex manufacturing techniques and digitally controlled fabrication. In fact, the basic characteristics of this approach were not altered over time, and they can still be traced to 19th century.

Modularity is an interesting example of this type of approach to construction, implying the consideration of every assembly as a system, whose elements are designed in such way that can be replaced or updated with new elements without altering the other items. Modularity was not achieved just by standardized measurements but also by standardizing joints and connections.

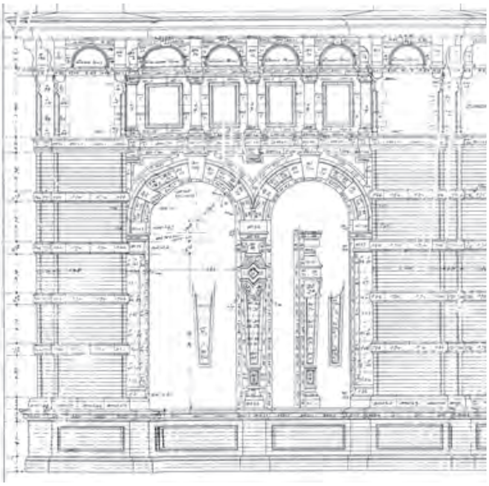
Modularity was also combined with scalability, by which each component could theoretically be attached to others in order to achieve further functions, whether they are functional, structural or ornamental. And finally, another important characteristic of such systems was re-configurability; meaning that components or systems had the capacity to be disassembled and re-assembled in other location in order to perform an analogous function. The Argentinean Pavilion by Albert Ballu is an archetypical example of this approach, to the point that several pieces are still usable a century after its initial deployment[17].

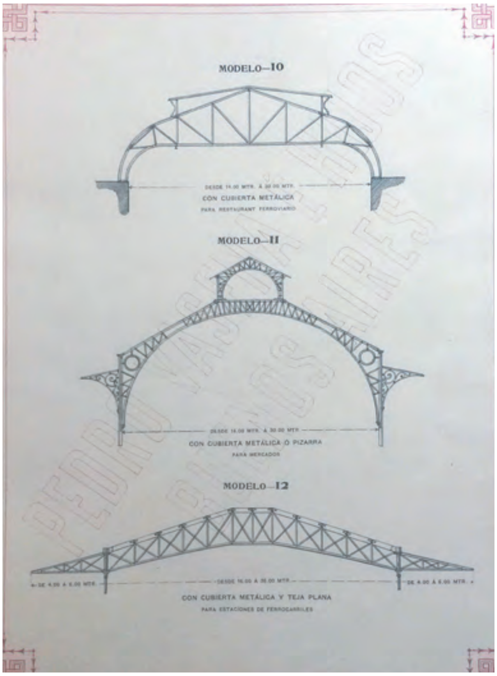
Buildings that were produced this way were initially manufactured, test- mounted under controlled conditions and their pieces numbered before shipping. A careful design of the building as an assembly system, as well as each component was required, for example, in terms of size, in order to fit commercial shipping crates. Also, several replacement parts were included on the shipment in case they were damaged during delivery or montage[18]. Once more, thanks to production techniques and design parameters there was almost no chance for any alteration of the elements after their fabrication.

'Portable houses', 'Export buildings', 'Kit buildings', 'Kit homes' were some names given to these types of constructions, spanning from park kiosks to residential houses, warehouses, markets and exhibition halls. For the purposes of this research, it is convenient to focus on the architecturally significant

17 Several parts of the pavilion were found in Buenos Aires in 2014 being sold as scrap metal and reusable structures. Aside from the sad note, it also proves the efficiency of modular capacities of iron construction, still usable after 125 years. Source: https://www.lanacion.com.ar/1693091-venden-por-internet-los-restos-del-pabellon-argentino-de-1889

18 In the Museo de Aguas (Palacio de Aguas Corrientes) several of these replacement pieces are exhibited. On a side note, they were never required as the building stood in relatively good conditions since its erection, which is a demonstration of its material quality.





4-6 Outsourced individualized fabrication. Terra cotta contract documentation from the Palacio de Aguas Corrientes (Buenos Aires, 1887).
4-7 Ready made trusses and flexible systems in structural design. Extracted from the Vasena Catalog.

examples, most of them from the early period of development.

Pedro Guedes compiled a great number of examples of this approach on his doctoral thesis[19], ranging from combinations of French wrought iron buildings with terracotta tiles, kit-buildings from Belgium or structures manufactures in Scottish foundries and domestic buildings from Glasgow.

It was also the case of a combination between imported mechanized parts and local materials. Particularly in colonies, the sourcing of materials reached several points of the globe. As an example, Guedes describes some mineworkers' cottages erected by a company for its employees in Johannesburg:

"They are built with imported corrugated iron roofs and walls on timber framing. Some of these buildings were brought in as kits but more often, built with stock materials shipped from overseas and held by local building suppliers. The framing timber was often also imported, coming from the Baltic or the United States and Canada."[20]

A number of structures were exported from Europe to its colonies, Guedes cites several examples like the aforementioned houses, warehouses, sheds, train stations, lighthouses, glasshouses, bridges and many other types, including building parts such as facades or trusses.

Guedes also accounts for many of the corresponding patents issued in order to secure the intellectual property for their designs. Of the many cases, the description of A. Develaye's construction system[21] by the author is a lucid example of the design criteria for buildings intended for export: metallic construction (in order to assure fireproofing), ease of erection (requiring little or no worker's skill at the destination), soundness (in order to sustain disassembly and reassembly without significant damage), scalability (in order to accept additions and improvements) and finally, cost efficiency.

The author also published a paper on a South American case study building , the Santiago Market in Santiago de Chile[22]. The example may be comparable to other case studies form this research like the Argentinean Pavilion or the Palacio de Aguas, Guedes' investigation about the conditions that preceded the final destination of the building from Great Britain to Santiago. It also accounts for the design iterations as well as material and building specifications, including published drawings and photographs depicting construction details and spatial organization.

Several ´kits´ were available at the time, reaching to different markets, requirements and budgets. The case of the Belgian kit buildings is just an example of them. Some of them were manufactured by the Société des Forges d'Aiseau according to patents by Joseph Danly[23]. He designed kits for houses,

19 Pedro Guedes, "Iron in building, 1750 - 1855: Innovation and cultural resistance" (Ph.D., The University of Queensland, 2010)

20 Guedes, "Iron in building, 1750 - 1855: Innovation and cultural resistance"

21 Guedes details these characteristics in addition to graphical support on the Image appendix of his thesis, also referencing A. Delavelaye, 'Constructions en Métal.' Revue Générale de l'Architecture et des Travaux Publics, vol. 4, 1843,

22 Pedro Guedes, "El Mercado Central de Santiago: Antes de su embarque a Chile," ARQ (Santiago), no. 64 (2006), https://doi.org/10.4067/S0717-69962006000300002

23 M. Braham, R. Le Roux, and G. Carré, "Joseph Danly (1839 – 1899)," http://maisons-metalliques-francaises.

barracks, hotels and field hospitals which were more advanced in terms of sophistication and complexity than many other of his competitors at the time.

In conclusion, the combination of a technological mindset (manifested in the complex technical detailing) coupled with an ornamental decoration of the structures is symptomatic of the 19th century's approach to constructive, structural and spatial design strategies.

Standardization, generalization and the decontextualization of construction.

On the chapter 'The infinitely shapeable structure – Structural iron and the decontextualization of construction', Mario Rinke[24] describes de evolution of the conception of structure after the advancements in fabrication techniques and the establishment of the material and building in the realm of sciences.

He defines the 'context' of the structure as a series of parameters that determine their specific construction as 'explicit relations between any factor which influences design and the final character'. The author details: '(…) spatial constraints, material, structural measures, and the formal language, (…) will here be called the context of a structure'[25].

And then, when defining the 'decontextualization', he states: 'The process of generalization and standardization –the change from specifically constructed to a generalized application of a certain type of construction- can, in this regard, be called the decontextualization of construction.'[26]

Although Rinke's position describes a theoretical decontextualization, it is also fair to notice that 19th century production and commercial networks provided a literal decontextualization; several case studies from this research are samples of this trend, as their construction elements were often fabricated on a different region, country or even continent (with the obvious exception of the Sayn Foundry).

Back to Rinke's account, the use of iron and consequently, finite structural elements, the connection technologies shifted from 'crafted, specifically adapted ends' of each structural member to 'standardized elements with no adaptation and simple rivet connections, or standardized hinges using bolts.'[27]

Rinke accounts for an optimization process involving the simplification and optimization of elements (which was common in timber constructions) and a second one, determining each element's shape according to their structural solicitations. These factors, combined with the iron's material and production characteristics (i.e. the possibility to cast any form without waste or discarded material), granted its use a level of flexibility and freedom unusual to designers.

Rinke explains: 'The new building material required less specific construction

org/sites/default/files/pdf/Joseph%20Danly.pdf

24 Mario Rinke, "The infinitely shapable structure: Structural iron and the decontextualization of construction," in Before steel: The introduction of structural iron, ed. Mario Rinke and Joseph Schwartz (Sulgen, Zürich: Verlag Niggli AG, 2010)

25 Rinke, "The infinitely shapable structure"

26 Rinke, "The infinitely shapable structure"

27 Rinke, "The infinitely shapable structure"

rules and thus caused less determination for the structure. This arbitrariness of use for any kind of possible structural layout heavily influenced the character of the structure. Iron therefore had a great impact on the structure's context as it lowered the significance of the construction material for the design of the structure.'[28]

Furthermore, Rinke supports the decontextualization of the structure in several aspects. The first are the liberation or relaxation of spatial constraints; by separating the supporting elements and the supported ones, iron introduced a new degree of freedom in the design of architectural space. Before the introduction of iron and steel, architectural space was bound by building elements which operated simultaneously as structure and enclosure (columns, walls, vaults), but thanks to the characteristics of iron (resistance to compression and tension, slenderness) and the subsequent dematerialization of supporting elements, they did not have enough material presence to enclose or define such spaces.

Rinke also accounts for the efforts of English engineers in order to compensate for the visual effect in iron support elements by increasing their dimensions (and incidentally risking the whole structure by adding unnecessary weight). As discussed previously, the dimensions of iron structures were significantly thinner than stone, brick or even wood ones, particularly for the spans that they were used in typically. Historically, there was a visual relation between slenderness (or the lack of) and structural capacity; iron altered this 'context' as well.

Lastly, architecture's formal language, and particularly, the structure's formal language was also modified thanks to the advancements in the use of iron. Once again, the interplay of forces and its representation had a key role in the progress of architectural history and many theorists accounted for the evolution of structural types running parallel to architectural styles. The Greek architrave, the combination of column and arch in Roman architecture, byzantine domes and pendentives and Gothic ogival arches are some examples of this approach matching every architectural period to a structural development. But then the question is, which is the structural type of 19th century? Rinke does not provide an answer to this matter, but his description of 'decontextualization' might render the question irrelevant.

The introduction of iron and the advancements in statics and calculations shifted the focus of structural design from structural type (lintel, arch) to a more 'formal' approach, by combining small elements in complex repetitive patterns. Structural design focused on how to achieve the maximum span or solicitation with the minimum amount of material or elements. The search for standard structural solutions, but flexible enough to solve diverse solicitations was a common goal to 19th century engineers and a driving force of structural research and experimentations.

For Rinke, decontextualization also meant that generalized, standardized structural solutions could be found by engineers via scientific approach to their design, completely isolated from any spatial, material or architectural parameter. A standard structural solution would also require the standardization of every other architectural parameters; standard spaces (architectural programs and typologies) and standard materials (isotropic materials, iron, steel). Rinke concludes:

'The design understanding of most engineers at the end of the 19th century is mostly limited to the supply of an economical solution of a certain load bearing capacity for a given

28 Rinke, "The infinitely shapable structure"

standard load and specific span. This leads to decontextualized structures, which are systemically represented and widely promoted in standard engineering textbooks for the correct application of modern, safe and material efficient design.'[29]

During the next chapters we will explore how these topics reflected on several case studies along with the variations and nuances each specific project presents. As explained on the introduction, the research went back and forth on the definition of theoretical issues, the study of projects and the design experiments, meaning that the sequential ordering of chapters is merely organizational and not of any narrative character.

Many of the questions issued on the Theory chapters will echo in a precise and clear manner on the case study projects while others may present themselves indirectly or subtle. Some of these subtleties found in the case studies prompted the study of other topics described here and triggered larger and more interesting inquiries. A similar procedure occurred with the Design Experiment chapters which were initially thought to ´test´ and explore design topics but ended up originating even more topics and projects as well.

29 Rinke, "The infinitely shapable structure"

PART 2

- *Case studies*

In order to identify the topics of interest of this research, a series of historical case studies from 19th century architecture were analyzed. This second part, consisting in ten chapters, will collect and study architectural projects in the form of technical drawings, building details, spatial diagrams, renderings and models.

This section intends to illustrate the topics described in the earlier 'Theory' chapter but also to provoke and present new topics. The illustrative and generative character of these chapters will prove an important asset of the research, fueling the search of relevant topics and stimulating experiments in the next part and its chapters.

The historical references exemplify the topics of interest at times very graphically, while others do it in a veiled manner. Naturally, not all topics can be described using representational tools, however the intention is to push their capabilities in order to broaden their ordinary scope finding new information and new meanings.

The intention of these next chapters is to visualize the relationship between the production techniques and their expressive and spatial manifestations on the selected buildings, from clear-cut mainstream examples to hybrid, less known yet relevant constructions. After the analysis phase, the experimental chapters will exploit these characteristics by using digital design tools to produce more variation, more detail and more quality architecture

CHAPTER 05

- *Sayn Foundry*

By 1817 the Sayn foundry was already established under the Kingdom of Prussia for more than 40 years when the engineer and iron master Karl Althans planned their new furnace and factory hall. Situated against a slope, the design of the factory used the height difference to load material and coal on the high end while the molten iron was situated on the bottom part in the factory hall. As an example of complex design strategy by which every aspect of the building supports, coordinates and articulates the production of the factory, from production to promotion, the Sayn foundry simultaneously performs the role of machine and building.

There is nothing classical or standard to this building, however its design is impregnated with the implications and references correspondent to the 19th century´s discussion and production.

To begin with, the floorplan corresponds to a cruciform basilica (indeed a strange typology for a foundry) on which the furnace occupies the position of the altar while the central nave functions as a casting floor. Initially, the foundry was supposed to be built in masonry, but Althans chose a cast iron skeleton, a material he mastered. Each piece from the structure is precisely tailored to fit the next one, without any regulating system like other 'open' construction systems for trusses and iron constructions.

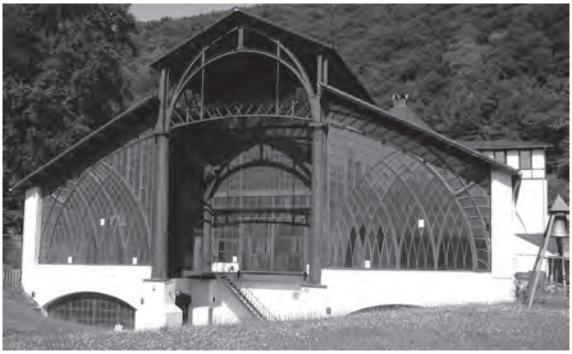
Peters describes this building as innovative as well as ambiguous: "We can read it on four discrete levels: iconographically, industrially, structurally and architecturally" [1]

In terms of iconography, the building floor plan is a manifest itself; the appeal of a typology related to religion ties the building and more importantly, its activity, to a sacred one. The importance of fire, of creation, refers not only to Greek mythology (through Vulcan, god of fire and metallurgy) or Christianity but to the Enlightenment and the pursue of truth and wisdom through 'science and progress'. This is more a deliberate effect than a poetic description, and as an example of this motivation, we could also mention the central nave, lit through clerestory windows, much alike a religious building.

On a more mundane plane, the building also acted as a publicity piece; as early as 1830 it already displayed the possibilities of cast iron, not capable as the prime supply material in industrial manufacturing but also as an architectural material, with plenty of expressive and aesthetic capabilities. On this topic, Peters states:

"(...) the building confidently boasts the strident commercialism of the nineteenth century. It is readily readable as an industrial icon and an early

1 Peters, Building the nineteenth century



5-1 Storefront, structure, machine, religious metaphor, advertisement. The many functions of the Sayner Foundry´s facade.
5-2 Iron tracery and structural patterns. Interior view of the Gießhalle.

example of a building as corporate symbol and advertisement."[2]

The foundry's structure was a combination of two distinct structural types, a bowstring truss supported by arched struts. Nothing in Althan's building seems to be rational or governed by structural or stylistic rules, every structural member appears to be superimposed and juxtaposed to another one. Structure and machinery pieces like gantries were combined complex constructs; girders were used as gantries, columns functioned as cranes, machine and building were one.

Juxtaposition, combination and amalgamation were not an aesthetical choice; Althans was an experienced engineer and was careful in the use of cast iron, particularly when subjected to static and dynamic forces, as a factory would require. It is likely that the combination of multiple structural systems like the iron girders braced to the lateral masonry walls had the purpose of creating a redundant structure, in order to effectively deal with the moving loads of molten iron and large cast elements. The gothic tracery from the façade and the furnace's walls were also part of this highly redundant stiffening system, in addition, the clerestory structure also functioned as longitudinal stiffening.

This way, Althan's design efficiently combined architecture, structure and machine; apart from their architectural function, building elements like columns or beams functioned as cranes, while simultaneously overlapped to each other in order to ensure structural stability. The building is an interesting case study mainly because these characteristics, nothing is decorated, simplified nor rationalized in the construction:

"In contrast to the conceptual clarity that contemporary engineering theoreticians like Franz Josep von Gerstnerm Johann Albert Eytelwein, or C.L.M. Henri Navier, Althan's structural ambiguity and redundancy may well have been his clear-headed and successful way of introducing a safety factor into the structure."[3]

Regarding architectural styles, the Sayn foundry is also a complex juxtaposition: the central nave is formed by superimposition of Romanesque and Gothic arches, the glass façade and the clerestory are composed similar to a gothic tracery while the interior cast columns are of a Tuscan style. However it not is the case of a pastiche or a combination of historical pieces; Althans studied each element and altered them in order to perform efficiently in multiple aspects and functions. Architecture, structure, machine, religious metaphor, advertisement: every building block can be analyzed under these parameters as well as the entire building.

In regard of this multi-layered, multi-styled building Peters states:

"Each of the many aspects of the building was dependent on all the others. Althans integrated the foundry's products, machinery, structure, form and cultural meaning in a way that made them inseparable aspects of the whole. We can explain the structural elements as advertisements, as machine supports, as religious form or as building parts, and we can read the Sayn Foundry's function either as a building that houses a production process or as a machine with space in it for humans to service the industrial process. This makes the foundry an even more complex organism than other large machines and industrial buildings that preceded it (...)"[4]

Althans' complex multi-purpose structure poses an appealing example of 19th century's innovative and unsophisticated approach to building and the adoption of new technologies.

2 Peters, Building the nineteenth century

3 Peters, Building the nineteenth century

4 Peters, Building the nineteenth century

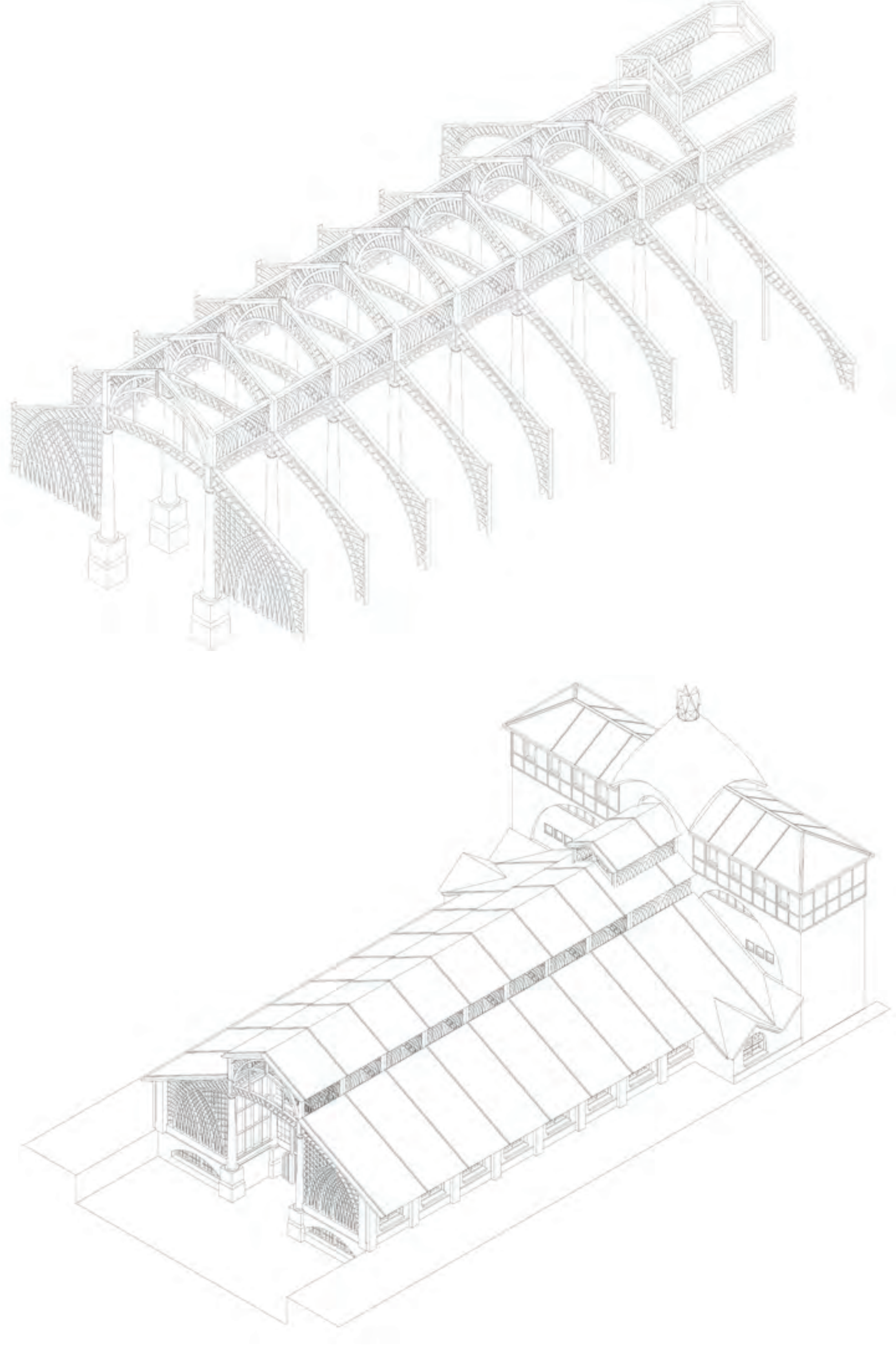
The combination of multiple materials, structural systems and functions is not just a matter of static redundancy; it is the embrace of a novel attitude towards the true role of material, technological, expressive and historic conventions in architecture.

The casting floor's columns, Tuscan in style but without base or pedestal, were cast in iron and also acted as a support for cranes and gantries. The column's historical function (apart from supporting) is to show and express support and strength as isolated, recognizable elements. The columns´ vertical thrust is on this case are blurred by the triangular shaped cranes attached to them. Moreover, the columns act not just as a representation of weight but of the axis around which the cranes rotate, articulated thanks to cannon-ball ball-bearing mechanisms developed by Althans.

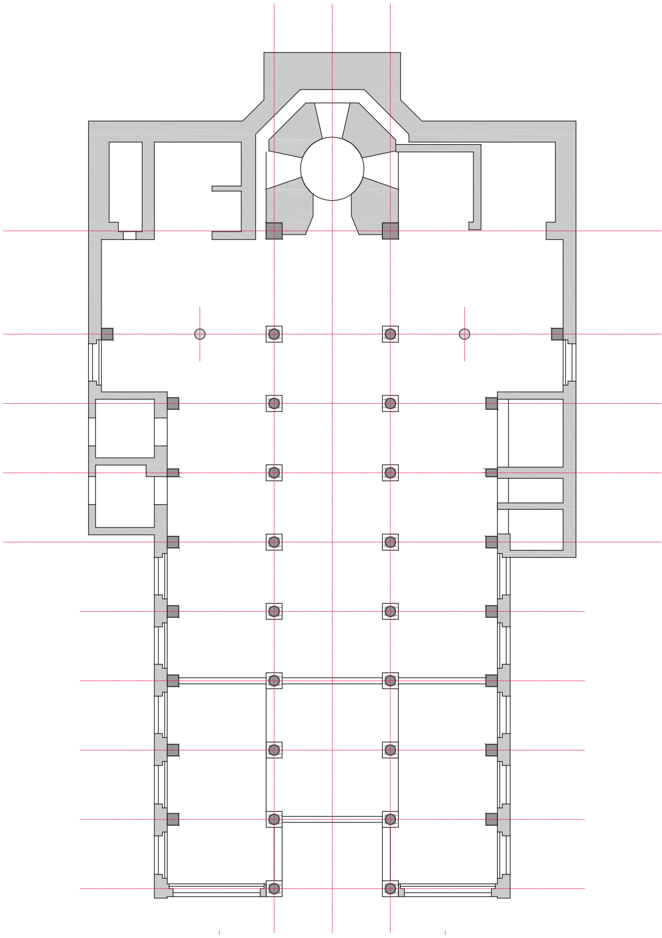
Althans' building was the physical expression of its function; it internalized and regulated a series of actions for its users (the foundry workers) by readapting a religious typology to a new activity while experimenting with novel materials. Sayn's hybridity wasn't just typological: architectural elements were hybridized, structural members were superimposed to one another, even its character was altered.

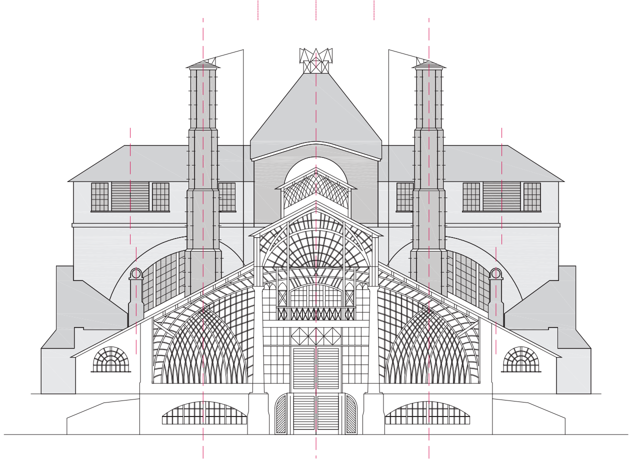
Foundries were typically dark, closed spaces whose extreme environments isolated their laborious workers. A year before the finishing of the construction works, Althans decided to open its interior activities by replacing a masonry wall with a glass façade. Again, the glass wall is of a hybrid nature, not just in stylistic terms but in its function, as it also works as stiffening for the longitudinal structure and bringing light into the shop.

The Sayn foundry's façade is also a reference for the century's affection to the combination of glass and iron, not just for greenhouses or factories, but for every type of building. Once again, Althan's amalgam of construction, machine and advertisement manifested 19th century's taste for innovation, hybridity and overall freedom.

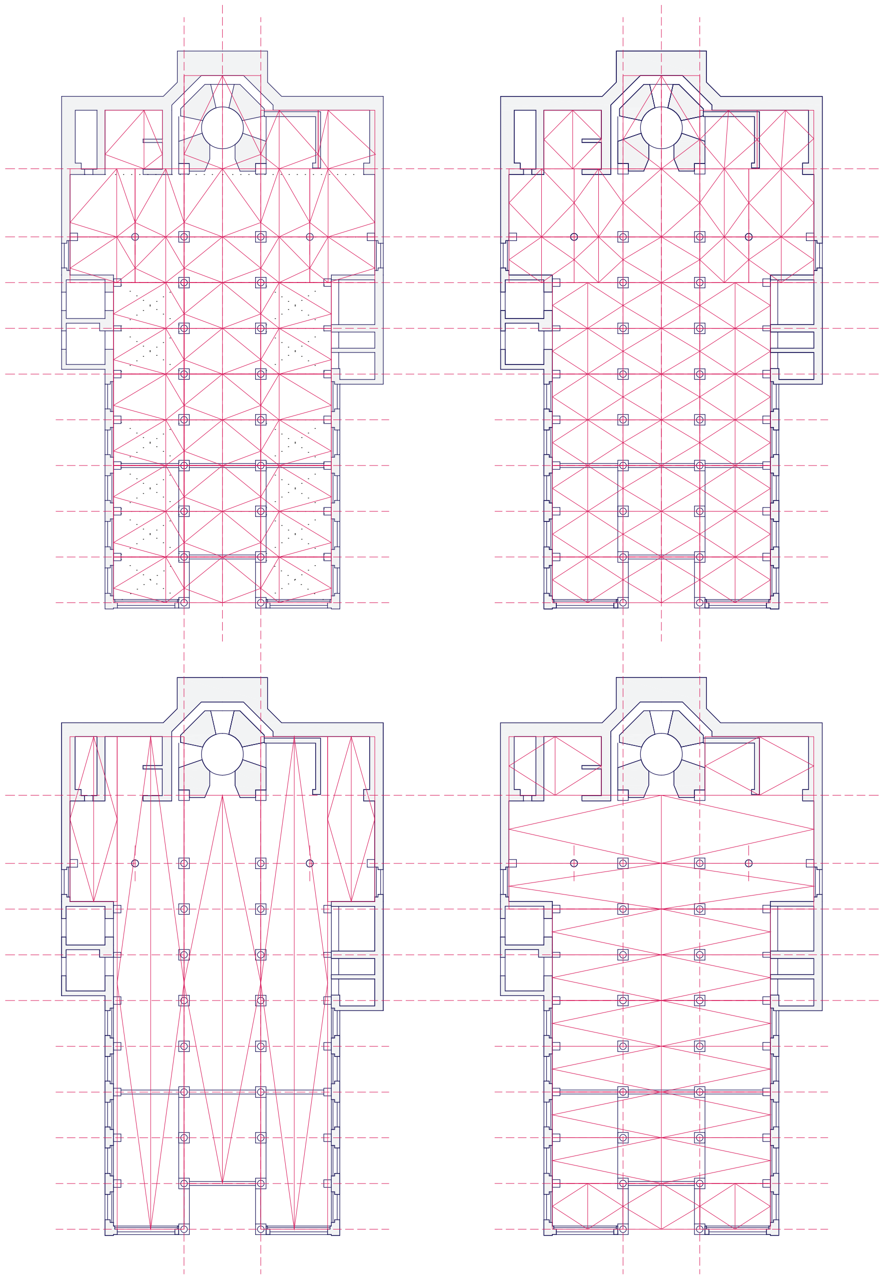


5-3 Isometric view of the iron structure and building enclosure. Hybridty at all levels: the combination columns, bowstring trusses and arched struts reveals the experimental approach of the design over stylistic or typological constrains.

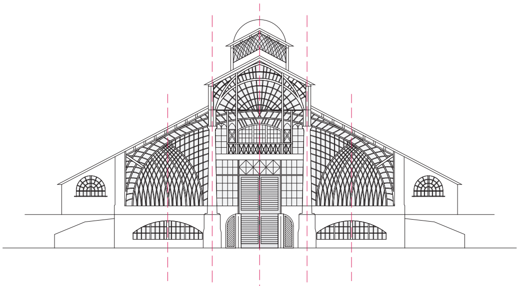


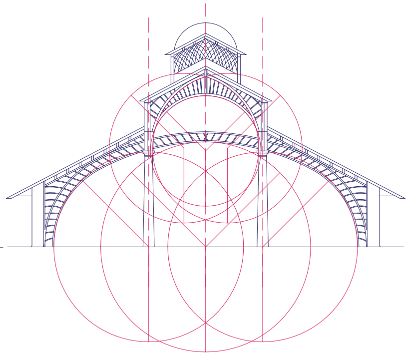


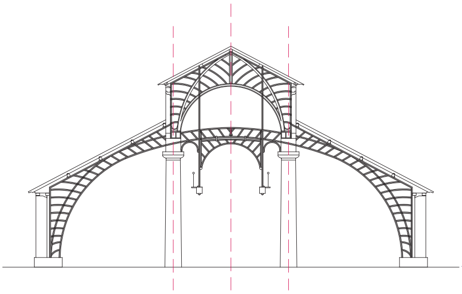
5-4 Sayn Foundry (C.L. Althans) Ground floor plan (interpreted from various sources). Note the organizational structure reminiscence to a basilica-type structures.
5-5 Front view. The gothic-like tracery in cast iron dominates the facade. On the background, the administrative annex building (interpreted form various sources)

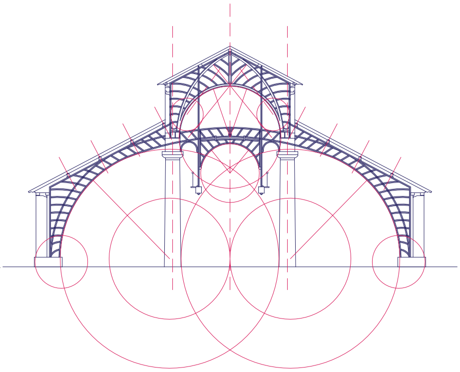


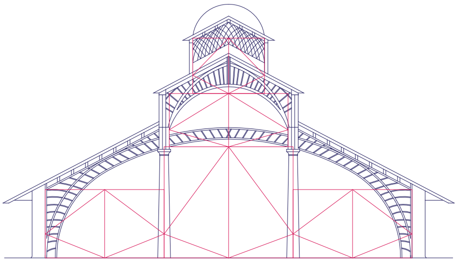
5-6 Diagram of the Basilica-like structure of the foundry; a disjointed narthex as entrance, main nave and two aisles leading to the ´altar´ or main furnace.
5-7 Structural modulation from nave and aisles. Regularity breaks in the transept.
5-8 Spatial flow towards the ´Altar´ or main furnace.
5-9 Spatial flow and structural segmentation. The access is receded generating an entrance hall. Structural modulation is slightly altered generating a brief expansion when approaching the main furnace.

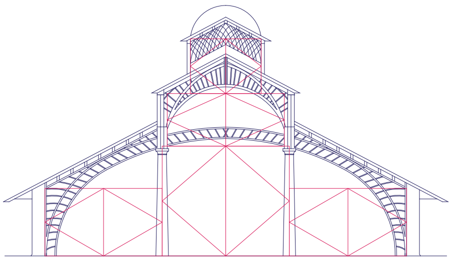




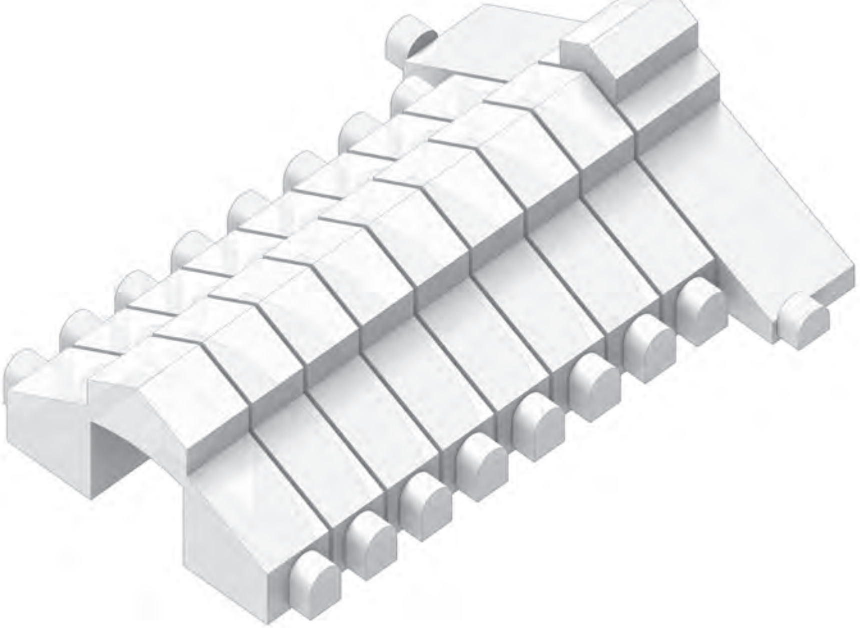




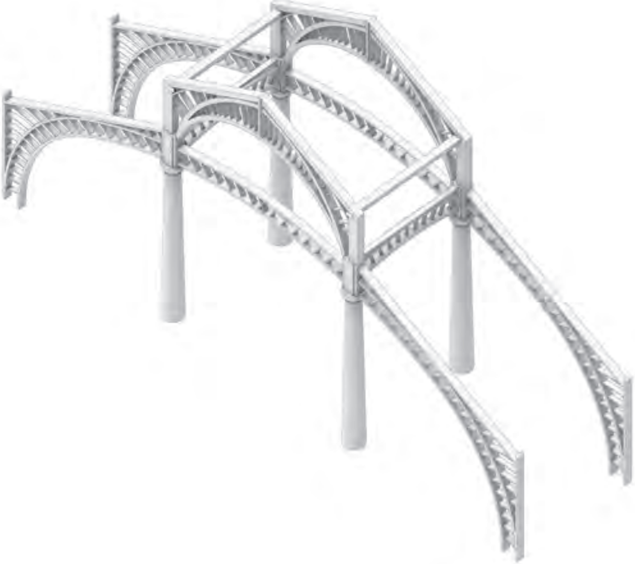




5-10 Front view with gothic-like tracery in cast iron (reconstructed).
5-11 Diagram illustrating the variety of arches and curve types used on the structure of the foundry. The main structure is a lowered hybrid arch leading to buttress-like supports, Gothic and round arches on the clerestory and vaulting are combined seamlessly.
5-12 Section and composite structure organization. Added to the unusual structural geometry of the lowered and Gothic arches, the substructure was added to aid the metal casting process directed to the main vat.
5-13 Section and composite structure organization. The combination of a lowered arch, cast iron Doric columns and Gothic ojival geometry is most unusual.
5-14/ 5-15 Aisle proportion in the composite structure.

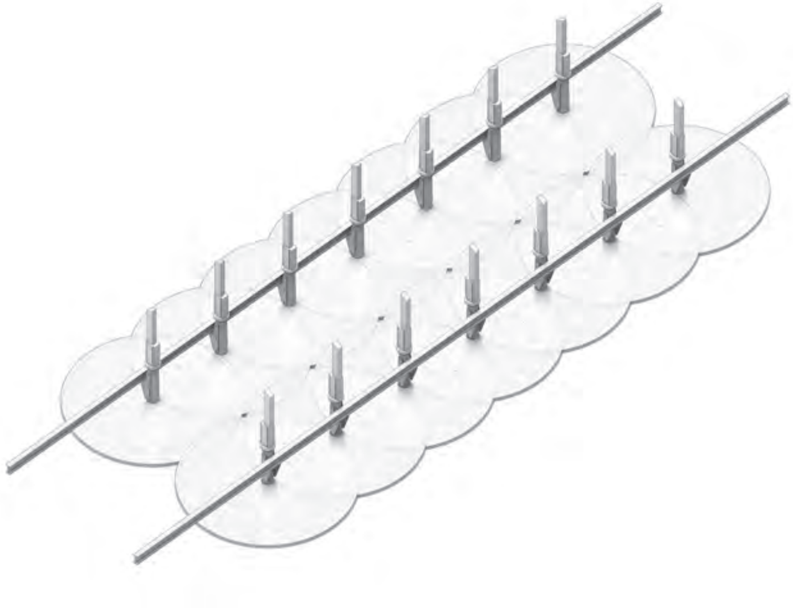


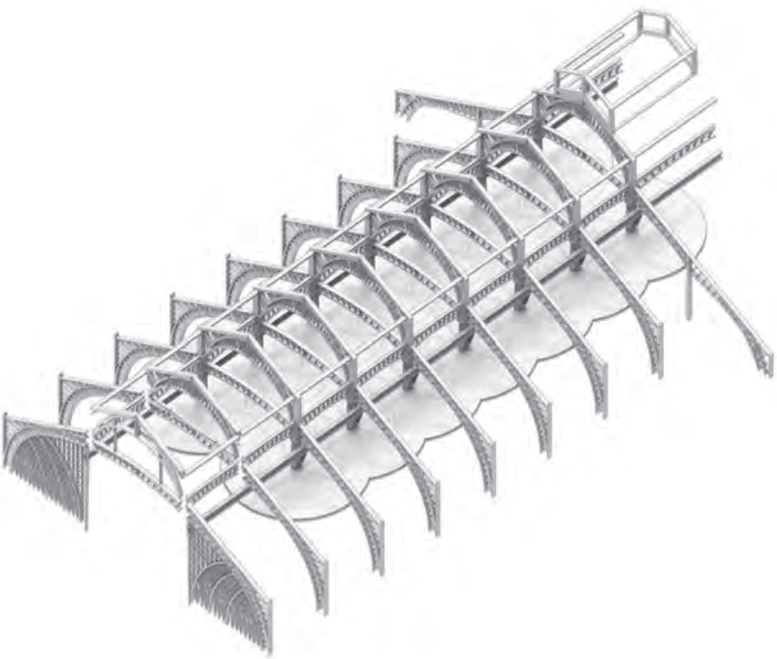
5-16 Representation of volume void. Regular structural rhythm breaking on the last segment next to the main furnace corresponding to the transept.
5-17 Representation of volume void. Structural module.
5-18 Representation of volume void. Transept next to the furnace.



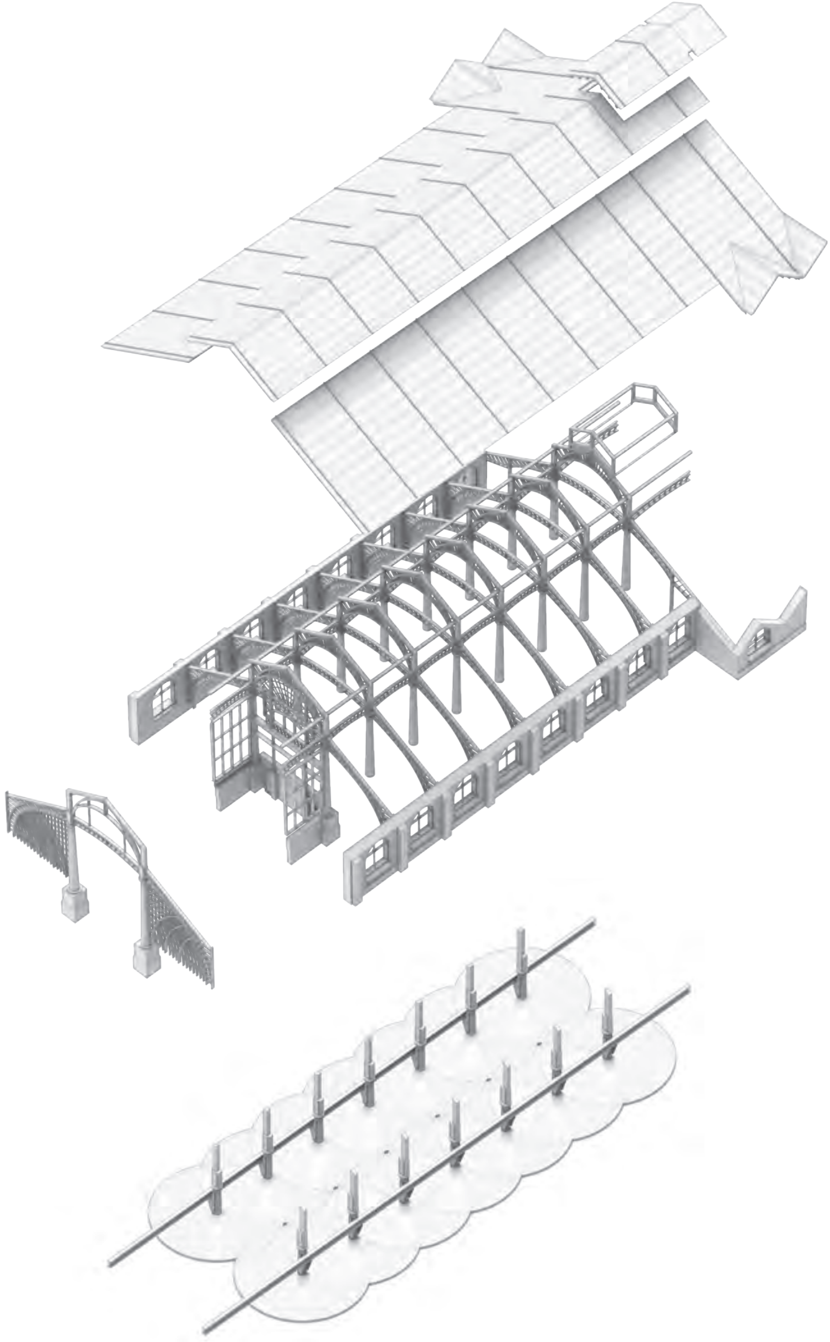
5-19 Structural module of the foundry. Improvised redundance: hybrid structure consisting in a lowered arched girder ending in buttress-like supports, cast iron columns, Gothic archery and cross-bracings.
5-20 Structural module of transept next to the furnace. The structural function is completed with the lateral walls assisting against the lateral loads.

5-21 Support with a function. Half-structural module. Column acts as a support structure for the smelting process. Gantries and cranes are fused with the iron structure blurring the distinction between building and machine.
5-22 Probability space. Half-structural module. Void volume within the reach of the column / gantry composition. The spatial influence of these fabrication aids clearly influences the overall perception of the basilica-like spatial arrangement.





5-23 Probability space. Cast iron structure. Volumetric representation of crane scope.
Bottom: Cast iron structure. Mechanical devices and volumetric representation of crane scope and gantry.



5-24 Exploded isometric view. Roofing, structure, frontal Gothic-like tracery, mechanical devices and volumetric representation of crane scope and gantry.

CHAPTER 06

- *Sainte-Genevieve Library*

Former student in the École des Beaux-Arts, winner of the Prix de Rome and later a professor at his home institution, French architect Henri Labrouste was commissioned for the new Bibliothèque Sainte-Genevieve in Paris in 1838. Construction took place from 1843 to 1851, at the Place du Panthéon, on the site that was originally located to the conventual library of the Abbey of Sainte-Genevieve.

Right in front of Soufflot's Pantheon, the library acts as a critical counterpoint to the church's classical presence, not only in terms of scale but also in stylistic interpretation and a sober ornamental expression. Labrouste's project clearly departs from French institutional architecture; its severe façade shows no prominent decoration, projections nor recessions, departing from classical compositional rules contrasting his immediate neighbors.

The building is composed by two stories, articulated by a sober frieze and garland decorations and topped off with a cornice partially hiding the sloped roof from the pedestrian level. The effect works, the bystander is overwhelmed by the laconic block without prominences or sculptures accentuating the facade rhythms.

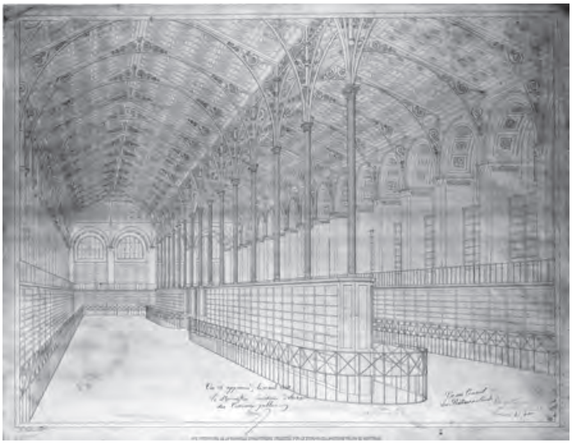
The ground floor does not show any sort of rustication but a sequence of undersized windows that appear to be perforated rather than articulated, while the upper level displays large arched windows, organized between pillars and bow arches.

Labrouste's understanding of façade ornamentation was more aligned with a rational interpretation of the building´s character, beyond classical motifs, which was popular in his time. The project explores character and ornamentation as an instrument to emphasize the building´s function, in this case, a library. The program is no small topic, it represented a treasured program to the society still under the illuminist influence.

Although the general proportions and contour of the repetitive, (monotonal?) façade may follow classical compositional canons, its rigidity lacks any sort of volume articulation nor classical elements like pediments, rustications, pilasters and architectural orders.

However, the façade has an interesting element in its composition, a sort of catalogue consisting in the inscription of 810 names of famous writers between each pilaster on the top floor. An interesting paper by M. Bressani and M Grignon[1] first compares the Bibliothèque to a mausoleum (due to its severe geometry) but furthermore as a metaphor to a book, aligned not

1 Martin Bressani and Marc Grignon, "Henri Labrouste and the lure of the real: Romanticism, rationalism and the Bibliothèque Sainte-Genevieve," Art History 28, no. 5 (2005), https://doi.org/10.1111/j.1467-8365.2005.00486.x



6-1 Sainte-Geneviève (H.Labrouste, 1851).
6-2 Interior view of the reading room. Note the roof structure coordinating the sloped chords and interior arches.
6-3 Facade as a communication and navigation device. Author´s names are carved on the exterior suggesting the position of their works on the interior.

only to the building's program but also to its own period, inherited from the Enlightenment. Reinforcing this particular view, the list of writers on the façade has a double function, both equally interesting. The first one being an ornamental device similar to a texture or rustication, and second, as a modern orientation mechanism, suggesting the position of such authors in the reading space, from the outside to the inside. On this regard, the paper clarifies:

"The Bibliothèque Sainte-Genevieve was thus, according to Levine, an occasion for Labrouste to develop a new kind of architectural expression, one entirely congruent with a society whose cultural expression was dominated by the printed word: the articulation and decoration of the library should then be comprised of signs that required a quasi-linguistic reading, as opposed to a more bodily engagement. Emblematic of this orientation was the list of names carved on the 'flat' facade which, according to Levine, could be quite literally assimilated to a catalogue: not only does this list allow users to 'read' the authors of the books preserved in the building, but it also signals the actual position of the books in the reading room"[2]

The correspondence between exterior and interior, often associated to modern architectural theories plays a decisive role on the library. On the Bibliothèque, the projection of the interior to the exterior does not occur via transparency but through a series of architectural operations. The structure of the interior space from the ground floor as on the reading space is translated and expressed on the façade, to the point that the structural fasteners form the roof tension rods are also manifested as ornamentation, complemented with organic and geometrical decorations.

Labrouste's rational approach both to design and ornamentation finds a perfect affiliation between the Bibliothèque program, its architectural expression and the use of new building technologies, like cast and wrought iron. The intention of the architect was to introduce iron to the architectural realm, by carefully designing each of the cast iron elements, not only functionally but also ornamentally.

In order to introduce the new material alongside traditional ones like stone, masonry and timber, Labrouste sought to find a unique expression, one that combined not only plastic features but also performative ones, particularly in terms of dimensions, slenderness and the representation of their structural purpose.

On this regard, the Bibliothèque faced an uncommon architectural problem for its time thanks to iron technologies: the structure could then be separated from the wall enclosure, thus forcing the designer to make a pronouncement in terms of how and to what extent the relationship between support and supported elements is shown. Moreover, in terms of the discussion regarding monumental architecture styles, this decision should as well define the relationship between the actual (iron) structure and its representation (in masonry). For this reason, Labrouste was careful concerning what to reveal and what to hide. The cast iron arches on the reading room supports a barrel

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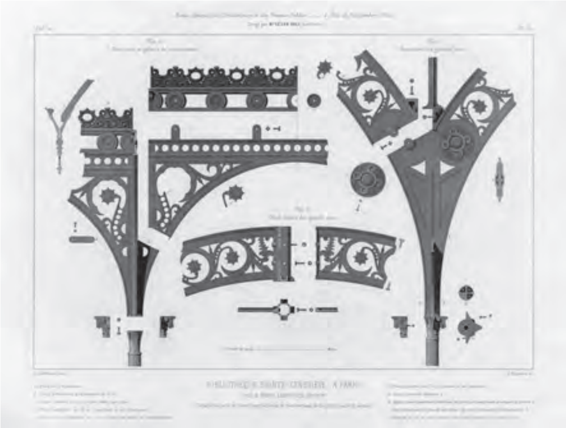
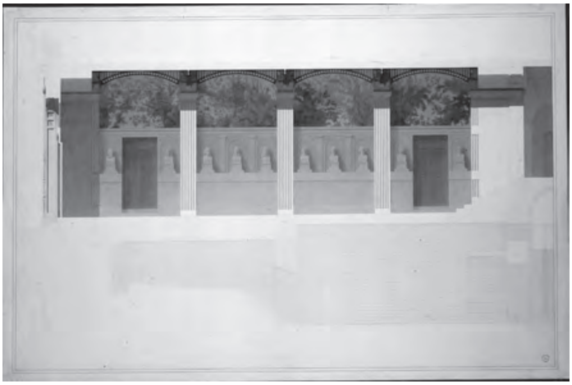
2 Bressani and Grignon, "Henri Labrouste and the lure of the real"





6-4 Detail of the reading room structure parts. It appears that ornamentation preceded the rationalization of the structural elements.
6-5 Weight and darkness in the entrance hall. When approaching the staircase, the foyer compresses in height and depth. Ascending to the reading room represented the quest for illumination and knowledge. .

vault, but above it, the is still a larger and more complex iron structure that remains hidden to the user.

The upper floor is entirely dedicated to a reading room, divided by a series of slender iron columns supporting the arches. It is also worth mentioning that by the time the Bibliothèque Sainte Genevieve was conceived, the spans that needed to be saved were short enough to be covered by a single structural truss. Thus, Labrouste deliberately wanted to have an architectural intention regarding the iron structure. Firstly, to divide the space by interposing 16 cast iron columns in order to divide the space (a spatial choice rather than a structural one) and secondly, to consciously decide which parts of this structure were to be perceived by the visitors. This shows a preeminence of the architectural parti, above technical or functional resolutions, but without conflicting with them.

Bressani and Grignon also accounted for rejected drawings showing Labrouste's decision in favor of cannon-vaulted soffits, combined with a plaster ceiling instead of showing the sloping flat planes that were typical of wrought iron structures like sheds or railway stations.

Besides the central spine of supports, a perimeter of perpendicular piers hides the iron structure and organize the space both on the reading room as well as the ground floor spaces. The length and organization of these piers allows them to act as buttresses against lateral push, but turned to the inside of the building, while keeping the façade clear.

The structure reaches its climax on the reading room, where the combination of cast vaulted plaster ceiling, decorated arches, slender cast iron columns and stone pedestals organize the space. Once again, Labrouste's decision to show the inner iron structure as a way to reveal the constructive section of the building was by itself, an educational gesture.

It is on these types of gestures that descriptions of Labrouste's work in terms of functionalism or rationalism fall short; the preeminence of architectural intentions in terms of façade, program, expression and the definition of interior space are some of the arguments supporting this point of view.

Labrouste departed from the Classical architecture cannon that proposed the idea of an independent façade in terms of a design strategy, supporting immanent characteristics such as symmetry, proportion and harmony. Instead, the façade of the library intended to express the interior function and the definition of its spaces, while reacting to the structure, function and overall organization. The façade worked as a screen, intimately related to the building's structure allowing the user to 'read' its arrangement both internal and external, even displaying ornamented elements of the structure.

The Bibliothèque Sainte-Genevieve was a key step in the process of the complete separation of the façade and structure. While expressing each architectural element according to its constructive function and material, Labrouste endowed each of them with ornamental qualities in order to ease their exhibition to the user. Once again, the reasons for the decision of what to show and what to conceal was manifold; spatial definition, structural clarity and ornamentation quality were determinant. Moreover, the significance of such gestures is amplified by the fact that they are applied to an interior of a public architectural space, but unlike a train station or a factory, this one is tied to a relevant cultural program such as a library. Labrouste embedded the Library with the Illuminist quest for knowledge, light and truth. Its pedagogical gestures reinforce this essence.

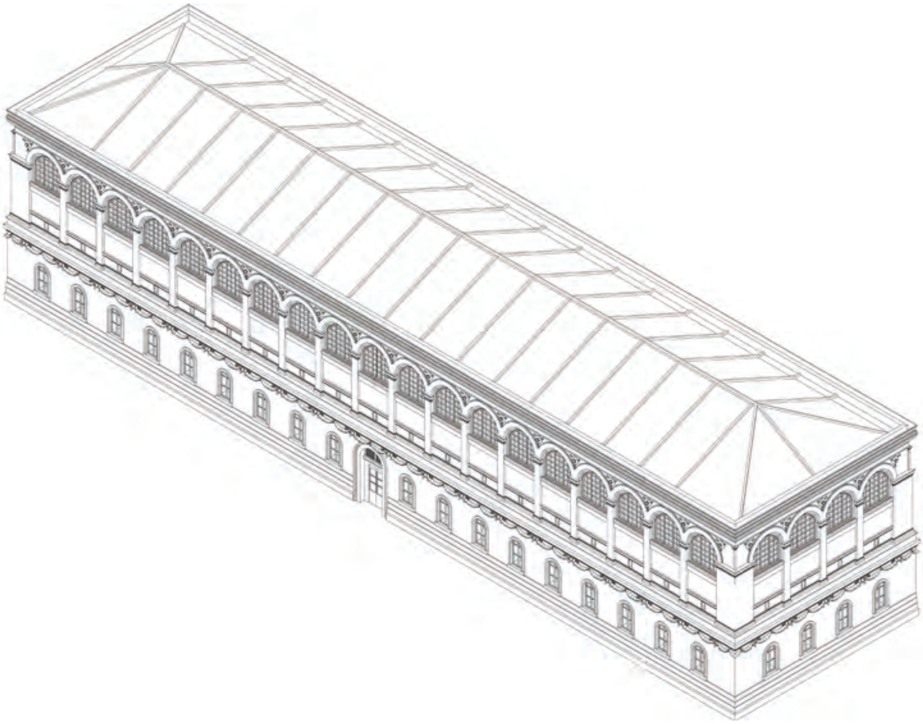
The significance of the Bibliothèque Sainte Genevieve well exceeds Labrouste himself, but it also manifested a moment of experimentation in the search of a new language still performing in terms of a classical canon and irruption that the use of iron implied. Later on his career, such explorations regarding iron structure touched another milestone in the Bibliothèque Nationale, where the openwork cast iron arches mutated into wrought iron and diagonal struts, minimizing ornamentation and exposing rivets and joints. This turn towards "constructive honesty" in favor of technical expression, but away from geometrical or natural ornamentation was also a part of the debate amongst builders in 19th century.

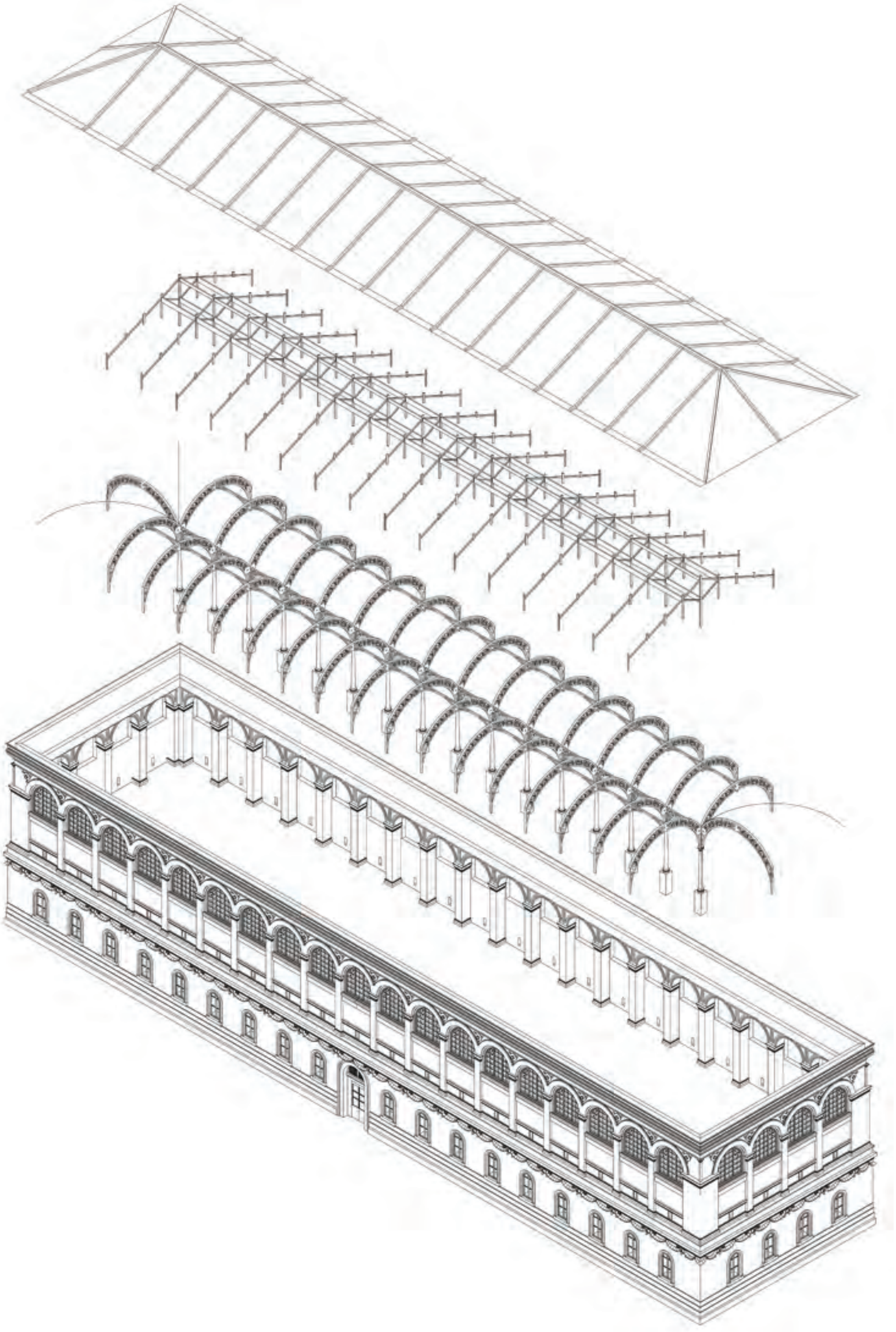
The balance between traditional 'classical', massive elements and the lightweight iron structure was also noteworthy; the cast iron pieces do not seem to put stress on the walls but appears to be self-balanced. This contrast between light and heavy, old and new, was also manifested in the level of decoration, but inverted in its values; cast iron components were more profusely decorated than the severe, rational, masonry. The passage from the decorated cast iron arches of Sainte Genevieve to the riveted wrought iron of the Bibliothèque Nationale relate to an exploration of tectonics in expressive terms, by which ornamentation and construction techniques are interdependent.

As previously stated, hybridity is also a key concept in order to recognize the value of Labrouste's work. The apparent contradiction between classical and rational, stone and iron, severity and exuberance, mass and weightlessness should not be perceived as divergences but as contrasting components in an integrated, unified project.

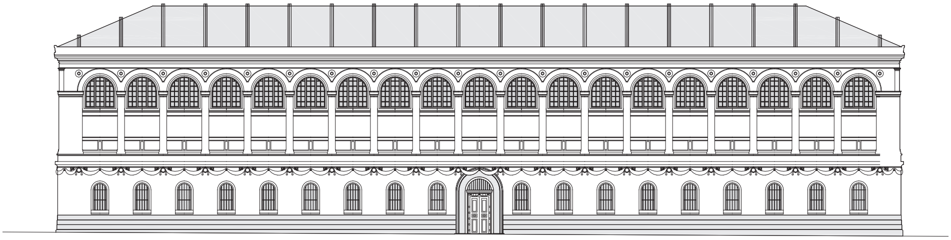
Sainte-Genevieve represents a midpoint between classical tradition and proto-modernism, it depicts 19th century's search for innovative solutions to new programs, while approaching new materials and conceiving new design strategies. Cast iron is here applied both structurally and ornamentally, pieces are displayed and hidden, the façade performs a screen but also a communication device. The library works as a complex construct; a rational resolution of an architectural programme, an elaborated use of architectural elements, challenging classical interpretations yet not defying them openly.

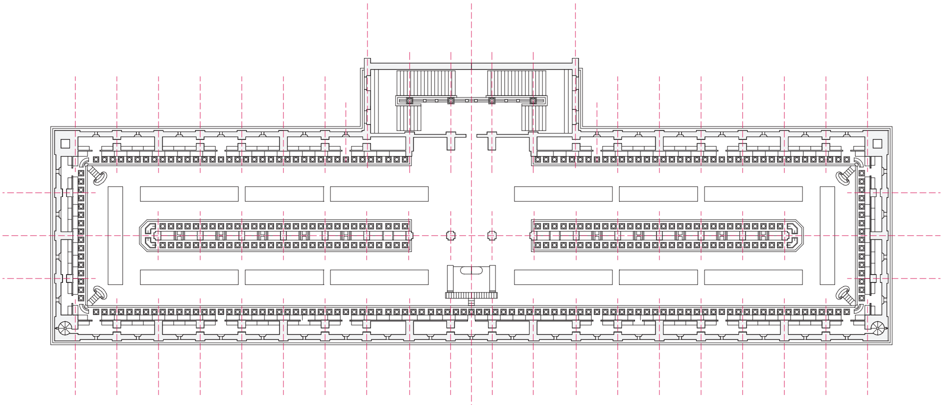
6-6 Axonometric view

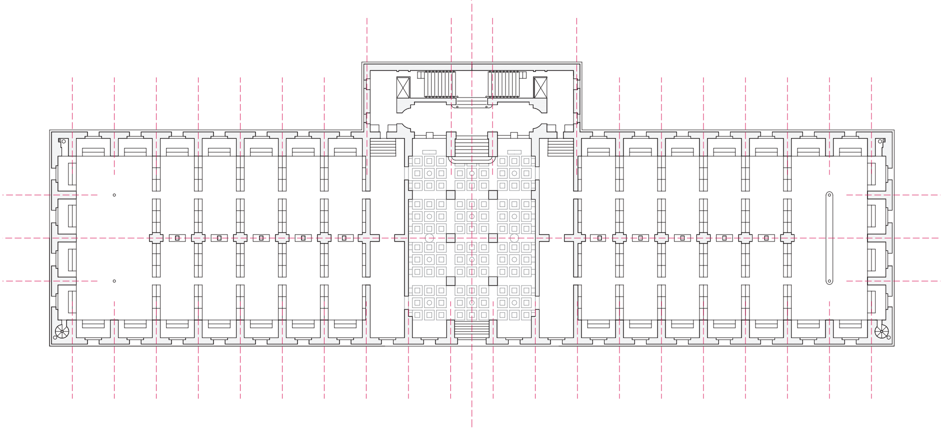




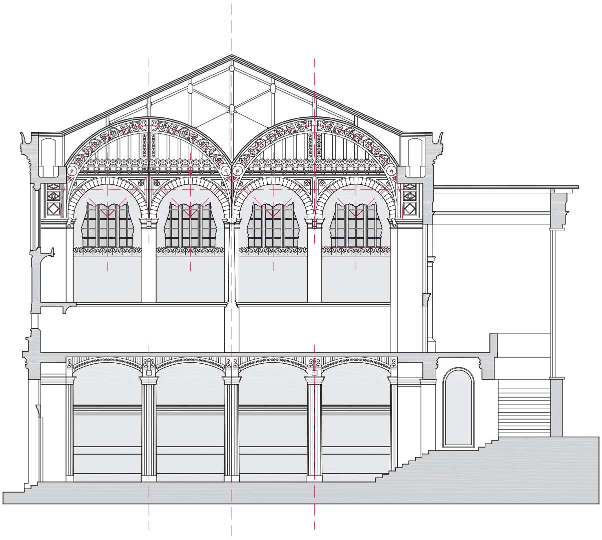
6-7 Exploded isometric view. Roof, structure, cast iron structure and reading room.

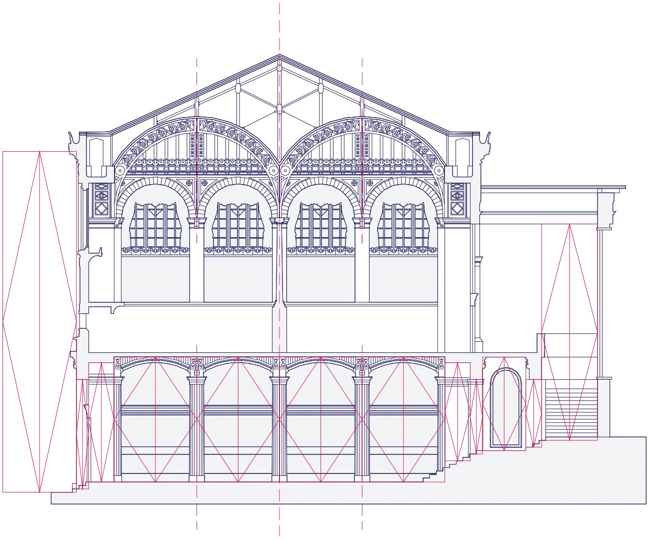




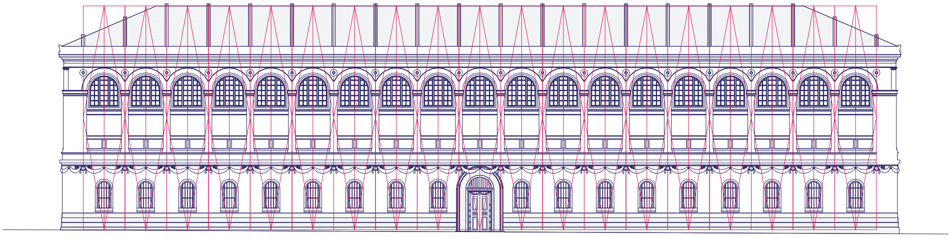


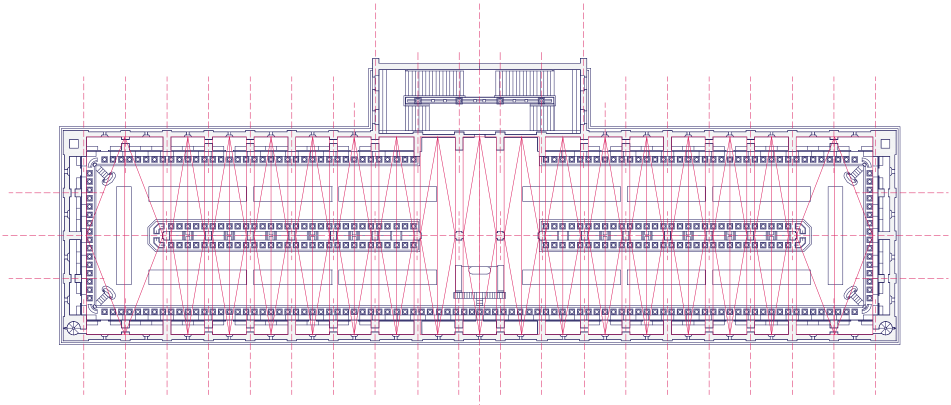
6-8 Front View (according to publication from Labrouste: ´Plans et dessins relatifs à la construction et au décor de la bibliothèque Sainte-Geneviève´)
6-9 Reading room floor plan (according to publication from Handbuch der Architektur)
6-10 Ground floor plan (according to publication from Handbuch der Architektur)

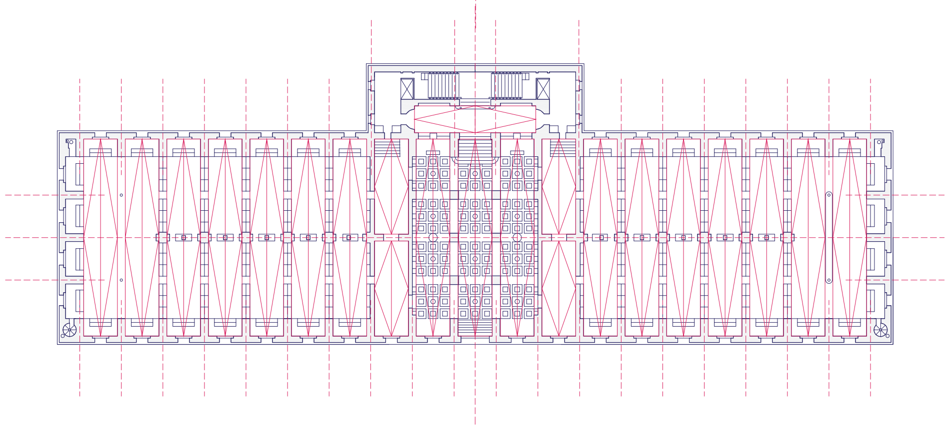




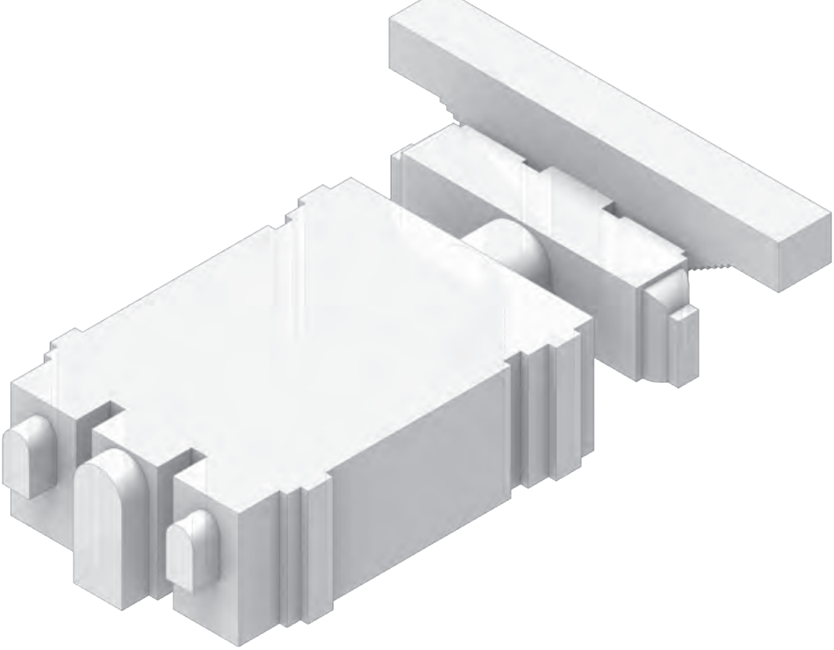
6-11 Section trought access hall, foyer, staircase and reading room (reconsturcted from various sources).
6-12 Spatial variation going trough the building. Compression in access and staircase foyer and spatial expansion in stairs is reinforced via natural lighting.

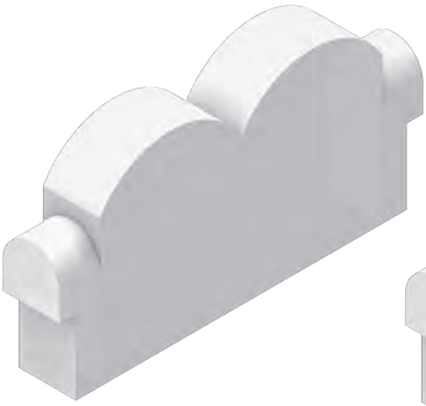




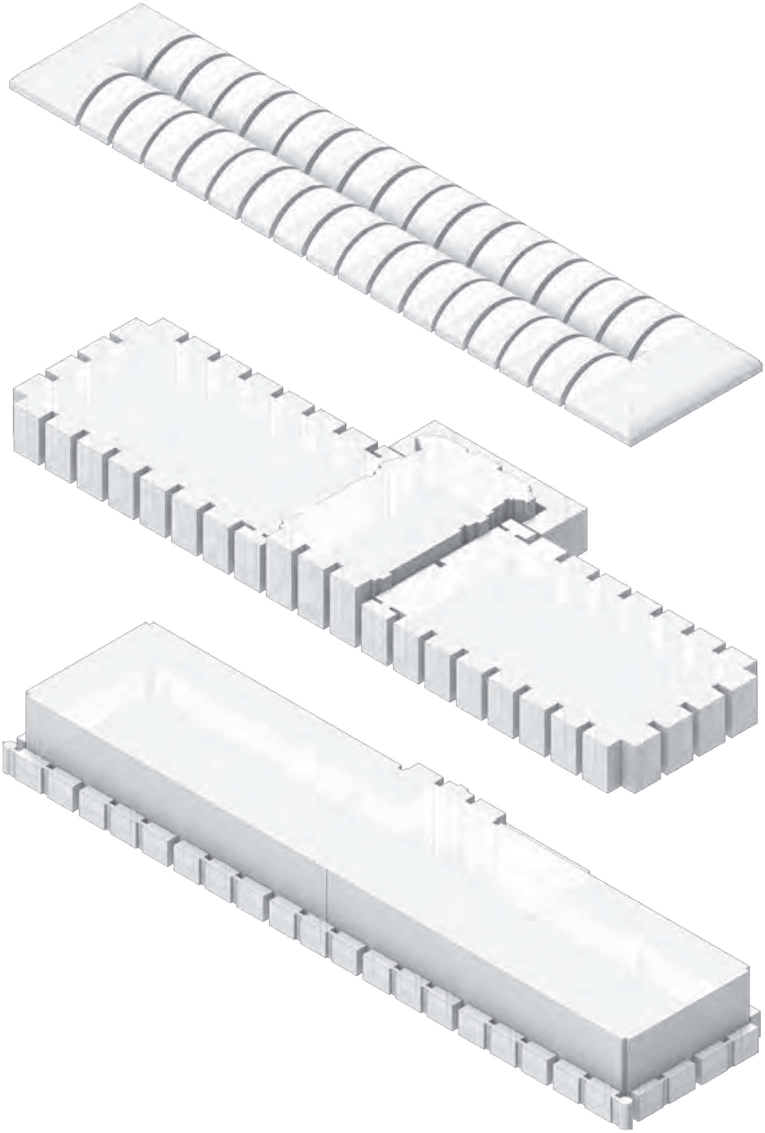


6-13 Front view. Façade modulation. Diagram operates on the regular modulation of structural (filled) segments and open segments. As the pilasters protrude, window modules appear subtly recessed. A regular rhythm prevails in the organization (A-A-A)
6-14 Reading room floor plan spatial flow. The original arrangement of desks intended to break the structure´s direction, creating larger, luminous spaces flowing longitudinally.
6-15 Ground floor structural organization and spatial flow. According to the original drawings, the archives were organized differently, segmenting the space in two aisles, which in turn were interrupted by the shelving.

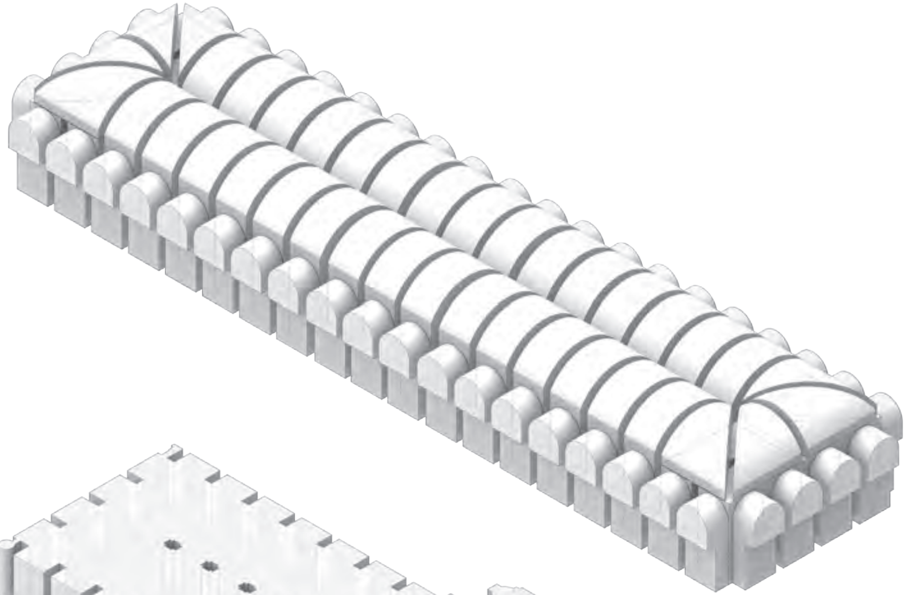


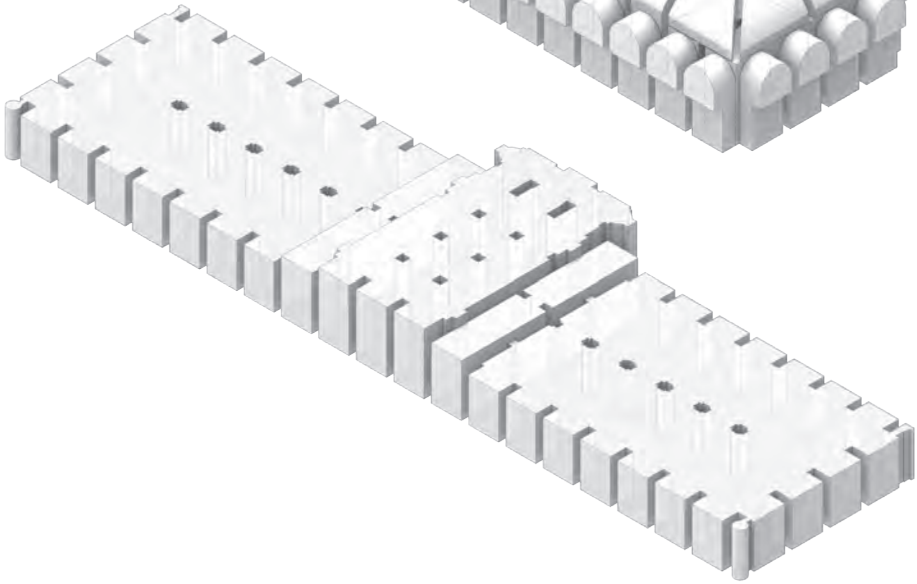


6-16 Public access volume void. Progression of expansive and compressive spaces until the staircase is reached. After the large entrance hall the space compresses while puncturing the building´s structural back wall. It expands again longitudinally on the dim foyer and re-expands again on the luminous staircase volume.
6-17 Reading room volume void. Spatial syntax is defined by vaulted ceilings sectioned by structural arches and expanding through windowing systems.
6-18 Reading room closing module volume void. Vaulted ceilings and large windowing systems above eye level define the spatial atmosphere.

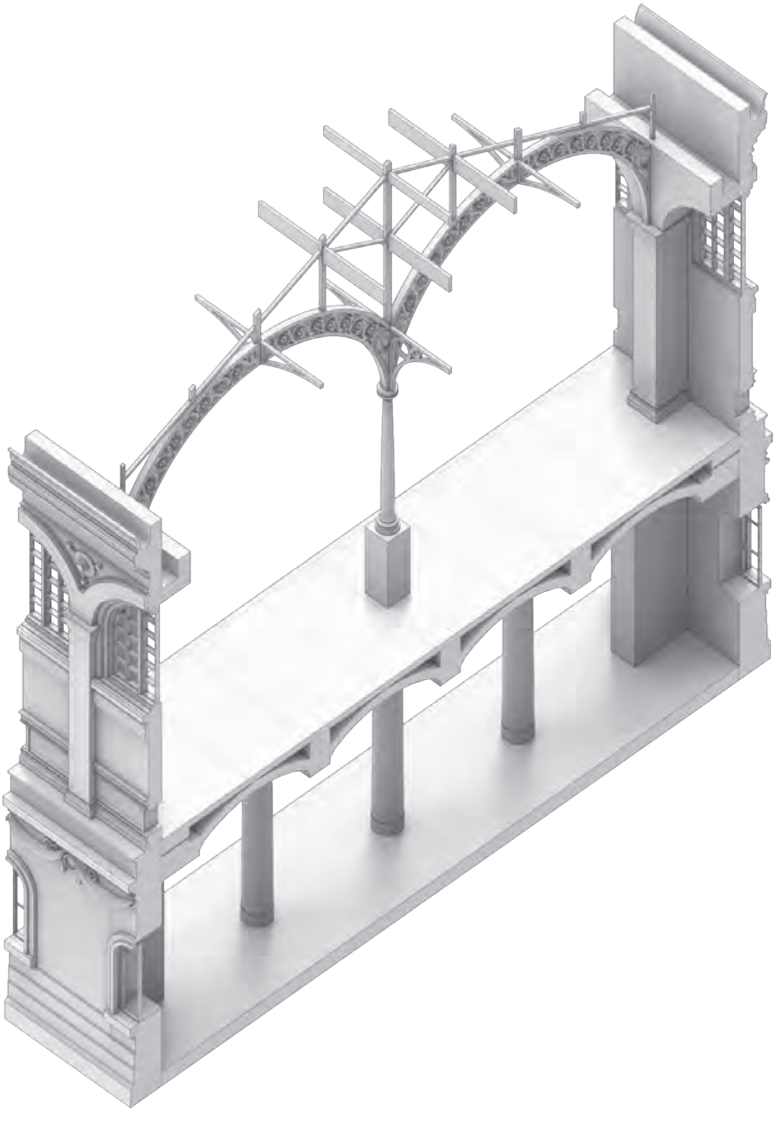


6-19 From top to bottom:Vaulting volume void of the reading room.
6-20 Reading room volume void. Differentiation between reading space and user-level shelving.
6-21 Ground floor volume void. Volumetric contrast between public hall and archival deposit.

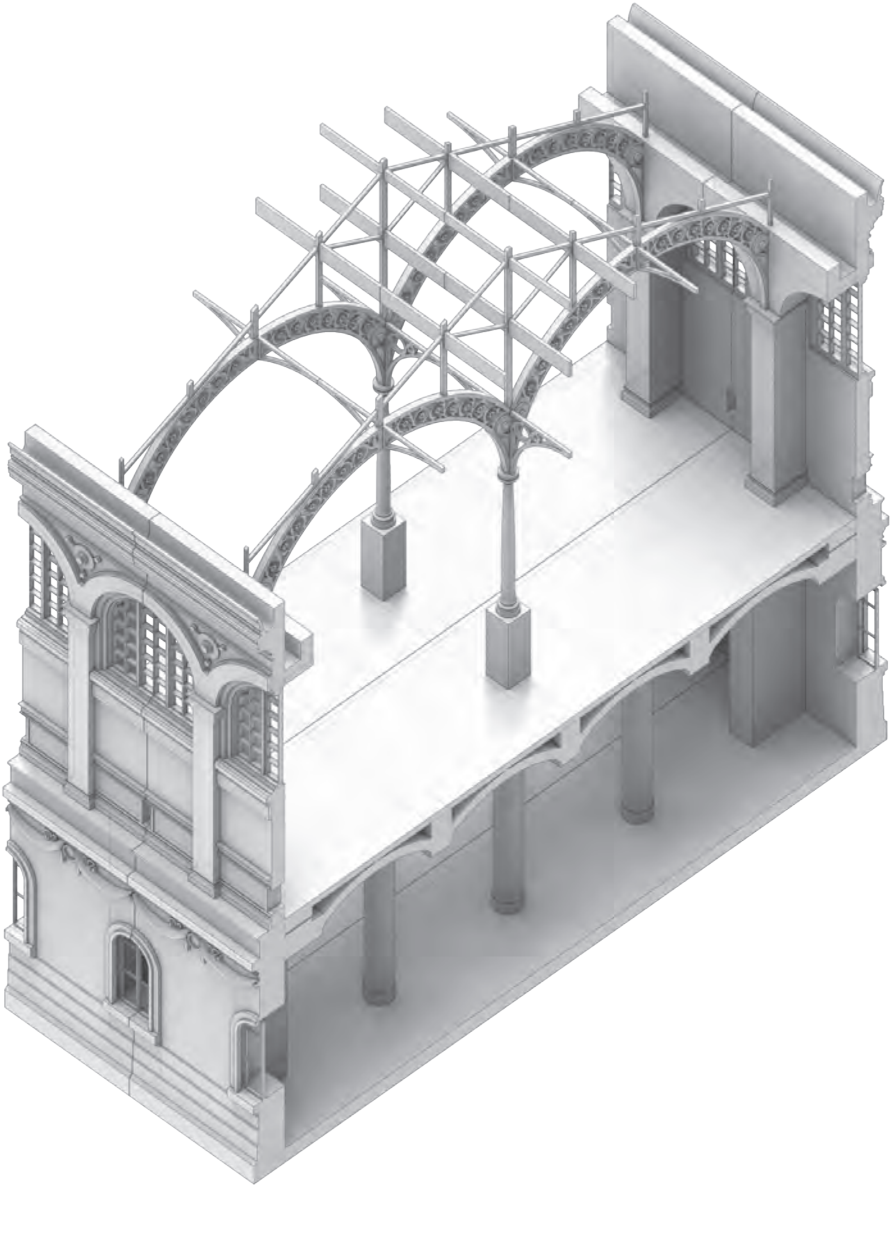




6-22 Reading room volume void. Spatial syntax is defined by vaulted ceilings sectioned by structural arches and expanding through windowing systems.
6-23 Ground floor volume void. Volumetric contrast between public hall, administrative offices and archival deposit.



6-24 Structural module section. Outer structure composed of load bearing walls while the reading room floor is composed by slender cast iron columns supporting decorated arches. The arches are manifested on the facade in the form of an ornamented tensor between the windows.



6-25 Reading room volume void. Spatial syntax is defined by vaulted ceilings sectioned by structural arches and expanding through windowing systems.
Bottom: Ground floor volume void. Volumetric contrast between public hall, administrative offices and archival deposit.

CHAPTER 07

- *Berliner Börse*

The architectural debate of 19th century was fueled by several factors; for this thesis, one of the most relevant ones was the inclusion of technologies and its progressive impact on the design domain. By the 1860's Berlin was a key epicenter of this debate along London, Paris and Vienna, through its architect's associations and publications[1]

Set to maintain the legacy of Karl Friedrich Schinkel, a generation of architects (among them, Friedrich Hitzig, R Lucae and M Gropius) participated actively on these debates. The nature and the character of the relationship between architects and engineers was a key issue as the engineer's role was already more relevant than 'technical help' or 'foreign assistance' for designers. Friedrich Hitzig, a former student of Schinkel, took active part on this debate, and the Berlin Stock Exchange is a clear embodiment of these concerns.

Located in front of the Spree over the Burgstrasse, the Berlin stock exchange was contained in the consolidated urban tissue. The building was projected on an irregular plot with two consolidated facades, yet it still managed to generate apparent mirror symmetries on its two main axes, thanks to a series of geometrical adjustments, like side galleries and segmented spaces.

The Berlin stock exchange displayed two main facades, the main one facing the Spree, the secondary, aligned with the new Friedrichs-Strasse. The parti intended to create a double screen to the pedestrians coming from the Friedrichs bridge and the Berlin Cathedral towards the Burgstrasse.

Designed in a Neo-Renaissance style, Hitzig´s stock exchange was divided in two major parts: a socle basement and a main floor. The socle consisted in a central body with Doric columns covering the receding entrance and rusticated masonry on the corners. The top segment consisted in two stories, supported by Corinthian columns; the center segment (two fourths of the facade) was again receded creating a small terrace while the laterals with double columns were aligned with the socle walls.

The decoration of the façade was very limited; besides the rustication on the ground floor, a sober entablature with balustrades articulated the two stories. The upper part was crowned with a classical top entablature, dentils, modillions and a cornice. A series of blank bases located on top of the building aligned with the position of each column and large sculptures were located over them, highlighting the double columns from the side bodies. The center of the façade was emphasized by a larger sculpture set, present as well in the building corners.

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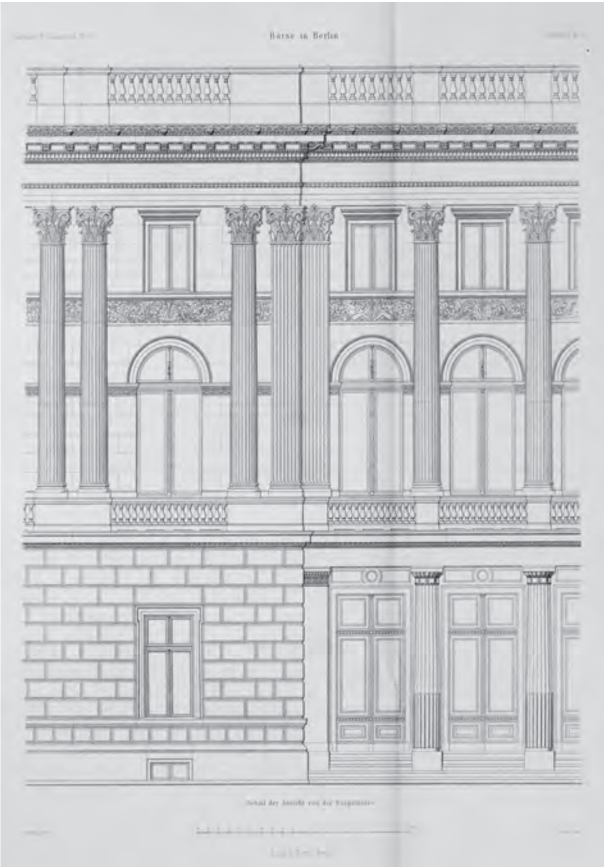
1 Marco Pogacnik names 'Deutsche Bauzeitung' and 'Zeitschfrift fur Bauwesen' among the most preeminent ones, on Marco Pogacnik, "Technology as a means of expression in the nineteenth century: Architects and engineers in dialogue," in Cooperation: The engineer and the architect, ed. Aita Flury (Basel: Birkhäuser, 2012)



7-1 Perspective view of the Berliner Börse (F. Hitzig, 1859) from the Spree river.
7-2 Monumetality and order. Facade detail drawing of the Stock exchange facing the river.

As mentioned before, an interesting feature of the Berliner Börse was its bi-axial composition; despite its location on an irregular plot, both facades were arranged according to a specular symmetry and a series of design devices, such as adjustment surfaces and blank volumes juxtaposing to its neighboring buildings. These buffer spaces allowed the central one to remain characterized and pure.

The building's ground floor was also organized around two main axes, the main one cutting through the trading floor, materialized as a colonnade that evenly divided the large space. The secondary axis was more subtle, as it was only visible on the Friedrich-Strasse façade, cutting through the trading hall longitudinally.

The main access to the building occurred through the Burg-Strasse, crossing through three series of columns, a sort of 'Propylaea' before entering the main trading floor, separated in two large spaces: the Funds Exchange and the Products Exchange. Both spaces were divided by a two-storey colonnade, a sort of arched loggia that virtually divided a large space. This arched colonnade covered both trading floors, integrating the screen to each of the spaces and adding thickness to the partition element. This transparent wall was the materialization of the main symmetry axis.

The partition did not reach the decorated ceiling, allowing the user to sense its continuity, reinforcing the idea of a large, partitioned hall. A series of arched windows between each truss support added another layer on this effect, giving the idea of the ceiling separating from the walls, as an independent entity.

The low vaulted ceiling was certainly the most interesting element of the interior space. Spanning roughly 25 meters, the riveted, wrought iron arches were hidden from the user. Each truss was composed by upper and lower chords, divided in fourteen segments, and its vertical elements were projected one meter under the lower chord, most likely to support the ornamental pieces emphasizing the position of each truss on the ceiling. Pogacnik claims that these lower ornamental pieces also play a structural role, stiffening the vertical elements with the lower cord, which is set too high for a traditional truss.

A detailed drawing of this solution was published in the Atlas fur Zeitschift für Bauwesen in 1865[2]. The particularity is that the drawing is divided in two, the left side showing the truss and its elements (the engineered solution) while the right one depicts the ornamental plaques (the architectural effect).

Pogacnik argues that a distinctive design strategy can be defined from the particularities of this detail:

"The detail drawings allow us to reconstruct accurately the architect's method of working: first he defined the spatial effect, a function that is performed here by the beautiful decorative ribs and the coffered ceiling elements lying between the trusses. After that, he resolved the question of how the ceiling as a whole should be supported. This step is documented in the left half of the drawing of the crescent truss"[3]

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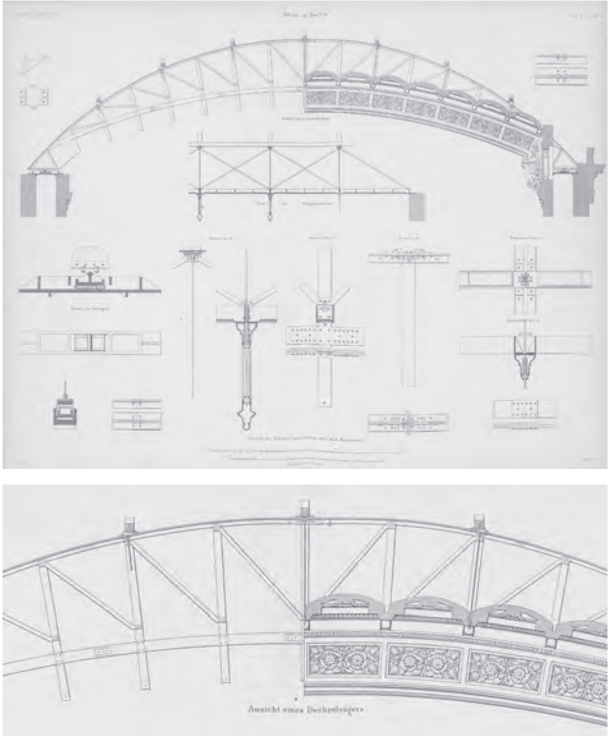
2 G. Erbkam, "Zeitschrift für Bauwesen. Edition XV. 1865, Atlas," 1865, https://digital.zlb.de/viewer/image/15239363_1865_07/1/LOG_0003/

3 Pogacnik, "Technology as a means of expression in the nineteenth century"



7-3 Ceramics and iron. Detail drawing of the truss structure and its ornamental cover.
7-4 Material axis. Trading floor of the Börse. The traversing loggia virtually slices the space into two exchange areas.

The author also relates Hitzig's building to Semper's 'hollow body' principle[4], by which the architect can achieve high load-bearing capacity in hollow elements, by means of corrugation, for example, by folding a metal sheet. Cast iron elements such as hollow columns or girders also follow this principle. What is relevant in the case of the Berlin Stock Exchange trusses is that the vertical elements projecting the lower chords appear to fall on this category; support and supported elements are no longer independent but act collectively. The linear ornaments under the trusses were not just decorative to the structure but also performed as structure itself.

Hitzig's procedure for the interior of the Börse was indicative of 19th century practitioners; the disconnection between an ornamented expression and a technical solution did not only account for the respective roles of architect and engineer, but also as a conscious design strategy, one that was impossible to achieve before iron. In this case, iron had a key role in the design and construction process but also the concept of prefabrication; the whole ceiling was designed relying on the capacity of producing identical pieces to be mounted covering a regular structure.

The iron trusses were therefore completely hidden from the inside thanks to large prefabricated tiles and on the outside under a sloped roof. The trusses rested on two mobile supports, most likely to absorb the strong lateral thrust due to its low vaulted geometry. For the same reason, these free-rotating were sustained on a double-wall, an elegant design solution since the possibility of a two-meter thick wall was restrained. This double-wall was materialized as the continuous two-storey loggia surrounding the trade floor. Once again, the articulation of architectural statement, expressive significance and technical solutions is a key feature of the period's architecture.

Like many buildings from the period, the Berlin Stock Exchange interior was almost entirely covered with plaster and ceramic ornamentation. The publication from 1865 shows prefabricated pieces not only in the façade like balustrades, columns, friezes, cornices, dentil ornaments, modillions and festoons, among others. The interior was ornamented as well; marble pilasters aligned with the round ones adding a depth effect on the upper level loggia, where marble plaques decorated the blind arches. It is worth to mention that even though the structure was based on masonry and wrought iron, every element and surface of the building was ornamented. From the aforementioned trusses to the window frames, there was no apparent conflict between technical rationality (or 'material honesty', in the period's terms) and decoration.

Regarding the composition strategy, the reconciliation of large and small spaces is also noteworthy in terms of an updated classical design methodology. The arrangement of three large spaces, two covered (the divided trading floor) and an open one (the Summer Exchange) around two orthogonal axes is not only traceable to the façades (where the symmetry is truly perceived) but also on the interior, thanks to design devices such as the colonnades, loggias and

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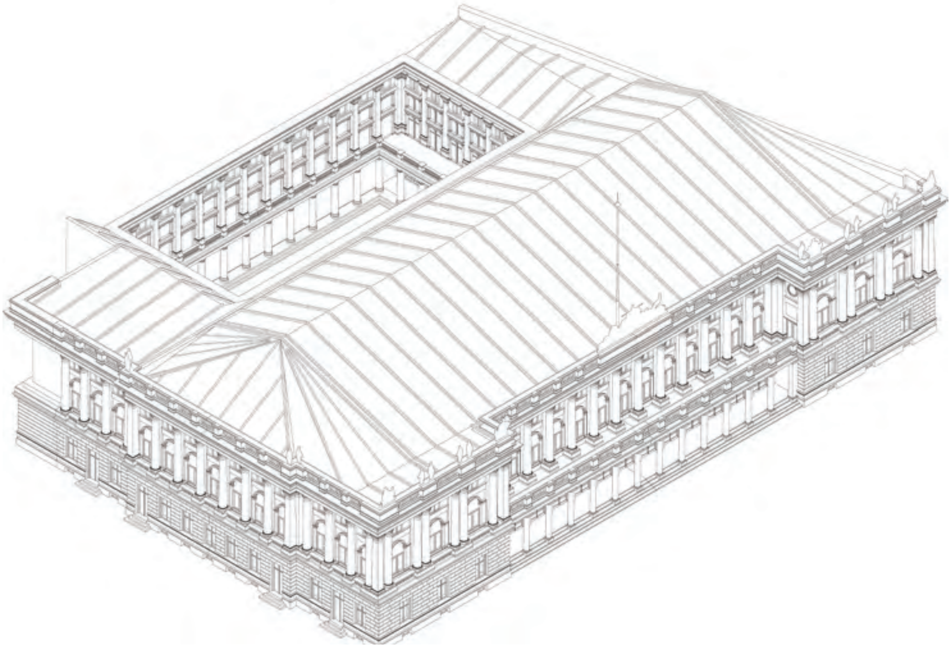
4 Discussed in Gottfried Semper, ´Style: Style in the technical and tectonic arts, or, practical aesthetics´

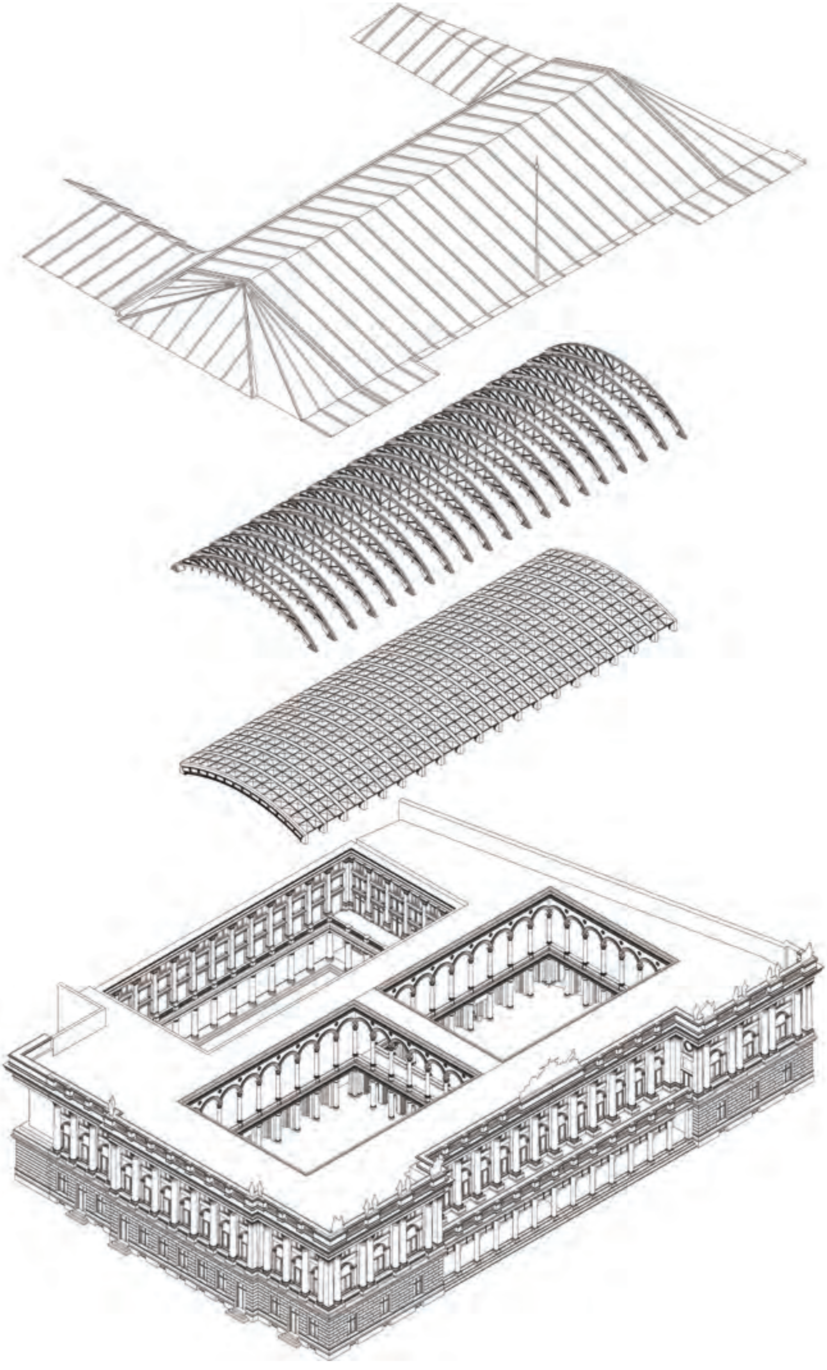
partitions reinforcing them.

These three main spaces were hierarchically emphasized; the articulation between them and their surrounding spaces was always articulated by a transition, a spatial buffer easing the passage between the access hall and the main space, or other smaller spaces and offices. These transitional spaces were not only of an architectural nature, as mentioned above, the longitudinal walls were thickened -by combining a round column, a rectangular pillar and a wall articulation- to additionally perform a structural function.

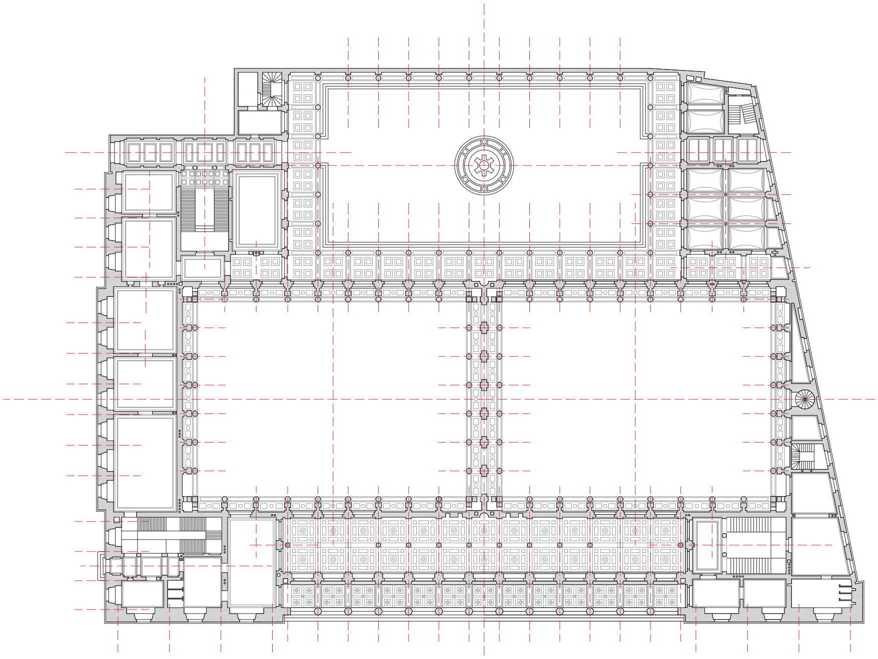
These intermediary spaces performed as an articulation internally (between large and small programs) but also externally, as a formal mediator with the building's limits. It is also interesting that these spaces, while irregular in shape, tend to perform secondary or support programs, such as staircases, toilettes, wardrobes and closets. These particularities tend to resemble poche-like spaces, but unlike them, they are not contained on the mural space, but rather progressively decompose the wall thickness by articulating architectural elements. Once again, space, ornament and structure are entwined in a complex, architectural gesture.

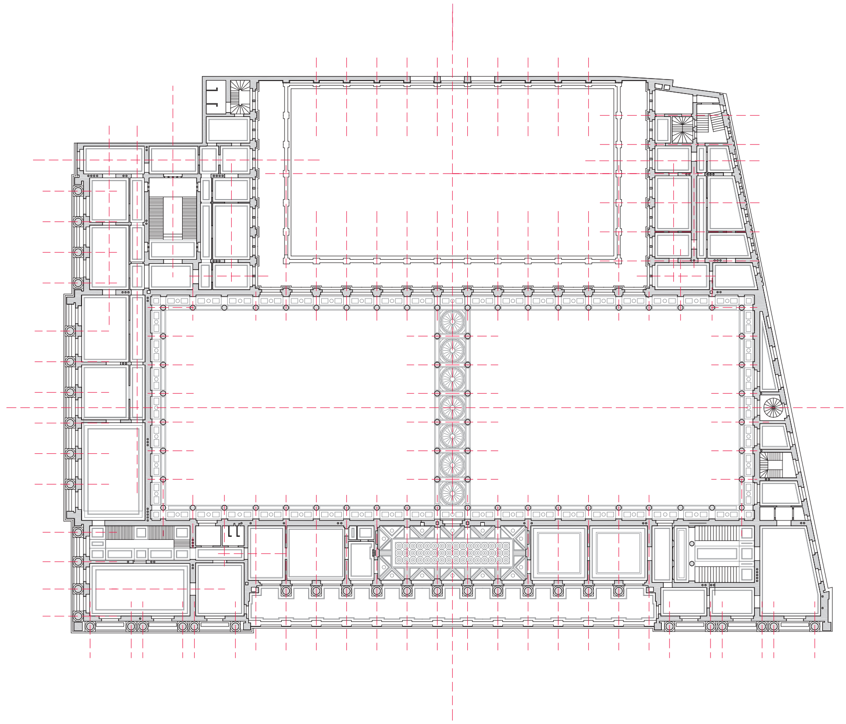


7-6 Axonometric view.

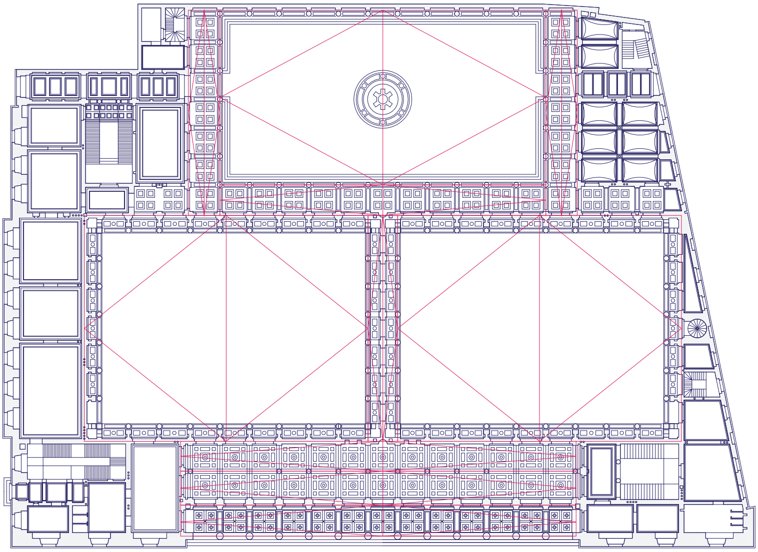


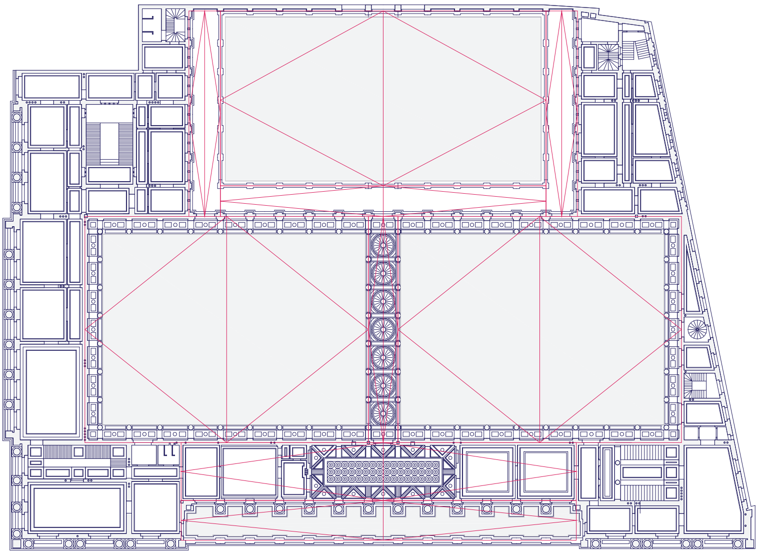
7-7 Exploded isometric view. Roof, truss structure, ceramic covering and trading spaces.



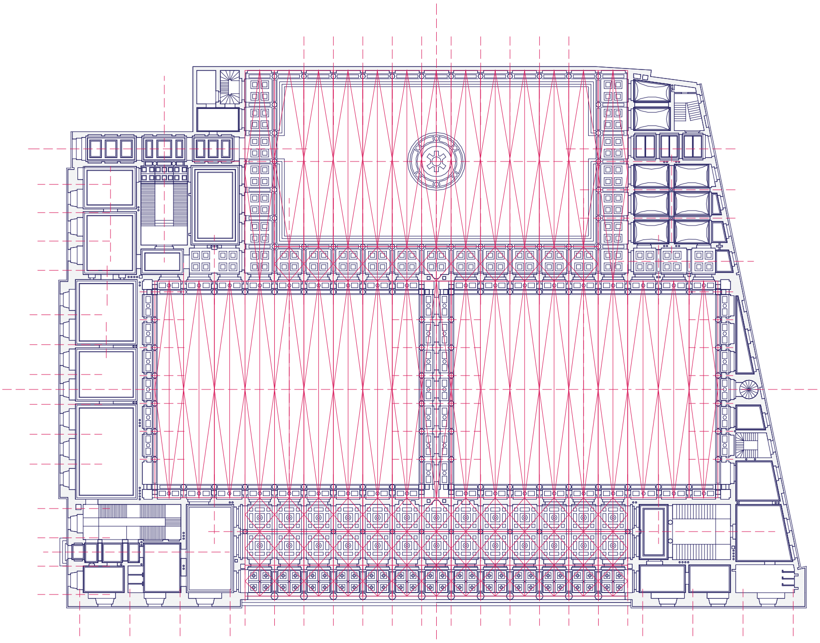


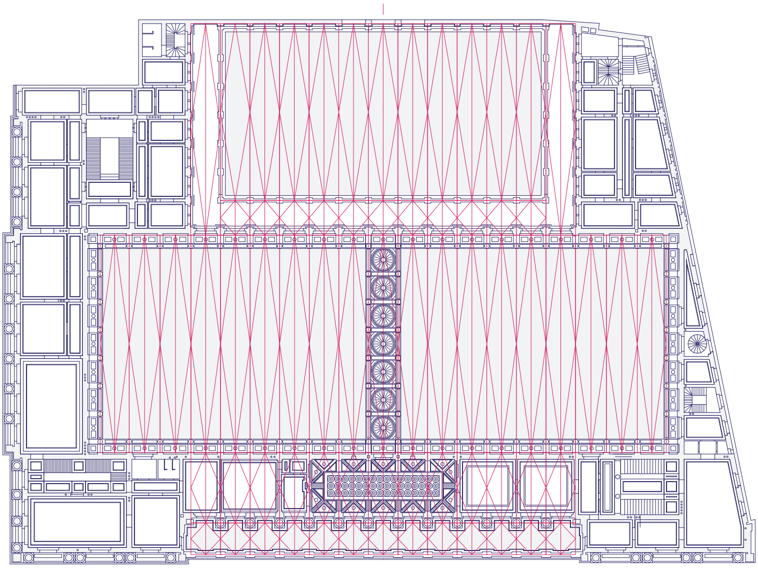
7-8 Berlin Stock Market (Friedrich Hitzig) Ground floor plan (according to publication from Zeitschrift für Bauwesen, 1865)
7-9 First floor plan (according to publication from Zeitschrift für Bauwesen, 1865)



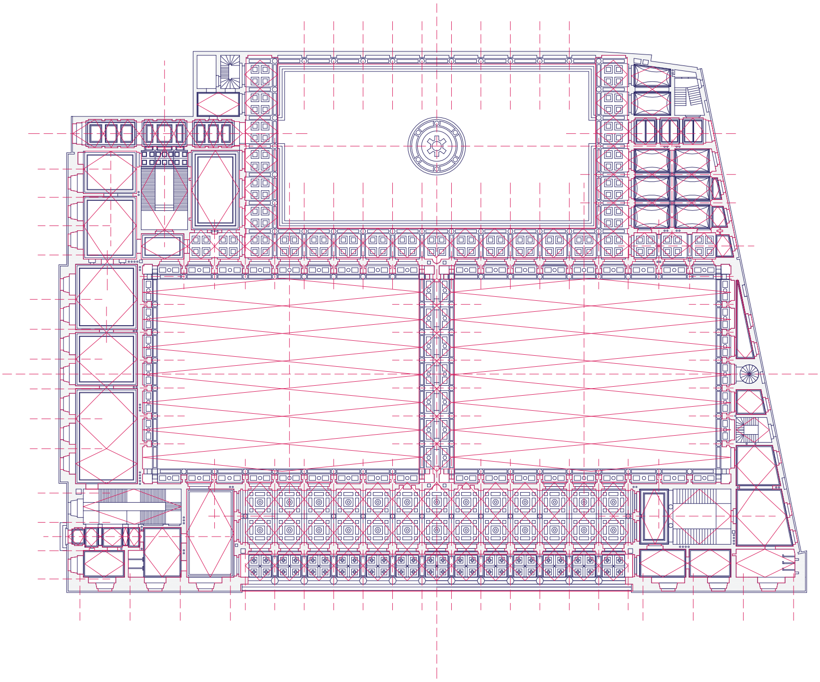


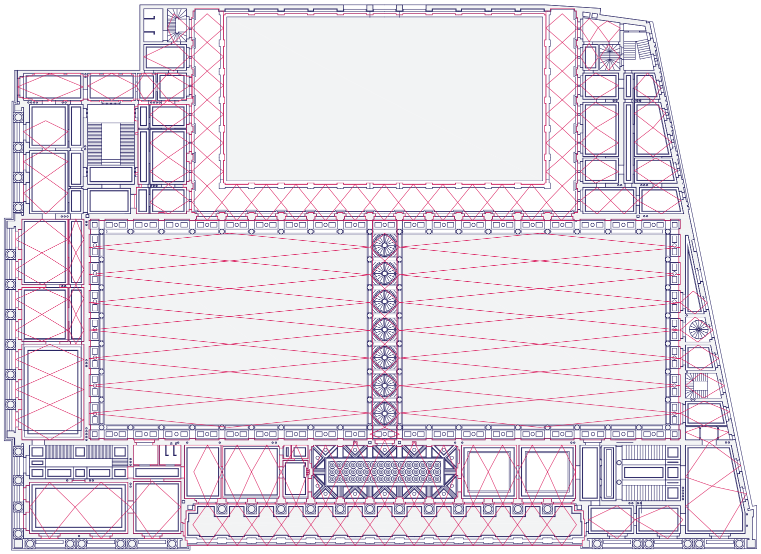
7-10 Diagram for large public spaces and their mutual spatial adjacencies. Spatial progression illustrates a succession of compressed halls, then an expansion on the main trade floor, followed by another compression, concluding in the inner court. Spatial progression can be also understood as a passage from open spaces to semi-covered ones, towards large covered spaces and back again to semi-covered and open spaces on the back.
7-11 Spatial progression illustrates a sequence of compressed semi-covered spaces and larger halls and courts. Similarly to the ground floor, the diagram illustrates the symmetrical relationships between the Börse´s main spaces and the ´adjustment´ spaces interposed between them and the building´s borders.



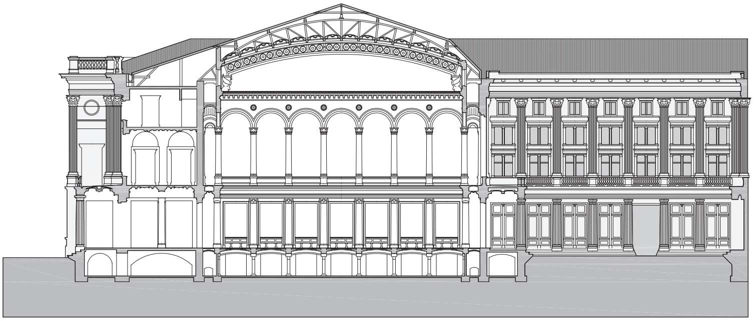


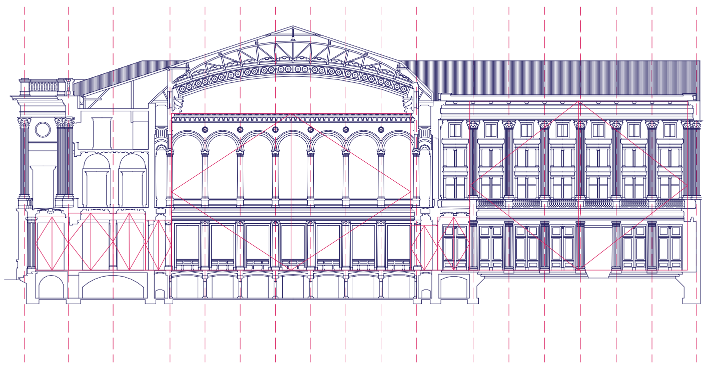
7-12 Diagram displays the basic structural rationality beneath the Börse´s apparent complexities, symmetries and asymmetries. On semi-public and semi-covered spaces such as halls and verandas the structure module is almost square. This rational modulation is then blurred on less significant spaces such as offices and services, treated as buffer spaces between main spaces and the building´s limits. These adjustment spaces, though harder to ´rationalize´ structurally, remain organized under classical cannons of proportion, symmetry and spatial progression.
7-13 The structure of the hall on the first floor is doubled in relation to the same space on ground floor; the entrance hall is present in the form of a terrace, while the rest of the structure remains identical.

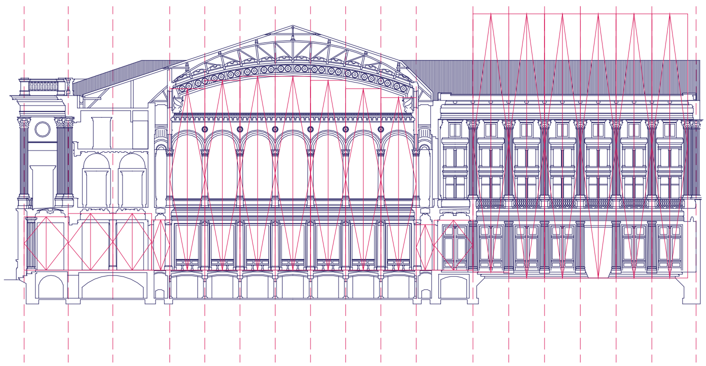




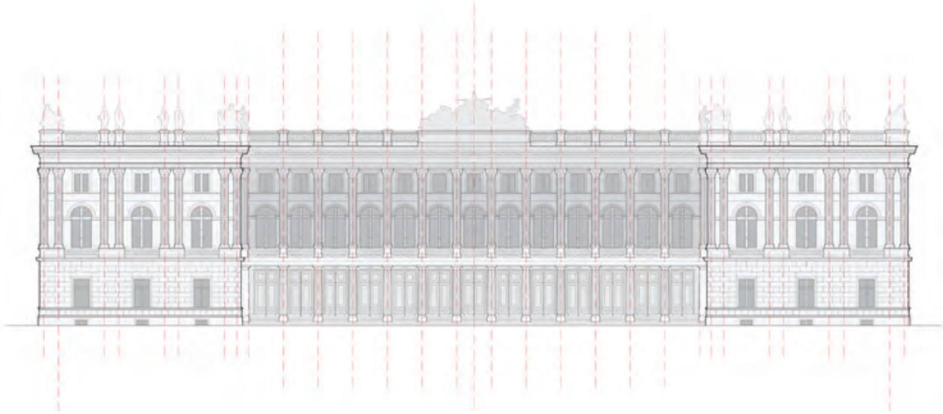
7-14 The diagram illustrates the structural flow of the ground floor, the direction of structural beams and archers and their particularities and adjustment between the main spaces and the building´s limits. The inner spatial distribution no longer adjusts itself to the structural grid; some columns are hidden behind walls, some are removed.
7-15 The diagram illustrates the structural flow of the first floor. Spatial segmentation diverges from the ground floor particularly on the adjustment spaces in relation to the building´s limits.

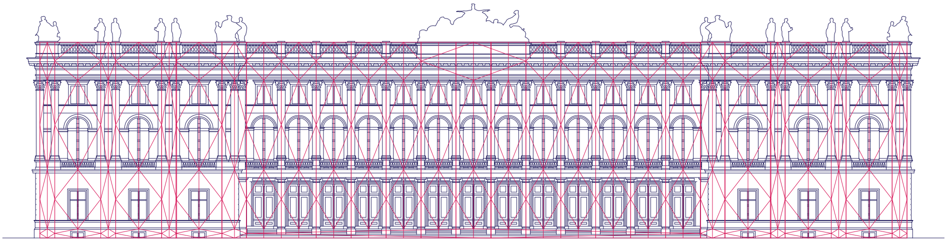




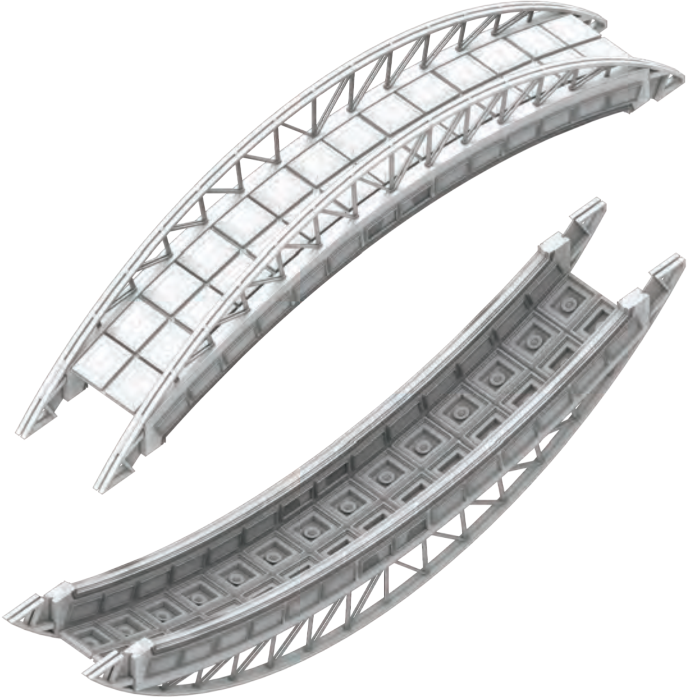


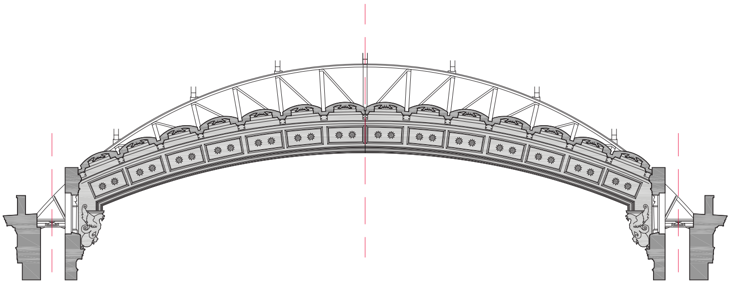
7-16 Section (according to publication from Zeitschrift für Bauwesen, 1865)
7-17 Diagram illustrates the structural progression ranging from the building´s entrance to the inner court. The sequence also compresses and expands spaces alternatively; open space, then compressed foyer, then open space again and so on.
7-18 Diagram illustrates the structural progression ranging from the building´s entrance to the inner court. Structural rhythm remains fairly regular when circulating on the main central axis, accentuating the rational grid from which the building was organized.

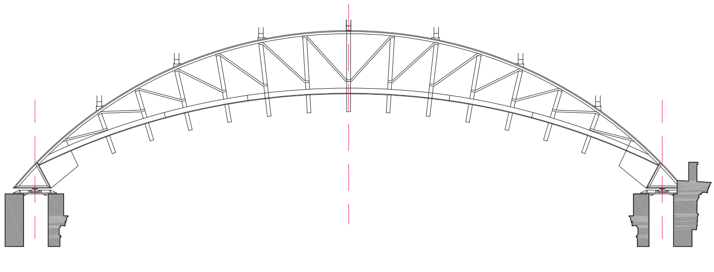




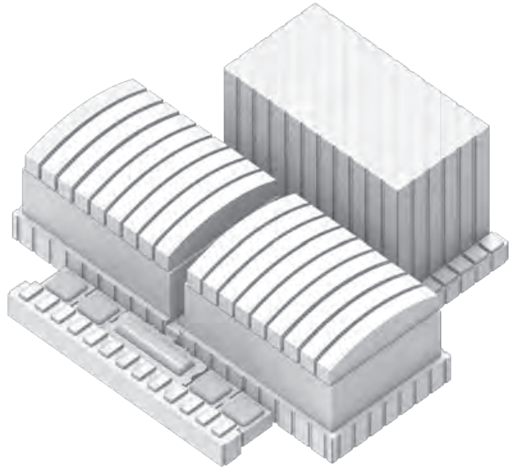
7-19 Front view from the Spree (according to publication from Zeitschrift für Bauwesen, 1865)
7-20 Diagram illustrates structural rhythm expressed in the façade divided in three symmetrical areas; the center where the segmentation is regular (A-A) and the sides, where the separation is emphasized by double columns (A-B-A-B). Such separation is also accentuated by two sculptures on the top of the entablature.

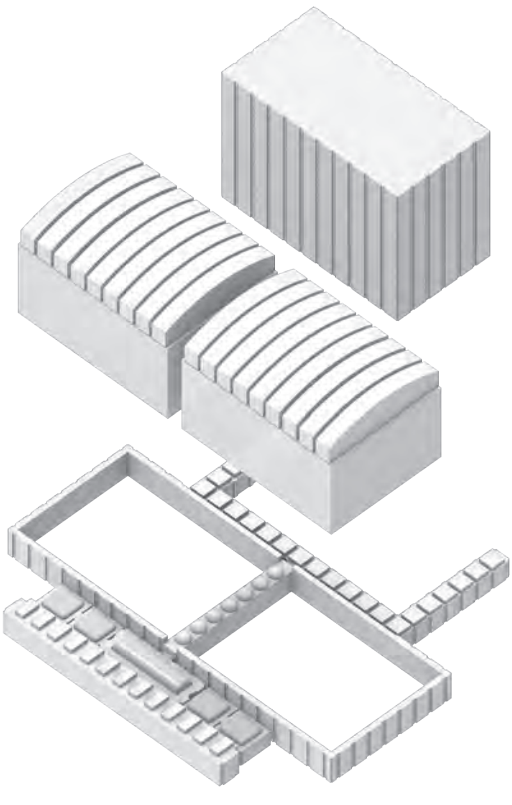




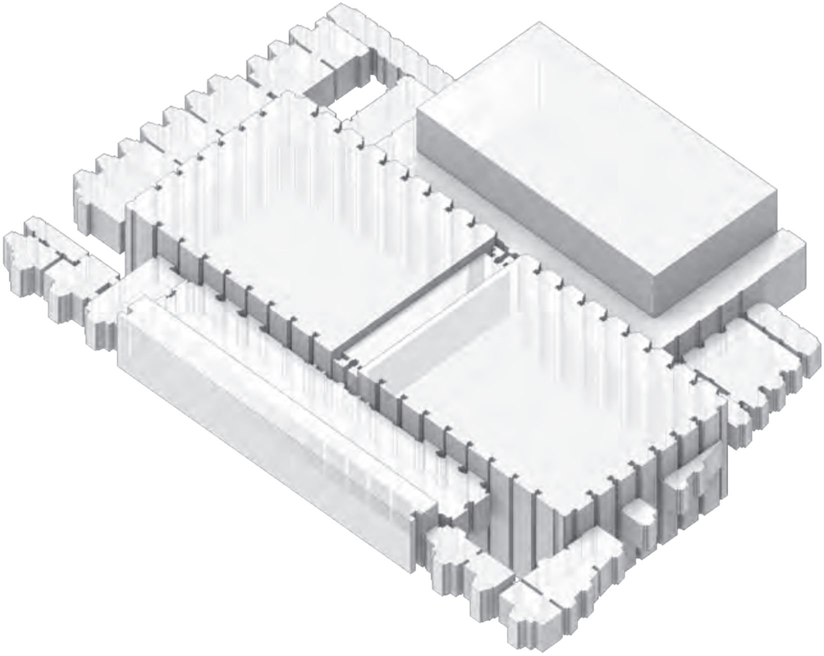


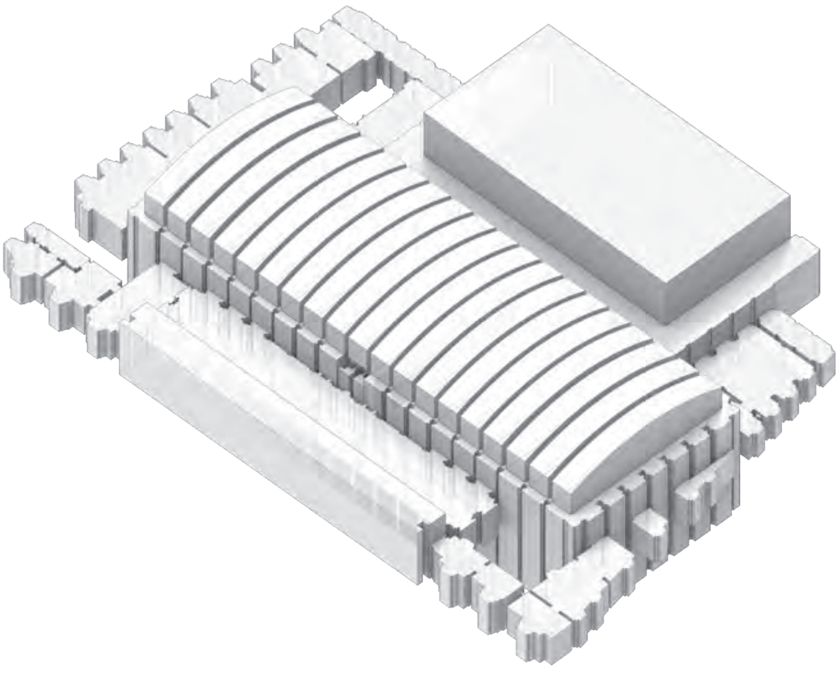
7-21 Structural module section from roof. Section over trading floor composed with arched iron truss covered with ceramic cladding.
7-22 Roof structure details (according to publication from Zeitschrift für Bauwesen, 1865). Steel structure and ceramic interior cladding.
7-23 Iron roof structure details (according to publication from Zeitschrift für Bauwesen, 1865).



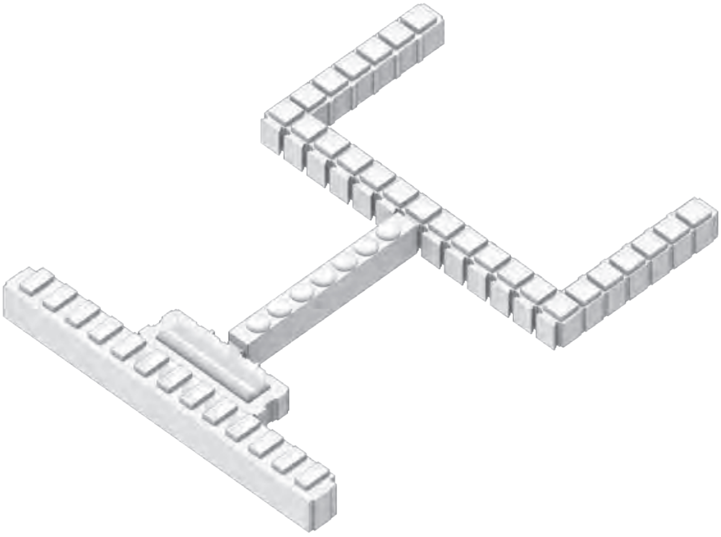


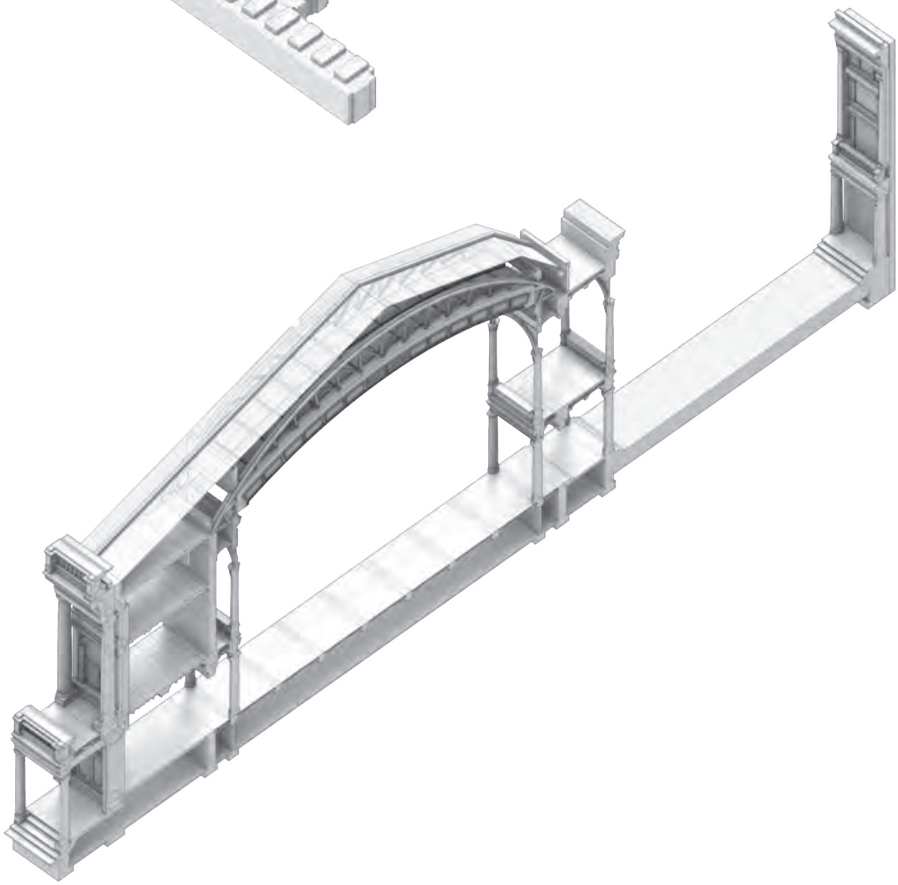
7-24 Representation of volume void. Ground floor access, circulation areas, trading floor and inner court. Note the progression from small semi-covered access, small spaces, then the large trading floor, a transitional colonnade and then the larger open court.
7-25 Exploded isometric view. Access and circulation areas, trading floor and inner court.





7-26 Representation of volume void. First floor administrative areas, circulation areas and connection with trading floor.
7-27 Representation of inner volume void. First floor administrative areas, circulation areas, trading floor and inner court.





7-28 Representation of volume void. First floor hall space and circulation areas surrounding the trading floor.
7-29 Structural module section. Section through access, trading floor, circulation areas and inner court. Alternation between small and large spans were possible thanks to the freedom provided by iron structures.

CHAPTER 08

- *Palais du Champ de Mars*

With the aid of the engineer Henry de Dion, the Palais du Chap de Mars´ impressive 725m long by 340m wide structure was indeed an impressive view to the visitors of the International Exhibition in 1878. Gustave Eiffel also collaborated in the design of the building by providing solutions to the roofs over the main gate and the lateral entrances.

In terms of technology, the building was innovative as the other enterprises typical of the international exhibitions. Aided by the railway technology, building materials and debris were taken in an out with ease. The railways were eventually covered during the exhibition in order to facilitate the dismantlement of the monumental structure. Among its many innovations, the water management system was one of the most remarkable; pumping water from the Seine through miles of pile and lead tubes to the exhibition´s ponds and fountains and provided thermal cooling while running under the Palace´s floor along with a similar air ventilation system.

In contrast to its neighboring Trocadero Palace, the Palais du Champ de Mars´ extensive use of iron organized its entire expression. The main entrance building is an impressive 340m long gallery and 25 meters wide called the Vestibule d´Honeur located in front of the Seine. It is composed by three main bodies with connecting galleries. Their modulation is accentuated by twenty-two "Statues of the Powers" representing the nations officially recognized by the Third Republic. This modulation was transferred to the inner organization but perhaps the most popular feature of the Palace was the ´Rue des Nations´, where each of the participating countries designed the entrances to their exhibitions. Buildings within buildings, organized over an avenue, each of them more eccentric and diverse than the next one. A perfect metaphor for the 19th century eclecticism enclosed on one building.

Behind the main entrance building, the palace´s interior consisted in nine galleries running parallel with various heights through its entire 725m length. The difference between this quasi-industrial configuration and the other pavilions is striking, yet the expressive potential of iron would be exploited some years later in the famous Galerie des Machines. However the research considers the uniqueness of this building not only on its record-breaking extent but also in the hybrid character of its composition.

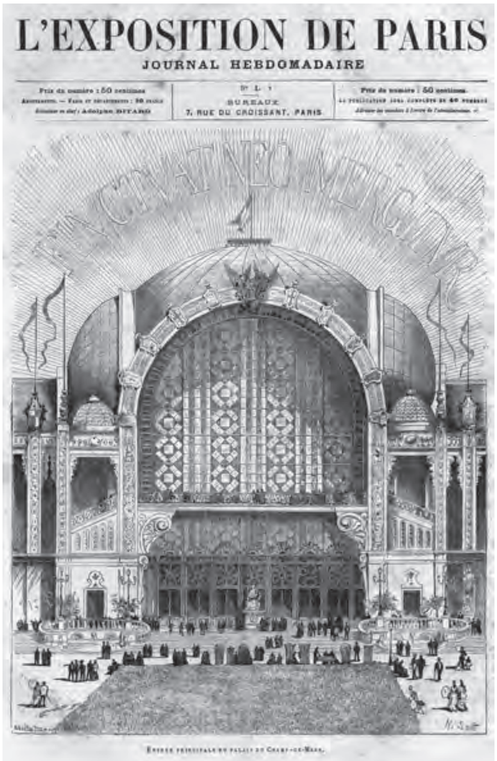
The combination of large galleries organized according to Beaux Arts tradition (the Vestibules of Honor and Work) and the exhibition spaces in between them built with the most practical mindset is somehow similar to the configuration of large 19th century train stations. We´ve cited them as metaphors for the collaborative efforts between architects and engineers, illustrating the clear-cut separation of both approaches to utilitarian construction and its expression.

In contrast to the large single space of the Galerie des Machines from

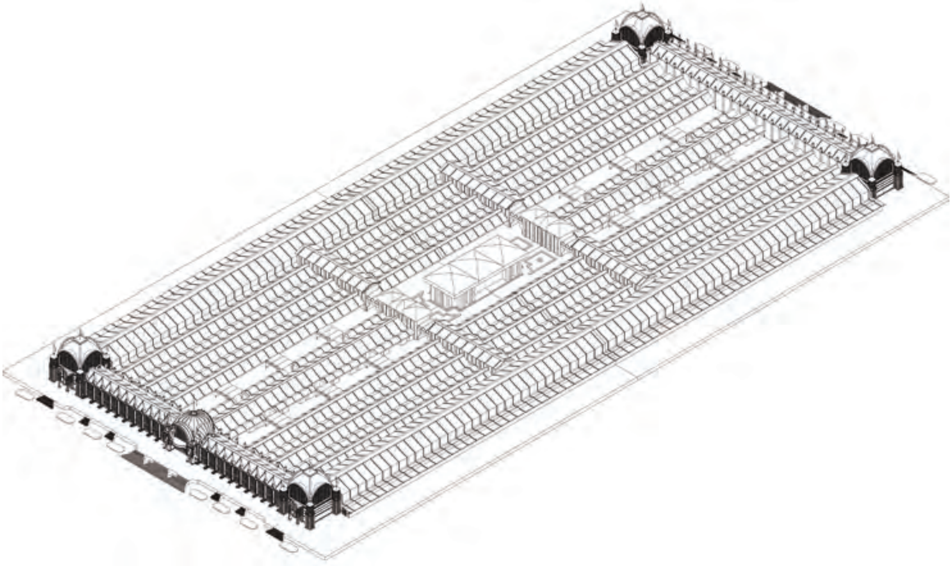
1889, the exhibition space in the Palais du Champ de Mars is structured along ´streets´ or ´boulevards´, similar to the trusses ordered on the side of rail tracks. Like train stations, the contrast between both parts is not only structural but stylistic; the Vestibules were ornamented with colored bricks, glass and statutes while the exhibition spaces were clear-cut utilitarian structures, waiting to be filled with the nation's pavilions.

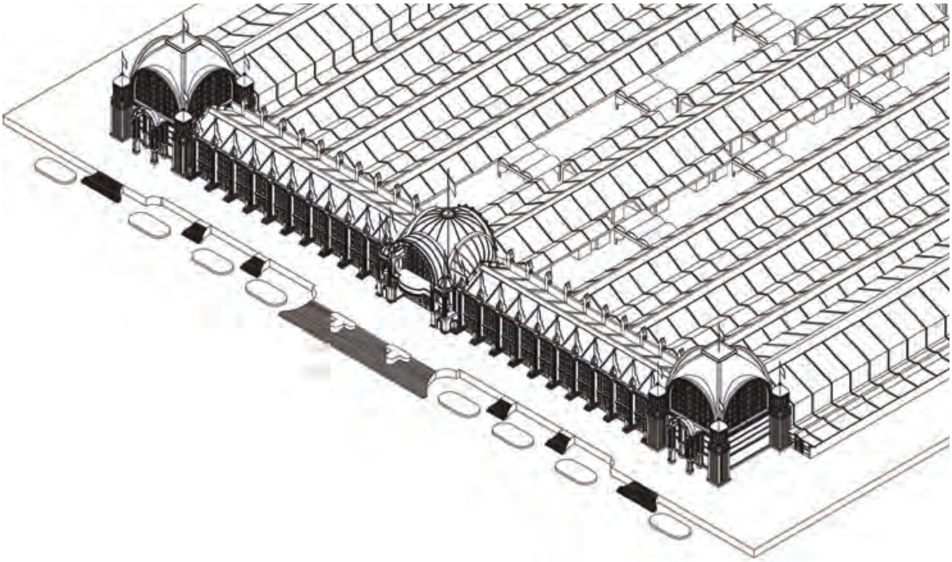
Organized as it was, the Palais could have been of any size, since its modularity and the repetition pattern it followed was strictly horizontal and did not require any extreme structural effort or any large span. Thanks to this modularity, large parts of the Palais were reutilized on several parts of Paris and even to military uses, being conserved up to this day.

8-1 Palais du Champ de Mars. Entrance court. Extracted from Gallica BNF.
8-2 Lateral arcades with international exhibitors mimmicking middle-eastern street markets.
8-3 The magnificent space in the Vestibule d´Honneur.

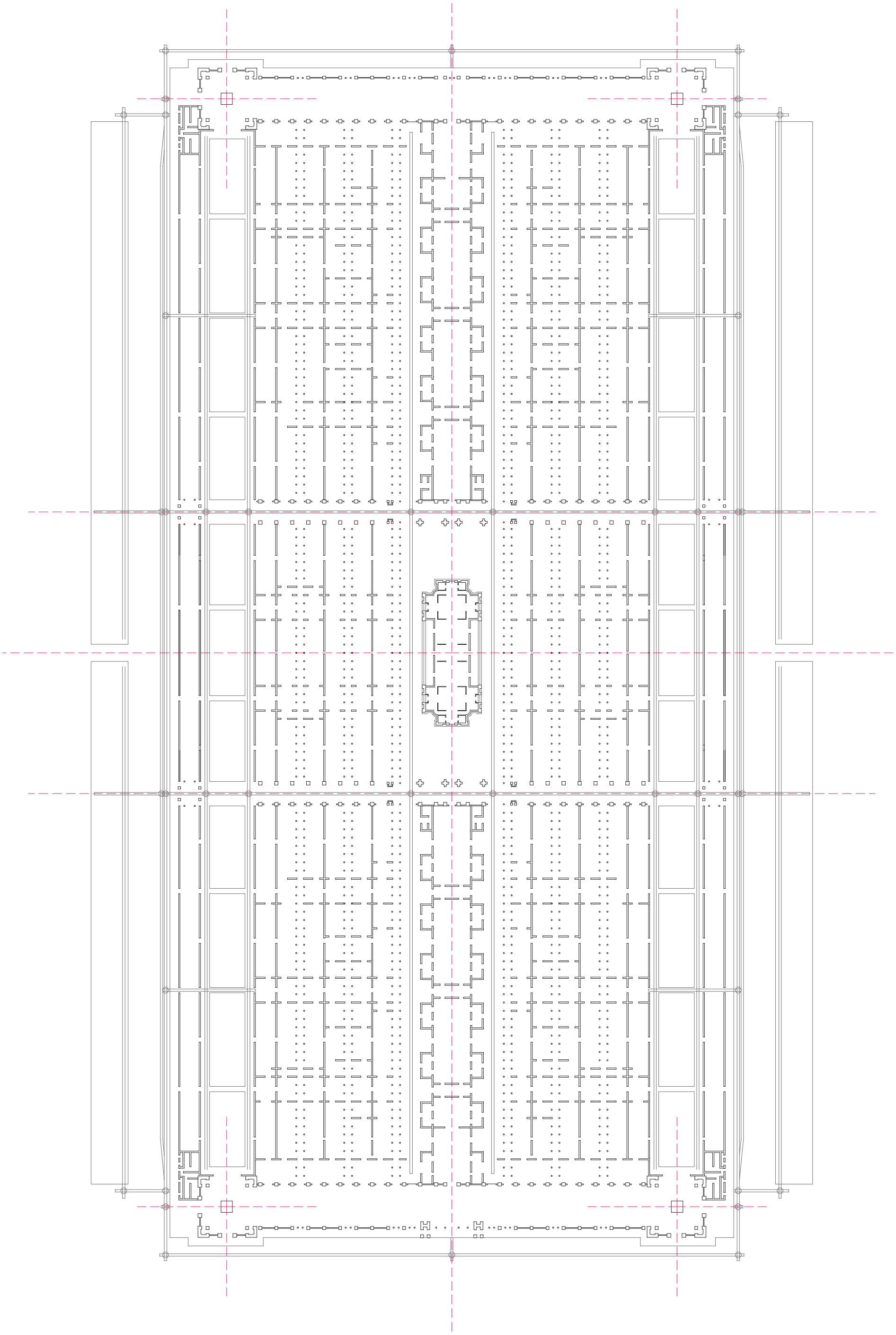


8-4 Advertising poster forthe exhibition. Main access to the Palais.

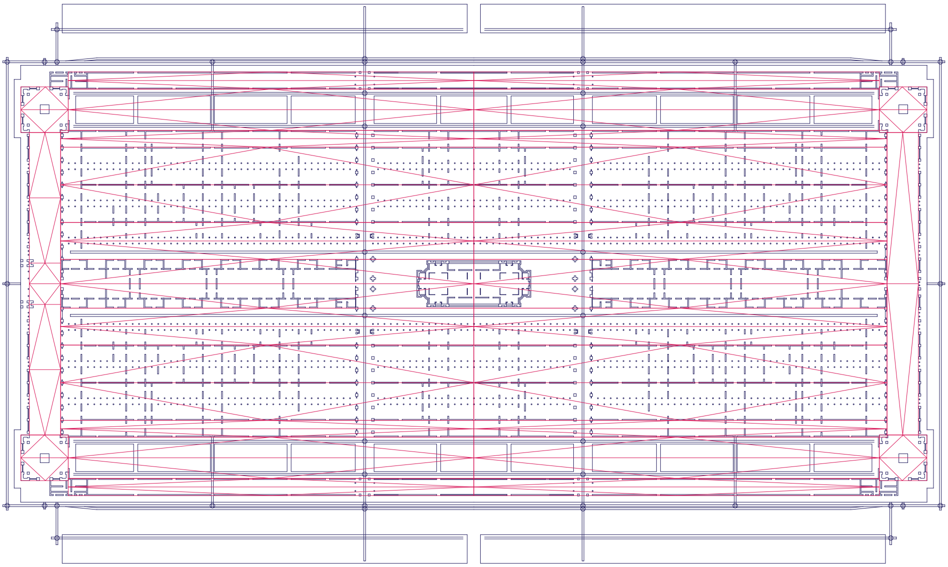


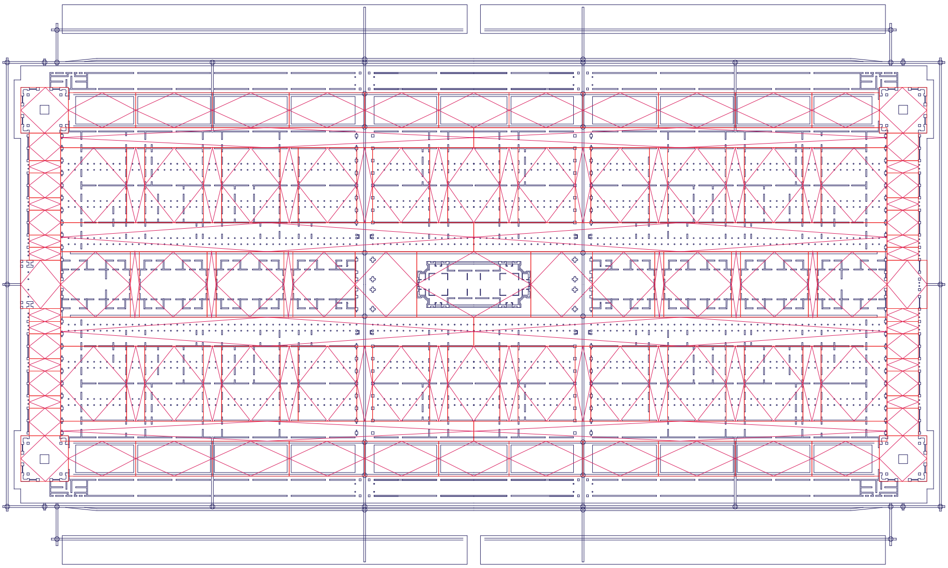


8-5 Axonometric view. The 725m long by 340m structure was a record breaking construction in the International Exhibition in1878
8-6 Detail of the Vestibule d'Honneur

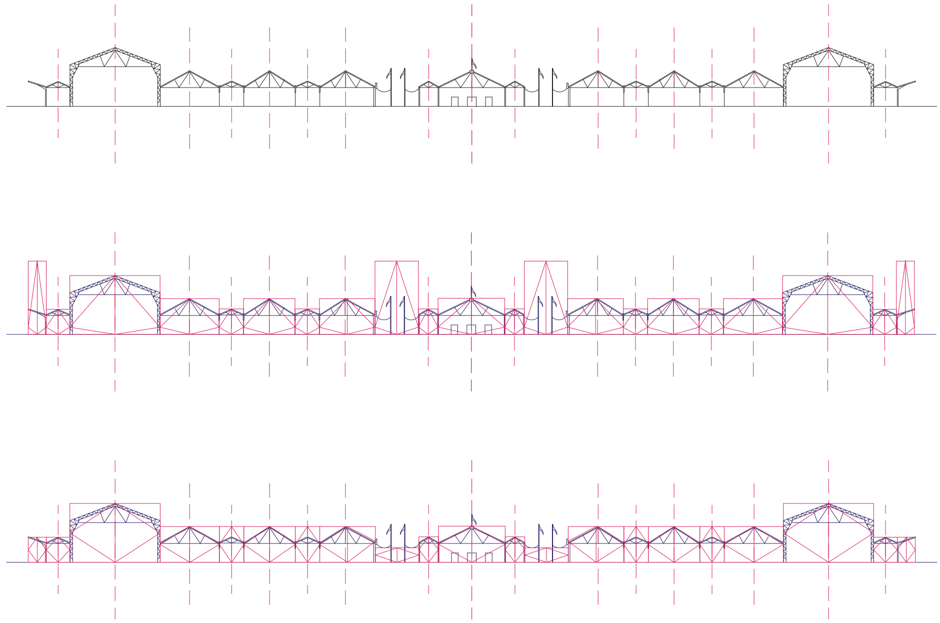


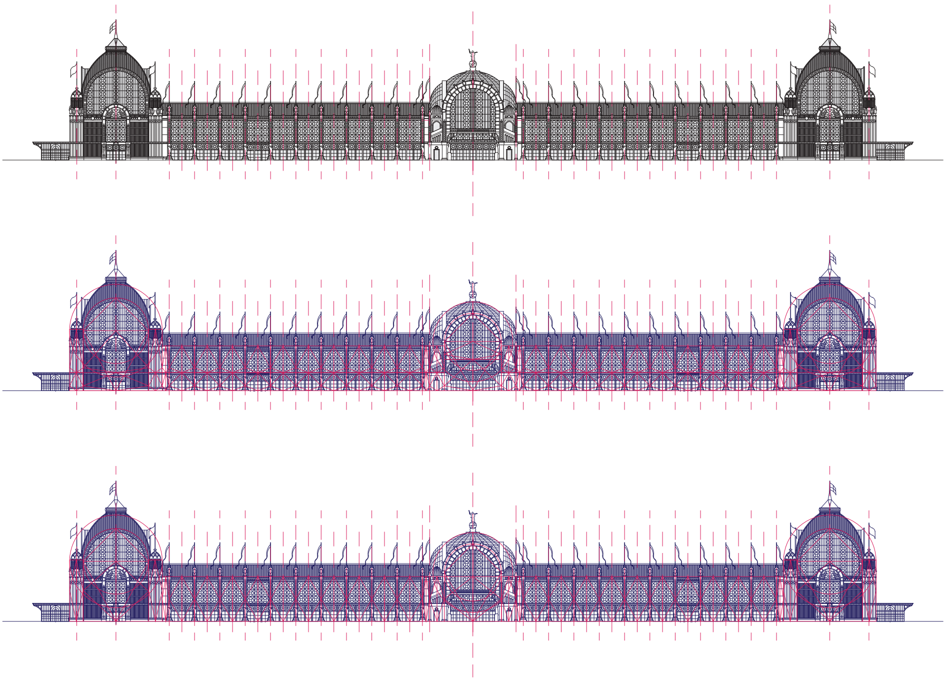
8-7 Palais du Champ de Mars (H. de Dion) Ground floor plan (according to Bitard´s publication and the Catalogue Populaire)





8-8 Spatial flow diagram. Symmetrical organization was privileged over structural alterations and facade subdivisions.
8-9 Spatial flow diagram. Diagram modulated by inner pavilion subdivisions.





8-10 Section through exhibition area (according to Bitard´s publication) and inner structure modulation of the exhibition space and street partitions.
8-11 Front view (according to the Engineering Magazine) and structure modulation rhythm and panel subdivision.

CHAPTER 09

- *Palacio de Aguas Corrientes*

By 1886, the government of Buenos Aires commissioned the project for the Great Water Deposit to the engineering office Bateman, Parsons and Bateman. The original idea was to build a water deposit and distribution facility for the newly appointed capital of Argentina, upgrading its status to an international metropolis, comparable to cities like Paris or London. This change of status was not just nominal, the vast influx of European immigrants boosted the construction and sanitation facilities were in need of a modernization.

The designation of Buenos Aires as a city capital was not just a nominal status as it also influenced the city's infrastructural presence and architectural character. By the end of 19th century, government and administrative buildings were established in the city defining a particular architectural profile, aligned with the idea of a European democracy. For this reason, the eclectic style imposed for government buildings like the use of Greco-Roman in the National Congress, Neo-Greek style for universities and justice buildings, among others.

Thus, the construction of the city water deposit or 'Gran deposito' (Great Deposit) presented also de opportunity to reveal this newly appointed European (and metropolitan) character on its expression. After the designs of the Norwegian architect Olaf Boye, the building's name changed to 'Palacio de Aguas' (Palace of Waters), aligned with the late 19th century treatment and denomination of official buildings in Buenos Aires, joining 'Palacio de Correos'(Post office palace) 'Palacio de Justicia' (Justice Palace), 'Palacio de Congreso' (Congressional Palace) and 'Palacio Pizzurno' (Ministry of education). The city and its buildings became the background and the crystallization of modern republic and its institutions.

Trained in a polytechnic school, Boye became skilled in the contemporary Eclectic style by collaborating in several architectural offices from Buenos Aires, such as J. Buschiazzo and C. Altgelt. He later joined Bateman's office, where he was in charge of the Palace's façade.

From a stylistic point of view, it is hard to define the architectural style of the Palace's façade: it is undoubtedly eclectic, but the details and intricacies of its design avoid further classification into other comprehensive categories such as Neo-Renaissance or Neo-Colonial. The architect's European education and training in Argentina had definitely a certain degree of influence and his carrier after the experience in Argentina also showed his masterful dominion of architectural styles.[1]

About the Palace's style, Tartarini asserts:

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1 Jorge Tartarini accounts for some of Boye's biographical facts, along with his career after his return to Norway. See Jorge Tartarini and Celina Noya, El Palacio de las Aguas Corrientes: De Gran Depósito Distribuidor a Monumento Histórico Nacional (Buenos Aires, Argentina: AYSA, 2012)

9-1 Palacio de Aguas Cprroentes - Gran Deposito Distribuidor (C. Nyströmer , O. Boye) Exterior view from the Av. Cordoba
9-2 Detail of 1st floor faux-window

“Boye projected the architecture of the Great Deposit as in Historicist Eclecticism booming on the main capitals of the world. That is, a style combining diverse historical references, formally related with Second Empire’s French architecture and certain center-European models like the Justice Palace in Antwerp, Belgium. But beyond this stylistic consideration, it is clear that it was the inclusion of Terracotta, diverse in variety as in textures, colors and forms, what accentuated its ornamental and decorative exuberance, giving the Palace its own character, typically Victorian.”[2]

Regarding the ornamental character of the façade, the use of colored, glazed ceramics is a distinctive feature. Polychromy was a topic of enthusiastic discussion on 19th century thanks to theorists like Hubsch, Semper and Hittorf. The last one, having strongly advocated in its favor, criticized the neoclassical reading of ancient buildings disregarding strong colored decoration, concentrating on shape and composition.

The open use of color and texture on top of a highly detailed elements is a bold statement in terms of this discussion, perhaps for the reason that the architectural program of the building is limited or almost nonexistent. A water deposit and pumping facility there is no archetypical typology to follow nor architectural character to impose. Perhaps is this lack of restrictions that allowed Boye to experiment in these aspects, a freedom not uncommon in 19th century architecture.

It is also interesting to note that the original project approved by the national administration included three materials on the façade: the socle should be built in granite, the cladding of the first floor in local marble and the rest in terra cotta pieces. Bateman, responsible for the project, advocated for a façade entirely made of terra cotta and managed to convince the government which approved the changes two years later. According to the administration, it would result in savings of time and money, even though every item should be imported from England.

The project composition consists in a brick construction of 90 by 90 meter square footprint by 20 meters high, with towers reinforcing its corners and an 18 by 18 meter central courtyard for the illumination and ventilation of reservoir levels. The center portion of each façade is highlighted by a protrusion, pointing the entrances for the public and carriages. Each of the four facades are segmented with slight buttresses, providing a rhythm that organizes each of the elements such as windows, oculus and various ornamentations. The central volume corresponding to the entrance is crowned by a square dome, decorated with a rectangular volume, the country’s emblem and a flagpole.

It could be stated that the building is utterly a perimeter wall, since its architectural program is limited. With a thickness ranging from 1,80 meters on the ground floor to 60 centimeters on the cornice level, the façades concentrate all the architectonic and ornamental efforts. Heavily but harmoniously decorated, this perimeter hides the iron structure and machinery necessary to manage the water distribution for a large part of the city.

2 Tartarini and Noya, El Palacio de las Aguas Corrientes

9-3 Front view by O. Boye. Extracted from J. Tartarini, C. Noya, ´El Palacio de las Aguas Corrientes: De Gran Depósito Distribuidor a Monumento Histórico Nacional´.
9-4 National emblem ornament in terra cotta. Extracted from J. Tartarini, C. Noya, ´El Palacio de las Aguas Corrientes: De Gran Depósito Distribuidor a Monumento Histórico Nacional´.

As mentioned before, the perfect square is located at the center of the urban four sided block, typical from Buenos Aires. Although the inherited colonial planning proposed a perfect quadrangular grid, it has progressively deformed while it distances from the city center. The location of the Palacio de Aguas is on one of these deformed city blocks, a rhomboid with non-parallel edges.

Bateman's project remains a perfect geometry on an imperfect frame, a rational gesture that subsumes architectural and urban articulation to the organization of its internal structure a regular grid of four-column pillars. It is also interesting to note that the irregular plot's boundaries are materialized with a cast iron fence, also imported from Scotland[3]. Parcels of grass and trees function as a buffer zone between the plot limits and the building's façade.

The façade is composed by 170.000 ceramic pieces and 130.000 vitrified bricks, bought to the Royal Doulton & Co. Company from London and Burmantofts from Leeds[4]. Each piece was designed, fabricated and mounted in place thanks to detailed planning process. Beginning from Boye's sketches, the company produced factory drawings that once approved, were arranged in detailed organizational diagrams, crucial to the assembly process and logistics. Each terra cotta piece was tagged with a number describing its position on the façade, intended to be mounted over a masonry brick wall.

Beyond any stylistic appraisal, the façade organization follows classical compositional cannons. The socle is built on rusticated masonry, emphasized with a darker, crimson color, while the first floor displays large, red ceramic bricks ornamented with pyramidal decorations, inspired in renaissance ornaments.

To emphasize the tectonic effect, there is also a progressive subdivision of the window openings, from the socle the ground floor single windows with lowered arches, and then the second floor the windows are smaller or subdivided in two on the corner towers. Below them, there are four small arches supported by colored columns with glazed panels decorated with flowers, imitating small windows. The subdivision of openings from blind, then one, afterwards two and finally four, works somehow likes an inverse tectonic effect, positioning smaller windows on the top floors and bigger ones in the bottom one. One reason for this operation could be found in the building's program; the ground floor is dedicated to administrative offices while the upper levels belong to the water tanks, the primary function of the building. Furthermore, some of the upper floor windows and oculus are blind, since there is no possible use for them.

The building's main program, the water tanks are supported by a grid of 180 pillars, each one composed by four round columns. If the building is divided in four quadrants, the 12 central columns of each quadrant have fixed bases while the remaining 33 have articulated ones. Similar to the window openings,

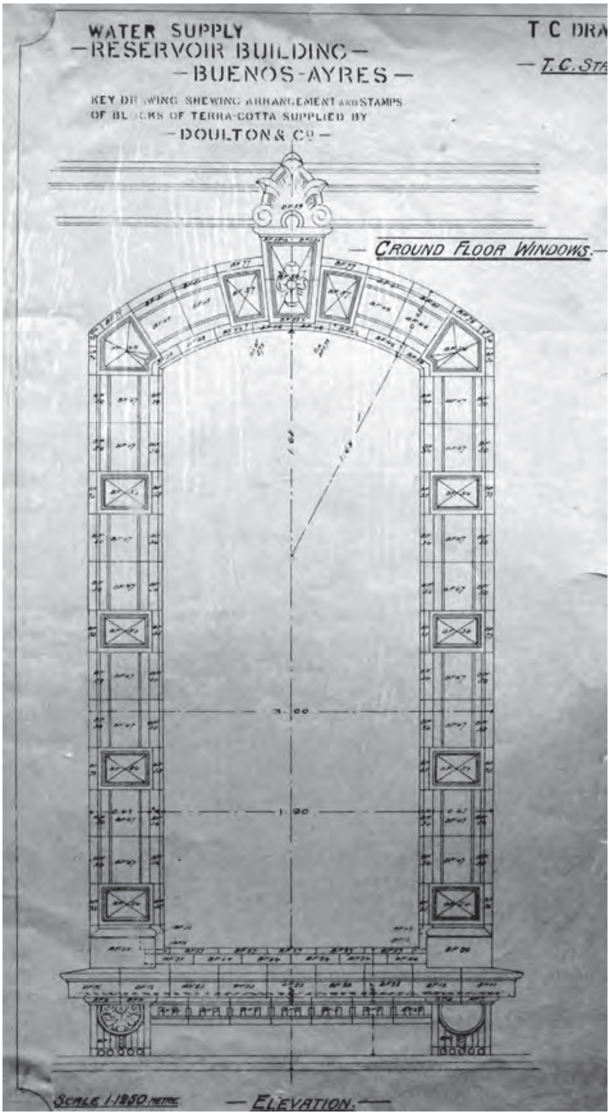
3 For detailed references of cast iron imports from the Saracen Foundry in Argentina and the Palacio de Aguas pieces see Lucia Juarez, "Documenting Scottish Architectural Cast Iron in Argentina," in Function and fantasy: Iron architecture in the long nineteenth century, ed. Paul Dobraszczyk and Peter Sealy (New York: Routledge Taylor & Francis Group, 2016)

4 Tartarini and Noya, El Palacio de las Aguas Corrientes

the pillar's columns are thicker in the lower position, and unifying themselves from four columns to one on the top segment. Like the terra cotta and cast iron pieces, the metallic structure and piping components of the building were manufactured in Europe, by the Belgian firm Marcinelle & Couillet.

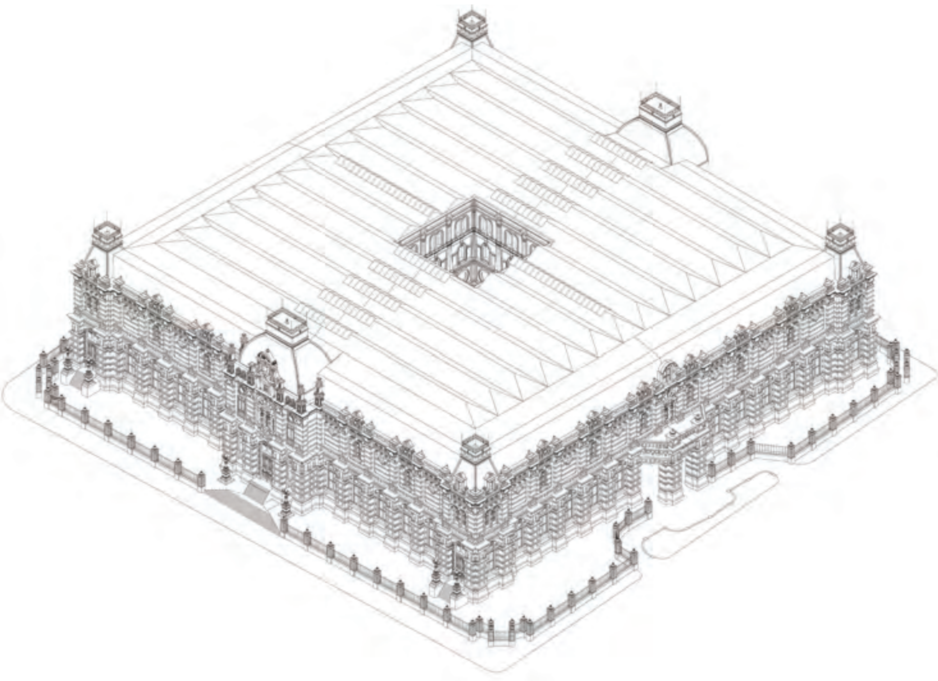
Similar to the Sayn Foundry, the Palacio de Aguas is simultaneously a building, a machine and a governmental advertising piece; a portion of metropolitan infrastructure, the symbol of a modern nation looking up to its European roots. It describes a formal experiment on which design freedom is fueled by technical advancements, aided by precise logistics. Its façade departs from classical cannons, not only in terms of style and color but also in the role of the designer; the Palace is a major illustration of the fluid negotiations between architecture, engineering, government and the manufacturing companies.

For this reasons the Palacio de Aguas Corrientes remains a prime example of the design freedom distinctive of the 19th century. It describes the multifaceted network of relationships that was able to produce complex constructions: variations of classical composition and stylistic canons, state-of-the-art engineering solutions and a metropolitan scope.

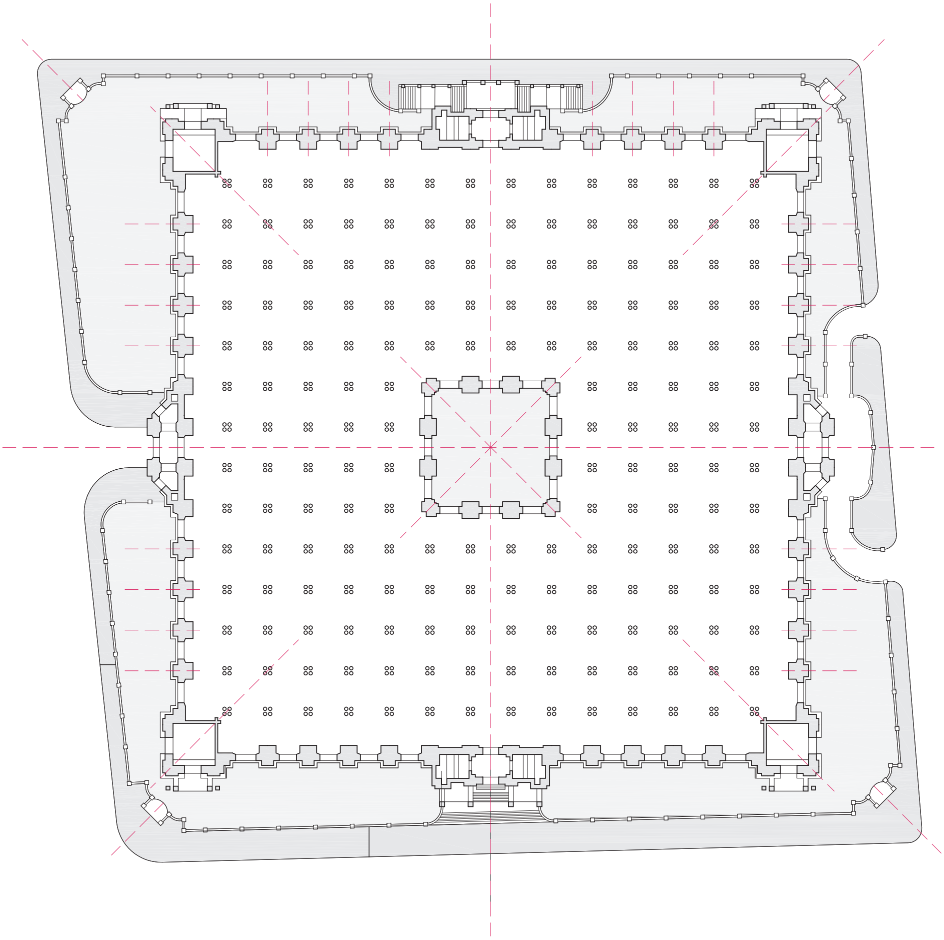


9-5 Window frame elevation. Extracted from the Terra cotta contract documentation at the Museo del Agua Archive.

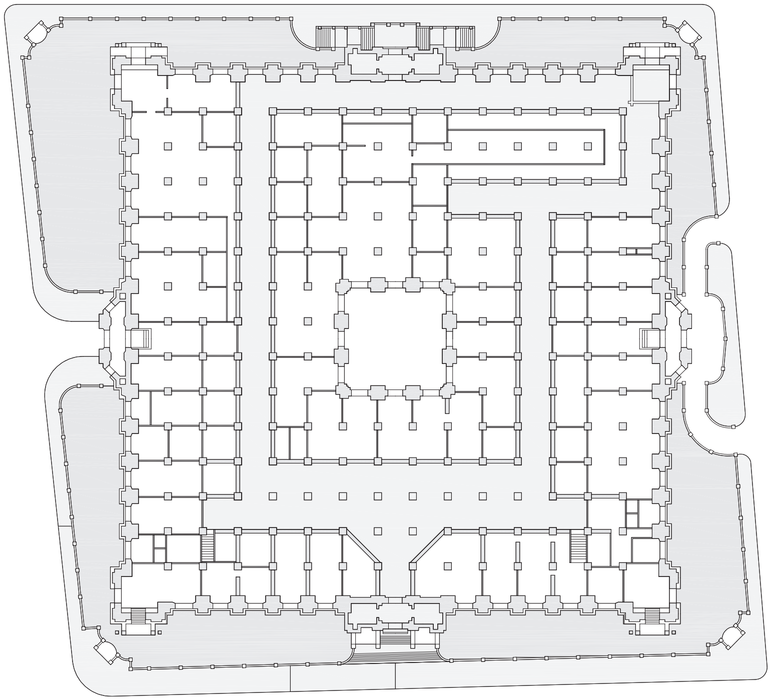
9-6 Interior view of the water tanks. Extracted from J. Tartarini, C. Noya, ´El Palacio de las Aguas Corrientes: De Gran Depósito Distribuidor a Monumento Histórico Nacional´.

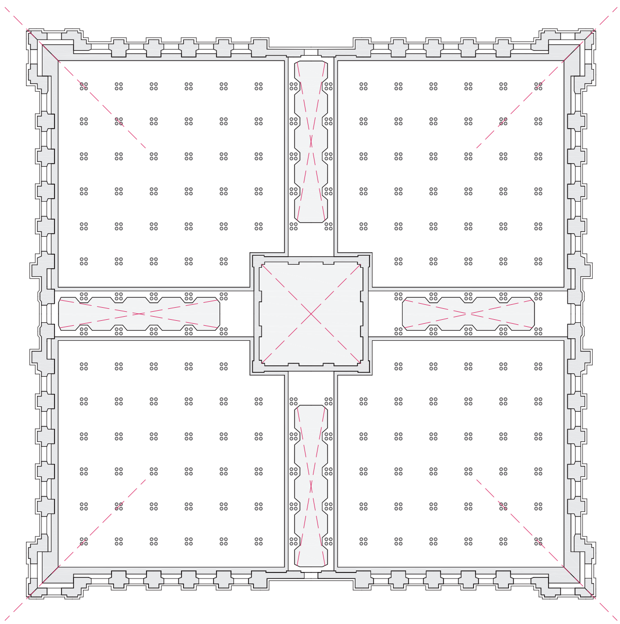


9-7 Axonometric view.

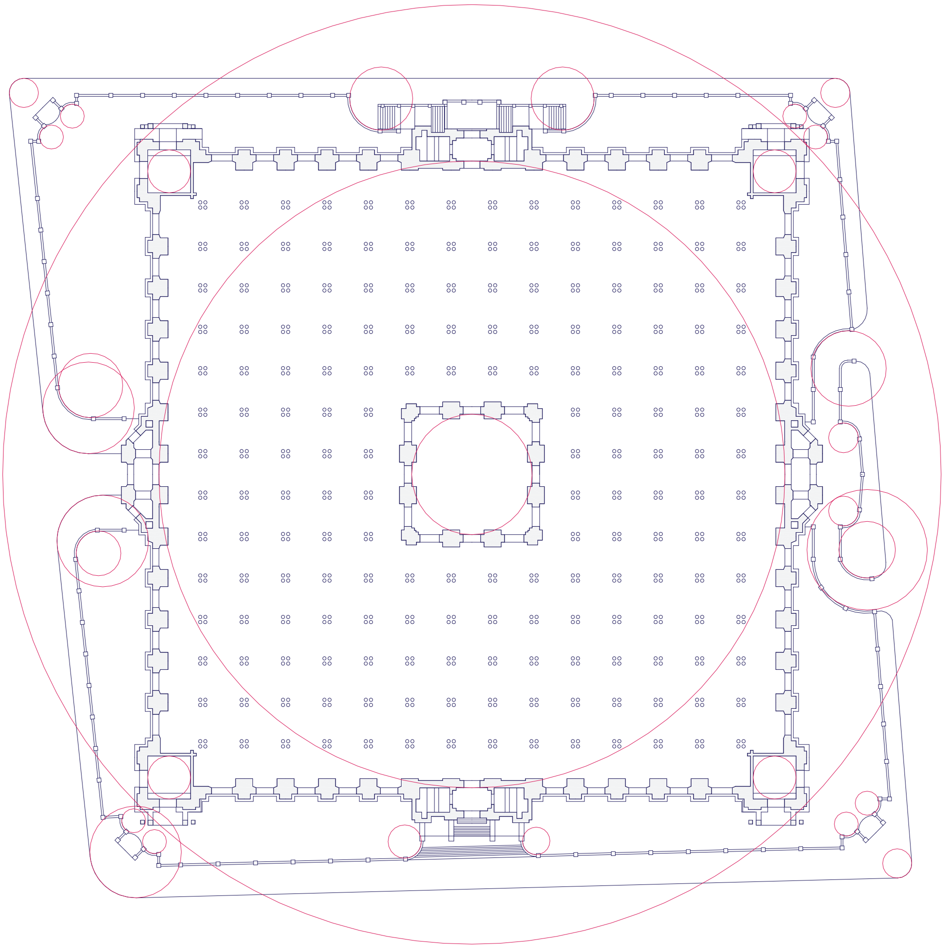


9-8 Palacio de Aguas Corrientes (C. Nyströmer and O. Boye) Structural organization (according to Museo del Agua archives)

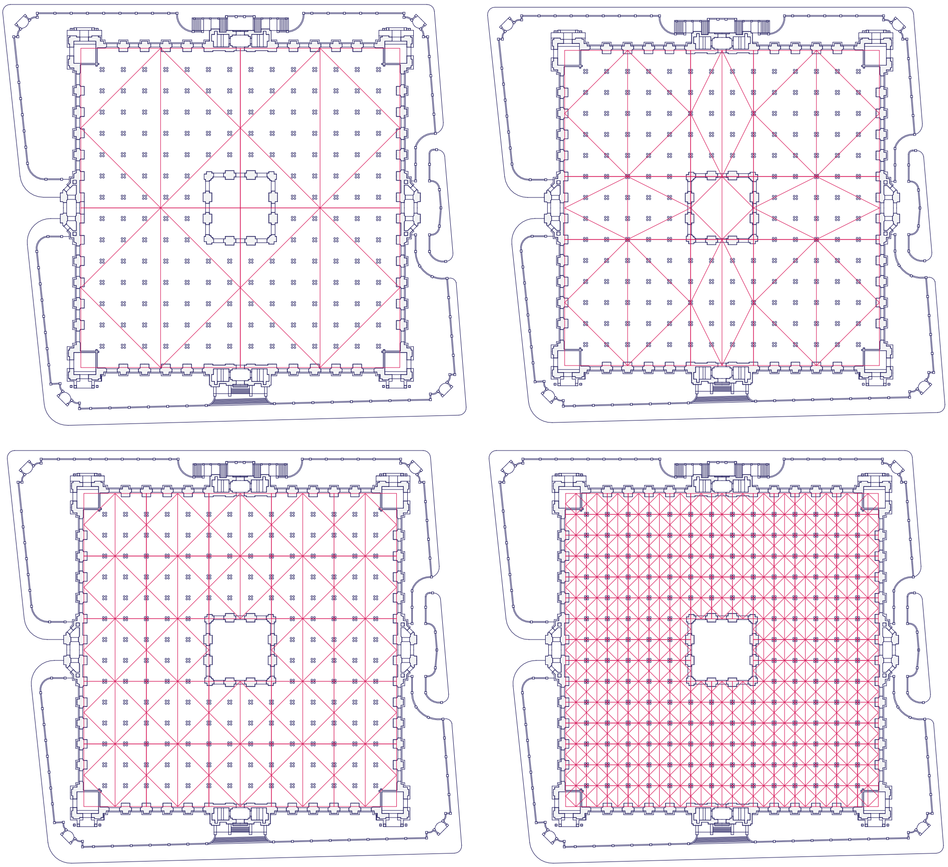




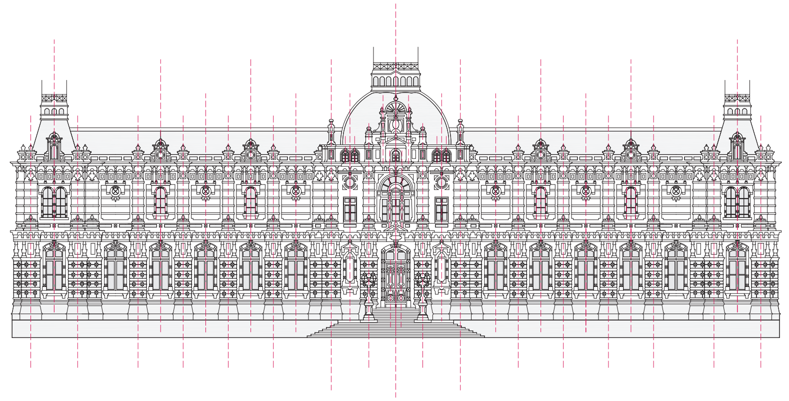
9-9 Ground floor plan and administrative offices (according to Museo del Agua archives) Structural grid allowed a great level of freedom in the internal organization of the office space.
9-10 Water tank level (according to Museo del Agua archives) The imposing structure held three levels of water tanks hidden behind the building´s eclectic facades.

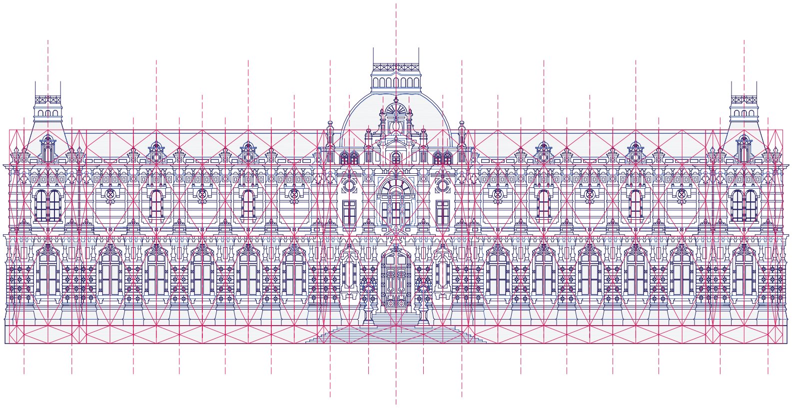


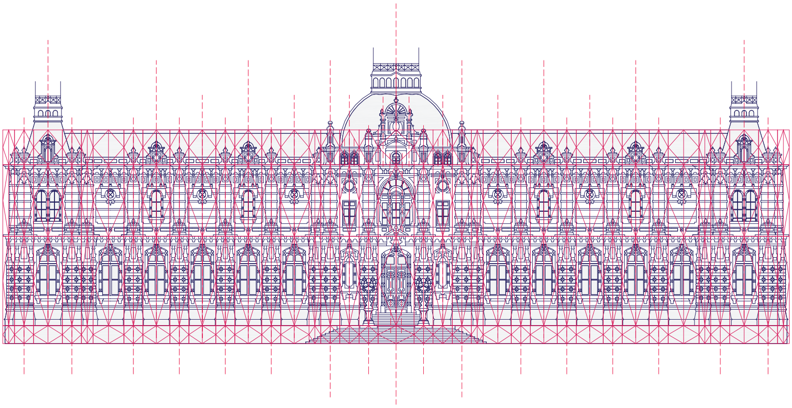
9-11 Front view by O. Boye. Extracted from J. Tartarini, C. Noya, ´El Palacio de las Aguas Corrientes: De Gran Depósito Distribuidor a Monumento Histórico Nacional´.
9-12 National emblem ornament in terra cotta. Extracted from J. Tartarini, C. Noya, ´El Palacio de las Aguas Corrientes: De Gran Depósito Distribuidor a Monumento Histórico Nacional´.



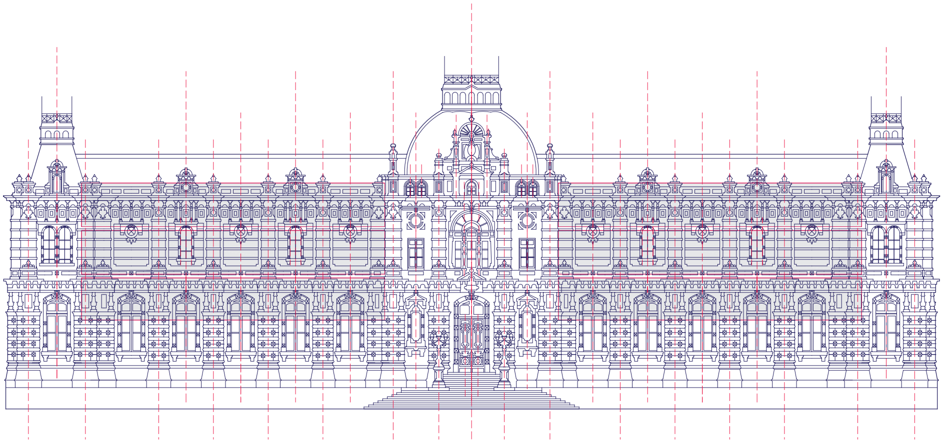
9-13 Quadrant subdivision corresponding to tank organization on upper levels. Three-by-three structural module, inner court modulation and base structural grid.

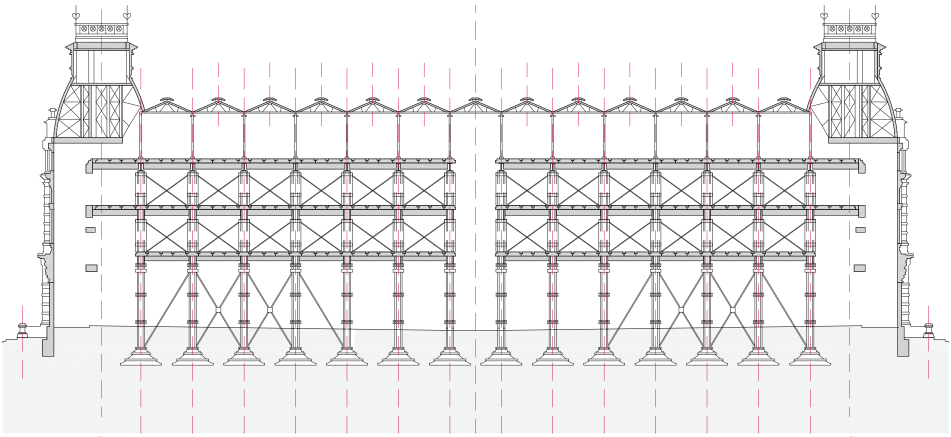


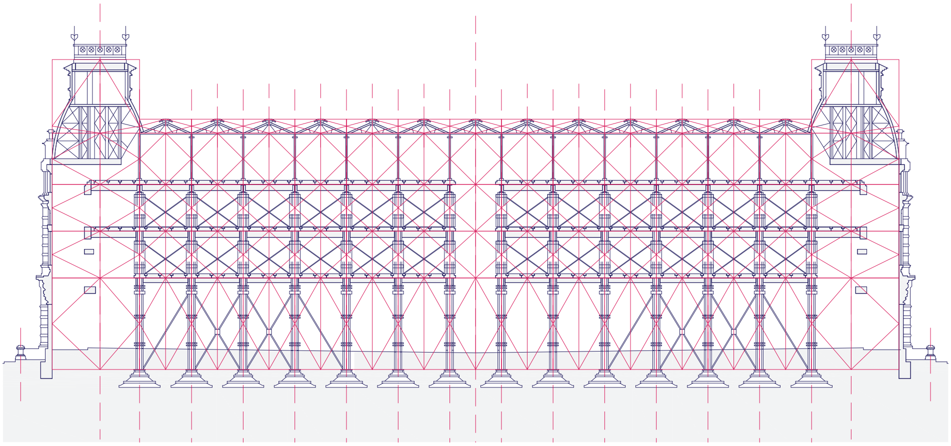




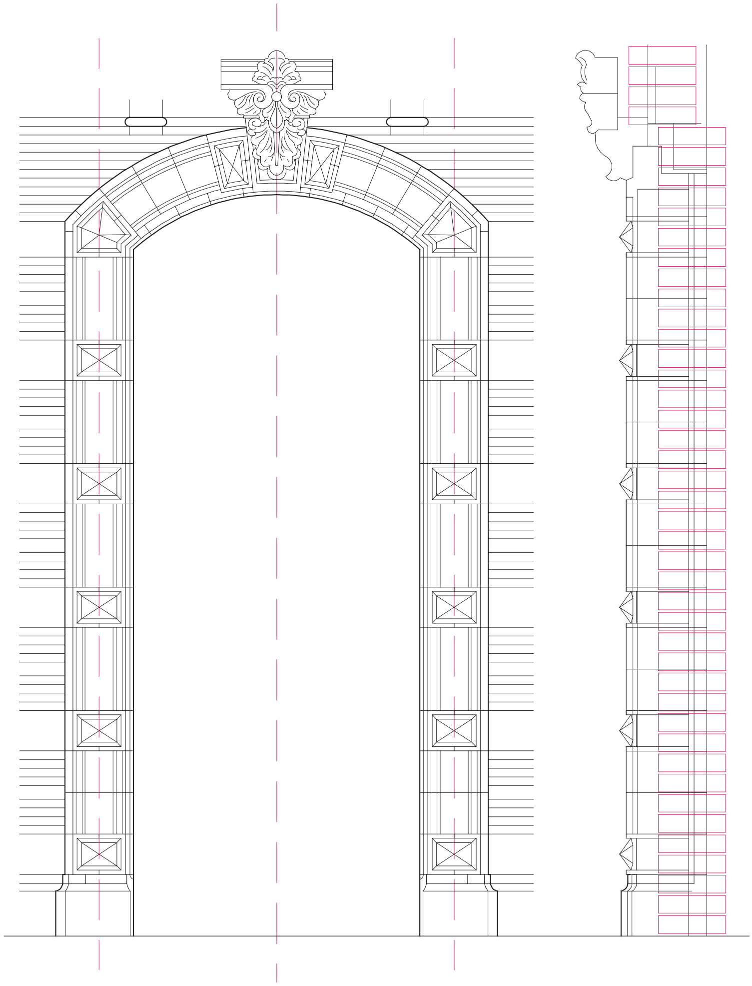
9-14 Front view over Corrientes Av. (according to Museo del Agua archives)
9-15 Modulation according to structural subdivision
9-16 Modulation rhythm (A-B-A) alternating faux windows and pilasters.



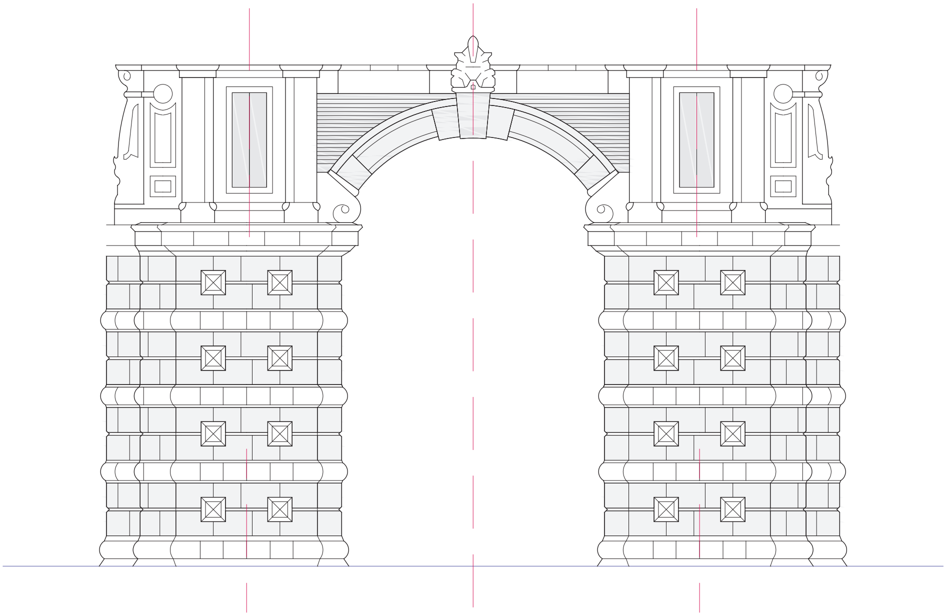


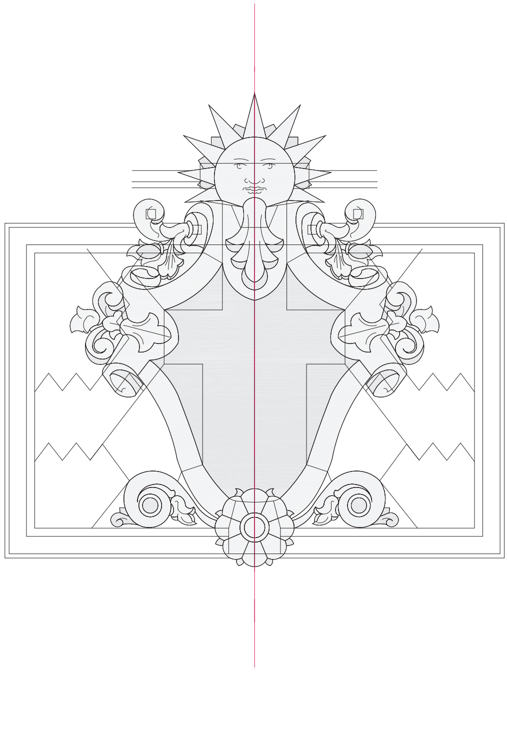


9-17 Superposition of tank geometry over façade modulation
9-18 Front Section (according to Museo del Agua archives).
9-19 Section diagram. Modulation according to structural subdivision

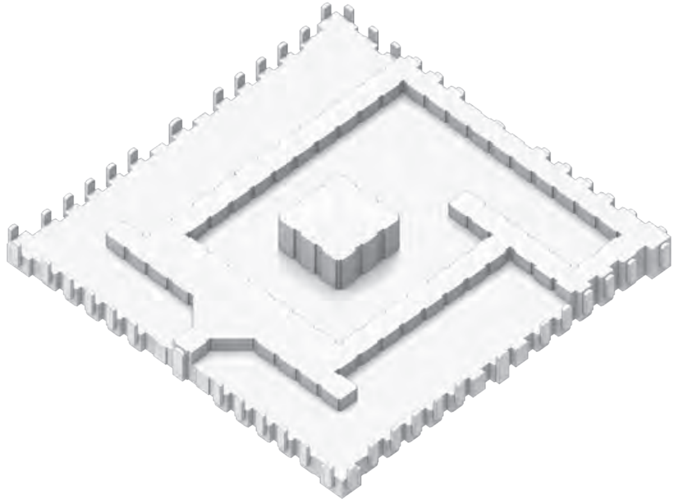


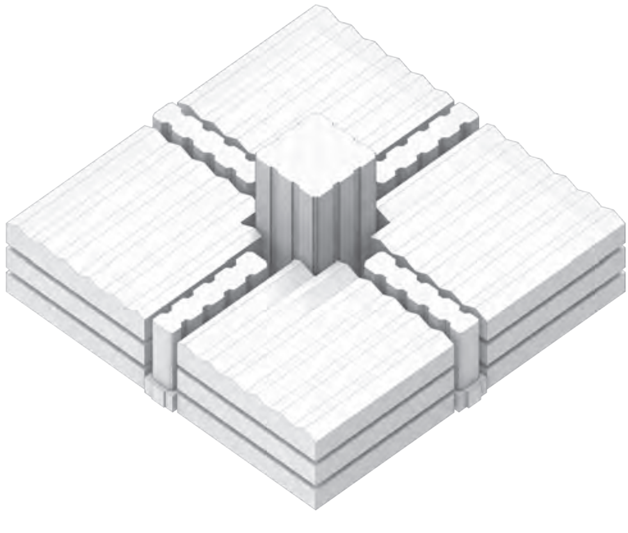
9-20 Window frame – Terra cotta detaling (according to Museo del Agua archives).



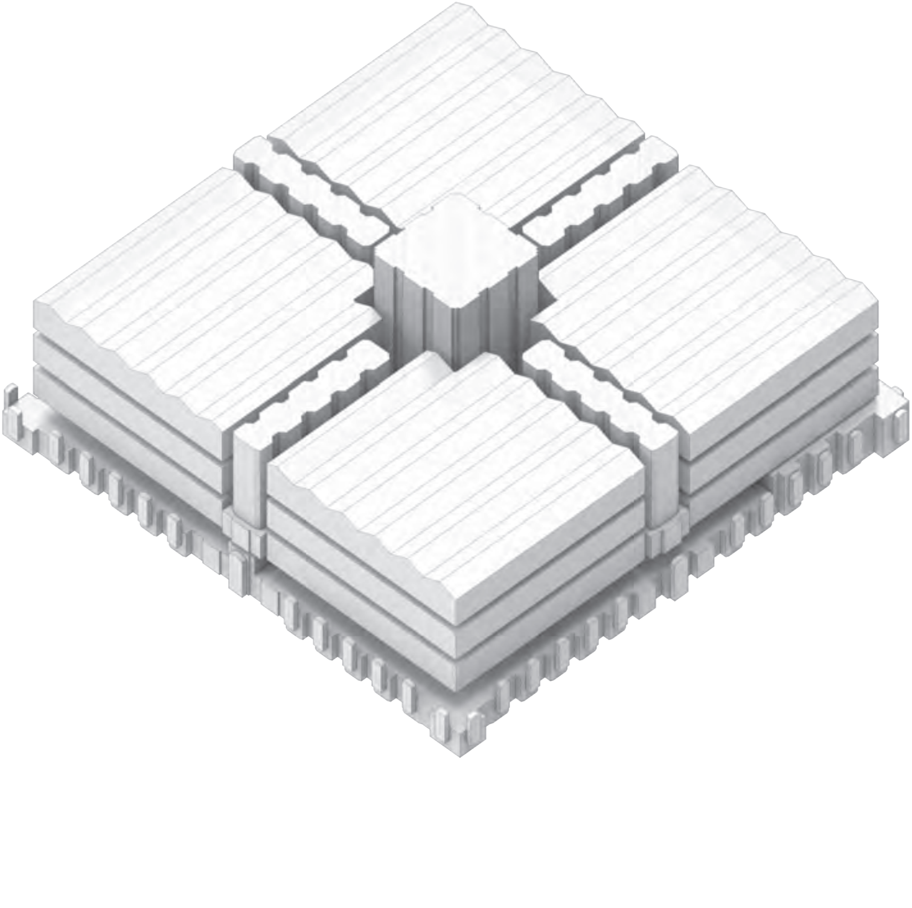


9-21 Semi covered access (according to Museo del Agua archives).
9-22 Terra cotta ornamentation – Frame for regional emblems (according to Museo del Agua archives).





9-23 Representation of volume void of the ground floor, circulation spaces and inner court
9-24 Representation of volume void from the tank sections and inner court.



9-25 Representation of volume void of the ground floor, water tank sections and inner court.

CHAPTER 10

- *Galerie des Machines*

The Galerie des Machines, as well as several other milestones, like the Eiffel Tower, was designed and built for the 1889 Paris Exhibition in order to commemorate the centenary of the French revolution. Technically impressive, the Galerie broke the world record for an interior space with its 115-meter span structure, 420 meter long hall and 43-meter high arches.

Many authors define the Galerie des Machines as a machine itself or a hybrid between building and machine; similar to a piece of infrastructure, the hall was much more than a large exhibition space. It was powered by steam machines, feeding overhead drive shafts that drove the mechanisms of the exhibits by leather bands (exactly like in a factory) while a moving platform bridge carrying visitors through the entire length of the hall.

The hall is a prime example of the sobriety in terms of decoration on functional structures. While still being discussed at the time, the plea for 'honesty' in construction and the use of materials received a different treatment across the Exhibition. Whereas the Eiffel tower or the Galerie des Machines addressed it by vindicating structural types and appealing to the beauty of iron elements themselves, other buildings resolved to rationalize construction elements, employing prefabricated elements and industrial construction techniques. Tom Peters states on this regard:

"Architectural theoreticians like Ruskin, Pugin, Cole, Semper, and Pickett had called for 'honesty' in the use of materials after the design excesses of the products shown in the Crystal Palace. But each defined honesty differently, and public taste still surrounded the Galerie des Machines stood witness to this demand."[1]

But, unlike other pavilions, the Galerie was a large hall, it was perceived as an engineering project, a facility, this way the typical architectural debates from late 19th century seemed to avoid it.

Following 'functional rationalism', Dutert was more aligned with bold bridge builders than typical engineers; the guiding principles of the building are bound by a technical and technological logic and limitations rather than rational geometrical calculus.

Peters states on this regard:

"The Galerie was certainly not the first iron frame in which structure determined formal expression. But it did mark the point at which the analytical engineering model, the material, and the manufacturing method became the form. In 1851 the Crystal Palace had expressed the open system by default

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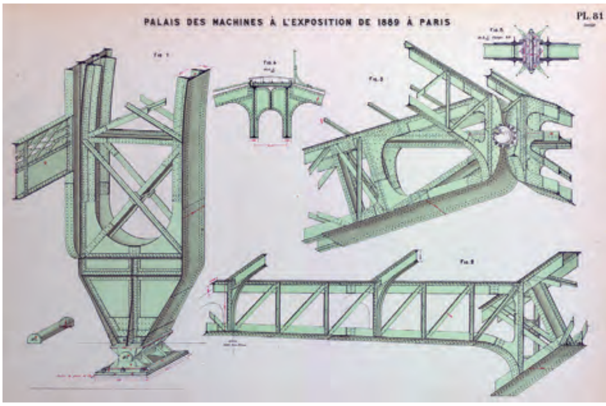
1 Tom F. Peters, Building the nineteenth century (Cambridge, Mass., London: MIT Press, 1996)



10-1 Access to the Galerie des Machines (C.F. Dutert) under construction.
10-2 Galerie des Machines mobile support detail.
10-3 Mobile joints construction detail. Source Gallica Bibliothèque nationale de France.

because there had not been time to cover it appropriately. Thirty eight-years later, the Galerie des Machines expressed system and structure by choice."[2]

One of the most important contributions of the Galerie was that it synthesized the possibilities of collaboration between two separate branches in building design; engineers were responsible for the construction techniques and calculation while architects were in charge of decoration and ornamentation. The hall was the product of a partnership between Dutert and Victor Contamin, engineer and metal structure entrepreneur, the first a Beaux Arts student and Prix de Rome winner, the second educated in the Ecole Centrale.

In one of their initial collaborations –the train stations-, the demarcation of their fields of expertise was rather clear; engineers were in charge of the trusses and sheds while architects dealt with the façades and halls. The Galerie des Machines embodied a step forward on this cooperation effort; two disciplines conceiving projects combining structure, construction techniques, materials and architectural design.

The Gallery's design was based on a three-hinged structure (typical of bridge building) in order to allow the hall to deform with temperature variations and also, to simplify the foundations, saving time and money. To this end, two competing construction companies were hired in order to finish the works on schedule. The massive hall was built with a total of 18 three-hinged arches and two double-arches on each end. The building was complemented by two two-storey galleries on each side, stiffening the construction laterally.

The geometry of the arches is also noteworthy; the line of the arches does not match the anti-funicular curve, the most efficient structural shape with distributed loads. The anti-funicular curve would describe a parabola, which would guarantee that every segment of the structure would be working under compression loads. Since the use of iron also allows supporting tension and flexure forces, the material is able to tolerate different structural shapes.

The particular shape is manifested in last section of the arches is almost rectilinear, giving the Galerie its characteristic section. This last section was the one covered by glass panels, manifesting the interplay of structural, aesthetical and functional decisions, supported by technical and material knowledge.

The iron frame of the hall was exposed at each end in order to display the organization and complexity of its construction system. The side walls and partitions were glazed with painted panels, colored glass, mosaics, paintings and ceramic elements.

The overall proportions of the arched structure were untypical for the 19th century public, not just for their materiality but for the sheer scale of the composition. The trusses were smaller at the base and enlarged in height, which, coupled with the use of a glass ceiling accentuated a vanishing and luminous effect.

Due to its unusual dimensions, it was suited for several different uses; it housed a full size replica of a ship in 1900, hosted a circus in 1901, a velodrome in 1903. It also hosted battalions, police troops and cavalry regiments in 1906.

2 Peters, Building the nineteenth century

The Galerie des Machines was finally demolished in 1910 subjected to an urban decision, in order to open up the perspective of the Champ de Mars since apparently, it spoiled the view of the church of Les Invalides.

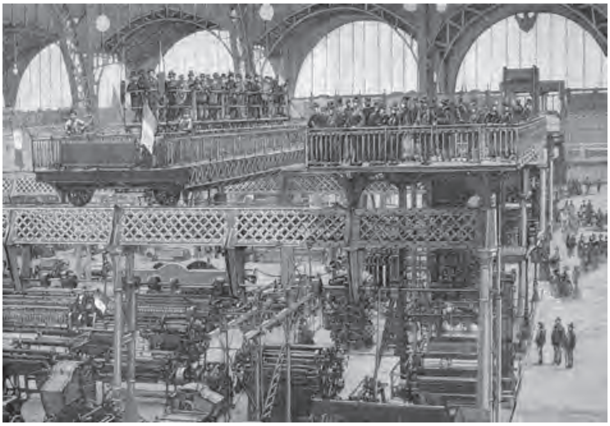
The legacy of the Galerie however spanned far greater than its brief lifetime. The tri-articulated arch system was popularized and its use was expanded, mostly in train stations thanks to the similarity of both typologies. Javier Cimadevilla[3] traced several examples that followed its influence both historically and geographically, like the Reading Station by F.H. Kimball (Philadelphia 1891), the Broad Street Station by Wilson Bros. (Philadelphia, 1894) and the Mercado de Ganado by Tony Garnier (Lyon, 1909), all of them with somewhat smaller spans than the Galerie.

In terms of computational design strategies, the Galerie's approach to structural design combined analytical thinking as well as aesthetical decisions. Thanks to Karl Culmann's 'graphic statics' method, the engineers could calculate with precision each structural member, leaving a certain part of the arch´s shape to an aesthetic choice. With the use of parametric design tools and structural calculation software is it possible to test several alternatives and verify them statically before committing to a solution. Moreover, the use of more complex tools, like genetic algorithms and finite element analysis can fully automate the design cycle, from shape definition and static analysis to final testing, in an autonomous form finding process.

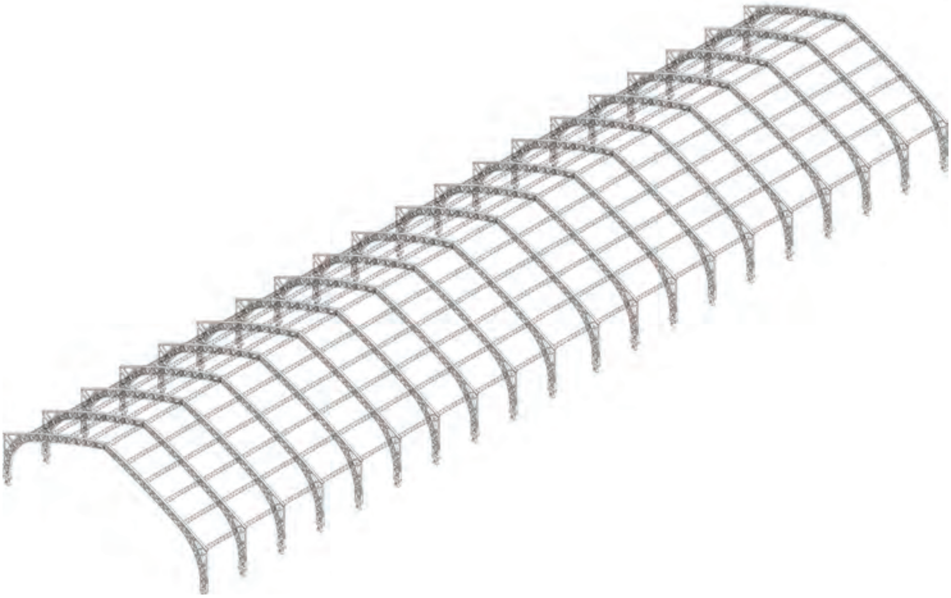
The Galerie´s arch system is a complex assembly composed with upper and bottom multi-segment chords, with diagonal elements and saltire crosses that vary in height in order to adjust to them. An interesting design strategy could be defined through a parametric model that links these elements to each other, and automatically adjusts to an arch shape defined architecturally. Simultaneously, the shape of the arch could be defined by static analysis, like the anti-funicular curve for example, or altered by punctual distortions and still be readjusted to ensure its structural performance. Some explorations on this typology and its design strategy were carried out and can be found in the Experiment chapters.

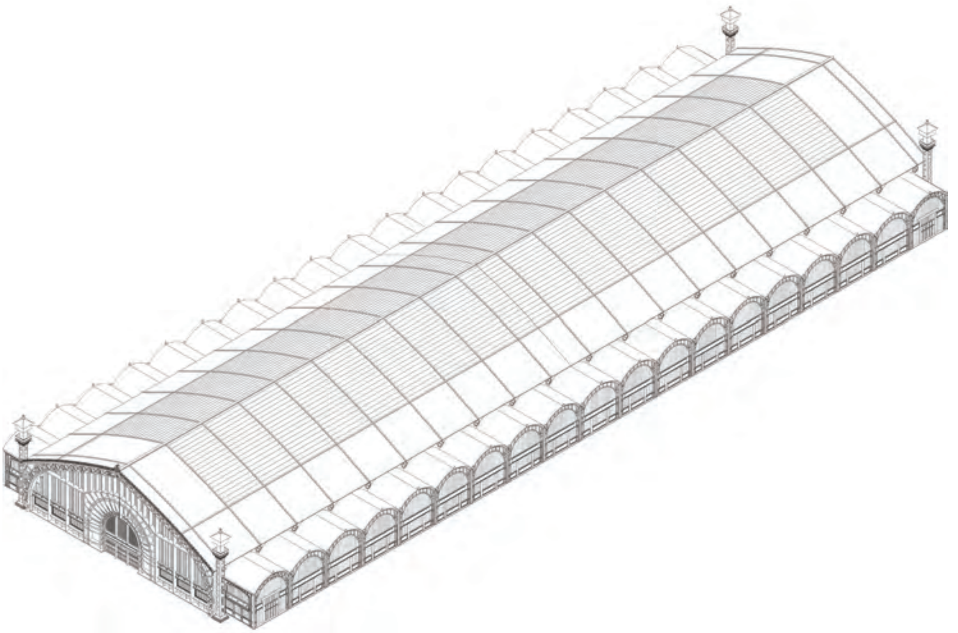
The Palais des Machines masterfully articulated both approaches to the design of a large span hall, a structural and an architectural one. The digitalization of this strategy may become a powerful design tool, allowing the designer to explore alternatives in an iterative process linking functional, material, structural and aesthetical parameters.

3 Javier Estévez Cimadevila and Isaac López César, "La Galería de las Máquinas de 1889. Reflexiones histórico-estructurales," VLC arquitectura. Research Journal 2, no. 2 (2015), https://doi.org/10.4995/vlc.2015.3598

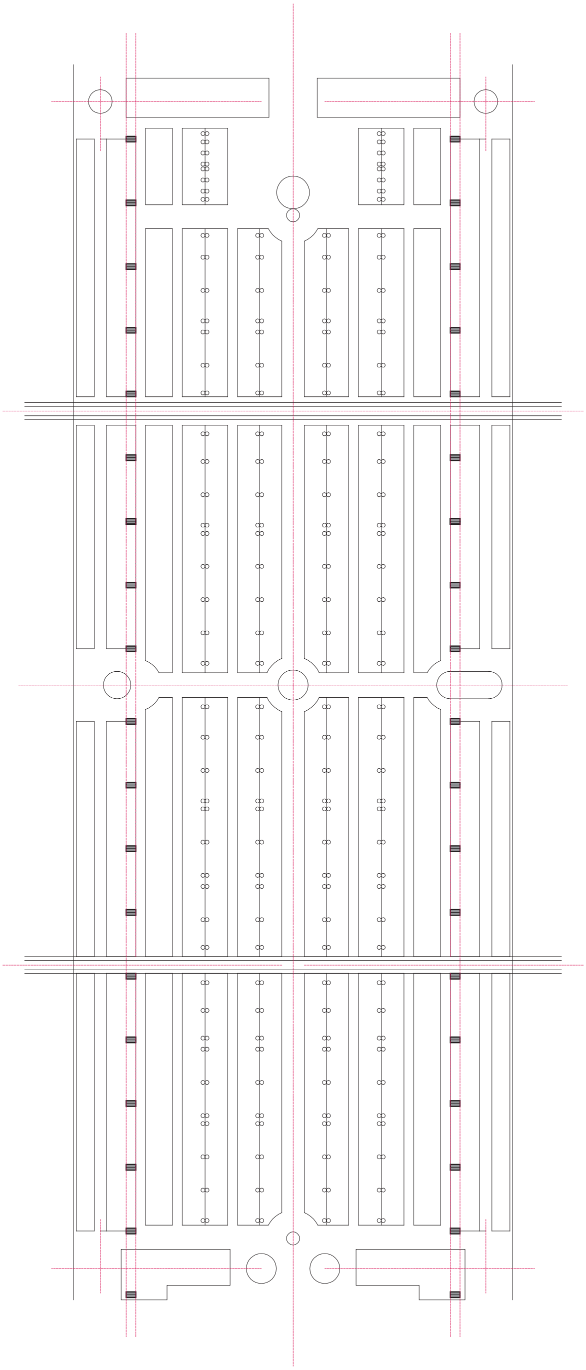


10-4 Machine hall and its exhibition pieces.
10-5 Machine and hall. A mobile platform could travel the entire exhibition carrying dozens of espectators each time to explore the hall from another perspective.

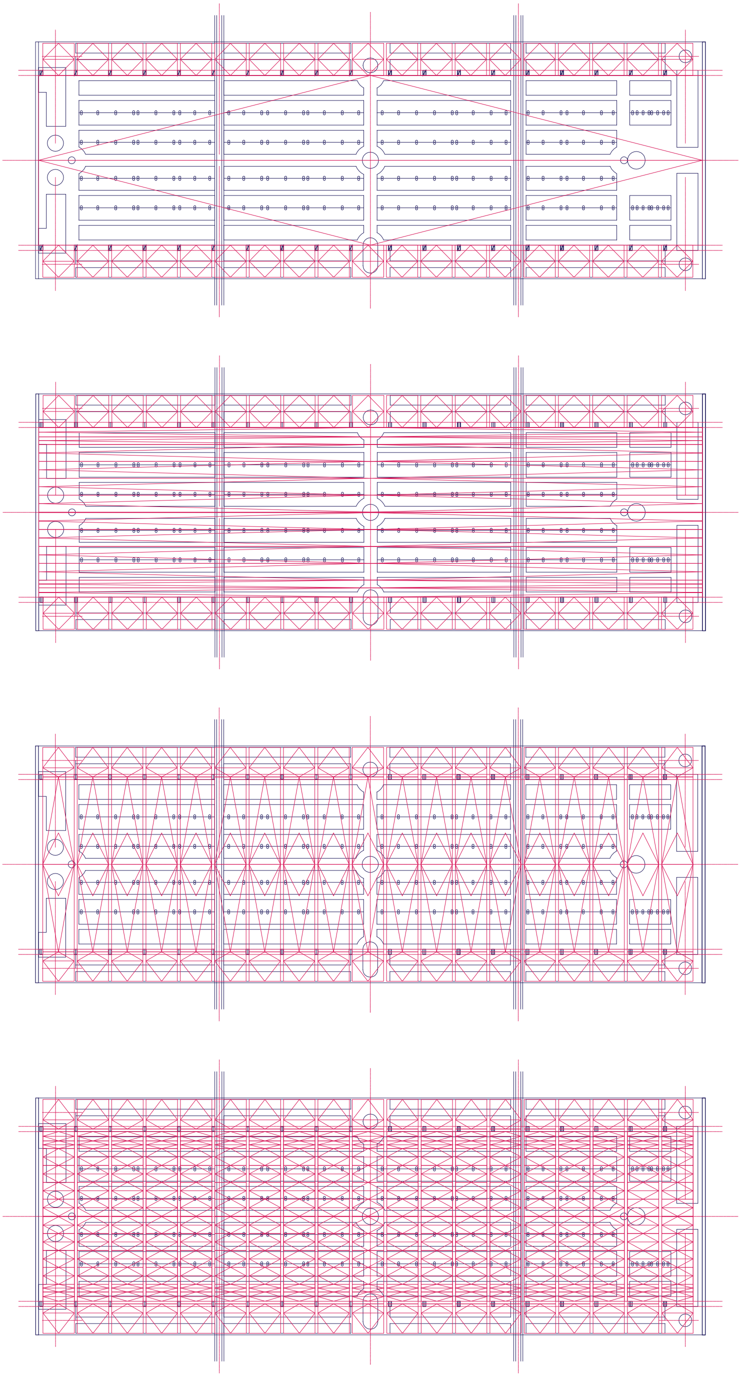




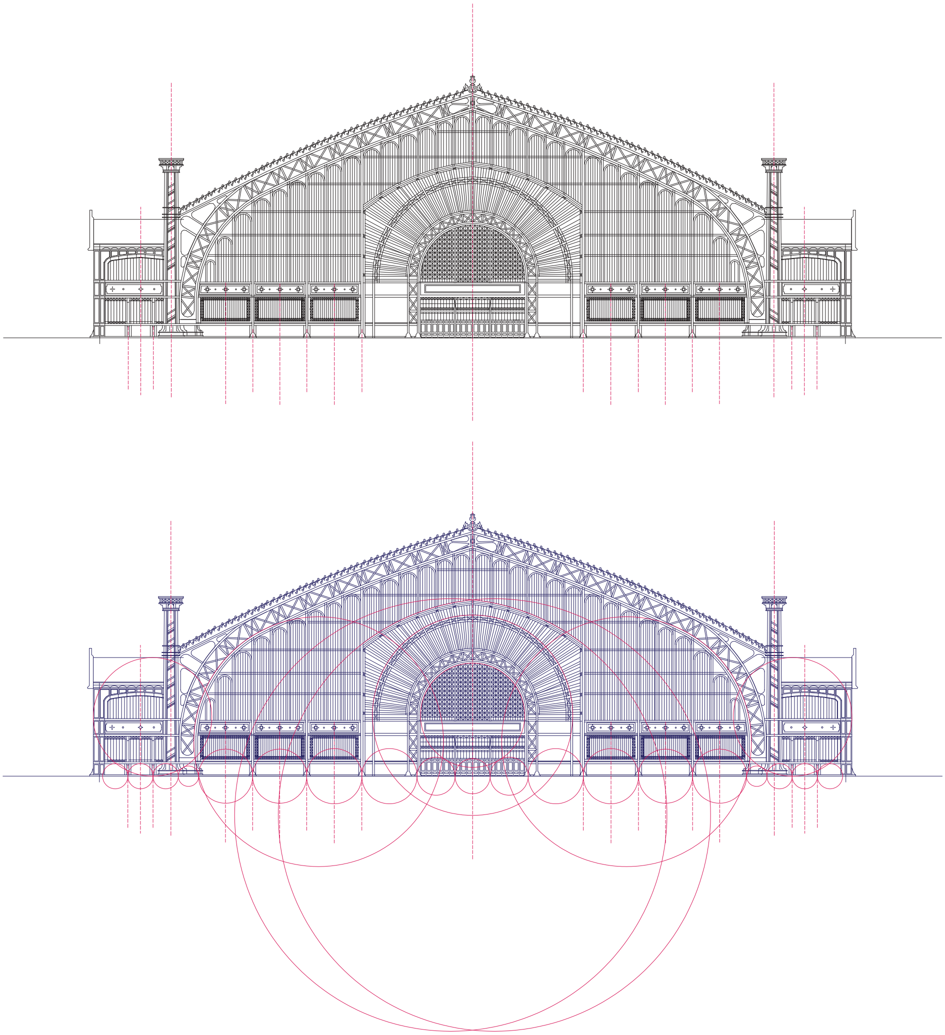
10-6 Isometric view of the Gallerie structure.
10-7 Isometric view of the Gallerie including lateral spaces.



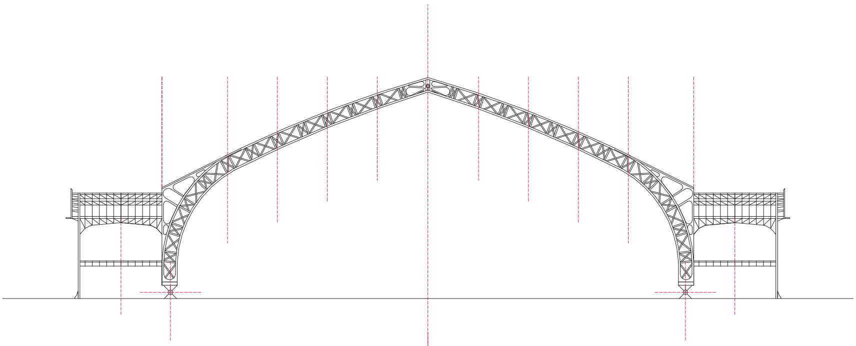
10-8 Galerie des Machines (F. Dutert) Ground floor plan (according to Handbuch der Architektur and Engineering Magazine)

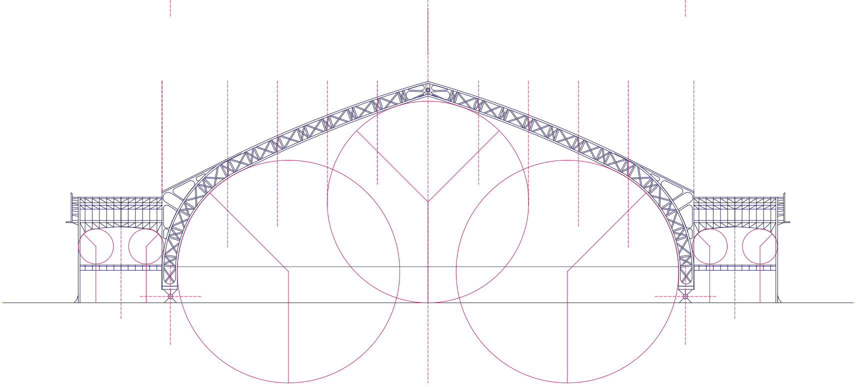


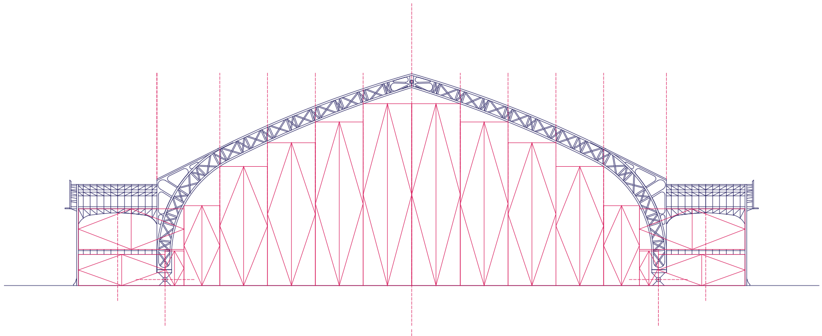
10-9 Spatial flow diagrams: From top to bottom: Main exhibition space and lateral exposition areas, Subdivision according the galery´s substructure projection, Subdivision aligned with main structure and Subdivision of truss partition projection.

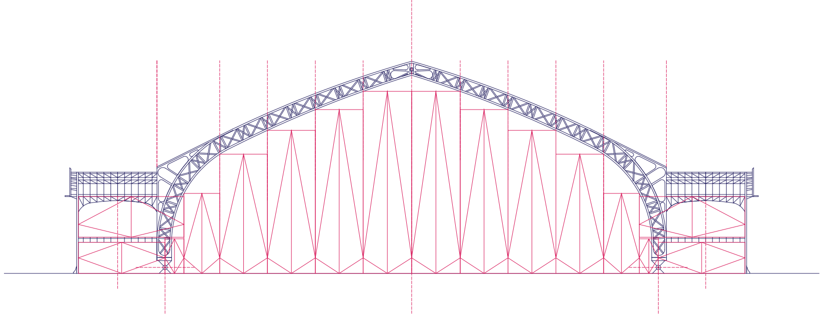


10-10 Front view (according to Engineering Magazine)
Bottom: Geometry, modulation and curve analysis, symmetrical axes and arch openings on front view.









10-11 Section (according to Engineering Magazine)
10-12 Geometry, modulation and curve analysis, symmetrical axes and arch proportions on section view.
10-13 Spatial modulation aligned by main structural segments.

10-14 Representations of volume voids. Main exhibition space and lateral galleries.

CHAPTER 11

- *Argentinian Pavilion*

In order to celebrate the first century of the Bastille, France invited countries from all across the globe to participate in the events of the International Exhibition. The most important countries placed their pavilions on the Champ du Mars, while the less significant ones were at L'esplanade des Invalides. Some authors note that these last group mostly exemplified traditional, even vernacular 'styles' (like Asian or Hispanic-American) at the same time as the main countries showcased the new and trendy styles, exemplified in the use of iron and glass.

Gustavo Brandariz describes the role of international exhibitions in the architectural debate:

'... those exhibitions were resonating vehicles of the new ideas about itinerant space, new meanings of perspective and new relations between architecture, object, graphics and signage design. Moreover, since architecture is not only a visual spectacle but also materiality on space, it is also interesting that we can also identify on its new polemic ideas about the relationship between solid and fragile, permanent and demountable construction, and between inherited building processes and novel montage procedures.'[1]

The case of the Argentinian Pavilion began as the first group showcasing traditional construction traditions, since the French organizers suggested that the Latin-American countries should share one pavilion. The Argentinian officials refused the proposal and demanded 6000 square meters for a pavilion of their own, but were offered 1600 square meters. The final placement of the Argentinian Pavilion right next to the Eiffel Tower may respond to the audacity of the request, in an effort to minimize its impact on the public.

Argentina experienced an economic boom mainly thanks to its commercial and financial ties to Europe, coupled with a strong immigration influx. The country decided to leave a testimony of this temporary opulence on the pavilion, calling a project completion in Paris itself. The construction was finally awarded to the second place, by Albert Ballu, who collaborated with several artists and sculptors for the design of the two-storey pavilion.

As a former École des Beaux-Arts student and Prix de Rome winner, Ballu was fully committed with its time and faithfully captured its spirit, reflecting the French taste for end of the century Eclecticism. It is also fair to state, that Ballu did not follow these stylistic canons to the letter, by fully adopting a progressive iron and glass construction technologies.

By the end of the century, iron and steel products from European foundries

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1 Gustavo Brandariz, "Argentina. Arquitectura para un siglo de exposiciones 1829 a 1933," Anales del IAA FADU UBA, http://www.iaa.fadu.uba.ar/ojs/index.php/anales/article/view/148/136 - translation by the author.

11-1 Argentinian Pavilion at the Paris International Exhibition (A. Ballu). Source: Archivo General de la Nacion.
11-2 Access to the Argentinian Pavilion.

were available worldwide and they were particularly attractive in terms of logistics; iron structures were easily mounted and demounted, which combined with other prefabrication techniques allowed to move the buildings when the exhibition was finished. The Argentinian and Chilean pavilions are an admirable example of these possibilities as they both returned and were rebuilt in South America afterwards.

From the competition rules, the program proposed an exhibition building to be demounted and transported to Buenos Aires, hence the choice for the steel structure fixed with screws, filled with tiles, ceramics, mosaics, porcelain and glass. Colored glass and polychrome ceramics covered the entire building, from the base to the domes. Its thirty-meter dome was crowned with a yellow 'Sun', referring to the national flag, while the four facades were decorated with Argentinian coat of arms manufactured in ceramic.

The interior was divided in two stories (doubling the 1600 square meters assigned by the organizers) was entirely decorated by paintings and sculptures. The main dome's pendentives were ornamented with golden plaster sculptures representing the four main pillars of the Argentinian nation (or at least the most important ones for the ruling class); Science, Art, Agriculture and Commerce and Industry.

The pavilion's architecture of iron and glass (no longer hidden behind masonry or plaster), the interplay of lightweight construction and natural light and the absence of traditional materials earned several prizes for the building, among them, the prize for the best foreign pavilion.

Once the Paris exhibition was over, the pavilion was dismantled and packed in order to be sold, most likely due to the financial problems in Argentina at that time. Eventually, the government organized the shipment to Buenos Aires, where it arrived in 1891. According to the ship's captain, the biggest crate was discarded to the sea because of a severe storm, losing many painted panels in the incident. The remaining 6000 packages and crates totaling 1690 tons arrived in Buenos Aires.

Two years later the pavilion was assembled as a concert and theater venue, however it turned to be financially unsuccessful, abandoning the construction until 1898, when it was commissioned for the Exposición Nacional (National exhibition). Once again, the pavilion was put to its original use, the exhibition of artistic pieces, but after the event was finished, it remained without a purpose until 1910, when it hosted another art exhibition because of the commemoration of the revolution's centenary.

The Museo de Bellas Artes (Fine arts museum) ultimately commissioned it to its final use; hosting the museum's collection after some renovations, which were not sufficient in order to adequate the building to its new use and location. Leaks and heating problems were a constant problem, often deteriorating the exhibits and tapestries. Nevertheless, the building remained under the Museum's administration for more than 20 years, being dismantled in 1933.

"A curious dichotomic expression was born that way in which the architect 'dressed' the engineered skeleton, in a perfect disagreement and divorce between function and form."[2]

The bare metal structure divided in three aisles give the pavilion the appearance of an engineering solution applied to a typical 19th century program like factories, warehouses and magazines. However, unlike these typologies, Ballu's pavilion is crossed by a short transept from which intersection is crowned by the large 30m dome articulating the access and the stair body. This way, the three-aisle warehouse and the three-aisle central transept configure three nine-square bodies, one central and two laterals.

The central body supports a large dome on its center and four small domes on each corner. These small domes and their bases also articulate a typical problem of these typologies; by articulating the main gabled roof and the three gabled roofs from the transept. A series of towers or minarets accentuate this three-way division on the façade, while four larger towers are on the corners of the building, crowned by large cast iron sculptures.

Aside from stylistic decisions, the building construction system is rational and systemic. The lessons learned from the Crystal Palace are artfully applied on this example, adding even more variation by adjoining domes, loggias on the second floor and the ornamented towers. The building is divided on three main bodies, their facades are also divided by three matching the steel structure, and then again, each façade panel is once again divided by three clearly distinguished by the structure of the loggia. Once more, the symmetry of each building block is accentuated by balconies on the laterals and larger arches and sculptures on the central one.

"It does not matter that the Argentine Pavilion had a series of temporary concessions –copper domes, cards, coat of arms, loggias, balustered columns, etc. – and would result inadequate for its assigned functions. It should be conserved as a noteworthy example of a period of rebellion and exploration, as a symbol of vigor and distant and envious strength, as a milestone in the history of our architectural taste. Its destruction was an irremediable mistake, as many of other architectonical monuments of our country, disappeared by a misunderstood sense of progress."[3]

The pavilion's paneling and progressive subdivision of surfaces can be easily translated into a digital model. Surface subdivision is also a common tool in contemporary digital design tools, furthermore, it is also a powerful morphological strategy. Parametric tools like Rhinoceros Grasshopper and Paneling tools make use of these strategies, allowing the designer to apply different elements like tiles or panels to each subdivided surface.

The Argentinian Pavilion is an interesting approach to a systemic design strategy; every system has its dependent sub-system, governed by a set of general as well as local rules. For example, the entire building is divided on three large blocks, which in turn are also divided by three aisles, while the trusses are also divided by three, and so on. This way, tripartite division is a general rule applied to almost all topological levels independent of scale.

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2 Mario Buschiazzo, "El Siglo XIX en la Argentina. El Pabellon Argentino." Nuestra Arquitectura, no. 420 (1964). Translation by the author.

3 Buschiazzo, "El Siglo XIX en la Argentina. El Pabellon Argentino."

11-3 First floor. Interior virw of the exhibition spaces. (Fine Arts Museum in Buenos Aires)
11-4 First floor. Interior virw of the exhibition spaces. (Fine Arts Museum in Buenos Aires)

Symmetry involves yet another regulation, also applied to almost all axes and elements.

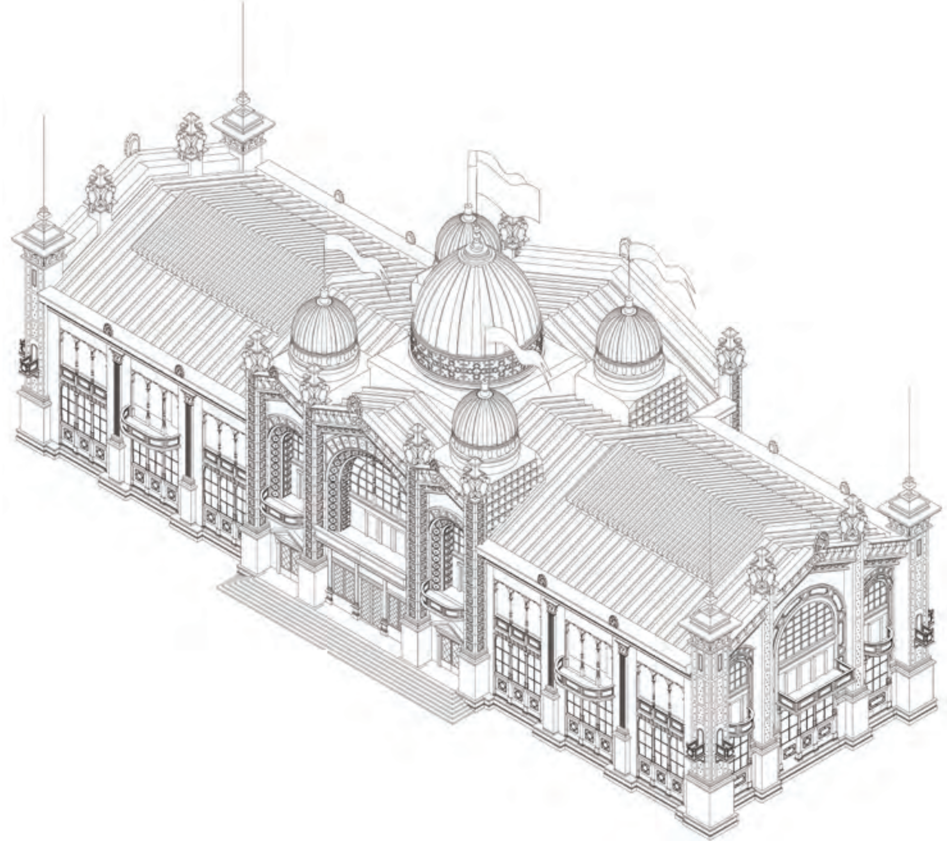
Centrality however, is dependent from a global set of rules that are applied locally, only influencing particular elements on particular instances of the building, for example, the central naves are taller than the lateral ones, and are decorated with arches (which in turn are also subdivided). As discussed previously, this systemic approach to design was also related to the advancement building technologies as much as a novel mindset from the designers. On this regard, the Argentinian Pavilion is of interest for this research particularly because it shows the relative high levels of complexity (in terms of ornamentation and technique) that these strategies can deliver with a moderately low quantity (and complexity) of rules.

Needless to say, the sheer variety and possibilities that such strategies provide are on this case limited by the building's typology, nevertheless it is merely not limited to it.

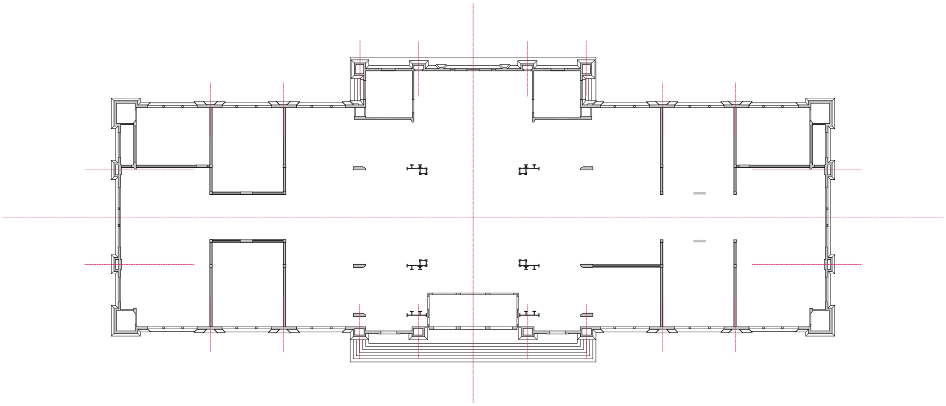
The importance of these strategies lies in the fact that they allow the translation of their design rules to a digital parametric model. Each parameter is a value governed by each rule, and simultaneously, different parameters can be tied to one another in order to create dependencies between them. For example, one parameter like the height of a truss can be connected to the height of a window. This way, once these rules are 'digitized' the designer can explore different parameter combinations and explore large amounts of solutions, each and every one of them related to the other, as they depend on the exact set of rules, but with different base parameters.

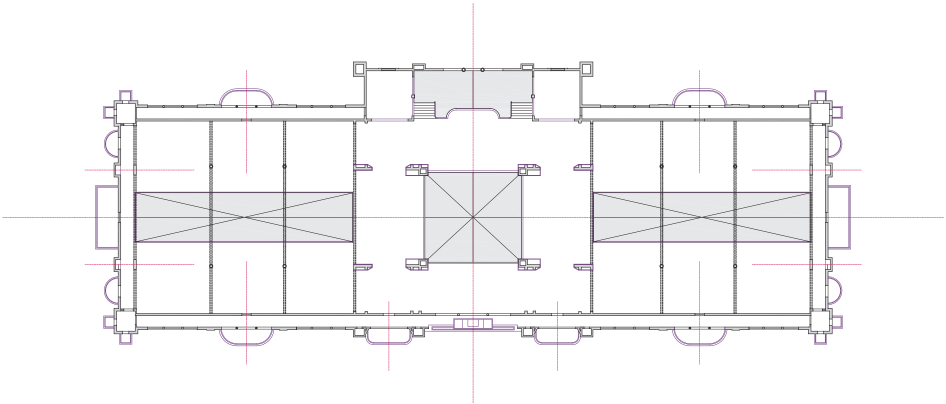
The design strategy adopted by Ballu could also be understood through these concepts, proving that associative, methodical thinking through structural and formal constrains is still a powerful and flexible tool that we should not abandon -nor merely reproduce- acritically.

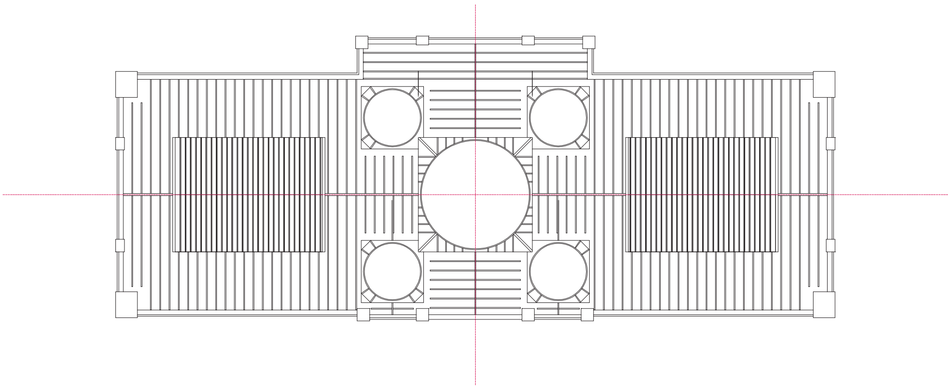
11-5 Birds-eye view of the Argentinean Pavilion reassembled in Buenos Aires, hosting the Fine Arts collection.
11-6 Perspective view of the Argentinean Pavilion reassembled in the Plaza Retiro, Buenos Aires. On the background, the Plaza Hotel by A. Zucker.



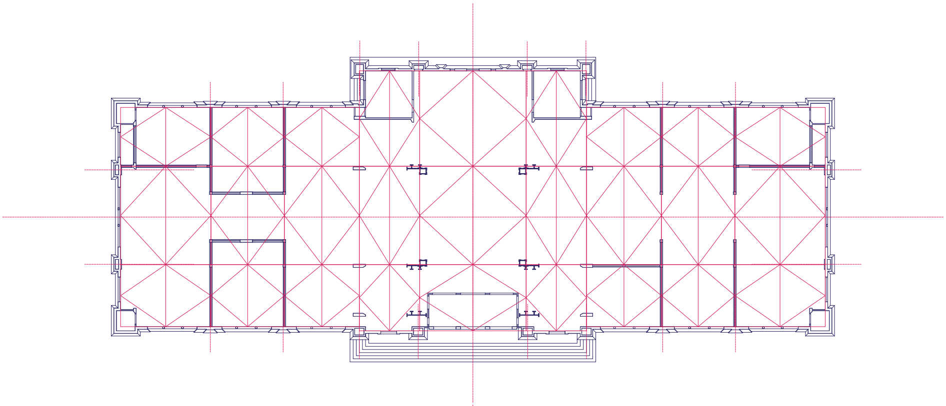
11-7 Argentinean Pavilion in Paris. Isometric view.

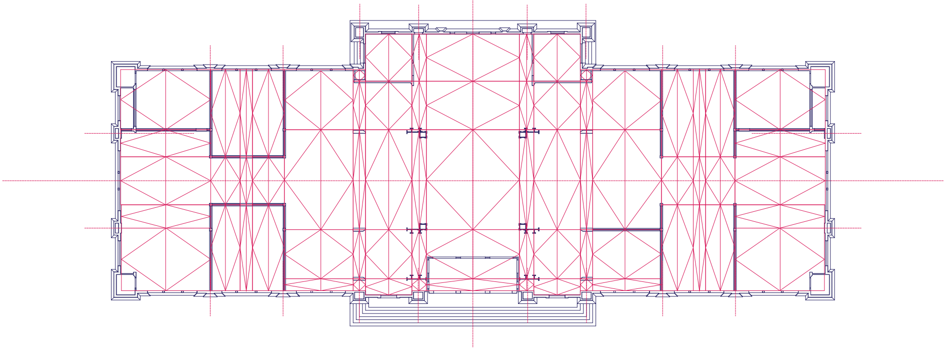


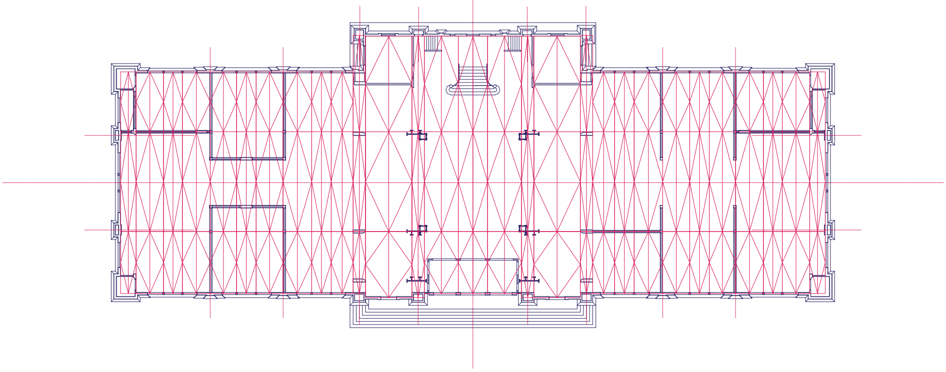




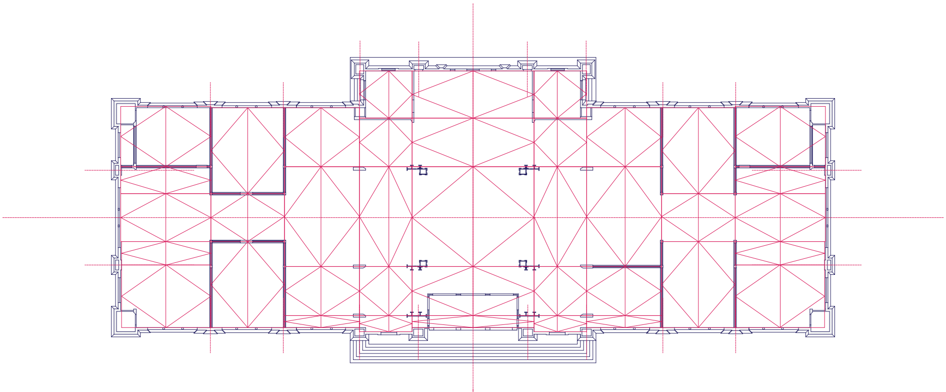
11-8 Argentinean Pavilion in Paris (A. Ballu) Ground floor plan (according to CEDIAP Archives)
11-9 First floor plan (according to CEDIAP Archives)
11-10 Roof plan view (according to CEDIAP Archives and other sources)

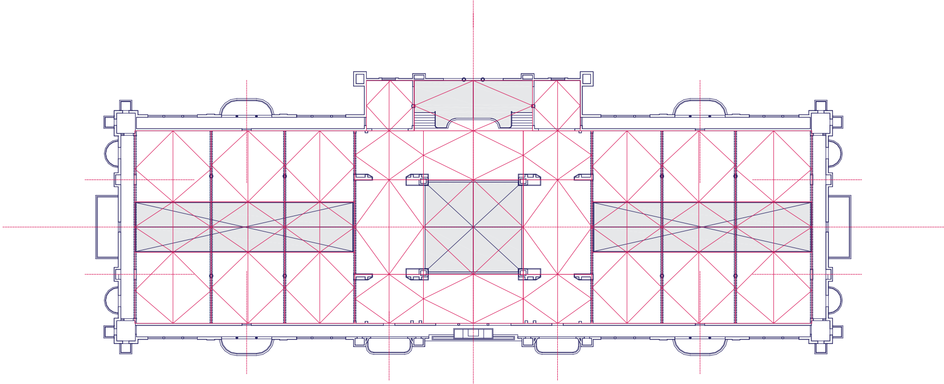


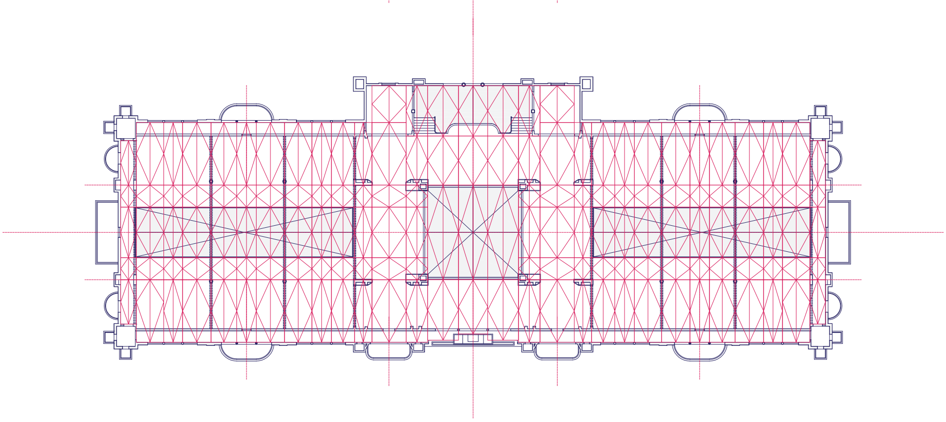




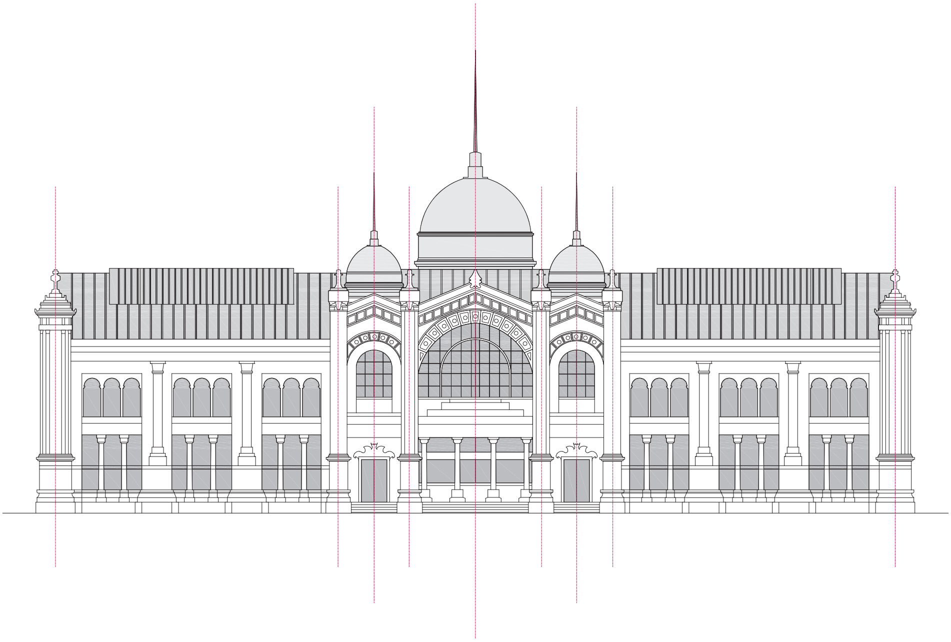
11-11 Structure and spatial flow diagrams. Rhythm alterations from structure and substructure subdivisions. The pavilion is divided in a main body and two slightly receded laterals expressed in the façade. The structure divides each section in nine irregular quadrants. On the central body, the central and each corner quadrant corresponds to a dome.
11-12 The subdivisions do not correspond to the original nine-quadrant diagram but to the dimensions of the structural members distributed inside the building and their role defining spatial relationships.
11-13 Variation of the nine-quadrant grid altered by subdivision in façade. Each original quadrant is re-divided again in three parts corresponding to the loggia and window divisions.



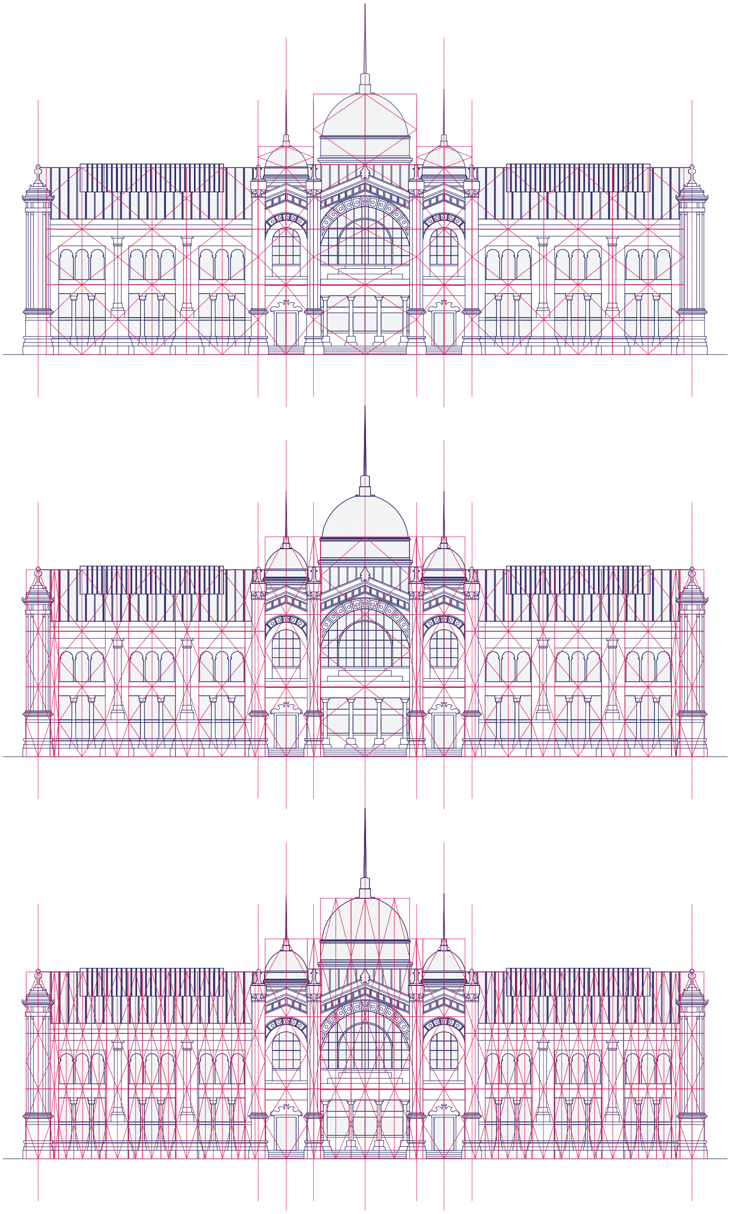




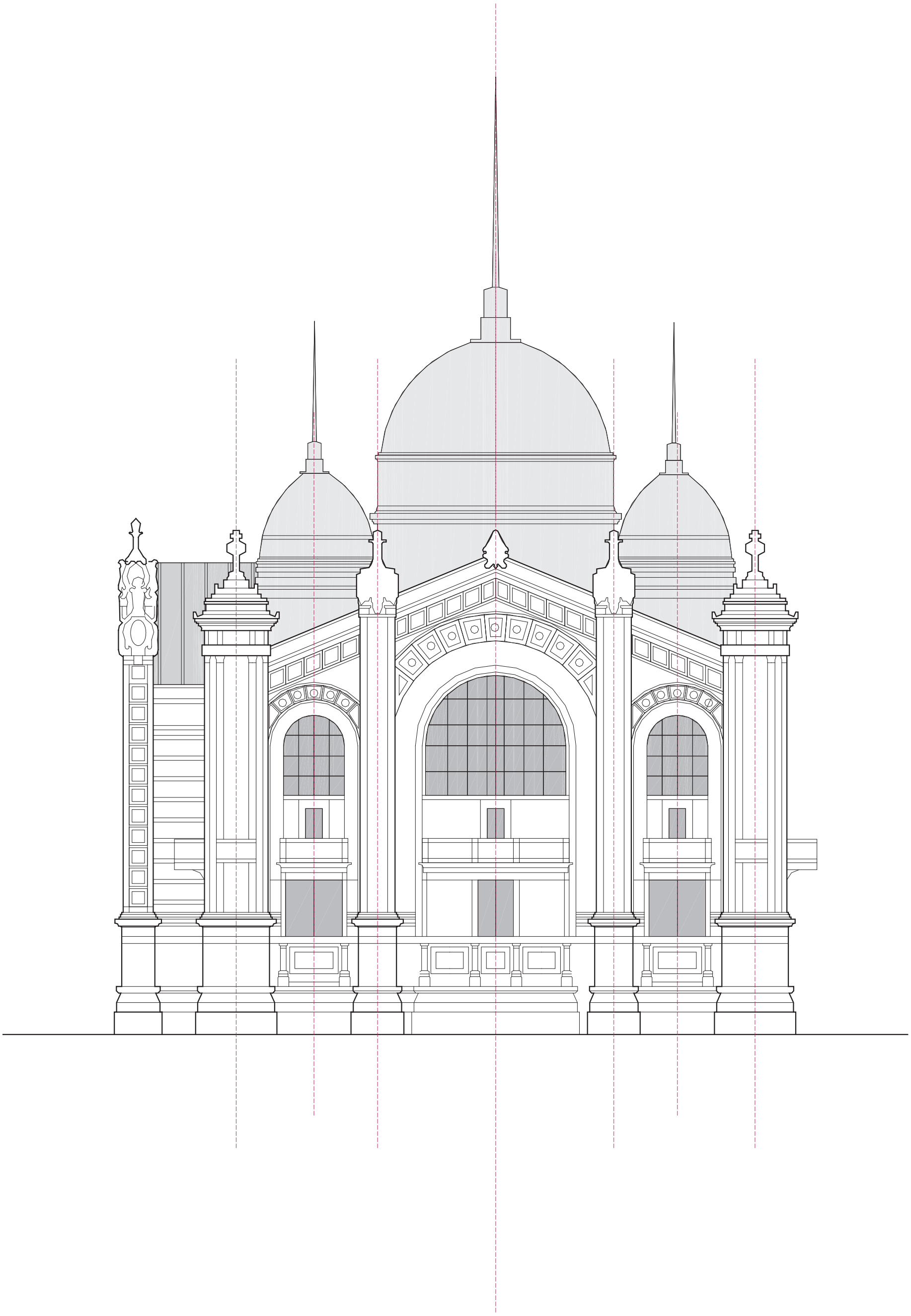
11-14 The pavilion is divided in a main body and two slightly receded laterals expressed in the façade. The structure divides each section in nine irregular quadrants. The staircase body, though attached to the back of the central body is slightly receded on the sides and is also divided on three quadrants. The middle quadrants of each body are perforated generating galleries over the ground floor. On the central body, the central and each corner quadrant corresponds to a dome.
11-15 / 11-16 Variation of the nine-quadrant grid altered by subdivision in façade. Each original quadrant is re-divided again in three parts corresponding to the loggia and window divisions. The central row of quadrants is also subdivided in three as the gallery over the ground floor is also defined by a structural line.



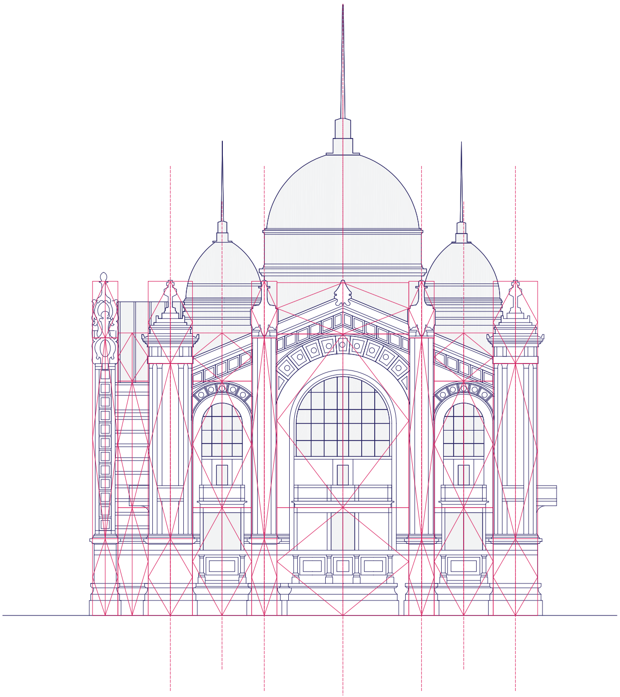
11-17 Front view (according to CEDIAP Archives)

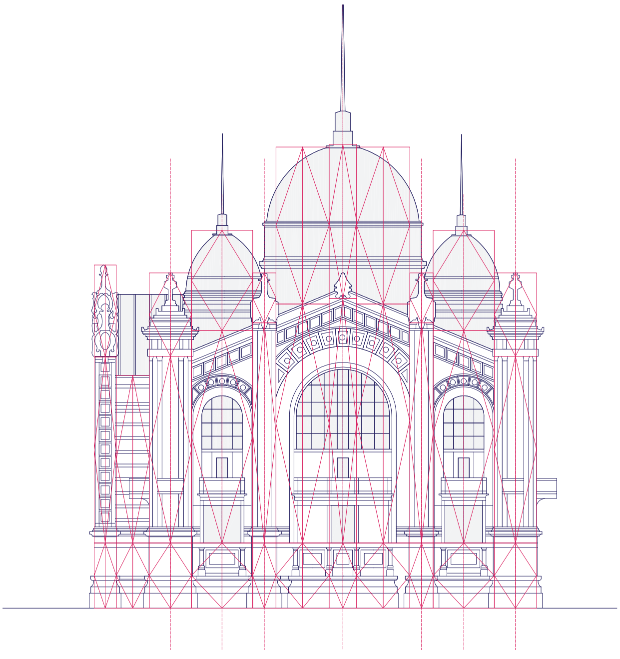


11-18 Façade organization and structure diagrams. Rhythm alterations from structure and substructure subdivisions. The pavilion is divided in a main body and two slightly receded laterals expressed in the façade. The structure divides each section in nine irregular quadrants; the ground floor, the first floor and the roof structure.
11-19 The structural rhythm of solids (supports) and voids (windows) organizes the original tripartite subdivision adding ´thickness´ to its limits.
11-20 The structural rhythm of solids and voids organizes the original tripartite subdivision adding ´thickness´ to its limits. Each central quadrant is re-divided again in three parts corresponding to the loggia and window divisions.

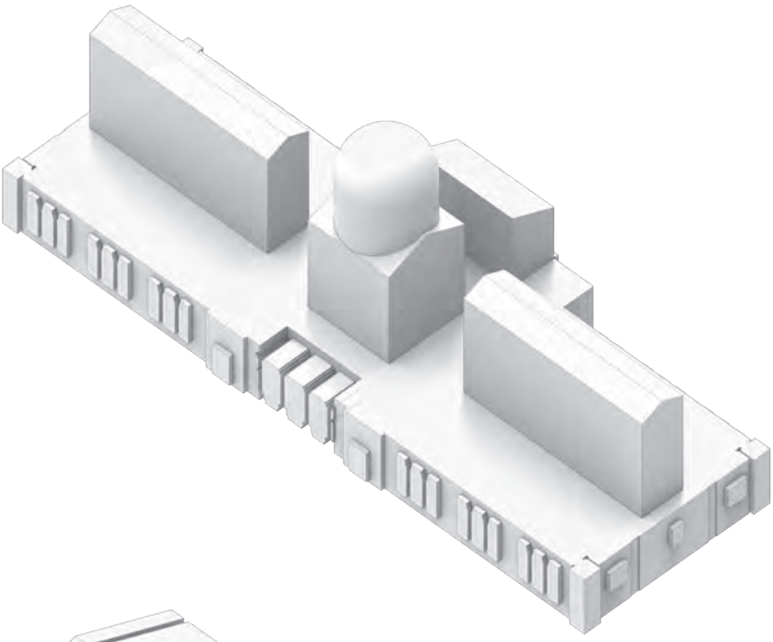


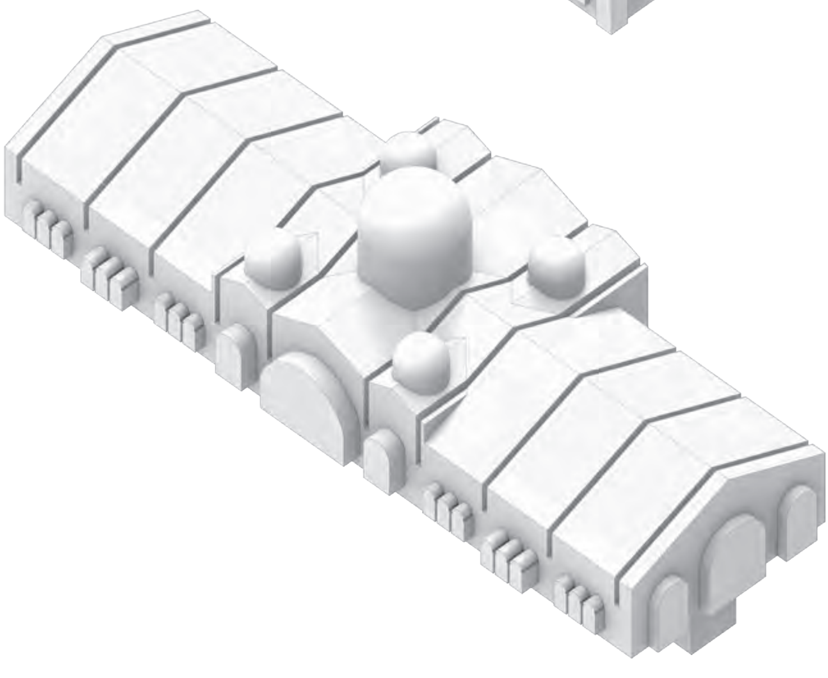
11-21 Side view (according to CEDIAP Archives and other sources)





11-22 Façade organization and structure diagrams. Rhythm alterations from structure and substructure subdivisions. The pavilion is divided in a main nave and two laterals expressed in the side façade. Minarets are added at the end of each segment. The staircase body protrudes disbalancing the otherwise symmetrical organization.
11-23 Tripartite segmentation in height; base, main body and domes.





11-24 Representation of volume void of the ground floor flowing towards the first floor, roof and domes. The galleries also intend to expand the space virtually through the continuation of the ceiling generating semi-covered loggias.
11-25 Representation of volume void of the first floor flowing towards the roof and domes. The galleries also intend to expand the space virtually through the continuation of the ceiling generating semi-covered loggia-type extensions.

CHAPTER 12

- *Porte Monumentale*

In order to celebrate the first century of the Bastille, France invited countries from all across the globe to participate in the events of the International Exhibition. The most important countries placed their pavilions on the Champ du Mars, while the less significant ones were at L'esplanade des Invalides. Some authors note that these last group mostly exemplified traditional, even vernacular 'styles' (like Asian or Hispanic-American) at the same time as the main countries showcased the new and trendy styles, exemplified in the use of iron and glass.

Gustavo Brandariz describes the role of international exhibitions in the architectural debate:

'... those exhibitions were resonating vehicles of the new ideas about itinerant space, new meanings of perspective and new relations between architecture, object, graphics and signage design. Moreover, since architecture is not only a visual spectacle but also materiality on space, it is also interesting that we can also identify on its new polemic ideas about the relationship between solid and fragile, permanent and demountable construction, and between inherited building processes and novel montage procedures.'[1]

The case of the Argentinian Pavilion began as the first group showcasing traditional construction traditions, since the French organizers suggested that the Latin-American countries should share one pavilion. The Argentinian officials refused the proposal and demanded 6000 square meters for a pavilion of their own, but were offered 1600 square meters. The final placement of the Argentinian Pavilion right next to the Eiffel Tower may respond to the audacity of the request, in an effort to minimize its impact on the public.

Argentina experienced an economic boom mainly thanks to its commercial and financial ties to Europe, coupled with a strong immigration influx. The country decided to leave a testimony of this temporary opulence on the pavilion, calling a project completion in Paris itself. The construction was finally awarded to the second place, by Albert Ballu, who collaborated with several artists and sculptors for the design of the two-storey pavilion.

As a former École des Beaux-Arts student and Prix de Rome winner, Ballu was fully committed with its time and faithfully captured its spirit, reflecting the French taste for end of the century Eclecticism. It is also fair to state, that Ballu did not follow these stylistic canons to the letter, by fully adopting a progressive iron and glass construction technologies.

By the end of the century, iron and steel products from European foundries

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1 Gustavo Brandariz, "Argentina. Arquitectura para un siglo de exposiciones 1829 a 1933," Anales del IAA FADU UBA, http://www.iaa.fadu.uba.ar/ojs/index.php/anales/article/view/148/136 - translation by the author.

12-1 Porte Monumentale (R. Binet) at the International Exhibition in Paris (1900) were available worldwide and they were particularly attractive in terms of logistics; iron structures were easily mounted and demounted, which combined with other prefabrication techniques allowed to move the buildings when the exhibition was finished. The Argentinian and Chilean pavilions are an admirable example of these possibilities as they both returned and were rebuilt in South America afterwards.

From the competition rules, the program proposed an exhibition building to be demounted and transported to Buenos Aires, hence the choice for the steel structure fixed with screws, filled with tiles, ceramics, mosaics, porcelain and glass. Colored glass and polychrome ceramics covered the entire building, from the base to the domes. Its thirty-meter dome was crowned with a yellow 'Sun', referring to the national flag, while the four facades were decorated with Argentinian coat of arms manufactured in ceramic.

The interior was divided in two stories (doubling the 1600 square meters assigned by the organizers) was entirely decorated by paintings and sculptures. The main dome's pendentives were ornamented with golden plaster sculptures representing the four main pillars of the Argentinian nation (or at least the most important ones for the ruling class); Science, Art, Agriculture and Commerce and Industry.

The pavilion's architecture of iron and glass (no longer hidden behind masonry or plaster), the interplay of lightweight construction and natural light and the absence of traditional materials earned several prizes for the building, among them, the prize for the best foreign pavilion.

Once the Paris exhibition was over, the pavilion was dismantled and packed in order to be sold, most likely due to the financial problems in Argentina at that time. Eventually, the government organized the shipment to Buenos Aires, where it arrived in 1891. According to the ship's captain, the biggest crate was discarded to the sea because of a severe storm, losing many painted panels in the incident. The remaining 6000 packages and crates totaling 1690 tons arrived in Buenos Aires.

Two years later the pavilion was assembled as a concert and theater venue, however it turned to be financially unsuccessful, abandoning the construction until 1898, when it was commissioned for the Exposición Nacional (National exhibition). Once again, the pavilion was put to its original use, the exhibition of artistic pieces, but after the event was finished, it remained without a purpose until 1910, when it hosted another art exhibition because of the commemoration of the revolution's centenary.

The Museo de Bellas Artes (Fine arts museum) ultimately commissioned it to its final use; hosting the museum's collection after some renovations, which were not sufficient in order to adequate the building to its new use and location. Leaks and heating problems were a constant problem, often deteriorating the exhibits and tapestries. Nevertheless, the building remained under the Museum's administration for more than 20 years, being dismantled in 1933.

"A curious dichotomic expression was born that way in which the architect 'dressed' the engineered skeleton, in a perfect disagreement and divorce

12-2 Exterior view of the Porte Monumentale.
12-3 Access view to the exhibition through the portal

between function and form."[2]

The bare metal structure divided in three aisles give the pavilion the appearance of an engineering solution applied to a typical 19th century program like factories, warehouses and magazines. However, unlike these typologies, Ballu's pavilion is crossed by a short transept from which intersection is crowned by the large 30m dome articulating the access and the stair body. This way, the three-aisle warehouse and the three-aisle central transept configure three nine-square bodies, one central and two laterals.

The central body supports a large dome on its center and four small domes on each corner. These small domes and their bases also articulate a typical problem of these typologies; by articulating the main gabled roof and the three gabled roofs from the transept. A series of towers or minarets accentuate this three-way division on the façade, while four larger towers are on the corners of the building, crowned by large cast iron sculptures.

Aside from stylistic decisions, the building construction system is rational and systemic. The lessons learned from the Crystal Palace are artfully applied on this example, adding even more variation by adjoining domes, loggias on the second floor and the ornamented towers. The building is divided on three main bodies, their facades are also divided by three matching the steel structure, and then again, each façade panel is once again divided by three clearly distinguished by the structure of the loggia. Once more, the symmetry of each building block is accentuated by balconies on the laterals and larger arches and sculptures on the central one.

"It does not matter that the Argentine Pavilion had a series of temporary concessions –copper domes, cards, coat of arms, loggias, balustered columns, etc. – and would result inadequate for its assigned functions. It should be conserved as a noteworthy example of a period of rebellion and exploration, as a symbol of vigor and distant and envious strength, as a milestone in the history of our architectural taste. Its destruction was an irremediable mistake, as many of other architectonical monuments of our country, disappeared by a misunderstood sense of progress."[3]

The pavilion's paneling and progressive subdivision of surfaces can be easily translated into a digital model. Surface subdivision is also a common tool in contemporary digital design tools, furthermore, it is also a powerful morphological strategy. Parametric tools like Rhinoceros Grasshopper and Paneling tools make use of these strategies, allowing the designer to apply different elements like tiles or panels to each subdivided surface.

The Argentinian Pavilion is an interesting approach to a systemic design strategy; every system has its dependent sub-system, governed by a set of general as well as local rules. For example, the entire building is divided on three large blocks, which in turn are also divided by three aisles, while the trusses are also divided by three, and so on. This way, tripartite division is a general rule applied to almost all topological levels independent of scale.

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2 Mario Buschiazzo, "El Siglo XIX en la Argentina. El Pabellon Argentino." Nuestra Arquitectura, no. 420 (1964). Translation by the author.

3 Buschiazzo, "El Siglo XIX en la Argentina. El Pabellon Argentino."

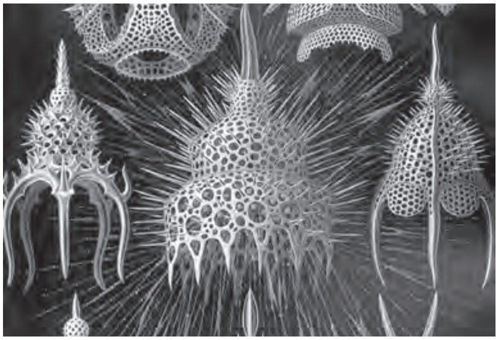
Symmetry involves yet another regulation, also applied to almost all axes and elements.

Centrality however, is dependent from a global set of rules that are applied locally, only influencing particular elements on particular instances of the building, for example, the central naves are taller than the lateral ones, and are decorated with arches (which in turn are also subdivided). As discussed previously, this systemic approach to design was also related to the advancement building technologies as much as a novel mindset from the designers. On this regard, the Argentinian Pavilion is of interest for this research particularly because it shows the relative high levels of complexity (in terms of ornamentation and technique) that these strategies can deliver with a moderately low quantity (and complexity) of rules.

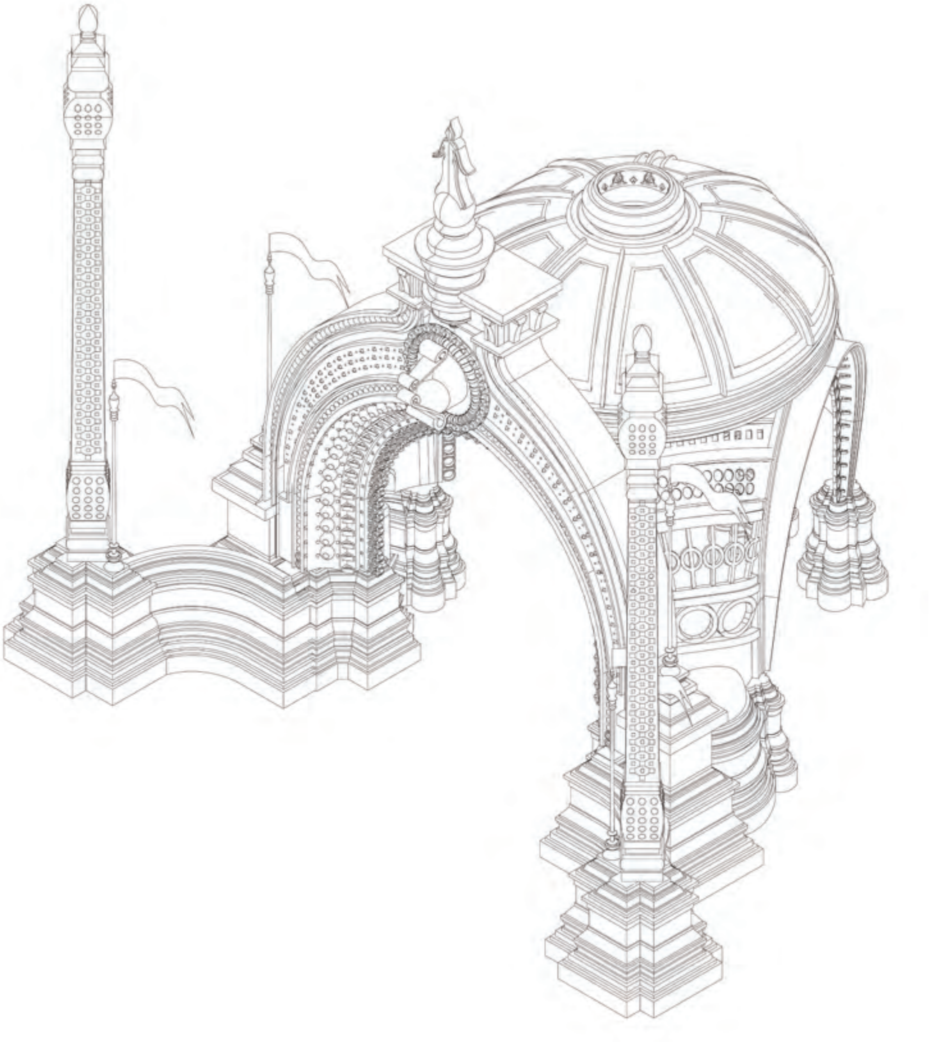
Needless to say, the sheer variety and possibilities that such strategies provide are on this case limited by the building's typology, nevertheless it is merely not limited to it.

The importance of these strategies lies in the fact that they allow the translation of their design rules to a digital parametric model. Each parameter is a value governed by each rule, and simultaneously, different parameters can be tied to one another in order to create dependencies between them. For example, one parameter like the height of a truss can be connected to the height of a window. This way, once these rules are 'digitized' the designer can explore different parameter combinations and explore large amounts of solutions, each and every one of them related to the other, as they depend on the exact set of rules, but with different base parameters.

The design strategy adopted by Ballu could also be understood through these concepts, proving that associative, methodical thinking through structural and formal constrains is still a powerful and flexible tool that we should not abandon -nor merely reproduce- acritically.

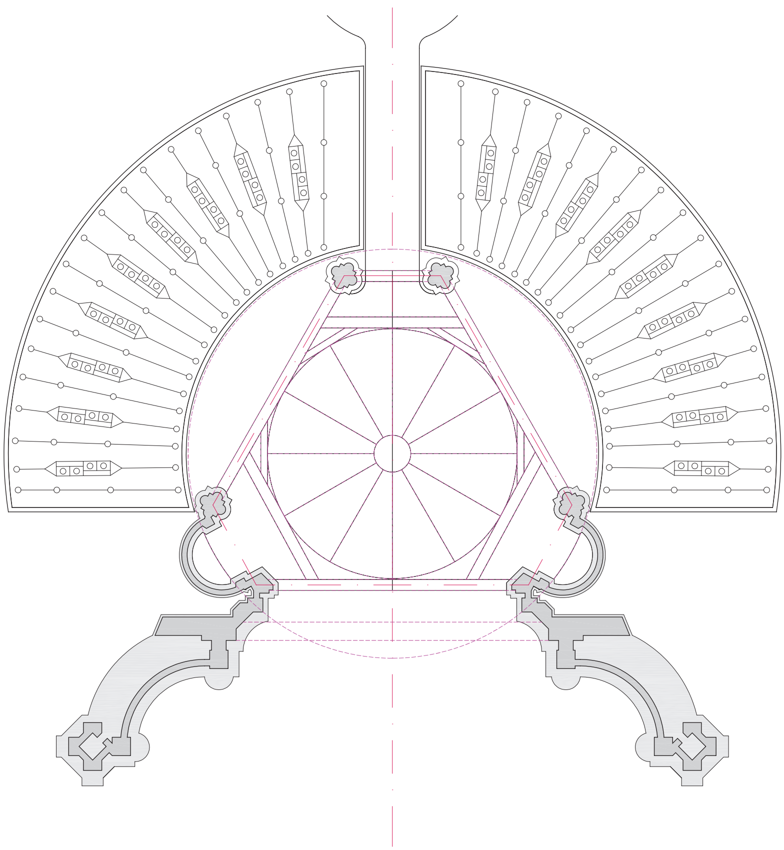


12-4 Cytrodea. Extracted from Haeckel E. ´Kunstformen der Natur´.
12-5 Nature-inspired ceiling lamps. Extracted from Binet R. ´Esquises Decoratifs´.

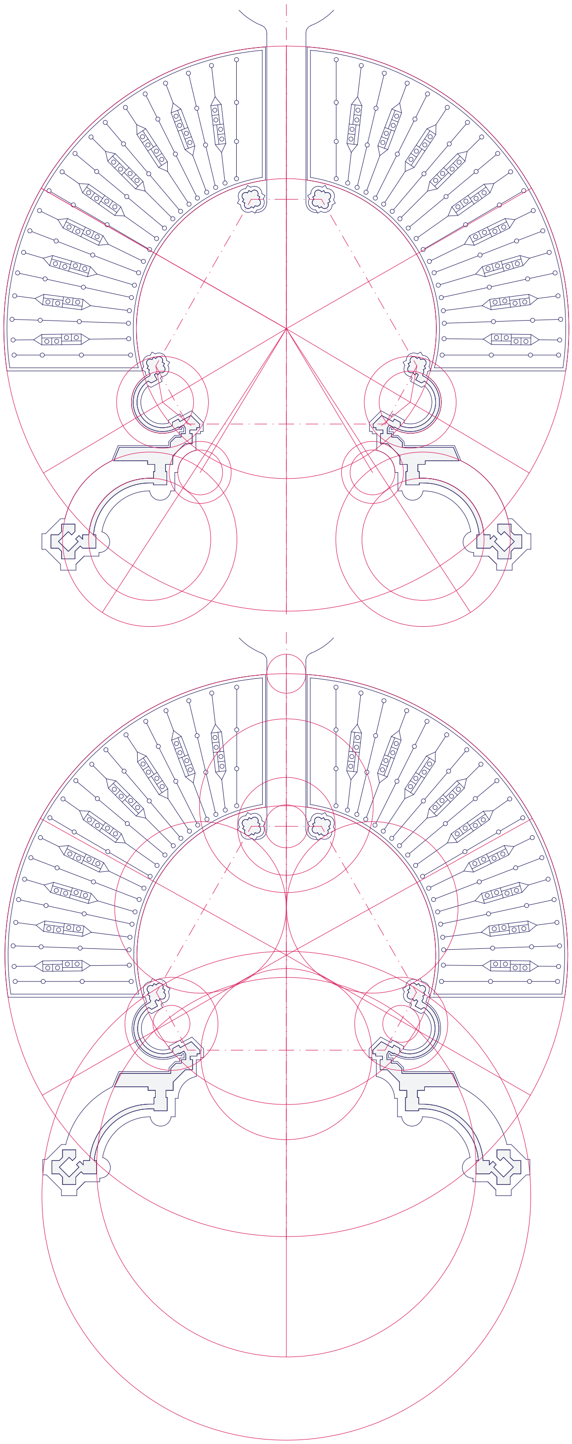


12-6 Porte Monumentale (R. Binet). Isometric view.

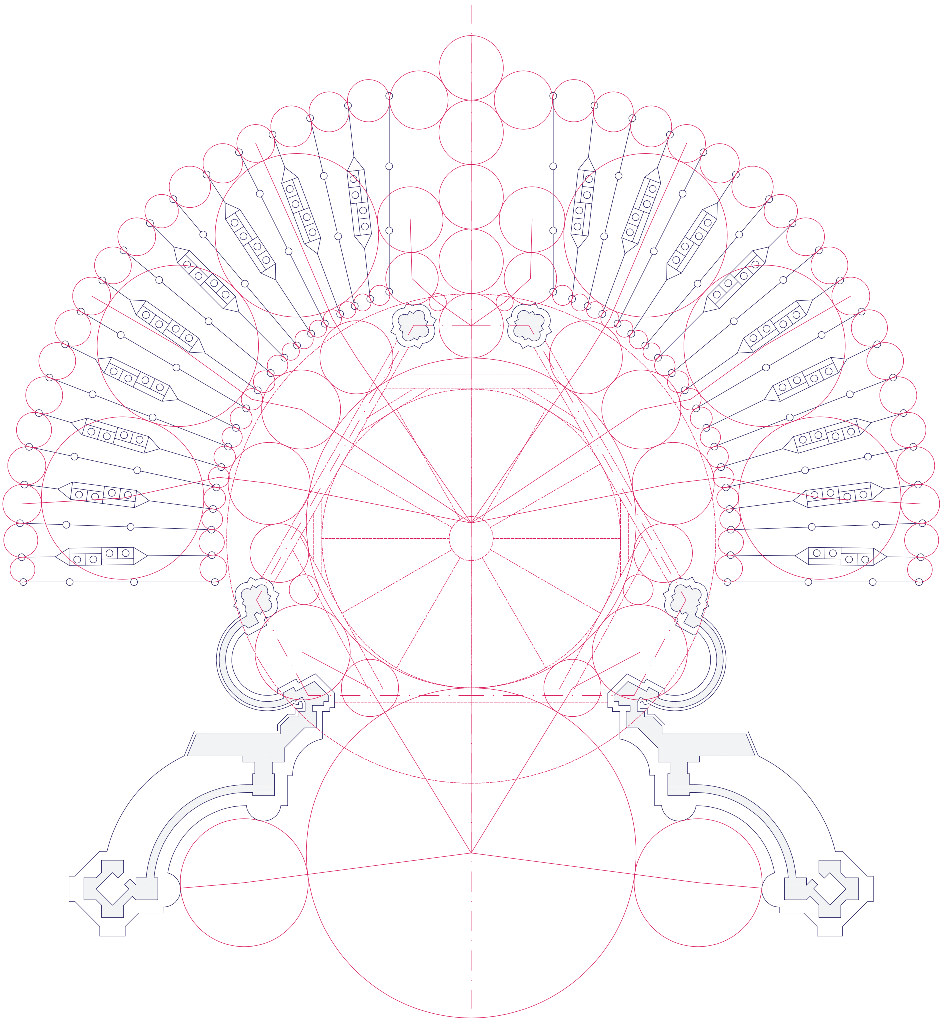
12-7 Representation of volume void of the main central space, front portal access and side absides.



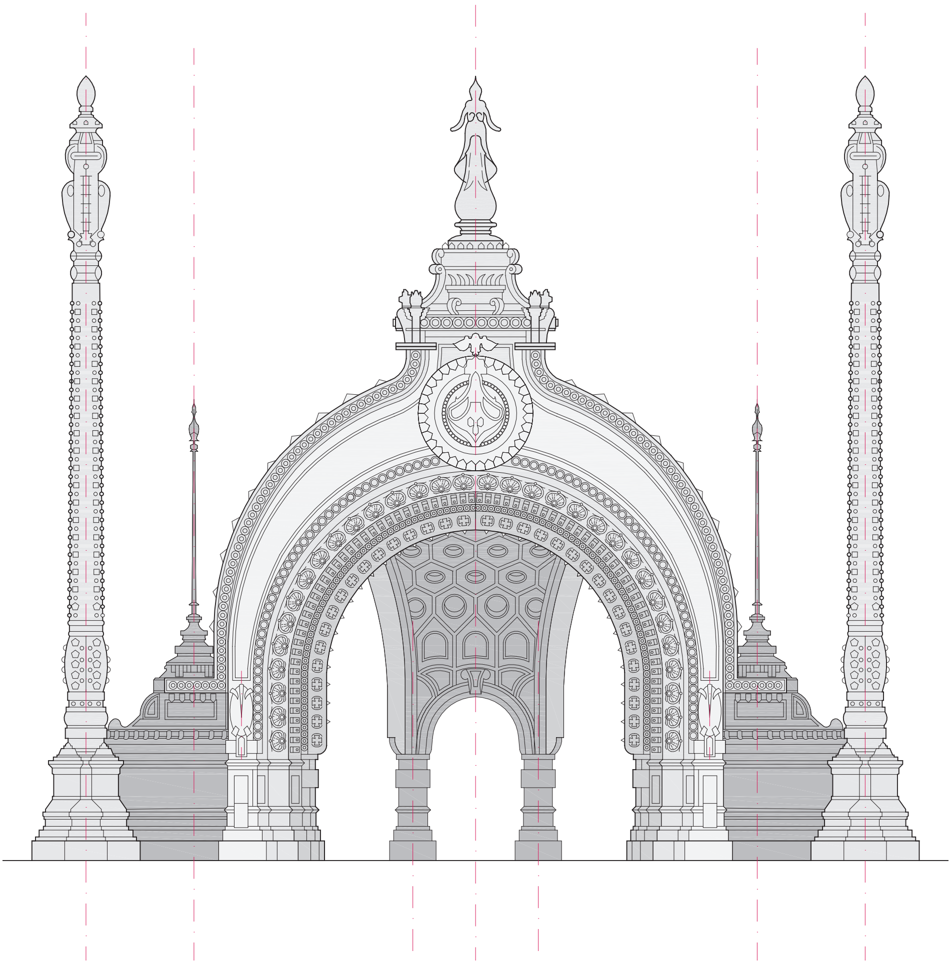
12-8 Porte Monumentale (R. Binet) Ground floor plan (according to publication from Engineer Magazine)



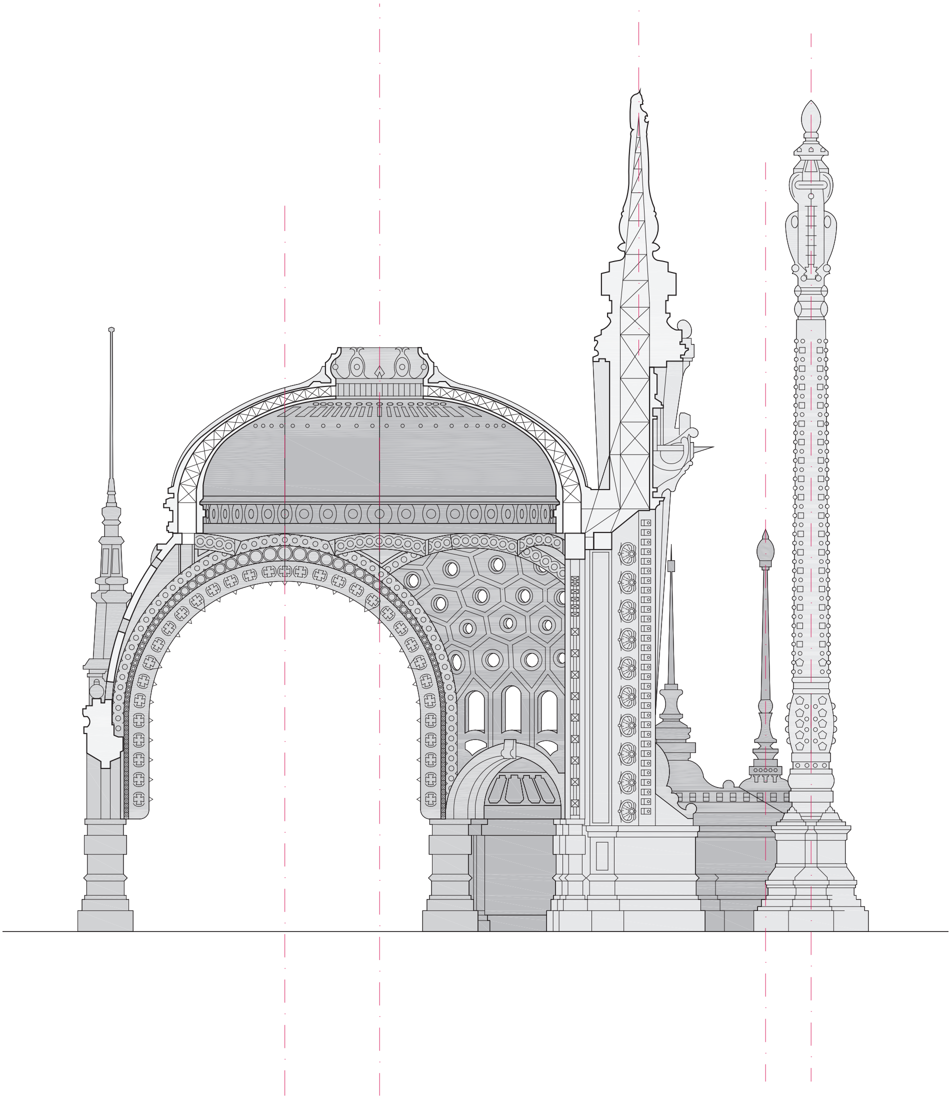
12-9 Geometry and curve analysis, symmetrical axes and arch openings on floorplan.
Bottom: Openness analysis. Each diameter shows the maximum expansion of each space.



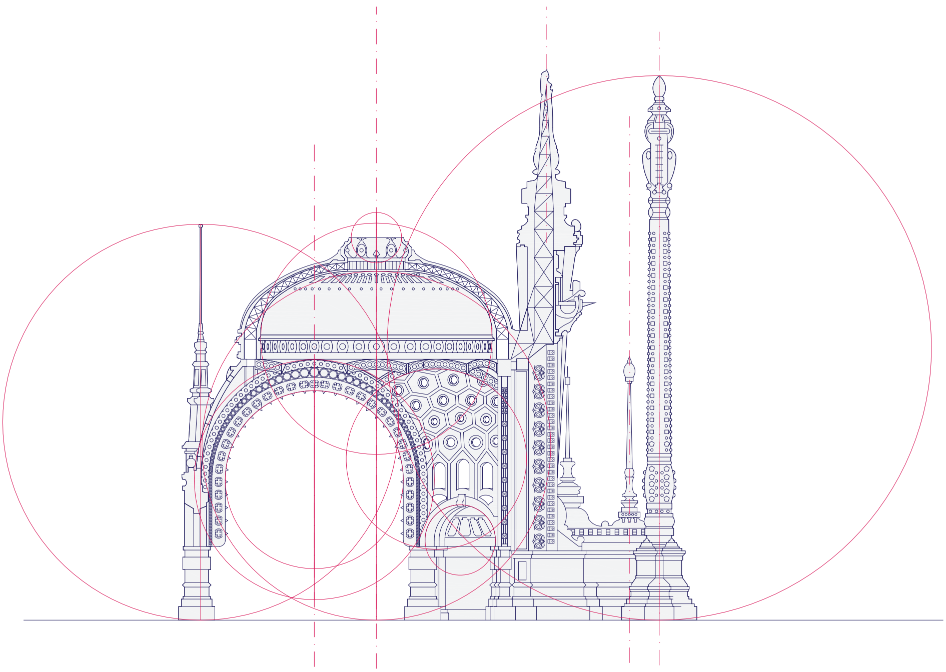
12-10 Geometry and curve analysis, symmetrical axes, arch openings and geometrical subdivisions.



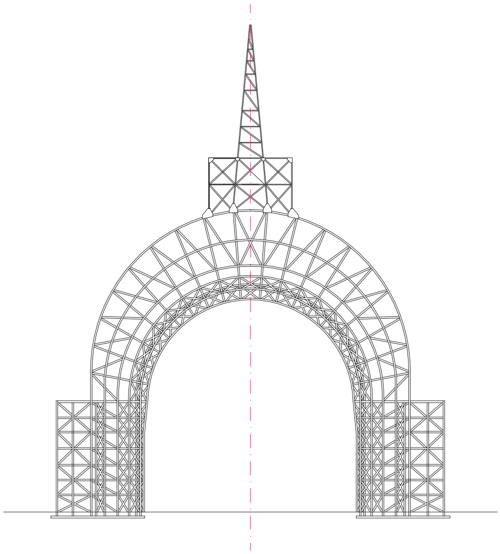
12-11 Front access view (according to publication from Engineer Magazine)

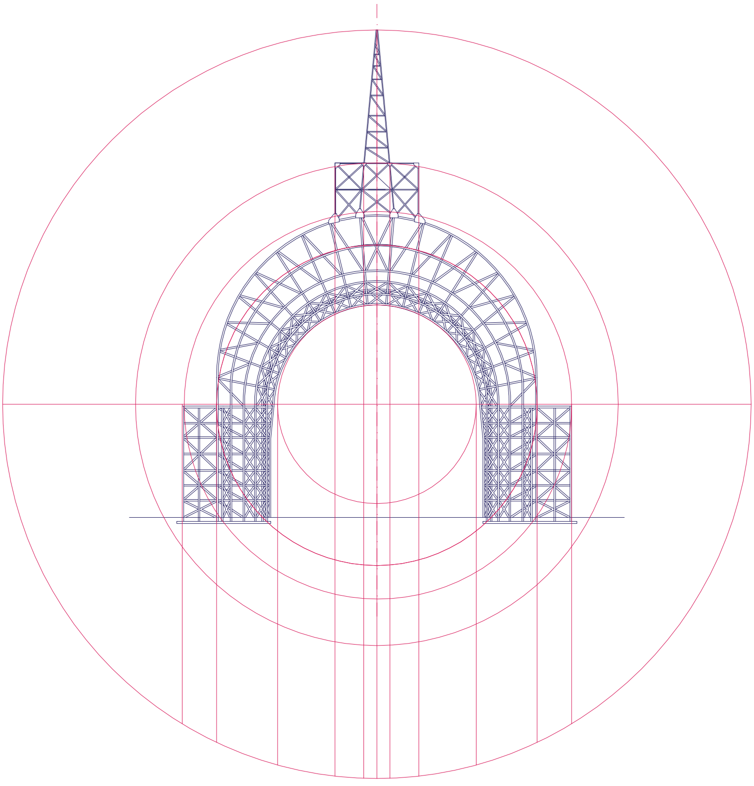


12-12 Porte Monumentale (René Binet) Section through access (according to publication from Engineer Magazine). The engineering journals admired the metal works and technical detailing, however the excessive decoration and hybrid construction type as in the combination of steel structure and ceramic and fibrous plaster cladding did not impress the engineering community as it lacked of real utility.



12-13 Geometry and curve analysis, symmetrical axes and arch subdivision surfaces on section through the building's access.





12-14 Front view of lattice metal work (according to publication from Engineer Magazine). The admirable metal work of the main entrance portal carried out by MM. Ducros Freres, consisted on three arches connected by lattice structures in order to support a commemorative sculpture.
12-15 Radii analysis of the front arch structure showing the different circumferences composing the main facade of the building.

CHAPTER 13

- *Palacio Paz*

José Clemente Paz came from a rich Argentinean family, he practiced journalism, later founded an important newspaper and served as diplomat in Madrid and ambassador in Paris from 1885 to 1893. Taking part of the so called '80s generation', an elite ruling class that governed the country from 1880 to 1916, he firmly believed in progress and modernization as its engine. Having attended the Paris Exhibition in 1889 as a diplomatic representative, he favored European architecture styles, based on its eclectic classic tradition, on which he based the commission for his residency in Buenos Aires.

The 'Palacio Paz' (Paz Palace) was the largest urban residency in its time. Jose C. Paz commissioned the project to Louis Marie Henry Sortais, a French architect, Ecole des Beaux-Arts alumni and Grand Prix de Rome winner in 1890. Sortais projected the 12.000 square meter residency (more than 140 rooms) without ever visiting Argentina, which was common practice at that time for wealthy families. The renowned engineer Carlos Agote was in charge of the building's construction, which regrettably, could not be witnessed by Paz himself, who passed away a year before its conclusion. Sadly, Sortais himself could not witness the final building for the same reason.

The Palacio Paz is a case study of 19th century architecture in Buenos Aires. Decidedly eclectic by design, its stands as a symbol of a metropolitan Buenos Aires which had Paris as its cultural role model, but also, the economic capability of its ruling class, taking advantages of the period's technical, financial and logistics advancements.

Even though the Palacio Paz belongs doubtlessly in Paris, its stylistic sources are scattered and widely rooted. The irregular plot (centrally located in the city) was resolved with a familiar reference to Sortais; the model used for the composition of the residence was the Château de Chantilly, which was rebuilt by Honoré Daumet, a former teacher of Sortais.

By following Blondel's lessons, Sortais parts from precedents and preexisting masterpieces; the aforementioned Château de Chantilly on one hand, some sectors of the Château de Versailles and the Musée du Louvre. The purpose of such references was to manifest the proprietor's political, economic and social stances as well as his preference for European, and more specifically, French culture.

However the Palacio Paz's references act well beyond cultural metaphors or stylistic references; for example, the choice of the Château de Chantilly is also strongly related a design strategy linking a sequence of spatially enclosed rooms, aligned in a series of axes while simultaneously adapting to an irregular plot. The articulation of spatial sequences, the use of multiple axes of symmetry and the articulation of the irregular geometry through towers were important lessons further developed by Sortais in Buenos Aires. We could argue that the

13-1 Palacio Paz (L. Sortais) view from Plaza Retiro.
13-2 Interior view of the garden and court.
13-3 Château de Chantilly (J. Bullant, J.Hardouin Mansart)

reference to Chantilly performs simultaneously as a parti reference as well as homage of the author to his former teacher.

The ground floor rooms of the Palace appear as an eclectic collection of historical styles, obviously with a preference of French origin, but readjusted according to the period's attitude. The names of the rooms were also evidence for this predilection for grandiloquent, overdecorated, luxurious spaces; the 'Mirror Room' was obviously inspired by its French homonym from Versailles, the 'Gran Comedor de Honor' (Great Dining Room of Honor), la Gran Galería de Honor (Great Gallery of Honor), el Gran Hall de Honor (Great Hall of Honor), among many others.

Regarding architectural styles, the assortment is even more evident: the Great Gallery of Honor was inspired in French Renaissance, the Great Dining Room in Neo-Gothic, the Ballroom in Regency style, the vestibule in Neo-Romanic, while smaller rooms were decorated in Empire or Louis XVI style. Some photographs of the patio area even show a marquee made of iron and glass in a simile Art Nouveau style.

The most important sequence is the Great Gallery of Honor, leading to the Great Hall, a circular room (16 meter diameter) with a superb dome (21 meter height). The top floor was destined to everyday life, living rooms bedrooms and guestrooms, while service areas and dormitories for the service staff (more than sixty for the ten members of the family) were located in the attic level.

The taste for European culture did not limit itself to stylistic references; it also reached the material realm by importing manufactures, raw materials and even skilled workforce. Most of all construction and finishing materials such as marble and fine wood were brought from France, Spain, Greece, Italy and Syria, among others. Decorative materials like upholstery and lighting were also imported, along with household and artistic objects such as custom made furniture, paintings and sculptures. Every room was decorated with high-end materials like Slavonian oak, ebony, walnut baseboards, boiserie covered walls, damask silk upholstered panels, together with other rich decorations.

Even the huge cast iron four-panel gate at the entrance of the Palacio was imported among other ironwork pieces, chandeliers and lanterns. Stylistic statements aside, the residency embraced novel technologies as well; every room was connected to the electric network and central heating. It also included ten elevators, three of them on the carriage area. The Palace's cellar also incorporated a gymnasium, a fencing court and a home cinema.

The Palace was a typical turn-of-the-century product, particularly in the relationship between technology and everyday life. Like many buildings and amenities of this period, the magnificent carriage annex was soon abandoned (and later demolished) due to the change in transport technologies.

As discussed previously, 19th century architecture was keen to adopt innovative technologies while preserving a classical or traditional expression. An amplified procedure took place in Argentina; as it imported manufactures and manpower, and in addition, it imported a foreign architectural culture, a foreign tradition, alien to the country's reality.

The Palacio Paz acted as a showroom of European styles, from the Middle Ages to Second Empire, and while reflecting the Zeitgeist, it was presented simultaneously as contradictory and experimental. The façade was stuccoed by a coat similar to a stone (an imitation of 'piedra de Paris' or 'Paris stone'), a technique imported by Italian stucco masters and plasterers. This French-Italian tradition was useful in order to impose the revival culture in Buenos Aires, having France and the French styles (Louis XIII, Louis XIV, Second Empire) as a beacon.

On top of architectural styles, material manipulation and deceit were also a feature of Revival architecture In Argentina; the Palace decoration also included trompe l'oeil, bas-reliefs evoking fictional trophies, false openings, windows and doors, marble pieces simulating fabrics and curtains, optical illusions covering walls and domes.

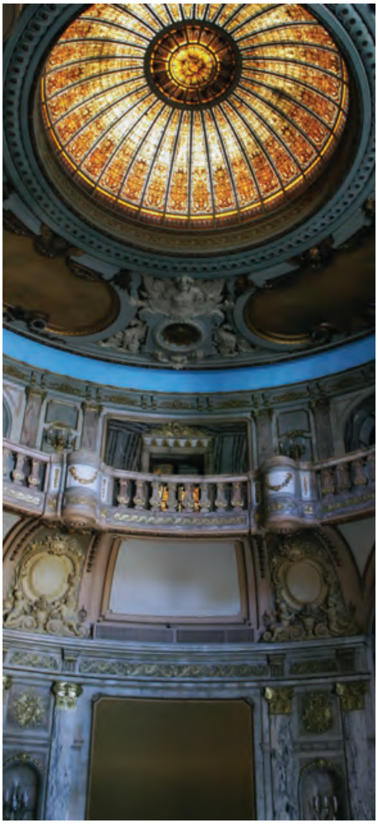
The Palacio Paz is a prime example of an all-encompassing organizational design strategy, as it displays several organizing axes as well as symmetry planes while being built in an irregular site. The Palace's main façade over the Plaza San Martin is the most important one, resembling the façade of the Louvre museum. Its central body is pronounced as the lateral bodies are slightly receded; mansard towers articulate both bodies but the overall effect is dissolved in the flattened façade, typical of Buenos Aires.

The central and lateral bodies are arranged in a symmetrical composition and both extremes are further articulated with the main entrance on the right and a tower, similar to Chantilly, on the left. Faithful to its French references, the basement displays a slight rustication, the ground and top floors also present horizontal stripes, pronounced and receded alternatively. After the cornice lines, the enlarged mansards (almost a third of the height in the central body) are pierced by portholes.

Regarding composition, the Palacio is organized around a series of spatial sequences, typical of Louis XIV arrangements; one magnificent space after the other, from the entrance, vestibule and then the route is divided in three: on the left, a succession of petit salons and the ballroom, on the center the Great Gallery of Honor, and on the right, the sequence of dining halls. This arrangement is coincident with the central body of the main façade, organized around a bilateral symmetry. The three sequences end in the Great Hall of Honor, a circular space, which acts as a joint, articulating both facades internally, while the tower does it from the façade.

The overall organization of the Palacio presents a combination of compositional strategies; on one hand the 'French' approach by which every room is connected to the next one through a central door (accentuating a symmetrical effect) and a more contemporary 'functional' approach by which the Great Gallery of Honor operates as a distribution corridor, an oversized passageway for the numerous staff to service the main rooms. A similar arrangement is present on the two secondary facades; the same hierarchy sequence remains; the main rooms on the front, a broad corridor and finally, secondary spaces turning to the interior garden.

This compositional hybridity mimics the stylistic one, to each spatial segmentation corresponds an architectural style. There is no central, hierarchical space articulating the whole composition, instead, a sequence of finite, enclosed rooms connected to the previous and the next one. There is



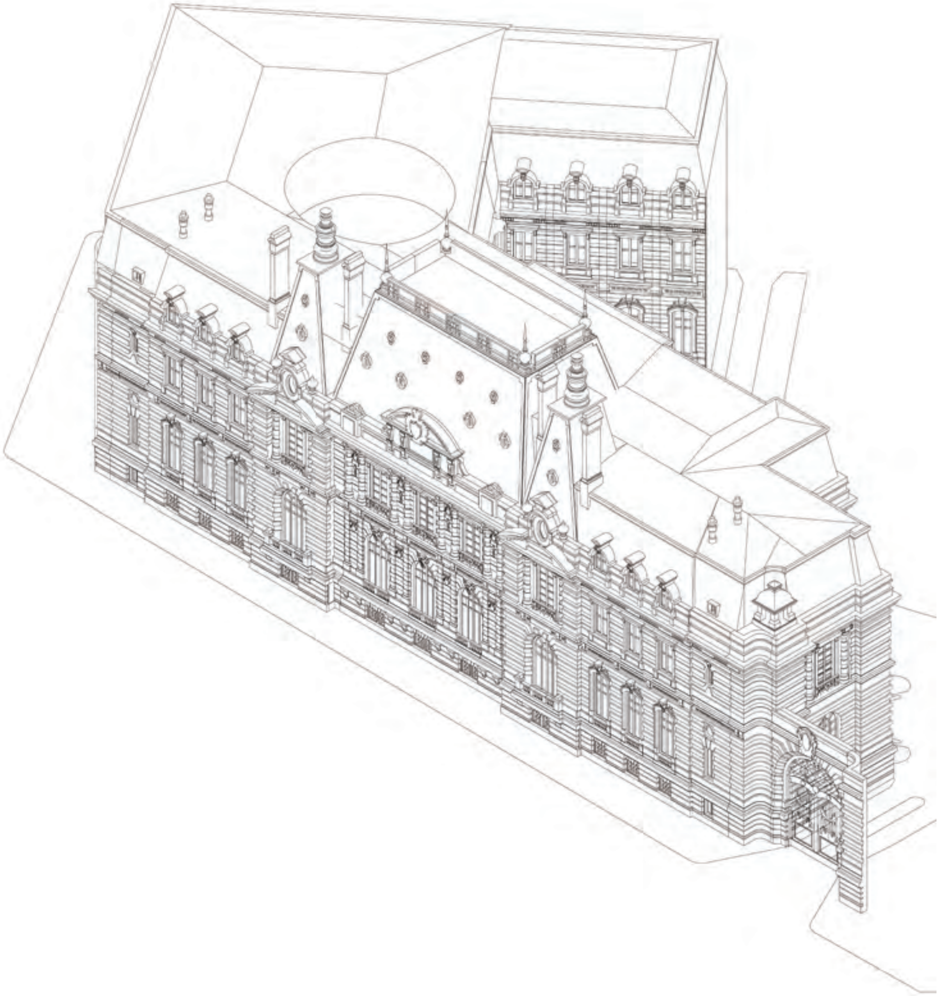
13-4 Interior view of the dome from the Grand Hall of Honour.
13-5 Exterior view from Av. Santa Fe.
13-6 Interior view of the Ballroom

an organizational strategy that is both global and local; the concatenation of spaces of variable form and shape (and style) appears of an entirely local nature while simultaneously regulated by a clear axial system. The stylistic decision results as a positive side-effect of a distinctive spatial distribution system.

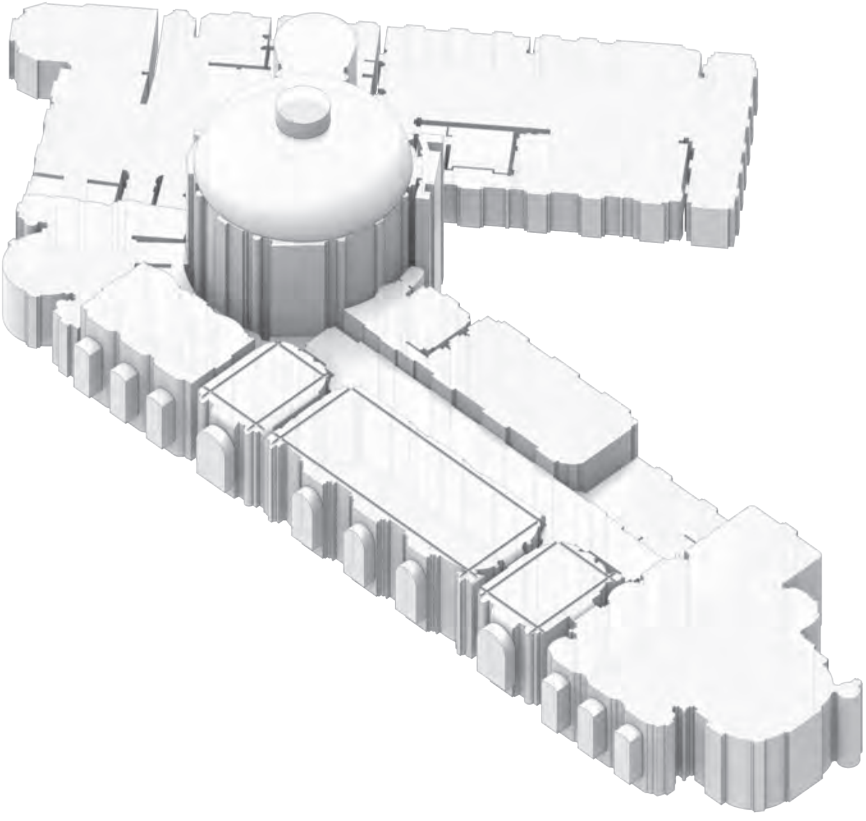
A compositional strategy that combines simultaneous global and local organizational rules remains an important topic regarding contemporary digital design strategies. Several digital tools operate on either one of these organizational systems; 'cellular automata' operates on a local member-to-member association while other tools such as subdivision or 'L-systems' act on a general, global plane.

This mixed-strategy is not gratuitous, the building needs to meet simultaneous and often contradictory requirements, including urban, stylistic or functional conditions, which are met organically and successfully.

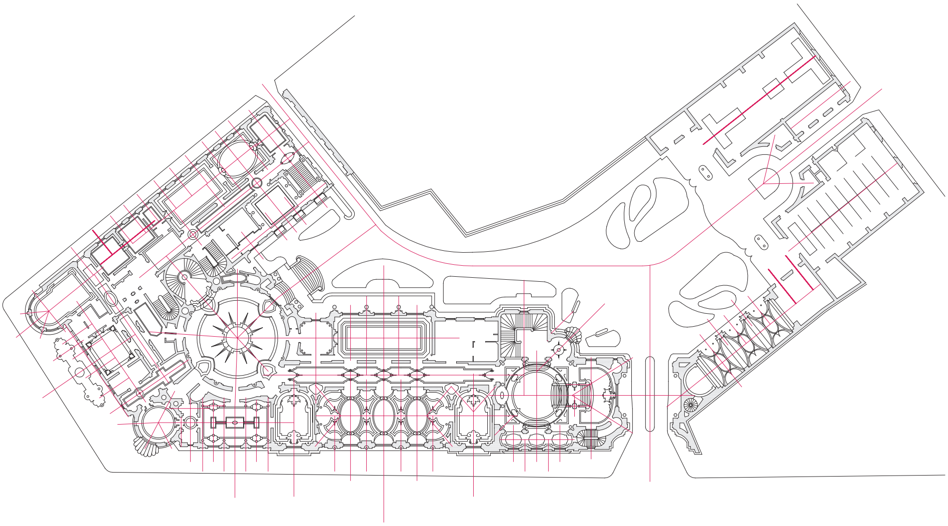
On this matter, a series of experiments were carried on for this research regarding spatial concatenation and axial organization systems. It is possible to read on the Palacio Paz the use of ´local´ rules (juxtaposition, adherence, affinity) combined with ´global´ ones (organization, patterning) which are present on digital design strategies performing as powerful tools as well.



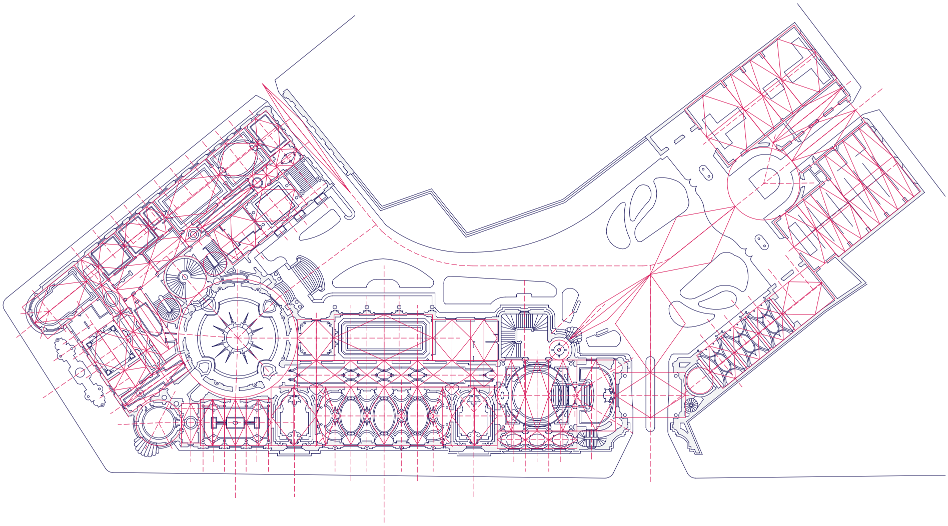
13-7 Palacio Paz (L. Sortais) Isometric view

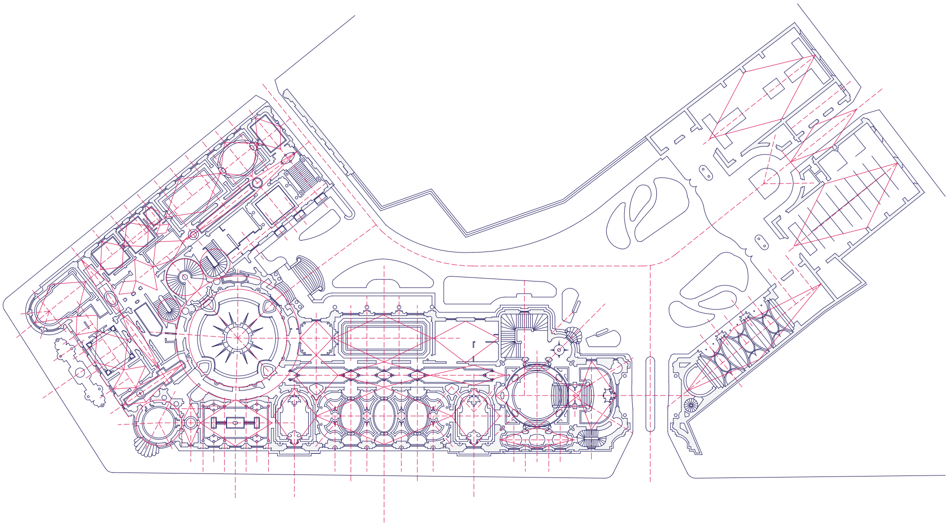


13-8 Representation of volume void of the ground floor. The diagram illustrates the concatenation of spaces towards the main circular hall.

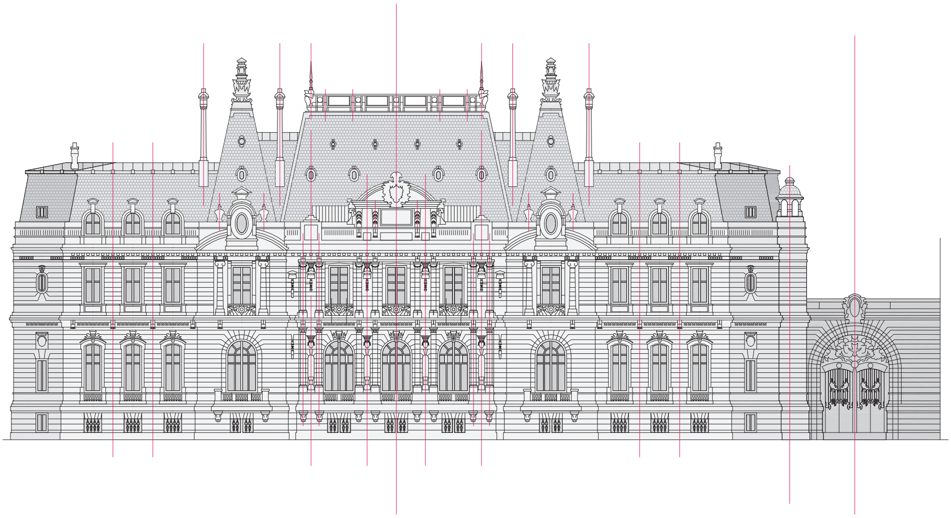


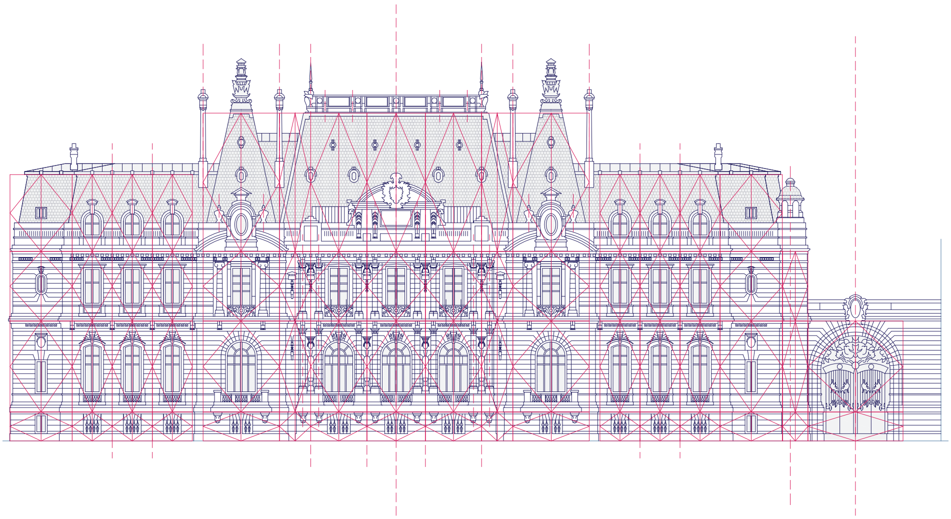
13-9 Palacio Paz (L. Sortais) Ground floor plan (according to publication from D. Lecouna and various sources)



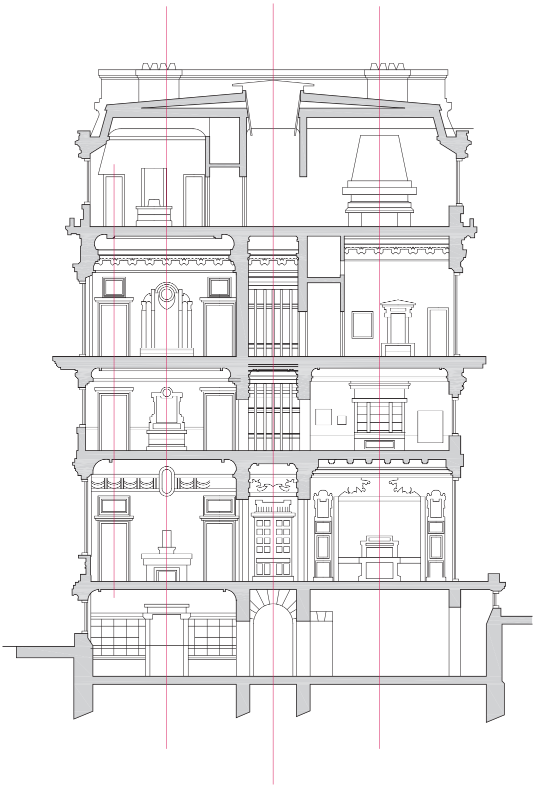


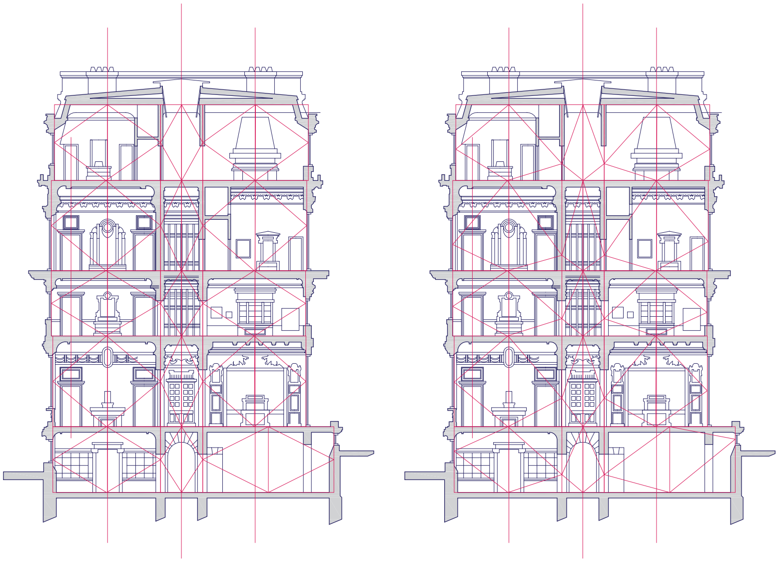
13-10 Spatial flow diagram. The spatial sequences arranged by the building´s organization range from consecutive progression to open circular spaces. The diagram is modulated by the structural rhythm present on each subspace. Central spaces act as articulation between the Palace´s two main compositional axes.
13-11 Spatial flow diagram. The modulation is defined by spatial boundaries ignoring the structural or ornamental subdivisions. Perception of spatial continuity is favored against real or virtual partitions.





13-12 Front view over Plaza San Martin (according by various sources and the author)
13-13 Global and local. Structural subdivision diagram. The facade is divided in five main corps with two of them protruding very subtly. Each of the corps has its own structural rhythm governing the position of symmetrically placed openings.





13-14 Section (according by various sources)
13-15 Spatial subdivision diagram. The main corp arranges spaces symmetrically on two sides from the circulation passage supported by the structural organization. This apparent symmetry is only present on the center of them main façade, as many other limited-range symmetries present on the building.

CHAPTER 14

- *Hotel Plaza*

At the beginning of the 20th century, there was not any hotel that matched the metropolitan status of Buenos Aires, nor in size or in accommodations suitable for an international public, equivalent to the ones in Paris, London or Vienna. The first of such establishments was built under the vision of Ernesto Tornquist, a wealthy businessman from the city.

Tornquist reached to Alfred Zucker, a successful German architect educated in the Hannover Polytechnic and the Berlin Bauakademie. Zucker worked in several cities in the United States, his prominent work was in New York, where he designed several buildings, among them the Majestic Hotel, the Decker Building and the Park Row Building, the tallest building in the world at that time. By 1904 Zucker's office was in financial struggle and fled to Buenos Aires avoiding a lawsuit by a former associate.

Undoubtedly, Zucker had intimate knowledge about skyscrapers, which was probably the reason why Tornquist commissioned his hotel. The synthesis of free-standing steel structures, stylistic freedom and a distinctive new Yorker skyscraper typology were the characteristic features of the Plaza Hotel in Buenos Aires.

The hotel construction lasted for little more than 2 years, a relatively short period, mostly due to the employment of an independent steel structure. By the time it was inaugurated, thanks to its 9 floors it was crowned as the highest building of the city (it was declared the first Argentinean skyscraper in 1909) and the most luxurious and modern hotel in South America.

The Plaza Hotel was equipped with deluxe facilities as well as state-of-the-art technology; pneumatic tubes for small packages connecting the offices and the apartments, the first 'American wardrobes' (which were automatically lit when opened), central heating system, low and high voltage electricity, centralized telephone connections, elevators and the first mechanic escalator in the country. The sub-basement level comprised modern machinery such as a water filtering and distilling plant, ice-making machinery and electric generators.

The opulent quality of the building was manifested on every architectural aspect; the public area includes Foyer, Restaurant, a luxurious Ball room, with a height of 9 meters incorporated a mezzanine floor, with a broad gallery overlooking the Foyer and the Orchestra balcony over the Dining Hall. Thanks to the terrain slope, there is a secondary entrance for the basement, designed for informal activities, such as the Grill room, the bar and the Billiard Lounge.

Located in front of the San Martin Park near the city center, the Plaza Hotel was built seven years after its neighbor, the Palacio Paz, sharing several characteristics like their unapologetic approach to style while differing in many others, such as construction technology.

14-1 Plaza Hotel (A. Zucker) in Buenos Aires, 1910.
14-2 Plaza Hotel (A. Zucker) in Buenos Aires, 1910.
14-3 Majestic Hotel (demolished- A. Zucker) in New York, 1894. There is a similar typological formation between both hotels due to the maximization of room area, light and ventilation requirements. This typology, though common in New York, is infreuqent in BuenosAires.

Similarly to the Palacio Paz, the hotel is situated on an irregular corner plot, but unlike its neighbor, it attempts to remain a compact rectangular block. For this reason, the corner of the plot was left unbuilt, reconstructing a 90 degree corner while serving as a carriage entrance. On the other side of the plot, a similar operation is performed, with a service patio working as a buffer area between the building and its adjoining neighbor.

The Hotel is horizontally divided; the lower body containing the ground and basement levels along with the public programs, a middle body, including 7 stories of hotel rooms and a mansard with an attic. The first parts two are articulated by a continuous balustrade balcony. The architectural language of both bodies is also different; the base is rusticated with large round arches and a clear 'French' outlook while the upper volume displays less ornamentation, only adorned by the interplay of steel bay windows. On top of the building displays the mansard body, also decorated according to the French tradition, including ornamented corbels, portholes and pointed pediments over the windows.

The division between lower and upper bodies is also structural; the use of an independent steel framework allowed Zucker to employ different structure spans on each segment. The lower body containing public programs demanded larger spans in order to enjoy large spaces without supports, while the upper segment required shorter spans, matching each section to the division between rooms.

The lower body is organized through a compositional strategy, juxtaposing spaces to one another, without any axial or spatial articulation. The two main spaces, the Great Dining Hall and the Ball Room are articulated by the Great Foyer with a series of enclosed spaces in-between them. The Foyer also presents a vertical dimension, accentuated by a glass dome which is used for illumination, while the stairs and a surrounding inner balcony, articulate the space with the Dining Hall and the Ball Room.

The steel structure on this body is entirely covered by 'classical clothing'. The Great Foyer's columns were covered in marble and gilded composite capitals. The Great Dining Room's columns are similarly covered, in the form of pilasters, leaving the large space without any intermediate structure. The Ball Room is decorated correspondingly, however instead of marble; the steel structure is covered with faux-marble Corinthian columns on the ground floor and double Caryatids on the balcony level. There is nothing on these three main spaces that hints the authentic structure, except for the stucco-covered beams, also decorated, revealing the structural modulation.

The upper volume of the Plaza Hotel presents a more rational approach in comparison. The building is divided in two volumes joined by the service area (staircases, elevators, kitchen). The shape of the upper floor volume interweaving built and empty spaces reminds of a horseshoe New York typology, well-known to Alfred Zucker. His design for the Majestic hotel from New York displays similar volume movements and thick cornices but without the 'French' styling.

The ventilation and lighting spaces are deeper in the Plaza Hotel in comparison to the New York buildings, giving the impression of two separate volumes instead of an in-and-out movement. This depth also allowed Zucker to allocate more rooms by taking advantage of the natural ventilation and illumination, critical to the success of any hotel typology. The organization of these volumes is almost symmetrical, two rows of rooms on each one, pierced by a corridor in between. The attic levels follow similar an organization structure, adding machine and washing rooms on the top floors instead of guest rooms.

The hotel rooms cover the entire façade, each one corresponding to a bay window, reinforcing the idea of a clear, coherent relationship between interior and exterior. This does not occur on the ground level, where basement, entrance and mezzanine levels are combined and masked.

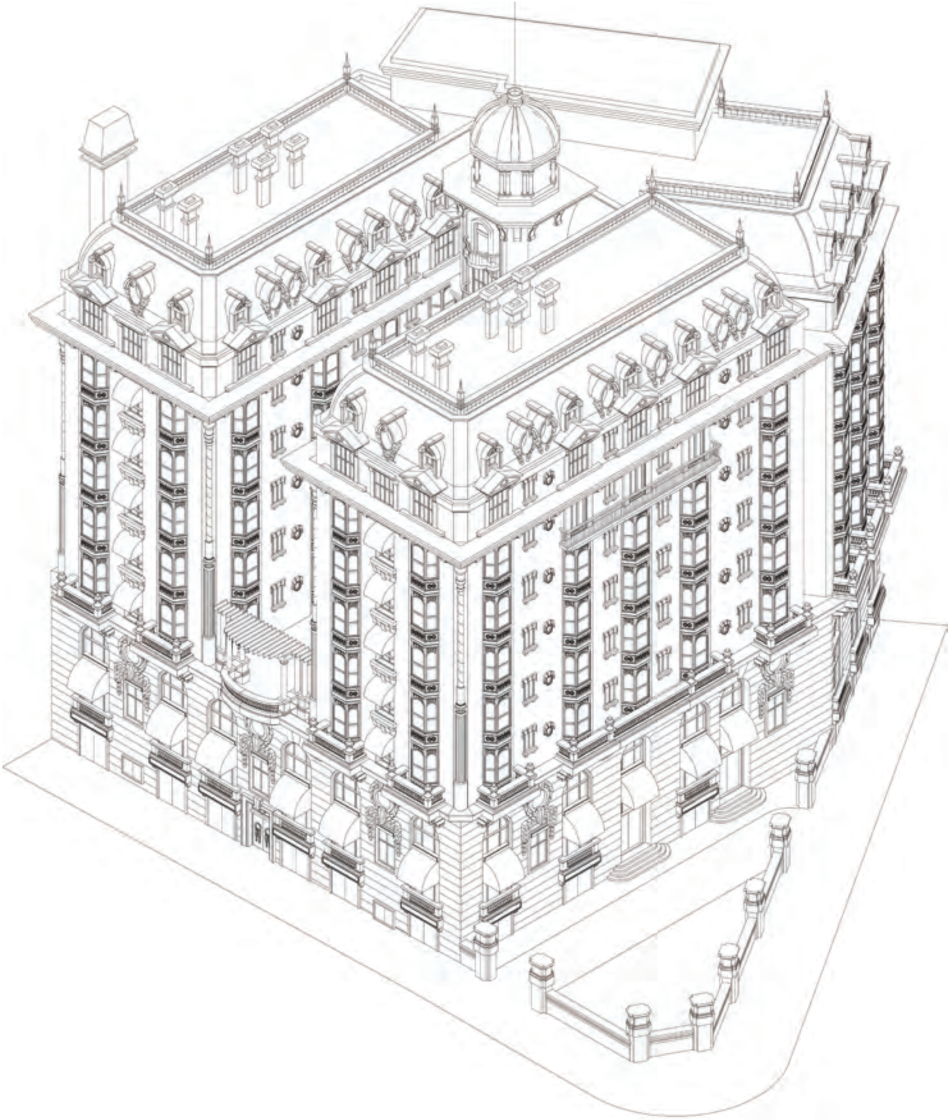
The construction of the addition on the corner ten years after the inauguration altered this two volume interpretation; adding a different set of shapes and proportions that appear somehow foreign to the original design as it altered the interplay of volumes and voids.

Hybridity is present in the Hotel Plaza on many levels; structural, typological and stylistic. The combination of large span structures on the lower volume and short span on the room levels was only possible thanks to a rational understanding of the role of steel structure in buildings; even though it is covered in ornamental clothing and hidden in the wall volumes, its conception and design was undoubtedly modern.

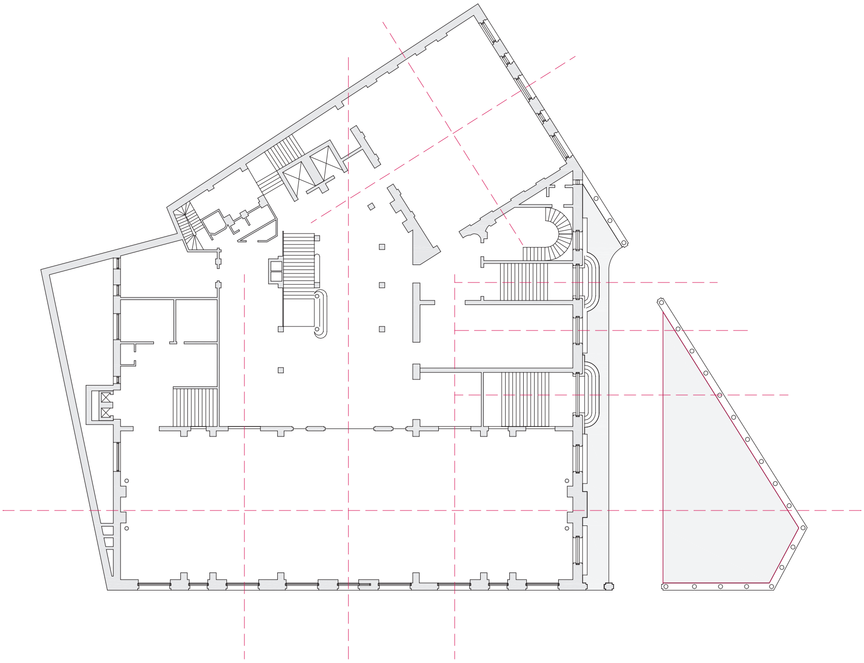
The hybrid structure defines a hybrid typology; open, decorated spaces are juxtaposed on the lower volume while smaller rooms are rationally aligned on the top volume. This hybrid condition is also manifested on the perception of the volumes; the lower being massive, the upper, articulating occupied and void spaces, manifesting a sort of ‘New Yorker typology´ aesthetic. The Plaza Hotel was French and North American at the same time.

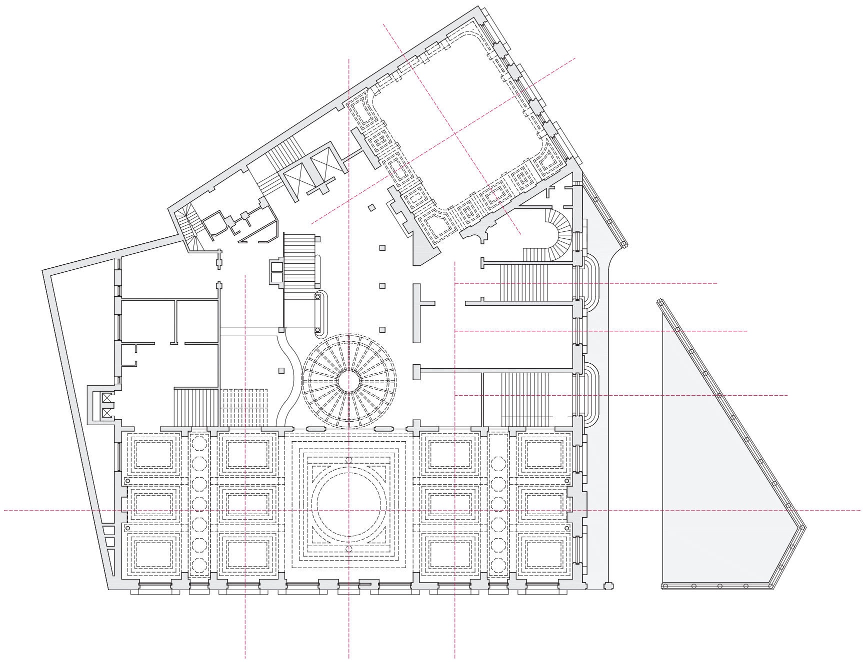
Finally, the stylistic structure is defined the two precedent qualities, the lower corpus, rusticated and heavy, the upper one, rational, alternating flat masonry and metal bay windows. The top floors in the mansard resume the style featured on the base volume, as if the rationally organized hotel rooms are sandwiched between two stylistic layers.

14-4 Interior view of the ballroom. The Plaza Hotel was the first all-iron structure in the city, however the ornamentation kept it safely hidden from the visitors´perception.

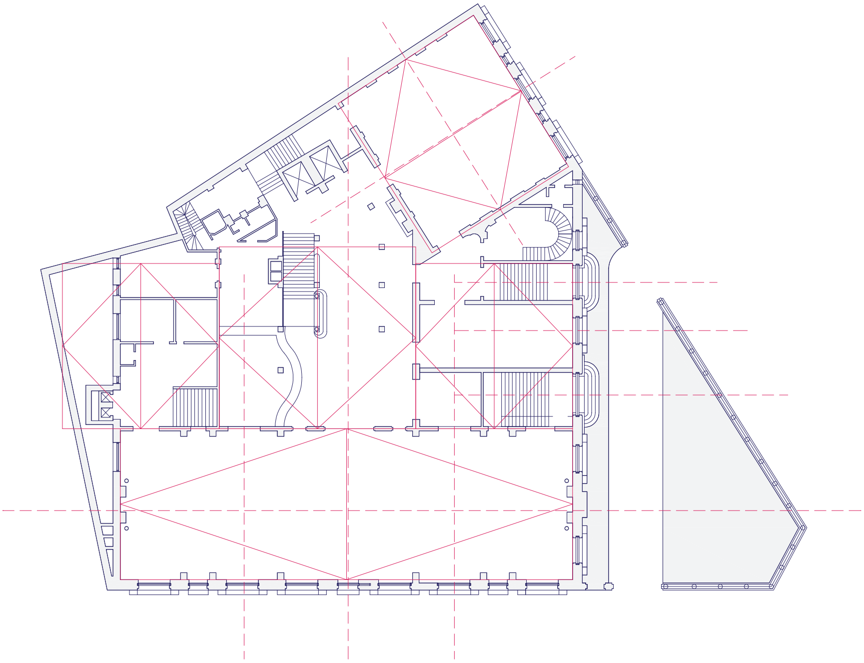


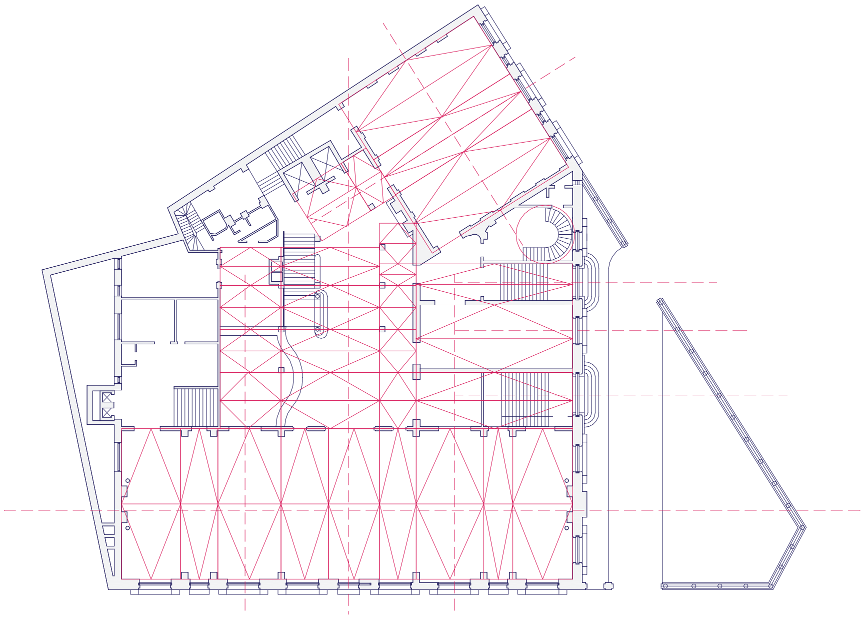
14-5 Plaza Hotel (A. Zucker) Isometric view.





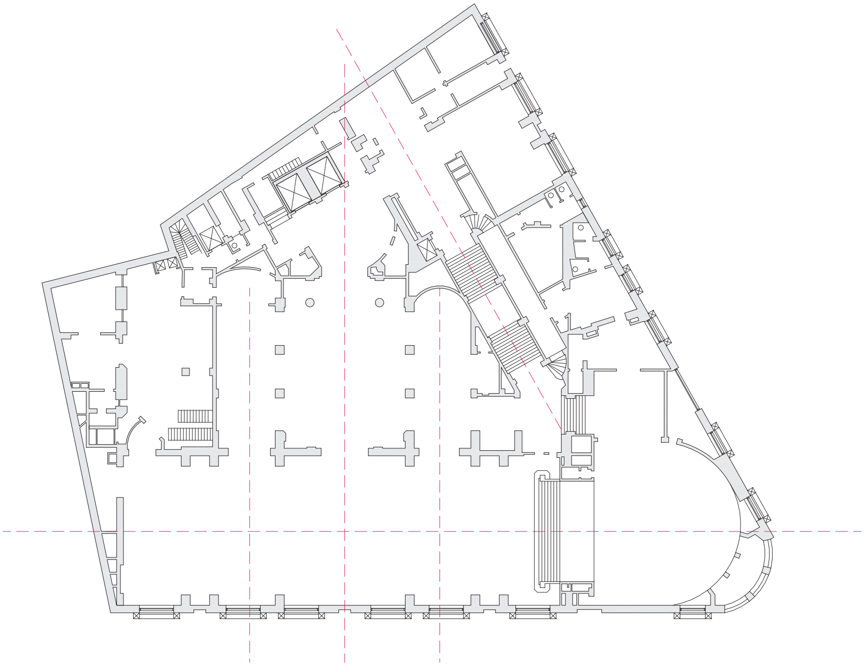
14-6 Plaza Hotel (A. Zucker) Ground floor plan (according to the publication Plaza Hotel R.A.)
Bottom: Ground floor plan with ceiling projections (according to the publication Plaza Hotel R.A.)

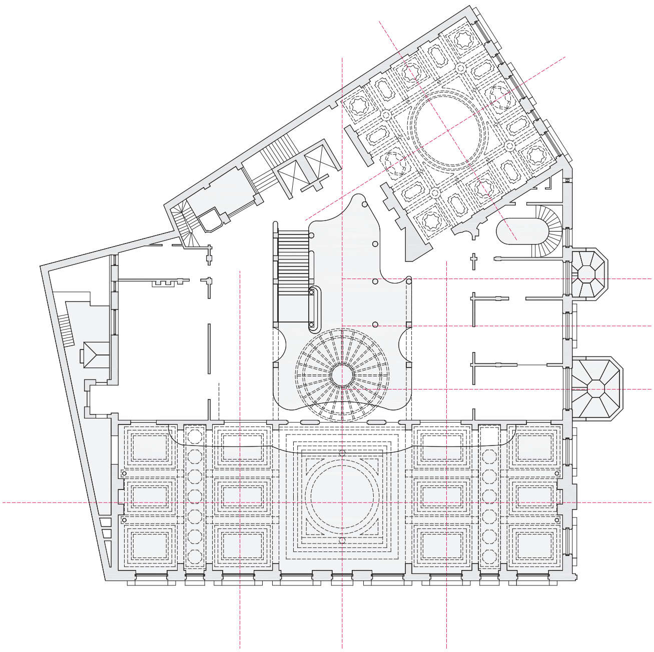




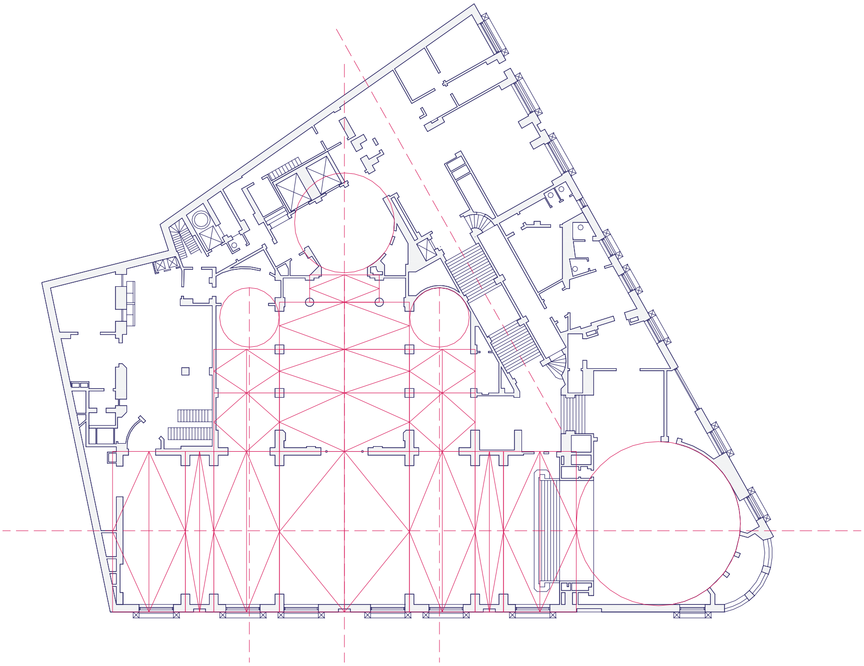
14-7 Diagram highlighting the main spatial areas of the ground floor. The almost symmetrical layout of the Main Hall and the Dining hall are consistent with the original project draft from Zucker, much more classical in terms of readability, which was subsequently hybridized to its final state. The addition of the pivoted Ballroom is also a part of later revisions.

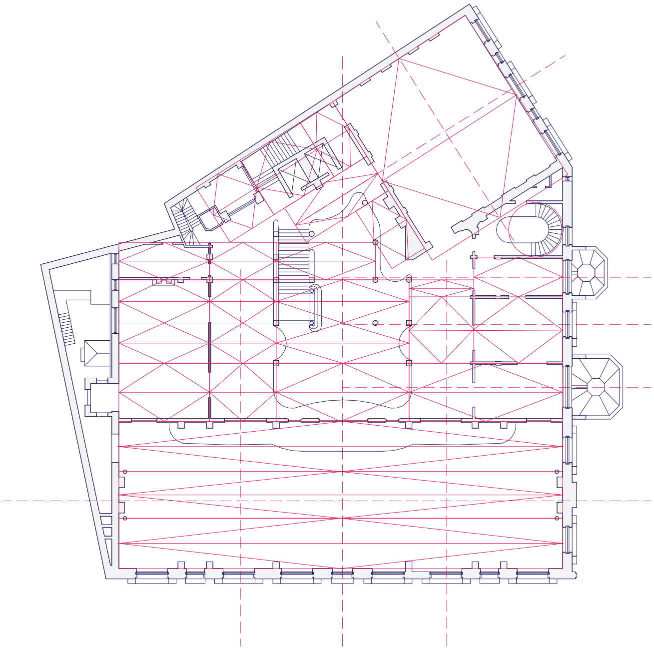
14-8 Structural flow diagram of the the ground floor. Altered structural rhythms are combined with partial symmetries in order to maintain an ordered spatial perception.



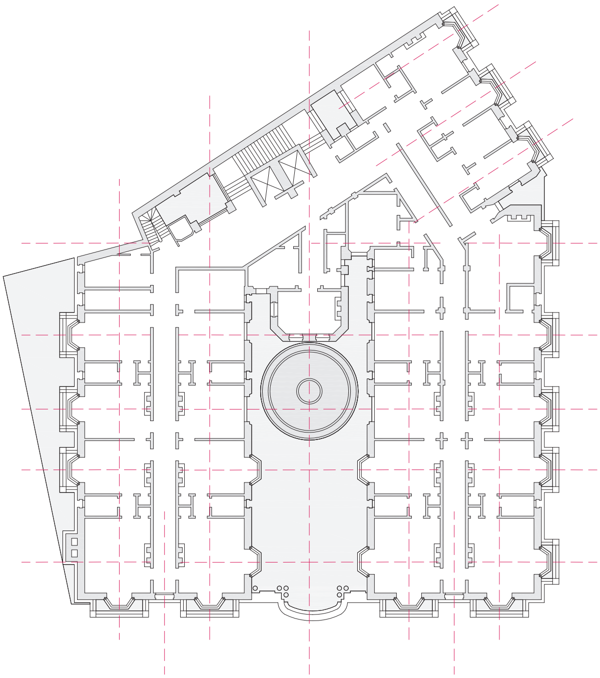


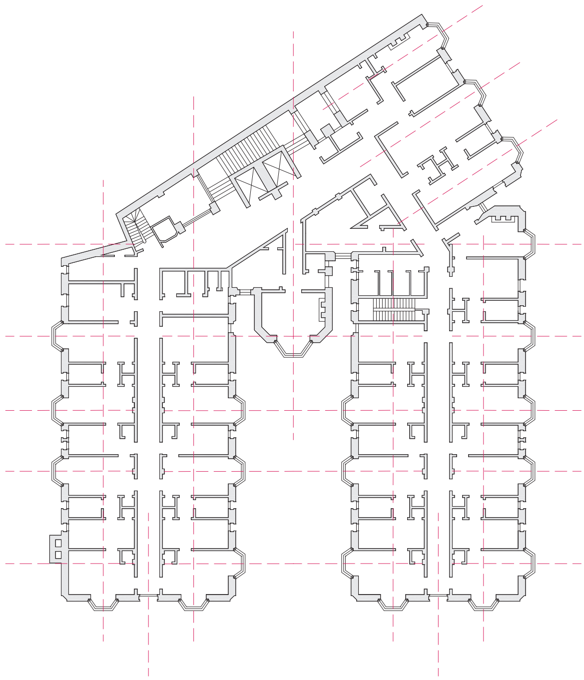
14-9 Cellar floor plan (according to the publication Plaza Hotel R.A.)
14-10 Mezzanine floor plan (according to the publication Plaza Hotel R.A.)



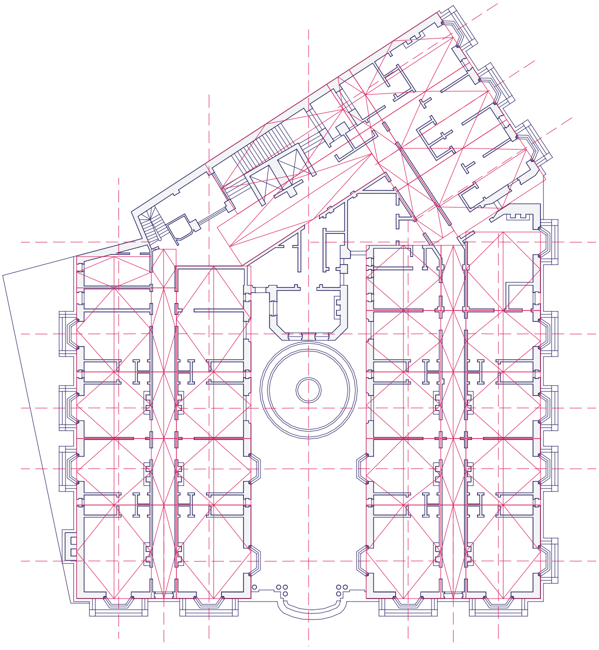


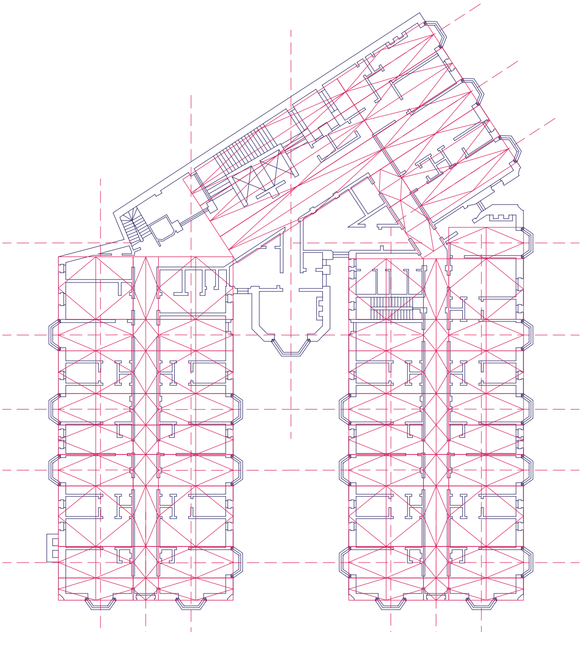
14-11 Spatial flow of the cellar. The presence of clear symmetry axes and organization are inherited from the first project drafts.
14-12 Spatial flow of the first floor.





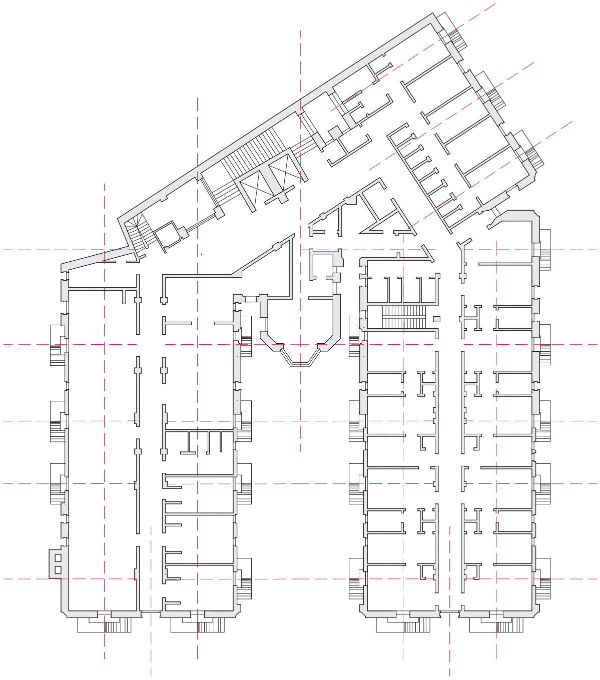
14-13 First to third floor plan (according to the publication Plaza Hotel R.A.)
14-14 Fourth to Sixth floor plan (according to the publication Plaza Hotel R.A.)

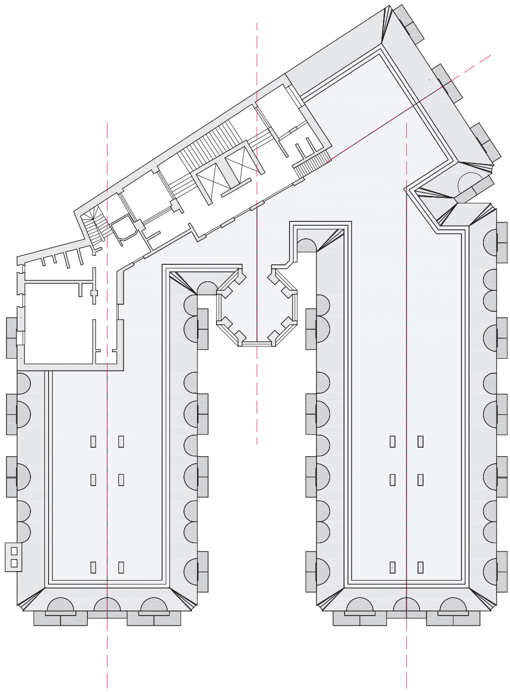




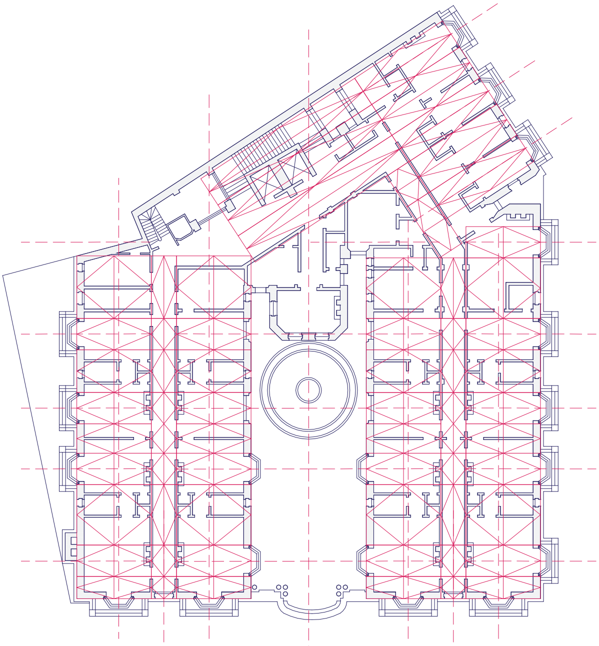
14-15 Spatial flow of the First-Third hotel floorplans. The hotel rooms are organized symmetrically on both sides of the corridors ending in the façade. Similarly, a horizontal symmetry axis organizes the hotel rooms and their windows on the side façade. The congruence of multiple organizational symmetry axes on a complex geometrical resolution an appealing feature of the Plaza Hotel.

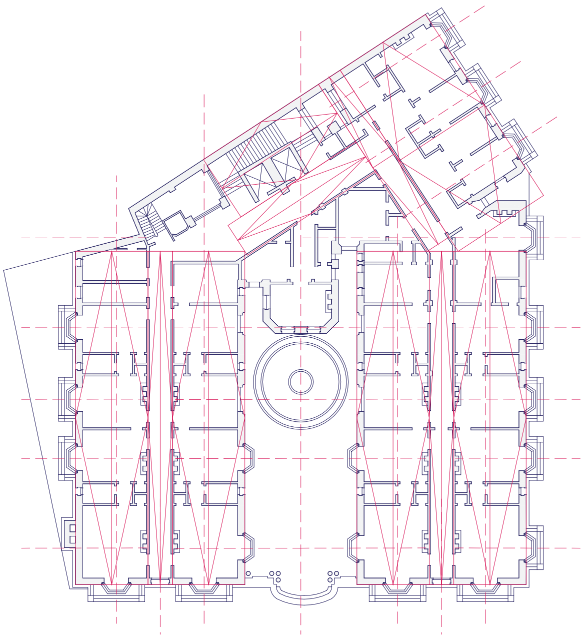
14-16 Spatial flow of the Fourth-Sixth hotel floorplans. The diagram is organized following the façade modulation coordinating the bay windows and walls. The congruence of multiple organizational symmetry axes on a complex geometrical resolution an appealing feature of the Plaza Hotel.



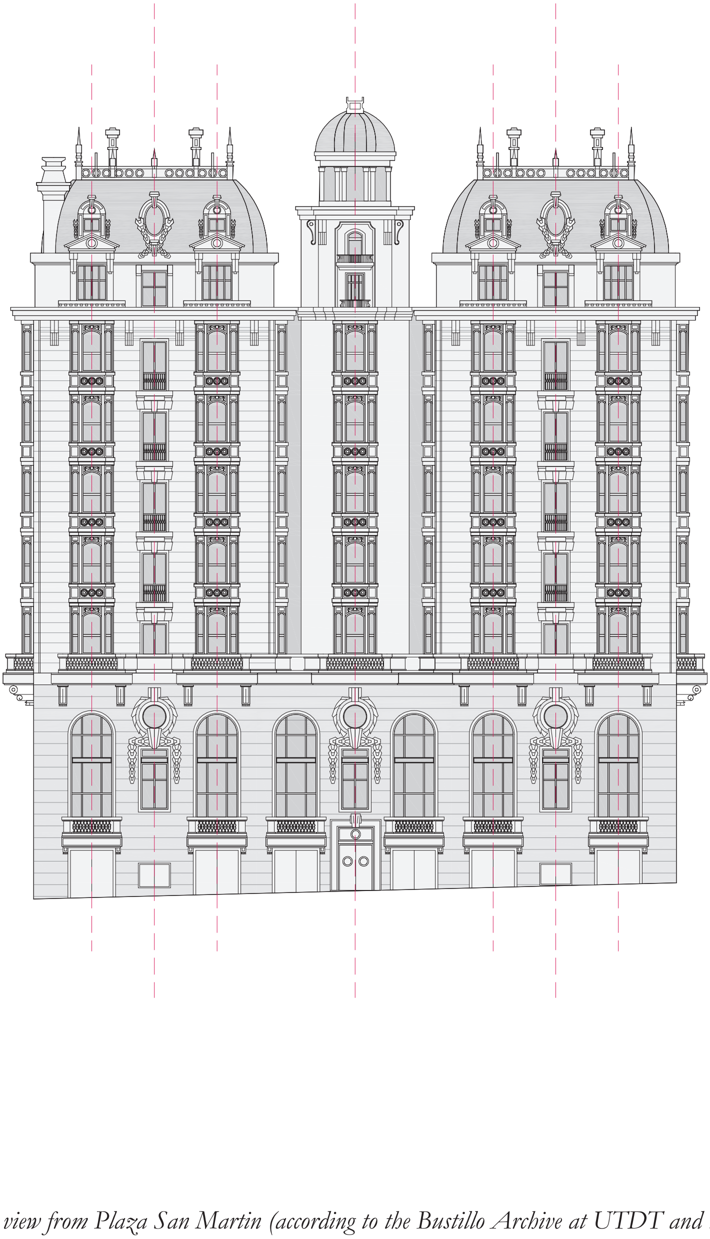


14-17 Seventh floor plan (according to the publication Plaza Hotel R.A.)
14-18 Rooftop floor plan (according to the publication Plaza Hotel R.A.)

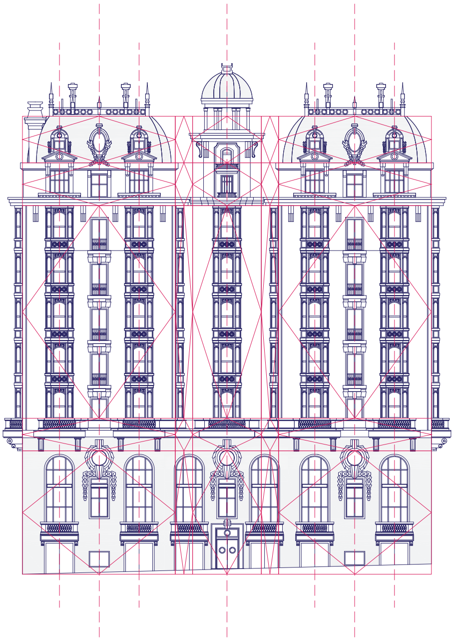
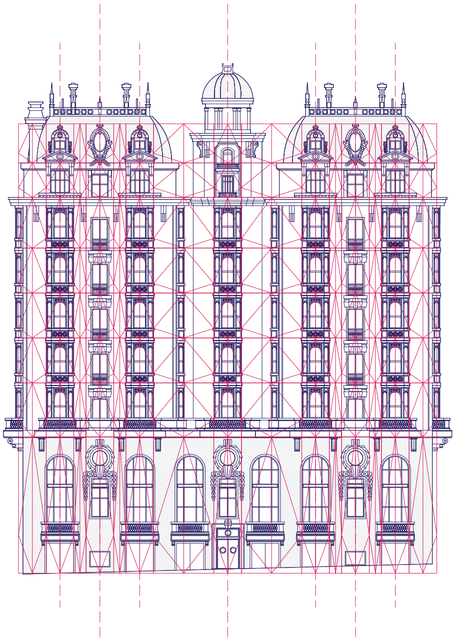
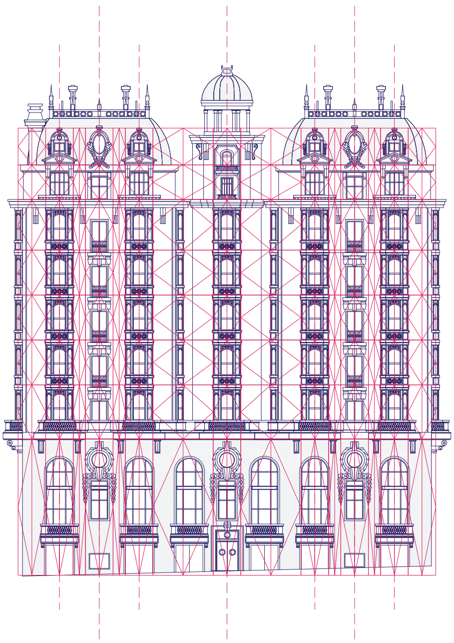
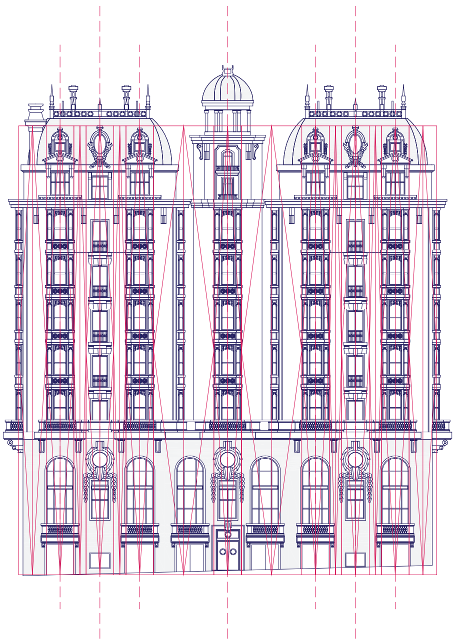




14-19 Spatial flow of the First-Third hotel floorplans. The diagram is organized following the façade modulation coordinating the bay windows and walls.
14-20 Diagram highlighting the main spatial areas of the First-Third hotel floorplans. The symmetrical organization of the hotel floors (A-B-A, building tower, void, building tower) is also repeated on each body (A-B-A, hotel rooms, corridor, hotel rooms).



14-21 Front view from Plaza San Martin (according to the Bustillo Archive at UTDT and various sources)

14-22 Facade tripartition; base, hotel rooms and mansard.
14-23 Subdivision according to floor height and proturding bodies.

14-24 Side view (reconstruction by the author from archival material)

14-25 Facade tripartition; base, hotel rooms and mansard.
14-26 Subdivision according to floor height and proturding bodies.

PART 3

- *Experiments*

The final part of the research compiles the 'Experiments' chapters, grouping all formal, material and compositional experimentations carried on with digital design tools. They intend to illustrate the scope of the topics registered by the research in terms of potential design methodologies.

The experiments are based on the topics extracted from the previous chapters as well as an exploration of the design tools themselves. The influence of the case studies and the design strategies that enabled them is located at the core of the experimental chapters, while simultaneously exploiting the capacities of native digital tools such as parametric design, subdivision modeling or genetic algorithms.

In some cases the affiliation between case study and experiment is straightforward and visible, while in others their relationship is mediated by the specificities of digital medium or by a speculative purpose.

At the same time, the experimental chapters collaborate to recreate a distinct ´19th century´ by exploring (and expanding) not only design techniques and methodologies but also a formal repertoire, particularly in relation to the influence of manufacturing techniques. This alternative 19th century based on formal exploration, continuous variation and overall formal freedom can also be found in certain case studies however the range of its true potential is explored on the following chapters.

The experiments intend to bring back this embedded knowledge and reinsert it into the contemporary debate around digital tools and design strategies. A partial division of the experiments regarding the scale of its objectives (in components and compositions) is merely indicative of their main goals and results, and how experiments and case studies concatenate with one another.

Due to its particular character, some experiments propose determined and finite results, while others suggest an infinite string of possible outcomes, often in the form of catalogues. The expression of its products in variation cycles, series or catalogues is not only a result of the indefinite nature of parametric tools but also as a proxy of 19th century´s approach to design freedom and the apparently endless possibilities of mechanization.

CHAPTER 15

- *Component experiments*

01 – TERRA COTTA PANELLING

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *terra cotta cladding, National Terra Cotta Association, Palacio de Aguas Corrientes*

DESCRIPTION:

The experiment began by studying the different cladding patterns and configurations available for terra cotta pieces. The investigation of the façade composition of the Palacio de Aguas Corrientes and the publication from the National Terra Cotta Association ´Architectural Terra Cotta´ provided interesting insights regarding the combinatorial possibilities of cladding pieces.

A brick wall operates as a substrate in the Palacio de Aguas´ façade; depending on the height of the wall and the position of the cladding pieces, horizontal brick rows protrude in order to fit inside the cavities of terra cotta blocks, like cornice pieces. These projected brick lines also provide a guide across the entire building, arranging an ordering pattern in order to organize the cladding procedure.

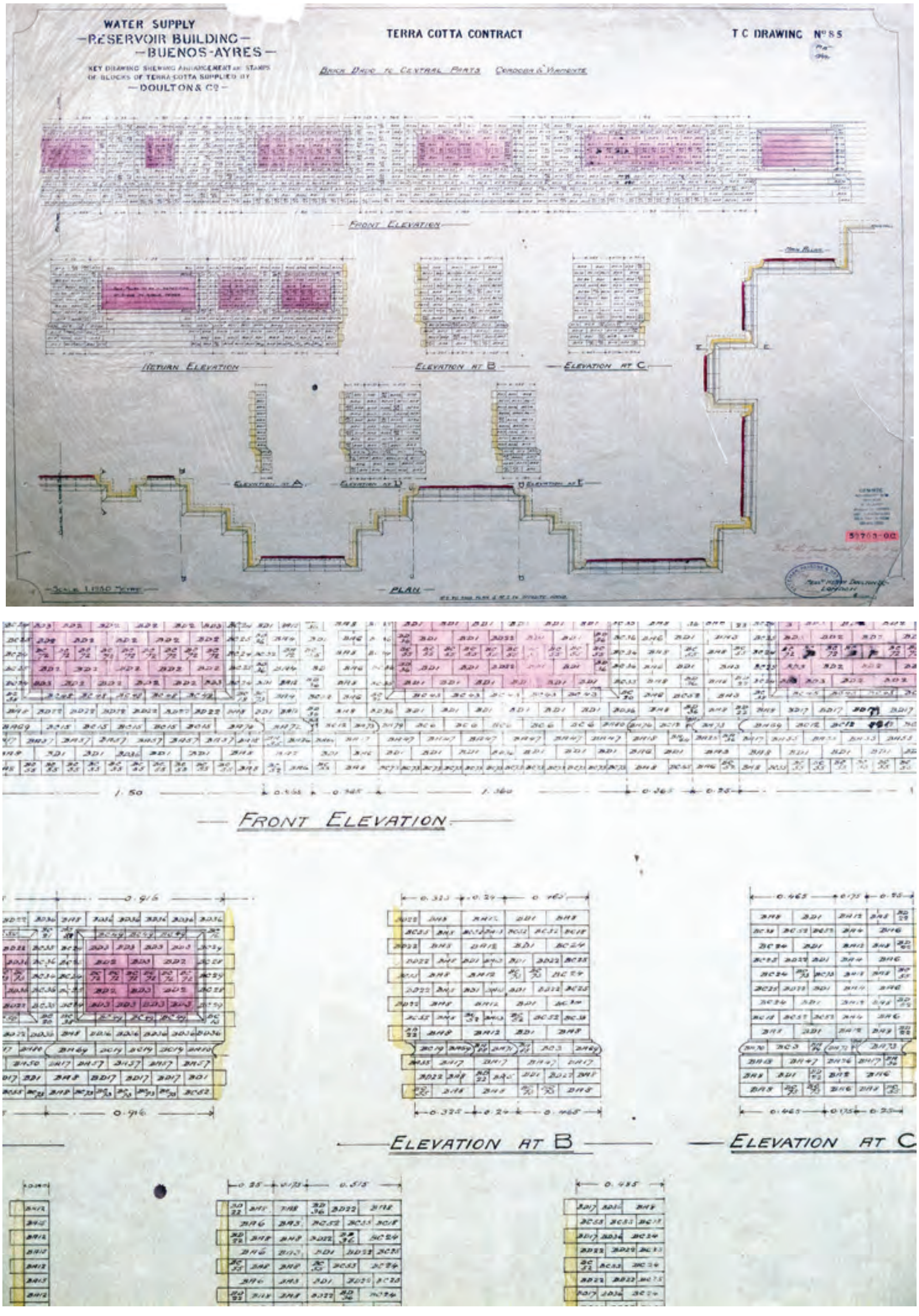
Similar to bricks, a bond pattern (such as running, English or stacked pattern) is required in the composition of cladding surfaces for constructive reasons and also to minimize mounting errors. Different patterns can be achieved either by rearranging similar pieces or by combining different types. Some of these patterns and combinations can be observed in Architectural Terra cotta.

The specific case of Palacio de Aguas Corrientes displays variations of these patterns (running bonds on the infill walls, stacked patterns on cornices and frames) and a complex combinatorial of different types of pieces, not only of colors and textures but also of sizes and geometries. The Palacio facade achieves incredible aesthetic effects by coordinating these dissimilar pieces, orange and cream bricks, glazed tiles, decorative pieces are arranged through mounting patterns which tend to dissolve in the grand composition of the facade.

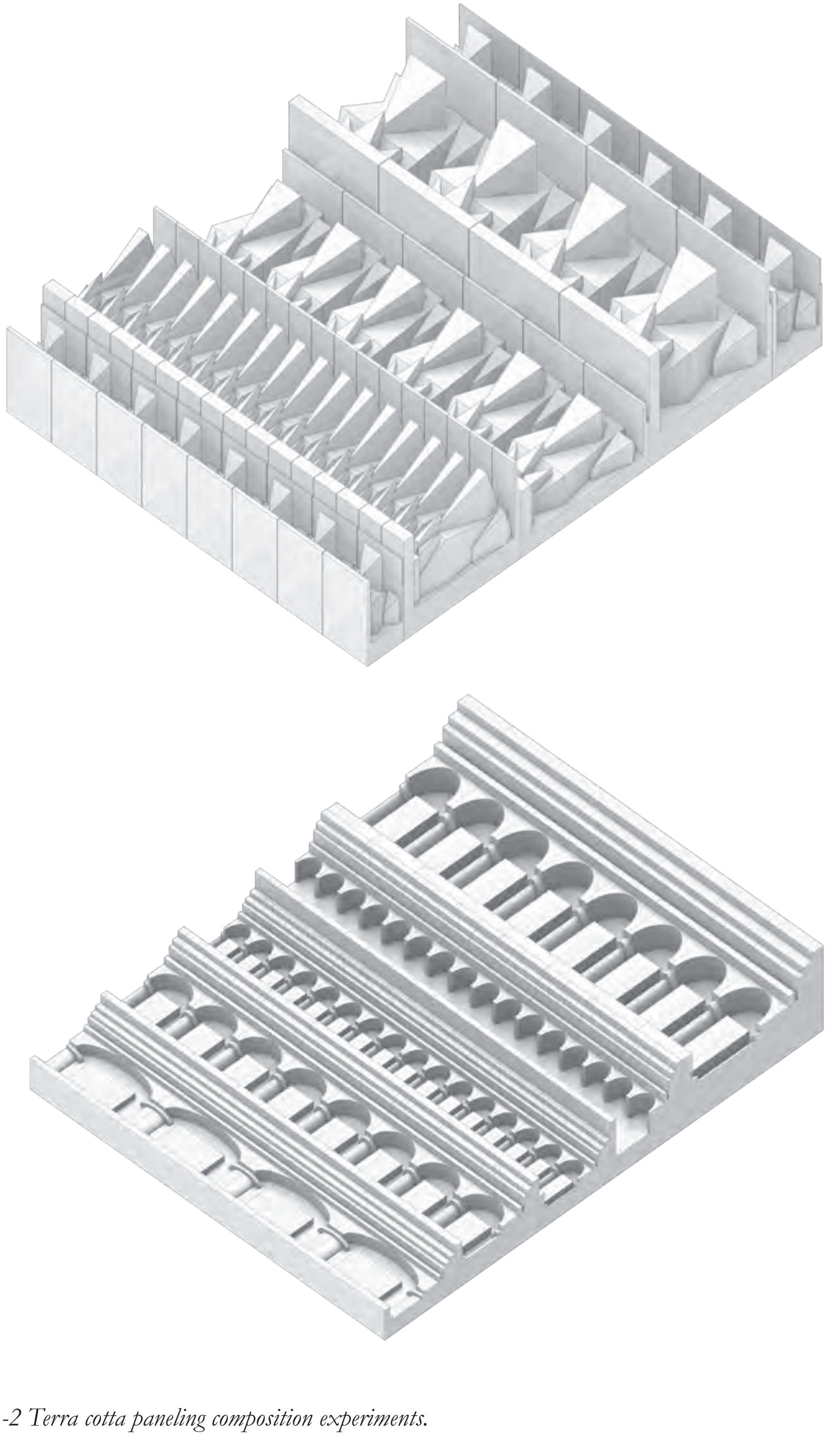
This experiment intends to investigate these aesthetic effects by exploring the combinatorial possibilities of terra cotta cladding by arranging several pieces of different sizes, thicknesses and geometries according to user-defined patterns. On this particular case, the experiment uses subdivision patterns on a planar object by creating a series of segmentations by halves; the rows are divided in segments of two, four, eight, sixteen and so on.

Each of these segments is then referenced to a block which will be adjusted to the panel´s dimensions. These types of design procedures (subdividing a surface and populating it with blocks) is often called ´Paneling´ and it is one of the key features of current parametric toolsets. According to these procedures, each block adjusts itself to its corresponding panel, regardless of their proportions or geometry. The outer dimensions and inner geometry of each panel can be further controlled with individual and global parameters, producing the famous ´fluid´ facade solutions, common in contemporary digital practices.

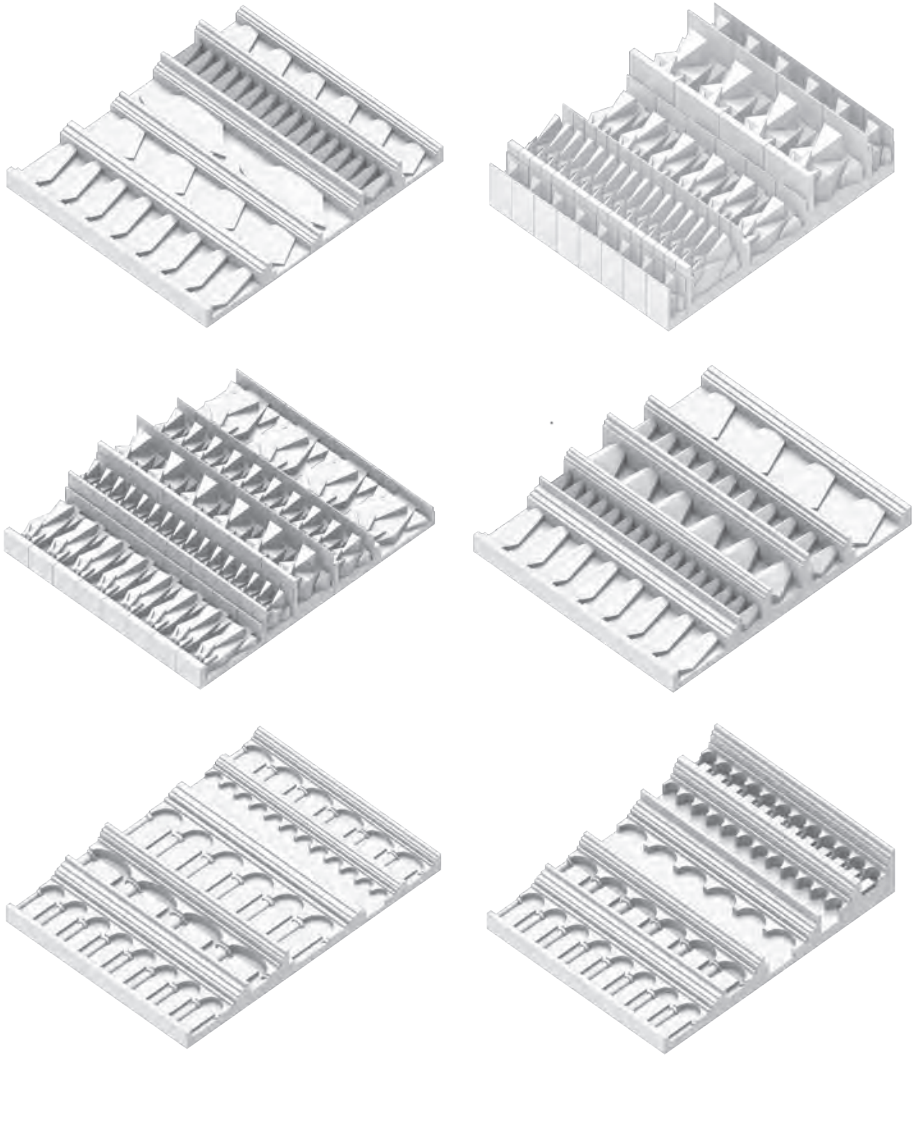
Pre-Fordist production and individualized manufacturing, such as the case of terra cotta facade pieces enabled a similar approach to cladding in 19th century; each project was tackled as an individual opportunity and produced unique results. Even though the production of pieces was handwork intensive, the flexibility of their conception and sheer variety of geometries, materials and finishing available in the market rendered them a powerful and expressive solution for the period´s facades.



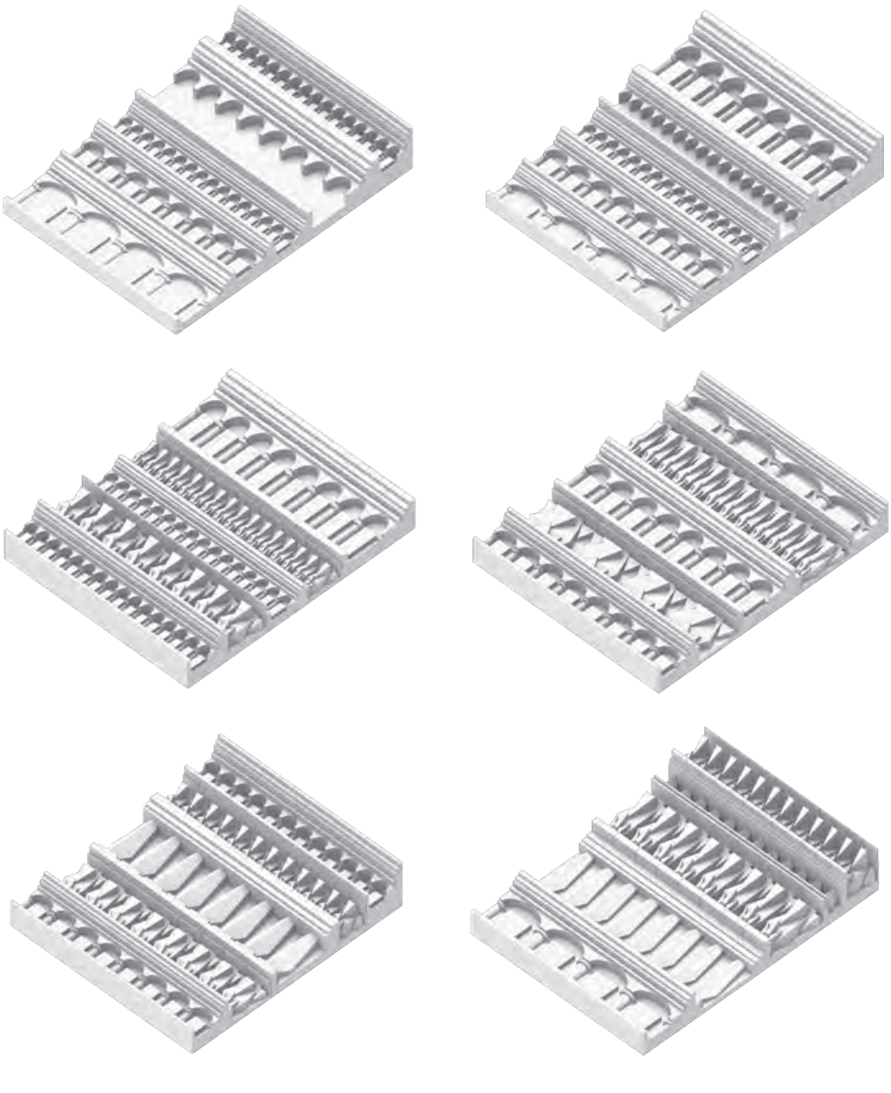
15-01-1 Terra cotta detail plans from the Palacio de Agua´s Facade. Source: Museo del Agua Archives, Buenos Aires.



15-01-2 Terra cotta paneling composition experiments.



15-01-3 Terra cotta paneling composition experiments.



15-01-4 Terra cotta paneling composition experiments.

02 – TERRA COTTA PROFILES

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *classical architectural profiles, Palladio, Serlio*

DESCRIPTION:

The experiment consists in a series of parametric definitions that produce architectural profiles such as cornices and pedestals through a number of procedures, whether by combination of parts or by subdividing a surface or a curve.

Several terra cotta profiles were studied in order to parametrize the dimensions, proportions, widths and thicknesses. The combination of volumes with the same width but different thicknesses achieves detailed compositions and ornamental effects.

Traditionally, stone profiles were cut by using a master profile or a stencil which is transferred to the stone block. The block is first cut with a large chisel (often by an apprentice or an inexperienced worker) and it is subsequently adjusted with the aid of finer tools on each phase. Each step of the cutting process uses a finer and more precise tool, while also requiring more time and control.

The cutting process works ´by approximation´ to the master profile. Similarly, the parametric definition works by adjusting the final shape to the user-defined profile by subdividing a NURBS curve. If the curve is divided in a lower number of steps, the profile definition will be low, evidencing the ´steps´ of each profile. If the curve is divided by a larger number, greater detail is produced, or in other words, the steps become smaller and imperceptible.

During 19th century, the popularization of single and multi-headed pantographs allowed a similar procedure in order to cut materials, particularly wood. In a similar manner, the fabrication of these sort of pieces with a CNC milling machine would also involve a ´stepped´ approximation. The CNC mill works by cutting through a block of material through a defined path, each pass of the tool removes a certain amount of material and over time, each cutting pass defines the final shape of the object. For efficiency and economic reasons, the first passes are rather coarse and quick, using a large cutting bit, thus removing more material in less time. Each part of this process defines then a ´stepped´ object and once the pass finishes, the milling bit is changed to a smaller one and set to cut again. Throughout the cutting processes, each object at the end of each phase is a stepped approximation of the final form, the step size decreases while the overall definition increases each time. Finally, a ´detailed´ pass, often slow and careful, gives the object a smooth surface by completely eliminating the step traces.

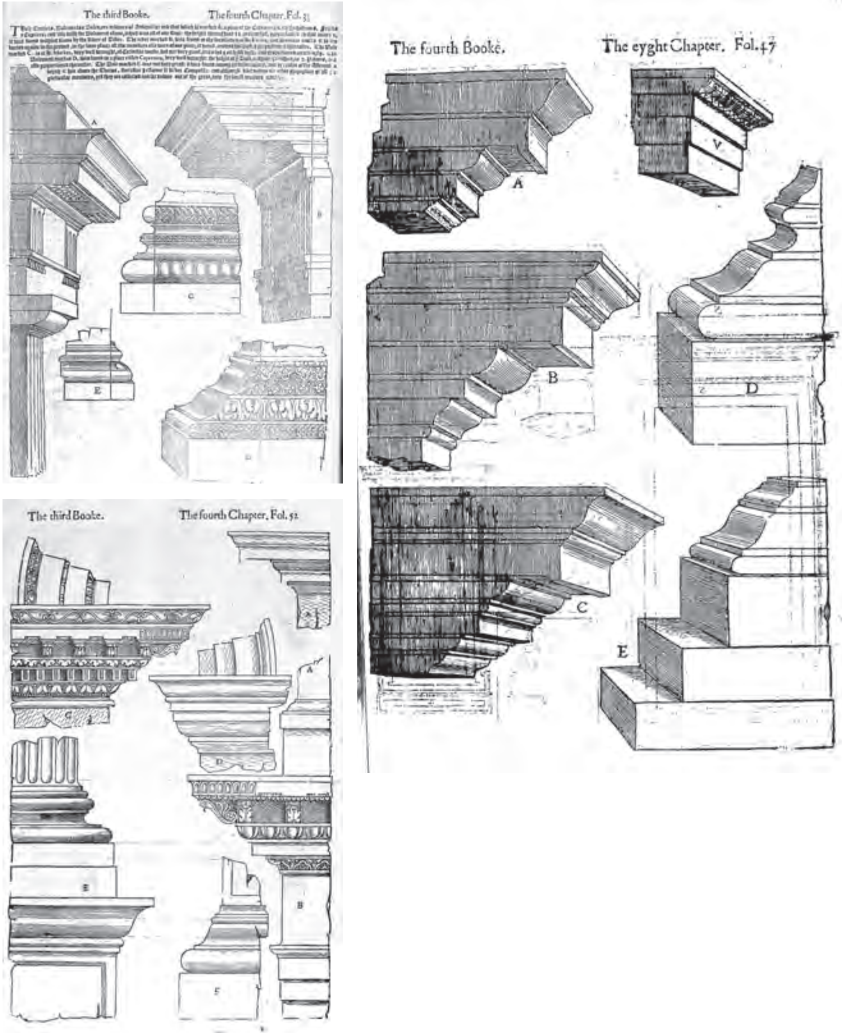
This experiments also relate to Greg Lynn´s research in CNC manufacturing (Die Pinakothek Der Moderne wall, the Prettygoodlife.com showroom) which made use of the aesthetic effects as a result to the toolpath traces and their textures.

On the experiments a smoothing operation is performed in order to polish the uneven surfaces and sharp edges producing a softer, continuous surface.

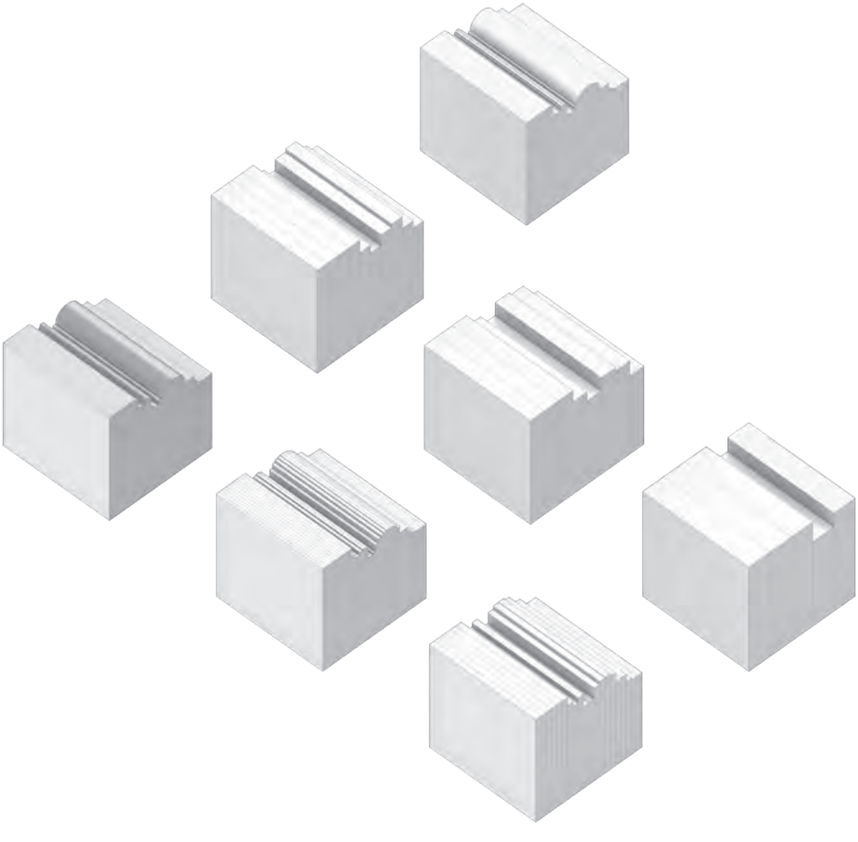
This operation produces a single NURBS surface which is linked to the base 'stepped' profiles. Depending on the relative distances of each of the profile 'steps' the curvature and angle of the smoothened surfaces are altered; when their differences are steeper, the angles are softer in order to cope with the heterogeneous base and a homogeneous surface, similar to a drape covering an object.

The correlation between historical manufacturing processes, digital design tools and digitally controlled manufacturing is a key interest of this research and this particular experiment is a compelling example of these type of design procedures.

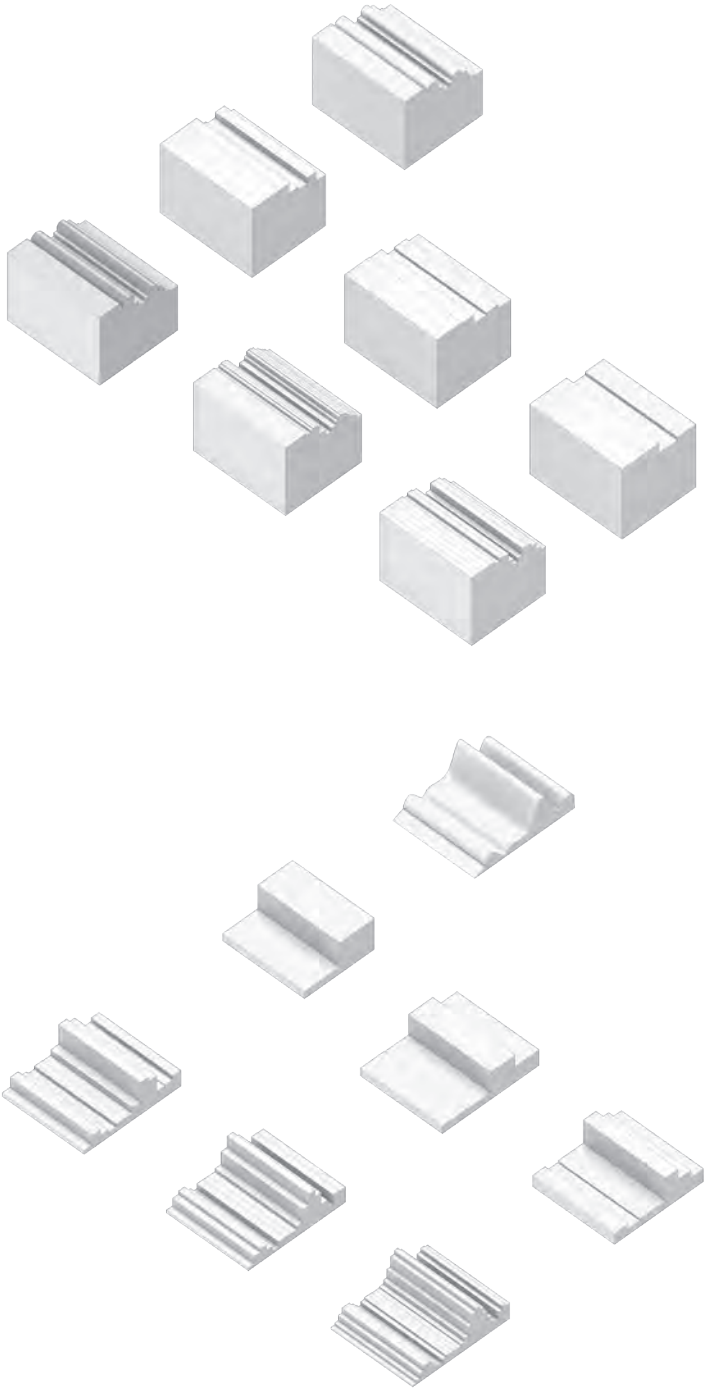
Top: Facade tripartition; base, hotel rooms and mansard.
Bottom:Subdivision according to floor height and proturding bodies.



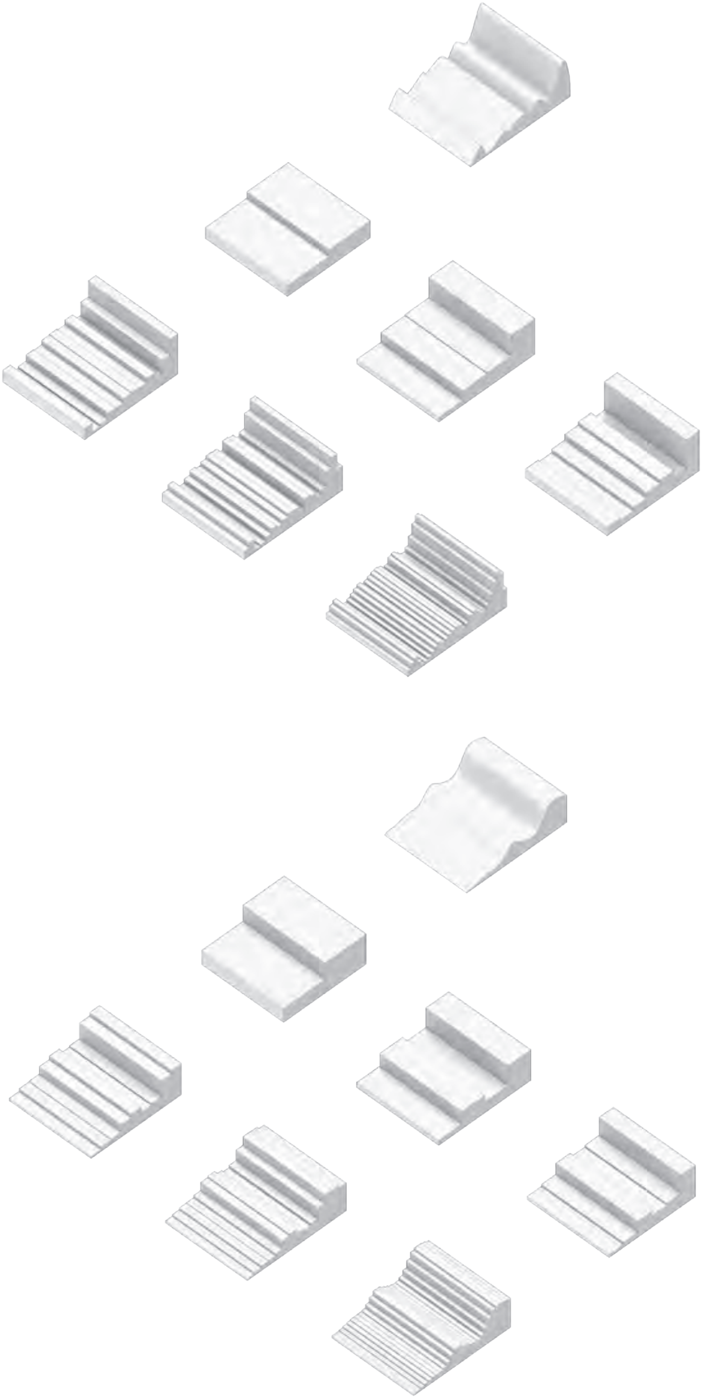
15-02-1 Corinthian profiles from Serlio S. ´The five books of architecture´



15-02-2 Terra Cotta profiles catalog. Original profiles and progressive subvision with fixed thickness.



15-02-3 Terra Cotta profiles catalog. Original profiles and progressive subvision with fixed thickness.



15-02-4 Terra Cotta profiles catalog. Original profiles and progressive subvision with fixed thickness.

03- OPPENHOFFALLEE RUSTICATIONS

SOFTWARE: *Reality Capture, Meshmixer, Zbrush, Rhinoceros*

REFERENCES: *Rustication studies by Blondel, Von Klenze, Palacio de Aguas Corrientes, Rustications in Oppenhoffallee boulevard, Aachen*

DESCRIPTION:

This experiment was carried for the Digital Humanities Conference and Workshop at Trier University in 2015. For the conference, a poster was presented showcasing a brief investigation of the rustication patterns found on the Oppenhoffallee Boulevard in Aachen. Around twenty one different rustication pieces were registered and catalogued via photogrammetry techniques.

The Oppenhoffallee Boulevard is a small urban intervention in the Frankenberger quartier in Aachen. It was created around 1870 to accommodate factories and housing, both for workers and administration personnel. The boulevard was designed to provide housing for the owners and hierarchical staff, consisting in three-storey houses with the typical three-window arrangement on the facades. The book of P. Ruhnau ´Das Frankenberger Viertel in Aachen´ includes several facade drawings of the Boulevard´s houses taken from the city´s archive.

Almost all the houses respect this three-window typology and classical tri-partition (access level, two floors of living spaces and the attic) and while being built during a relatively short period of time, no two houses are the same. The typical bay-windows on the center of each house, the variations in the mansards and sculptural decoration of the balconies provide them distinctive expression. Yellow bricks, stucco or Paris stone are some of the materials available on the facades. Variation and differentiation within a fixed typology are the key for the cohesive expression of the boulevard.

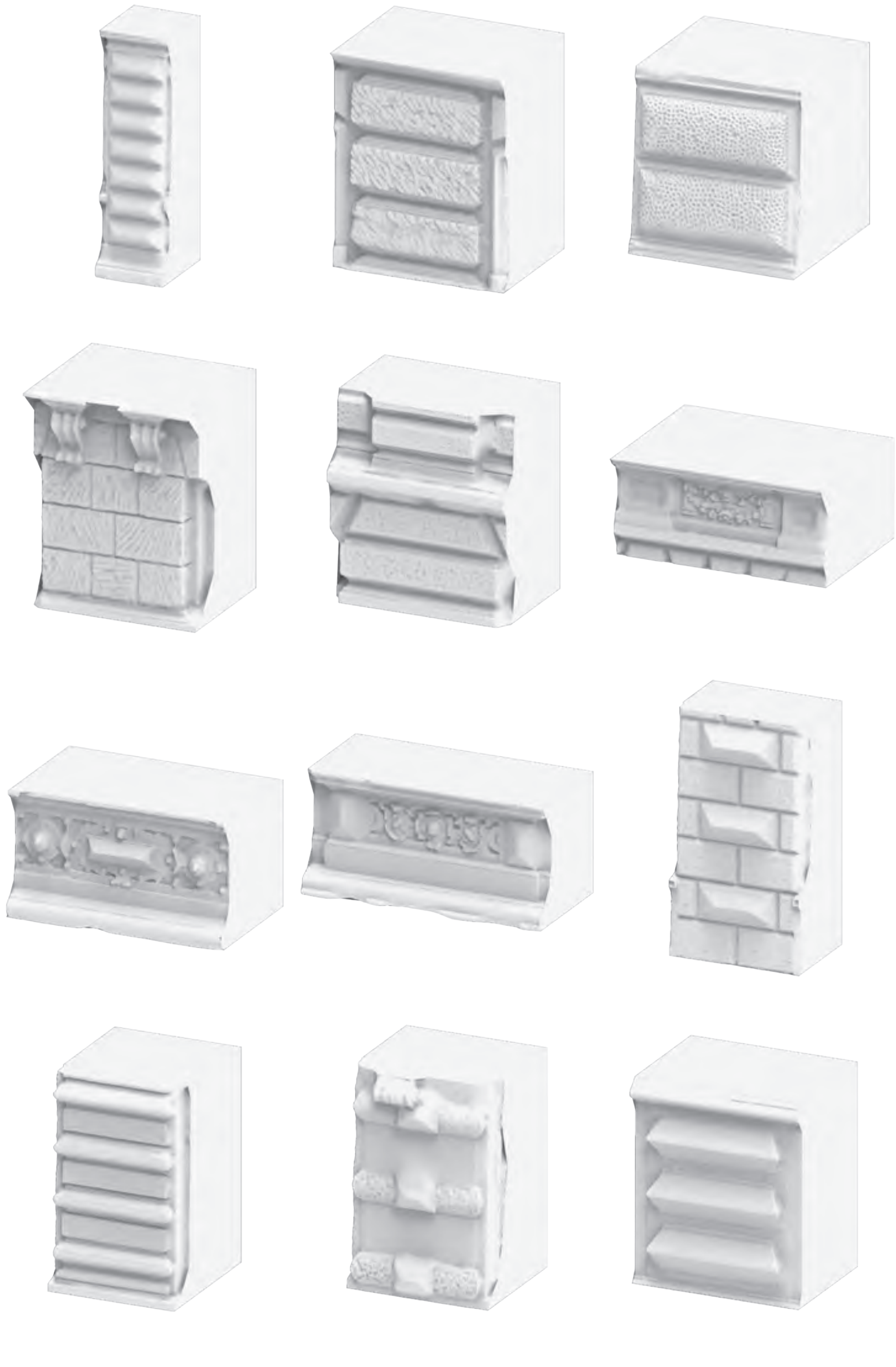
The rustication pieces on the ground floor are also another example of these characteristics. Several rustication patterns, textures and geometries populate the Oppenhoffalle Boulevard and this experiment was set to register some of them in a catalogue type structure by using photogrammetry techniques.

Photogrammetry is a digital procedure that creates three dimensional models by extracting information form an array of photographs. Each model requires between fifty and ninety photographs in order to capture a significant level of detail.

The result was a catalog of highly detailed 3d models, an illustration of the complex relationships between architectural ornamentation, style and manufacturing techniques in the late 19th and early 20th century. The combination of serialized and unique features of each piece is a critical evidence of the period’s compromise in terms of aesthetics and construction technologies.

15-03-1 Repetition and difference. Prefabricated ornamentation and rustications in the Frankenberger Viertel, Aachen. Extracted from Ruhnau, P - ´Das Frankenberger Viertel in Aachen´

15-03-2 Rusticated wall segments from Oppenhoffallee, Aachen.



15-03-3 Rusticated wall segments from Oppenhoffallee, Aachen.

04- RUSTICATED PODIUMS

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *Rustication studies by Blondel, Von Klenze, Palacio de Aguas Corrientes, Rustications in Oppenhoffallee boulevard, Aachen*

DESCRIPTION:

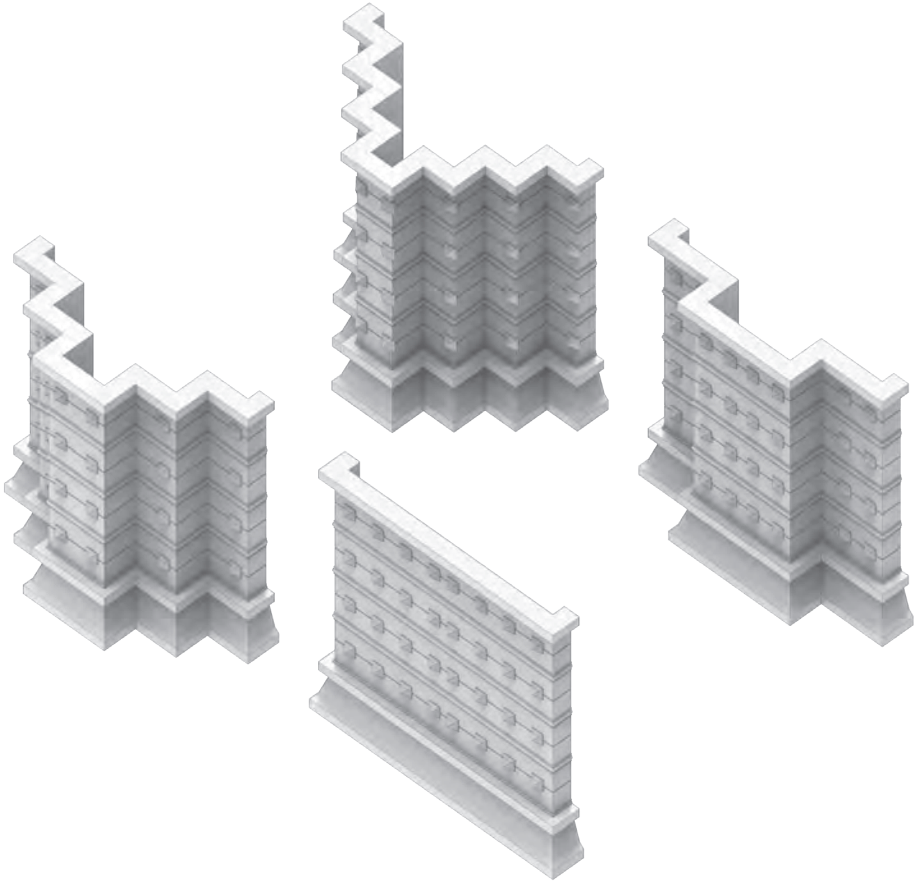
The experiment began with the study of rustication patterns for the exhibition 'Pavilions' (Rokokorelevanz, Kerstenscher Pavilion in Aachen on 05.06.15). For the exhibition, the research focused on the rustication profiles and their theoretical variant types, like Verona, Linotta, Pesaro, Strozzi, etc., typically present in many Renaissance projects.

This exercise is a series of parametric definitions that create wall geometries and rustication patterns parting from the study of the previous stages and particularly, the case of Palacio de Aguas Corrientes. A first definition creates rustication patterns similar to the ones present in architectural treatises and manuals like Blondel's. These patterns are generated geometrically in section and then extruded. Each wall is subdivided in a number of rows that are subsequently modified in creating sharp geometries, stone tiles or truncated bricks. The result is a series of wall modules with different rustications patterns.

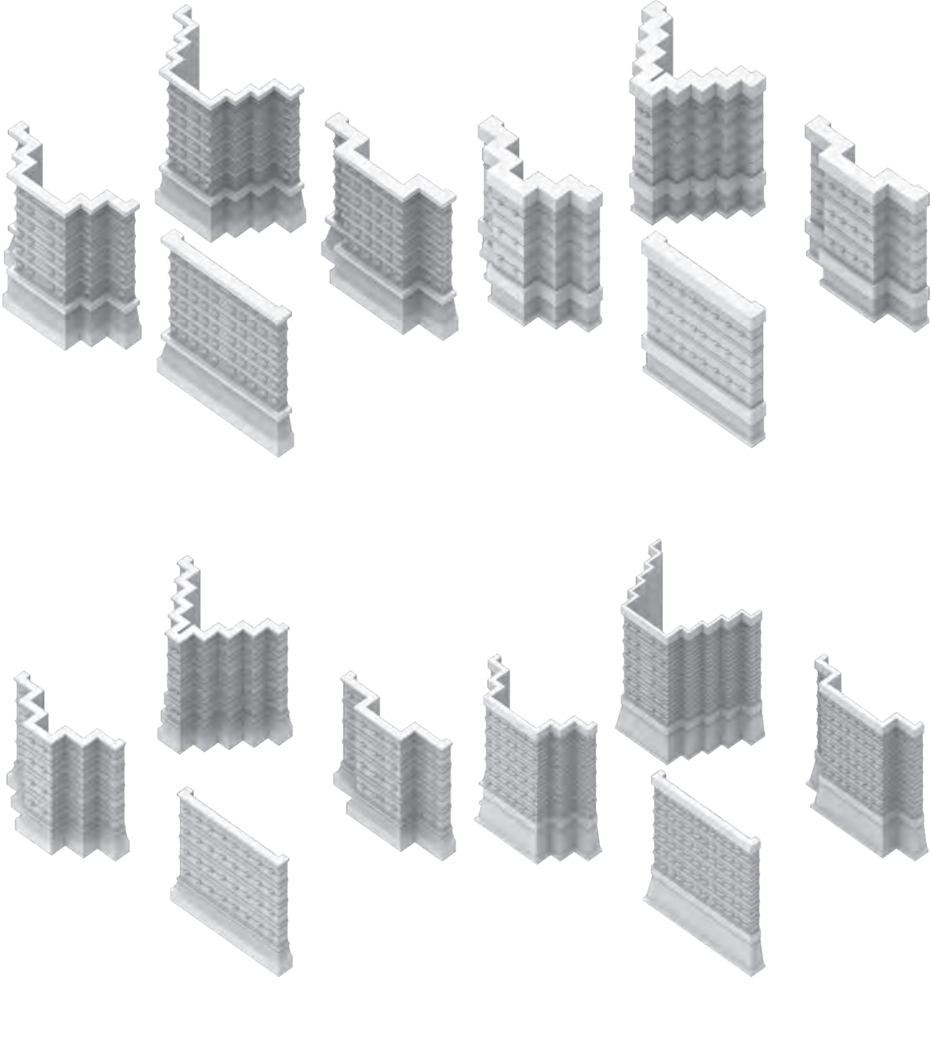
A second definition generates different wall types and geometries, including indentations, depressions and pillars. The overall geometric pattern that governs this definition is inspired in the Palacio de Aguas's ground floor walls. The particular geometries between walls and pillars are controlled by a series of parameters that act harmoniously. The design is flexible enough to produce variable wall lengths, ranging from short wall modules up until an infinite length.

The latest part of experiment consists in a definition that generates wall pillars similar as the ones in the access of Palacio de Aguas Corrientes, a series of packed pillars, inherited from the last definition and similar to a stepped column. These pieces are then decorated with small spikes or horizontal pyramids, which combined with fluted channels, give the building's rusticated walls their unique expression. The result of this exercise is a number of walls and pillars with different grades of detail according to the number of subdivisions and juxtaposition of columns.

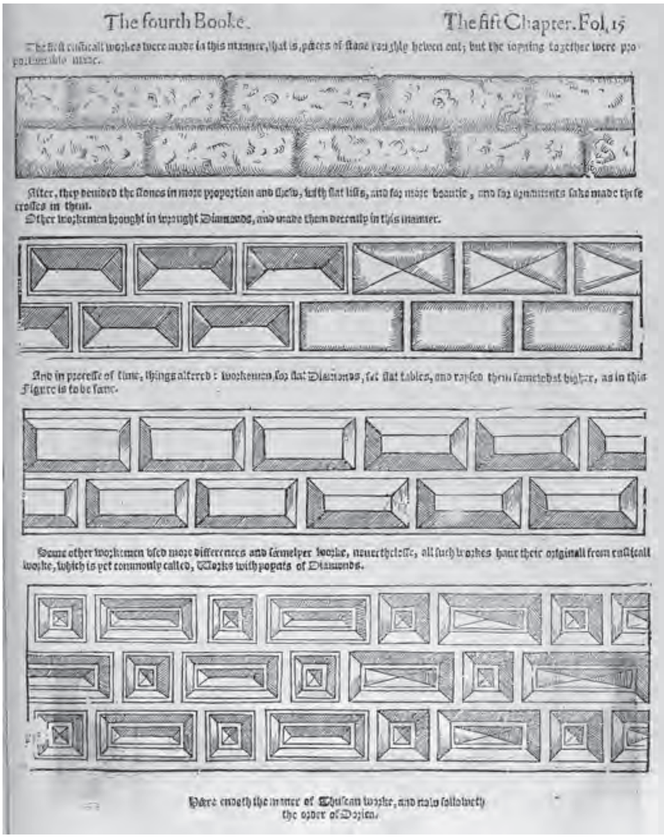
15-04-1 Rusticated pillar from the Palacio de Aguas Corrientes (Buenos Aires, 1887)



15-04-2 Rusticated pillars. Parametrical Variations 01.



15-04-3 Rusticated pillars. Parametrical Variations 02.



The fourth Booke. The fift Chapter. Fol. 15

The first rusticall workes were made in this manner, that is, pieces of stone roughly hewen out; but the ioyning together were proportionable made.

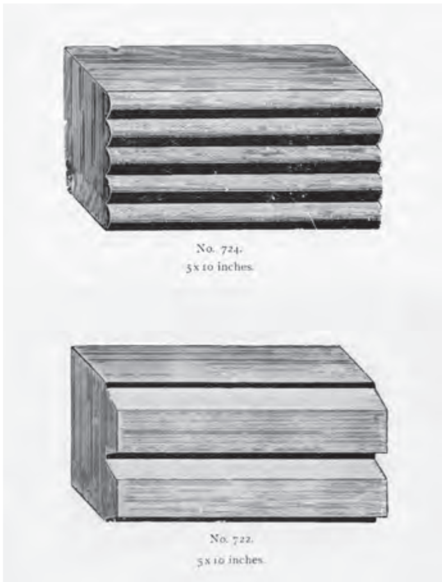
After, they deuided the stones in more proportion and shew, with flat lists, and for more beautie, and for ornaments sake made these crosses in them.

Other workemen brought in wrought Diamonds, and made them decently in this manner.

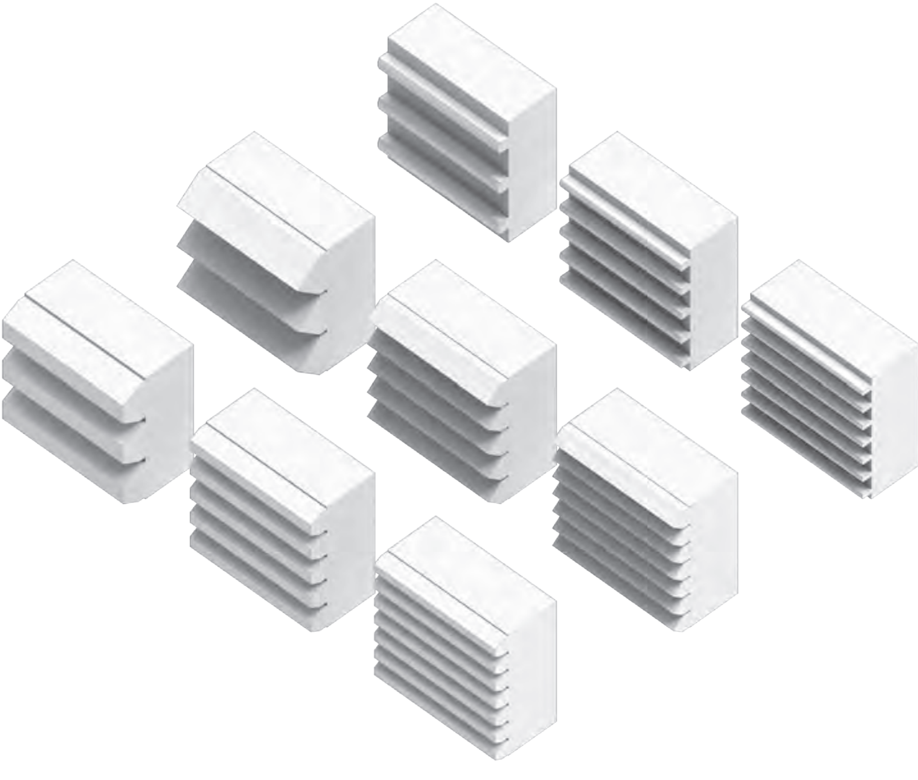
And in processe of time, things altered: workemen for flat Diamonds, set flat tables, and raysed them somewhat higher, as in this Figure is to be seene.

Some other workemen used more differences and seemelyer worke, neverthelesse, all such workes have their originall from rusticall worke, which is yet commonly called, Workes with poynts of Diamonds.

Here endeth the manner of Thuscan worke, and now followeth the order of Dorica.

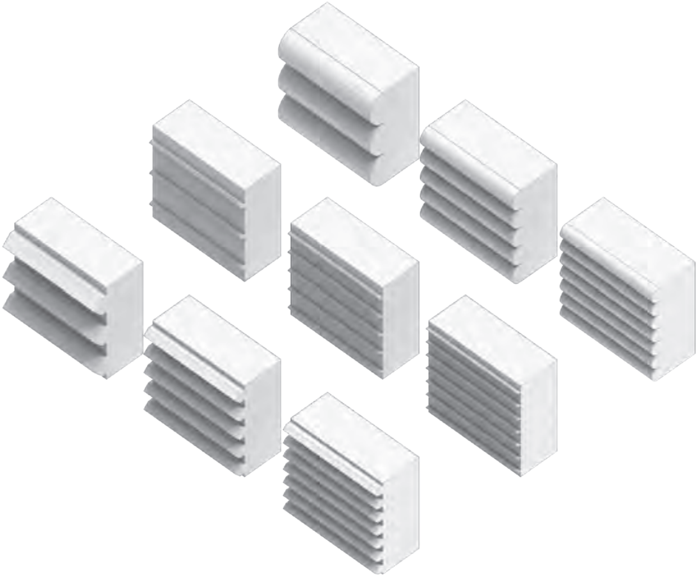


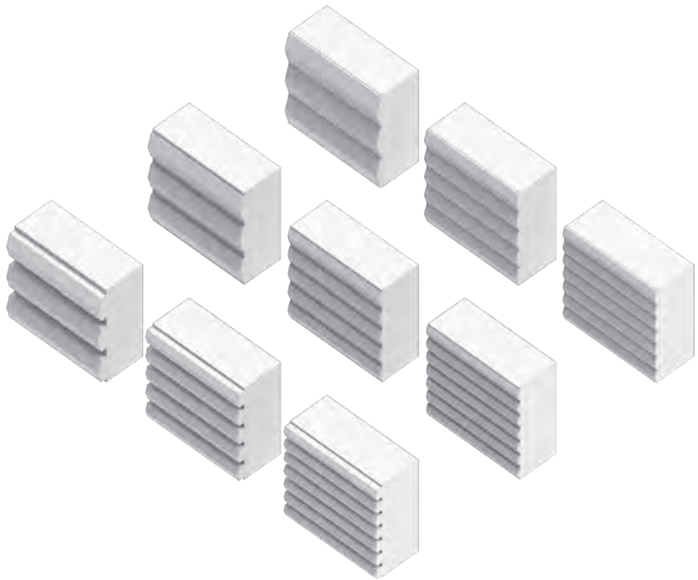
15-04-4 Wall rustications by S. Serlio ´Five books of architecture´ (1537)
15-04-5 Rusticated bricks. Extracted from the brick catalog by the Kansas Hydraulic Press (1904).



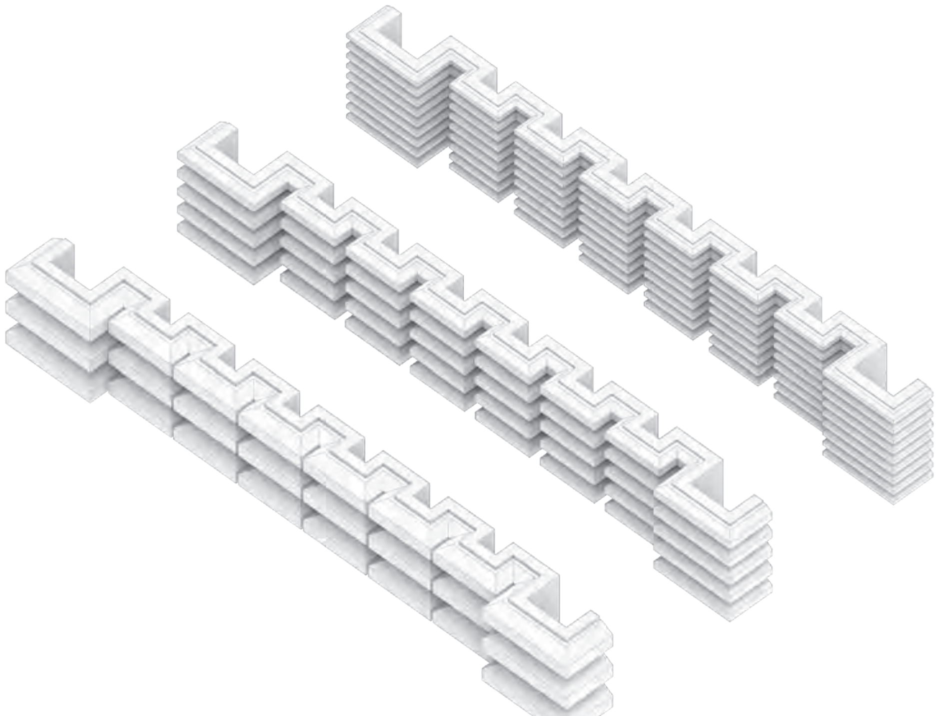
15-04-6 Rusticated walls 01.

15-04-7 Rusticated walls 02.

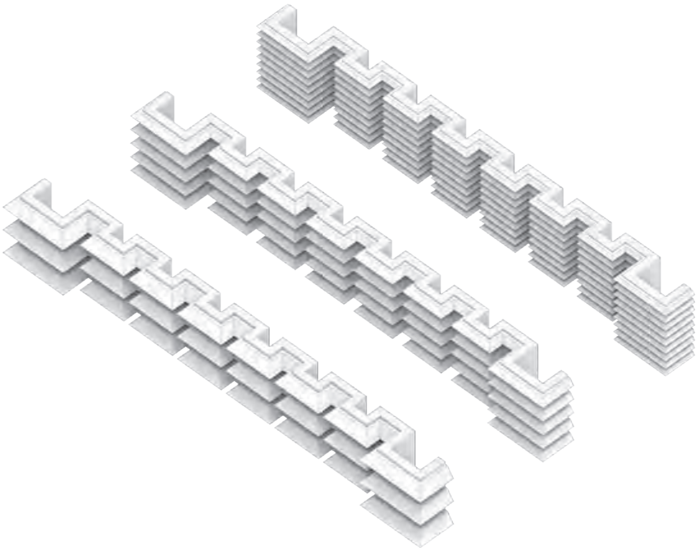


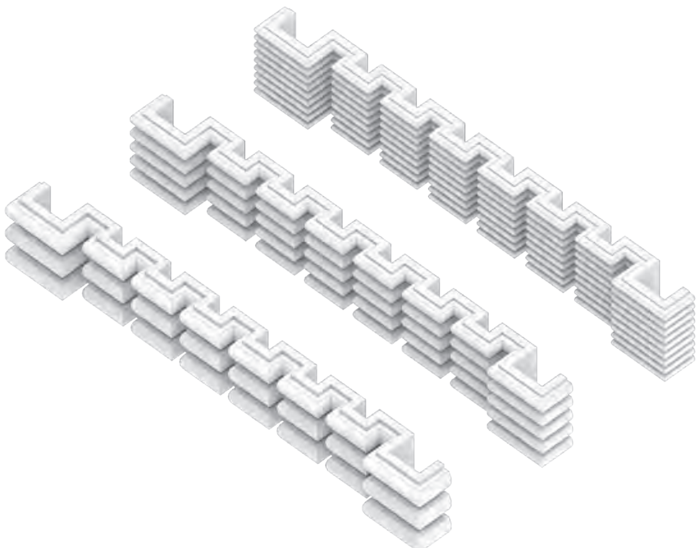


15-04-7 Rusticated walls 02.
15-04-8 Rusticated walls 03.

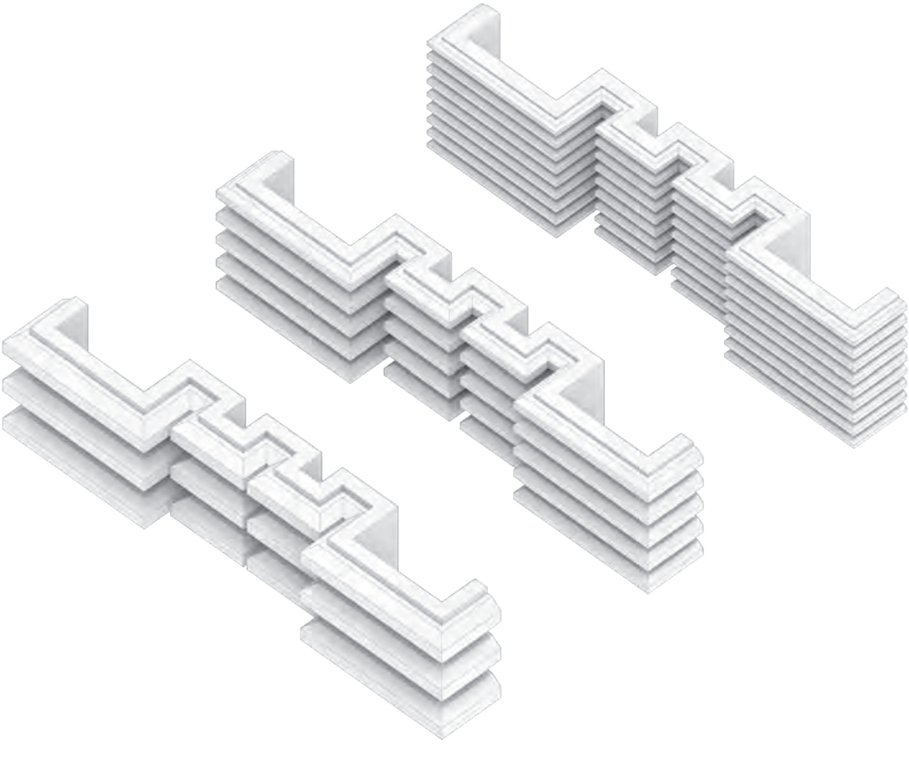


15-04-9 Rusticated ground floor walls 01.

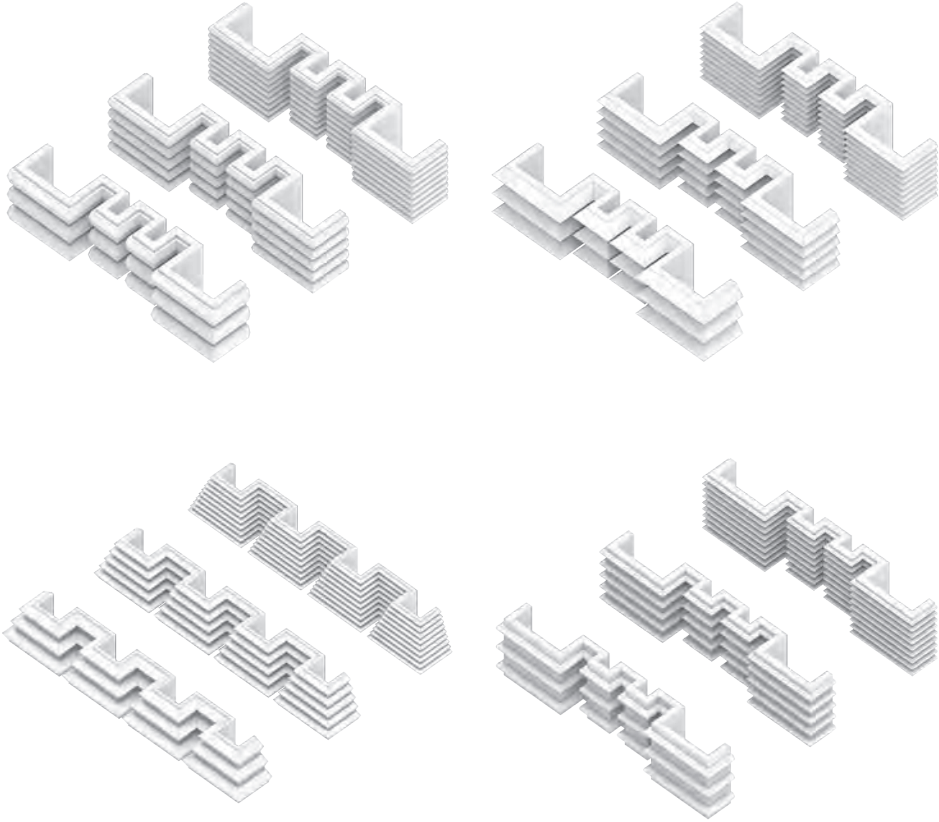




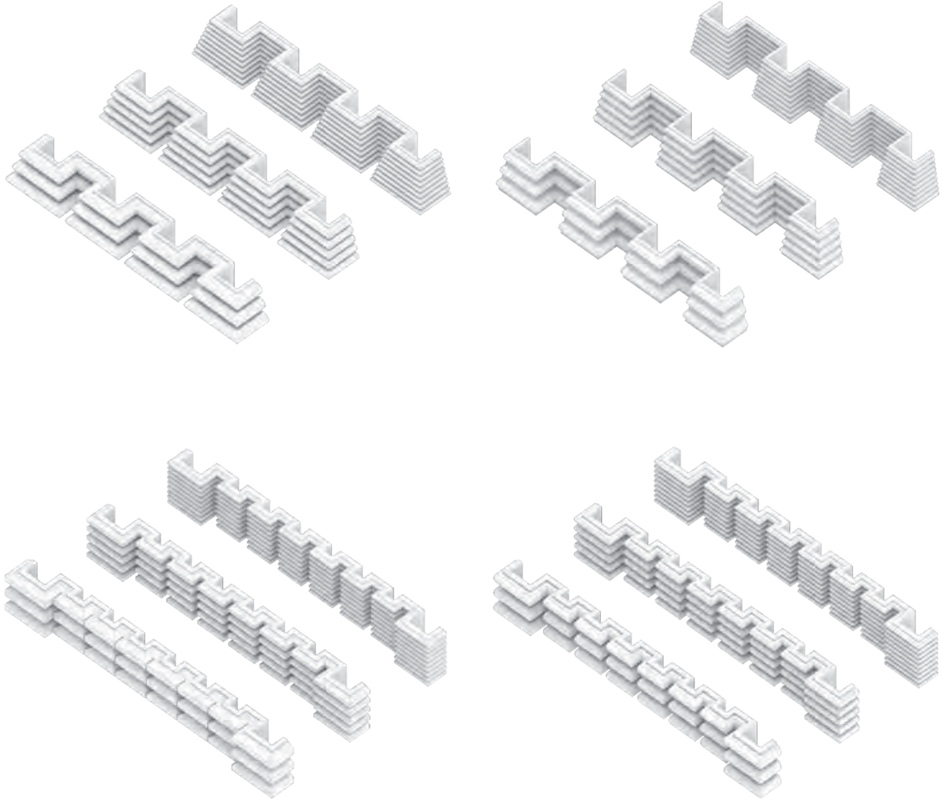
15-04-10 Rusticated ground floor walls 02-03.



15-04-11 Rusticated ground floor walls 04



15-04-12 Rusticated ground floor walls 05, 06, 07, 08



15-04-13 Rusticated ground floor walls 09, 10, 11, 12

05- PALACIO DE AGUAS ORNAMENTS

SOFTWARE: *Rhinoceros, Grasshopper, Mudbox*

REFERENCES: *Palacio de Aguas Corrientes by O Boye, 'Architectural terra cotta, standard construction' by National terra cotta society*

DESCRIPTION:

This exercise began with the investigation of terra cotta façade pieces from the Palacio de Aguas Corrientes. These ceramic pieces, fabricated by the Royal Doulton Company are a small sample of the 300.000 multicolored pieces that cover the entire façade.

The original purpose was to analyze the formal and material complexity of the pieces, combining organic and geometrical forms, glazings and textures, concordant with the Palacio de Aguas' French Renaissance style. The first task included the analysis of original drawings by Boye's office and exhibition pieces at the Palacio de Agua's museum. Secondly, a series of 3d scanned models from the pieces were generated. Ultimately, the 3d scanning procedure did not succeeded because of the induced errors by the glazing.The organic nature of the original pieces was faithfully translated, but due to reflexes on the glazing, unwanted geometry in the form of peaks appeared.

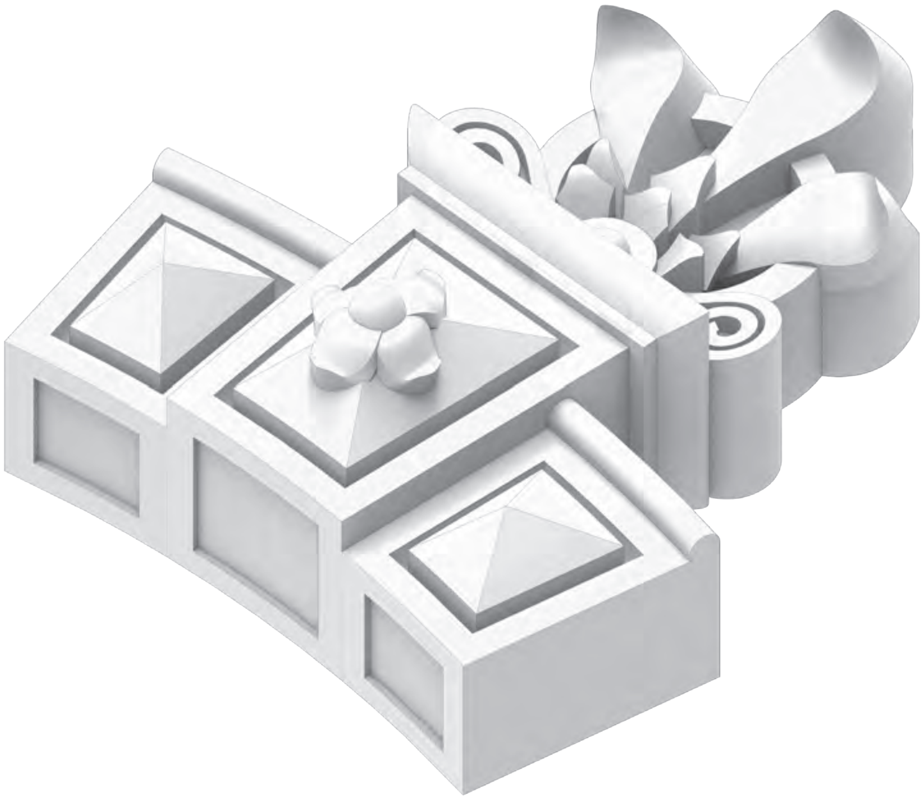
The third stage of this exercise consisted on the sculpting and parametric coding of ornamental pieces, generating detailed models. Each piece consisted on a geometric part and an organic one, making it difficult to complete the whole task with only one type of software. For this matter two distinct types of software were used; on one hand, architectural design software and parametric tools, responsible for the geometric component using polygonal modeling and NURBS tools.

Organic software was also used, in this case Mudbox, a tool used mainly in special effects and video game design. This type of software becomes helpful facing complex, organic geometries that are hard to describe with geometric tools such as extrusions or revolution volumes. This can be also explained by the origin of the Terra Cotta pieces; part of them was manufactured by machines, mostly the tiles and geometric pieces for repetition that required higher degrees of precision. The same pieces also contained sculptural, organic parts sculpted by workshop artists, according to the architect's designs.

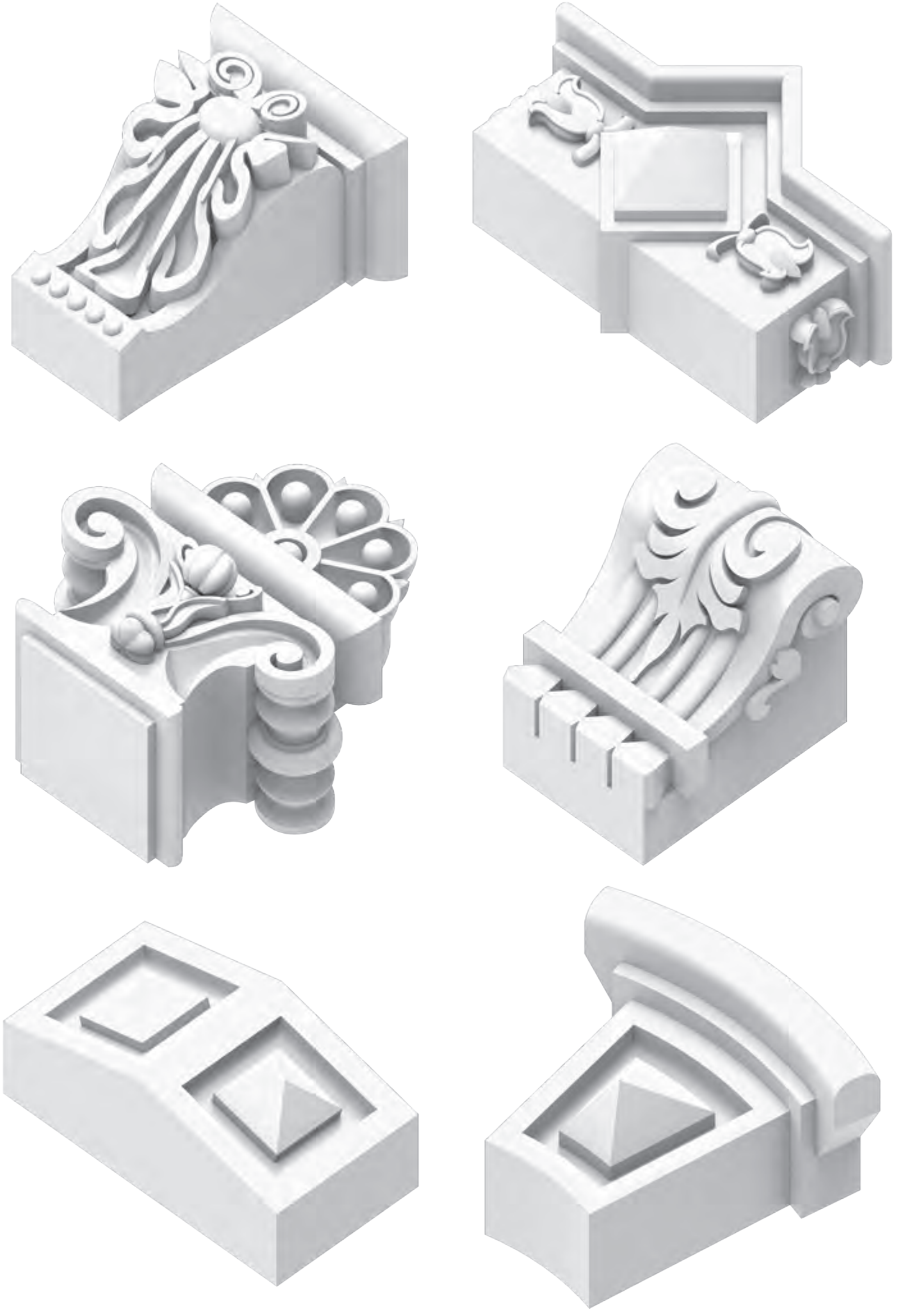
For this reason, a similar strategy was implemented regarding digital tools. Both software packages act complementary on this case; they cannot perform each other's tasks, but together they can achieve interesting, detailed and precise results.

Finally, all the designs were 3d printed in porcelain in a smaller scale in order to assess the objects materially, with the added details of the layering texture provoked by the printing process. It is also worth mentioning that the manufacturing process involved a great deal of material know-how, particularly in regard of the geometrical precision. The modeling and firing process of ceramics produces shrinking and deformations that need to be taken into account in the final position and fitting of each piece.

15-05-1 Terra cotta glazed ornaments from the Palacio de Aguas Corrientes. Image source: Tartarini, Jorge, 'El palacio de las aguas corrientes: de gran depósito a monumento histórico nacional'



15-05-2 Multi-piece Terra Cotta Ornaments 01.



15-05-3 Terra Cotta Ornaments 02, 03 ,04 ,05 , 06 ,07.

15-05-4 3d printed porcelain ornament from the Palacio de Aguas.

15-05-5 3d printed porcelain ornament from the Palacio de Aguas.

06 – MULTIMATERIAL FRAMES

SOFTWARE: *Rhinoceros, Grasshopper*

DESCRIPTION:

One of the relevant topics of this research is related to the inclusion of new materials for construction but also on how several of them were combined seamlessly in the building process both technically and aesthetically, resulting in harmonic and consistent architectural elements.

The experiments analyze several of such elements, for example portals, pillars and columns, parametrize their dimensions and characteristics in order to partition them, dividing them in smaller, standardized components. To this end, iconic elements were registered from the historical references and brought into the digital design process.

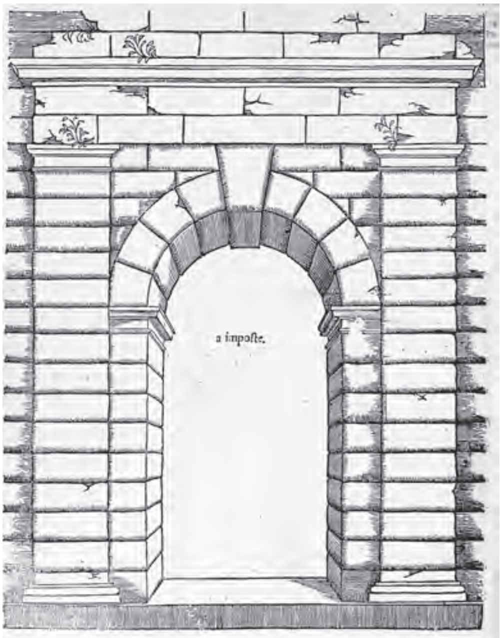
This experiment intends to design a portal. Each design is partitioned in three major groups of elements; the arch and two jambs or doorposts. Once again, each group consists in inward and outward elements, allowing different arrangements according to a parametrized pattern, maximizing the combinatorial possibilities with the minimum amount of pieces

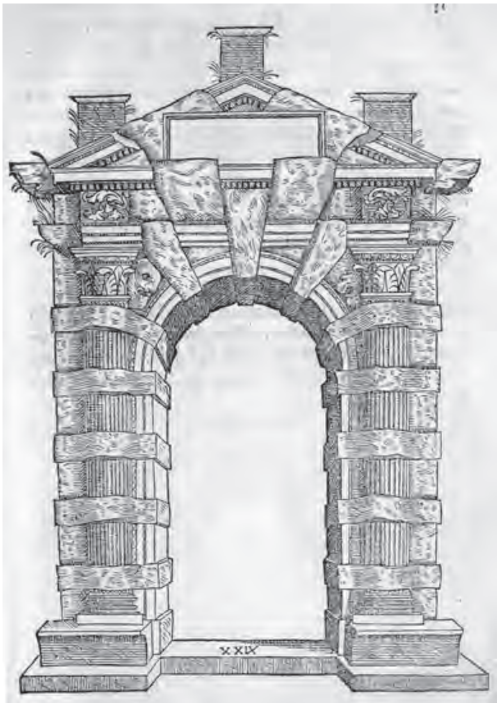
Apart from parametrizing their dimensional and material characteristics, their partitioning and articulation was taken into account. On this case, a series of portal and window frames were analyzed. The case of the terra cotta pieces surrounding the (fake) windows of the Palacio de Aguas Corrientes is also significant for this exercise.

The goal was to produce a parametric model of the portal pieces with two main restrictions; first, to allow the maximum degree of freedom in terms of geometry. For this reason, several parameters of the portal pieces can be altered such as height, arch diameter, rustication and spike scale, ornamentation patterns and so on.

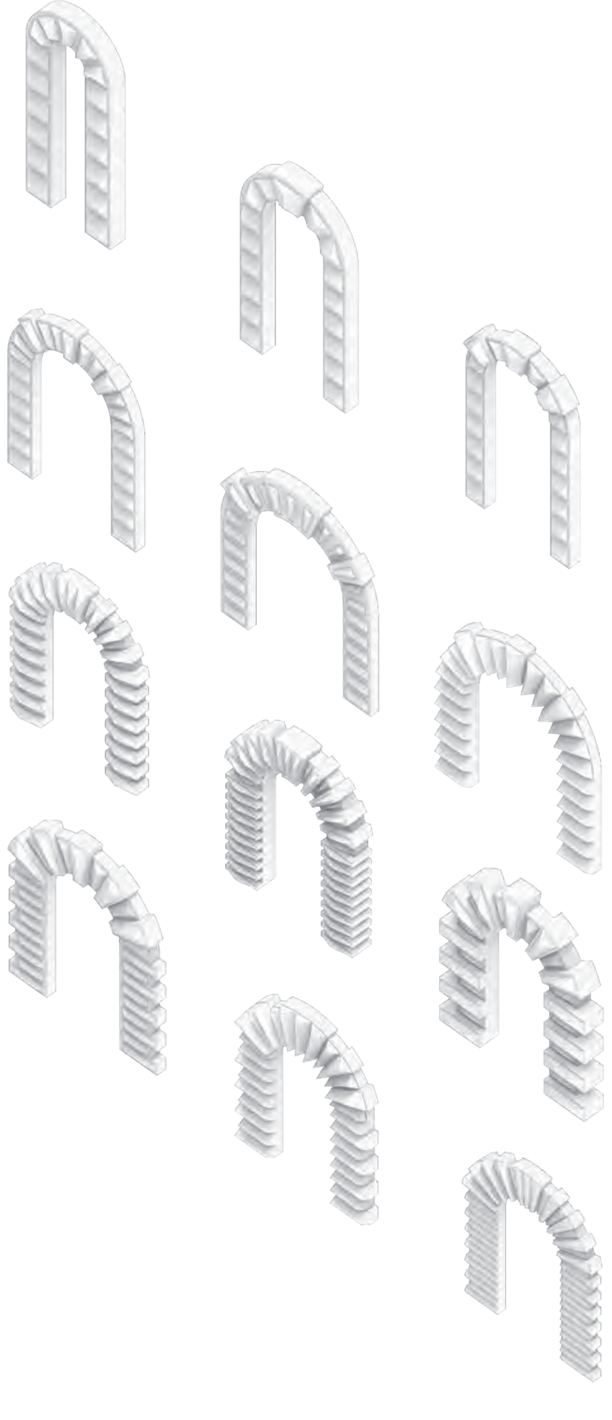
The secondary goal is related to optimization; the definition intends to generate the maximum number of pieces with the minimum variation. For this reason, many pieces like the jambs or the voussoirs (the individual elements that build the arch) are created with a single type of piece. In this case, repetition and manufacturing optimization are desirable traits.

The parametric definition also allows the designer to select the number of pieces on which the element will be segmented, as well as some technical and material details such thickness and constructive details. The definition is also organized in a way that, regardless of the number of segments, each of them are identical in order to be mass produced.

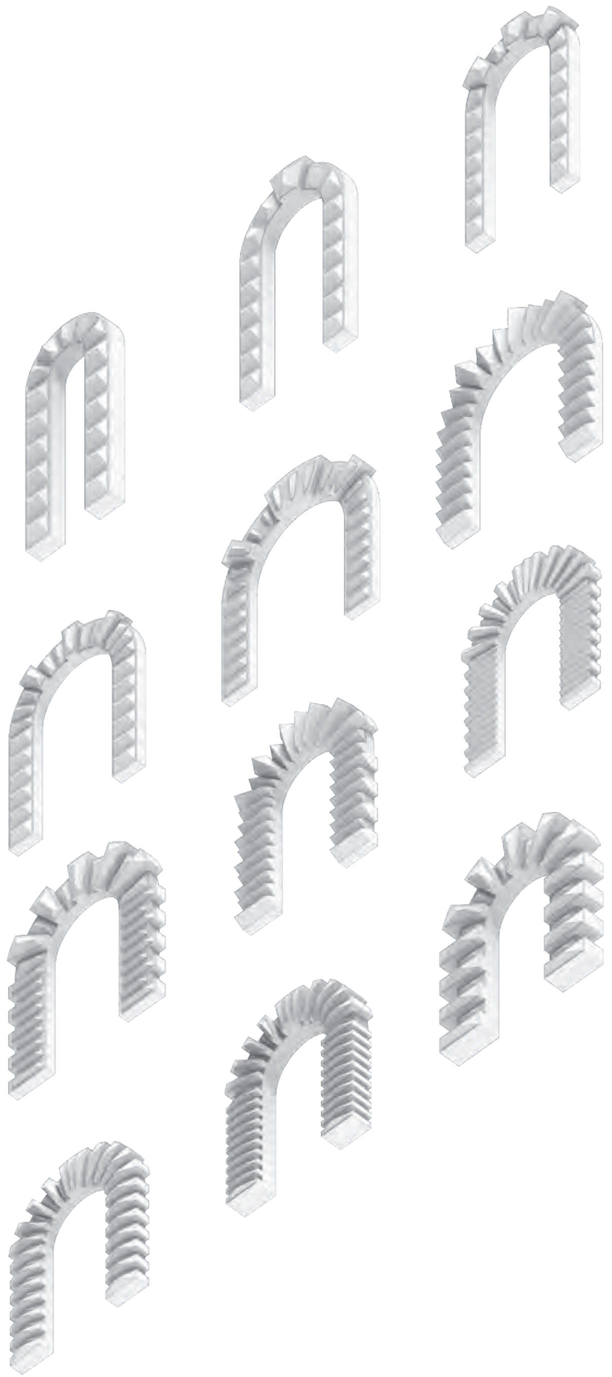




15-06-1 Window detail from Palacio de Aguas Corrientes.
15-06-2 Rusticated portals from Sebastiano Serlio. Extracted from Serlio S. ´The five books of architecture´ and ´Libro Extraordinario´.



15-06-3 Multimaterial Portal 01, 02, 03, 04. Terra cotta segments.



15-06-4 Terra Cotta Ornaments 05, 06, 07, 08

CHAPTER 16

- *Component experiments II*

07 – DORIC COLUMN CATALOGS

SOFTWARE: *Rhinoceros, Grasshopper, Galapagos*

REFERENCES: *Classical Doric columns, 19th century cast iron columns*

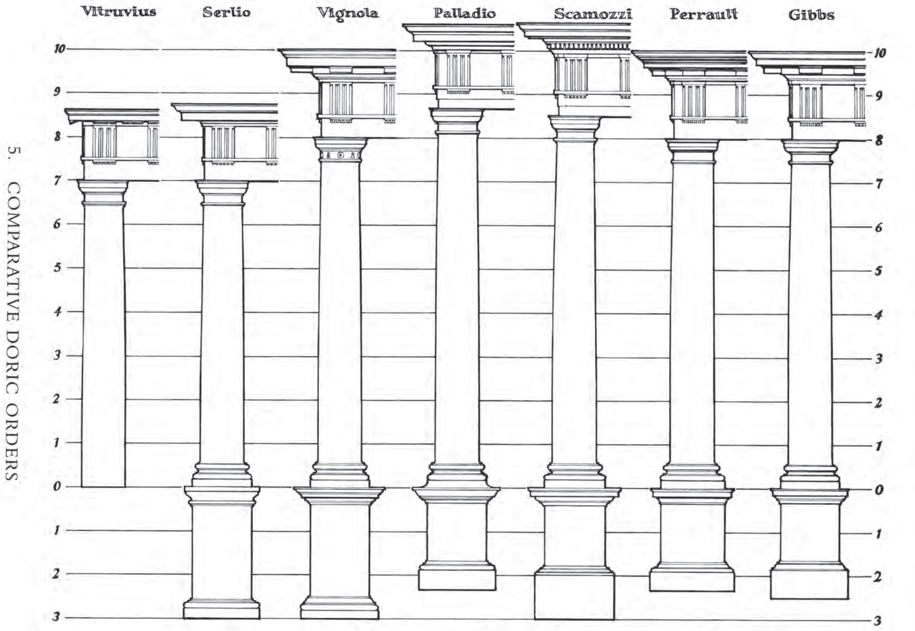
DESCRIPTION:

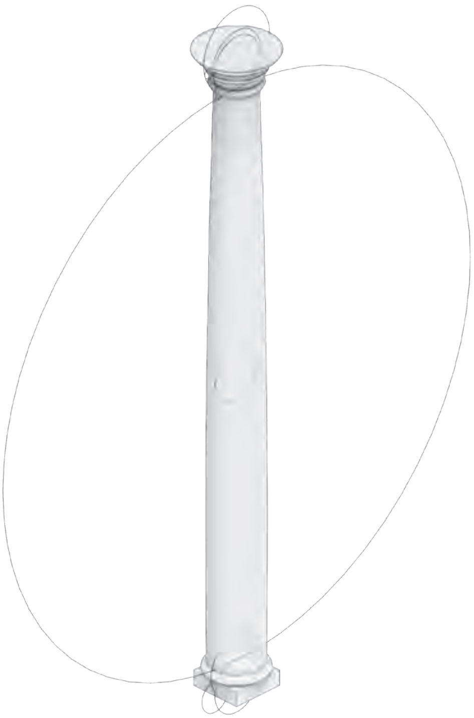
This experiment begins with a geometrical study of Doric columns, both in their classical definition and their 19th century variations, particularly when reproduced in terra cotta cladding or cast in iron, where their proportions and dimensions are significantly altered, for example, in the foundry catalogs.

The geometrical analysis focuses in three main aspects: the recognition of the column elements and their geometrical presence. The column elements are the distinctive parts on which the classical canon divides a Doric column, for example the abacus, the equinus, necking, astragal, fillet and torus. The geometrical shapes that define them in section relates to the specific forms present on the column pars, such as a half circumference in the torus, or an arch in the equinus, among others. Finally, the last step involves the geometrical definition of each element in section and their translation into a single value, allowing their control by a single parameter. This is a prerequisite in every parametric definition; for example, the abacus is represented as a tridimensional cylinder, which is defined by a radius and a height. Similarly, every column element is governed by one or several numeric parameters.

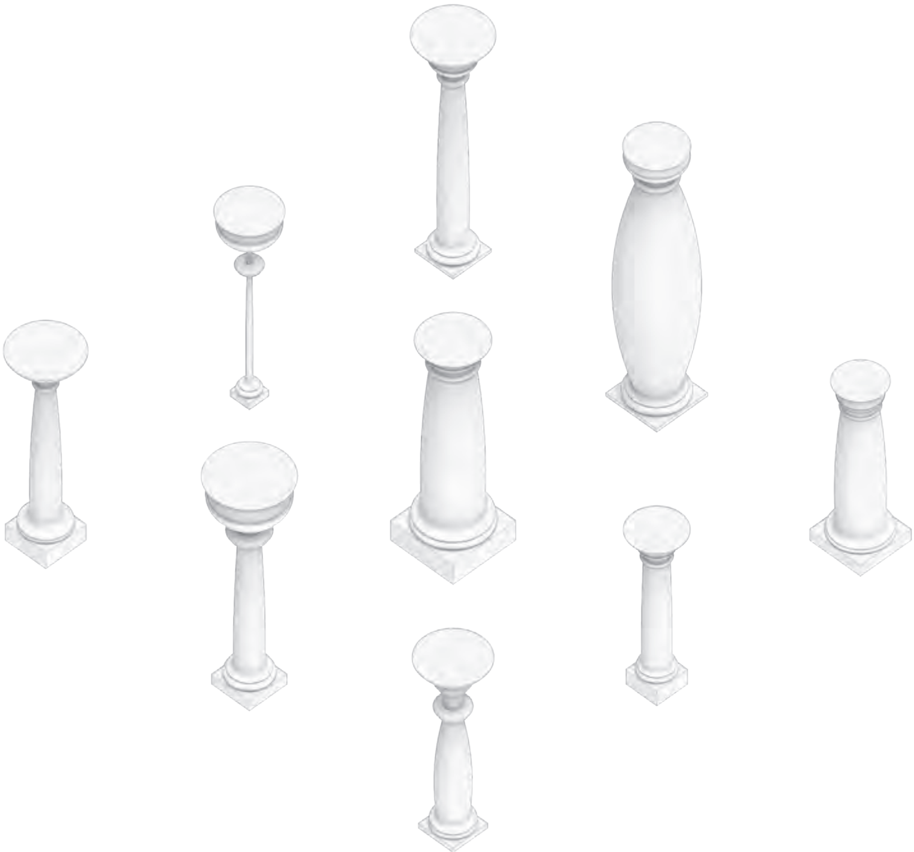
The result is a parametric definition that produces Doric columns by creating a two-dimensional profile and then revolving it around a central axis. As the elements of the columns cannot be suppressed but altered in dimensions and proportions, each column is slightly different from the next one, creating a 'family' of objects. The topology of the column however, remains constant; every element is still related to its neighboring parts and when a parameter is changed, the trail of its influence echoes through the entire column.

Finally, it is also possible to produce even greater variation along each column, by altering each of the governing parameters. A genetic algorithm plug-in was used for this last task. Genetic algorithms require a number of parameters which are entered as ´genes´, which on this case are several dozen geometric characteristics. It also requires a ´fitness´ condition, a desired goal or direction to orient itself to. This parameter could be a target volume for example, meaning that the algorithm would try different gene combinations in order to reach this target volume. On this case, the machine itself doesn't pursue any optimum value other than the production of sheer difference and variety.

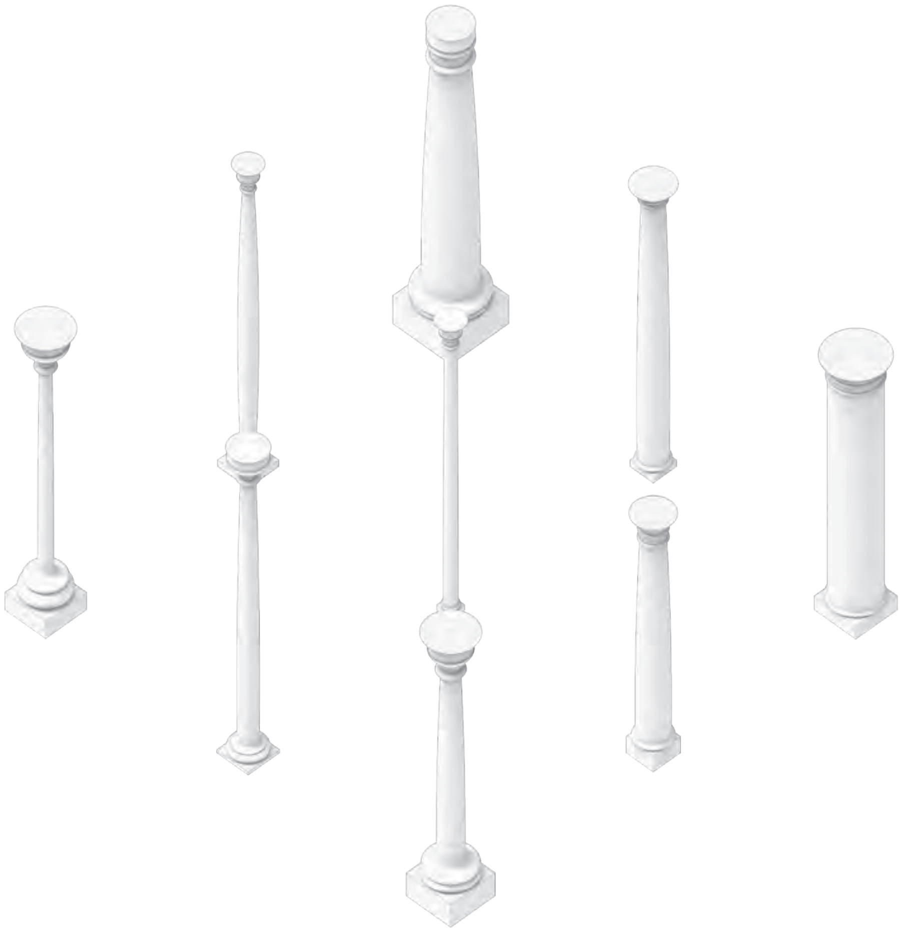




16-07-1 Comparison of Doric orders accoirding to various classical authors. Extracted from Chitcham R. *The Classical Orders of Architecture´ (1984).*
16-07-2 Top: Base column. Proportion analysis.



16-07-3 Parametric variations of column elements in Doric order. Doric Column Catalogue 01.



16-07-4 Parametric variations of column elements in Doric order. Doric Column Catalogue 02.

08 – DORIC ELEMENT CATALOGS

SOFTWARE: *Rhinoceros, Grasshopper, Galapagos*

REFERENCES: *Classical Doric columns, 19th century cast iron columns, Architectural Terra Cotta*

DESCRIPTION:

This experiment departs from the results acquired from the last one (07-Doric Column Catalogues); as it requires a Doric column to be set as input. The purpose is to convert the columns into manufacturable pieces in terra cotta. The idea is to slice the column in smaller, repeatable parts in order to produce them more effectively, but at the same time, taking advantage of the design freedom and production variety enabled by parametric design tools.

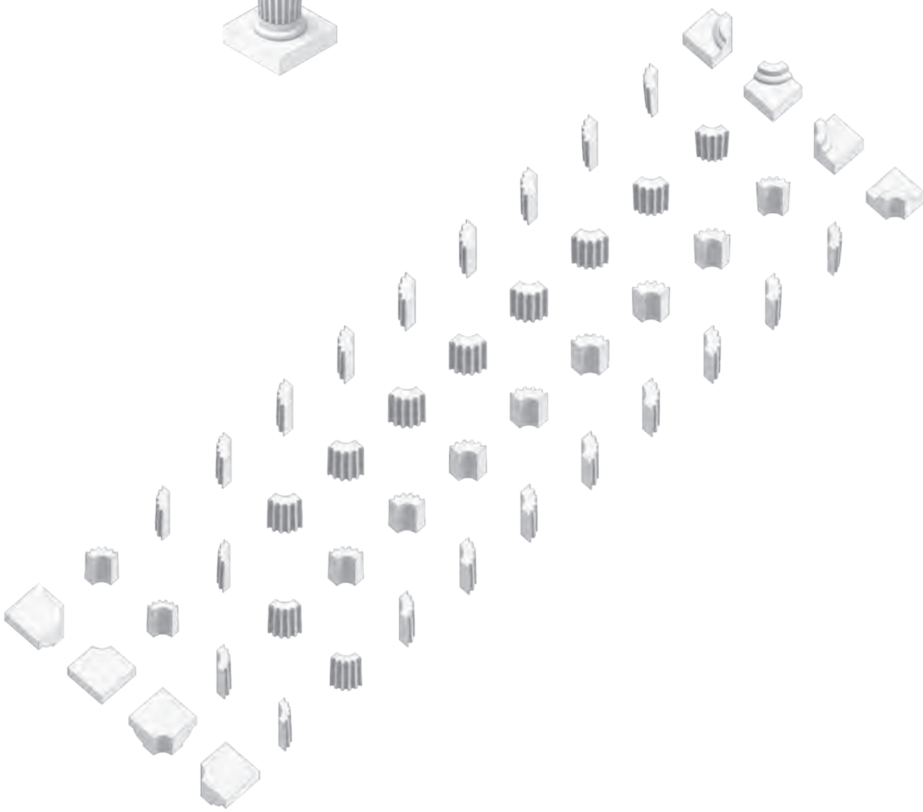
For this experiment ´Architectural Terra Cotta´ was consulted as well as other terra cotta details from historical buildings. There are basically two operations related to this experiment in order to manufacture a Doric column, the first is to add material constraints to the model, i.e. material thickness and secure the model integrity and the second is to actually slicing and splitting the model in parts suitable for manufacturing or printing.

The sectioning part first divides the column in three groups; capital, shaft and base. The second operation consists in slicing the three parts by using the same set of axes. The sectioning axes can be optimized in order to produce a larger range of similar pieces, for example, when dividing the column the power of two (two, four, eight and so on) the resulting parts would be exactly similar, meaning that the same pieces or molds would be usable multiple times. Naturally, when using an odd number of slicing planes for example, such pieces would be different.

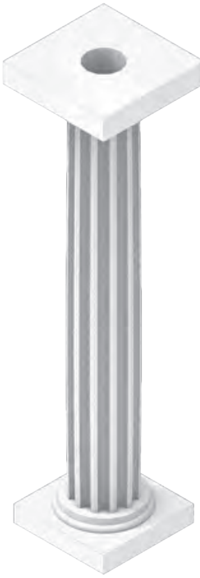
The final stage of this definition is to arrange the pieces on a grid, similar to a catalogue display.

The interesting result of this experiment is that the same definition could be used to manufacture any three dimensional model, regardless of its complexity, for example statues or ornamental models (without the optimization process on these cases).

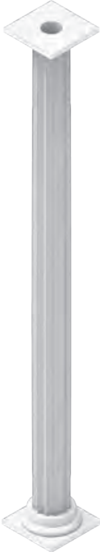
The experiment´s relevance in relation to both 19th century and contemporary digital manufacturing techniques rests on the same ambition, which is to convert any form or model into a manufacturable product, whether by press-mold terra cotta or by 3d printing technologies



16-08-1 Assembled doric column 01. Base model taken from previous experiments.
16-08-2 Doric column elements catalogue 01. Grid view of the individual pieces.



16-08-3 Assembled doric column 02. Base model taken from previous experiments.
16-08-4 Doric column elements catalogue 02. Grid view of the individual pieces.



16-08-5 Assembled doric column 03. Base model taken from previous experiments.
16-08-6 Doric column elements catalogue 03. Grid view of the individual pieces.

09 – MULTIMATERIAL COLUMNS

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *'Cours d'architecture' by Augustin-Charles d'Aviler, , 'Architectural terra cotta, standard construction' by National terra cotta society, 'A handbook of Ornament' by Franz Sales Meyer, Plaza Hotel.*

DESCRIPTION:

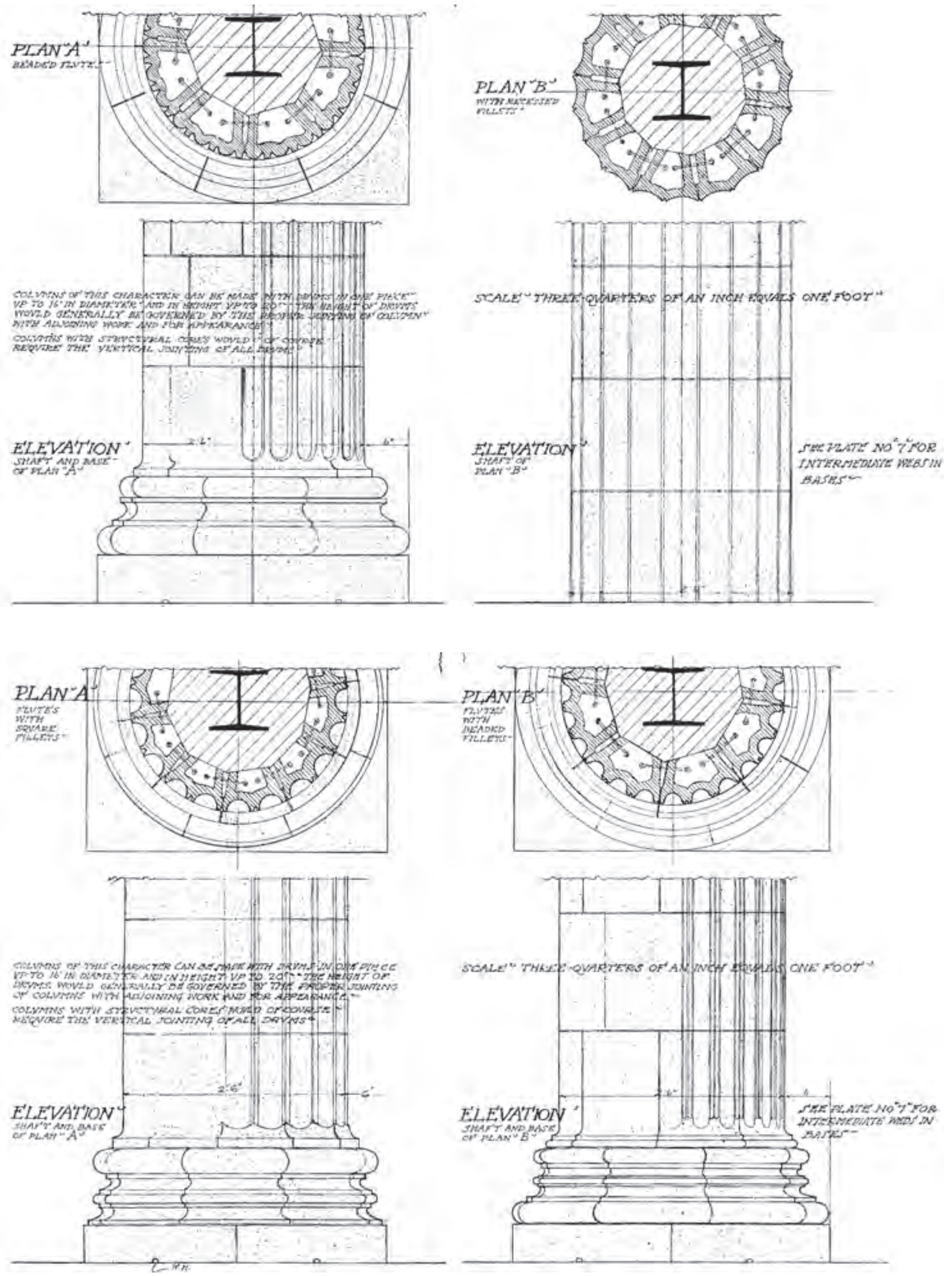
This experiment analyzes terra cotta columns, its formal characteristics, details and geometrical features. The purpose is similar to the combination of the two previous experiments, that is, to create a detailed design and then to partition them, dividing them into smaller, easier to manufacture components. In the same way to previous experiments, the intention was to study canonical examples from past periods in order to understand how the elements were designed and manufactured.

In addition to this research own case studies, several architecture treatises from France as well as the terra cotta catalog by the National Terra Cotta Association were consulted in order to comprehend and then parametrize its geometrical characteristics.

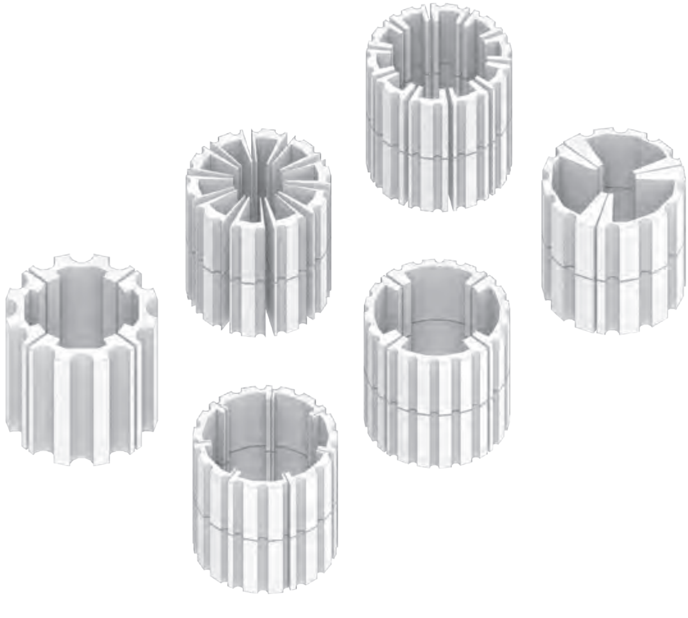
Apart from parametrizing their dimensional and material characteristics, their partitioning and articulation was taken into account. When producing a striated column, a terra cotta detail was selected in order to be attached to a steel structure. The diameter and height are manipulated through numeric variables, along with their corrugations both in size and quantity. Finally, the experiment also allows the designer to select the number of pieces on which the element will be segmented, as well as some technical details such as support structure and fasteners to the iron structure. The parametric definition is organized in a way that regardless of the number of segments, each of them is identical in order to be mass produced.

Once again, the balance between mass produced repetition and variation drives not only the material outcome of this experiment but also its expressive manifestation. In order to produce identical pieces and integrate them into a complex geometry, the experiment makes use of radial symmetries.

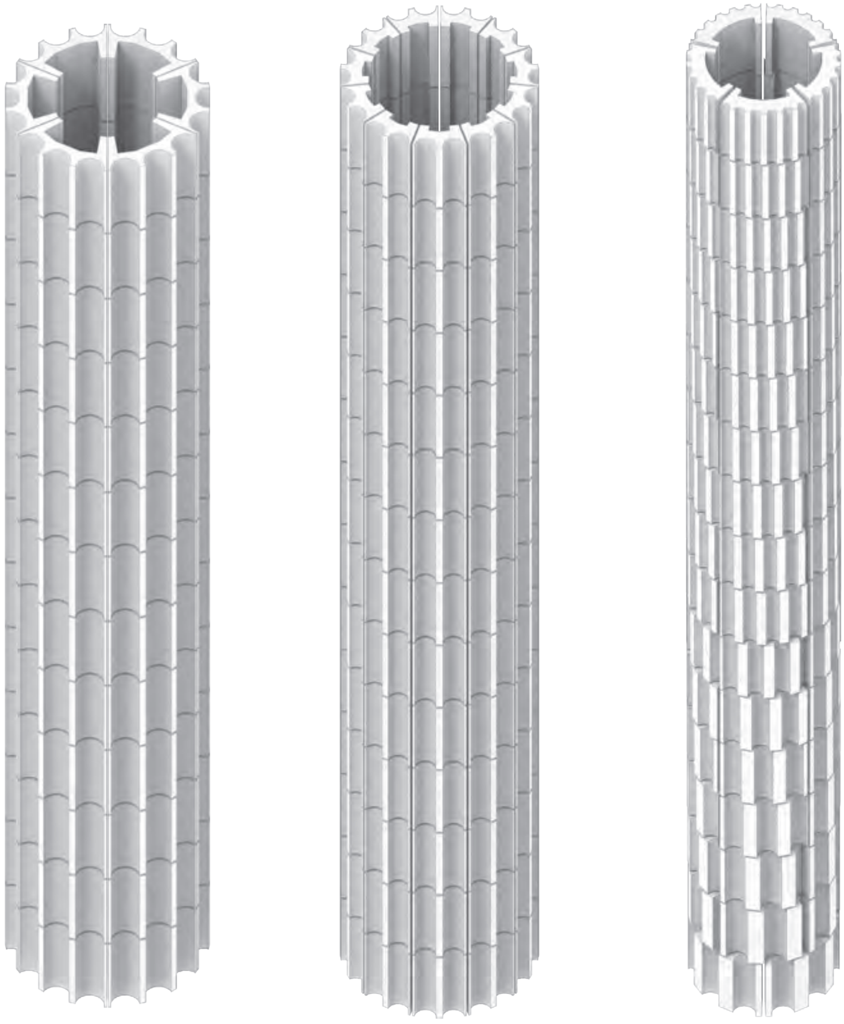
Finally, a series of variations were introduced, both in the column´s geometry as well as in the repetition patterns. Architectural effects such as ´entasis´ or ´mushroom-type´ columns could be recreated by altering these variables. The potential of this experiment relies precisely on this double factor; creating powerful expressive effects while controlling material and geometric characteristics.



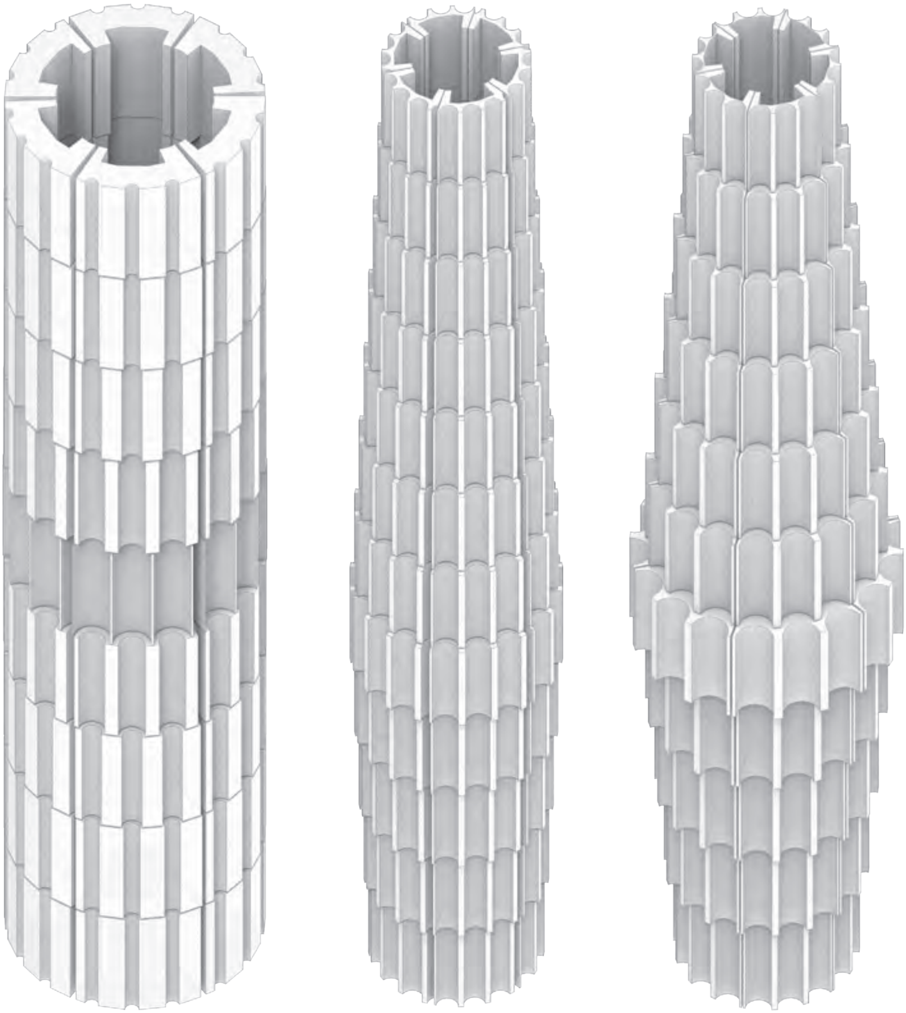
16-09-1 Terra cotta column profiles for fluted columns. Extracted from the handbook from the Natiional Terrac Cotta Association.



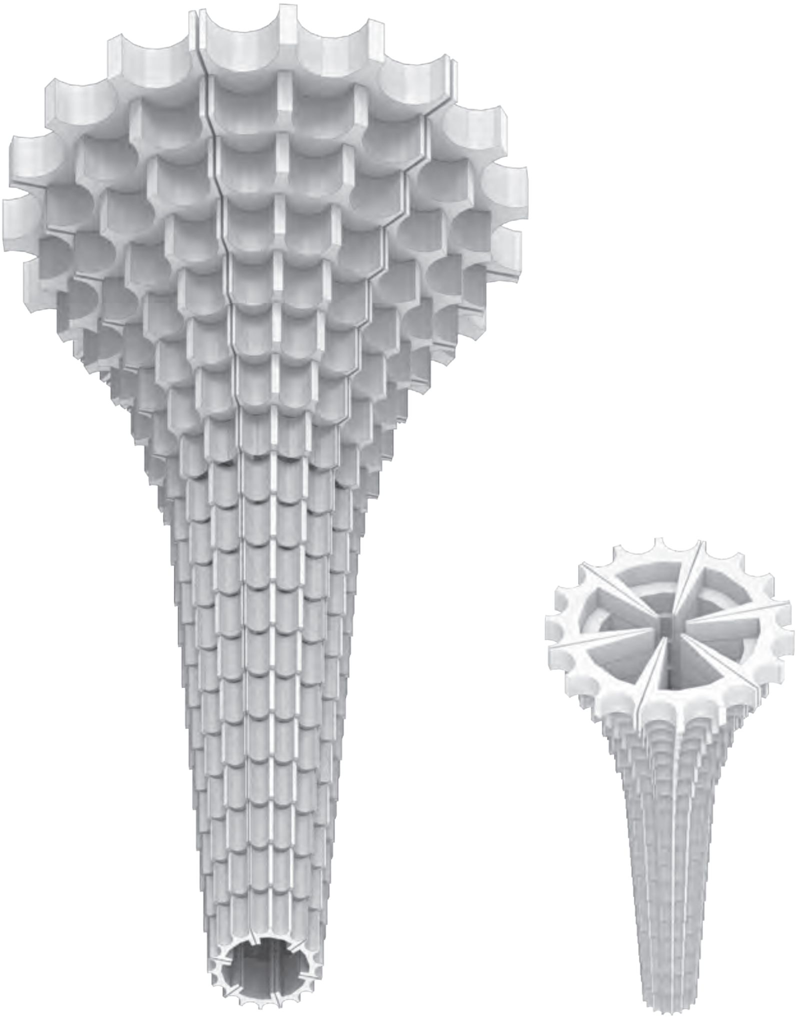
16-09-2 Multimaterial column. Based on the columns from the Banco Uruguayo Argentino by E. Le Monnier (Buenos Aires, 1928)
16-09-3 Terra Cotta Column. Segments catalogue.



16-09-4 Left and center: Multimaterial Column 01-02. Fixed segments on fluted column. Right: Multimaterial Column 03. Segment variation, torsion effect.



16-09-5 Left: Multimaterial Column 05. Segment variation through thickness. Center and Right: Multimaterial Column 06-07. Artificial entasis through shaft diameter variation.



16-09-6 Multimaterial Column 08. Mushroom capitel through shaft diameter variation.

10 – MULTIMATERIAL CROSS PILLARS

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *'Cours d'architecture' by Augustin-Charles d'Aviler, , 'Architectural terra cotta, standard construction' by National terra cotta society, Palacio de Aguas Corrientes.*

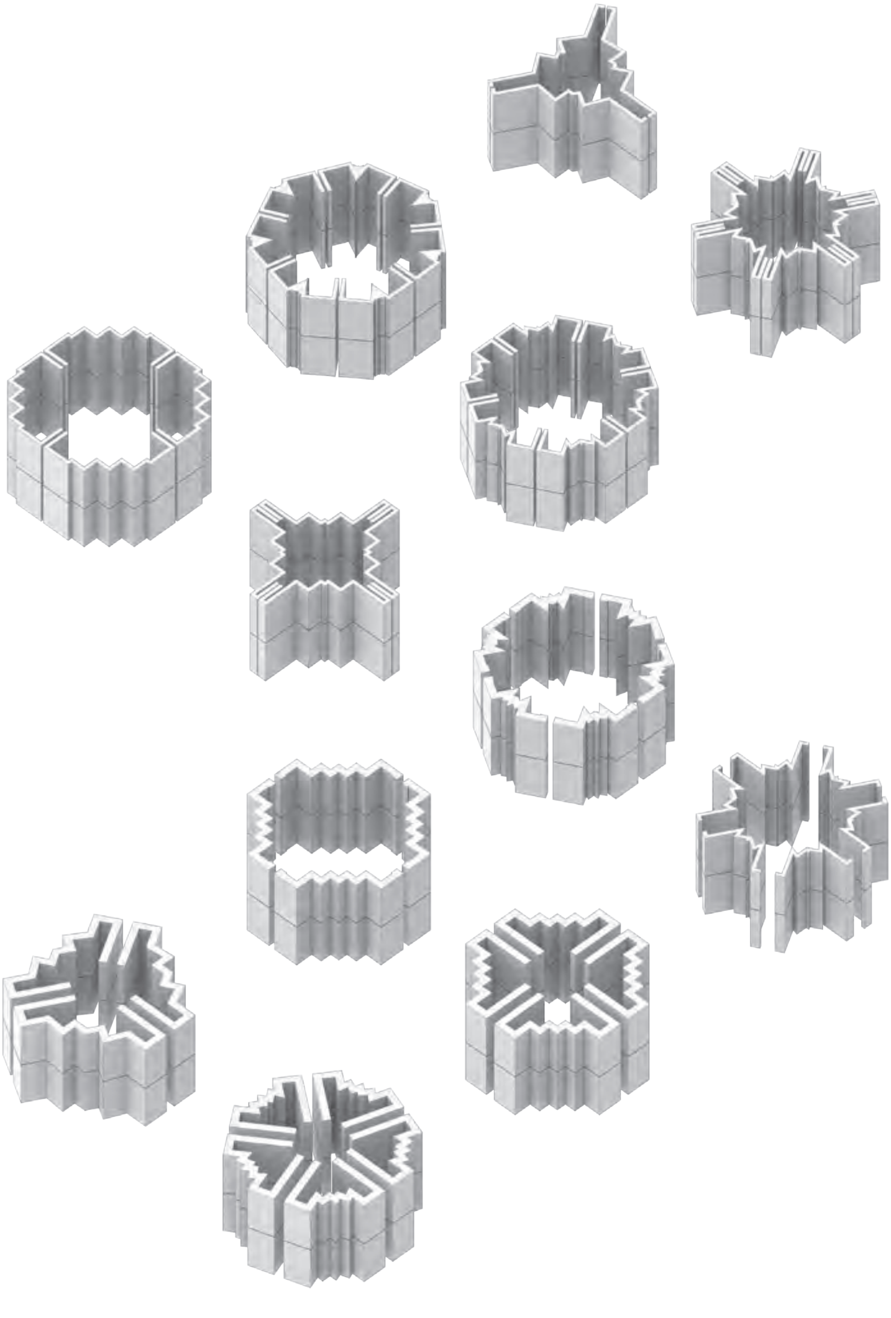
DESCRIPTION:

Similar to the previous experiment, this exercise draws on the gathered knowledge from earlier experiments. The point of departure is exactly the same as ´09 – Multimaterial Columns´ but instead of composing a round column, this experiment deals with polygonal sections.

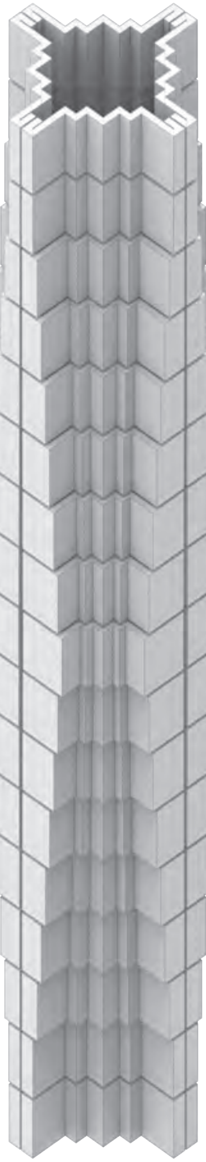
The exercise was initially thought to operate as an alternative to canonically defined columns, following a more geometrical section, yet sustaining the same level of detail and ornamental articulation as their classical counterparts. Geometric and material parameters such as thicknesses, grips and other constructive details can also be manipulated.

A similar set of generative rules apply on this experiment; radial symmetries, repeatable parts on each section, are set in order to optimize their manufacturing process and theoretical costs. Mass produced variation and repetition still plays a key role in this group of experiments. The parametric definition resulted flexible enough to recreate cross-section columns as well as star-shaped sections.

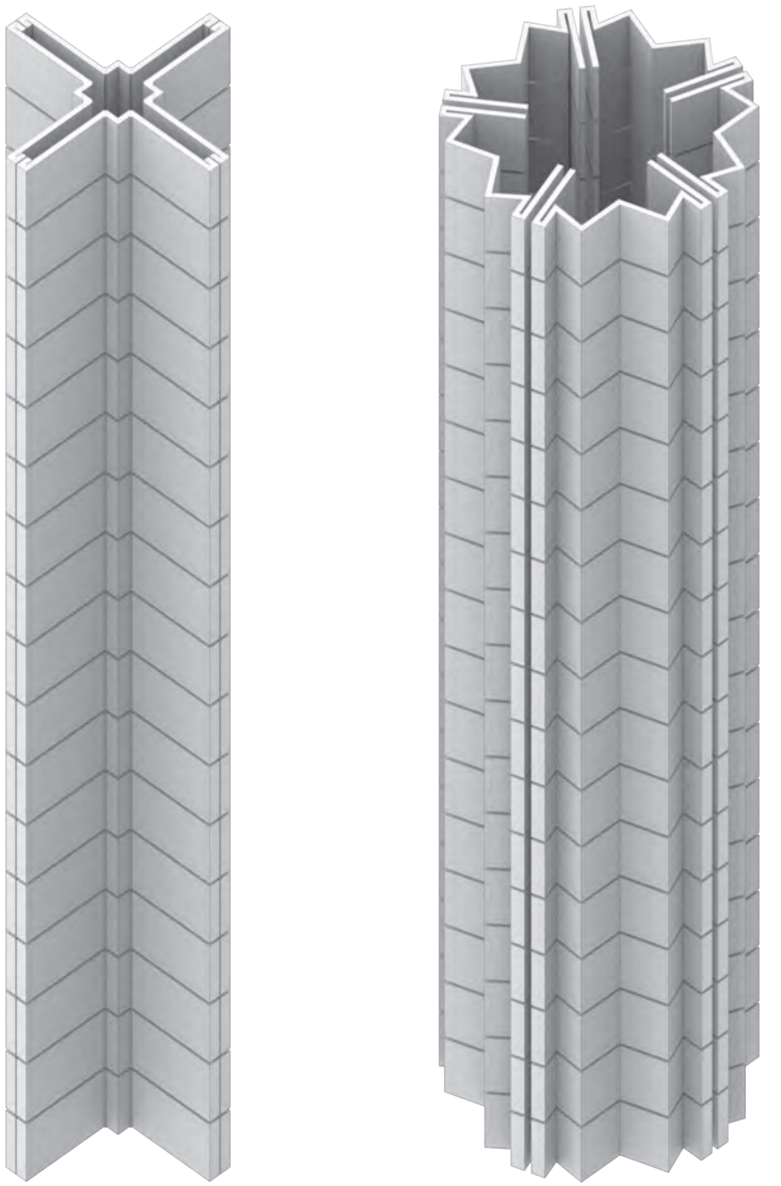
The last part of the experiment involves variation in the repetition pattern of each section. Aesthetic effects can be achieved through manipulating geometric characteristics of the single parts as well as global variables such as variations in size of each section ring. Similarly to the previous exercises, the double focus on expressive effects and ease of fabrication gives this set of experiments a significant value.



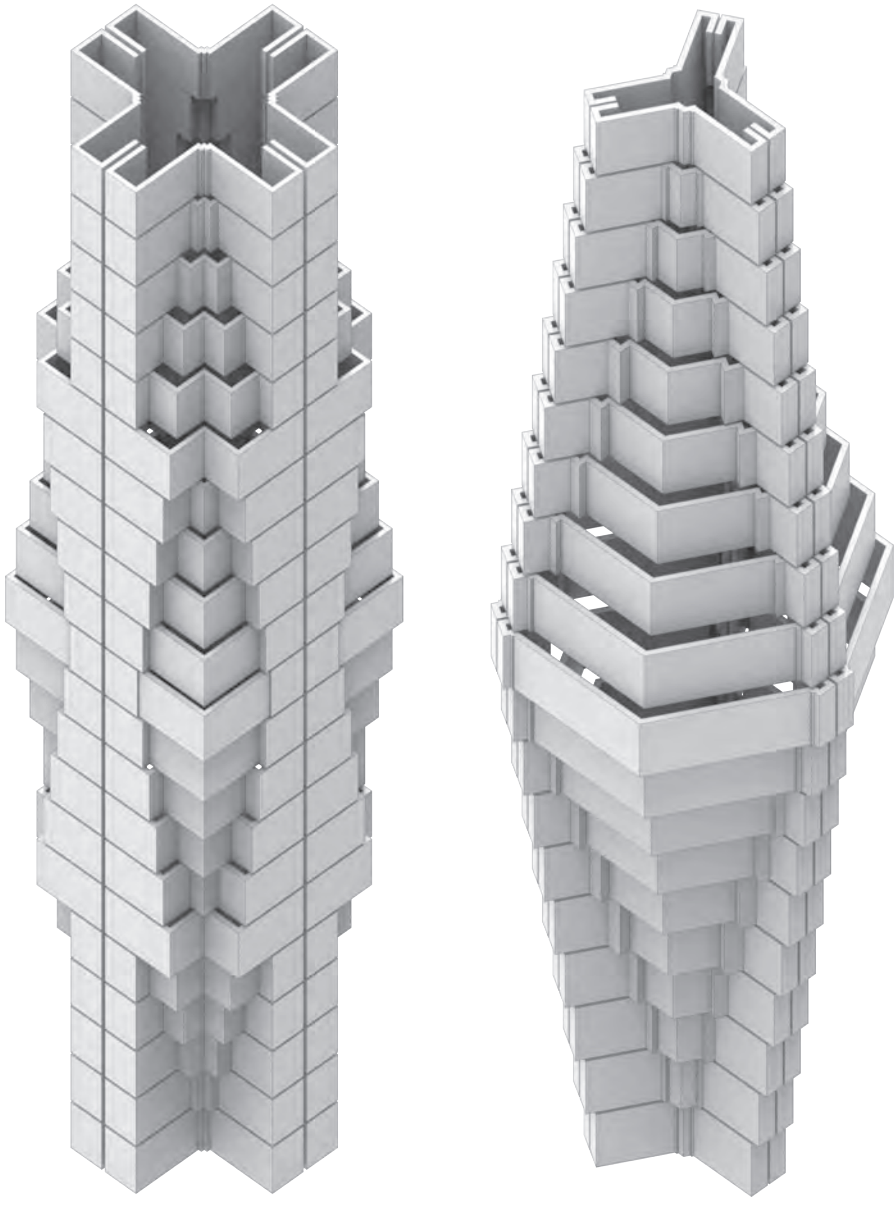
16-10-1 Multimaterial Cross Pillar 01-02. Terra Cotta profile pieces catalogue.
16-10-2 Multimaterial Cross Pillar 01-02. Terra Cotta profile pieces catalogue.



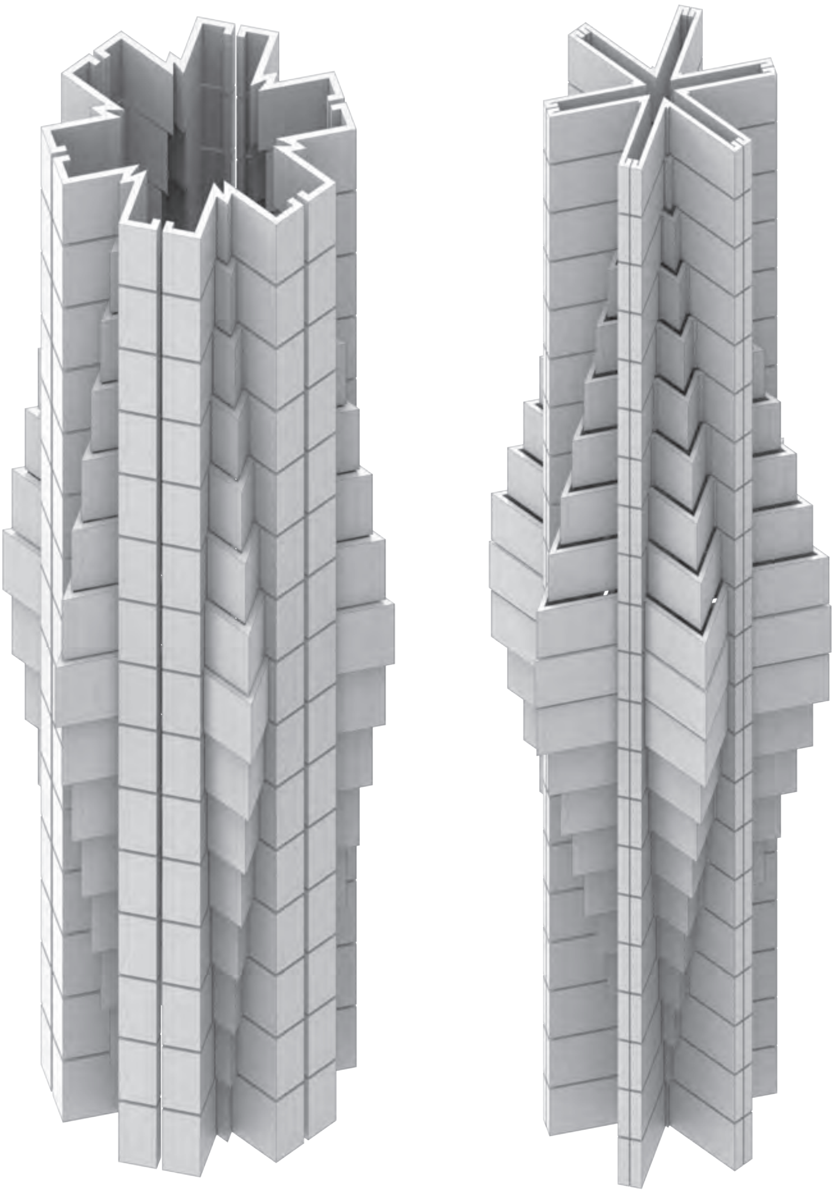
16-10-3 Artificial entasis through segment variation. External envelope remainis constant.



16-10-4 Multimaterial Cross Pillar 04-05. Identical segments.



16-10-5 Multimaterial Cross Pillar 06-07. Artificial entasis through segment variation.External envelope remainis constant.



16-10-6 Multimaterial Cross Pillar 07-08. Artificial entasis through segment variation.

11 – MULTIMATERIAL PILASTER

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *'Cours d'architecture' by Augustin-Charles d'Aviler, , 'Architectural terra cotta, standard construction' by National terra cotta society, Palacio de Aguas Corrientes.*

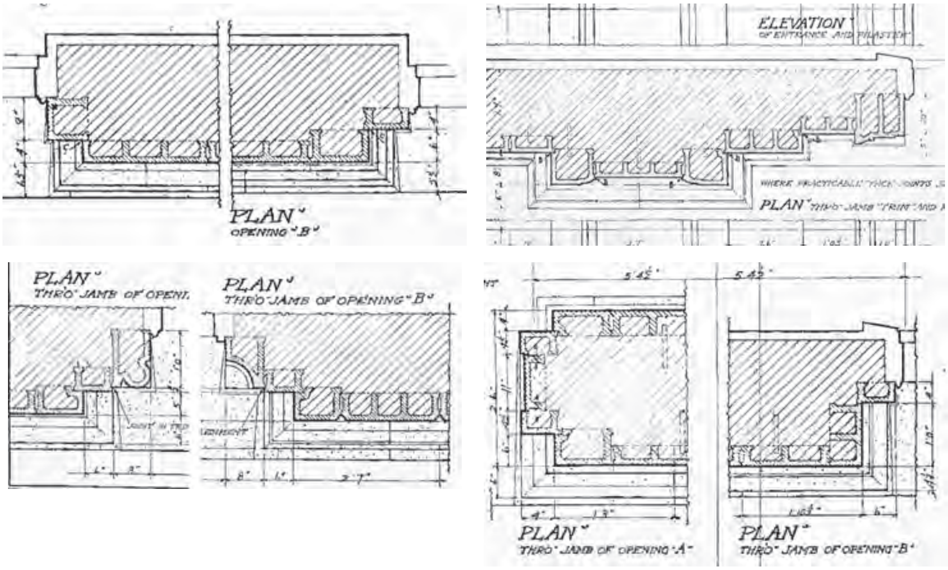
DESCRIPTION:

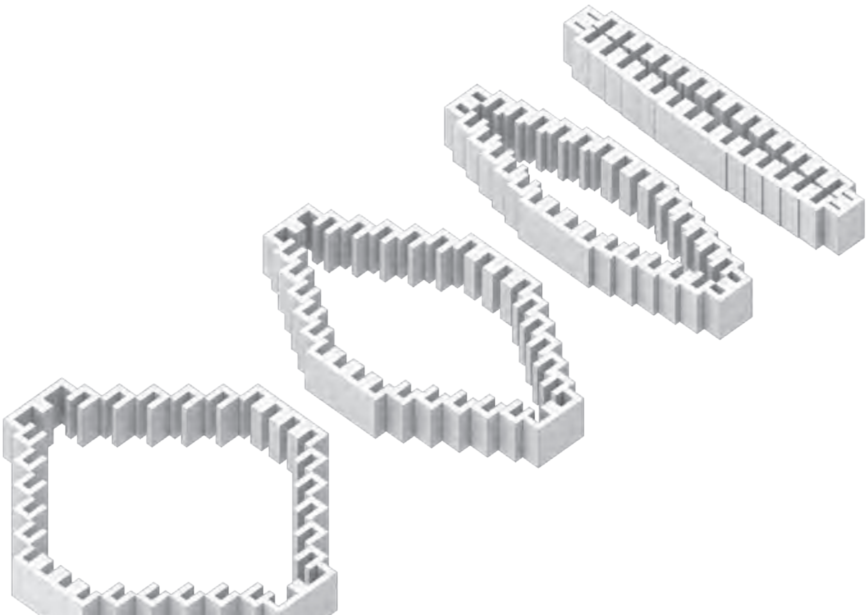
The final experiment of this series takes as a reference the ground floor pilasters from the Palacio de Aguas Corrientes. Its purpose is analogue to the previous column experiments yet the geometrical characteristics and formal rules differ.

The main difference lies in the generative rules or more precisely, the repetition algorithm that combines the terra cotta blocks. Instead of repetition via radial symmetry, each segment of the pilasters is generated by combining three types of blocks on a cross type configuration.

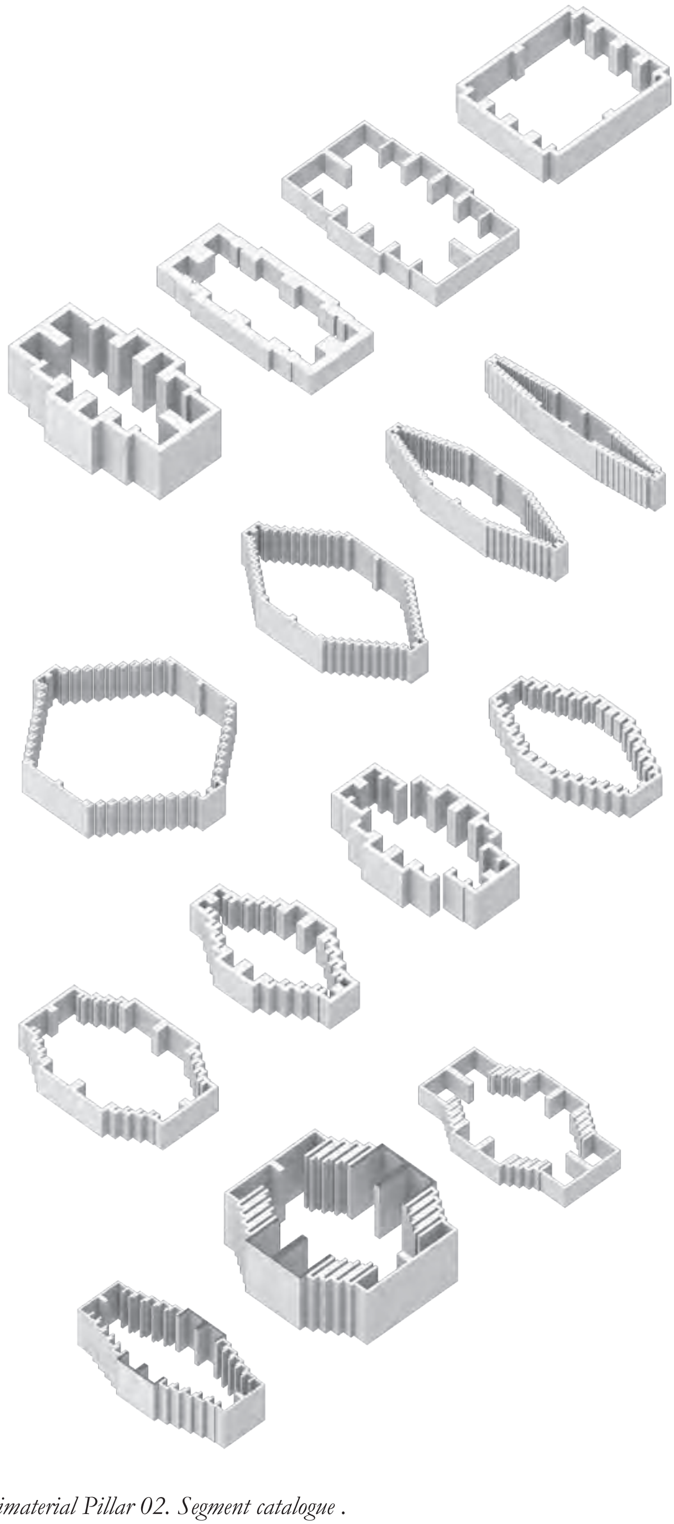
A group of blocks faces the front of the pilaster, a second group faces the sides and the third one fills in the gaps between them. The purpose of these pieces is to cover brick and mortar columns, which are significantly larger in section than iron columns from the previous exercises, hence the wide interior space left inside each section on several examples. Other examples can be used as concrete formwork but that possibility was not further explored.

Similarly to the last experiments, the terra cotta pieces can be parametrized in their dimensions and thickness and optimized for cost-effective reasons. The combination of multiple sections with different dimensions can also be manipulated in order to achieve aesthetical effects.

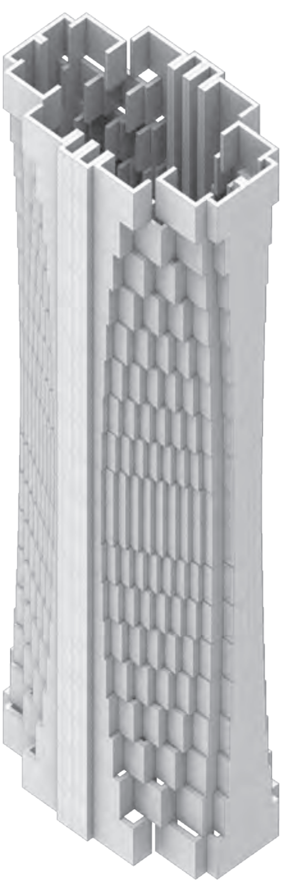




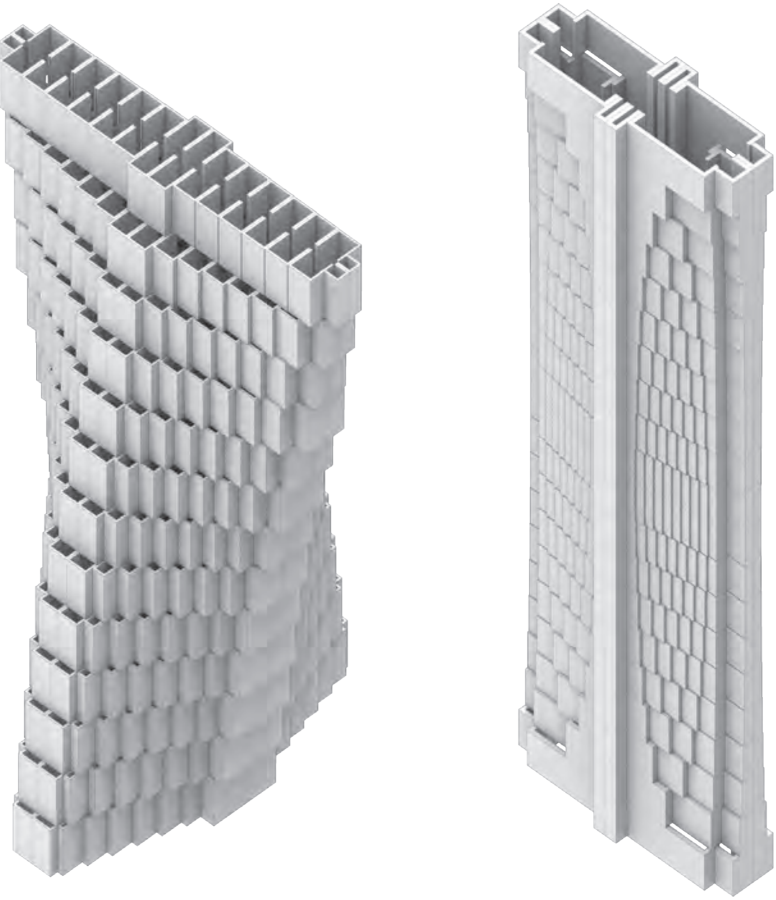
16-11-1 Pillaster designs in terra cotta. Extracted from ´Architectural Terra cotta´ by the National Terra Cotta Society.
16-11-2 Multimaterial Pillar 01. Segment catalogue



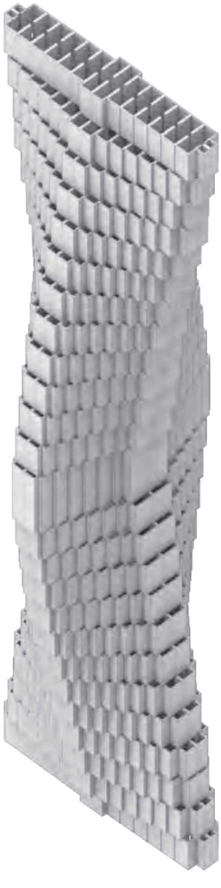
16-11-3 Multimaterial Pillar 02. Segment catalogue .



16-11-4 Multimaterial Pillar 04. Segment variation whithin constant envelope.
16-11-5 Multimaterial Pillar 05. Segment and envelope variation.



16-11-6 Multimaterial Pillar 06. Segment and envelope variation, torsion effect.
16-11-7 Multimaterial Pillar 07. Segment variation whithin constant envelope



16-11-8 Multimaterial Pillar 08. Segment and envelope variation, torsion effect.
16-11-9 Multimaterial Pillar 09. Segment and envelope variation.

12- VASENA COLUMN EXPLORATIONS

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *'The fireproofing of steel buildings' by J K Freitag , Vasena Foundry Iron Catalog.*

DESCRIPTION:

The experiment was inspired by the 'Vasena' column system, described in the Vasena trade catalog from the Argentinean foundry (Talleres Pedro Vasena e Hijos). The distinctiveness of this column system lies in the fact that it is composed by two elements: a cast iron column and a fireproof ceramic cladding.

The study of the Vasena column system motivated a deeper study of the foundry's products related to cast iron and steel columns, in particular, the connection pieces. Pieces like the base plate join the column's shaft with their supporting substrate, head plates connect them to upper columns, beams and other substructure elements.

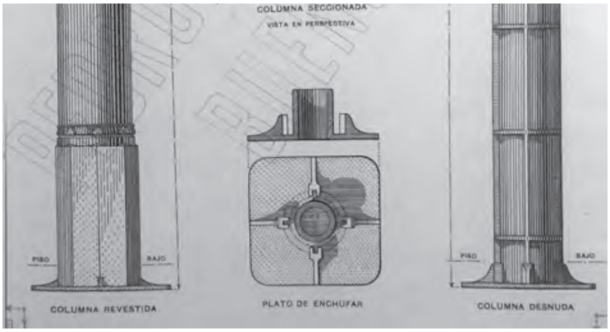
These pieces are an essential part of the system because they define the extent and flexibility of the whole system. Unlike concrete or masonry, the connections need to be precisely executed while simultaneously flexible, enough to be mounted and perhaps corrected on site. At the same time, they have to be generic enough to be used as much as possible; taking advantage of off-site and mass fabrication in order lower costs by standardizing forms and features. Standardization of joints and variable connections are the key to robust, flexible construction systems.

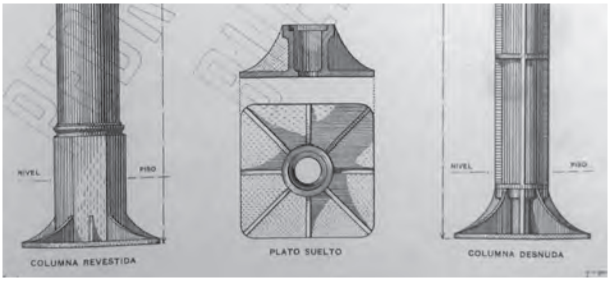
The combination of iron (cast or wrought) with ceramics is not just an aesthetical choice; accidental fires could rapidly collapse the structures if their components were not properly protected. The use of ceramics as fireproofing material has been common thanks to the ease of adaptation between both constructive systems. Ceramic material qualities, insulation capacity, weather resistance and the possibility of mass produced pieces as well as limited quantities made this material particularly relevant not just as fireproof but also as cladding material.

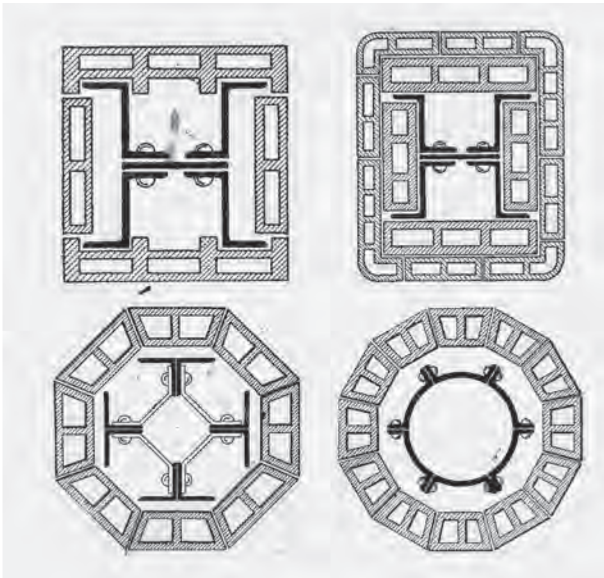
The publication by J. K. Freitag explores these flexible systems, focusing on the use of fireproofing material and the interaction between iron structures and ceramic cladding on columns and floor structures. This experiment analyzes Freitag's drawings, the formal and geometrical relationships between iron and ceramic pieces not as unique objects but as systems. Systemic thinking is a key aspect; analyzing how repetition is produced, how variation is generated how unique pieces are dealt with.

The experiment analyzes 3 parts of the iron-ceramic constructs; the base plates, the shaft and the head plates. Parametric definitions produce a series of variations regarding sizes, thicknesses, partitions and divisions on each member. The Vasena system was intended as such; it was manufactured on several sizes and thicknesses, but the 'topology' of the column remained intact.

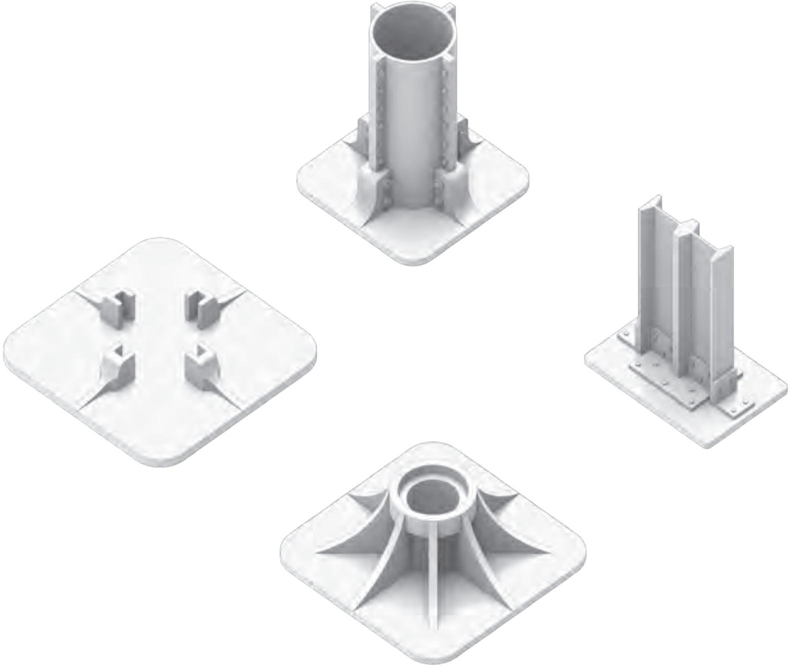
The parametric definition also produces the ceramic pieces; the cladding can be further subdivided to match the column's flanks while also adjusting the separation between elements to be sealed with filling material. The design can either define how many pieces per segment are required or the dimensions of each element. The relationship between iron column and cladding is depends also on the brick's height since the column contains a series of rings on which the bricks are supported.

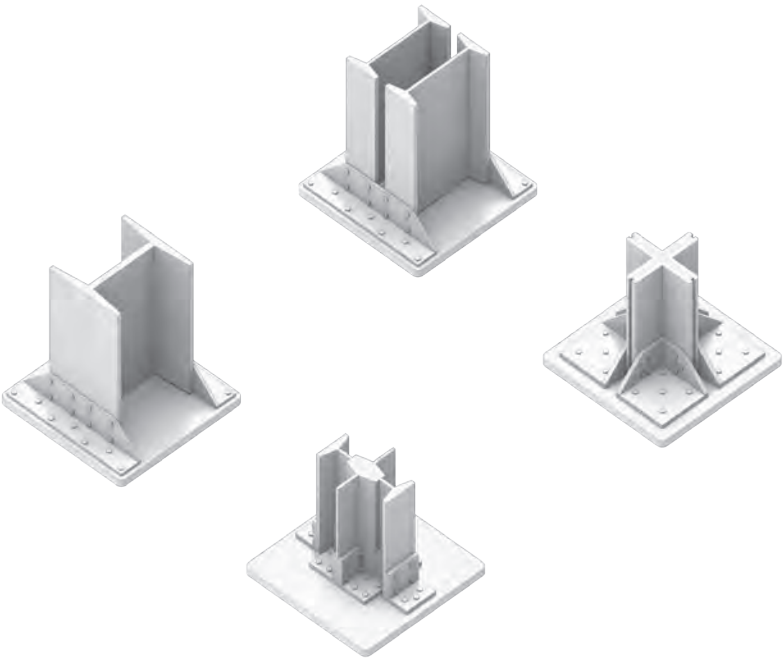




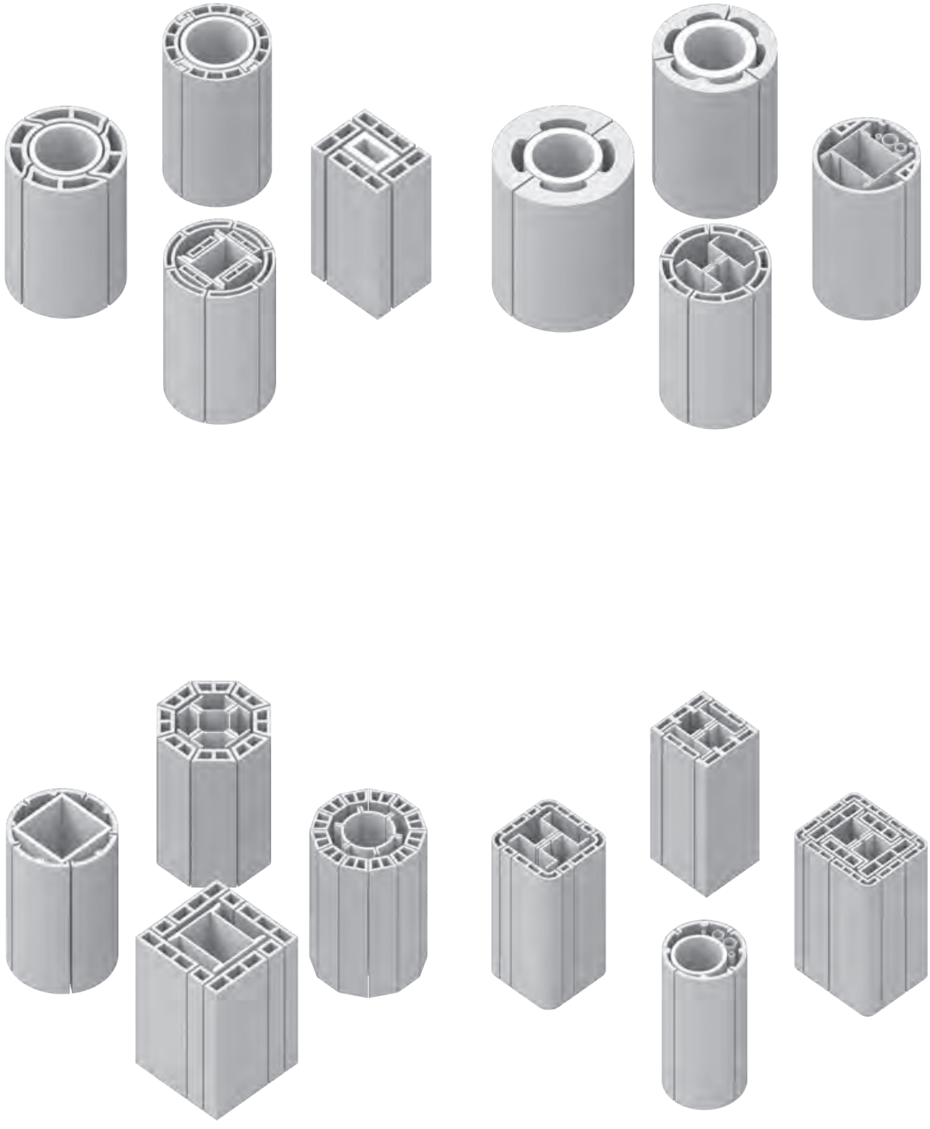


16-12-1 Vasena Column System. Independent and plugged base plates. Extract from the Vasena Catalog (La Europea, talleres mecánicos : fundición de hierro, acero y bronce; herrería y calderería)
16-12-2 Fireproofed ceramiciron columns. Extracted from Freitag J.K. ´The fireproofing of buildings´.

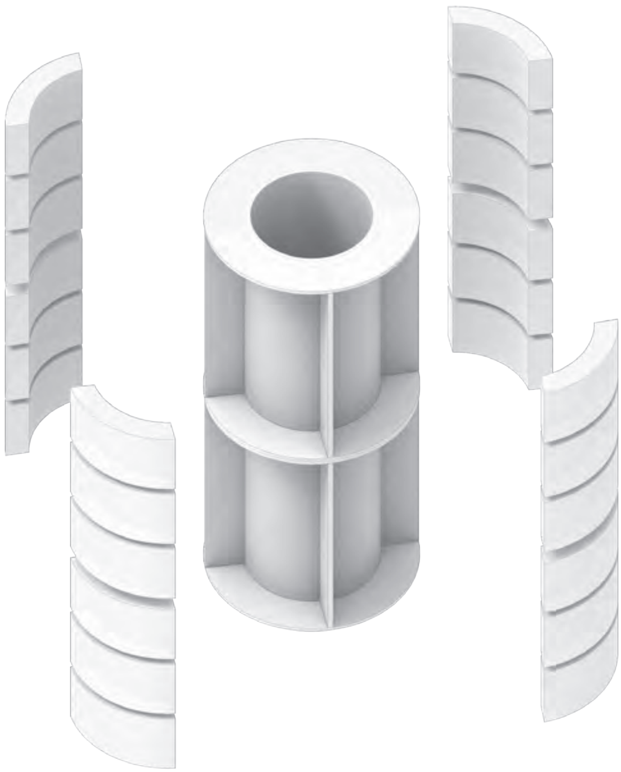


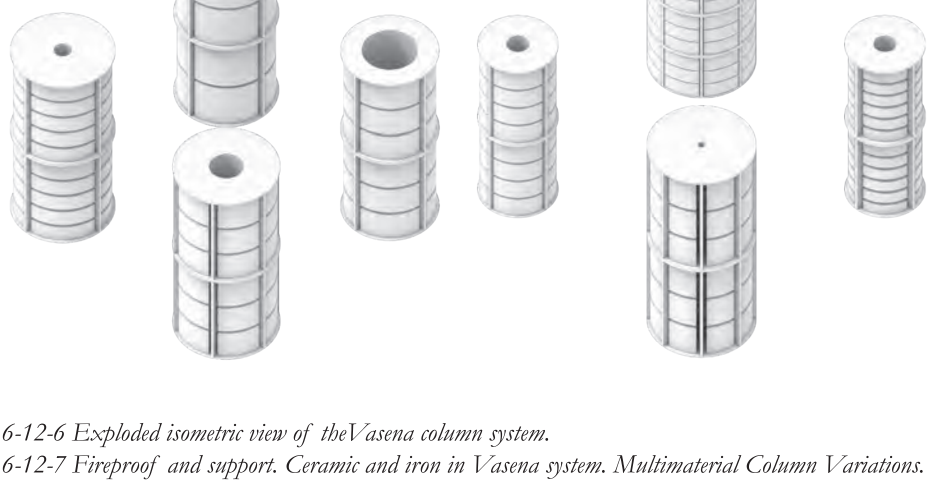


16-12-3 Baseplate variations from Vasena system plates.
16-12-4 Baseplate varioations from standard iron plates.

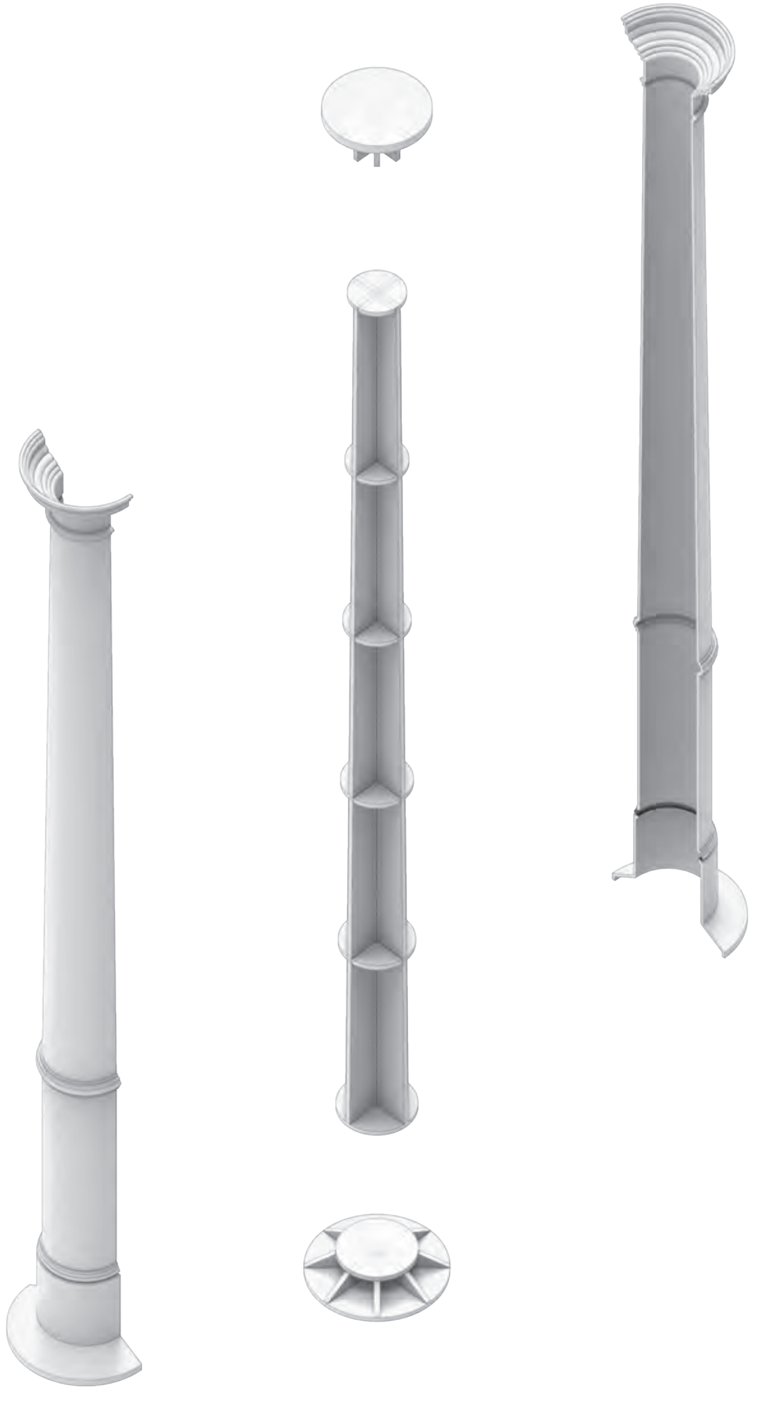


16-12-5 Terracotta and iron. Ceramic column variations 01,02,03,04 based on J.K. Freitag´s handbook.

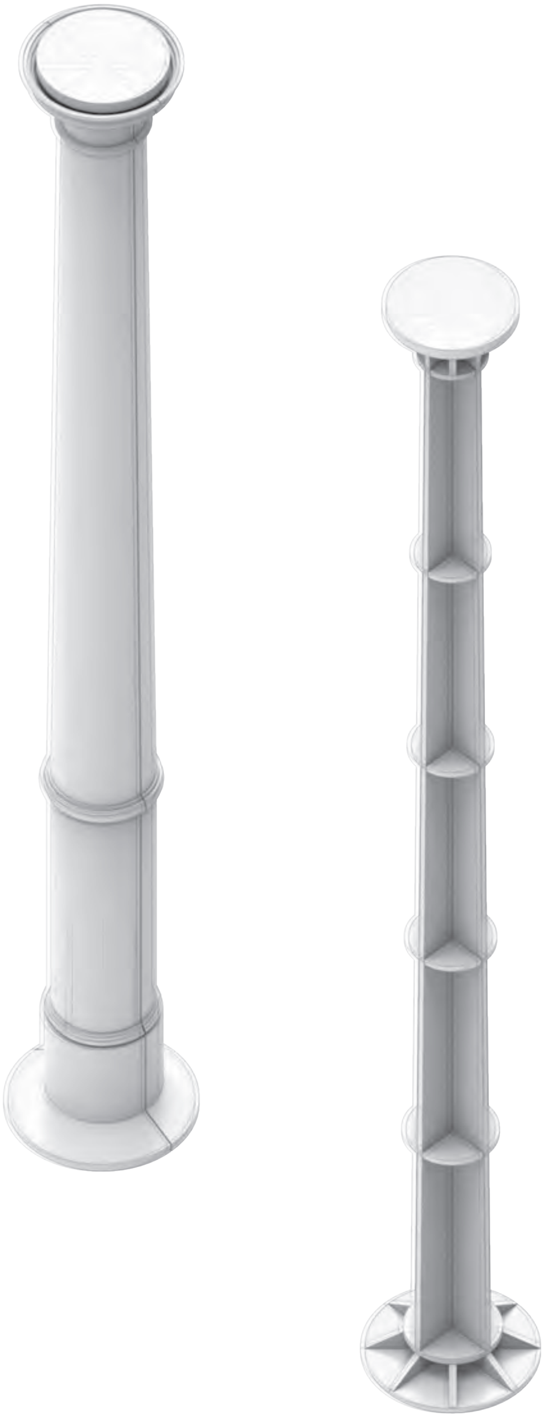




16-12-6 Exploded isometric view of theVasena column system.
16-12-7 Fireproof and support. Ceramic and iron in Vasena system. Multimaterial Column Variations.



16-12-8 Exploded isometric view of the Vasena Column cover and support system.



16-12-9 Structure, finction and ornament. Supporting profiles and cover pieces of the Vasena column system.

13 - MULTIMATERIAL MEZZANINE

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *‘ by J. K Freitag*

DESCRIPTION:

This experiment draws inspiration from J.K. Freitag´s publication, concentrating in the floor structure elements. The structural system consists in two main elements: iron profiles and ceramic bricks. Naturally, the structural effort is supported by the iron beams, while the floor bricks act as insulation and filling material between the beams. Several systems are described in Freitag´s book, depending on the type of profiles, distance between them and the structure´s thickness. An important factor is also the type of mounting that the floor bricks require, resulting for example in arched compositions or an interlocked pattern.

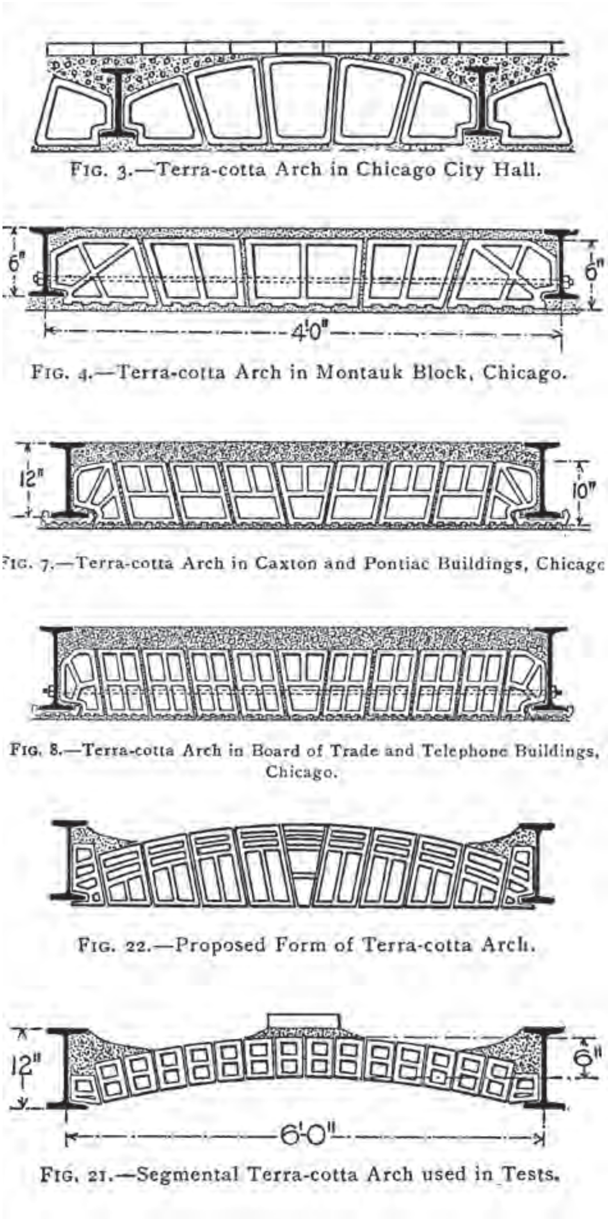
The parametric definition creates floor structures as a combination of I profile iron beams and ceramic hollow bricks. On this configuration, the design can adjust the type and number of bricks, curvature, position in relation to beams and other relevant factors. Similar to the columns, Freitag’s book depicts several possible configurations according to the structural span, brick size and manufacturer. By mid-19th century the I beams and their dimensions were fairly standardized, but the ceramic pieces were incredibly diverse as Freitag’s drawings demonstrate.

The floor brick definition distinguishes three types of elements: connection pieces, filling and key bricks. Connection bricks are the first piece in the composition; they are directly coupled with the iron beams and they can be locked in or slide in place in order to provide a mechanical lock.

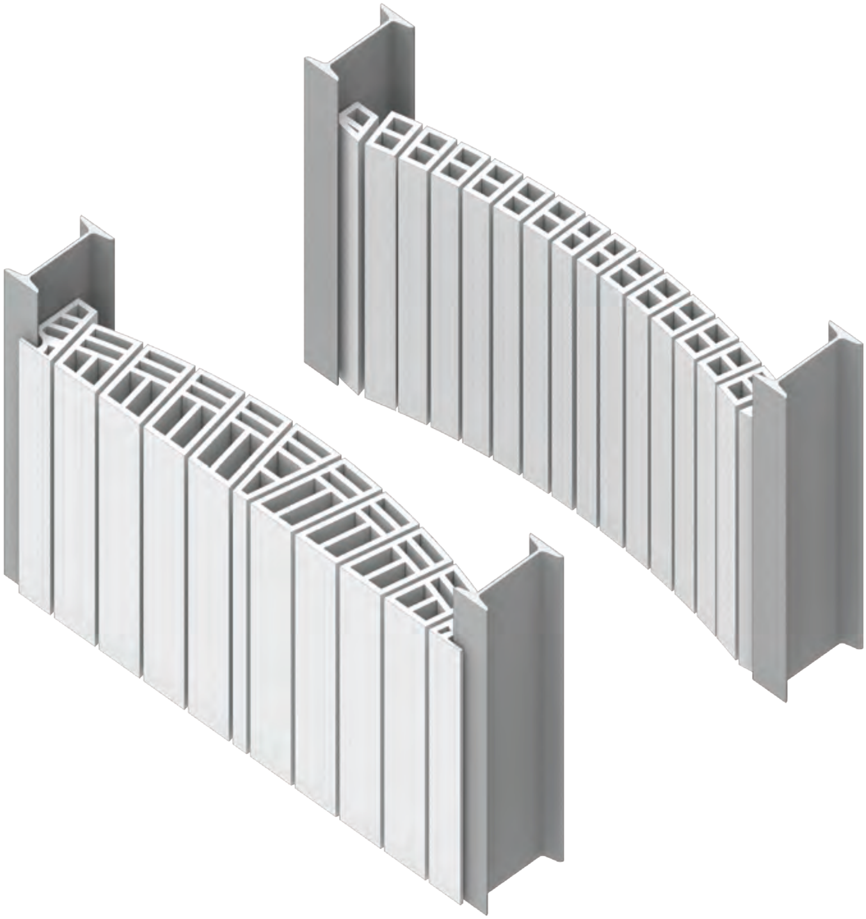
Their geometry of the bricks is defined by the type of connection with them as well as the angle of contact between them and the filling pieces. Filling pieces are the elements disposed between connection pieces. Their shape depends on two variables: the angle of contact (whether their organization configures an arch or not) and whether the definition configures identical pieces or not. In case the designer opts for identical filling pieces, the final geometry will be limited by the number of pieces and their own dimensions. Finally, the key pieces are the central elements used to lock the structure in place. Like any arch composed by finite elements, the key piece is put in place at the end of the montage sequence.

Independent of their function, all bricks can be further parametrized in their dimensions, wall thickness, number of holes, number or pieces and whether or not they are identical to each other.

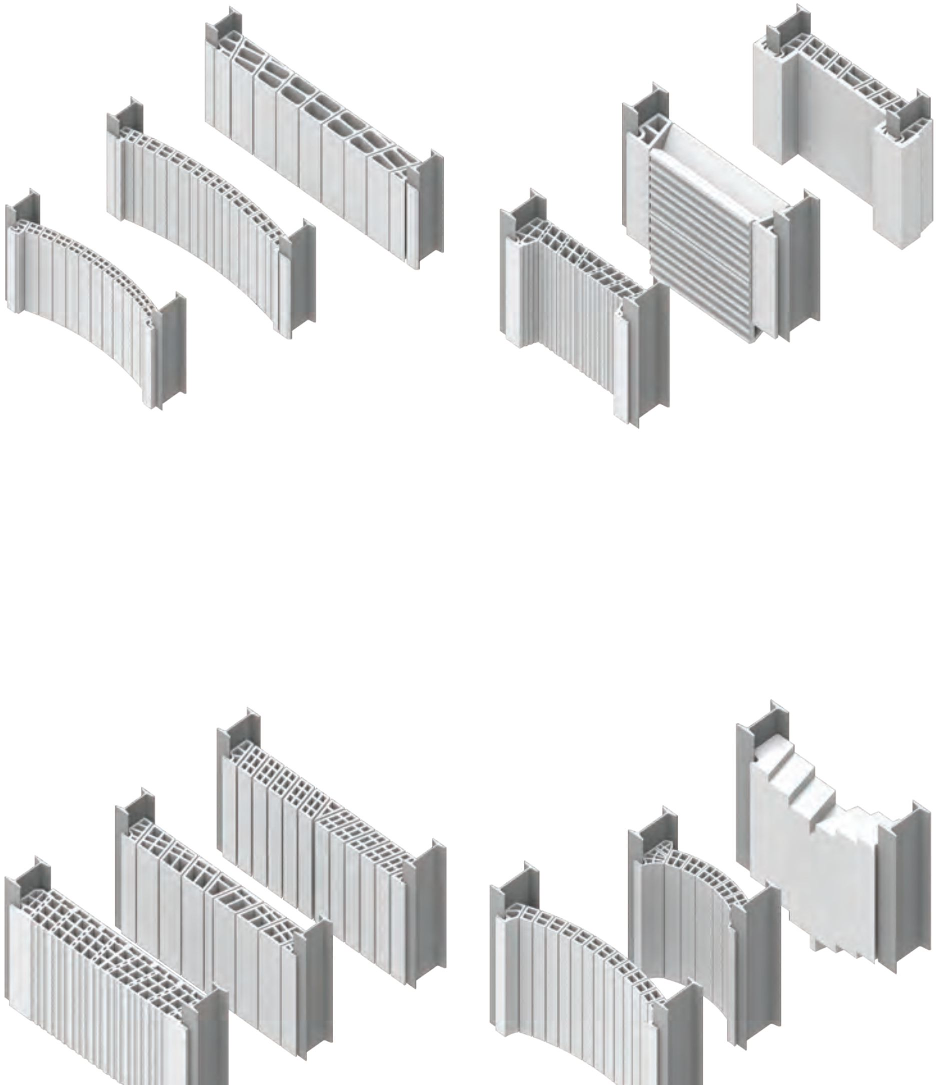
The experiment explores multiple constraints and parameters illustrating the technical and aesthetic potential of these multi-material configurations. Even though most of these elements were usually not exposed in the construction, their aesthetic qualities may well allow them to be expressed openly.



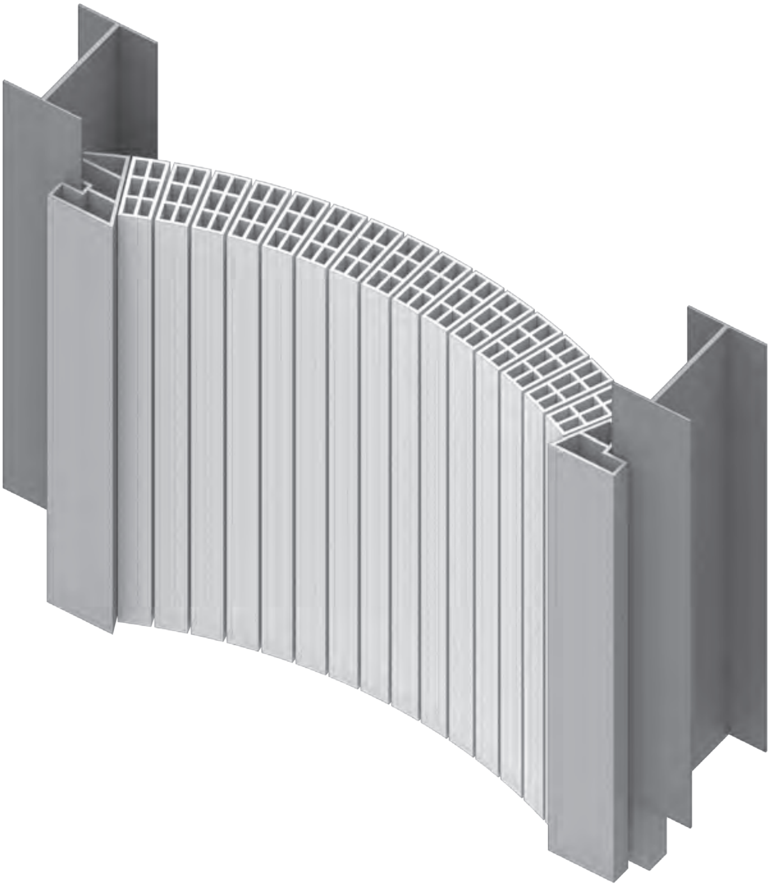
16-13-1 Different types of terra cotta arches. Extracted from Freitag, J.K. ´The fireproofing of steel buildings´.



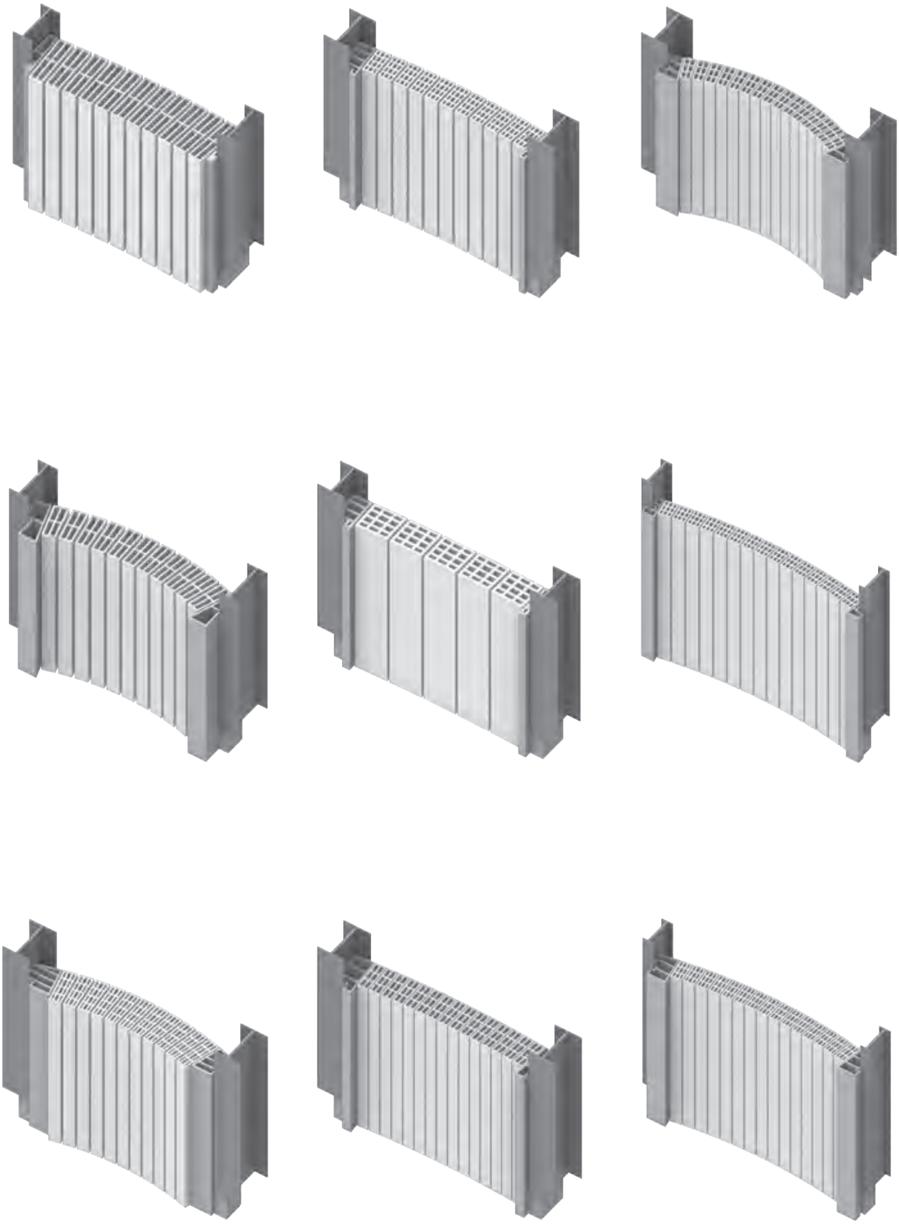
16-13-2 Three-dimensional study models of terra cotta arches.



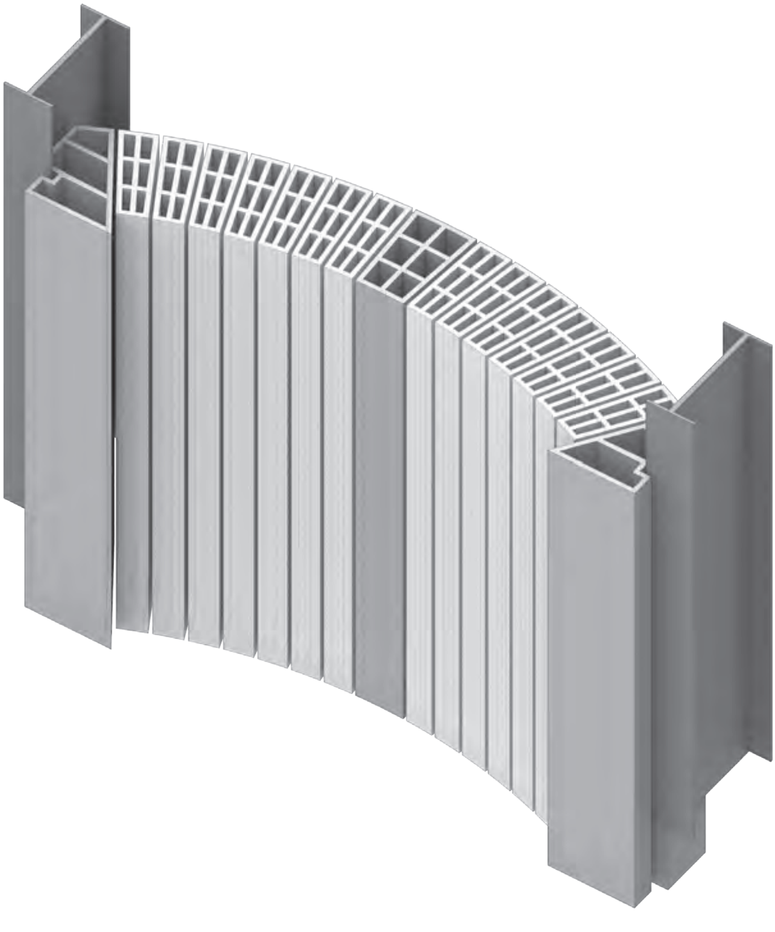
16-13-3 Three-dimensional study models of terra cotta arches.



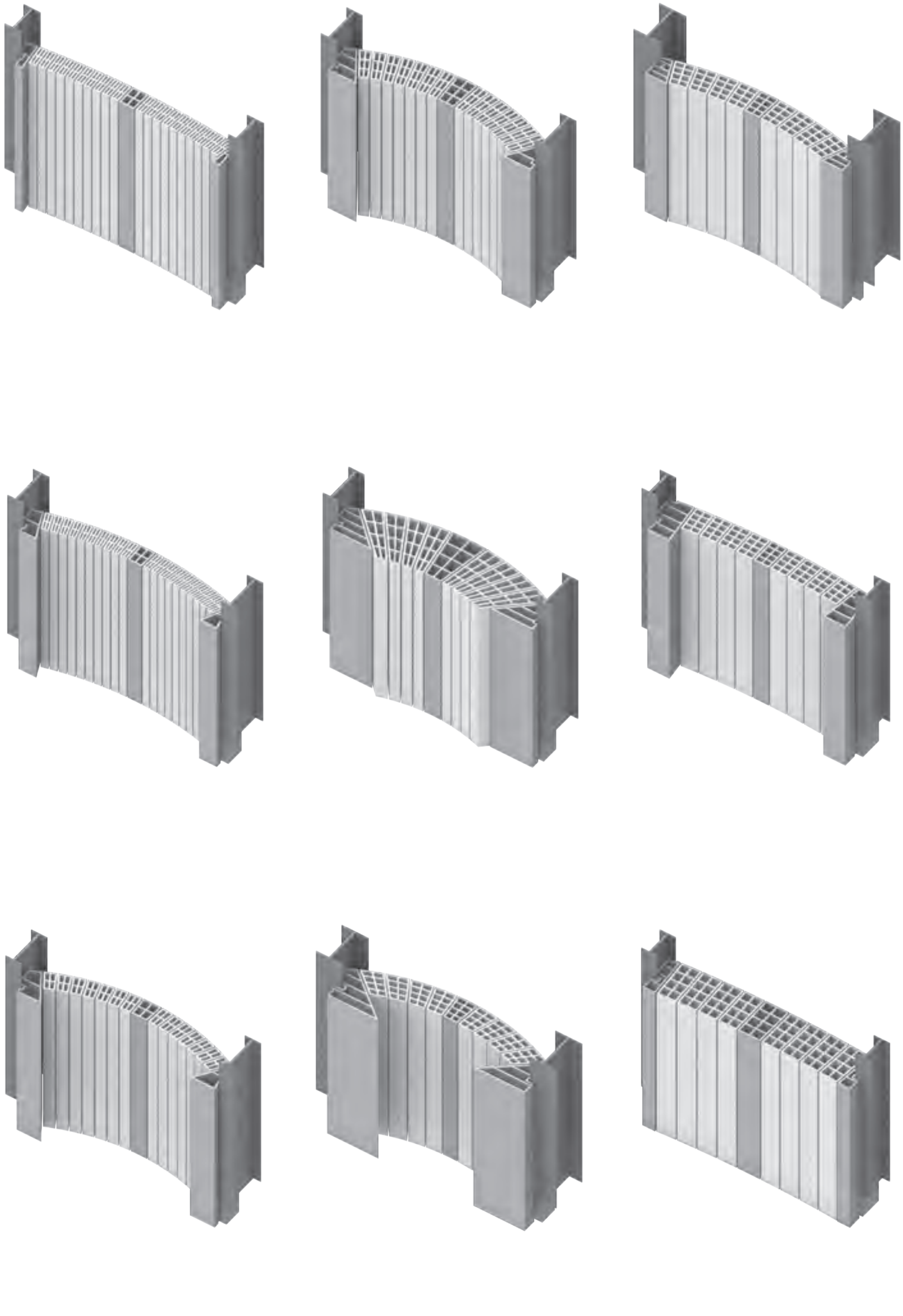
16-13-4 Parametric terra cotta arches. Optimized to use identical pieces.



16-13-5 Parametric terra cotta arches catalogue.



16-13-6 Parametric terra cotta arch with keystone piece.



16-13-7 Parametric terra cotta arches with keystone catalogue. Individualized pieces.

14- TERRA COTTA DETAILS

SOFTWARE: *Rhinoceros, Grasshopper, Mudbox*

REFERENCES: *'Architectural terra cotta, standard construction' by National terra cotta society*

DESCRIPTION:

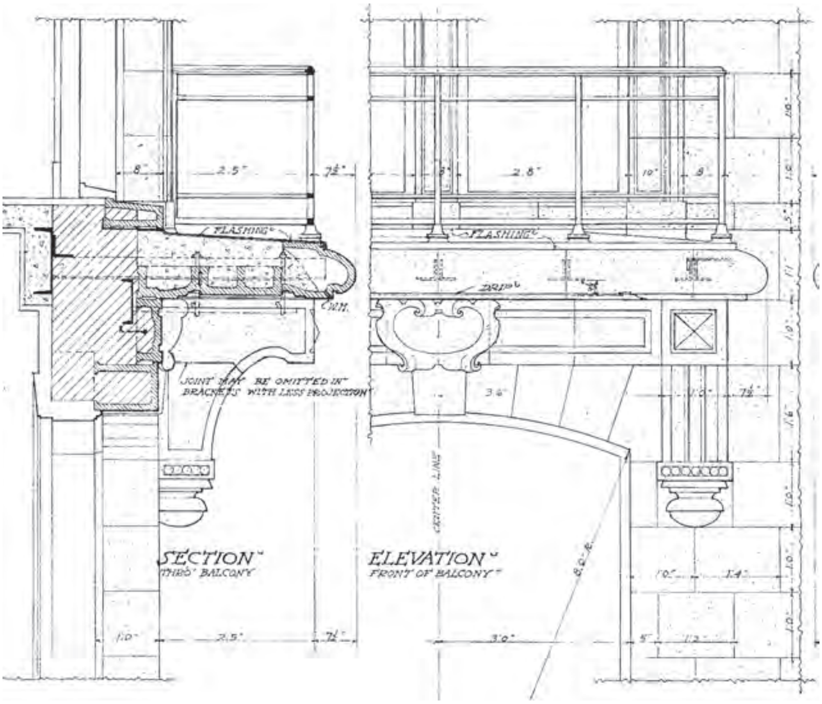
The experiment intends to assess the complexities and intricacies of terra cotta construction by analyzing and reconstructing a series of architectural details, in this case, two balconies. The relevancy of such assemblages' rests in the fact that they condense several building components and their interlocking joints.

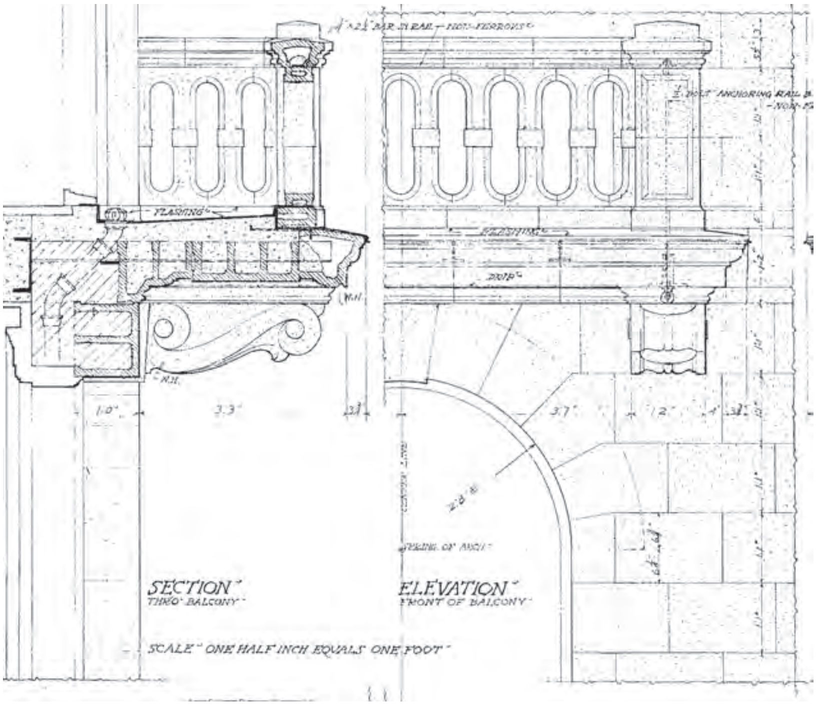
Pieces like floor tiles or wall cladding operate in a surface pattern, while lintels, jambs or sills are disposed in a linear configuration. These differences in their function (or class) also resonate on their final form, how they connect to each other and how the joints operate between each different class.

Each class (surface cladding, floor tiling, window lintels, etc.) is also differentiated according to their montage type. As terra cotta pieces are prefabricated elements, they need standardized connections not only to each other but to a substrate or substructure. For this matter, for each construction technology, there is a specific montage sequence to be followed.

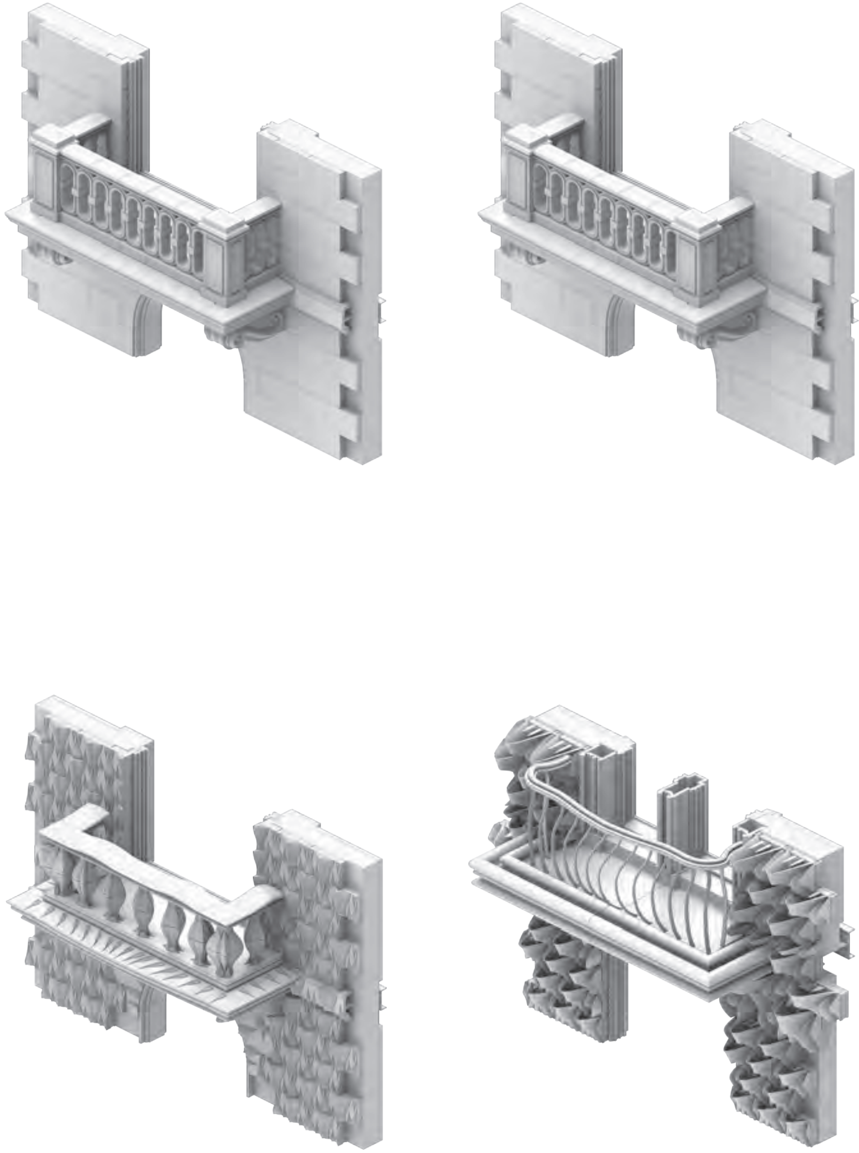
The series of constructive details describes these types of technologies as well as an illustration of their technical and expressive capabilities. The formal and geometrical complexities of the assemblages require a tridimensional understanding of both elements and their arrangement. For this reason, the montage is expressed as a sequence of drawings.

The experiment also serves as an illustration of the formal variety derived from a flexible method of production. Some pieces are arranged as a surface, for example as tiles or cladding, thus being the most versatile in terms of their use and position in the arrangement. Other types are disposed linearly, also allowing the use of identical copies of pieces, and finally, there are special 'closing' pieces, like corners or special ornamentation elements that are used just one or two times. Terracotta production tolerated precisely this type of formal variation; mass-produced pieces, small quantities and singular elements as well.



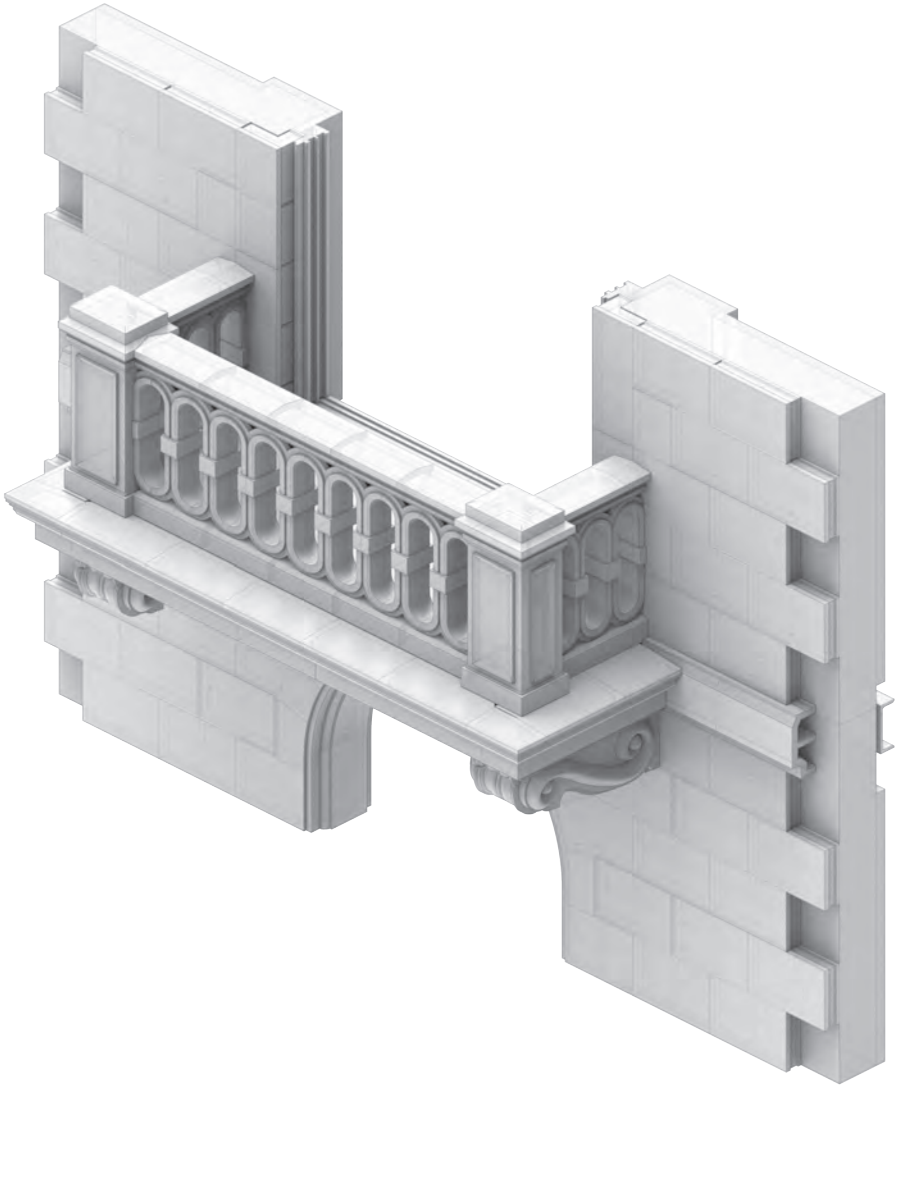


16-14-1 Terracotta Balcony with concrete platform. Extracted from ´Standard construction´ by the National Terracotta Association.

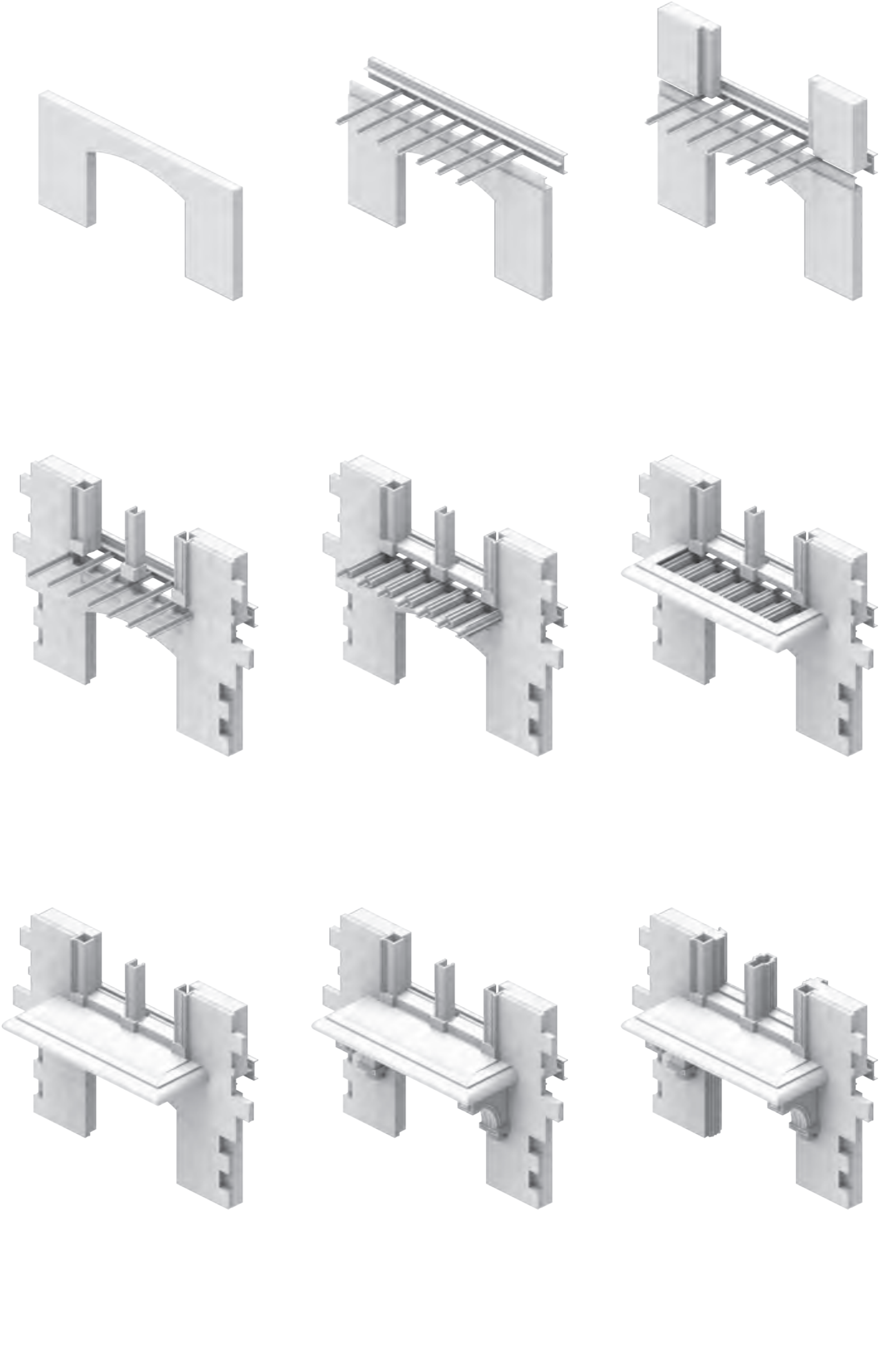


16-14-2 Example balconies from 'Standard Construction' and parametric modifications

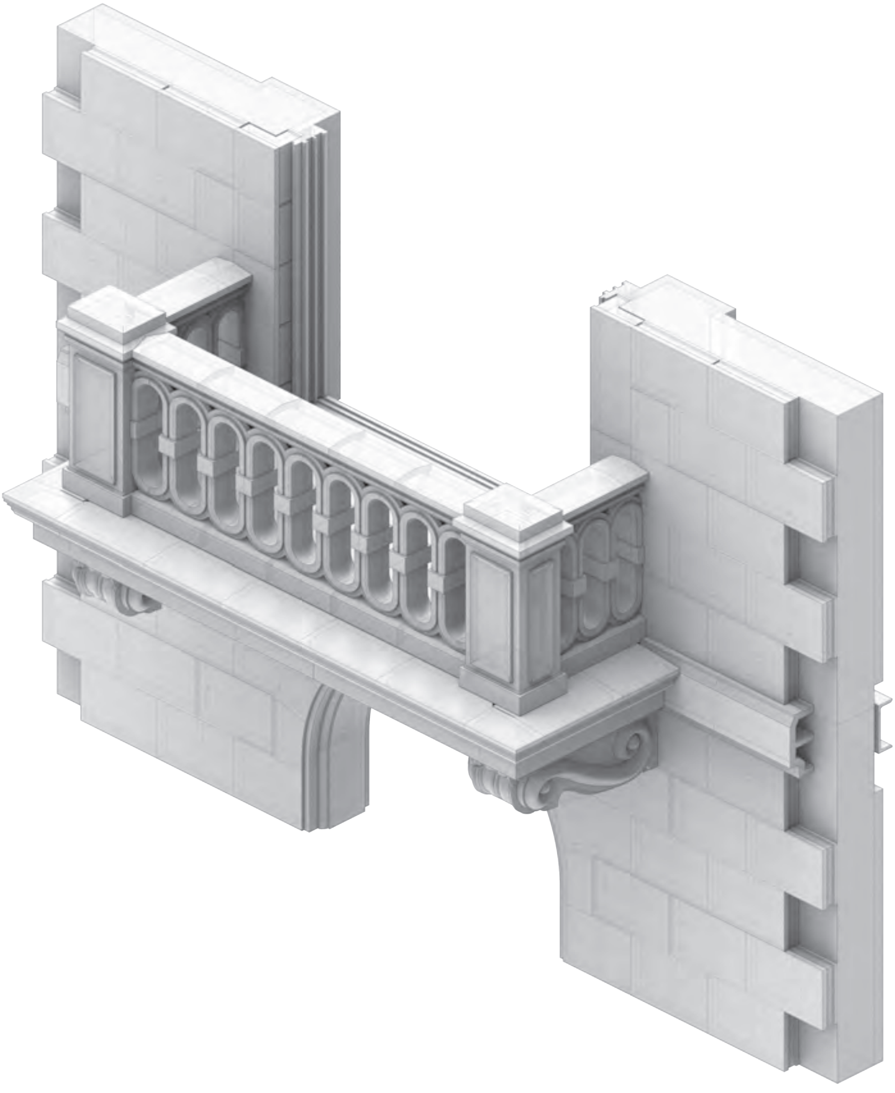
16-14-3 Terracotta balcony assembly progression.



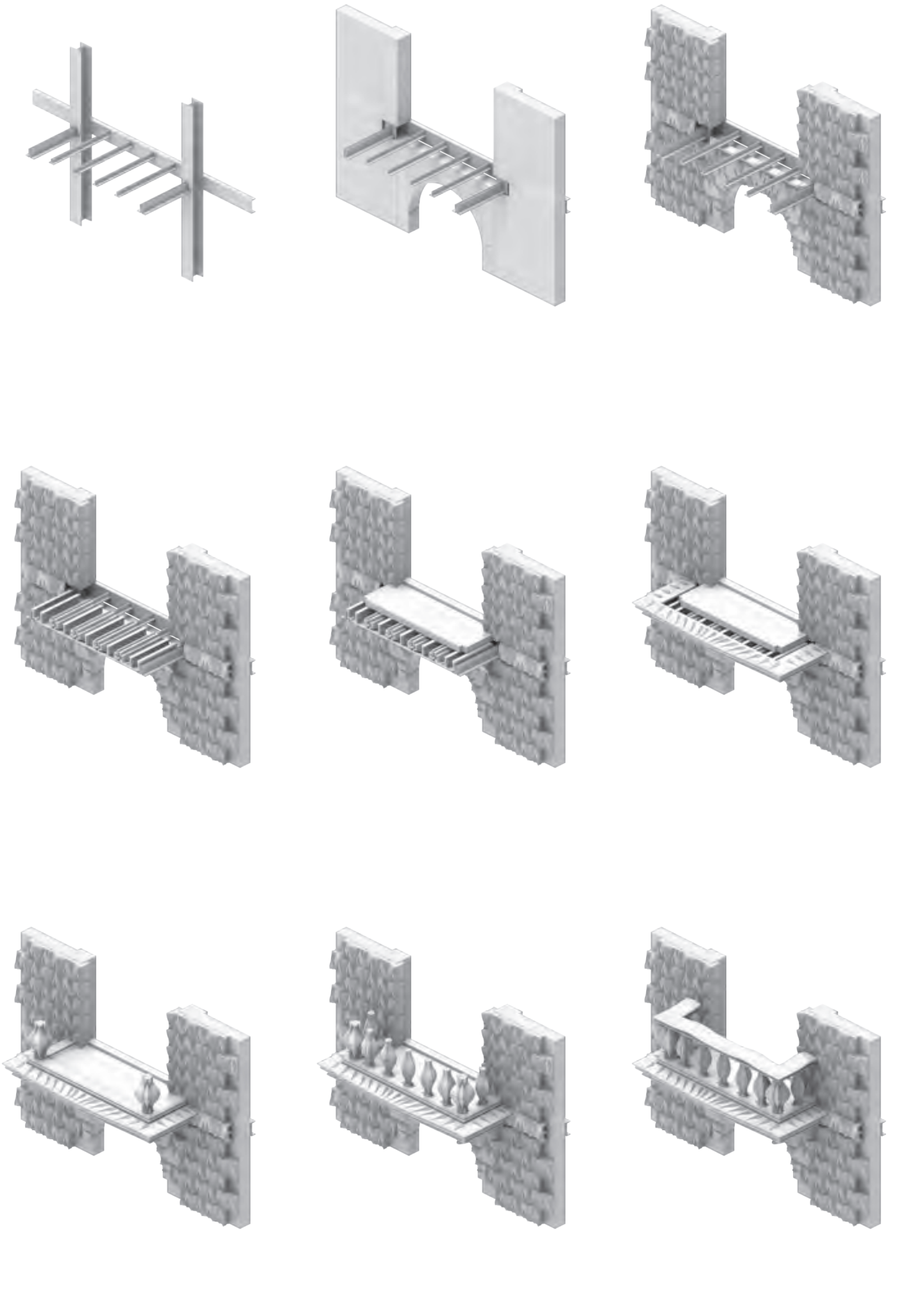
16-14-4 Terracotta balcony final design.



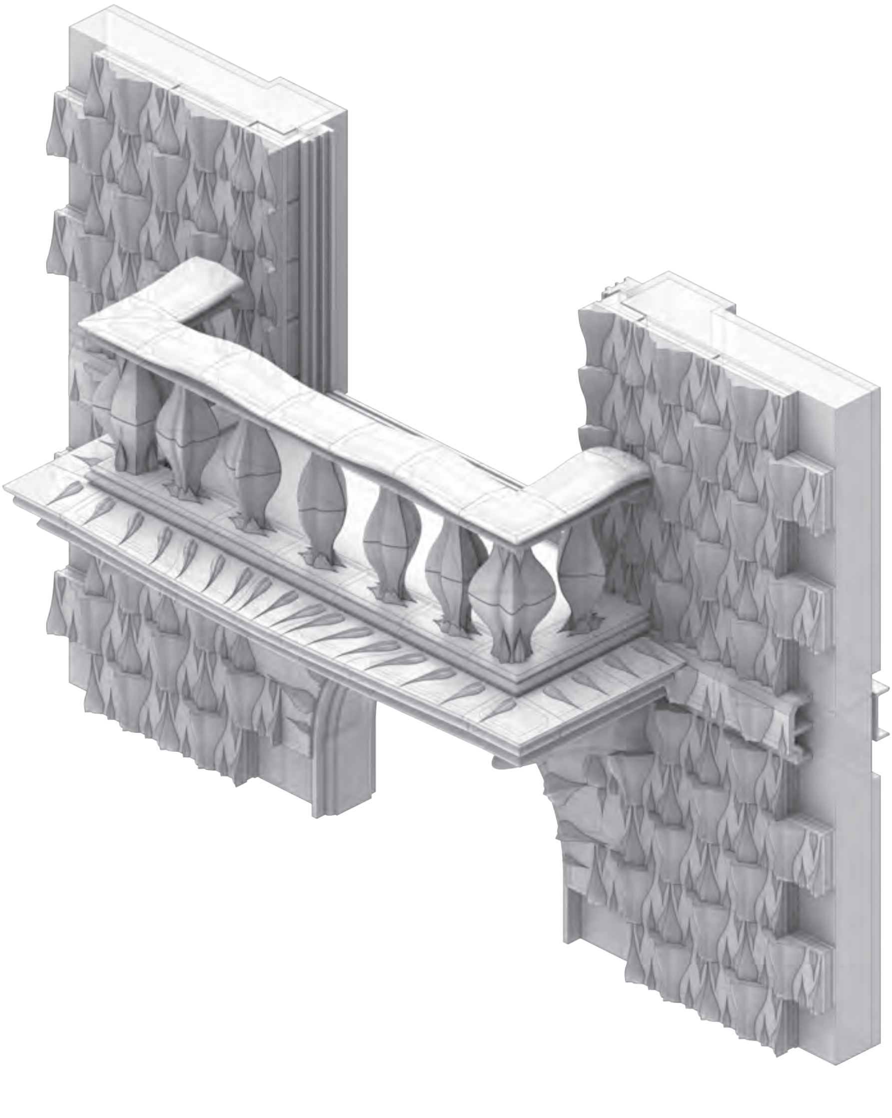
16-14-5 Terracotta balcony assembly progression.



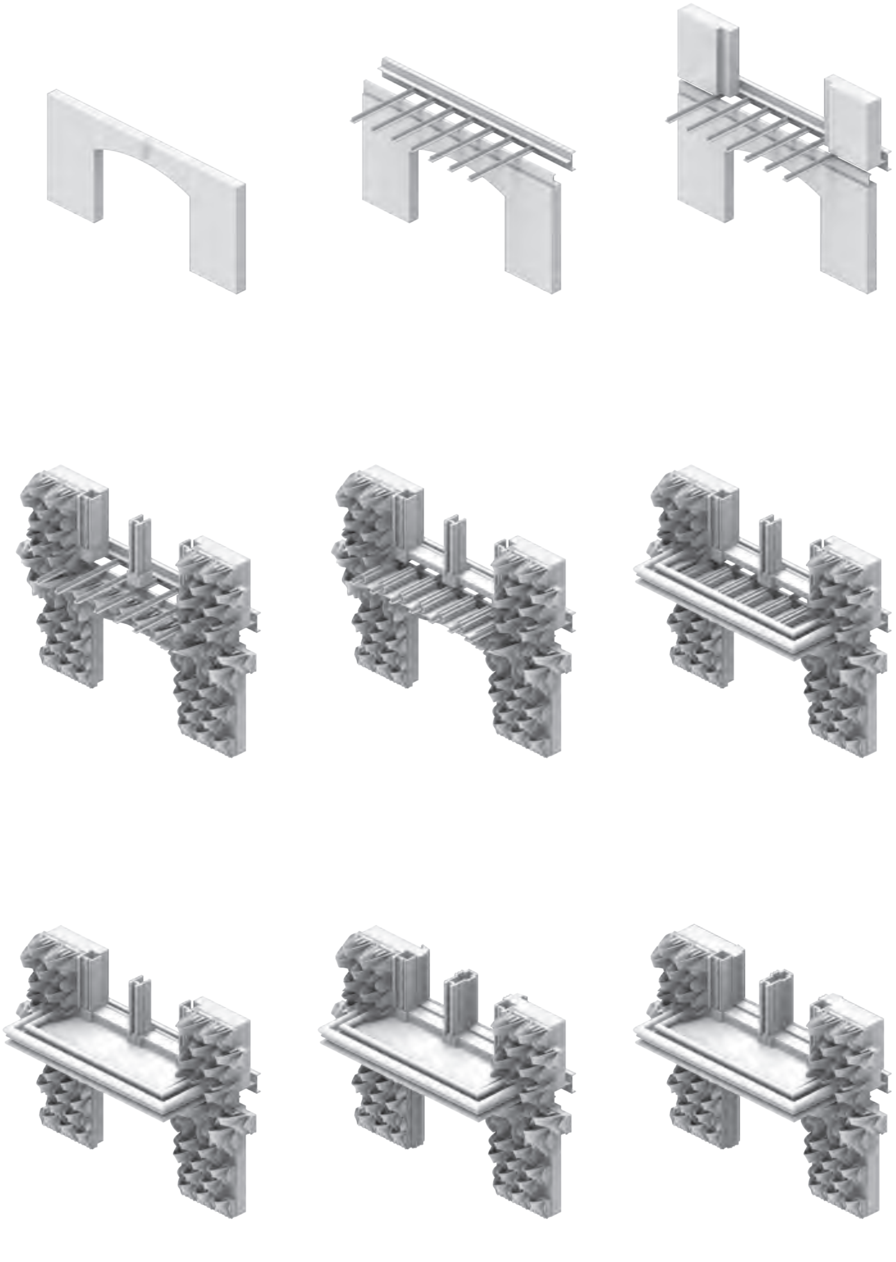
16-14-6 Terracotta balcony final design.



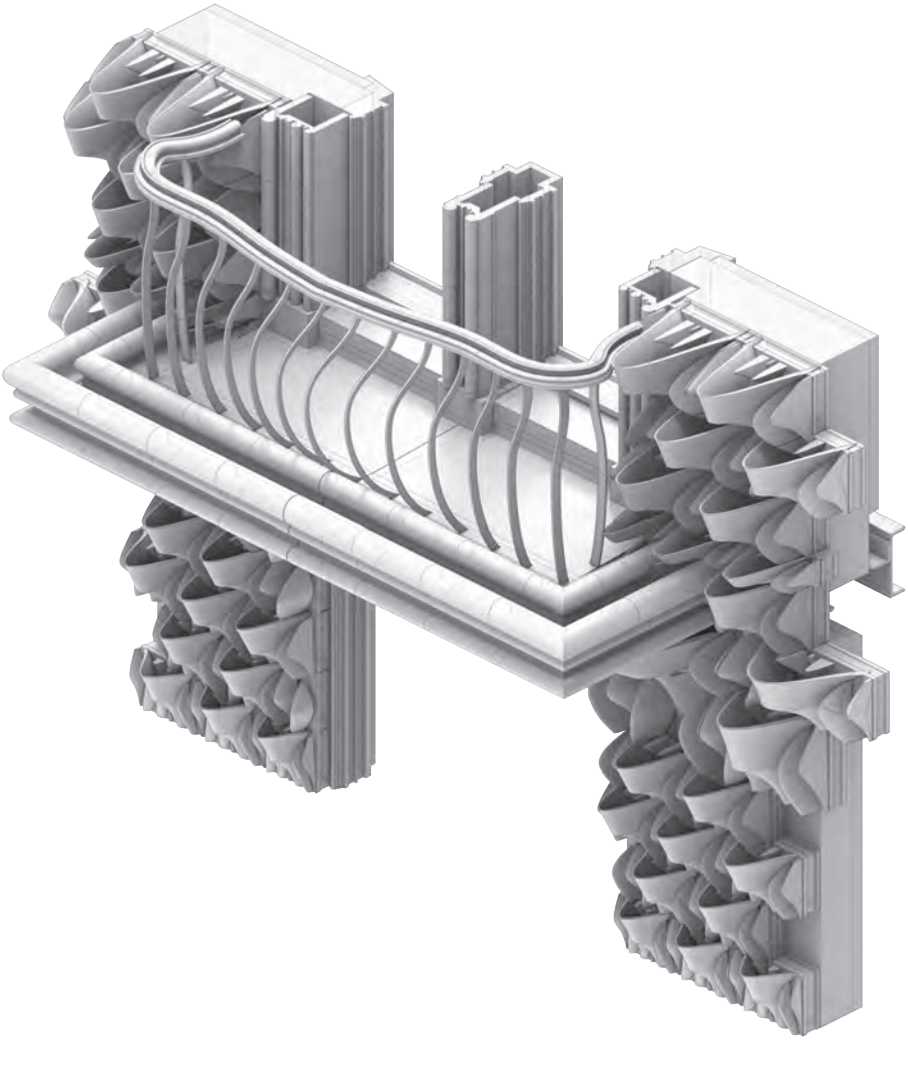
16-14-7 Terracotta balcony assembly progression.



16-14-8 Terracotta balcony final design.



16-14-9 Terracotta balcony assembly progression.



16-14-10 Terracotta balcony final design.

15 – STAIRCASE EXPLORATIONS

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *Magasin au Bon Marche by Boileau, St Pancras by Gilbert Scott, 'Eléménts et théorie de l'architecture' by Guadet, 'Traite d architecture' by Reynaud*

DESCRIPTION:

This experiment began with the study of a series of staircases from different periods, mostly from baroque, rococo and 19th century buildings. Parting from the interest in geometry and manufacturing tools studied by the Rokokorelevanz research group, the analysis collected not only drawings and pictures but also architectural treatises and carpentry manuals such as the ones from Gaudet or Reynaud.

With the introduction of novel fabrication technologies and industrialized production, the design and manufacture of stairways, once dependent on expert carpenters skilled in complex geometries, was certainly modified. It was also significant that these renovated architectural elements were used in innovative programs as well; the case of the Magasin de Bon Marche in Paris is a prime example of the use of a sculptural staircase articulating a large commercial space.

This is the distinctive role of staircase design in 19th century (and it will be revised by modern architecture as well); to gracefully articulate and connect a series of spaces, managing the flow of users while simultaneously manifesting its fluid function via its form and expression.

The experiment intends to create a series of stairways, connecting two or more hypothetical spaces, similar to the reference models studied above. In order to achieve the 'fluidity' of such stairways NURBS curves and surfaces were used as guidelines.

The parametric definition works the following way: first, the two edges corresponding to the top and bottom floors must be selected. Each edge represents the beginning and arrival of the stairway; either it is a proper space or a stairway rest. Then, the two sides of the stairway are also defined by two NURBS curves, defining a surface, similar to a ramp connecting two levels.

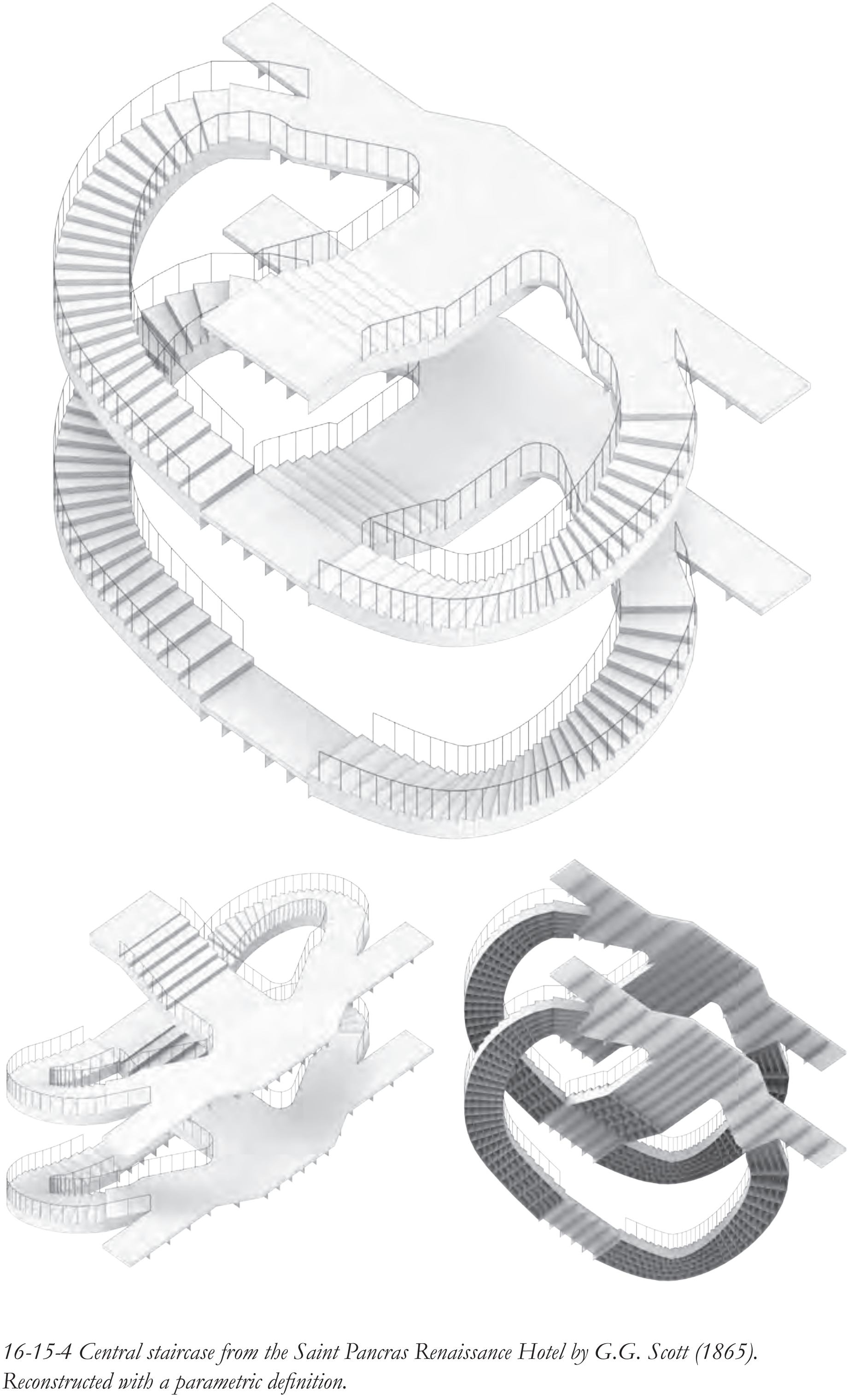
The parametric definition operates by creating a series of steps defined either by their quantity or by their separation in height (being adjusted according to building codes, for example). Each step width is defined automatically through the similar parameter. The definition also configures a railing and the supporting structure according to metal building and carpentry techniques.

This experiment does not differ so much from the approach of current BIM tools. BIM software is also capable of generating customized staircases in various typologies and materials; however they lack the flexibility and geometric plasticity of this exercise.

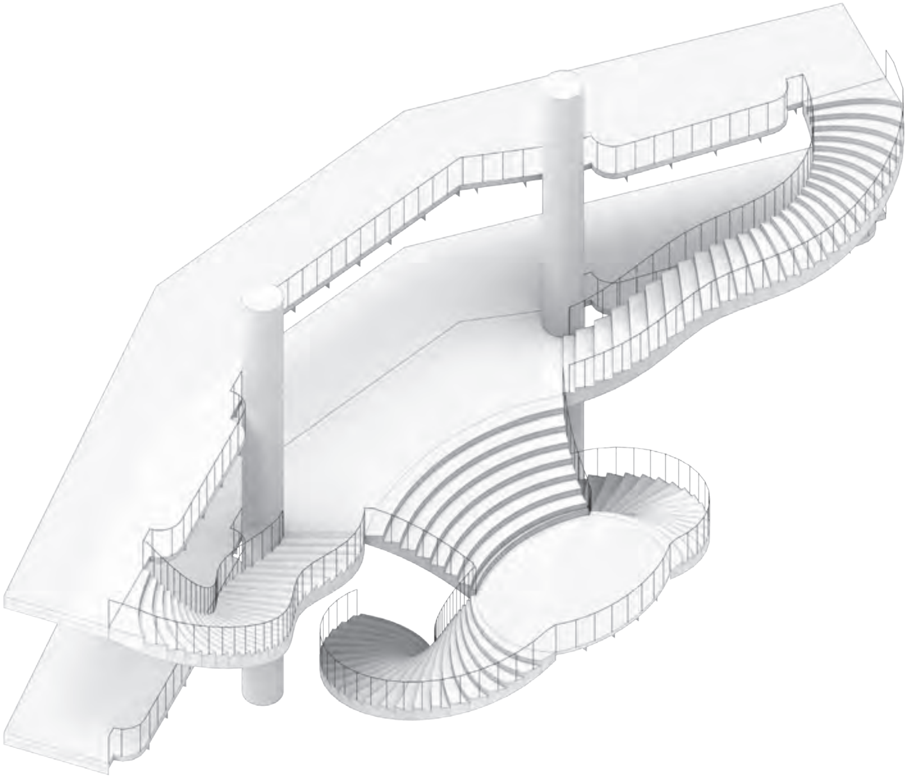
The experiment visualizes the sheer flexibility of iron building techniques, coupled with a plastic conception of space and form as it illustrates a possible path to improve contemporary design strategies. Not just fluid designs but constructive soundness and flexibility are at the core of this experiment as well as a key topic for this research.

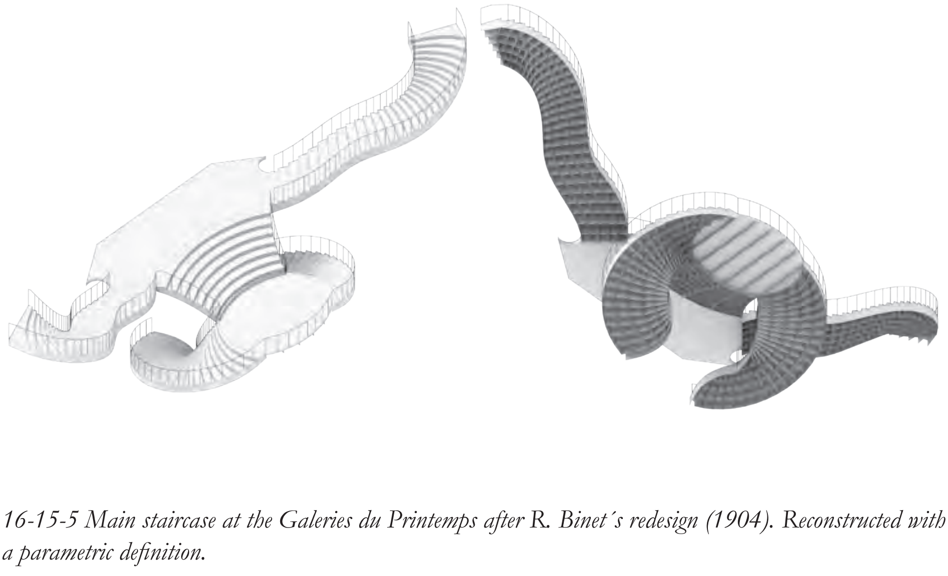
16-15-1 Main staircase at the Galeries Lafayette (1912)

16-15-2 Grand central staircase at the Galerie Bon Marche by L.C. Boileau (1867)
16-15-3 Great branched staircase at the Grand Magasins Dufayel (1890)

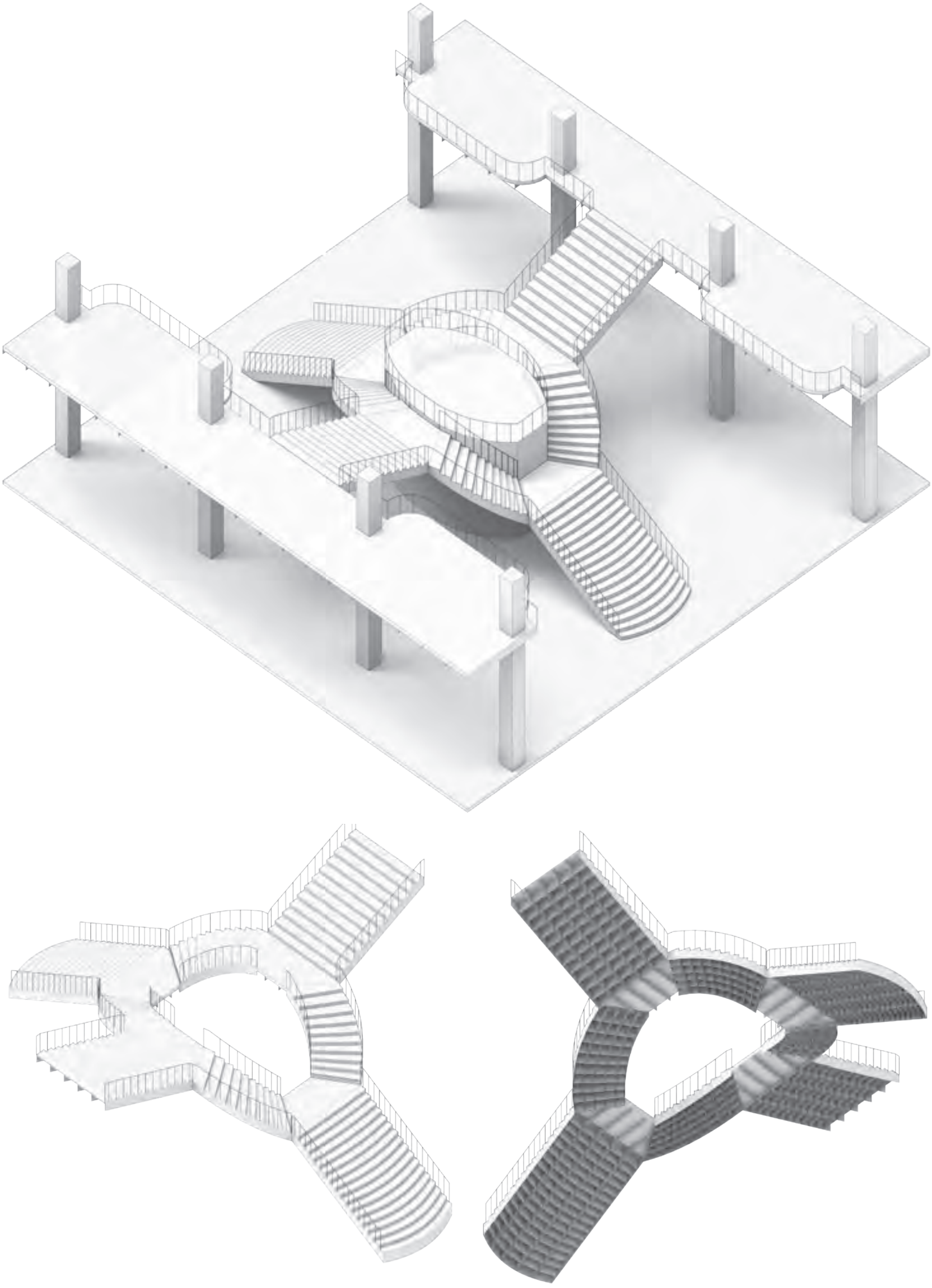


16-15-4 Central staircase from the Saint Pancras Renaissance Hotel by G.G. Scott (1865). Reconstructed with a parametric definition.

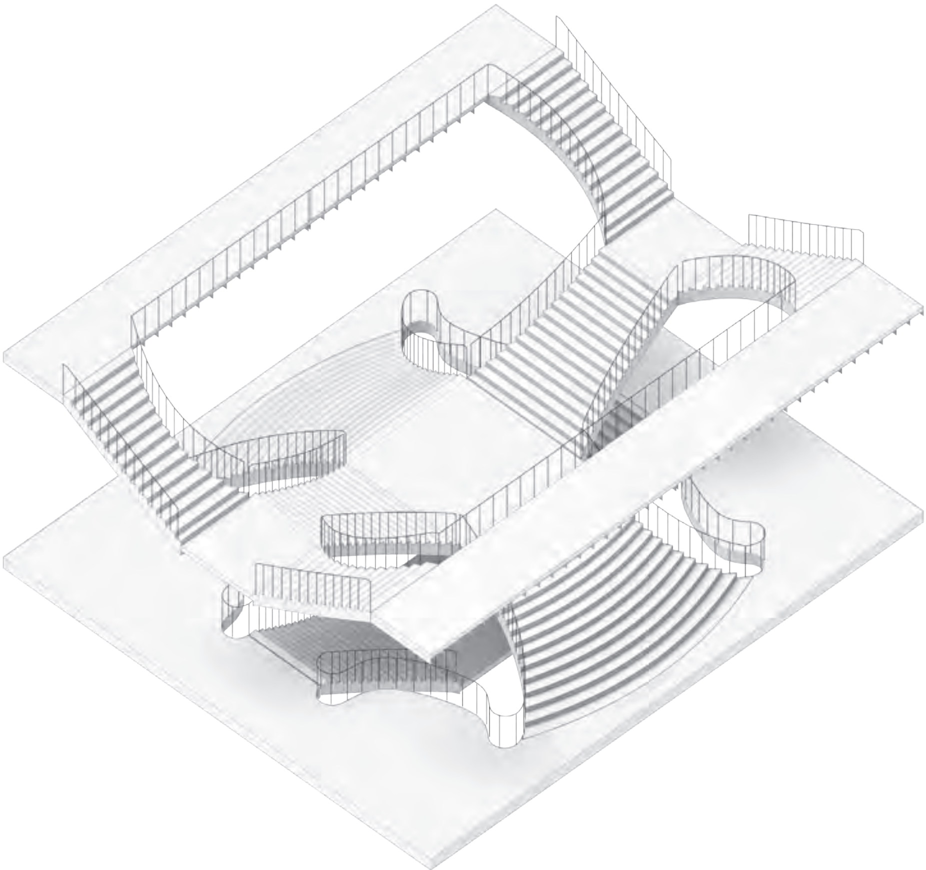


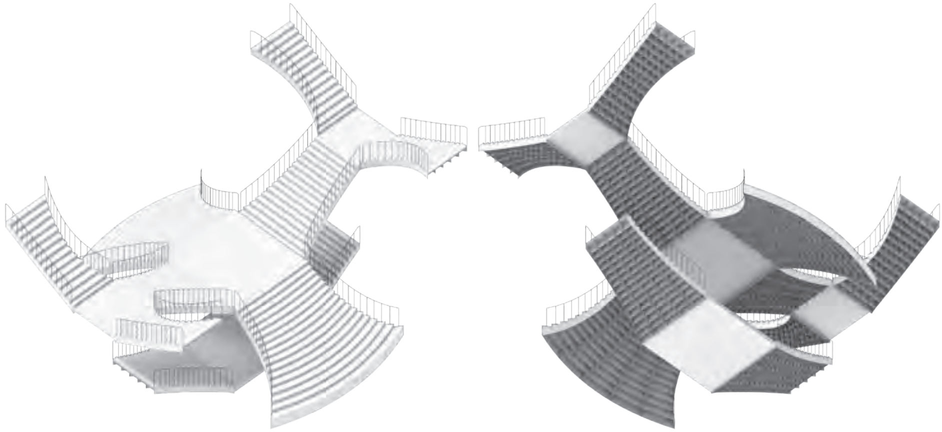


16-15-5 Main staircase at the Galeries du Printemps after R. *Binet´s redesign (1904). Reconstructed with a parametric definition.*

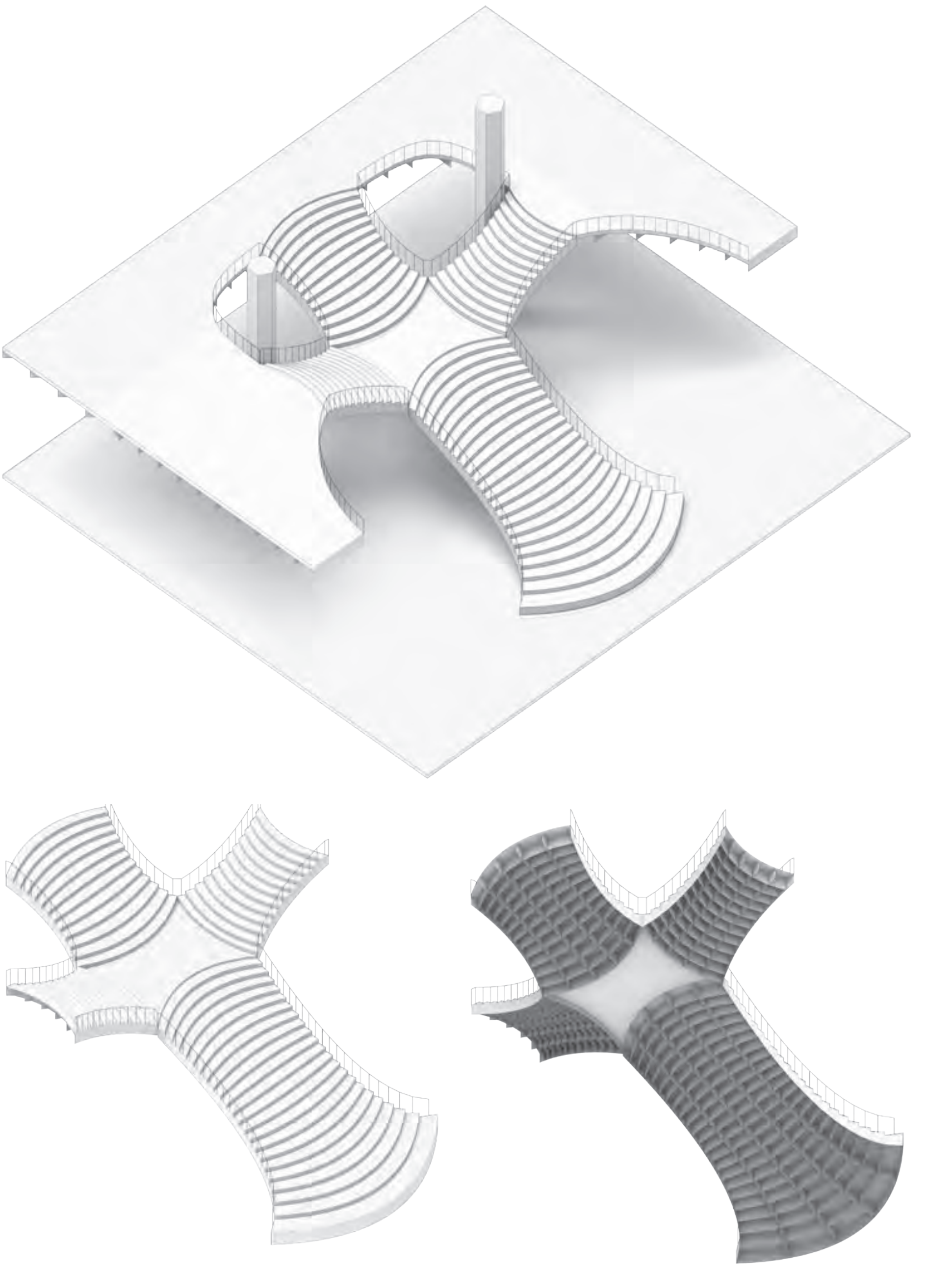


16-15-6 Main staircase at the Galeries du Printemps after R. *Binet´s redesign (1904). Reconstructed with a parametric definition.*





16-15-7 Great branched staircase at the Grand Magasins Dufayel by A. Le Bègue , G. Rives (1890). Reconstructed with a parametric definition.



16-15-8 Main staircase at the Galeries Lafayette by G. Chedanne and F. Chadut (1907). Reconstructed with a parametric definition.

CHAPTER 17

- *Composition experiments*

16 – FREEFORM IRON STRUCTURES / GALERIE DES MACHINES VARIATIONS

SOFTWARE: *Rhinoceros, Grasshopper, Karamba.*

REFERENCES: *Galerie des Machines, iron structures from the 19th century*

DESCRIPTION:

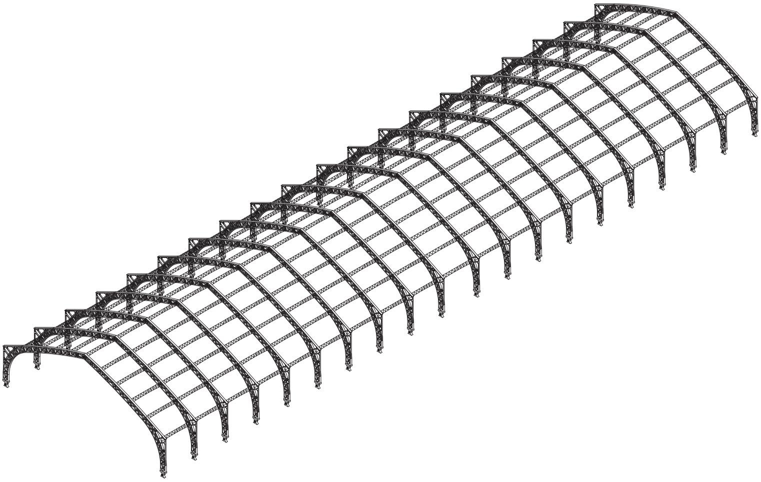
The design experiment intends to reproduce innovative structural typologies from 19th century and simultaneously test their material and aesthetical capacities under the control of new parameters on a digital environment.

The Galerie des Machines was studied as a reference and its structural typology parametrized; support types, upper and lower chords, vertical posts, bracings and articulations, along with the separation of the supports and the general shape of the structure.

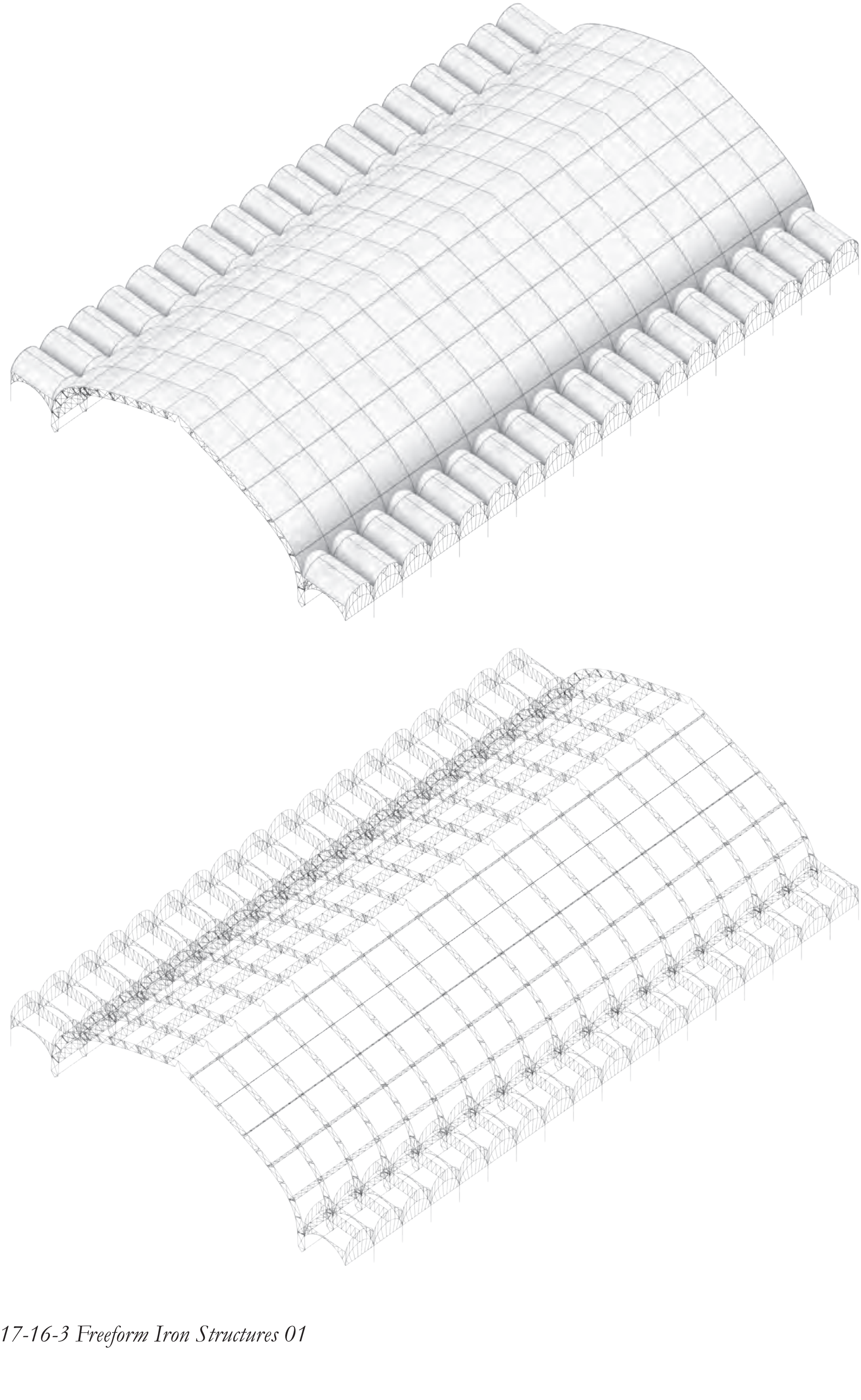
The parametric model works according to the following procedure: first a structural surface is defined (either manually or by a different parametric definition) and it is used as an input shape. This shape will be subdivided by a number of structural elements (beams, supports) that will be evenly spaced along the initial surface. Each structural row can be further altered in height, width and number of divisions. Cross-bracing elements are also inserted on every other division for stabilization according to the original reference.

A second experiment is carried on by altering the base surface (matching the top chord of the structure). The base surface is modified by a form-finding algorithm taking into account gravitational forces, the structures' own weight and the structural member´s own strength. This way, the shape of the structure is molded not by the designer's touch but through the interplay of forces (the support and the supported) and how they reach equilibrium with each other. The parametric model allows the designer to alter not shapes and surfaces but forces, distributed and punctual, while observing in real time how they modify the resulting structure.

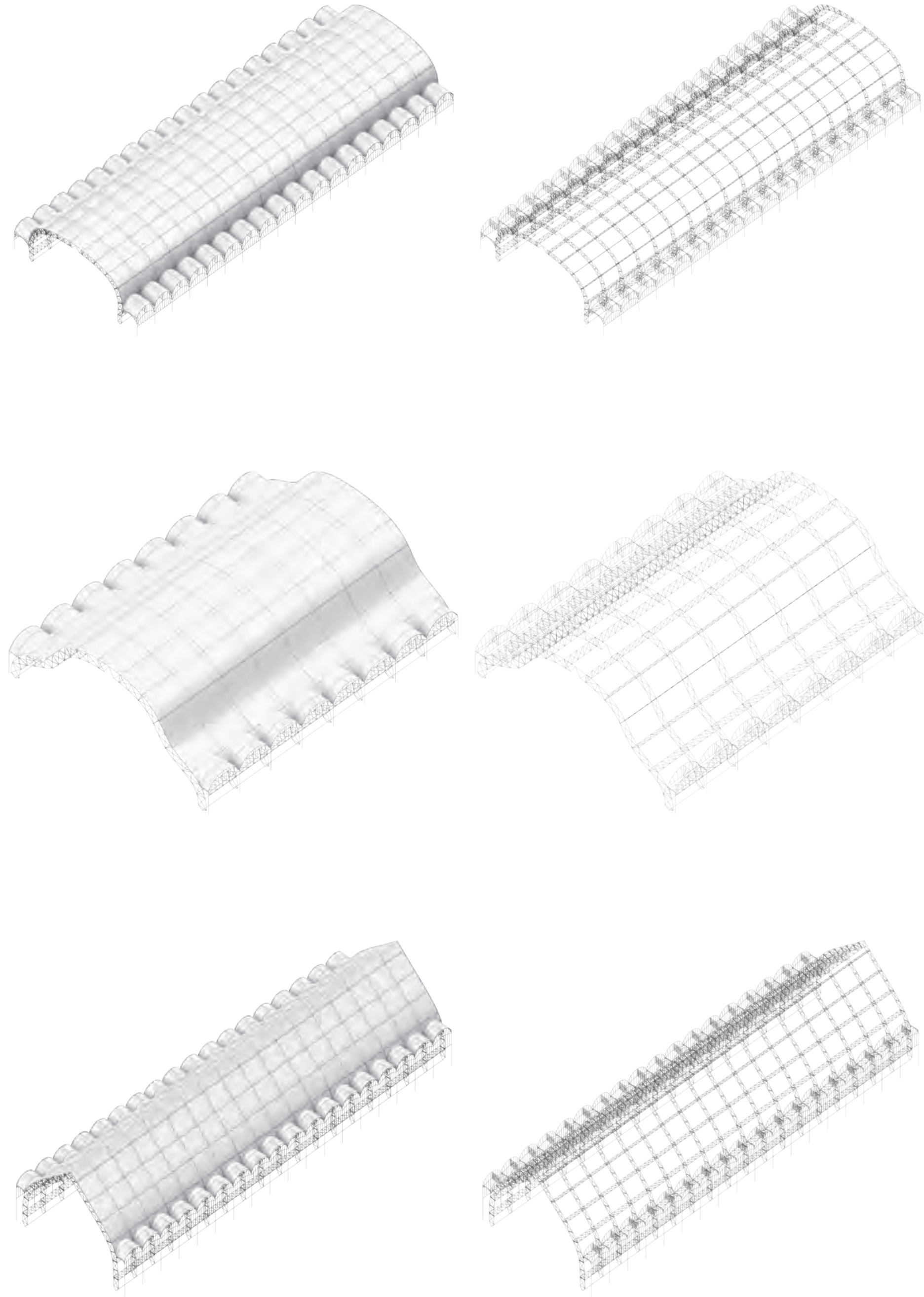
Iron structures in the 19th century were designed according to precise statics but were also heavily defined by material and financial constrains; the intimate relationship between architectural and structural elements and fabrication techniques advocated for a rational understanding of building components and their connections. Still, the aesthetic possibilities arisen from this apparent rational approach were greatly exploited by courageous architects and engineers. The record-breaking Palais des Machines and its potential variations from these experiments are arguably a proof of these values.



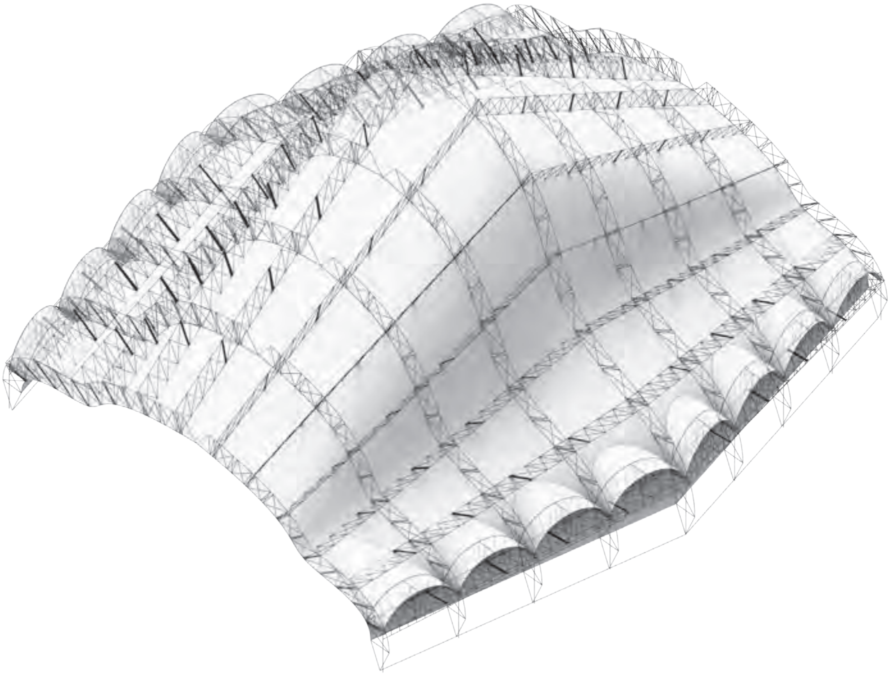
17-16-1 Gallerie des Machines (Paris, 1889) interior view of the hall.
17-16-2 Structural organizaton of the machine hall.

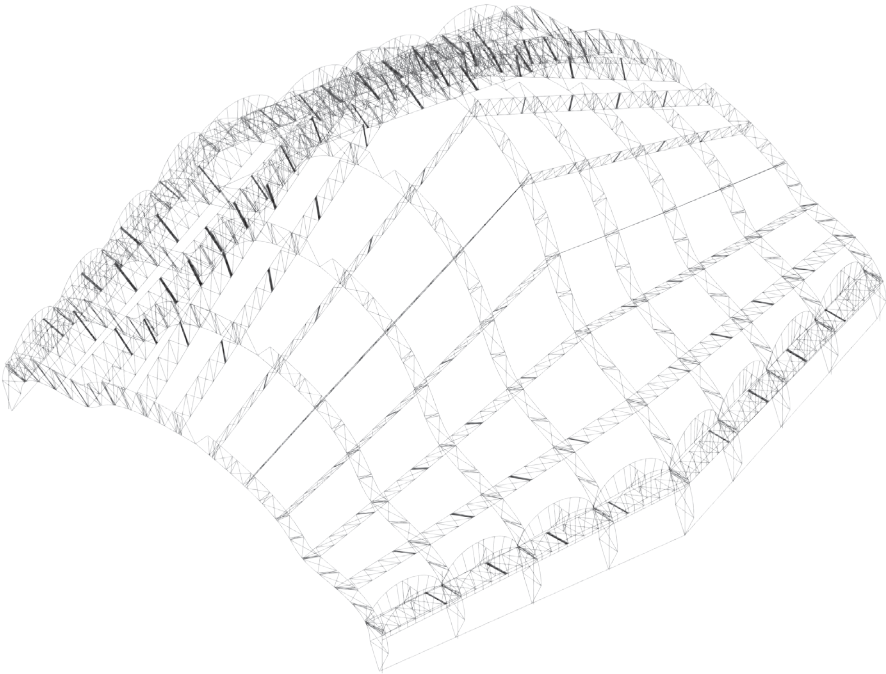


17-16-3 Freeform Iron Structures 01

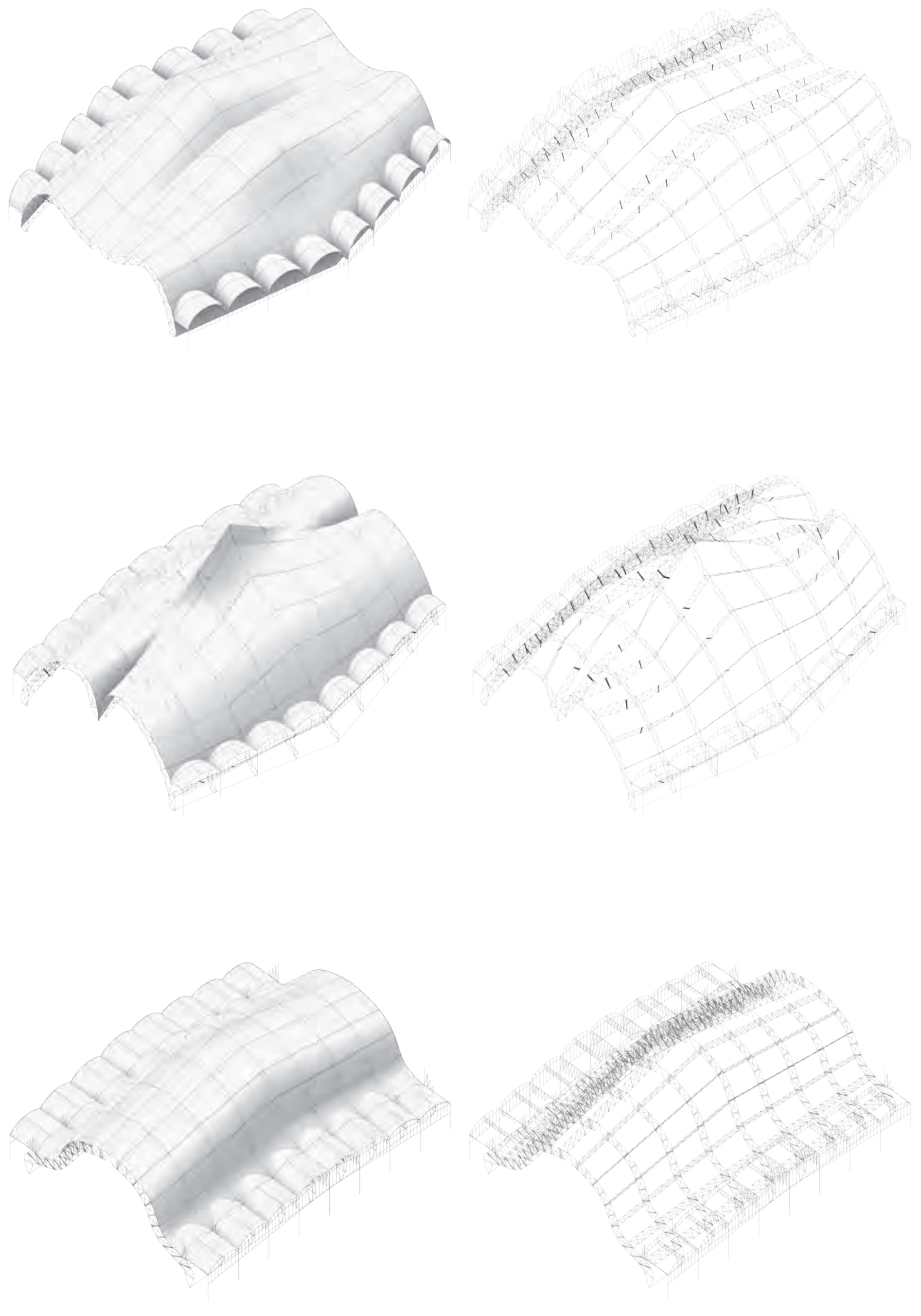


17-16-4 Freeform Iron Structures 02-03-04





17-16-5 Freeform Iron Structures 05



17-16-6 Freeform Iron Structures 06-07-08

17 – FLUID / SUBDIVIDED SPACE

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *'Nouvelle forme architecturale' and 'Histoire critique de l'invention en architecture' by : Louis-Auguste Boileau*

DESCRIPTION:

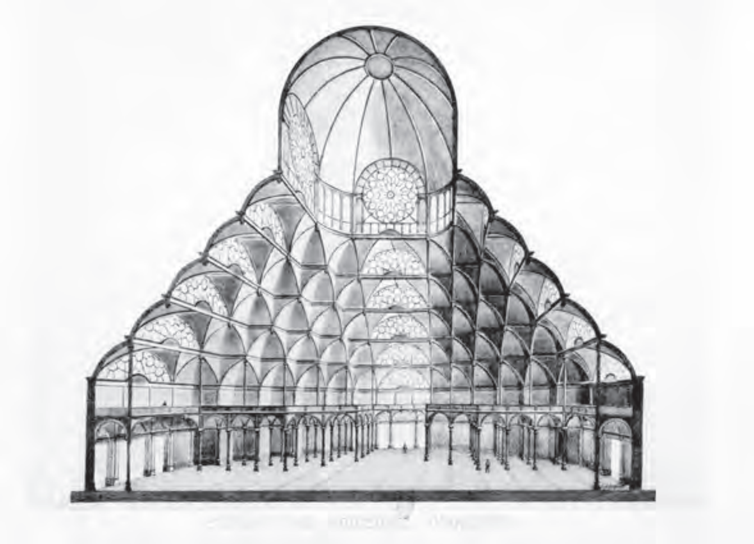
For this experiment a series projects by Luis-Auguste Boileau were studied. Boileau's projects in 'Nouvelle forme architecturale' dealt with a particular composition strategy based on a modular array of spatial units, arranged in a three dimensional organization. He presents three architectural systems based on material, structural and spatial modules. Boileau's invention makes use of iron as a distinctive material, allowing slender elements and luminous spaces, which combined in a three-dimensional array, achieved a distinctive aesthetic, contrasting to their contemporary shed-like structures or religious buildings.

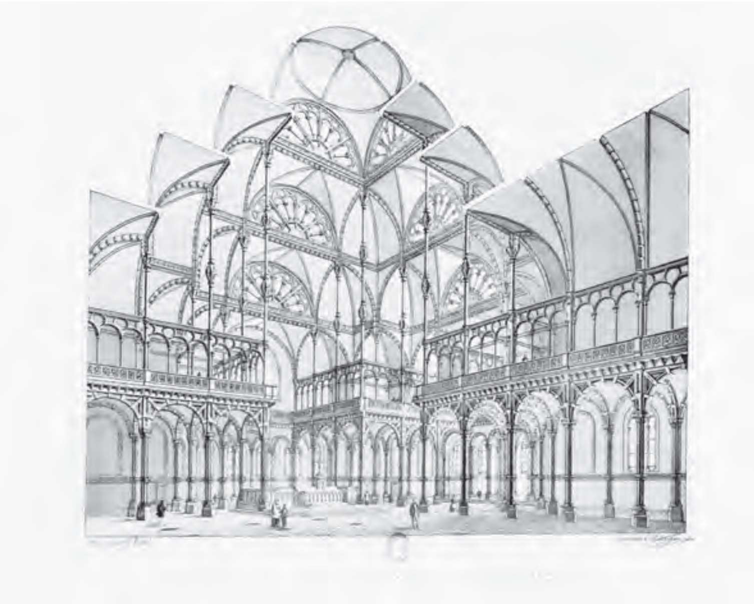
His three systems 'Systeme de voussures imbriquées', 'Systeme des Pendentifs a Nervures' and 'Système des Fermes Éclairantes' explore the spatial possibilities derived from the combination of structural iron modules. The arrangement of the modules in Boileau's projects are still related to classical composition techniques (symmetries, composition axis), but also reminiscent of modular gothic structures.

The experiments parts from this modular conception of structure, arranging the module´s organization according to a parametric definition, altering their characteristics and relation to each other. The base module is a cell, a three-dimensional four-sided iron structure composed by arched trusses, which will be altered by a top-down association between each module and the governing surface.

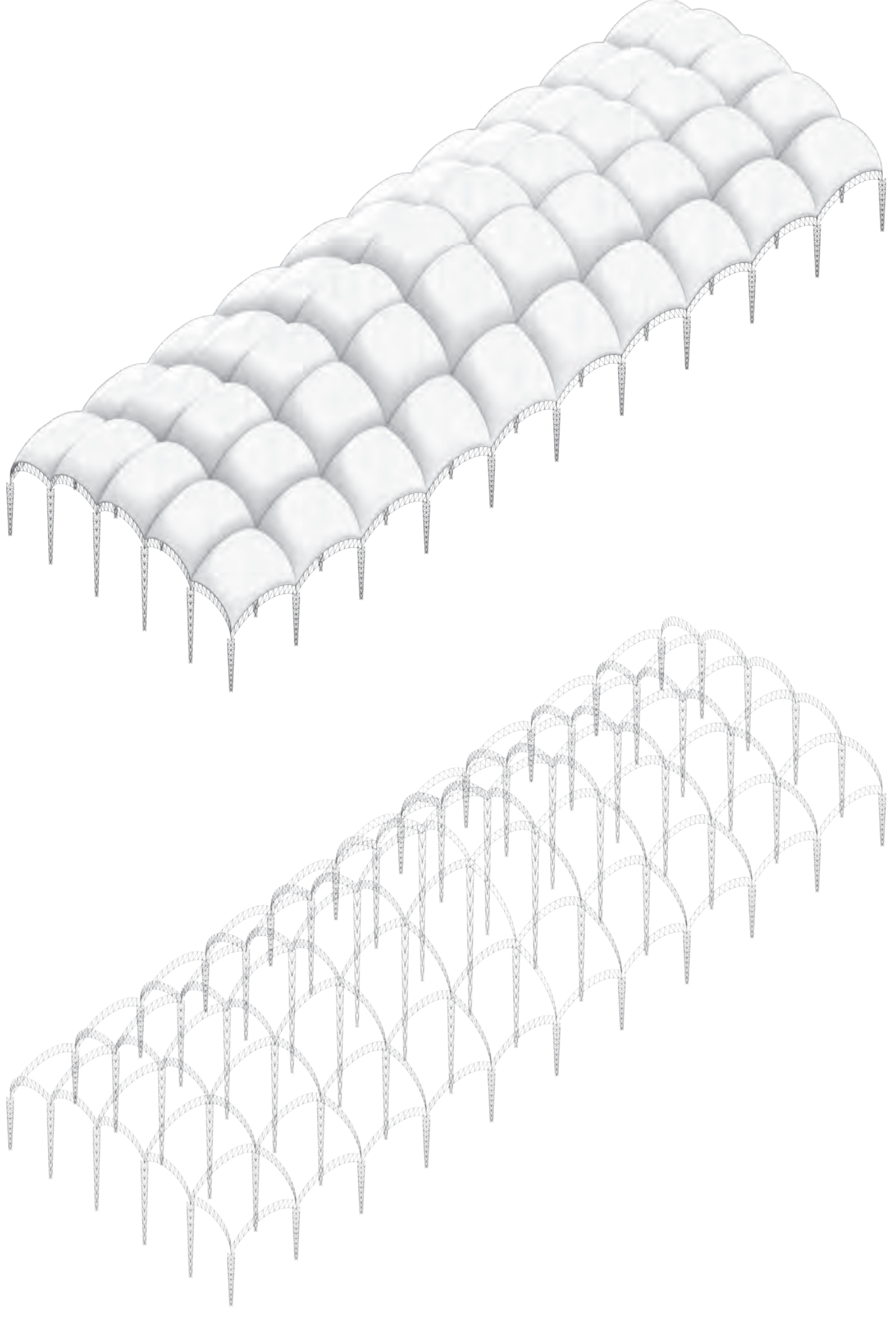
Each module is altered then by two sets of parameters, one is global, the base surface, operating on the whole system and the other is local, controlling the relation of each piece with their surroundings. Similarly, every module's own set of parameters is altered by the relations with their vicinity.

This experiment tries to replicate Boileau's system and expand its possibilities form a spatial point of view. The modules dimensions and parameters can be synchronized and orchestrated gracefully in order to achieve fluid spatial effects. Likewise, if the module's characteristics are contrasting or divergent, the perception of space will become subdivided and segmented.

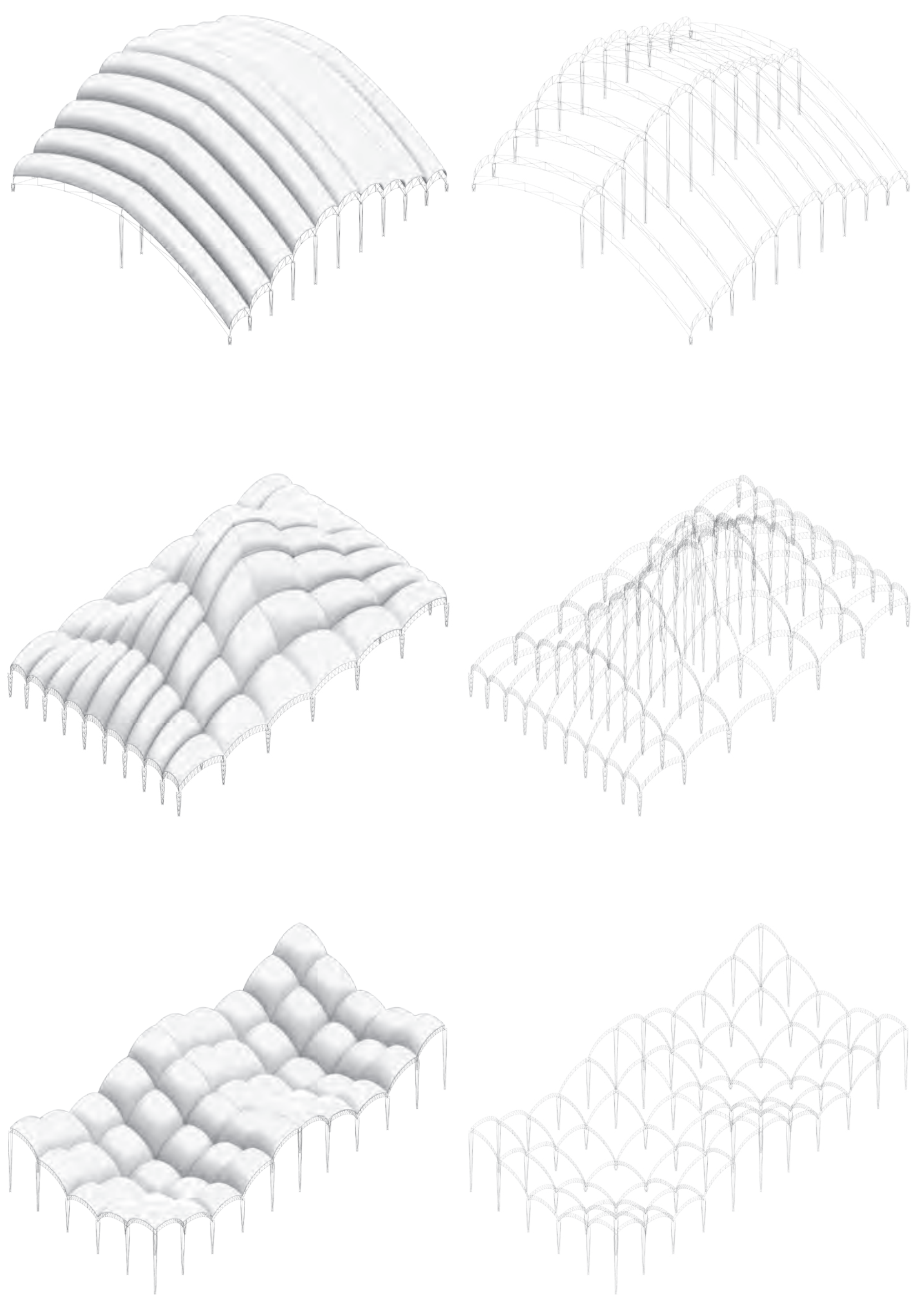




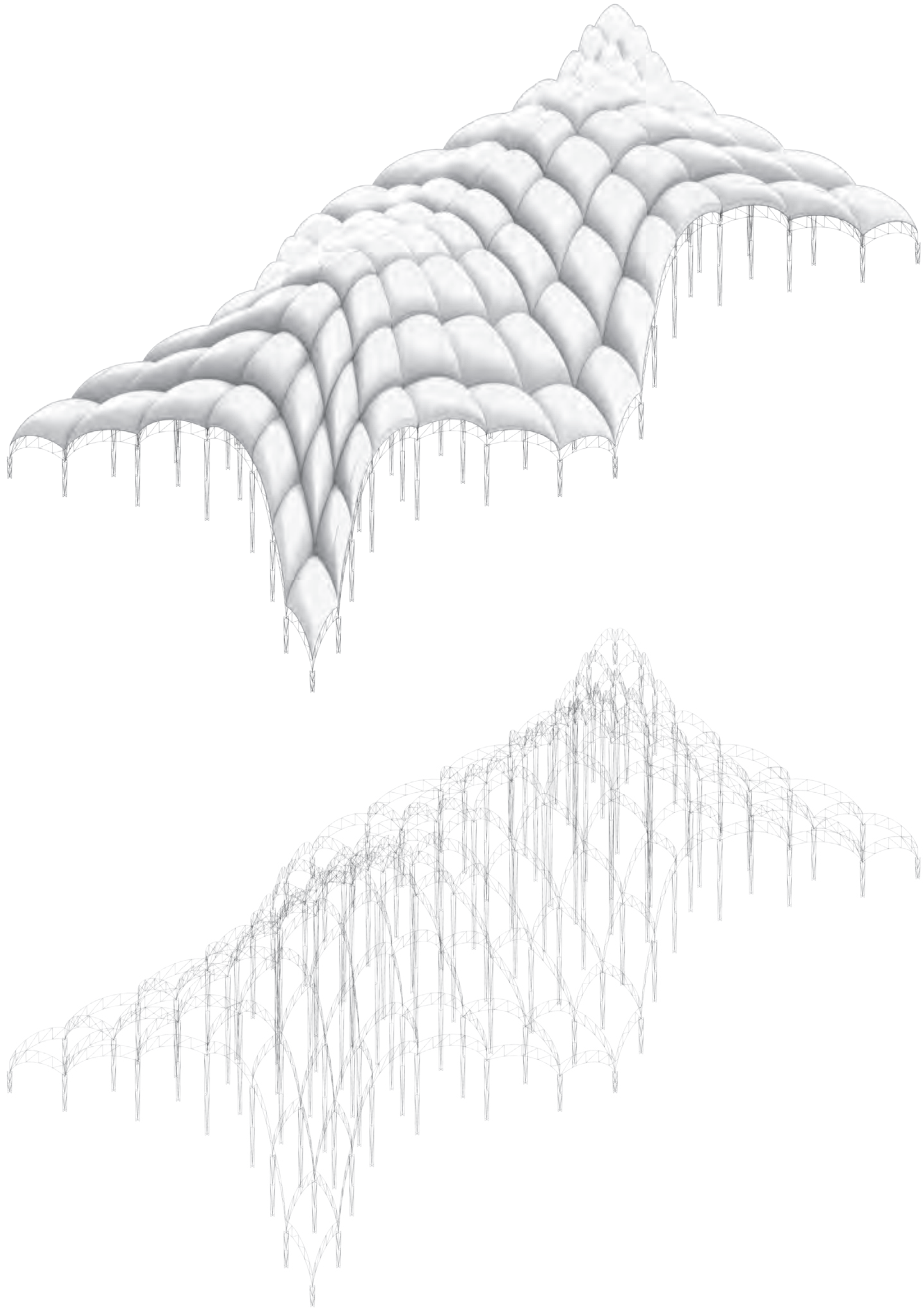
17-17-1 'Systeme de voussures imbriquées' by L.A. Boileau.



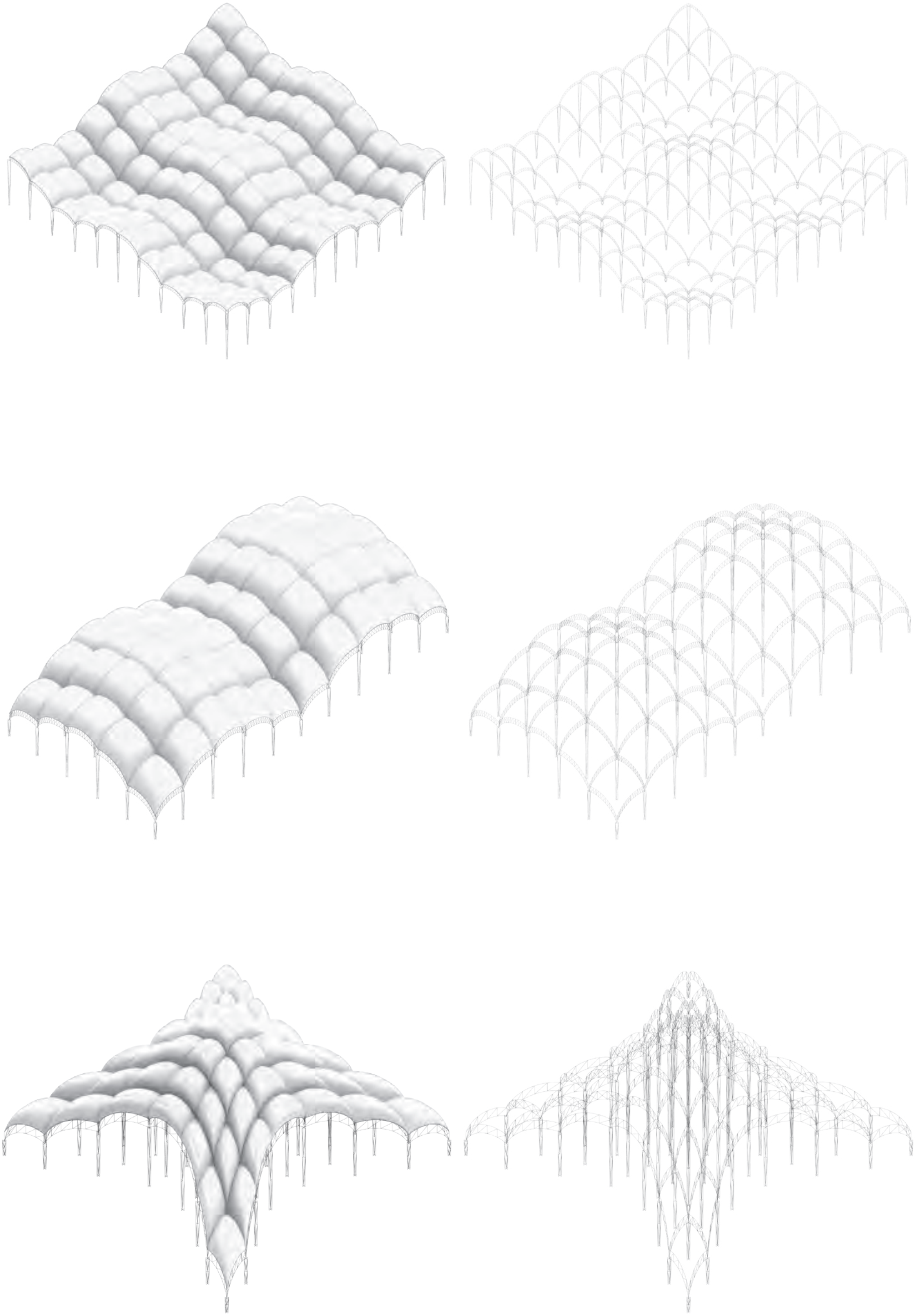
17-17-2 Fluid / Subdivided Space 01. Continuous variation in modular spatial structures.



17-17-3 Fluid / Subdivided Space 02-03-04. Continuous variation in modular spatial structures.



17-17-4 Fluid / Subdivided Space 05. Continuous variation in modular spatial structures.



17-17-5 Fluid / Subdivided Space 06-07-08. Continuous variation in modular spatial structures.

18 - PORTE MONUMENTALE VARIATIONS

SOFTWARE: *Rhinoceros, Grasshopper, Kangaroo, Karamba.*

REFERENCES: *Porte Monumentale by Rene Binet, Exhibition Universelle a Paris 1900*

DESCRIPTION:

This experiment proposes to analyze experimental 19th century projects, understanding both the construction technologies and the design strategies that enabled them, on this specific case, the Porte Monumentale by R. Binet.

Binet´s building communicated a complex geometry difficult to grasp, at least at first sight. The profuse decoration in ceramic and stucco also hid the perception of the portal´s structure, made in iron. This experiment intends to define a clear-cut geometrical model based on the generative elements that compose the final form of the building, aside from its decorative elements.

This particular exercise focuses on exploring the underlying topology of the portal, its organizational structure and the aesthetical possibilities unlocked by the unrestricted variation of its governing parameters.

This first experiment creates variations determined by a series of adjoining surfaces. These surfaces are generated through generative arcs, similar to the original pavilion. This parametric approach intends to develop a base model in order to understand the underlying topology of the building that will be later developed into a base mesh.

The result of this stage is a parametric model of the Porte Monumentale's topology, exploring the inner relationships between its generative curves and the resulting surfaces.

The result is a series of base pavilions, similar to canopies or tents. It is also noteworthy that each of the pavilions are structurally sound, thanks to the form-finding process that created them, secured equilibrium between gravitational forces and material resistance.

17-18-1 Topological surface. Porte Monumentale Variations 01.

17-18-2 Topological surface. Porte Monumentale Variations 02-03-04-05.

17-18-3 Topological surface. Porte Monumentale Variations 06-07-08-09-10-11-12-13-14

19 - PORTE MONUMENTALE VARIATIONS 2

SOFTWARE: *Rhinoceros, Grasshopper, Kangaroo, Karamba.*

REFERENCES: *Porte Monumentale by Rene Binet, Exhibition Universelle a Paris 1900*

DESCRIPTION:

This experiment proposes a second look at the previous experiment (18- Porte Monumentale Variations) with a similar purpose; to analyze experimental 19th century projects, considering construction technologies and design strategies of the Porte Monumentale by René Binet.

The previous experiment focused on exploring the underlying topology of the portal and its organizational structure.

This experiment tries to achieve similar results but parting from a different premise; by using contemporary parametric tools, a physics engine and interactive simulation, optimization and form-finding techniques. The purpose was to use on this case, not geometrical tools and parameters like lines, arches and surfaces but to design and apply active and passive forces on a responsive surface. Grasshopper and the physics engine plug-in Kangaroo operate by defining a base mesh, anchors and forces such as gravity or wind.

The reason for this experiment is to illustrate a possibly contemporary approach involving ubiquitous form-finding tools if a similar design task would be attempted today. On this regard, the use of form finding tools linked to parametric techniques is a common digital design strategy on contemporary practices; they propose to define a series of base conditions and then apply a number of punctual and distributed forces. The final form is then generated not by shaping geometries but by carefully applying forces into a ‘base mesh’. This way, the form is not determined by parameters but is ‘found’ by a process defined by the designer, on this case, the interaction of gravitational forces and the structure´s resistance to them.

With this method, the design is defined ‘indirectly’, shaped by the interaction of forces and not by the designer’s hand. These experiments intend to reproduce a series of variations from the Porte Monumentale by departing from a base mesh and applying forces in order to generate a similar result to Binet’s design.

This experiment deals with the use of a physics engine (Rhinoceros + Grasshopper + Kangaroo) in order to create a pavilion by generating a base mesh and then locating gravitational forces and anchors. The definition works by setting up a base flat mesh, similar to the building’s footprint. Once this footprint is defined as a triangulated mesh, the designer needs to establish anchor points, immovable nodes on which the building will be connected to the ground.

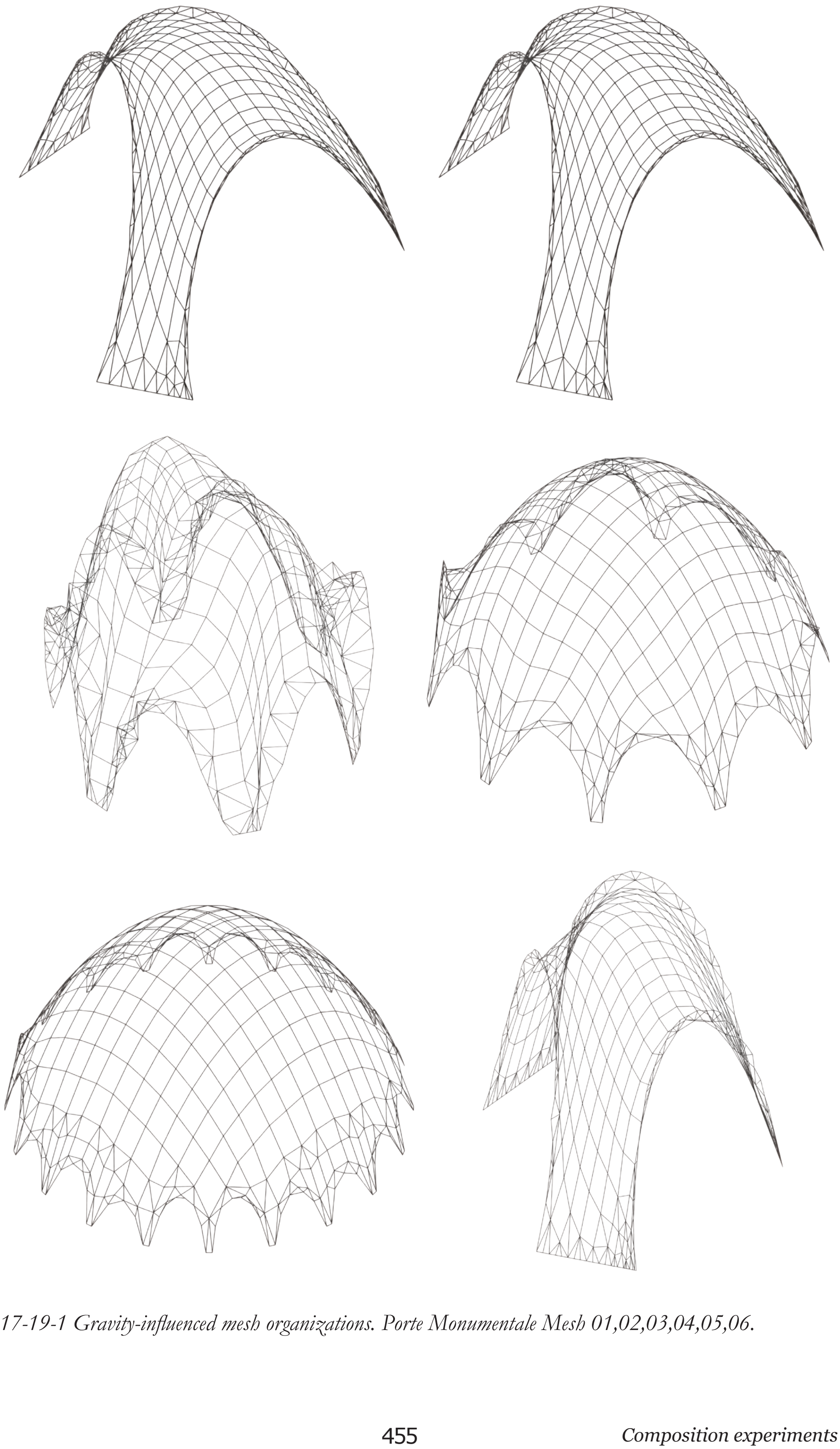
Finally, a series of forces or vectors need to be defined in terms of direction and strength. On this experiment, only gravitational forces were used, that means, evenly distributed vertical forces. After the mesh, anchors and forces are set, the parametric definition is activated in an iterative, interactive process. The process involves a number of calculations by which every part of the mesh interacts with their surrounding ones, displayed in an animation. The animation shows how a mesh is inflated and deflated iteratively, until it reaches an equilibrium point defined by user´s parameters.

On this particular case, the forces act as an anti-gravitational pull, defining anti-catenary arches and vaults. The reasoning behind these shapes is similar to the catenary arches; by inverting the distribution of the links on a hanging chain, their opposite shape, the anti-catenary would define a perfect load-bearing geometry, affected only by gravitational forces.

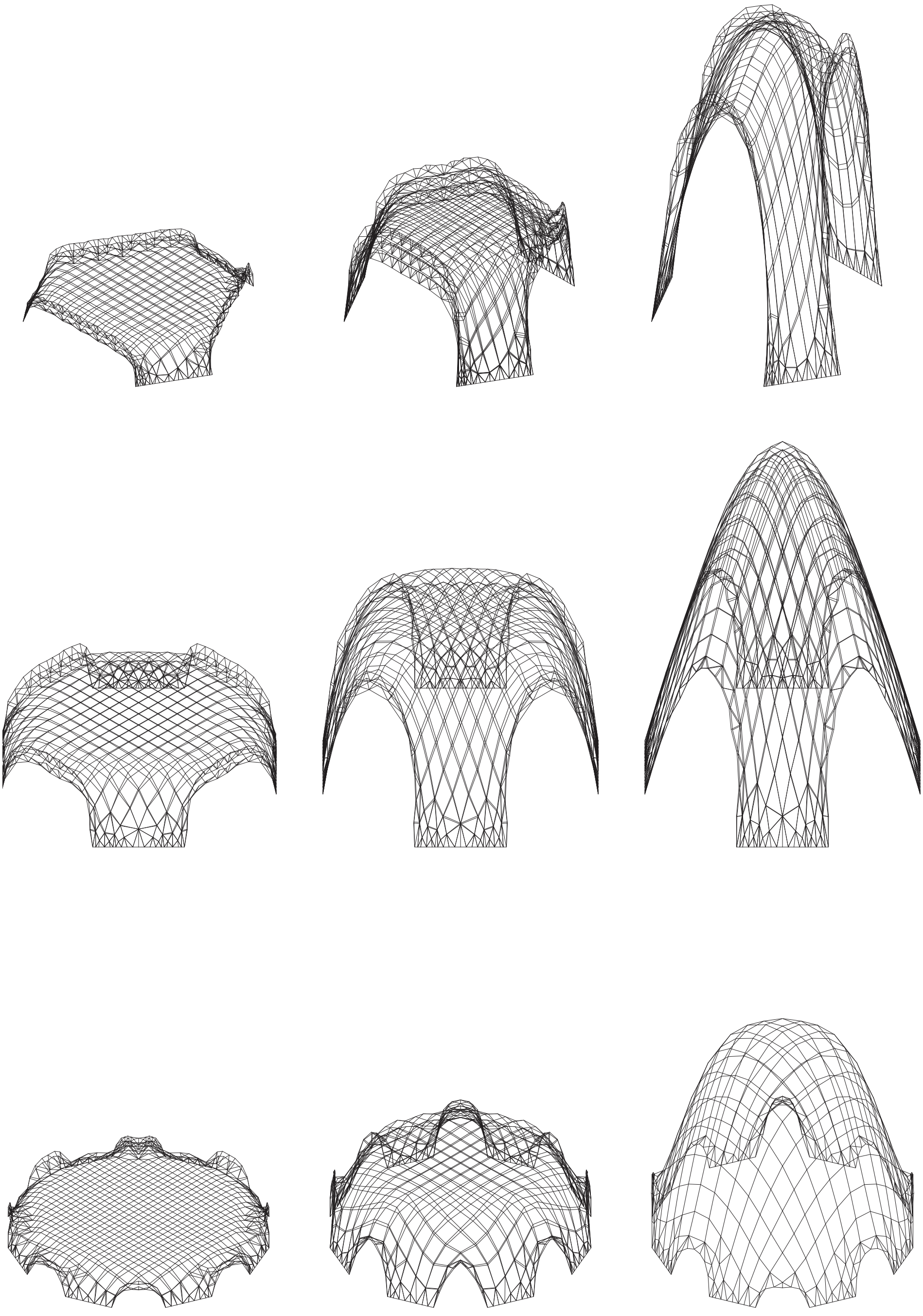
The definition also allows the designer to vary the distribution and strength of the gravitational forces, as well as the inner resistance of the meshes and arches. The interaction of the mesh, anchors, resistance and forces are the defining parameters of the shape, instead of user-defined geometry.

The result is a series of base pavilions, similar to canopies or tents. It is also noteworthy that each of the pavilions are structurally sound, thanks to the form-finding process that created them, secured an equilibrium between gravitational forces and material resistance of the structure.

The similarity of these results and the original Porte Monumentale is only typological; even though the geometries like arches, domes and their subdivisions may appear familiar, the Kangaroo defined morphologies are distinctively anti-catenary, when Binet's design were derived from circumference arcs.



17-19-1 Gravity-influenced mesh organizations. Porte Monumentale Mesh 01,02,03,04,05,06.



17-19-2 Gravity-influenced mesh organizations. Porte Monumentale Meshes.

20–PORTE MONUMENTALE PANELLING

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *Porte Monumentale by Rene Binet, Exhibition Universelle a Paris 1900*

DESCRIPTION:

The purpose of this experiment is to analyze experimental 19th century projects, understanding both the construction technologies and the design strategies that enabled them. The case of international pavilions is an excellent reference point precisely because they exploited new construction techniques and materials in order to achieve new architectural forms while pursuing to develop new architectural expression.

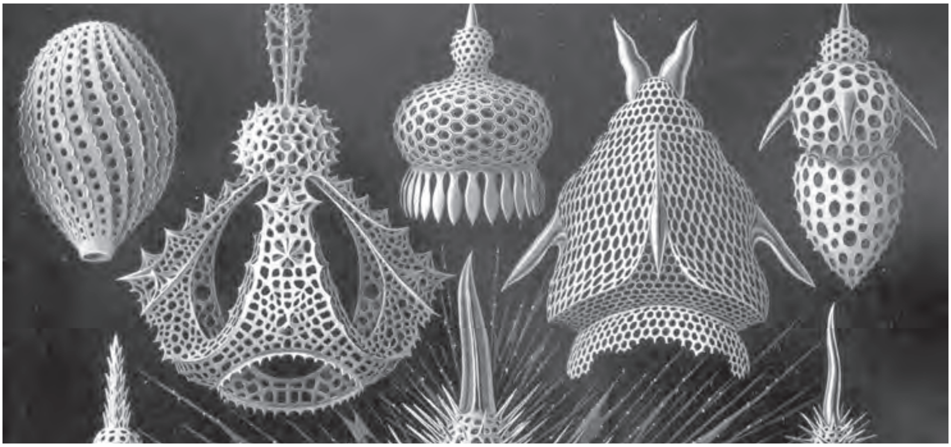
The Porte Monumentale is a prime example on this category, even though it is strictly not a pavilion but an entrance portal, ticket office and hall. The key objective of the experiment is to understand the underlying topology of the portal, that is, the organizational structure that governs the relationships between each part of the building.

Similar to other experiments, the first step is to recognize the Porte´s topological organization and the elements that compose it, such as structural arches, dome, pendentives, drums, lanterns and columns. The second is to parametrize its parts, that is, to translate them into an open, flexible model on which the relationships between elements remain more or less permanent while other parameters as dimensions, subdivisions or paneling characteristics can be altered.

Finally, the last step is to create a series of variations using the same parametric procedure, thus creating a 'family' of portals, a number of projects that share topological characteristics with the predecessor while differentiating themselves geometrically. The number of variations is almost infinite since the complexity of the model relies on a large number of parameters and values to be altered; the number of sides or access arches, diameter of the main dome, dimensions of columns, type and size of paneling elements and many others.

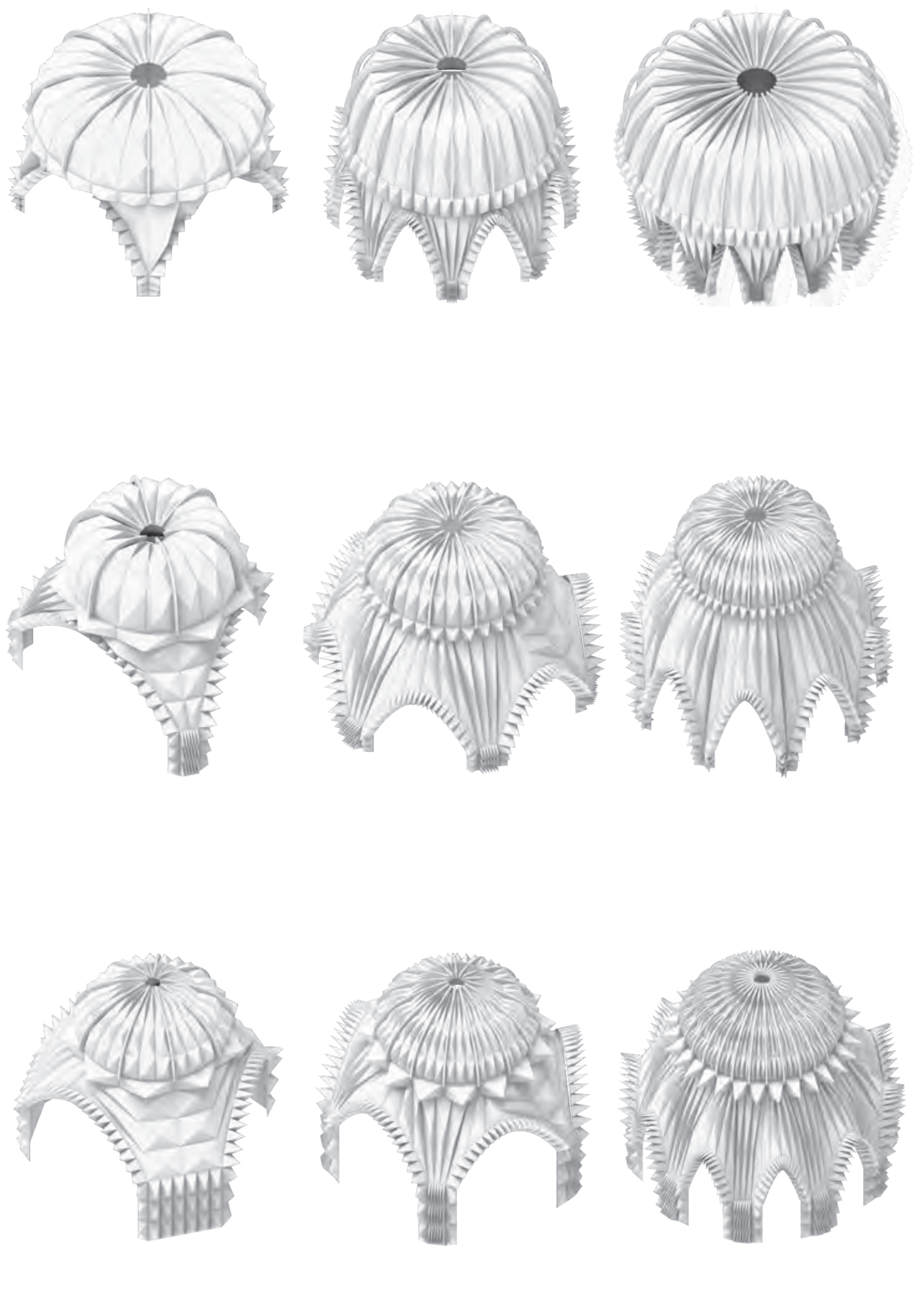
Each variation is by itself an instance of the open system that enabled the Porte Monumentale. In fact, the experiment is an illustration of such systemic approach to construction and design, while remaining 'classical' in their final materialization. Naturally, while some characteristics cannot be distorted or misrepresented like in previous experiments, others like radial symmetry will remain invariable. The succession and relations between elements are also fixed, acting as a 'frame' to be filled with 'flexible' geometry.

This experiment intends to emulate and update a 19th design strategy, differentiating the building´s topology and structure from its ornamental parts. In the case of the Porte Monumentale, several critics bashed its profuse stucco ornamentation precisely because of its ´infill´ quality. Quite on the contrary, however, repetitive and differentiated decoration was proof of the building´s flexible articulation between support and ornamentation, and the freedom gained thanks to the construction and design innovations.

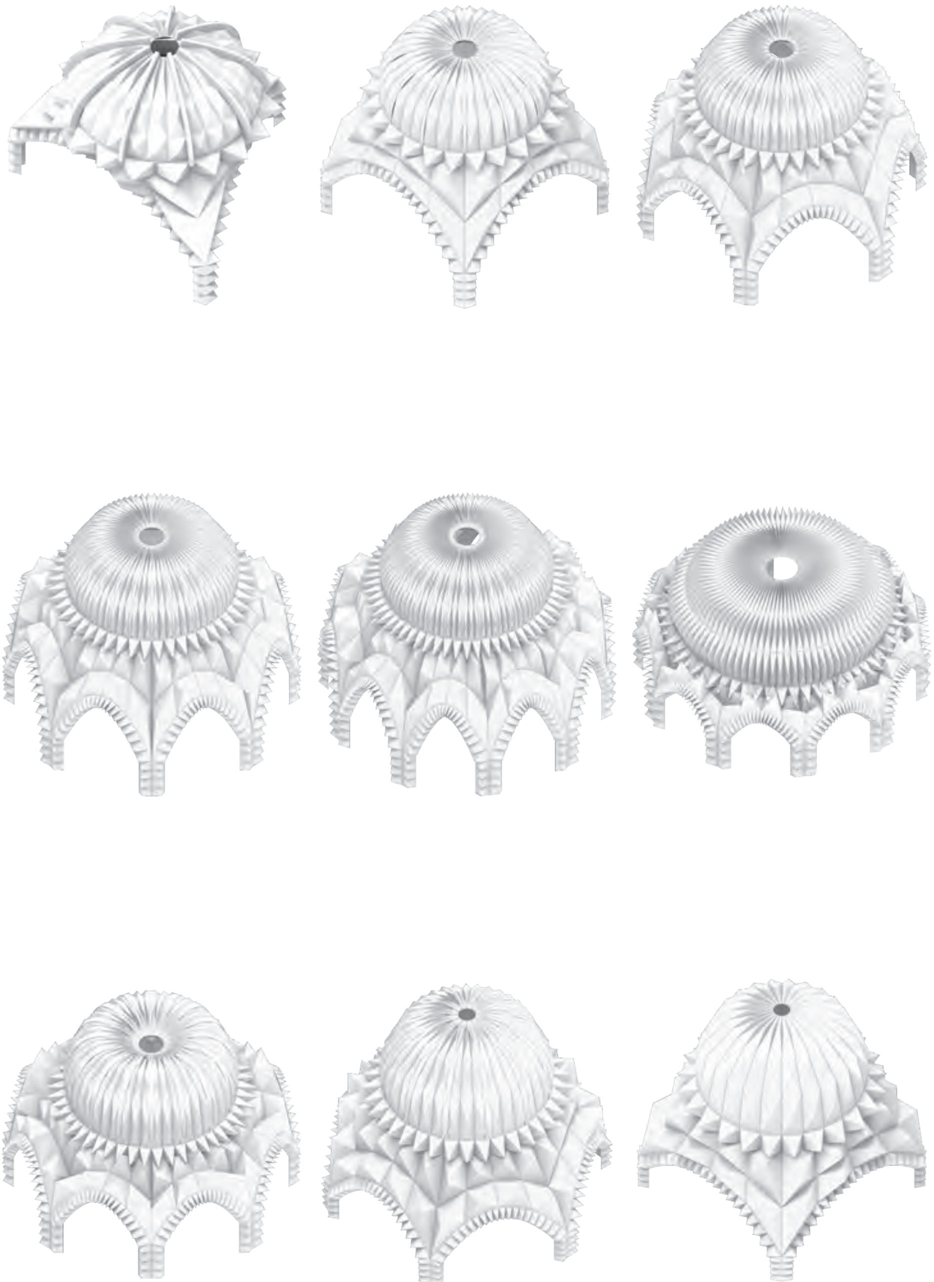


17-20-1 Porte Monumentale by R. Binet (1900)
17-20-2 Cyrtoidea drawings by E. Haeckel in ´Kunstformen der Natur´

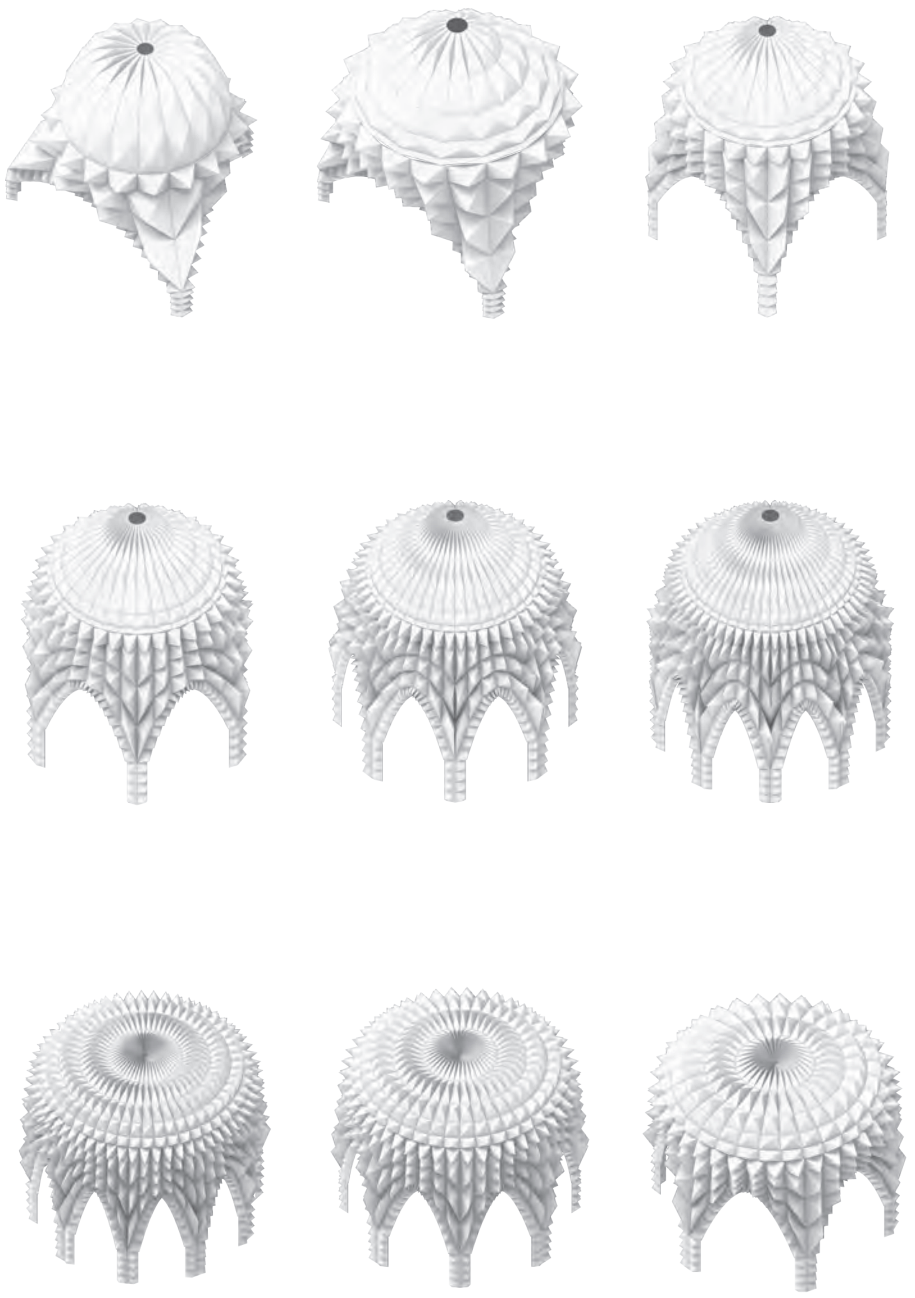
17-20-3 Parametric variations of the Porte Monumentale under a constant topologycal organization.



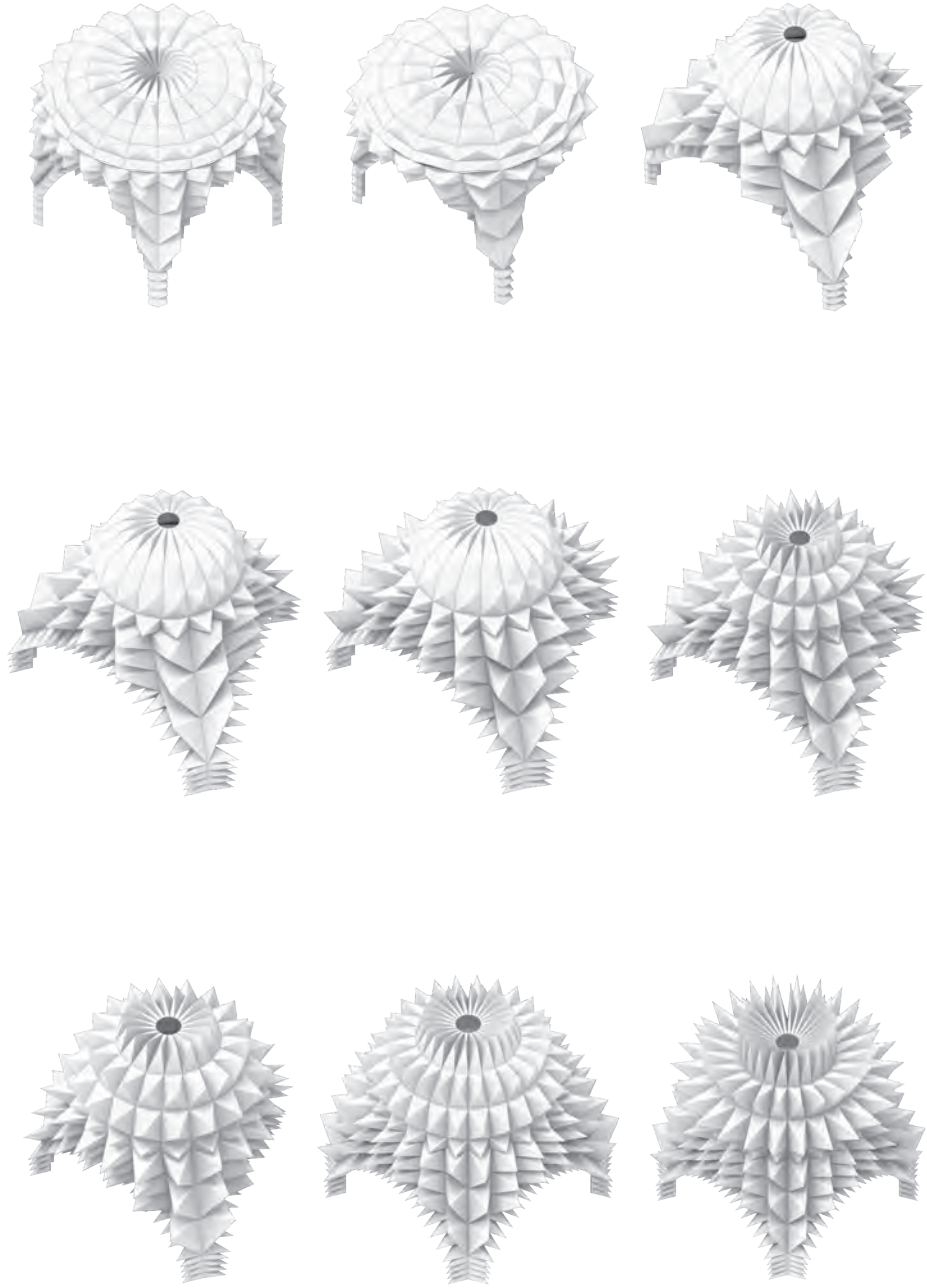
17-20-4 Parametric variations of the Porte Monumentale under a constant topologycal organization.



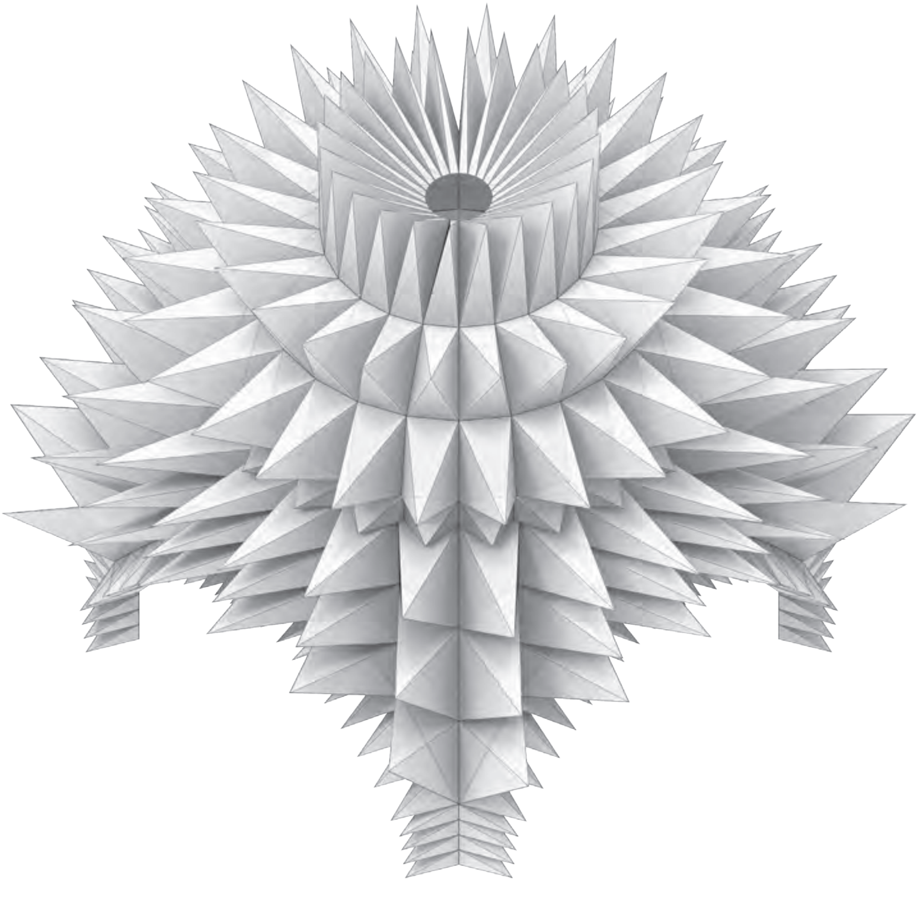
17-20-5 Parametric variations of the Porte Monumentale under a constant topologycal organization.



17-20-6 Parametric variations of the Porte Monumentale under a constant topologycal organization.



17-20-7 Parametric variations of the Porte Monumentale under a constant topologycal organization.



17-20-8 Parametric variations of the Porte Monumentale under a constant topologycal organization.

21 –ARGENTINEAN PAVILION VARIATIONS

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *Argentinean pavilion by Albert Ballu, Exhibition Universelle a Paris 1889*

DESCRIPTION:

The purpose of this experiment is to analyze experimental 19th century projects, understanding both the construction technologies and the design strategies that enabled them. The case of international pavilions is an excellent reference point precisely because they exploited new construction techniques and materials in order to achieve new architectural forms while pursuing to develop new architectural expression.

The Argentinean Pavilion from the universal Exhibition in Paris form 1889 emerges as a remarkable instance of these topics. Similar to the Porte Monumentale experiments, the goal of this exercise is to analyze the internal mechanisms control form, material and structure, while articulating each individual component of the pavilion.

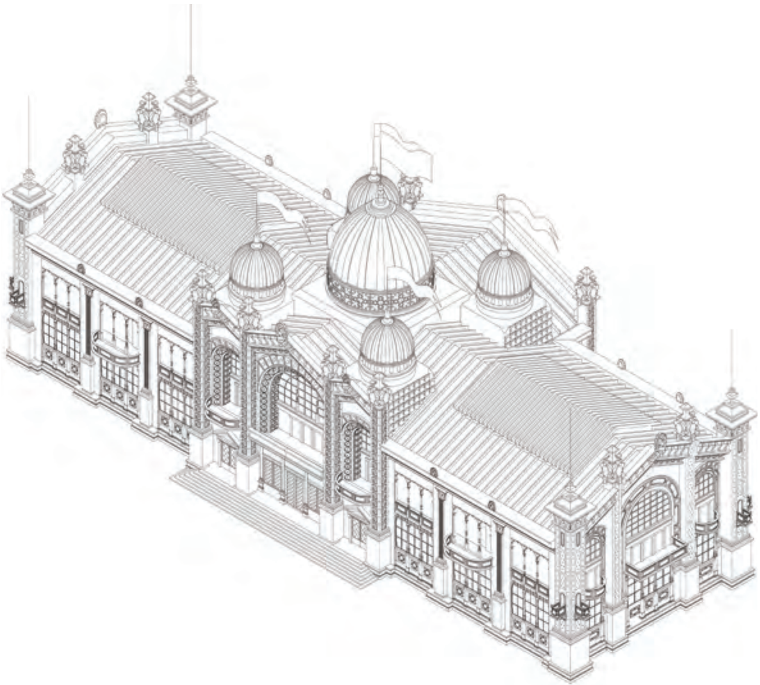
The first task of this exercise, similar to the case of the Porte Monumentale, is to distinguish its topological organization and the elements that compose the pavilion. This task is of relative relevance, since the formal complexity achieved thanks to the innovative building techniques from the late 19th century provided evidence of an unseen flexibility and freedom.

The capacity of subdividing a building form the structure, paneling, isolation and ornamentation demonstrated the expressive capabilities of such technologies. Elements such as domes, verandas, panels, arches and pendentives were documented on this stage, intending to separate them from one another, as well as to understand the relationships between them.

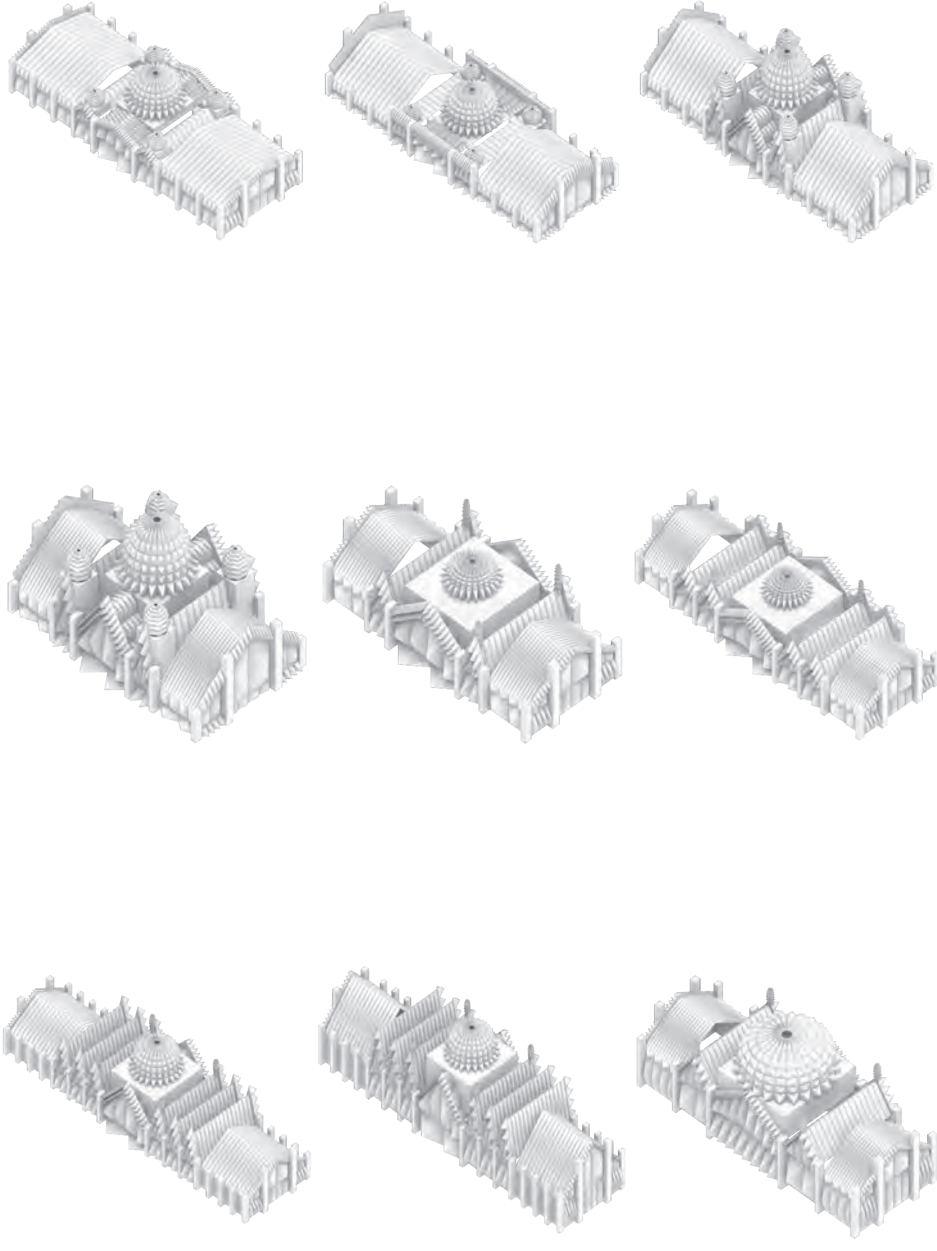
The second step of the process is to parametrize these elements and their relationships. This process of translation converts architectural or geometrical information into a flexible, open model, on which each element of the building is governed by a parameter, a function or a value. Similar to other parametric models, the underlying topology of the pavilion remains permanent, while dimensions, number of elements and other numerical information remains variable.

Finally, the last step is to create a series of pavilion variations using the previous parametric model. The result is a series of differentiated pavilions, but topologically identical. In comparison to the Porte Monumentale experiment, the geometrical variation seems to be of a lesser complexity, since the topology is more inflexible and can only grow in two dimensions.

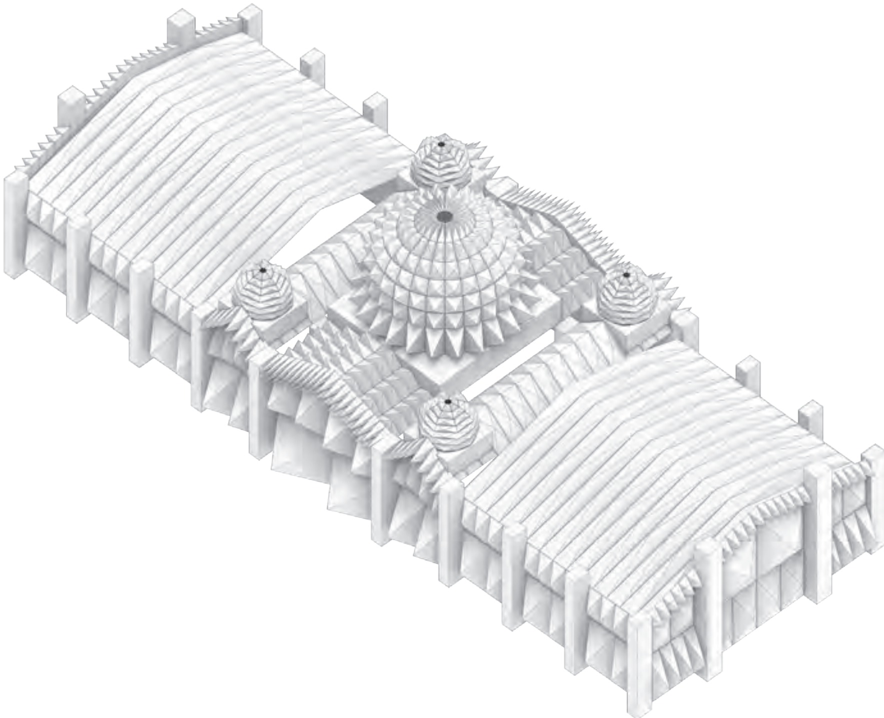
Thus, the family of pavilions explores other aspects of the internal organization and variability procedures, like proportions, subdivision surfaces and paneling. The last two are of relative importance in contemporary architecture, since the creation and panelization of complex surfaces has become a core topic in digital design research. The possibility of guided variation thanks to the combination of digital fabrication tools has rendered this subject pertinent.



17-21-1 Argentinean Pavilion by A. Ballu (Paris, Buenos Aires, 1889)



17-21-2 Argentinean Pavilion Variations.



17-21-3 Argentinean Pavilion Variation 01.

22 – *MULTI MATERIAL TRUSSES*

SOFTWARE: *Rhinoceros, per, Karamba*

REFERENCES: *Berliner Borse by Friedrich Hitzig*

DESCRIPTION:

19th century construction techniques coupled with an unprejudiced attitude towards classical building aesthetics brought up a series of interesting architectural experiments, manifesting the complex relationships between novel building technology, classical expression and innovative spatial effects.

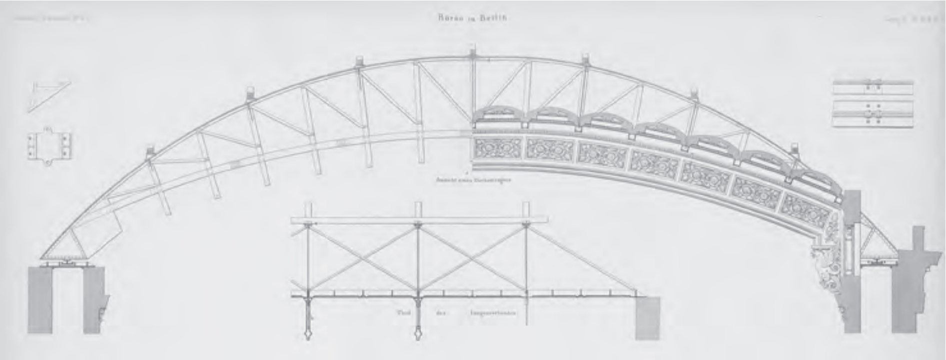
The roof vault of the Berliner Borse fits perfectly on this description; a combination of a (hidden) steel structure and the ceramic ceiling achieving a stimulating spatial effect. The large, detailed ceramic tiles provide a continuous intricate surface unifying two separate spaces on the main trading floor, yet the rational truss-like structure remains hidden from the user.

This experiment deals with the formal and material parameters that govern such structures and the elements that compose them: a truss-like planar structure, a covering for the structure and a ceiling to fill in the spaces between them. It also allowed to parametrize each of the element's dimensions such as height, width and contact angles. Moreover, these elements can be further subdivided into smaller, regular pieces, for example, the truss structure is subdivided and subsequently, kingposts and cross-bracings are added.

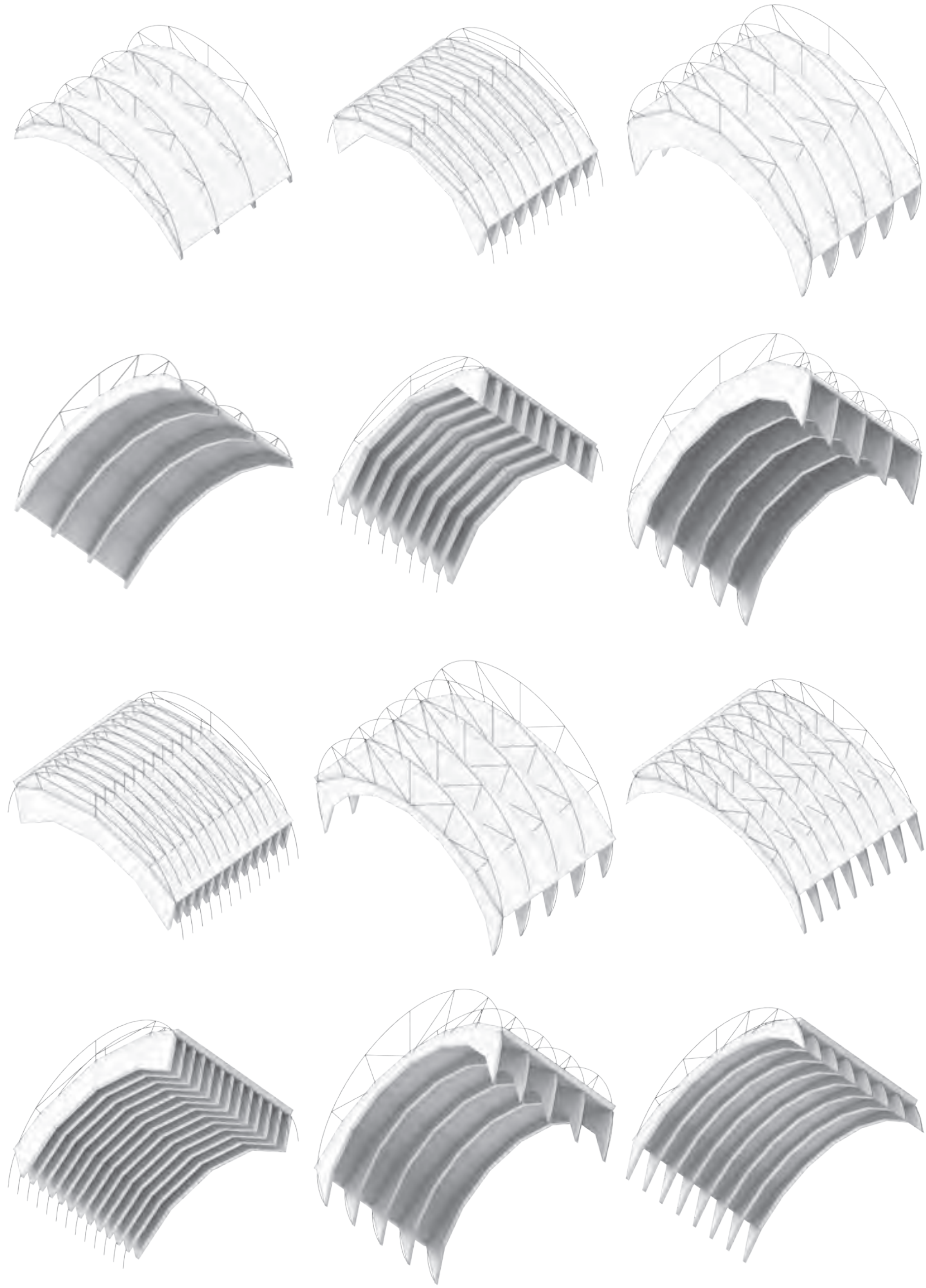
The structure's final form can be either manually defined by the author or to use form-finding techniques. A particular arch can be determined thanks to a series of sliders controlling its dimensions such as span, rise, springing, extrados and intrados. The form-finding method uses the Grasshopper Plugin Karamba by submitting structural forces such as gravitational loads, use load and wind in order to set them as defining parameters.

Likewise, the covering of the structure and the ceiling elements can be also subdivided further in order to be 'panelized'. Panelization is a key feature in parametric design process, allowing the author to place pre-designed elements into a series of simple volumes or 'placeholder' cage-like elements produced by each definition.

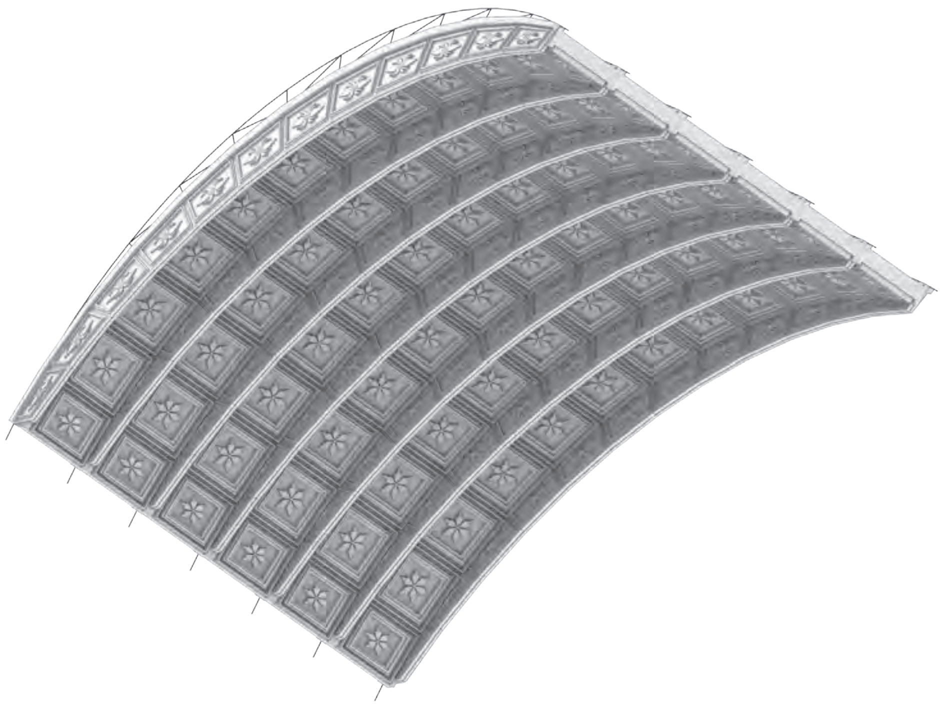
This experiment allows exploring the different spatial possibilities arisen from Hitzig's base design, tolerating different structural variants (arched structures, truss divisions) as well as several degrees of detail depending on the quantity and type of covering parts, comparable to the Borse's ceramic ceiling tiles.



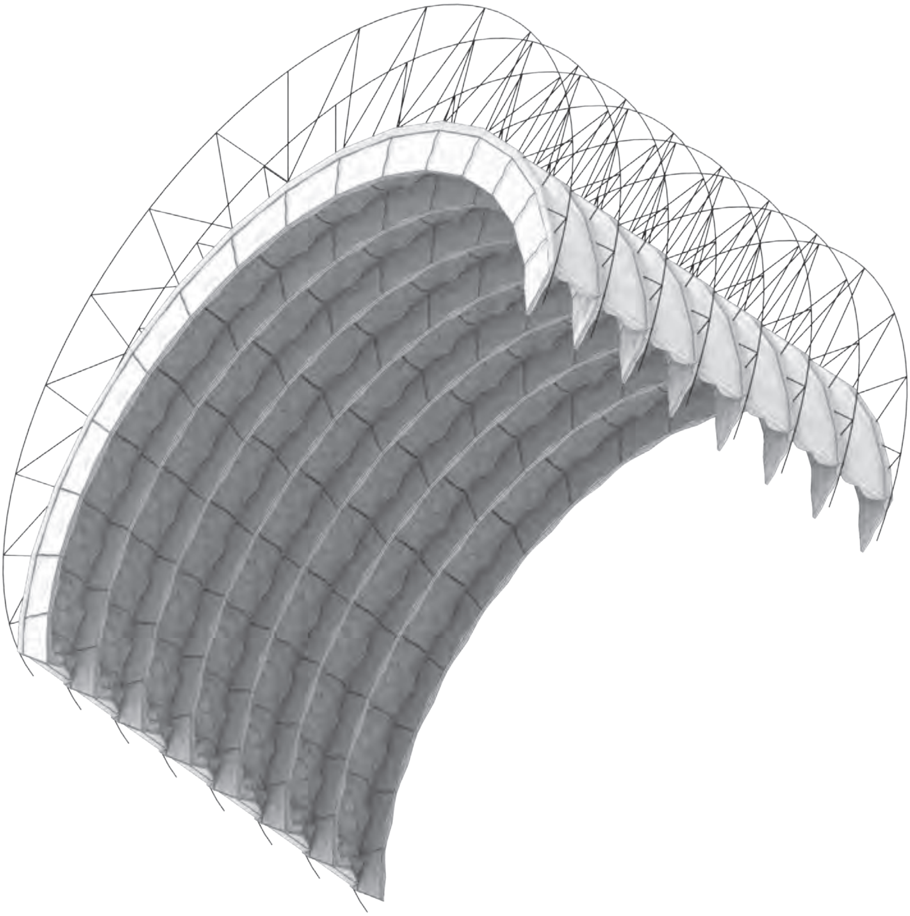
17-22-1 Iron and ceramic in Hitzig´s Börse ceiling from Berlin.



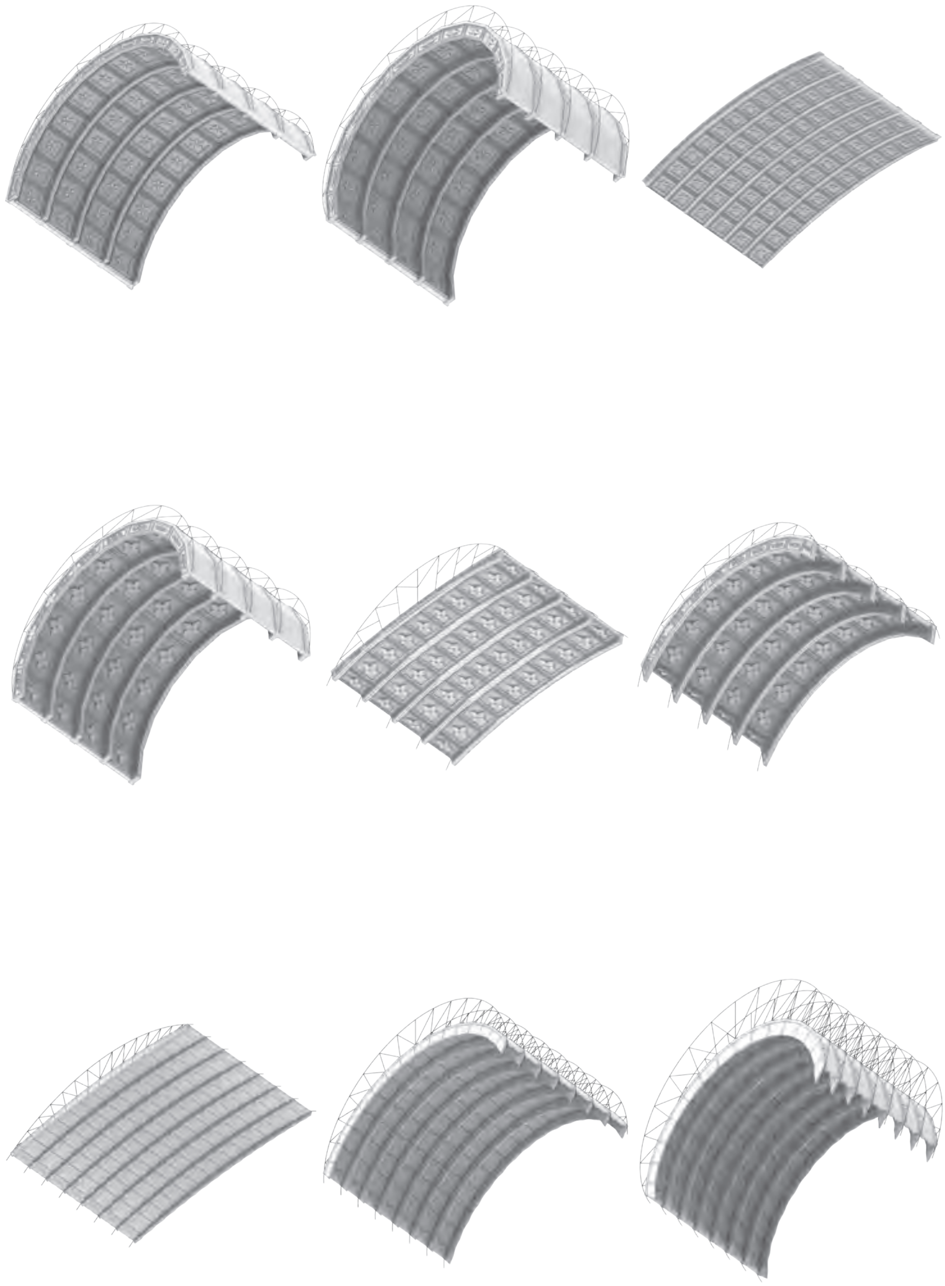
17-22-2 Support and supported. Multimaterial ceiling system 01.



17-22-3 Multimaterial ceiling system 01.



17-22-4 Multimaterial ceiling system 02.



17-22-5 Multimaterial ceiling system 03-11.

23 – SAYNER PROFILE MUTATIONS

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *Sayner Foundry by C. L. Althans*

DESCRIPTION:

This experiment explores the formal possibilities derived from the Sayner Foundry by Althans. As stated in the case study section, this building was selected because of its unique structural and formal characteristics. Being an early example in the use of iron structures in addition to the experimental character of Althans, the resulting structure is undoubtedly innovative and strange.

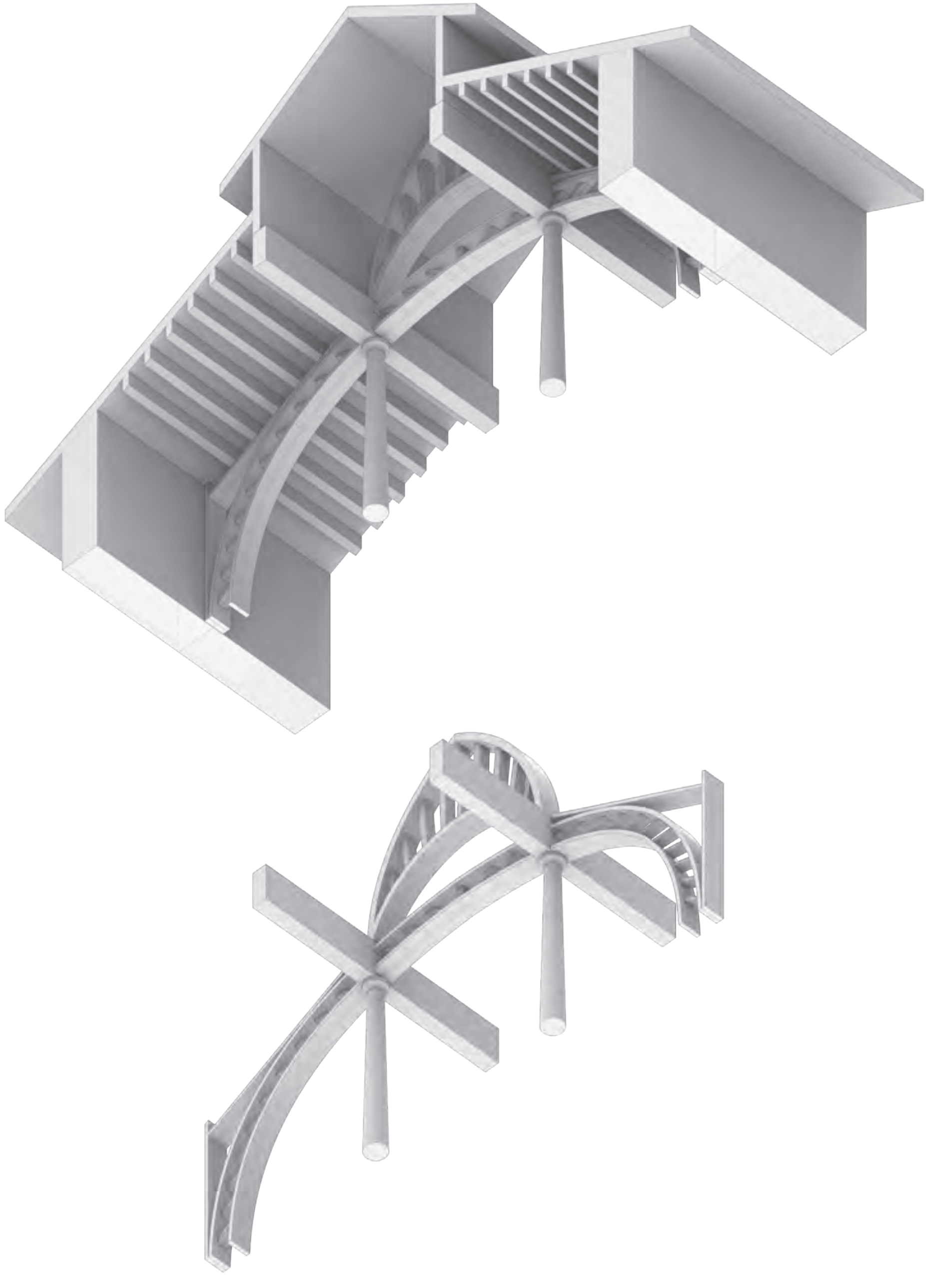
The building´s structure mimics a three-nave basilica, transept included, with the main furnace in place of the altar. The section of the foundry illustrates the hybrid character of the structure; a lower arch supported by the nave columns and a gothic arch on top of it bearing the clerestory. At the same time, the main nave columns carry a series of cranes and rails in order to assist the foundry´s activity. Althans certainly intended to use this building as a testing ground not only for the novel material but also as a foreshadowing of its ambiguous applications in architecture.

The exercise investigates the spatial and aesthetic opportunities in the manipulation of Althans work. The parametric definition produces variation within the typological framework of the foundry; dimensions of the structural arches, walls, columns and roofs can be altered yet the relationships between them remain stable.

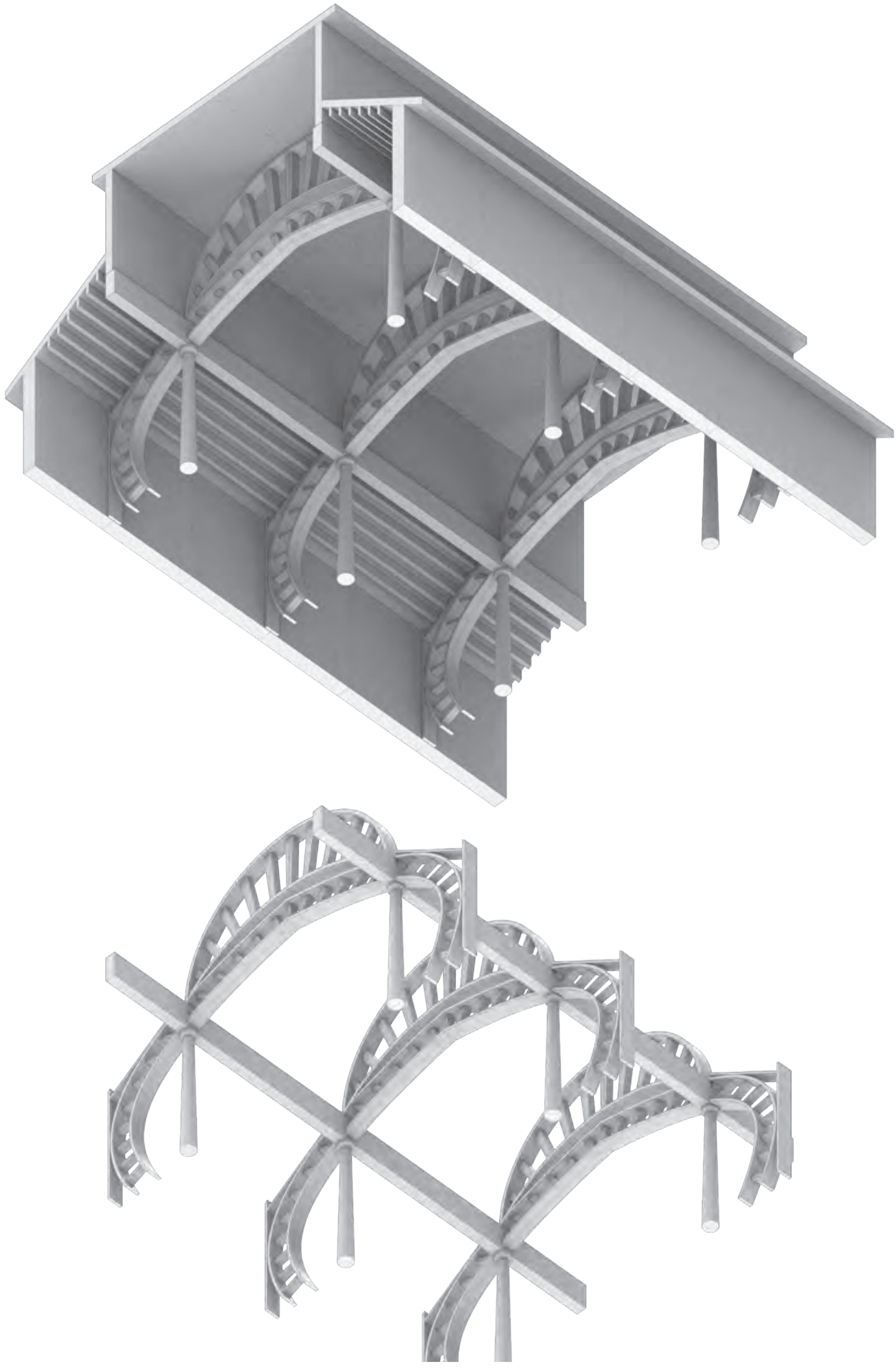
The possible variations produce interesting spatial and typological effects; some compositions resemble gothic proportions, while others are closer to Hallenkirchen or even industrial warehouses by modifying the relationships between the main and the lateral naves.

Redundancy is also a key feature in Althan´s structure. Part because of his devotion to iron, part to the lack of ready-made calculation techniques, the Sayner foundry had double or sometimes triple structural redundancies regarding bracing against lateral loads, traceries and load-bearing panels.

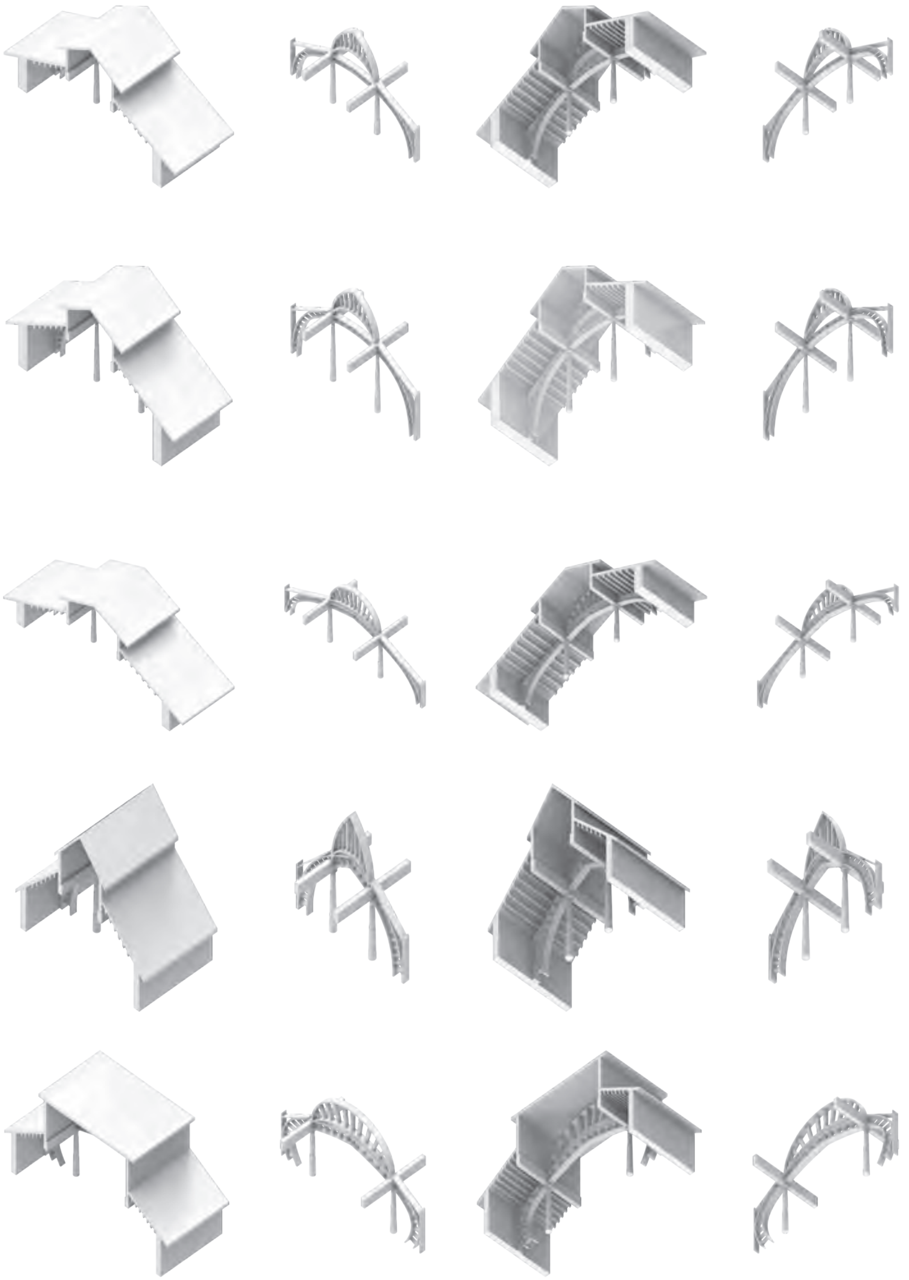
The experiment illustrates the flexibility and freedom obtained from the exploitation of a hybrid, complex and uncommon iron structure; a new aesthetic, spatial and typological possibilities are available when structural innovation and non-classical compositions are set to play.



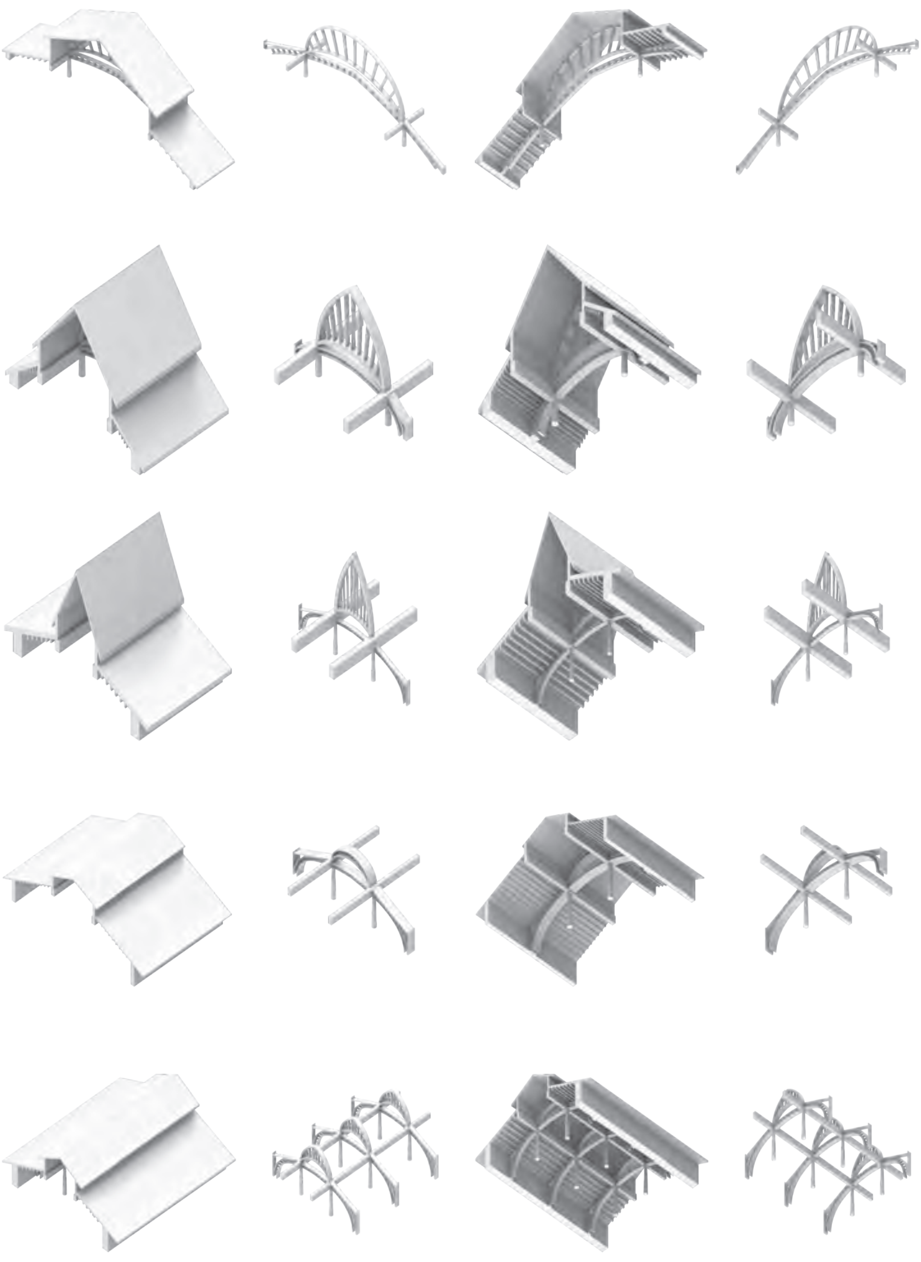
17-23-1 Sayner Hutte Variations. Redundant structure and hybrid typology.



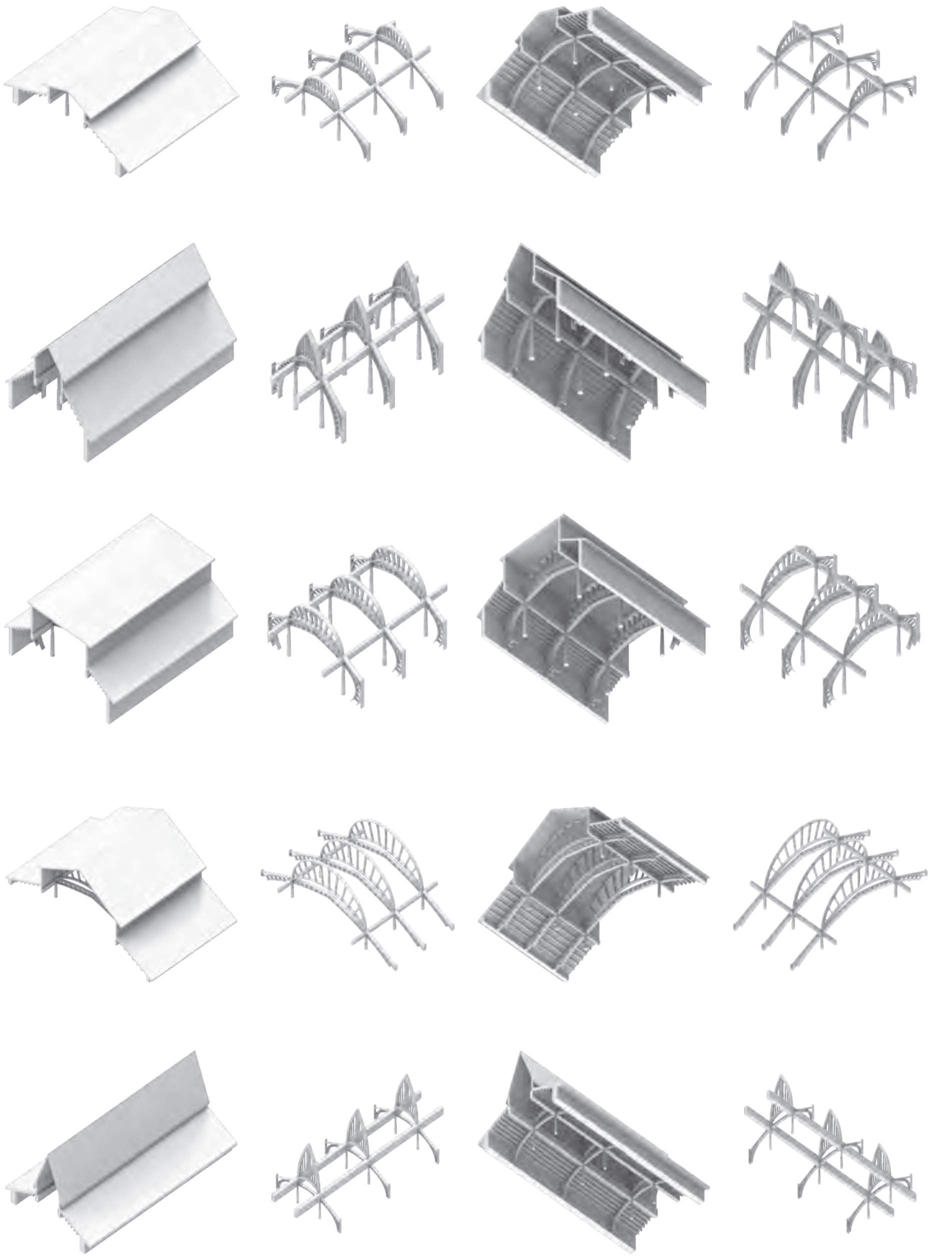
17-23-2 Sayner Hutte Variations. Redundant structure and hybrid typology.



17-23-3 Sayner Hutte Variation Catalogue.



17-23-4 Sayner Hutte Variation Catalogue.



17-23-5 Sayner Hutte Variation Catalogue.

CHAPTER 18

- *Composition experiments II*

24– ROOM GENERATOR

SOFTWARE: *Rhinoceros, Grasshopper, Galapagos*

REFERENCES: *French Chateaus, Chateau de Cheverny, Chateau de Maisons Lafitte, Chateau de Meudon*

DESCRIPTION:

The study of spatial types from 19th century buildings derives from the intention to understand and analyze common typological parameters regarding space, geometry and materials. Before the widespread use of the corridor in the 1800s, the variety deriving from the combination of rooms and their geometrical characteristics provided an idea of the formal and spatial freedom typically found in palaces and chateaus.

A series of experiments were designed to study these spaces in order to recognize the design strategies supporting them and then to replicate them under a controlled environment. In general terms, the parametric definition of the floor plan generators distinguish a number of elements composing each design, such as walls, pilasters, niches and columns.

There are several experiments on this stage; a 'circular room generator' (derived from the study of circular temples) and a 'rectangular room generator' both operating by parametrizing spatial dimensions, walls and columns. A later experiment, the 'Palace composer' creates chateau-like compositions by subdividing spaces with similar elements and parameters, and finally, a 'Basilica generator' essentially combining previously defined rooms within the limits of the typology.

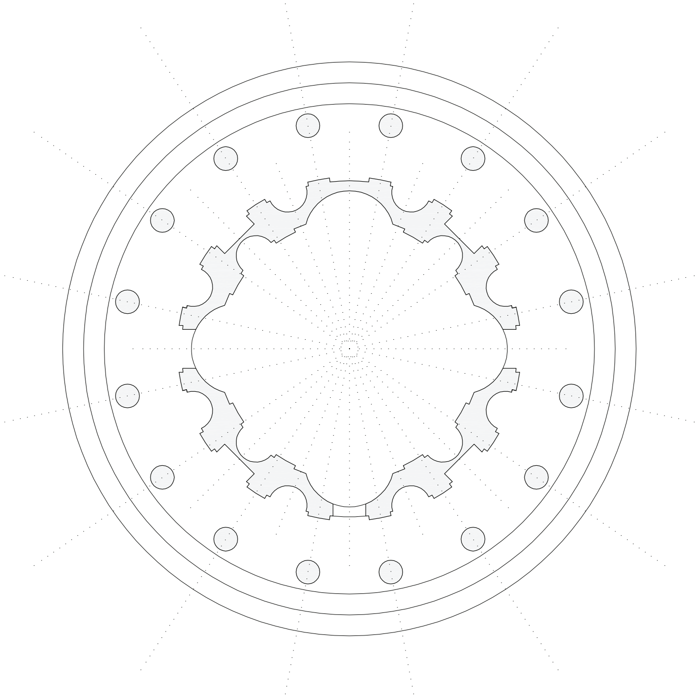
The experiment began with the study of dozens of central floor plans, from small temples to churches or pavilions. The analysis of the floor plans was the base for this set of experiments and it is described in more detail in a paper by the author .

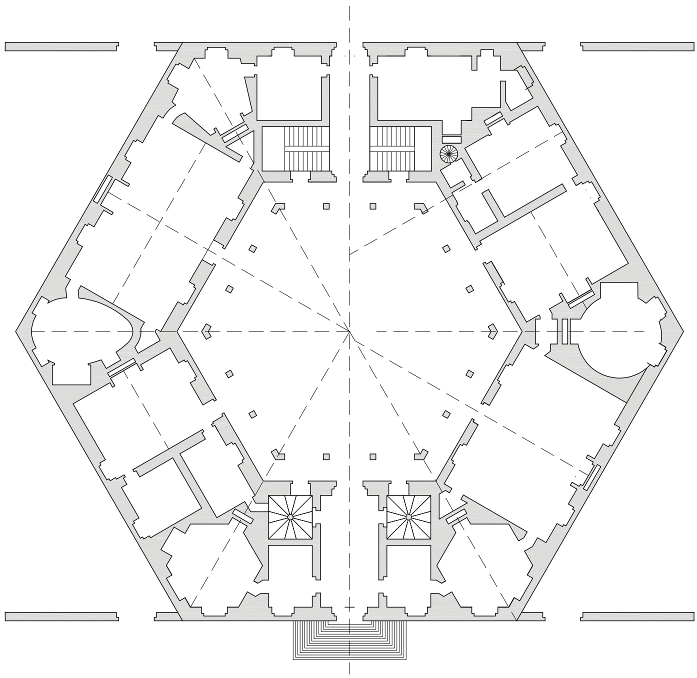
The 'circular room generator' composes central floorplans by parametrizing a numerous values controlling each architectural element, for example, the general dimensions, number of sides (in case of a polygonal space), niches, subniches, and columns. Likewise, each of these elements can be further defined by altering their dimensions and/or quantity, adding yet another layer of complexity.

The 'rectangular room generator' operates in a similar manner, with the addition of windows and door passages, defining complex shaped columns and pilasters, isolated from one another. The results from this experiment are comparable to 18th century chateau-like spaces, communicating to each other via central doors.

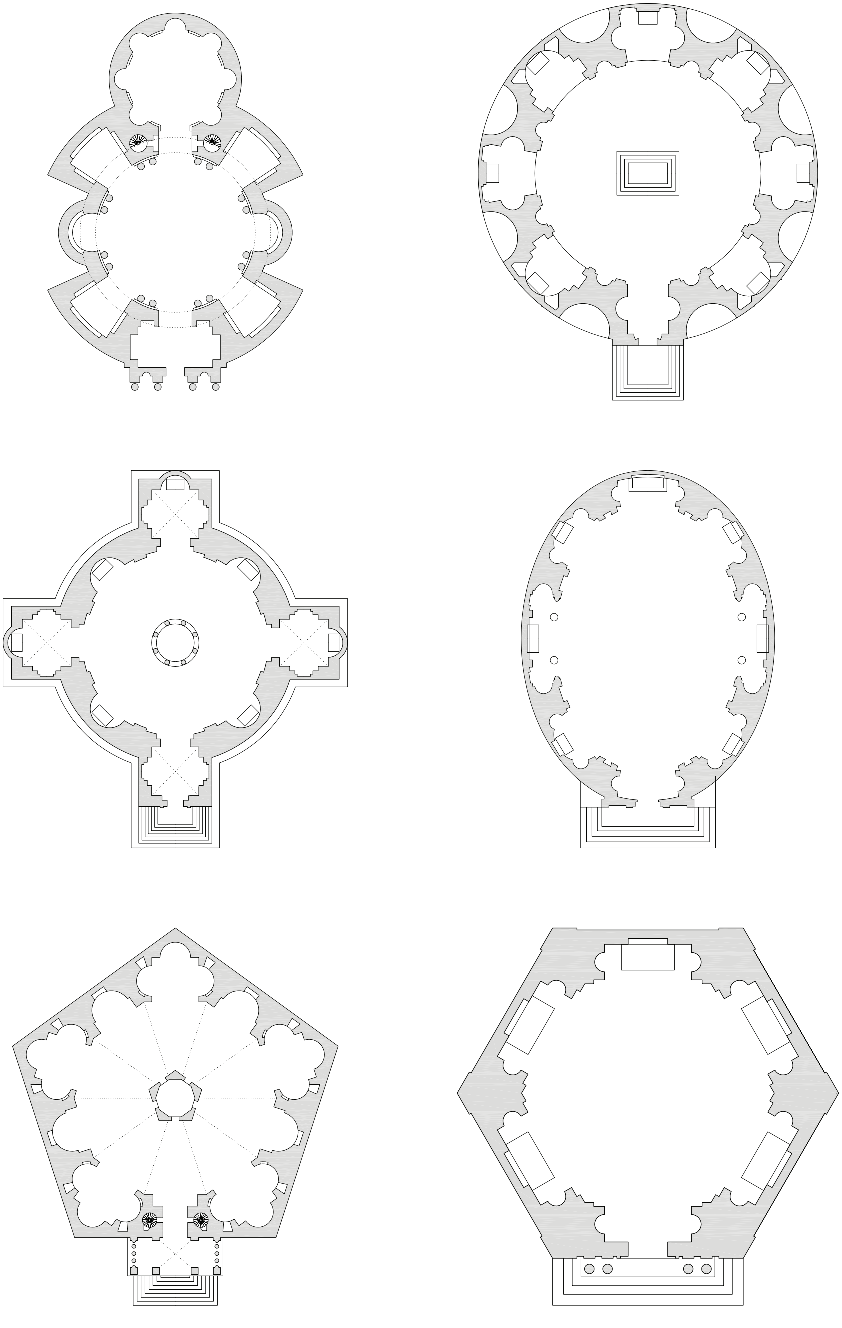
It is also worth to mention that the same algorithms can be used in order to produce random results, as a kind of chaotic machine. The procedure is similar to a genetic algorithm, except that there is no ´fitness function´ and therefore, the selected criteria should be unreachable, forcing the algorithm to run indefinitely.

Whether it is user-controlled or fully automated, the potential of this floor plan generator is of great importance for this research; not only because it defines geometrical and mathematical rules behind floor plan design also because its potential for architectural exploration. This experiment was also the base for further explorations in floor plan generators, beginning from simple, single space configurations to more complex compositions.

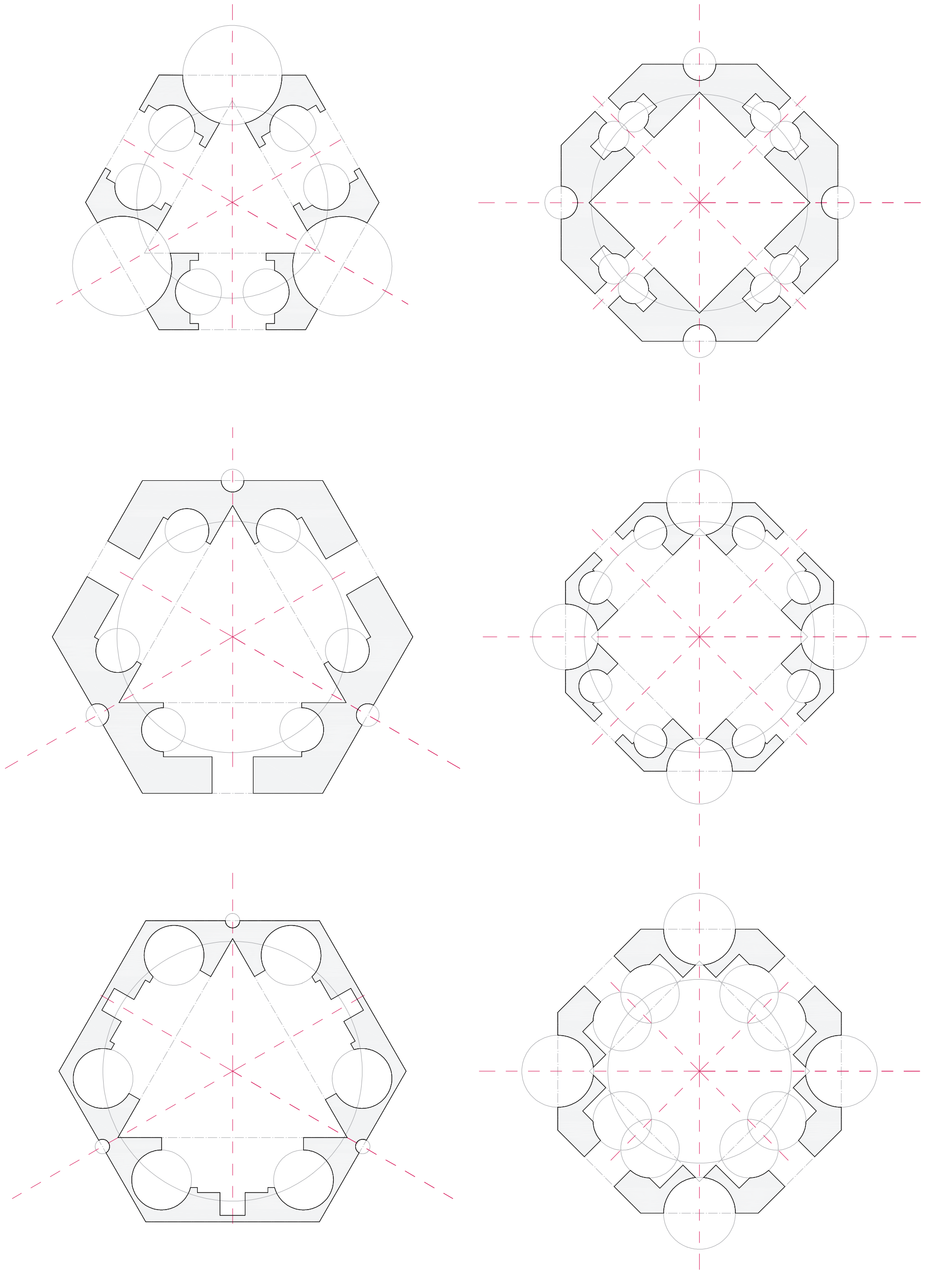




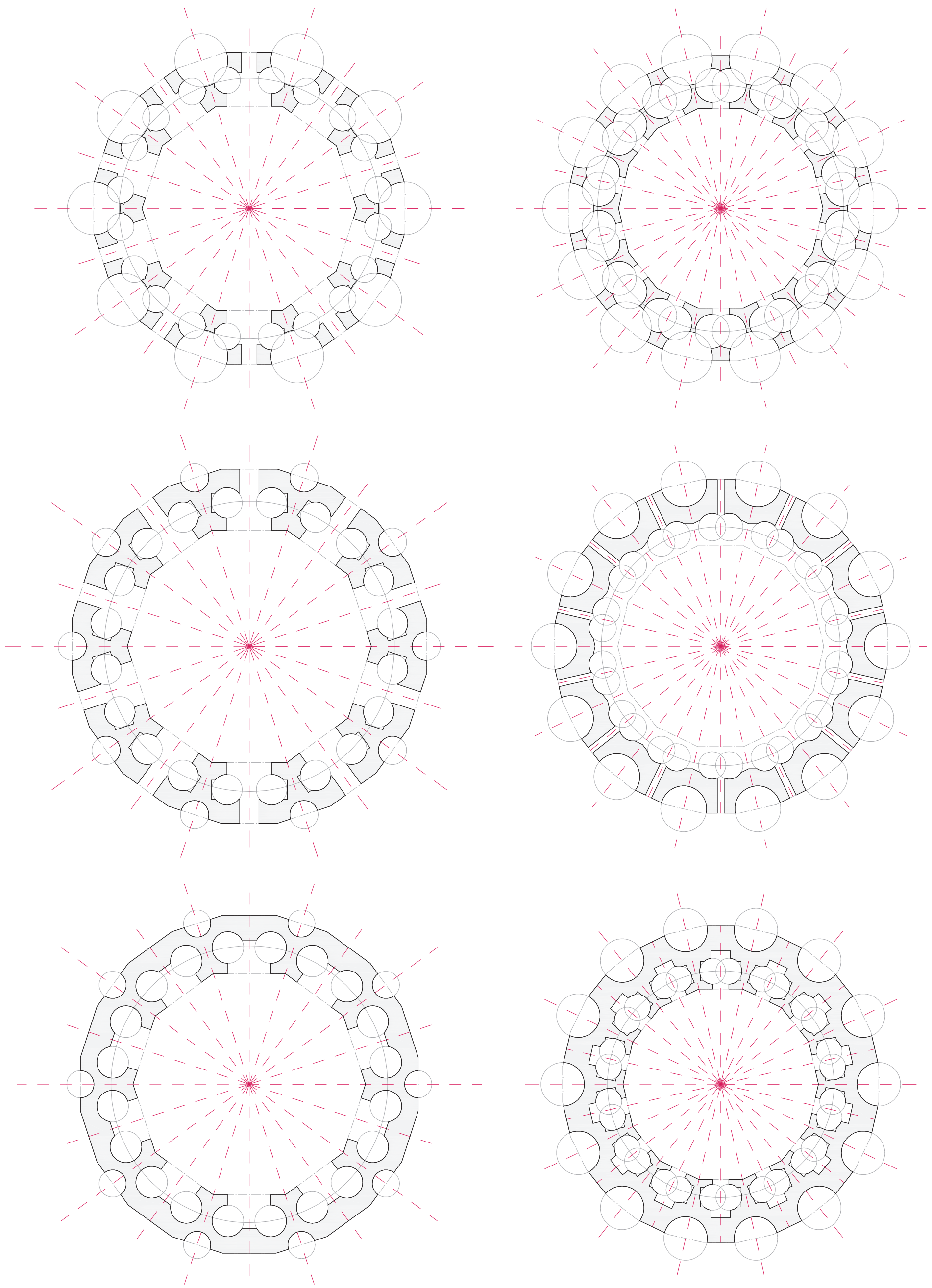
18-24-1 Tempietto in San Pietro in Montorio by Bramante (1502)
18-24-2 House for a rich man by S. Serlio (1611)



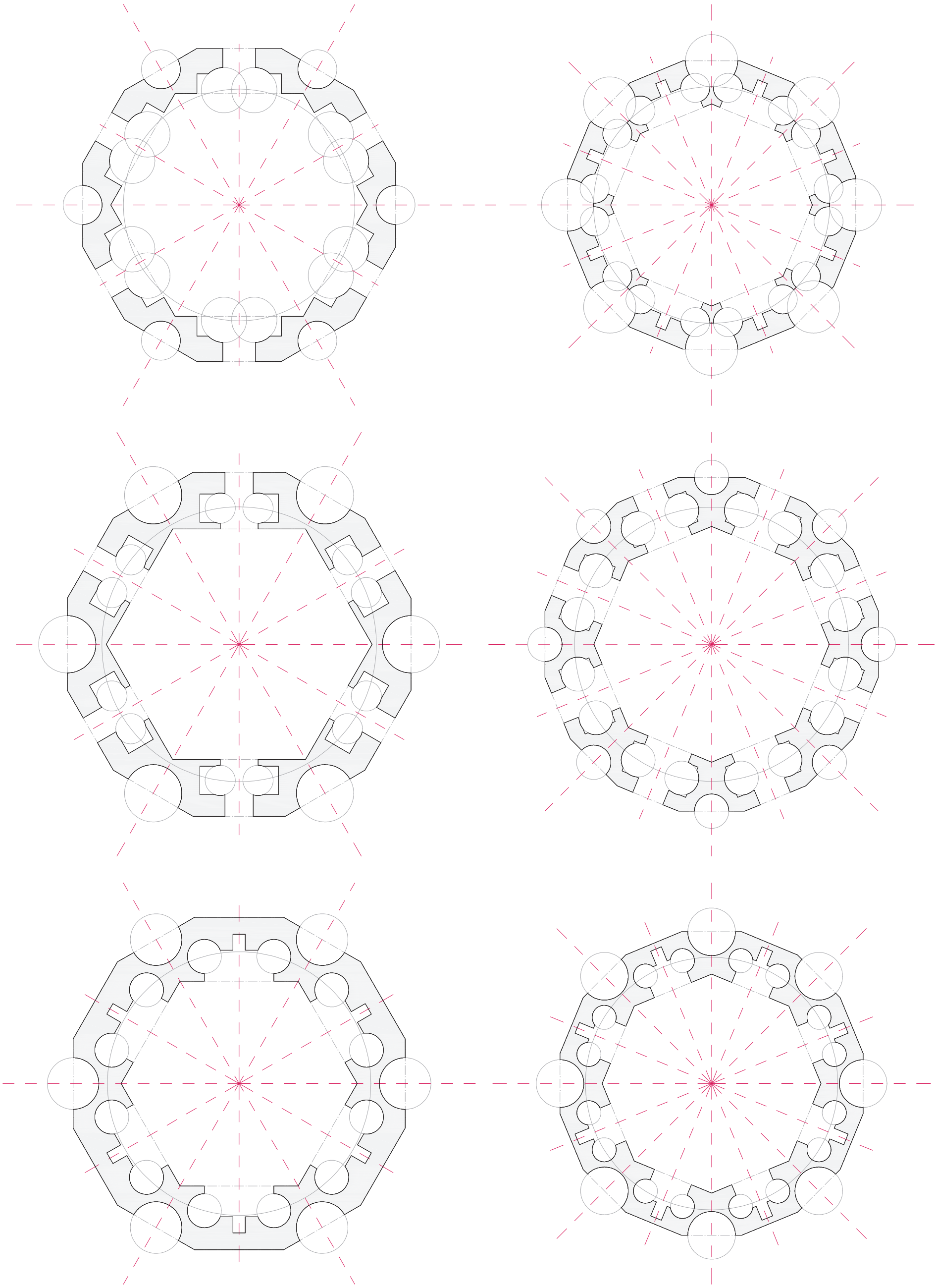
18-24-3 Temples by S.Serlio (1611)



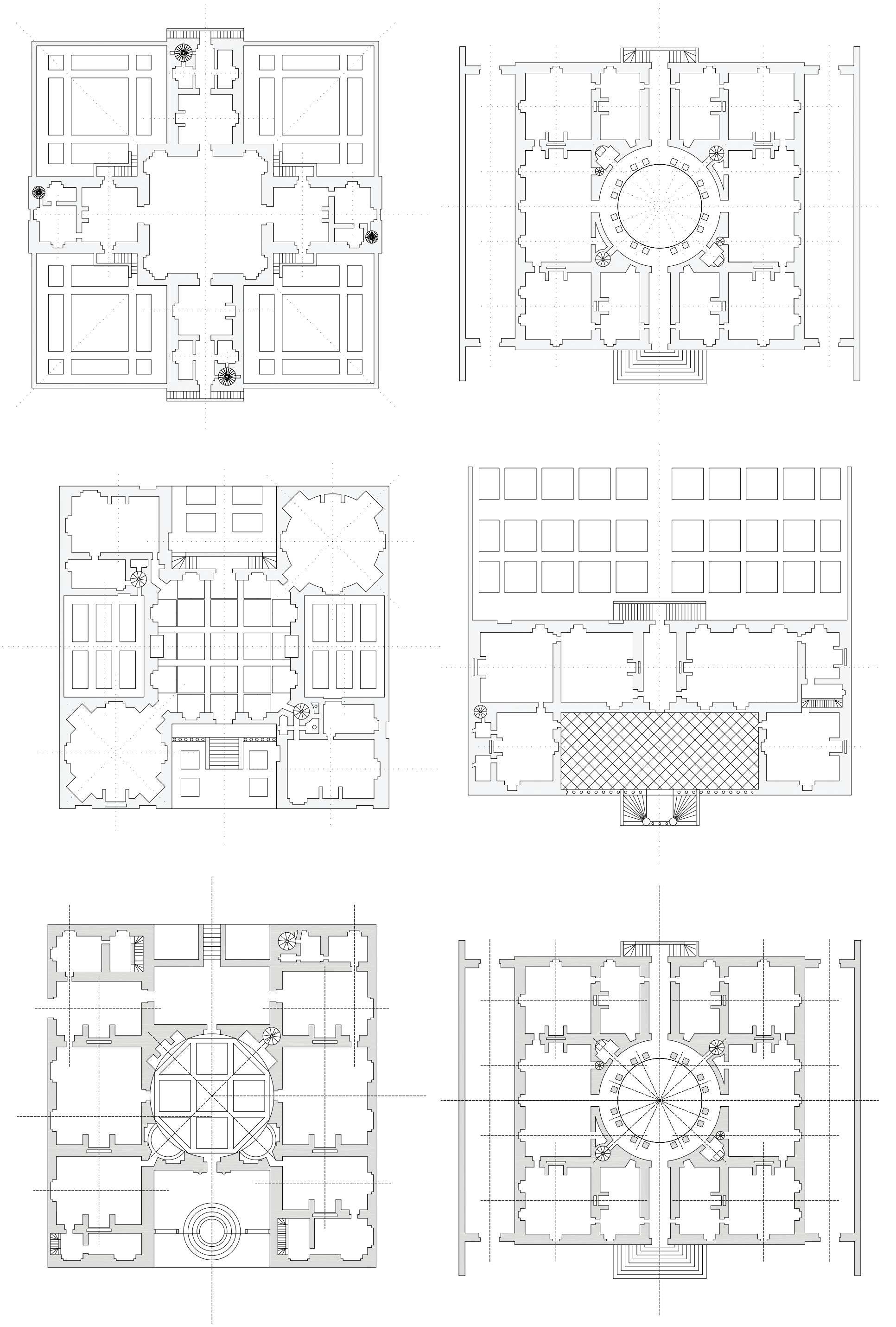
18-24-4 Computer generated central floorplans. Circular Room Generator 01.



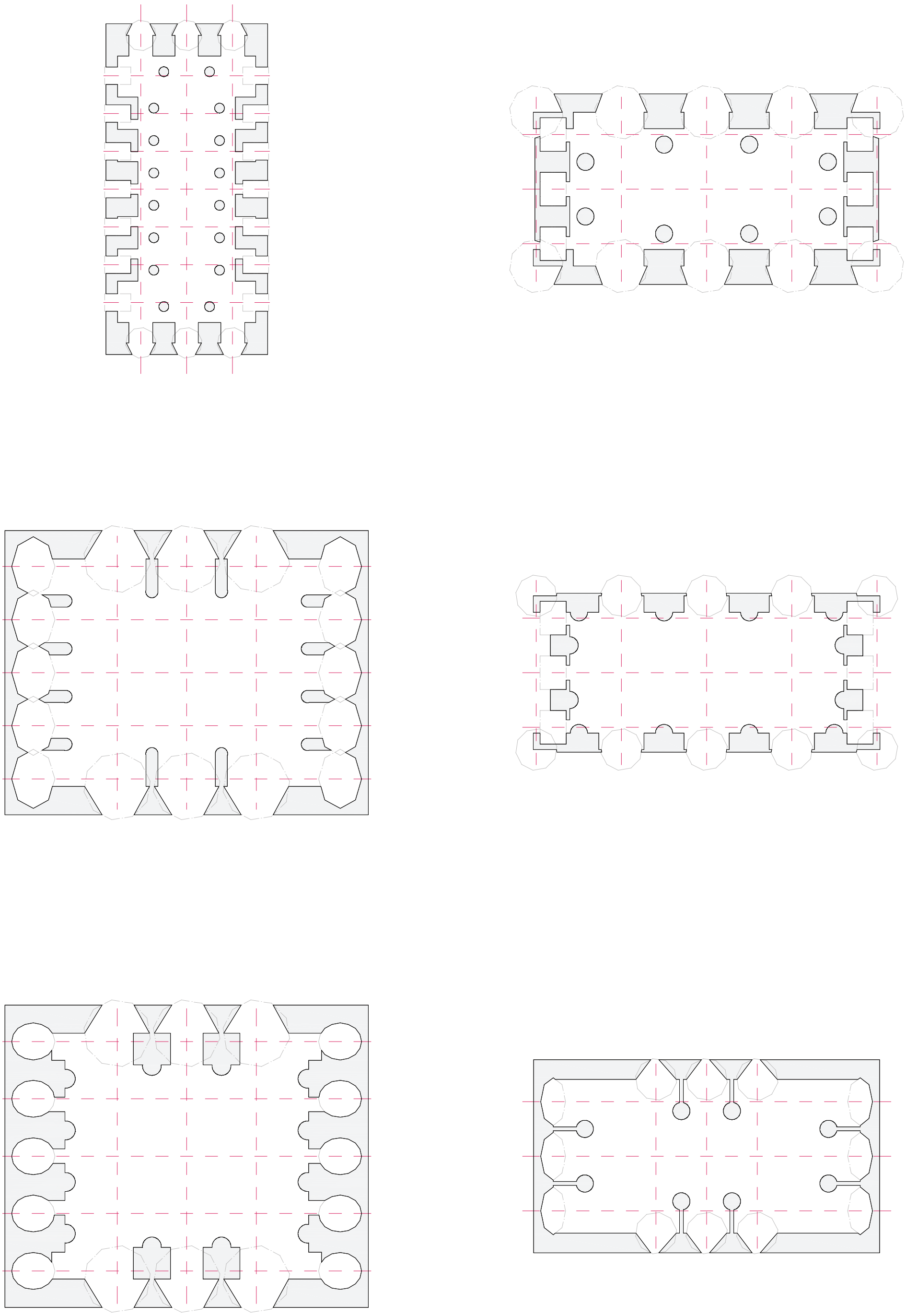
18-24-5 Computer generated central floorplans. Circular Room Generator 02.



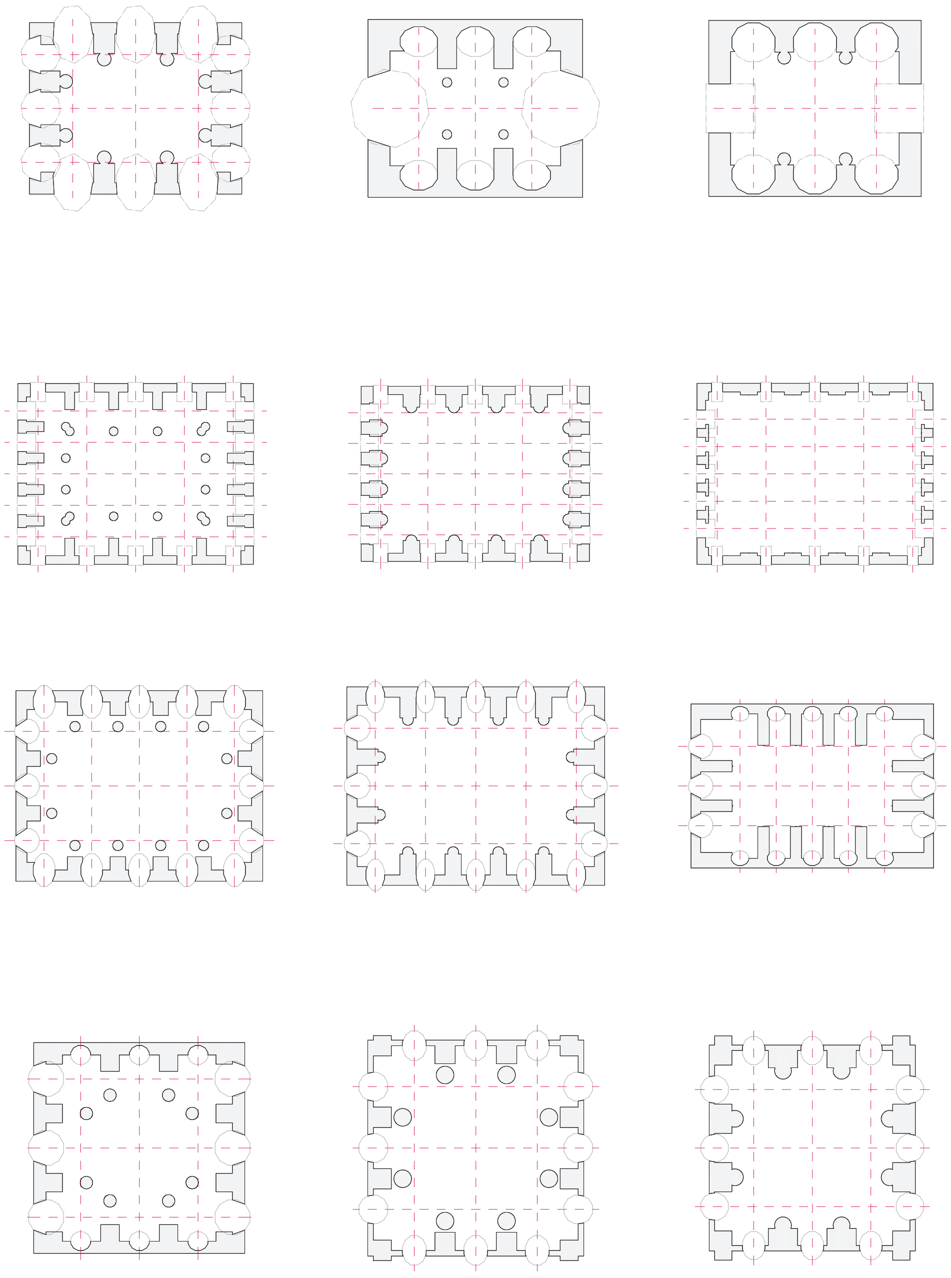
18-24-6 Computer generated central floorplans. Circular Room Generator 03.



18-24-7 House for a rich man by S. Serlio (1611)



18-24-8 Computer generated central floorplans. Rectangular Room Generator 01.



18-24-9 Computer generated central floorplans. Rectangular Room Generator 02-03.

25- SUBDIVISION SPACES

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *Berliner Börse by F Hitzig*

DESCRIPTION:

The experiment is based on the previous exercise regarding central floor plans, exploring a design strategy based on a geometrical procedure called subdivision. Subdivision is feature that many design programs utilize in order to produce more detailed and smoother surfaces (and objects), normally known as Subdivision surfaces.

Subdivision surfaces are defined in the field of 3d computer graphics as a method for representing a smooth surface by recursively subdividing a coarser surface. The coarse or primitive surface is progressively divided, from one to four smaller surfaces, and then each of them is further subdivided until a desired level of detail or smoothness is achieved. On every subdivision, the geometry acquires more definition which can be used for example to describe more detailed features or to achieve a more perfect ´roundness´. Think of a four-sided polygon, then double the number of sides and you have an octagon, double them again and you got 16 sides. If you continue this process, the polygon starts to assimilate a circle. This base procedure can be also applied to surfaces.

The important concept to be explored on this exercise is on how a progressive subdivision can be applied as a design strategy, departing from an architectural space, and then subdividing it in a number of smaller spaces, which will then be further subdivided until a certain criterion is achieved.

There are however, significant differences between the concept of a subdivision surface and this exercise. While the theoretical subdivision of surfaces operates recursively on the same surface, that is, dividing a polygonal mesh until it becomes smoother, this experiment departs from a single space and then creates a series of sub-spaces ´growing´ from it.

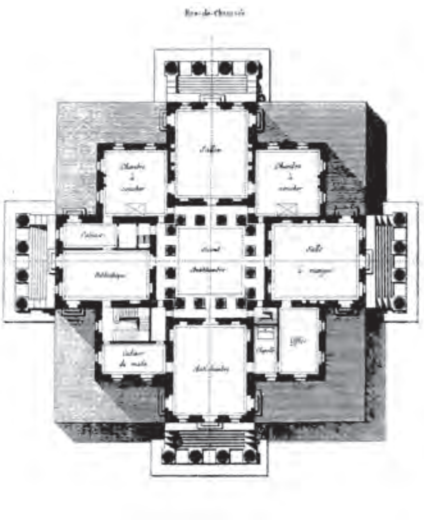
The reference for this experimentation began with the Berliner Börse building by Friedrich Hitzig in Berlin. The stock exchange (and many other buildings from the 19th century) deals with spatial sequences articulating large, medium and small spaces in a given manner. In the case of the Börse, there is a central space, the trading floor, which is divided in two, and then a series of medium and smaller spaces around it. The progression between large and small spaces is usually produced by transitional spaces such as colonnades or thickened walls.

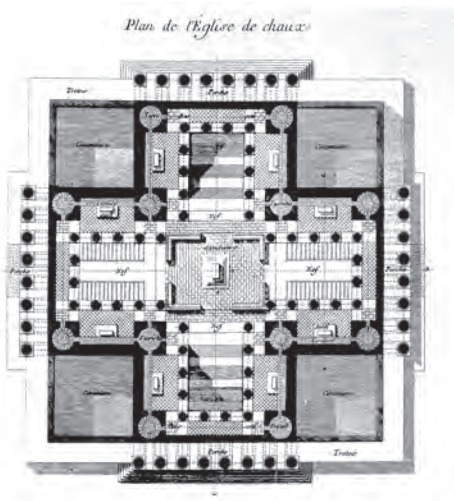
This experiment deals with a similar concept but applied in a more ‘ideal’ set of geometries. It begins with a central space which can be a rectangle or a regular polygon or even a circumference. On each side of the polygon a set of spaces will ‘grow’, but this time, divided in a number of sub-spaces. These subspaces will then be further subdivided in additional subspaces or smaller dimensions.

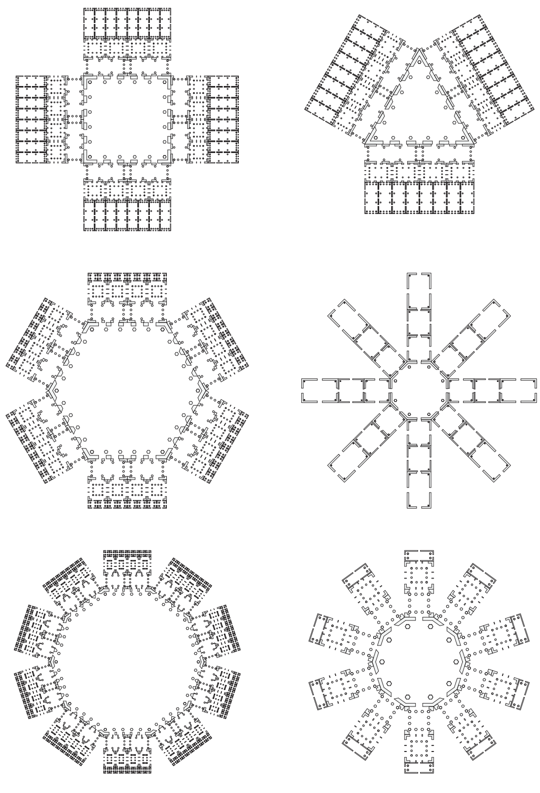
In addition, each space and subspace is defined by an outer wall and an inner gallery limited by columns. This configuration Is recursively repeated on each subspace, but are also feasible to be further parametrized, in order to individualize each configuration.

The experiment describes an interesting design strategy that creates spaces, subspaces and the transitions between them. It allows the possibility of detailed control of geometrical and architectural features but the premise is fairly rigid. The progressive subdivision, that is, the transition from one space to two, from two to four, and so on, appears as inflexible in view of a complex architectural program.

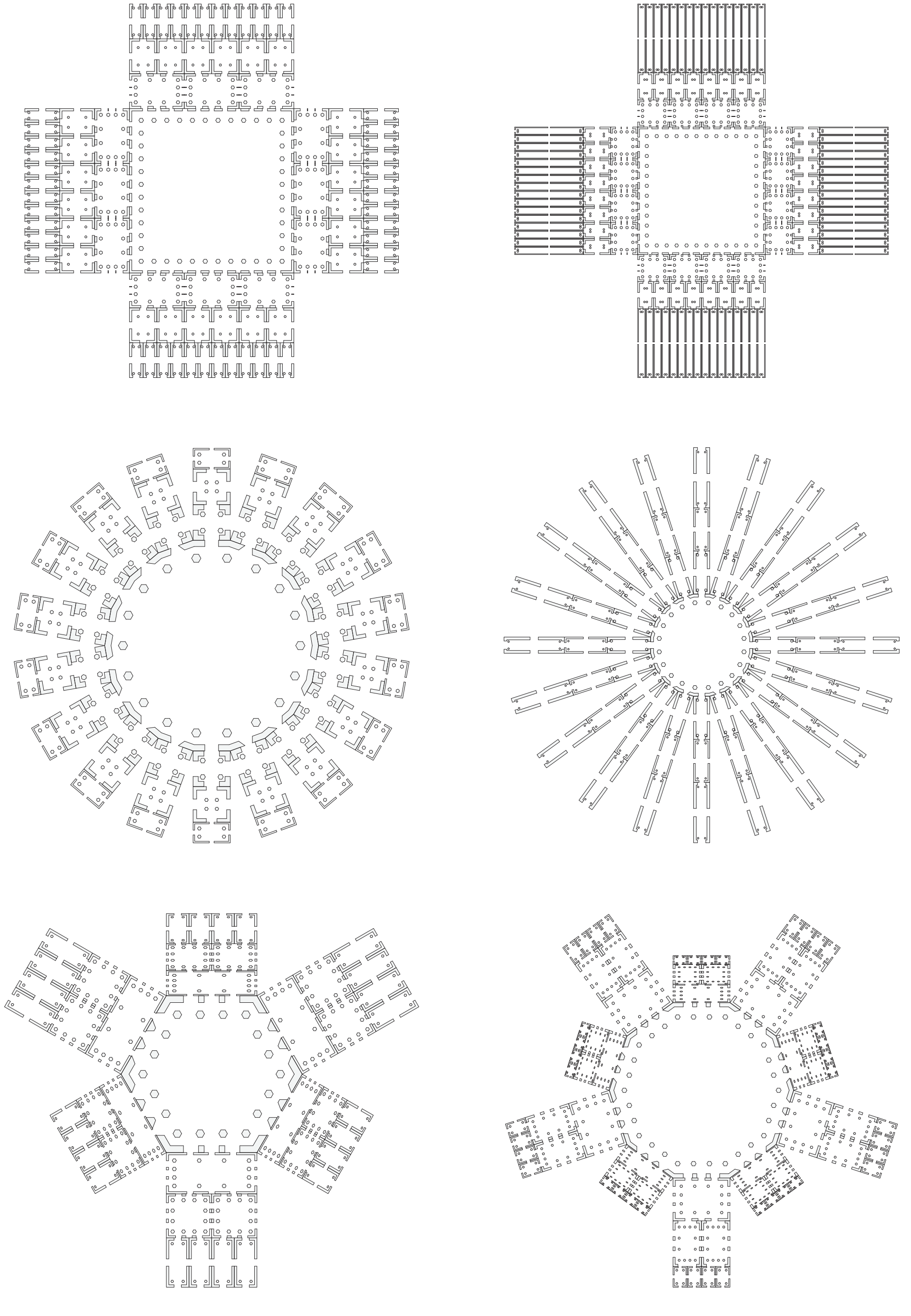
The expression of the ensemble comes into view as too ‘mathematical’ or even ‘machinic’ but with little resemblance to its case study origin. With further control and freedom in the design and its parameters more detailed and significant architectural results will be achieved.



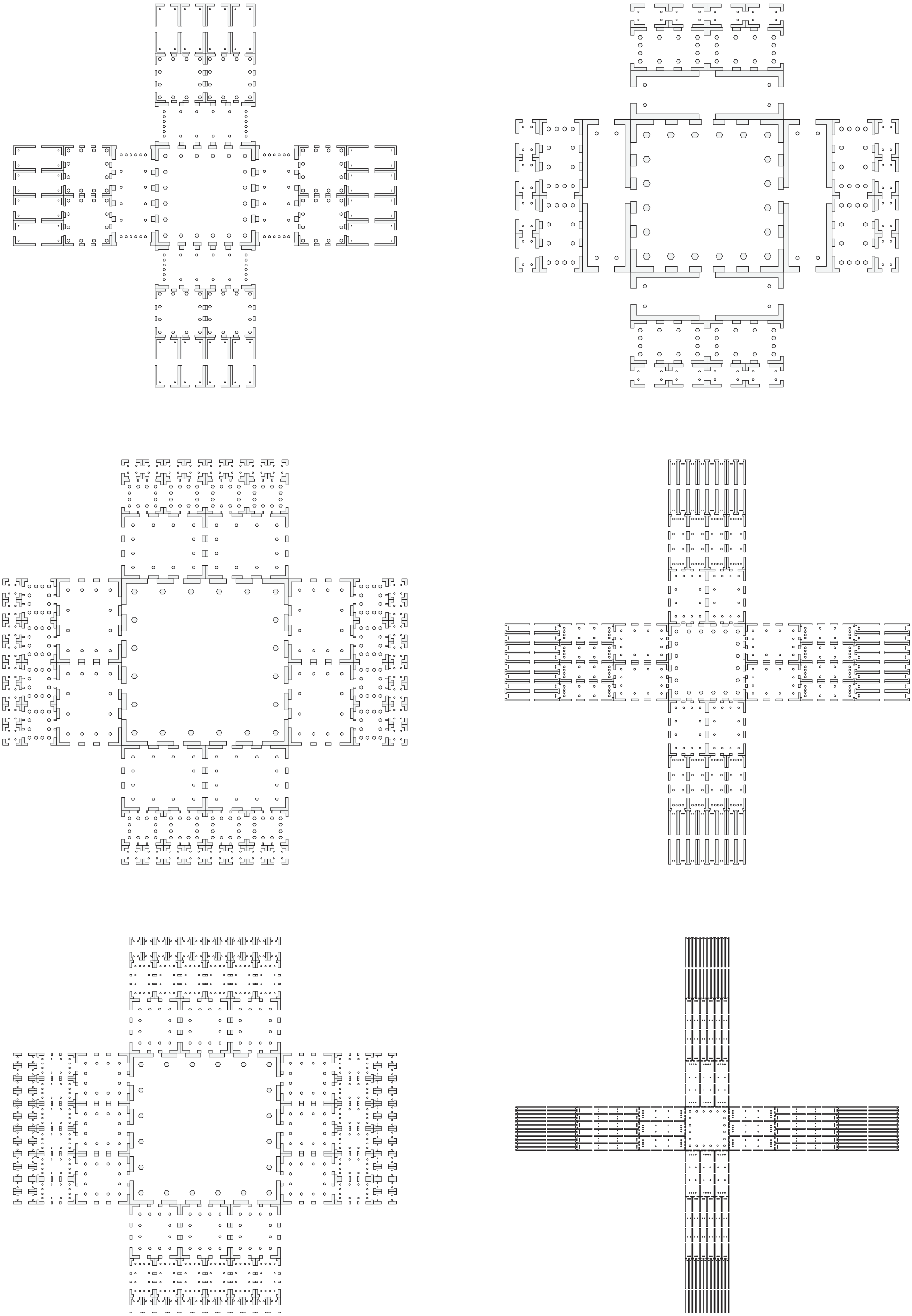




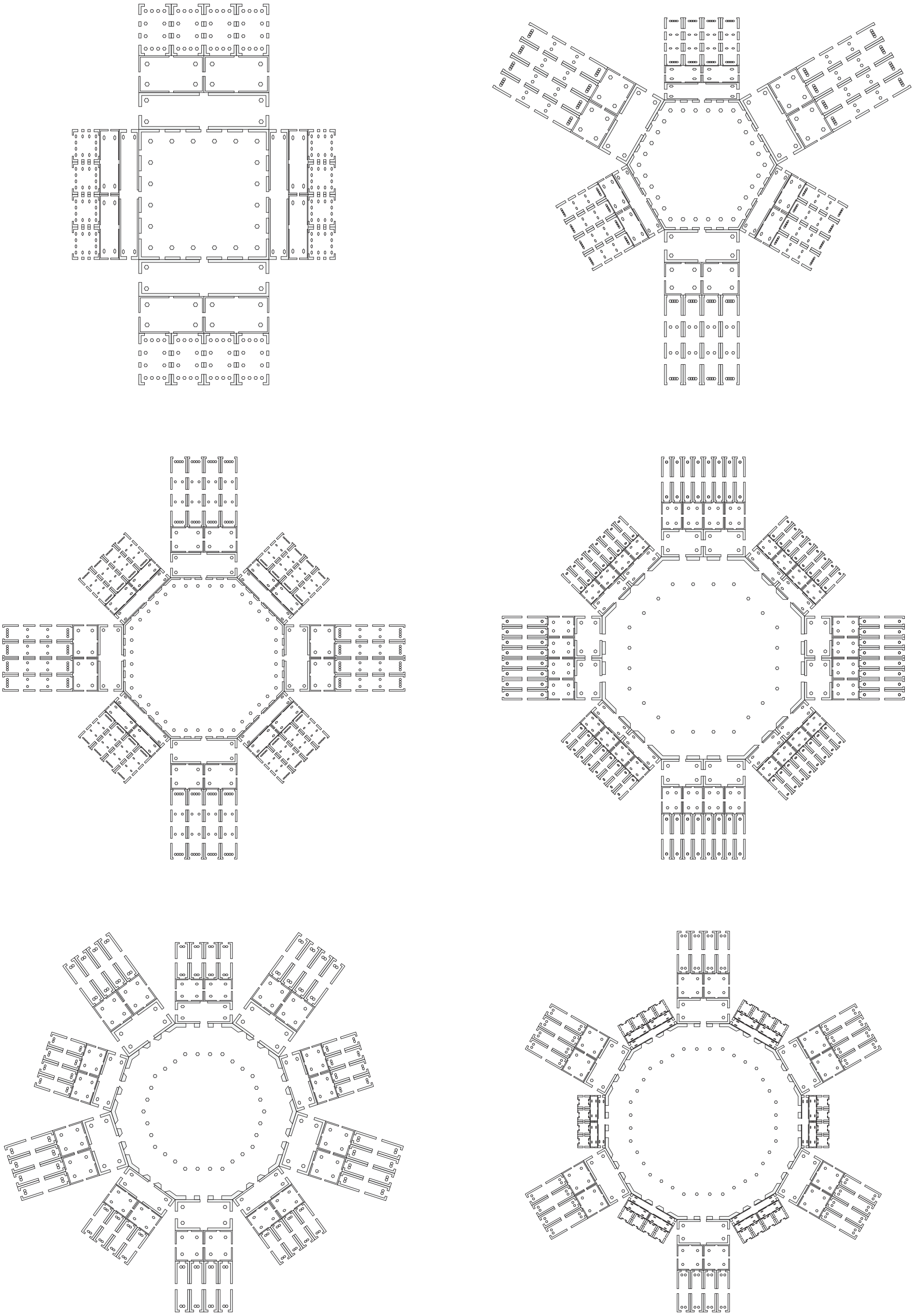
18-25-1 Palais Episcopale de Sisteron . Extracted from Ledoux C.N. ´Lárchitecture consideree´ (1804).
18-25-2 Eglise de chaux. Extracted from Ledoux C.N. ´Lárchitecture consideree´ (1804).
18-25-3 Progressive subdivision experiments. Subdivision Spaces 01.



18-25-4 Progressive subdivision experiments. Subdivision Spaces 02.



18-25-5 Progressive subdivision experiments. Subdivision Spaces 03.



18-25-6 Progressive subdivision experiments. Subdivision Spaces 04.

26 – PALACE COMPOSER

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *French Chateaus, Chateau de Cheverny, Chateau de Maisons Lafitte, Chateau de Meudon, Palladio Villas*

DESCRIPTION:

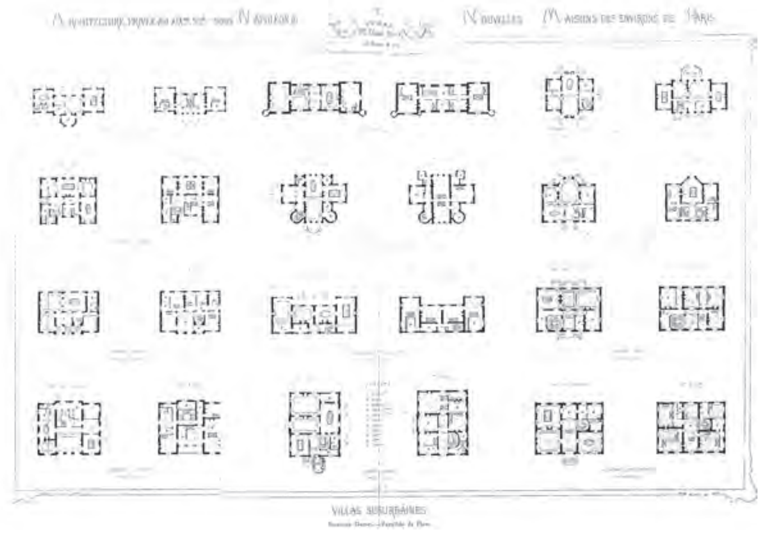
The study of spatial types from 19th century buildings derives from the intention to understand and analyze common typological parameters regarding space, geometry and materials. Before the widespread use of the corridor in the 1800s, the variety deriving from the combination of rooms and their geometrical characteristics provided an idea of the formal and spatial freedom typically found in palaces and chateaus.

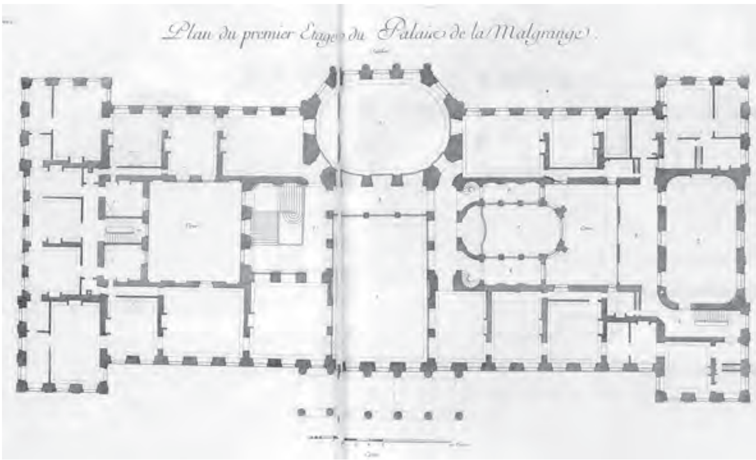
Similarly to the previous ‘room generator’ experiments, this exercise produces more complex arrangements relying on classical 18th century typologies. These chateaus are an example of classical design strategies applied with an advanced degree of complexity and at the same time, providing more design freedom.

Taking the previous experiment as a starting point, this experiment adds another set of architectural elements to the composition, integrating a sequence of spaces, subspaces, wings parting from a central Corp de logis. The articulation of the Corp de Logis, Avant corps y Arrière corps define this classical typology and can be controlled through a series of mutually influenced parameters in the definition.

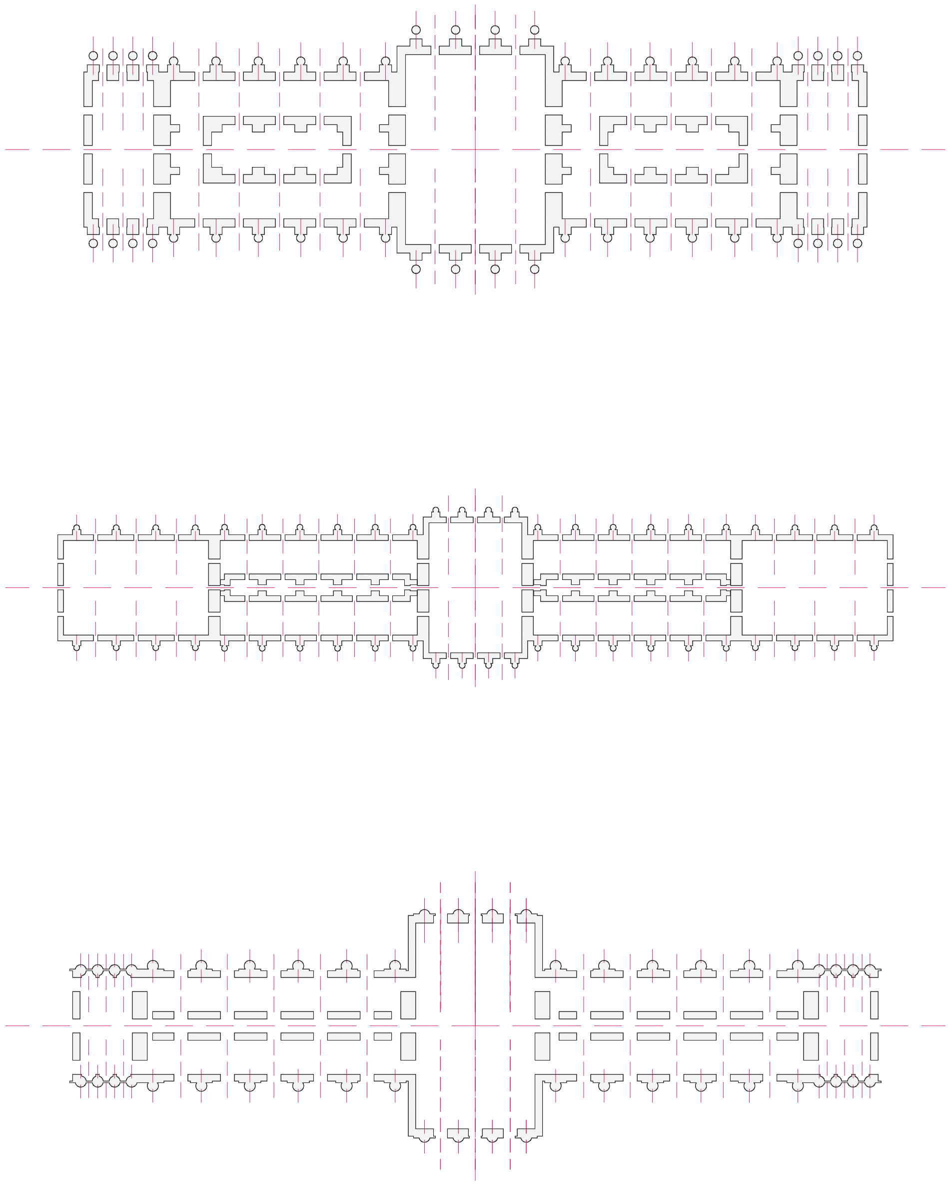
The parametric definition is remarkably flexible, allowing floor plan designs ranging from extended horizontal chateaus to compact compositions, which resemble some Palladian villas.

The experiment demonstrates that despite the apparent divergences between such references, there is still an underlying structure common to them, which is supple enough to contain a universe of possible projects. Similarly, these types of experiments illustrates that there is still room for a new set of proportions, new spatial relationships and moreover, new typologies.

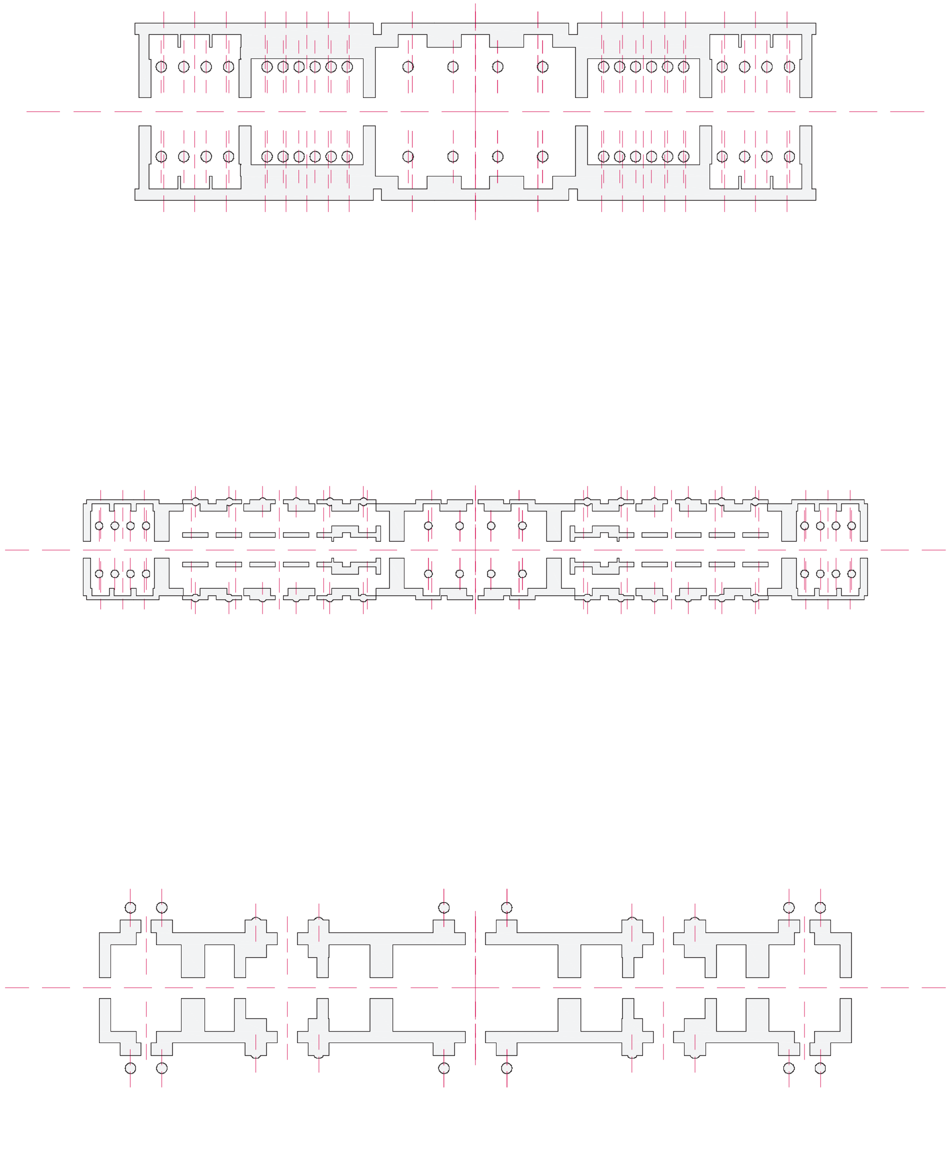




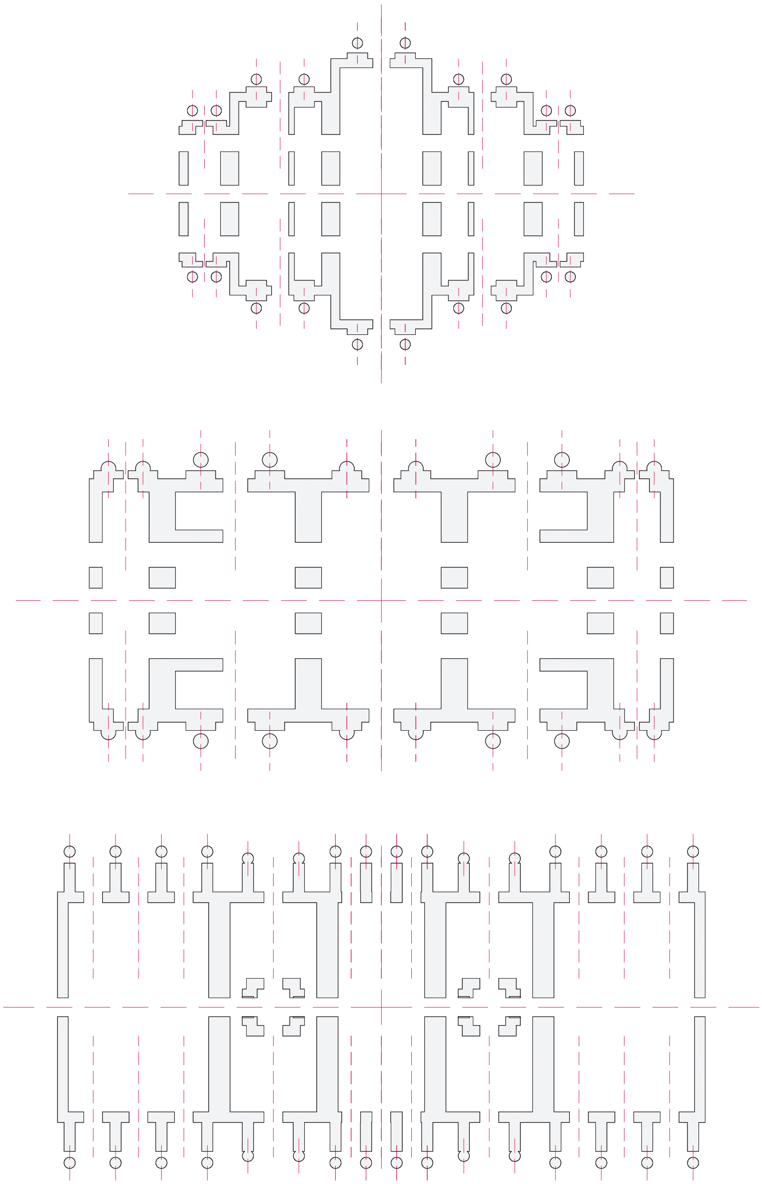
18-26-1 Catalogue of ´new suburban villas´. Extracted from Daly M.C. ´L'architecture privée au XIXe siècle´ (1864)
18-26-2 Château de Malgrange by G. Boffrand (1711). Extracted from L.Blondel ´Livre d'architecture´ (1745)



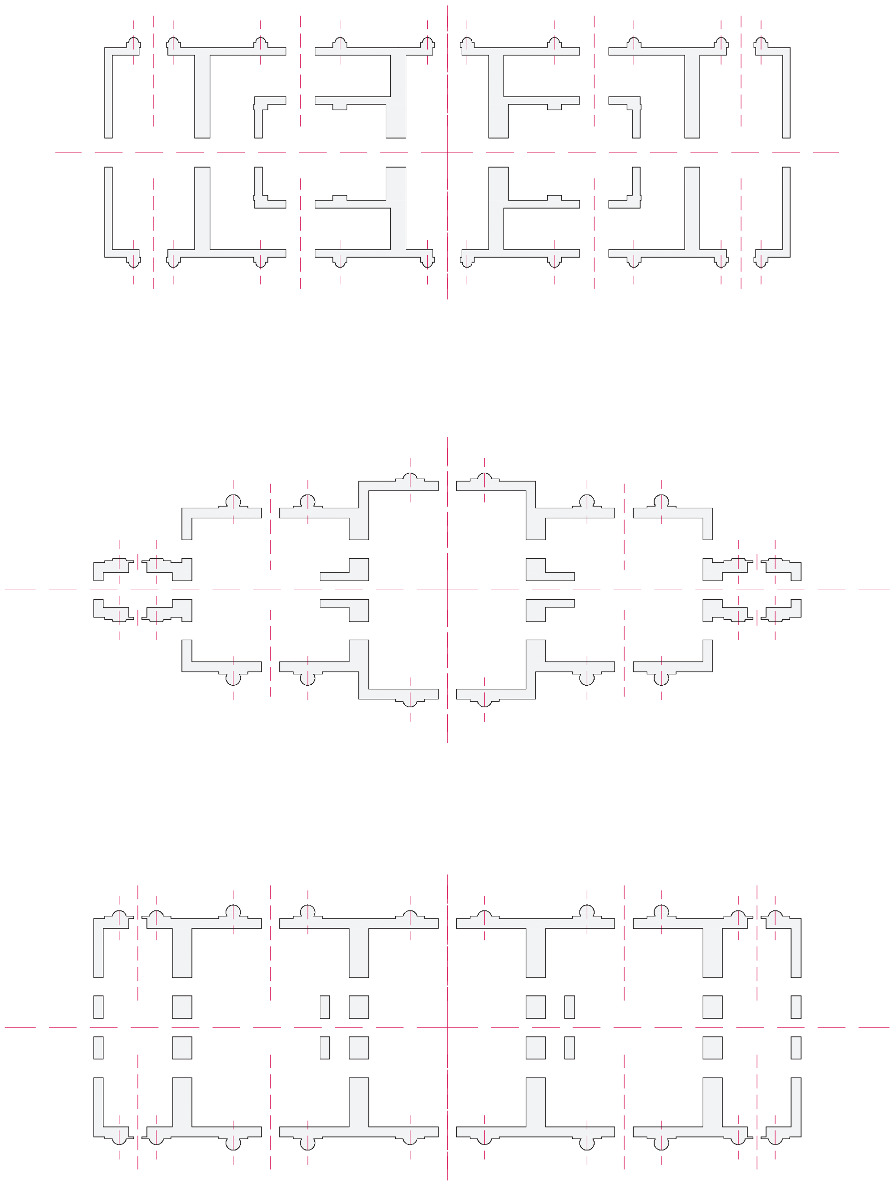
18-26-3 Parametric variations of French châteaux. Palace Generator 01.



18-26-4 Parametric variations of French châteaux. Palace Generator 02.



T18-26-5 Parametric variations of French châteaux. Palace Generator 03.



18-26-6 Parametric variations of French châteaux. Palace Generator 04.

27 –INFINITE BASILICA

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *19th century halls, Roman basilicas, Byzantine Basilicas*

DESCRIPTION:

This experiment parts from the study of spatial sequences as a classical design strategy. The concatenation of a series of spaces is a powerful design tool in order to produce progression as well as a tangible idea of order. The investigation, definition and manipulation of such ordering principles and instruments is one of the purposes of this research.

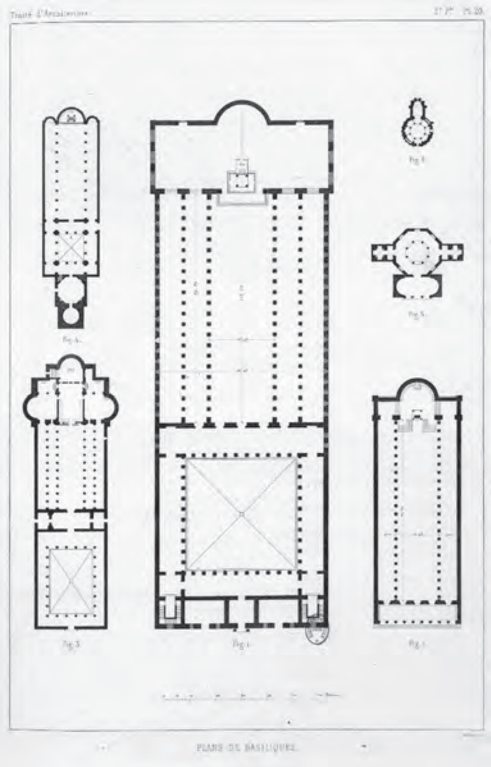
The 'Infinite basilica' definition works by combining the results from the previous experiments, by utilizing a series of predefined rooms that will be used as 'building blocks'. This definition operates as a combinatorial machine by placing blocks next to each other according to predefined criteria. Each row of spaces contains three sub-spaces, which, when concatenated with the next row, conforming a three-aisle spatial sequence, similar to a basilica.

Each floorplan presents a concatenation of complex-shaped spaces, providing multiple footpaths and potential routes for the user while simultaneously provide concrete spaces, places to be in, not to pass by.

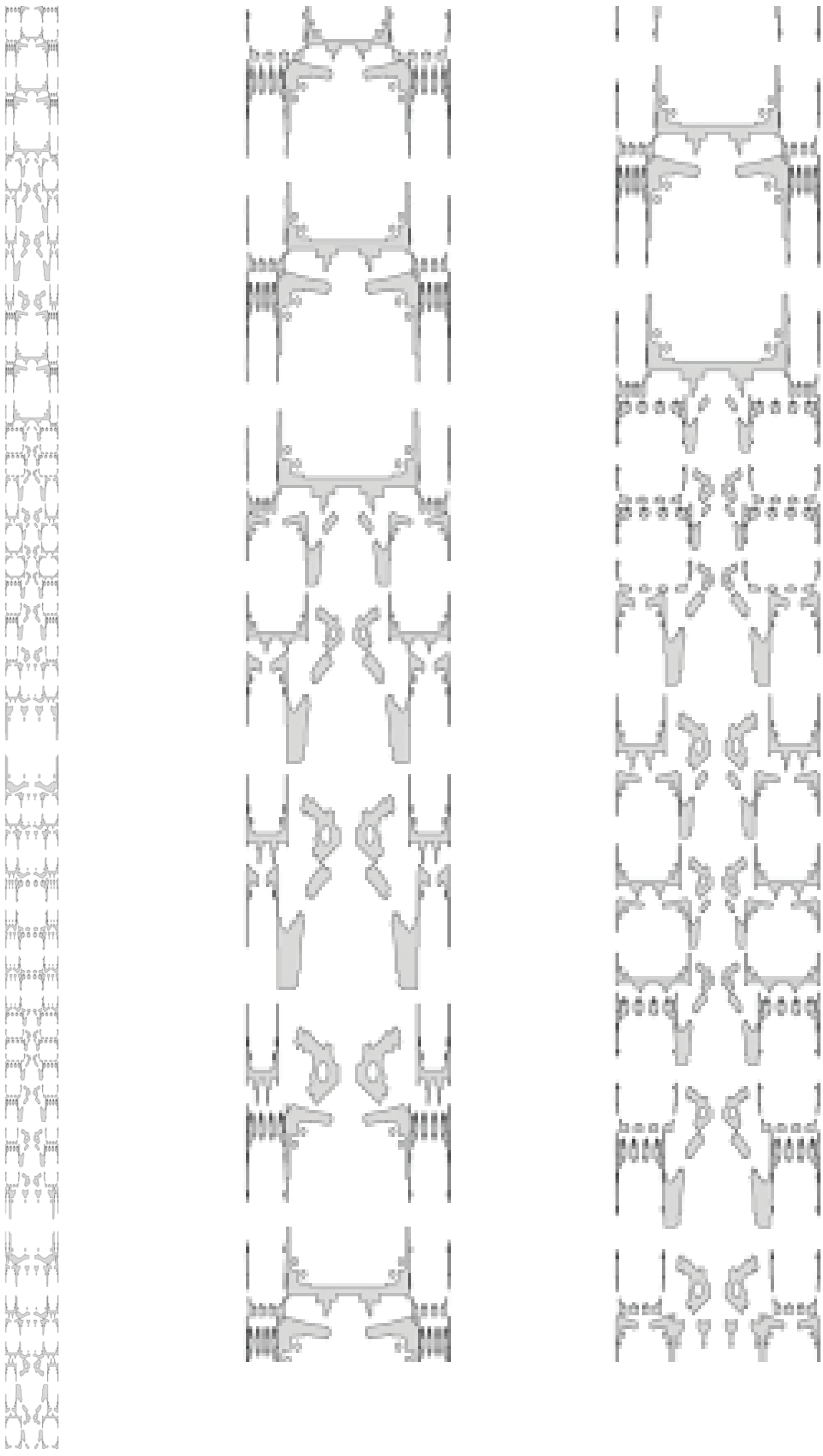
The definition that combines these rooms in the basilica-like typology can be also controlled by a genetic algorithm component, which evaluates each parameter value, such as the room dimensions or the type of space, and then alters it according to selection criteria. The selection criterion is never absolute but relative, for example, to try to attach as many 'similar' rooms together. When the parameters approximate to the criteria, a new variation is induced, thus creating a sort of 'directed' variation.

Likewise, the same parametric definition can be used combined with a genetic algorithm component in order to produce unsystematic outcomes and random results. The procedure is similar as the previous one, except the selected criteria should be futile or impossible to accomplish, therefore forcing the algorithm to run indefinitely looking for a solution.

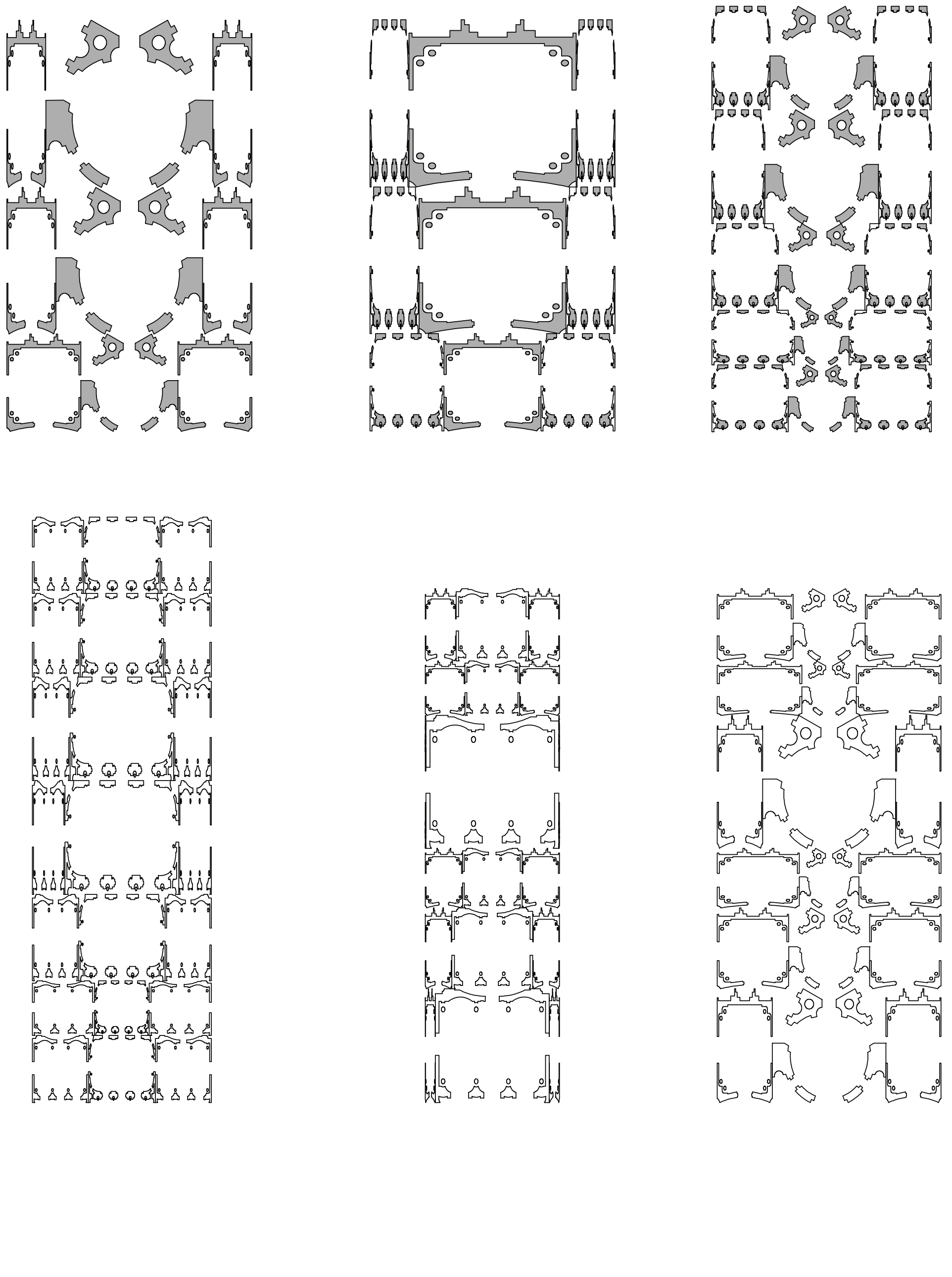
18-27-1 Computer generated central floorplans. Circular Room Generator 01.



18-27-2 Basilica floor plan catalogue. Extracted from L. Reynaud ´Traite d architecture´ (1870)



18-27-3 Typology as architectural placeholder. Infinite Basilica 01.



18-27-4 Typology as architectural placeholder. Infinite Basilica 03.

28–CENTRAL PAVILIONS - ZENTRALBAUTEN

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *Central Pavilions, Circular temples, Circular buildings, Couven Pavilions in Aachen, architectural treatises by Serlio, Palladio.*

DESCRIPTION:

The study of central floorplans began by the research interests of the Rokokorelevanz group and this Phd. The research on design strategies, both present in classical and contemporary (digital) methods encouraged the revision of several projects and floorplans that fitted a desired criteria. Since the concepts and procedures involving classical design strategies were too complex and multifaceted to be tackled directly, this experiment determined the review of simpler, intelligible buildings.

Thus, the conditions required for this study were related to the spatial characteristics of central buildings as well as the formal and geometrical processes that control them. The experiment required the study of central buildings or centrally organized compositions, most of them small pavilions or temples, consisting in one single space, or one large space surrounded by smaller, satellite spaces.

Around sixty buildings were selected for this survey, from diverse periods, programs and sources, ranging from triangular, quadrangular, polygonal or circular geometries. Later on, this selection well exceeded the hundred, by coupling this experiment with other ones, such as the Circular Room Generator.

The research process involved the re-drawing of every project, in order to present them on a similar format. For that reason, drafting standards were delineated determining line widths, types, projections, and other factors, assigning colors and widths to each element and most importantly, defining what to draw, which elements, details or features and how to draw them.

Some of the results of this exercise were presented in the exhibition 'Pavillons' organized by Rokokorelevanz in the Kerstenscher Pavilion in Lousberg, Aachen on 05.06.15.

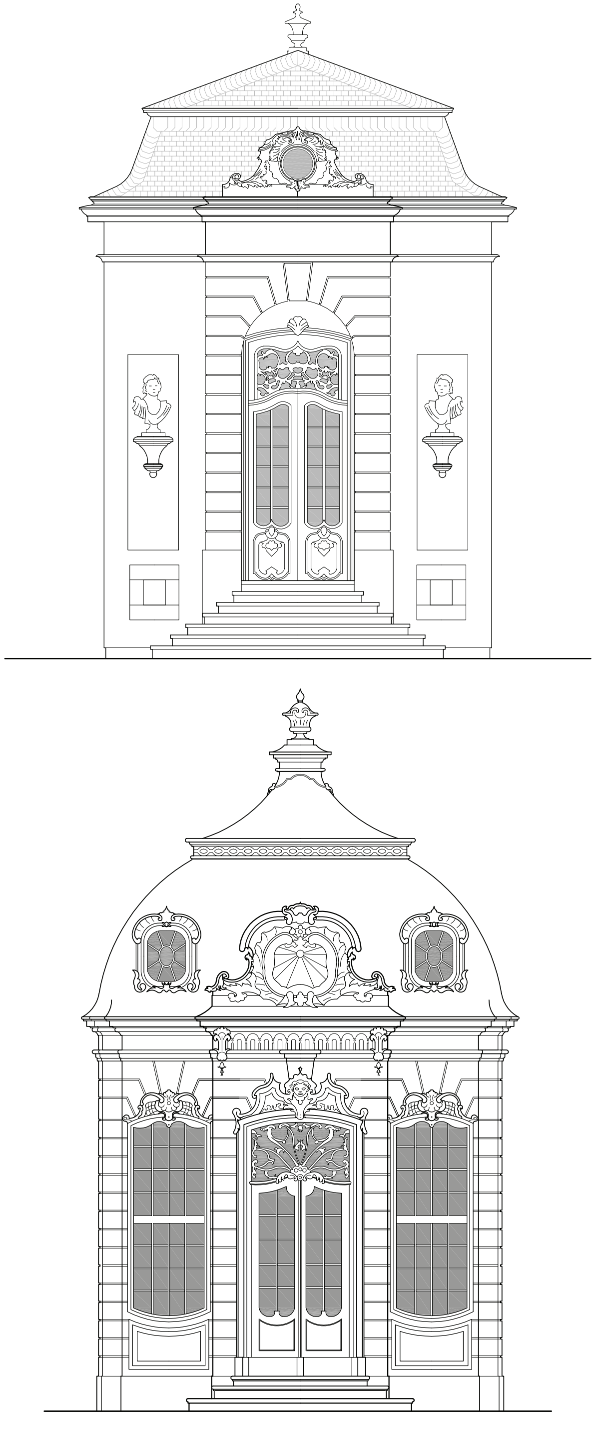
As a second step, this excise combines two previous experiments in order to generate a series of abstract pavilions. The experimentation parts from the study of profiles extracted from several treatises of classical architects such as Palladio, Serlio and Scamozzi as well as the floor profiles created by the previous 'Central floorplan generator'.

The profiles were collected from architectural treatises and drawings, most of them depicting architectural orders and their variants, proportion deviations and variant from other scholars of classicism. Similarly, profiles from Couven's pavilions in Aachen were drafted.

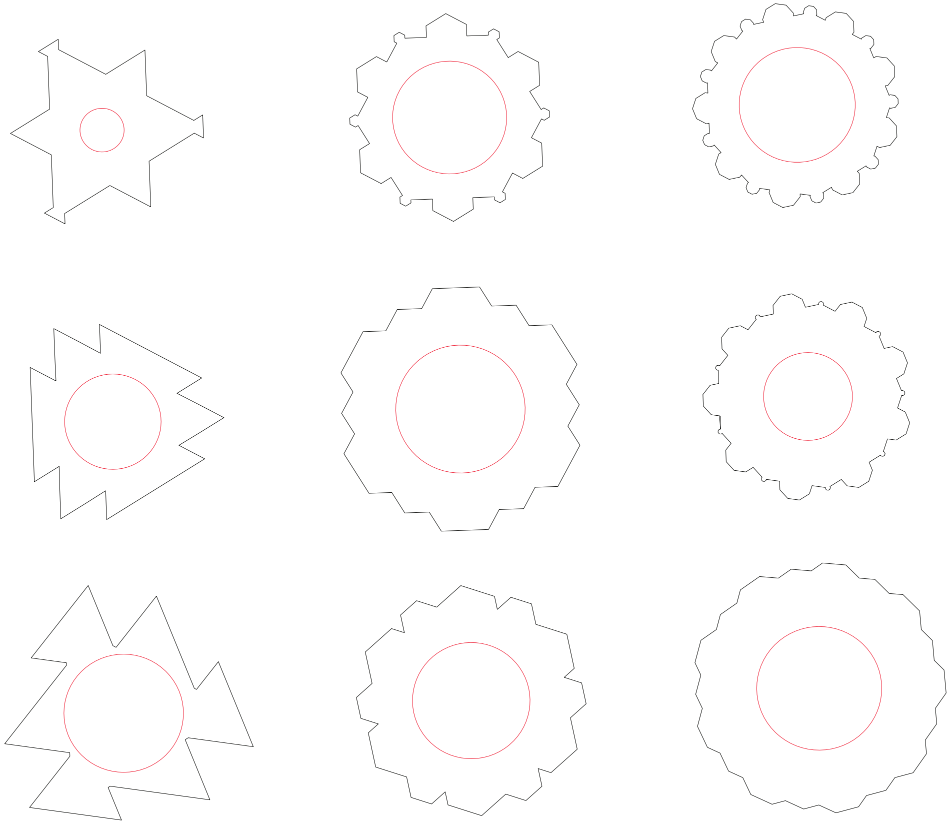
The reason for this selection is because the pavilion's profiles include information from the entire section of a building. Being a small building, pavilions condense architectural information of all kinds; base, columns, details, entablatures, roofs, among others. The complete building, a concentration of architectural elements and qualities are a useful source of valuable architectural information.

Using this information, a parametric definition combines these section profiles with the floor plan profiles generated previously. The floor plan outline acts as a directrix while the profile perform as a generatrix, producing a highly complex, closed volume.

The result is a series of abstract pavilions, vaguely resembling to a Couven pavilion, but geometrically different; some are simpler, some are more intricate. The exercise, however straightforward, demonstrates the formal and aesthetic potential of these classical profiles, especially in regard to detail and scale, fundamental in architectural experimentation.

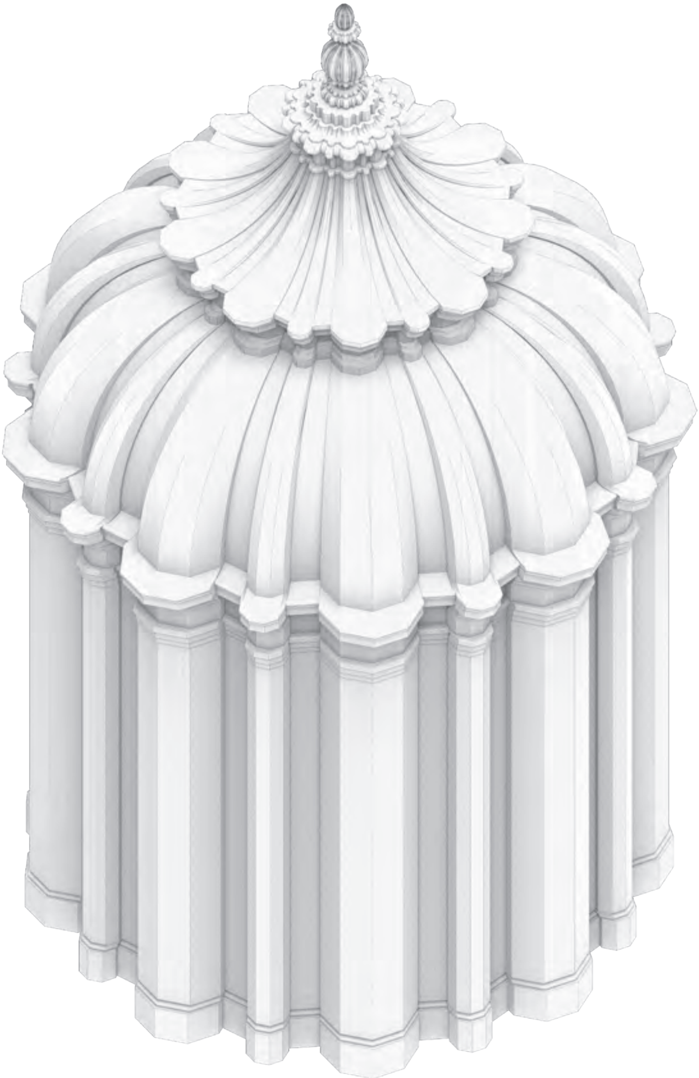


18-28-1 Kerstenscher Pavilion - Gartenhaus Mantels by J.J. Couven (Aachen, 1737)
Bottom: Nuellens Pavillon - Gartenhaus Nuellens by J.J. Couven (Aachen, 1740)



18-28-2 Pavilion Footprint Catalogue, parametrically generated.

18-28-3 Computer generated footprint and profiles. Central Pavilions Catalogue.



18-28-4 Central Pavilion Detail

29- PALACIO DE AGUAS COMPOSITIONS

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *Palacio de Aguas Corrientes*

DESCRIPTION:

This experiment was designed to explore formal variations based on the Palacio de Aguas Corrientes. Although the building does not bear a significant architectural program, its typology; the relation between form, character, site and program is a very interesting one, and particularly compelling to this research.

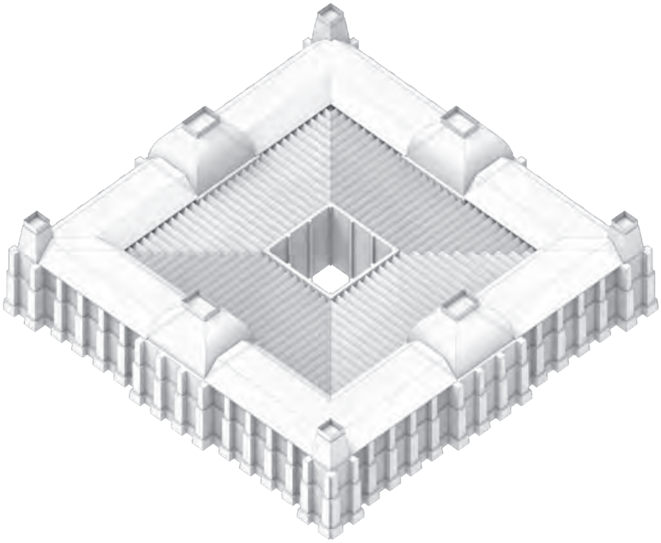
The exploration of this exercise intended to find formal and geometrical variables from the Palacio´s own architectural elements and their relationships, intertwining them in a coherent, open system. Naturally, the scope of this experiment does not cover all the formal details and ornaments that the building exhibits, however the main building elements like receding and protruding bodies, columns and pilasters are part of the system.

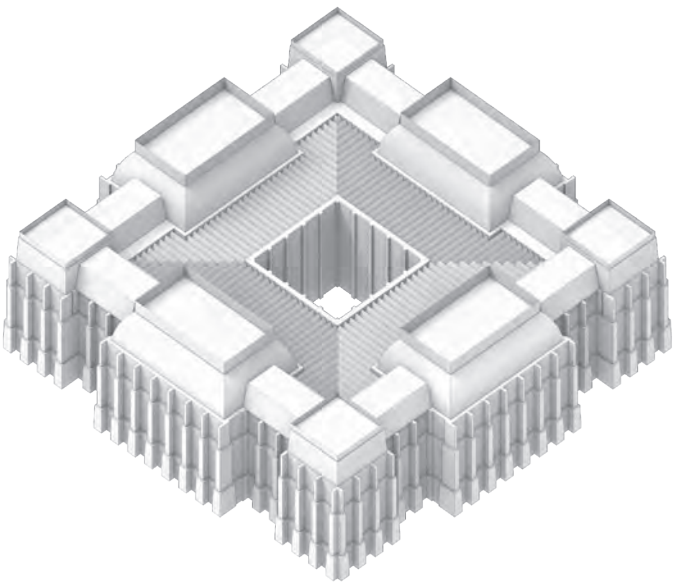
The definition works has several degrees of complexity in terms of control; some variables are global, some are local, some are non-hierarchical, meaning that they affect the entire composition up and down in the geometrical order, while some of them are hierarchical, affecting only the geometry downstream.

For example, one of the main controls is related to the building´s shape: depending on the number of sides of a polygon, the rest of the Palacio´s geometry will adjust to it, hierarchically. Other variables such as the number of windows or the type of window frames does not have any influence on the global organization of the building. This is not related to the element´s particular size, since for example, the parameters that govern the position of the columns and pilasters modify the Palacio´s global dimensions and proportions. A similar situation happens when altering the dimensions of the inner courtyard; it is related to the building´s usable floor plan but also to the structural module.

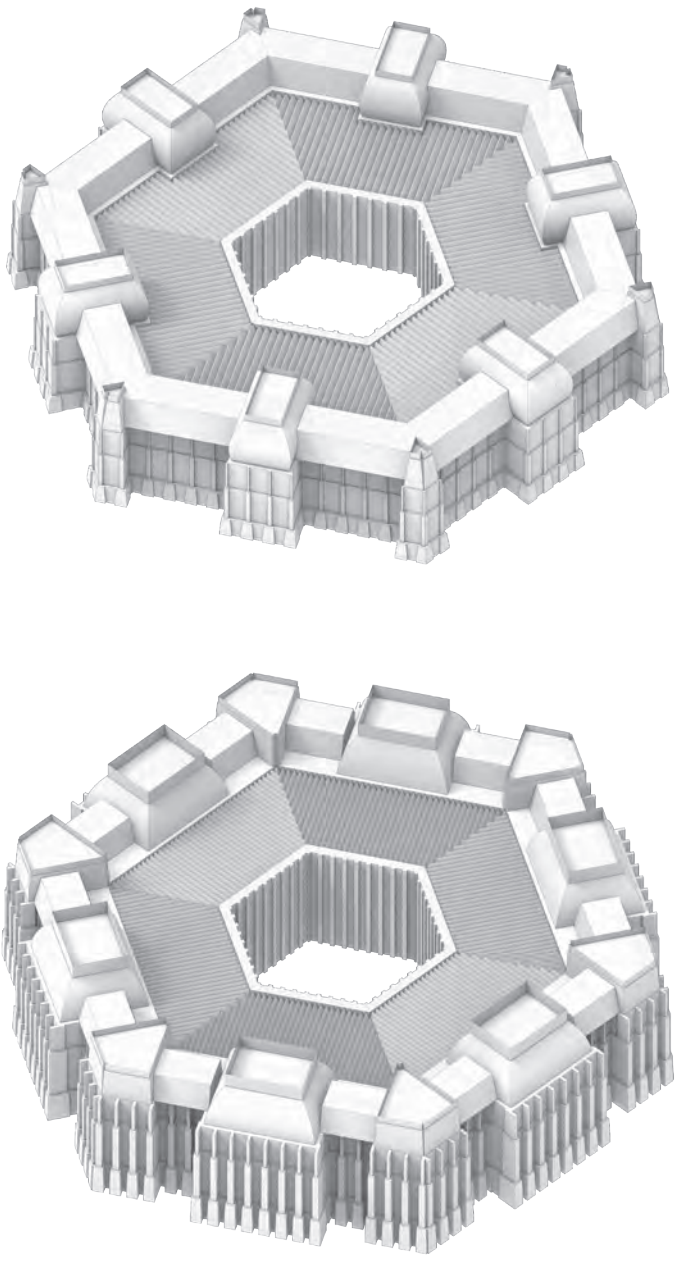
From this point on, several parameters are available to further alterations; number, size and position of the columns and pilasters, roof dimensions, type of windows, railings, among many others.

The sheer variety of outcomes that this experiment produced illustrates the geometrical and formal possibilities of typological variation within a parametric environment. It also depicts the relevance of typological studies and the unexplored opportunities within architectural design and experimentation.

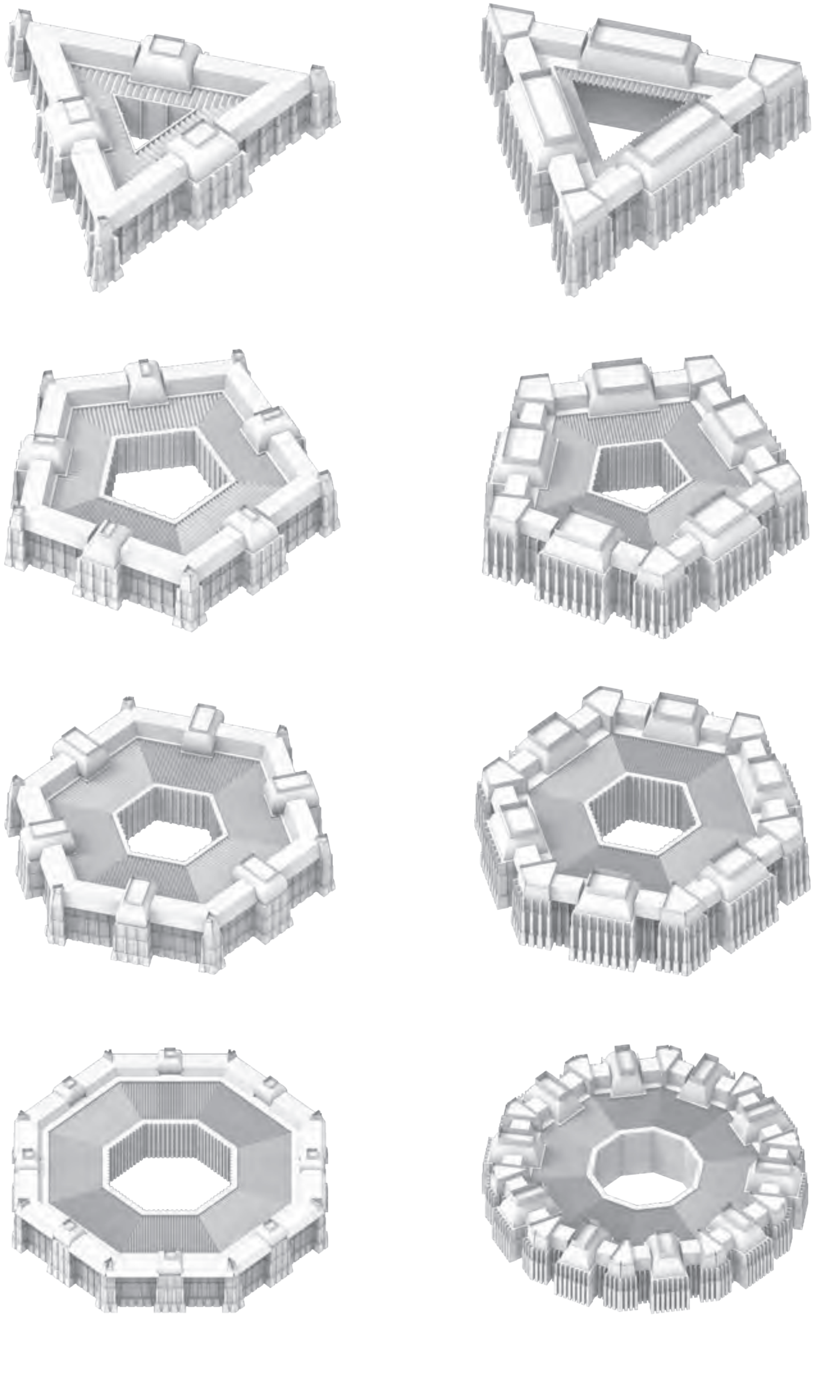




18-29-1 Typological experimentation. Palace of Waters Variations 01.



18-29-2 Typological experimentation. Palace of Waters Variations 02.



18-29-3 Typological experimentation. Palace of Waters Variations Catalog..

30- MODULATED COMPOSITIONS

SOFTWARE: *Rhinoceros, Zbrush, Mudbox*

REFERENCES: *Palacio de Aguas Corrientes, Porte Monumentale, Plaza Hotel, Palacio Paz, Argentinean Pavilion, Palace de Champ du Mars, Berliner Borse, Biblioteque Genevieve*

DESCRIPTION:

The experiment intended to explore the formal and aesthetic possibilities from the use of non-architectural software in the design of 19th century buildings and details. On this case, the investigation involved the study of software intended for film, special effects and game design.

Since the last decade, special effects and game design are able to produce life-like images, combining complex geometries, photorealistic textures and ambient light effects. To this end, software like Zbrush or Mudbox can handle intricate geometrical models, often composed by tens of millions of polygons. Just for comparison, a three dimensional model of a medium size building has up to fifty thousand polygons before the modeling software crashes. Even though these figures will eventually expand thanks to the exponential upgrade of computer components, the difference between both types of design software will remain radical, mostly because of the way each program handles geometyr.

Part of this interest in non-architectural software was fueled by a collaboration with Joost Meyer at the RWTH and his research module ´Digital Me´. Meyer´s own doctoral research regarding the analysis of dexterity in the modeling of human portraits in ceramics as well as a digital environment deals with analogue concerns to this exercise.

The complexities and capacities of organic modeling software exceed the scope of this research but as a brief summary, the interest of this investigation on them is based on three main characteristics. The first one is the software´s capacity to manipulate millions of polygons, the second is the optimization tools that allow to visualize them using a fraction of the required resources and third and most importantly, a novel way of dealing with three-dimensional geometry.

The capability to handle millions of polygons by organic modeling software provides unusual opportunities to architects and designers; the exponential increase in the number of polygons allows the focus on detail levels unreachable before. Architectural details such as profiles, textures, bumps, cracks and fractures, the simulating the passage of time and other material effects are part of the architect´s toolbox. Thanks to video game design software three dimensional models of buildings do not need to look like unused and uncanny.

Such levels of detail can be however approximated in traditional design software, but would require tremendous computational capacity. On this regard, programs like Mudbox propose a new approach to modeling by sculpting or ´painting´ geometry instead of modeling by using bump and displacement maps to handle high levels of details. Texture mapping is a common feature in animation and rendering software but Mudbox can convert maps to geometry and backwards when necessary, dramatically decreasing the computing power on each task. For example, in videogames, details and textures will remain as maps optimized for visualization but can be converted to true three-dimensional geometry for 3d printing. This reversible process between two-dimensional bump textures to three-dimensional geometry is a powerful asset of organic modeling software.

However one of the most important differences between Mudbox, Zbrush or Sculptris and architectural modeling software is the fact that they handle geometry radically different. When dealing with millions of polygons, modeling aids such as snaps, endpoints or edges are not available. Similarly, tools like extrusion, revolution or Boolean operations operate in a different way.

Since this type of software was initially designed for game asset design and special effects, its primary purpose was to facilitate the production of variety with the least amount of resources, for example, entire cities or landscapes as a background. The software packages allow to quickly create complex three-dimensional geometry by combining, duplicating, mirroring and pasting two dimensional maps. The program would seamlessly weld the meshes into a solid model, avoiding the always dangerous holes or non-manifold objects.

This experiment intends to draw on these capabilities, creating complex architectural models by using simple composition tools such as duplication and mirroring of 19th century building parts or modules. There is also a correlation between such techniques and 19th century´s own design strategies; the multiplication and mirroring of building elements through symmetrical axes was a common trait, particularly thanks to the introduction of machine technologies and standardized elements.

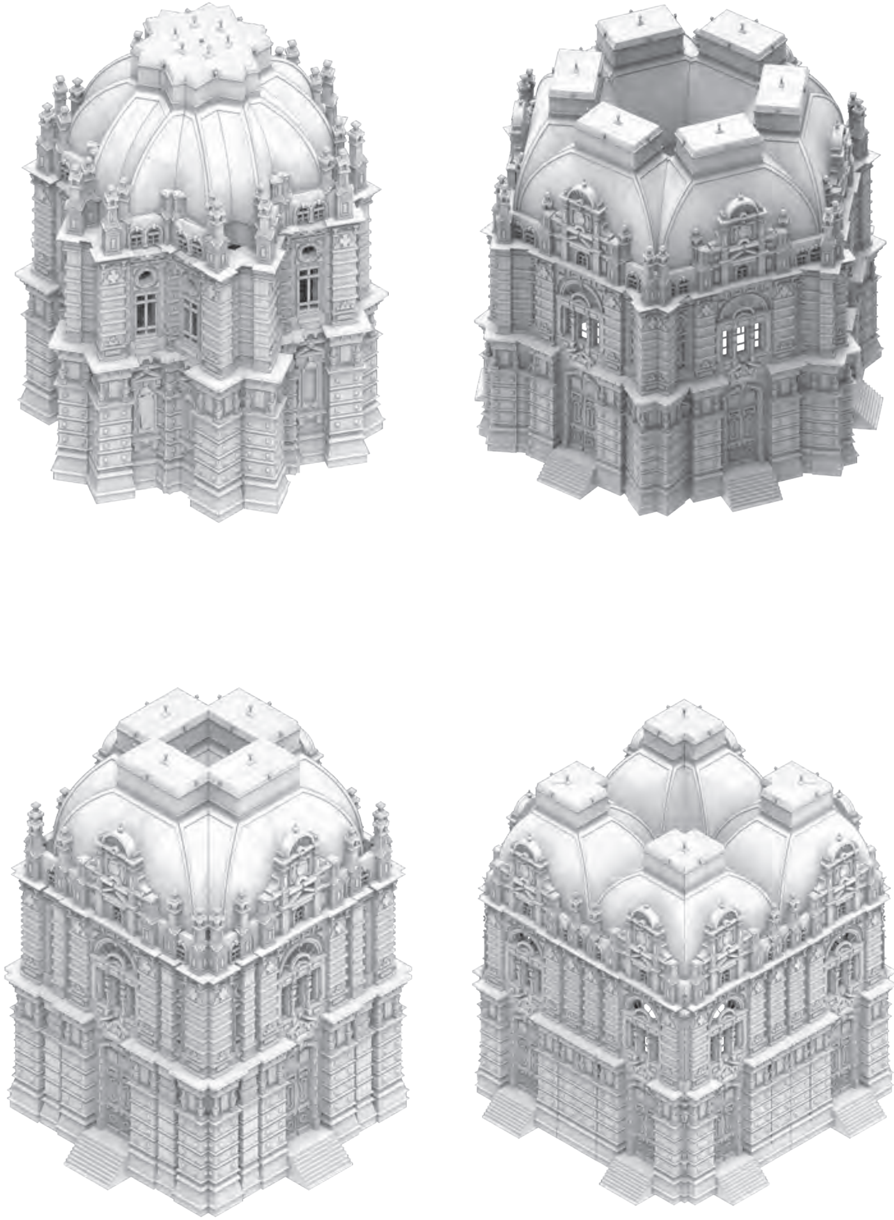
The result of this exercise is a series of compositions depicting precisely these design strategies; seamless multiplications, symmetrical configurations and classical tripartitions. Similarly, the software allows for an endless concatenation of modeling operations; buildings can grow on every dimension effortless.

While the purpose of this exercise was initially two fold; the study of 19th century design strategies and the exploration of organic modeling software, there is still room for experimentation with non architectural design tools. It is clear that they provide novel ways to deal with form and geometry, much more free and unrestrained than architecture´s own tools, and it is certain that the crossing between the two approaches would benefit design research.

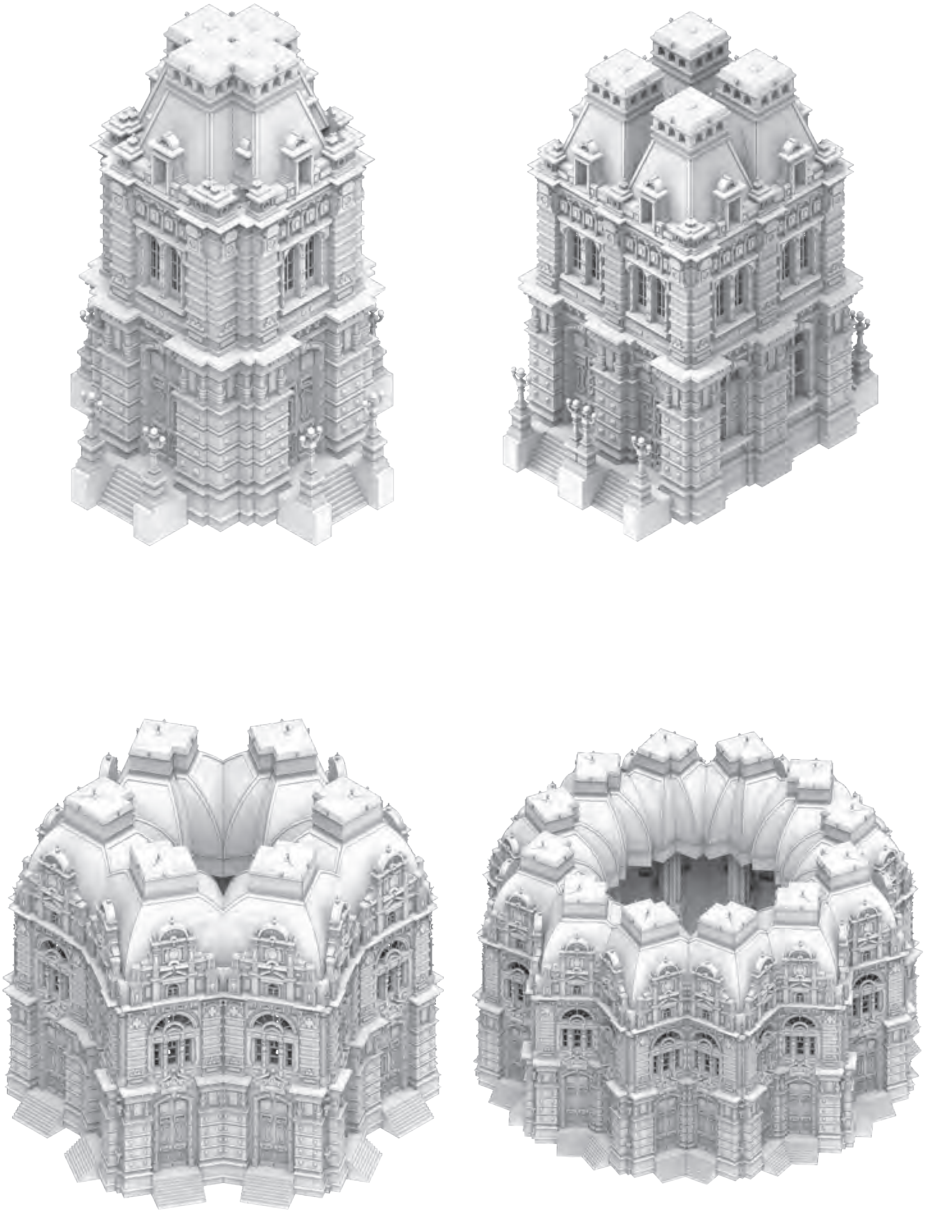
Oppositte : Temples by S.Serlio (1611)

18-30-1 Modulated Composition 01- Palacio de Aguas Corrientes.

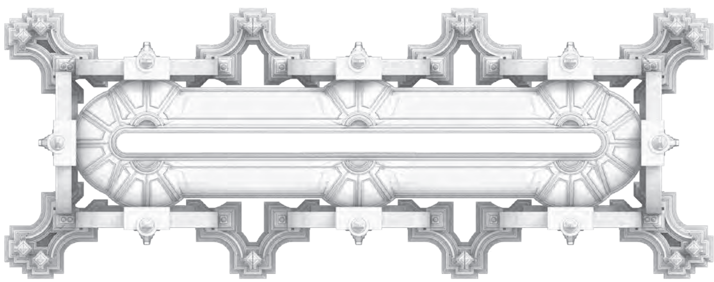
18-30-2 Modulated Composition 02-03- Palacio de Aguas Corrientes.



18-30-3 Modulated Composition 04-05-06-07- Palacio de Aguas Corrientes.

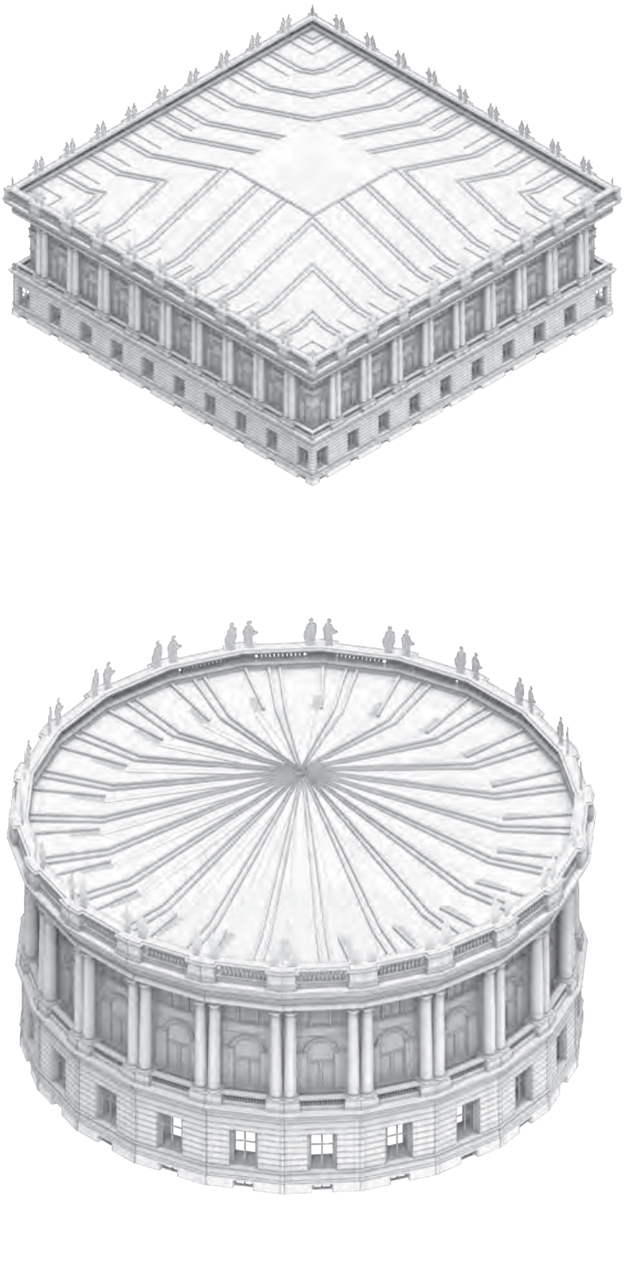


18-30-4 Modulated Composition 08-09-10-11- Palacio de Aguas Corrientes.

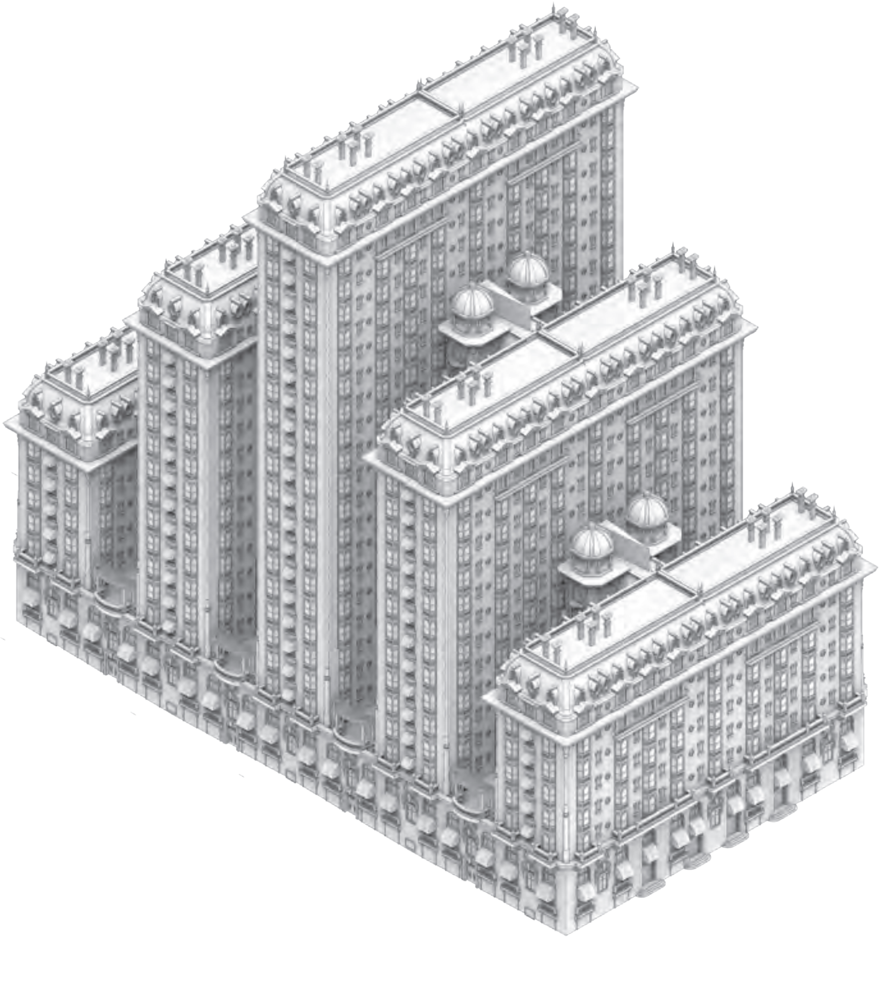


18-30-5 Modulated Composition 01- Porte Monumentale.

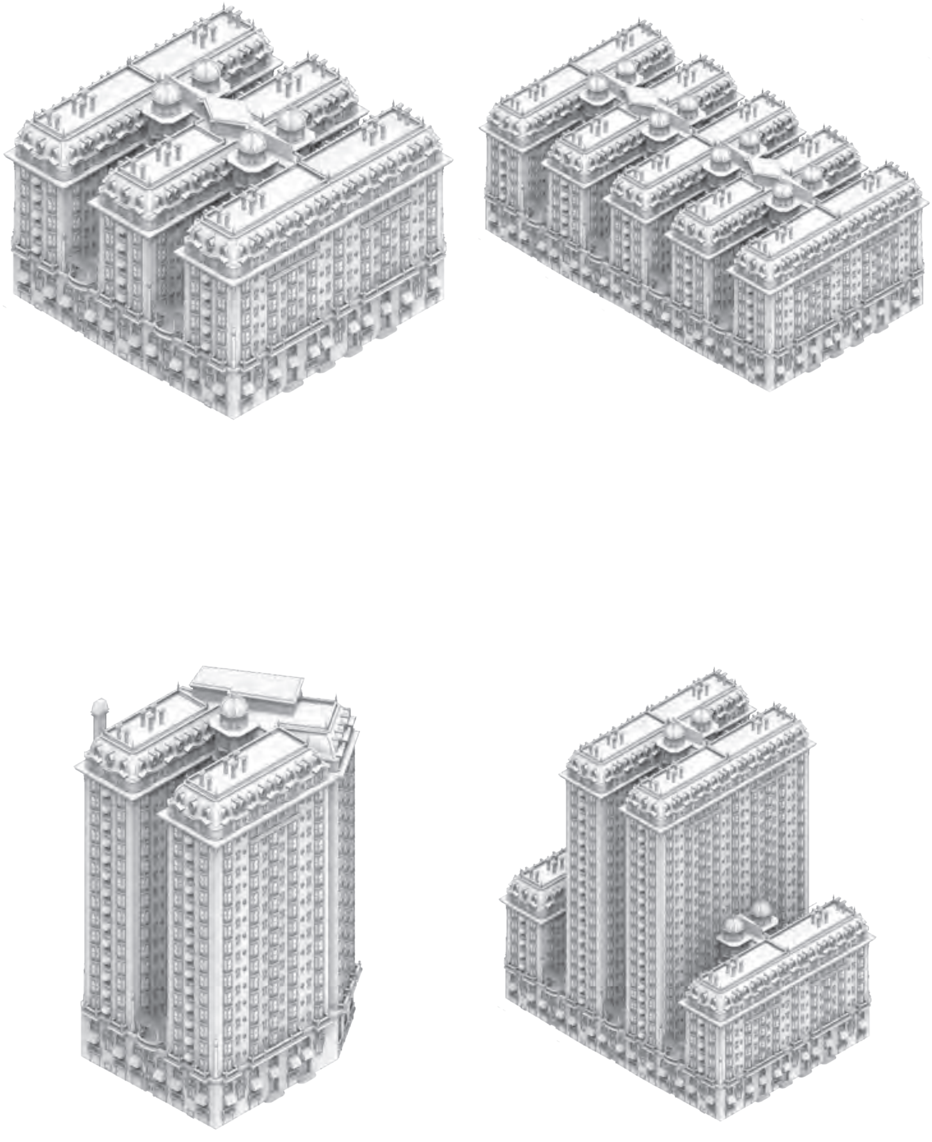
18-30-6 Modulated Composition 02-03- Porte Monumentale.



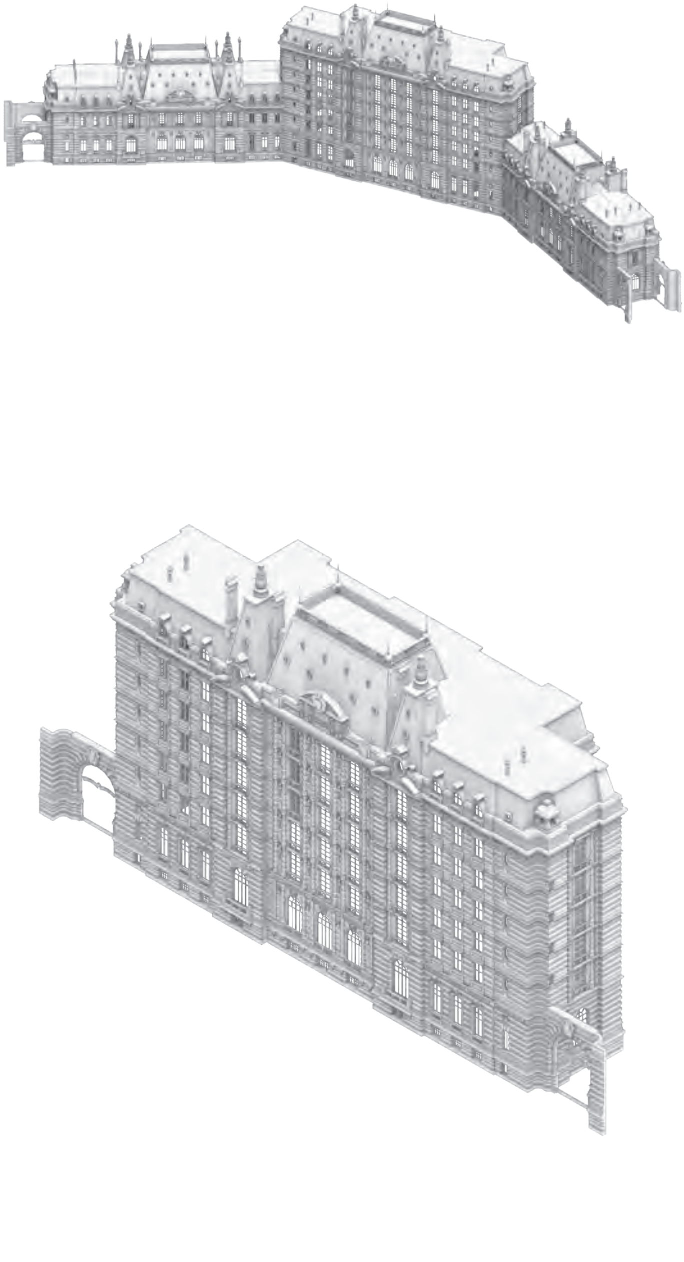
18-30-7 Modulated Composition 01-02- Berliner Borse.



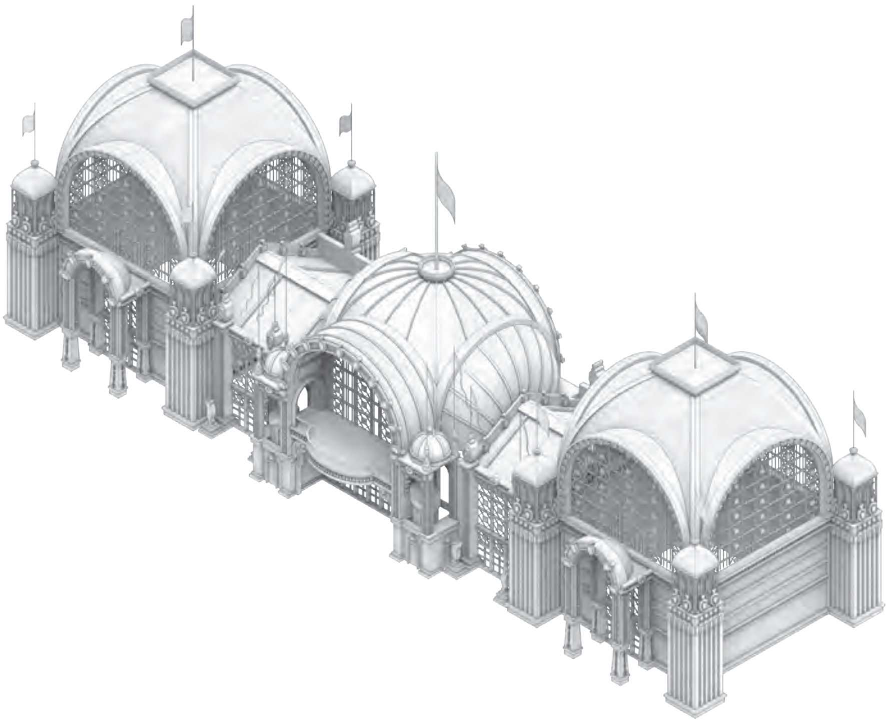
18-30-8 Modulated Composition 01- Plaza Hotel.



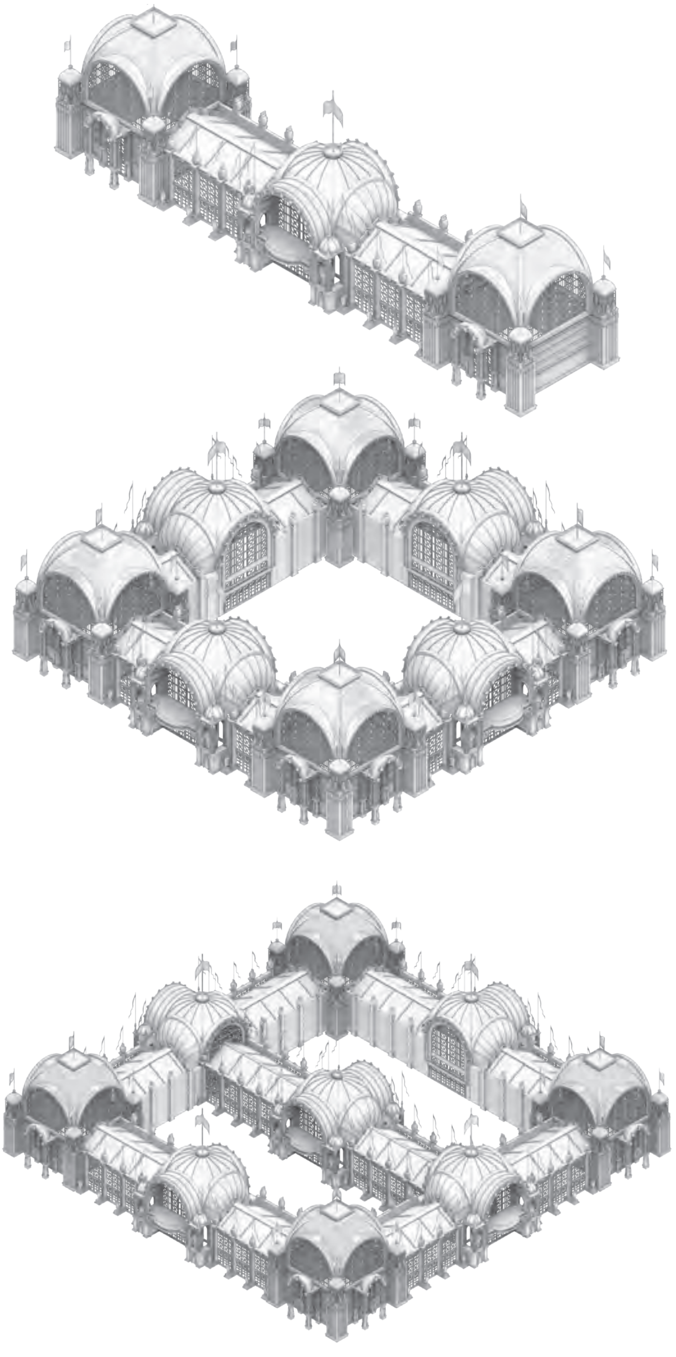
T18-30-9 Modulated Composition 02-03-04-05- Plaza Hotel.



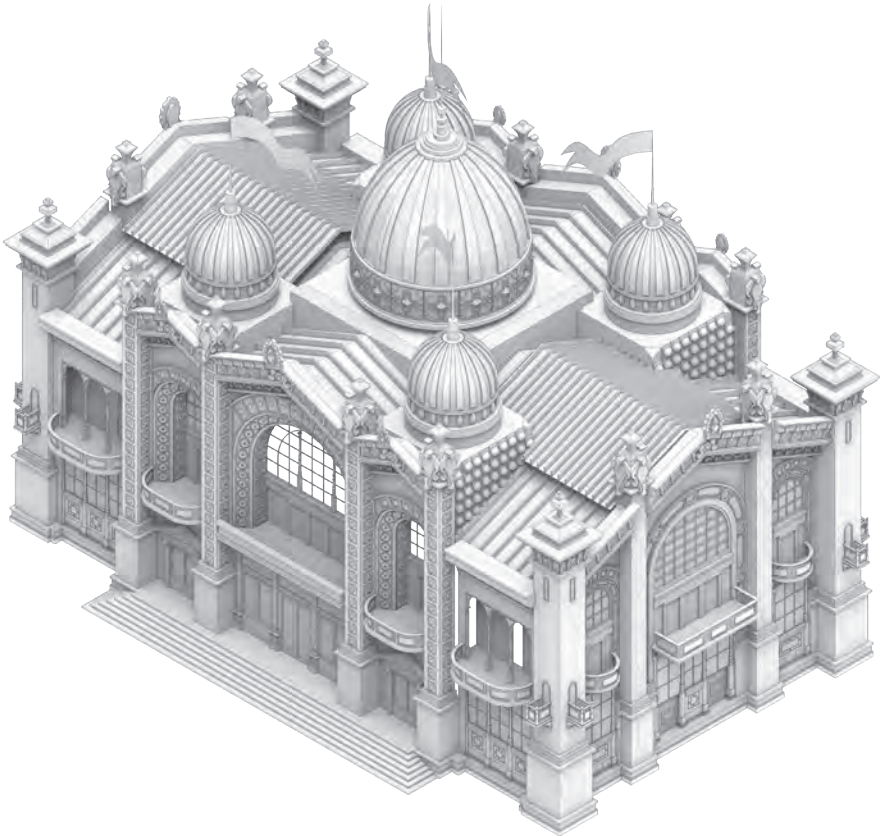
18-30-10 Modulated Composition 01-02- Palacio Paz.



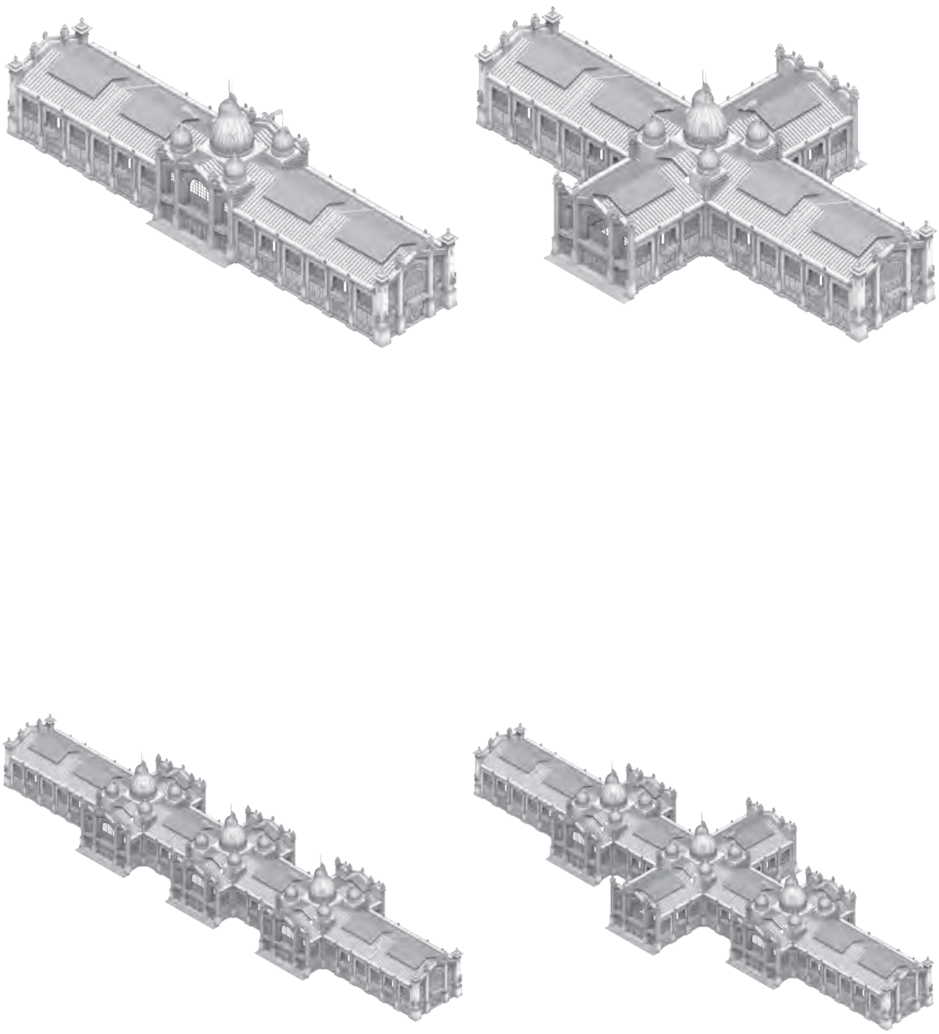
18-30-11 Modulated Composition 01- Palais du Champ de Mars.



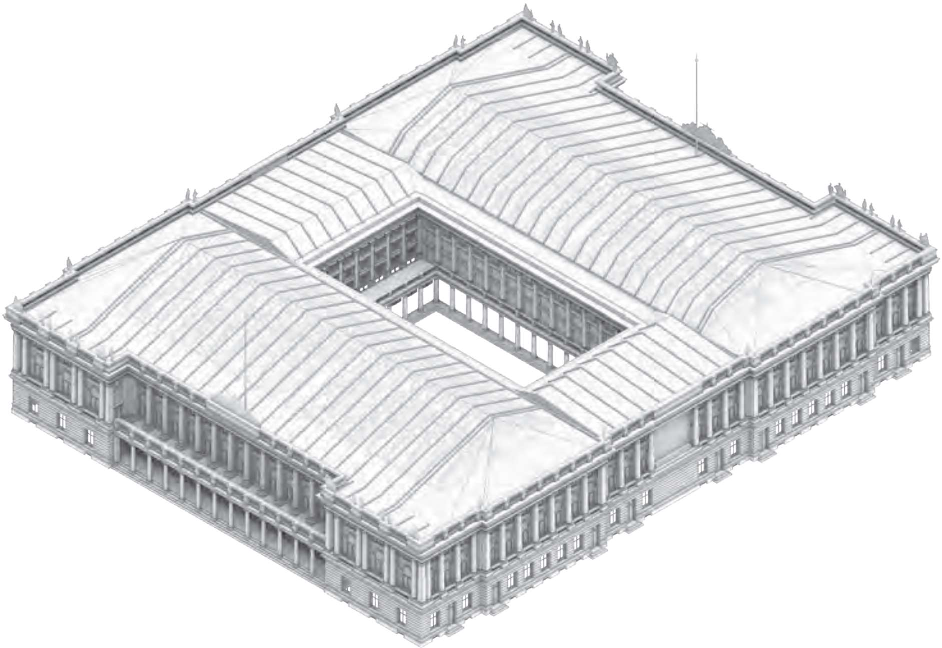
18-30-12 Modulated Composition 02-03-04- Palais du Champ de Mars.



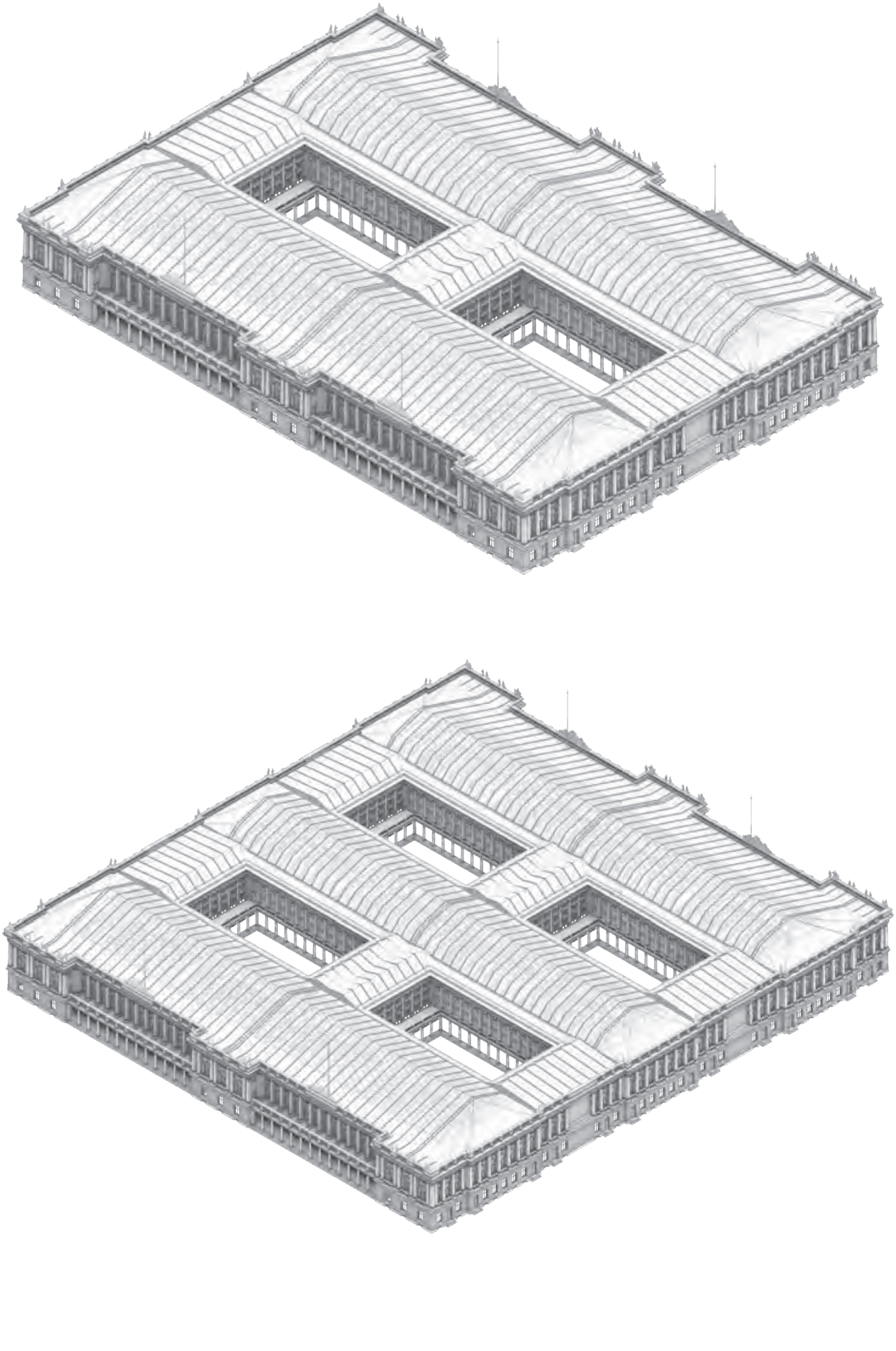
18-30-13 Modulated Composition 01- Argentinian Pavilion.



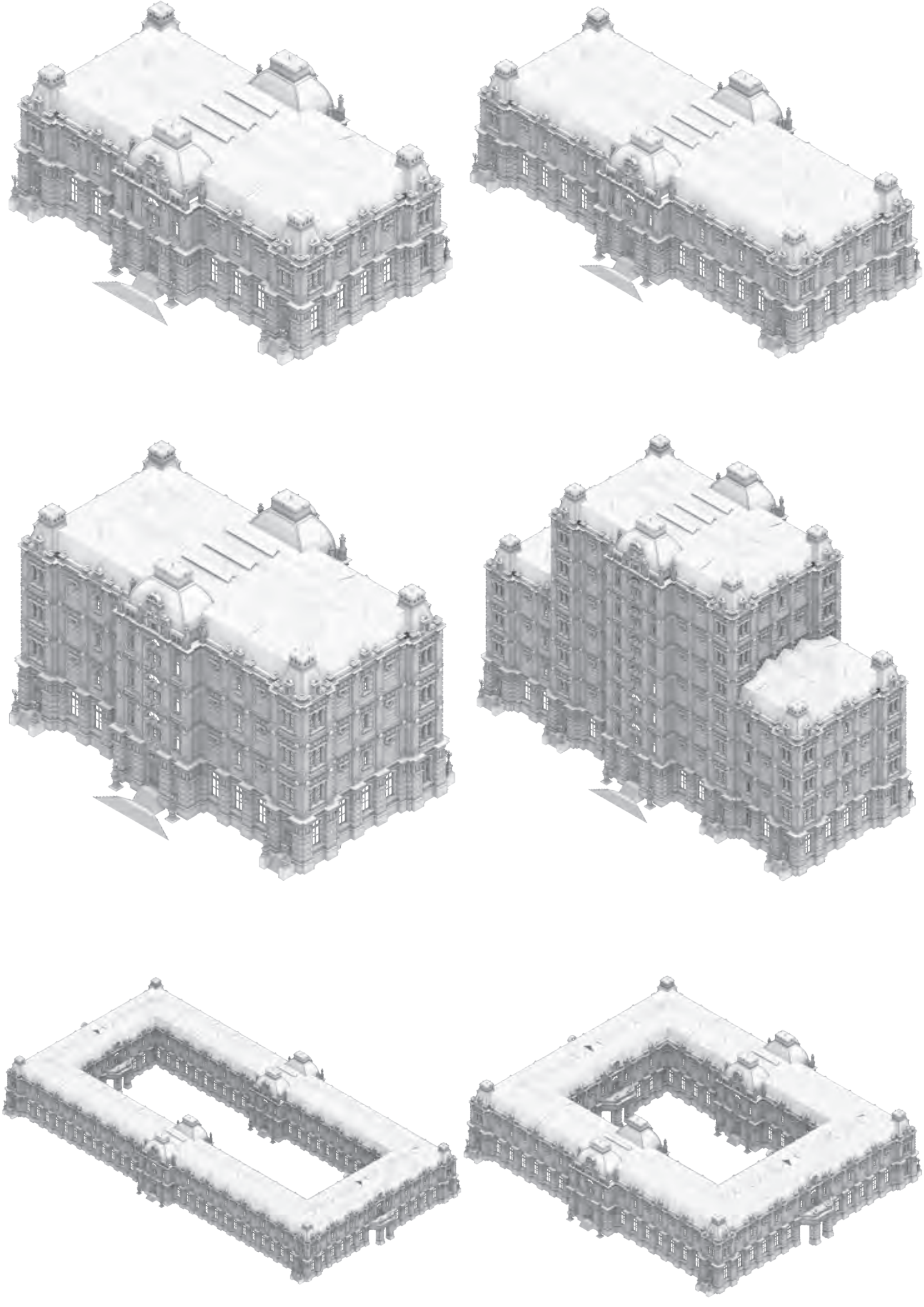
18-30-14 Modulated Composition 02-03-04-05. Argentinian Pavilion.



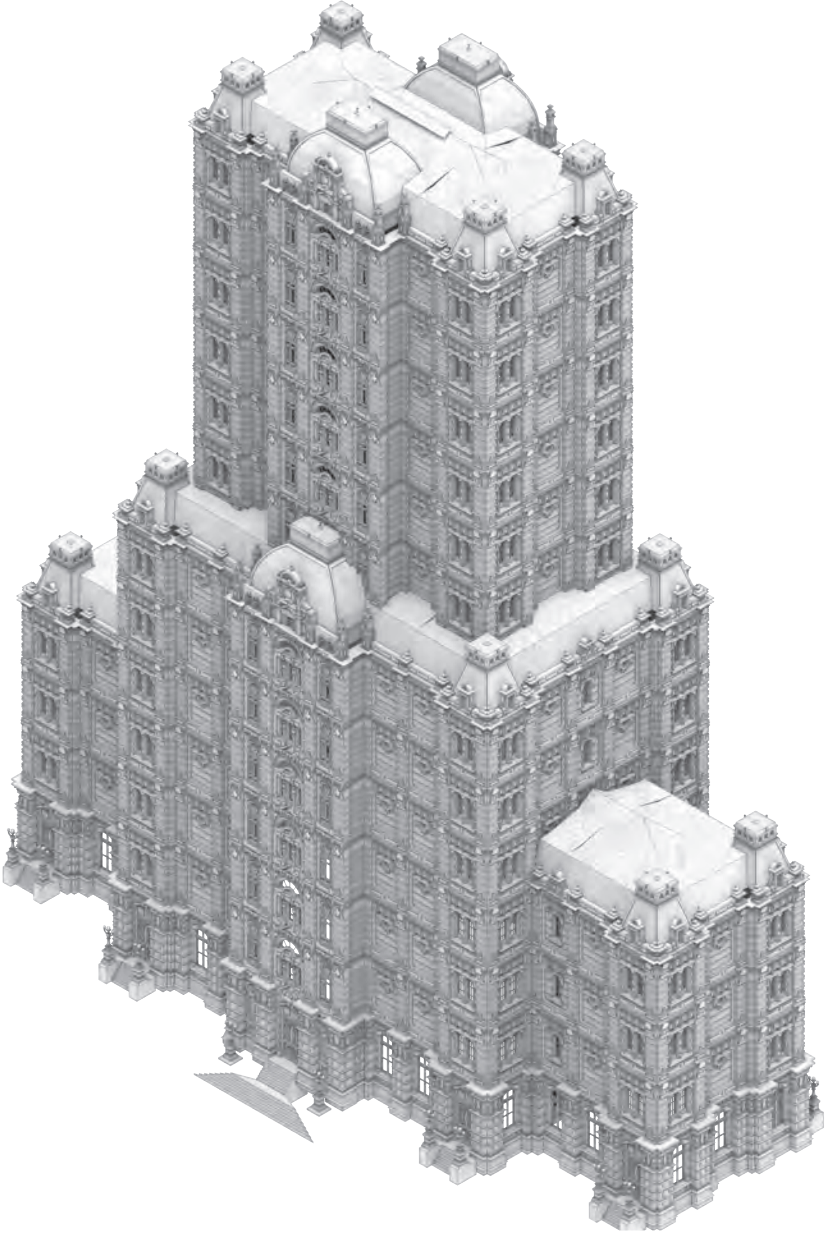
18-30-15 Modulated Composition 03- Berliner Borse



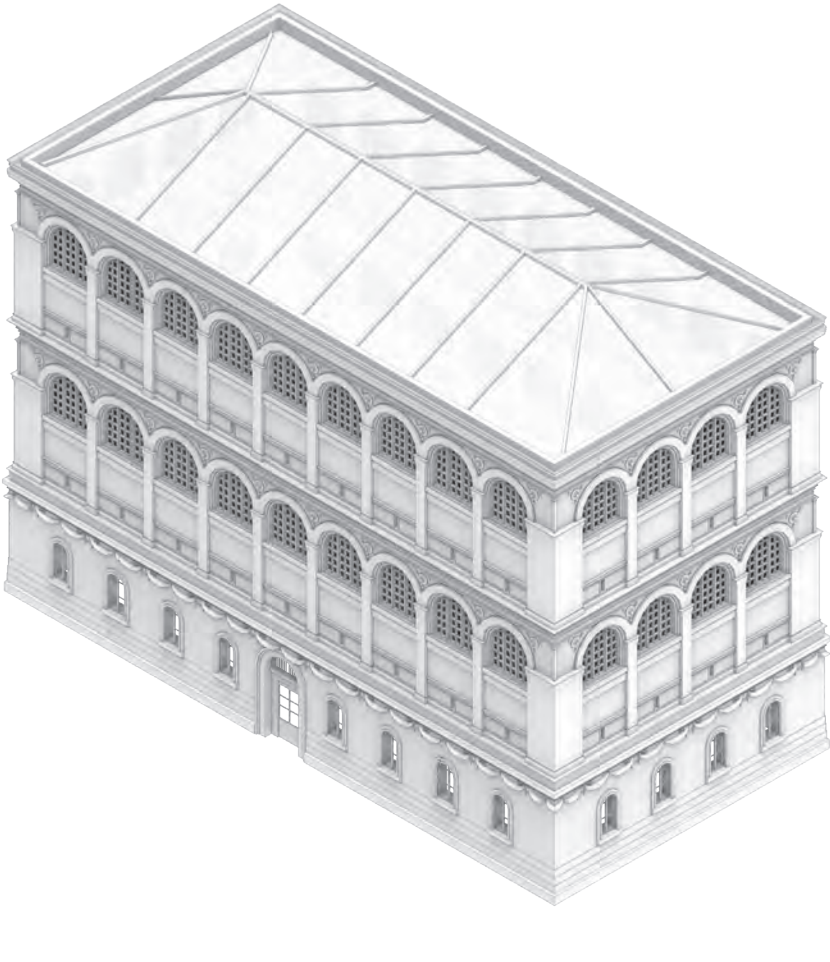
18-30-16 Modulated Composition 04-05- Berliner Borse.



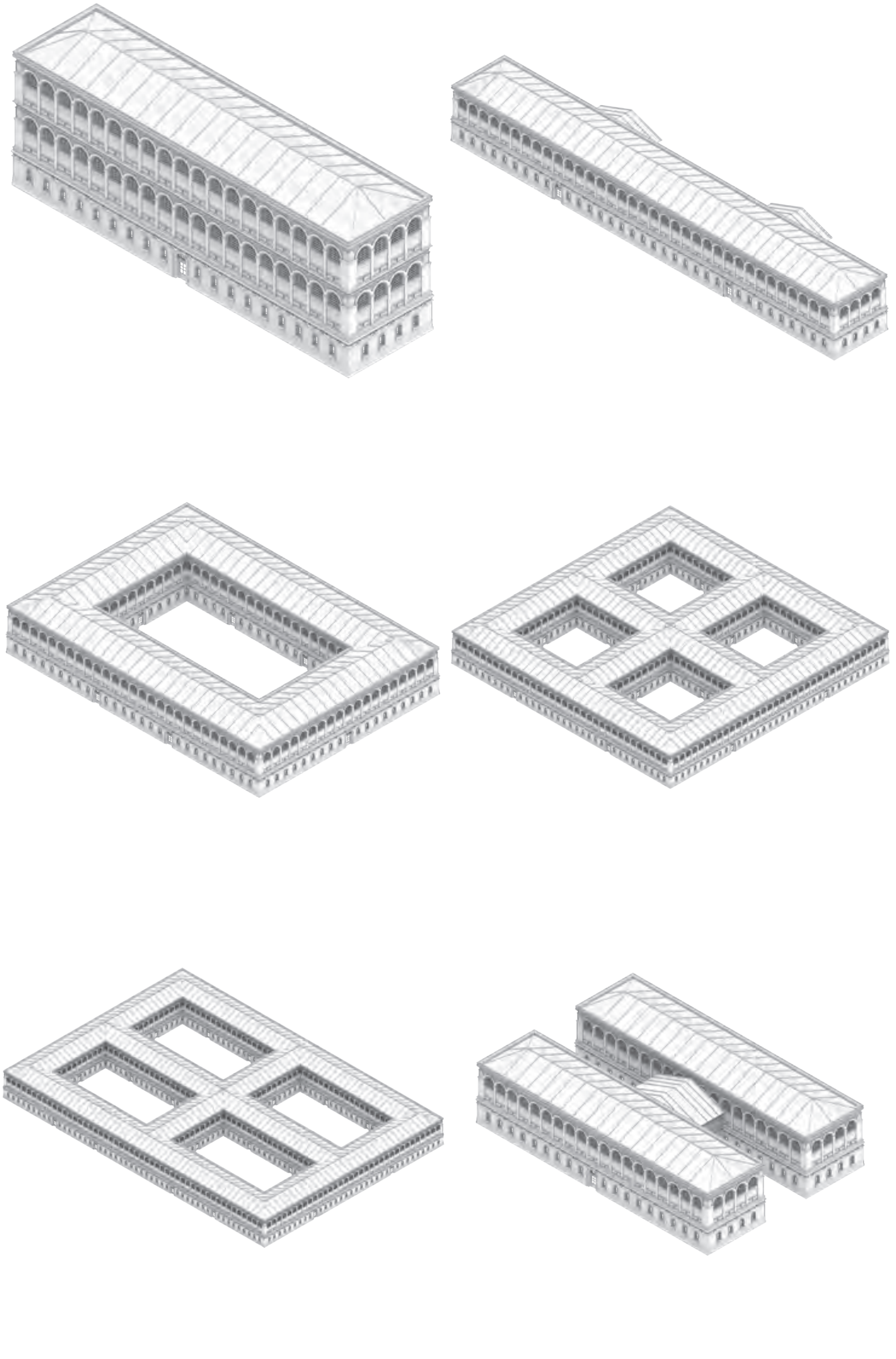
18-30-17 Modulated Composition 12-17 Palacio de Aguas Corrientes



18-30-18 Modulated Composition 18- Palacio de Aguas Corrientes



18-30-19 Modulated Composition 01- Biblioteque Sainte Genevieve.



18-30-20 Modulated Composition 02-07- Biblioteque Sainte Genevieve.

31- LINEAR PALACES

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *Palacio de Aguas Corrientes, Plaza Hotel, Palacio Paz*

DESCRIPTION:

The experiment was programmed as a typological exploration in order to create a flexible parametric model that could encompass several case studies recollected from this research. This aspiration for flexibility could also be understood as universality; the intention for this exercise proved to exceed the initial typological exploration while tapping into a digital design strategy that combined not only the investigation regarding typology, but also to include the site, proportions, expression and character.

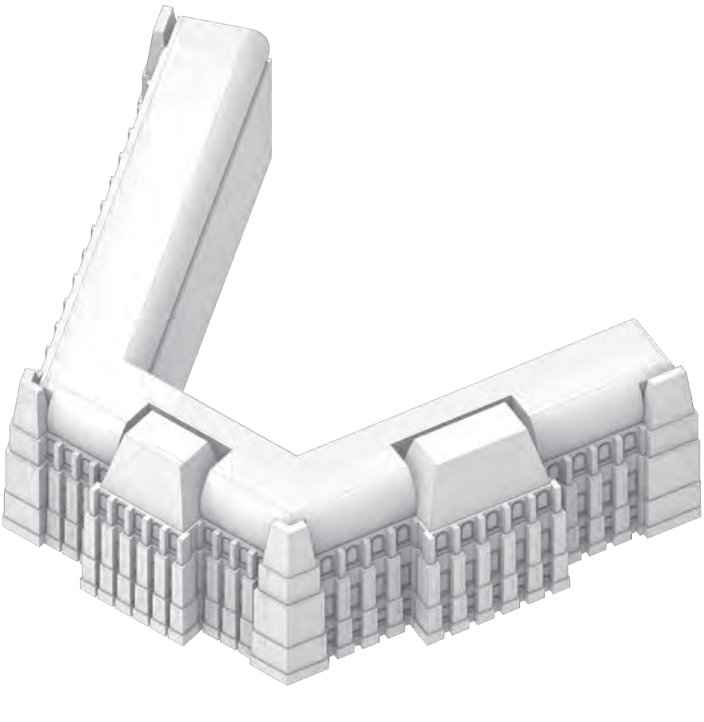
The purpose was to create a parametric definition able to produce a building's envelope, flexible enough to create 'closed' buildings around a courtyard, such as the Palacio de Aguas Corrientes or 'open' or 'linear' ones as the Palacio Paz. For this matter, the definition requires an initial poly-line or polygon to act as a generatrix, on which the building's façade will be placed.

From then on, the rest of the building elements will be generated; towers on the corners or vertices, columns, pilasters, mansard roof, domes, and so on. Each of these members is congruent to each other since they are all dependant on the same generatrix and linked through local and global variables.

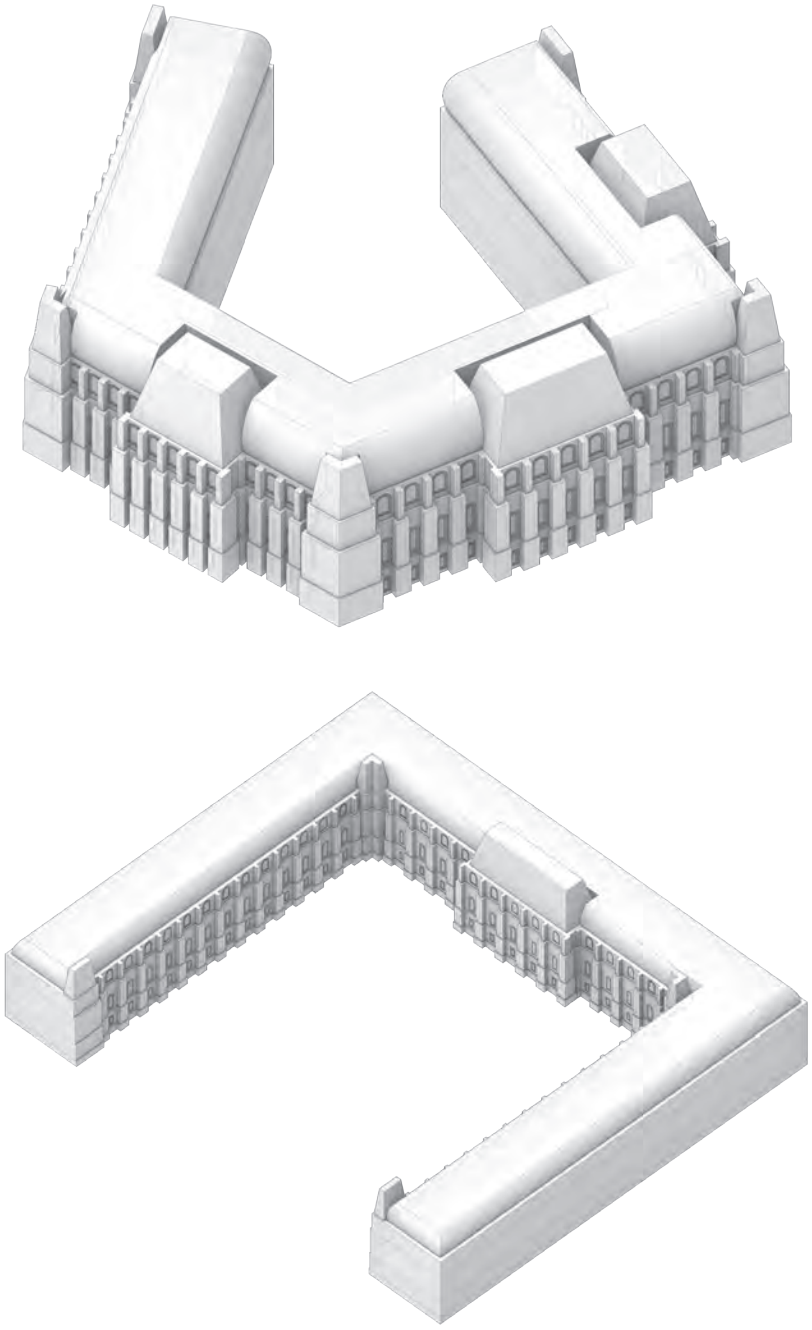
As a design strategy, once this line is defined by the user or another algorithm, each segment of the generatrix polyline or polygon is divided defining a module which will be used to place columns, pilasters, windows, doors, etc.

The modules also govern the building's 'depth' or usable surface, which in turn will also create an inner courtyard, similar to the Palacio de Aguas typology. Similar to other experiments, each of the architectural elements can be further individualized; in size, for example in columns, pillars, towers, or in type, for example in windows (round, rectilinear, mixed), or roofs (sloped, flat, mansard, curved).

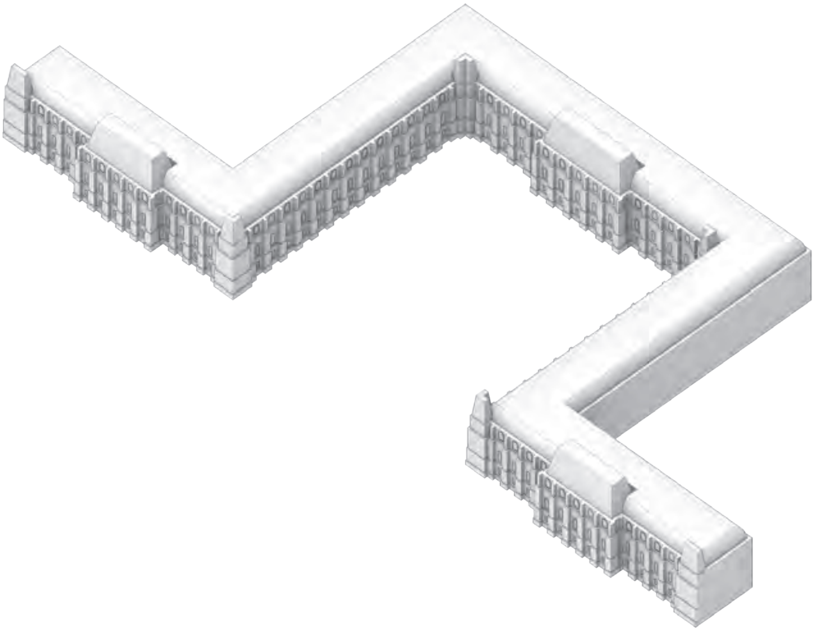
It is also noteworthy that while some parameters from these elements can be precisely defined, such as the height of the roof, other parameters are linked to one another, thus being indirectly defined by the user. An interesting example of such parameters are the façade pilasters; their height is dependent on each stage but their width and depth is indirectly defined by its immediate predecessor. The column from the second level will be slightly smaller than the one from the first, which in turn will be smaller than the ground floor pilaster. The reason for this is the need for a coherent 'tectonical' expression that the experiment intended to grasp. In order to explore the openness of the classical design strategies it seemed fit to uphold such aesthetical premises.

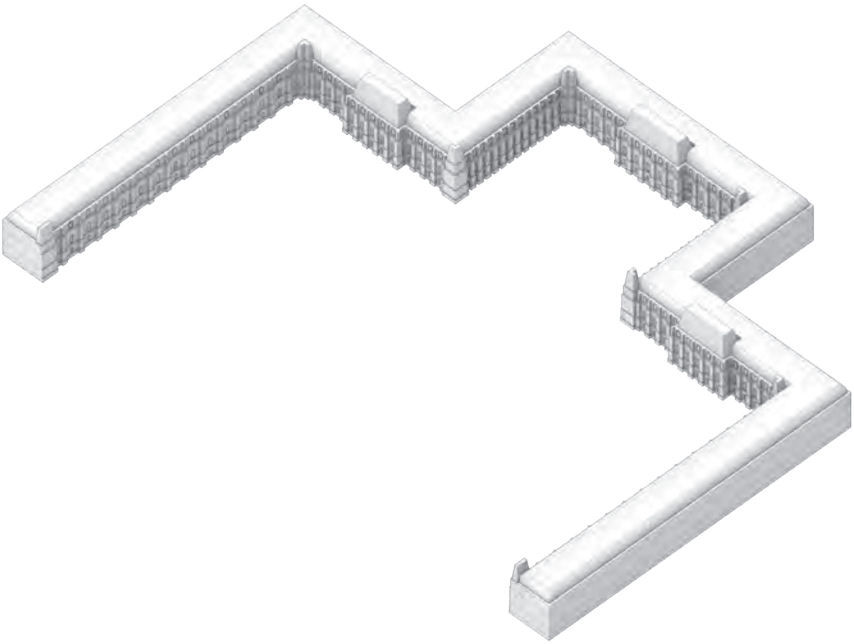


18-31-1 Typological experimentation towards Palacio Paz. Linear Palace 01-02.



18-31-2 Typological experimentation towards Palacio Paz. Linear Palace 03-04.





18-31-3 Typological experimentation towards Palacio Paz. Linear Palace 05-06.

32- LINEAR PALACES 2

SOFTWARE: *Rhinoceros, Grasshopper*

REFERENCES: *Palacio de Aguas Corrientes, Plaza Hotel, Palacio Paz*

DESCRIPTION:

As a continuation of the previous experiment (Linear Palaces) this exercise consisted in applying a parametric definition in order to generate buildings on specific sites with the intention to test other qualities of the results such as scale, proportion or character. These contexts are of a varied quality, for example Buenos Aires (the original sites of Palacio de Aguas and Palacio Paz), Paris (the former site of Les Halles) and Aachen, Germany (Blucherplatz). The reason for this selection was to test out the architectural outcome within different urban contexts, different scales, grid size, open spaces and surroundings. The exploration of these areas of opportunity and the specific relationships that each building ties with each site are also worthy of further research efforts.

This experiment intend to condense an assortment of architectural elements and parameters with the intention to control as much as them, seamlessly in a coherent model. This initial intention was then further expanded in order to incorporate the possibility of integrating more experimental features and explore different architectural characteristics, both in relation to the context as well as with its own internal geometry.

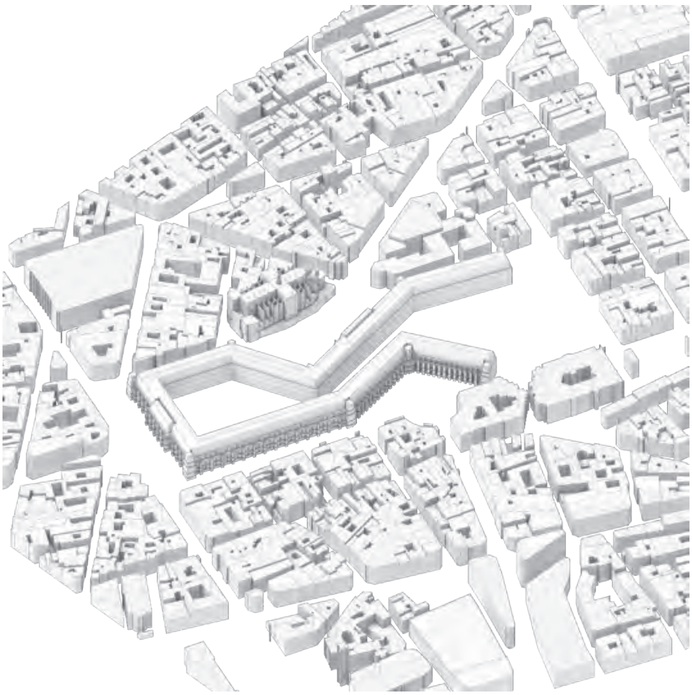
This experiment describes a tension present in many other exercises, a tension between three nodes; fidelity, universality and flexibility. Faithfulness is described as the more or less direct relationship not only with the case study project but also with the classical cannon that brought it into our interest. Universality means that the secondary purpose of each parametric definition is to describe as much architectural possibilities as possible, on this case, it intends to replicate the Palacio de Aguas typology as well as Palacio Paz or even a French chateau from the 18th century. Finally, Flexibility describes the opportunity for this experiment to develop even farther from the case study reference; to produce unexpected, experimental results is ultimately the goal for this research.

The tension between these three nodes is present in most of the experiments and it is one of the drivers of the research. The positioning of each of the exercises closer or farther from each node will determine not only the premises on which each experiment was designed but also the range of its results.

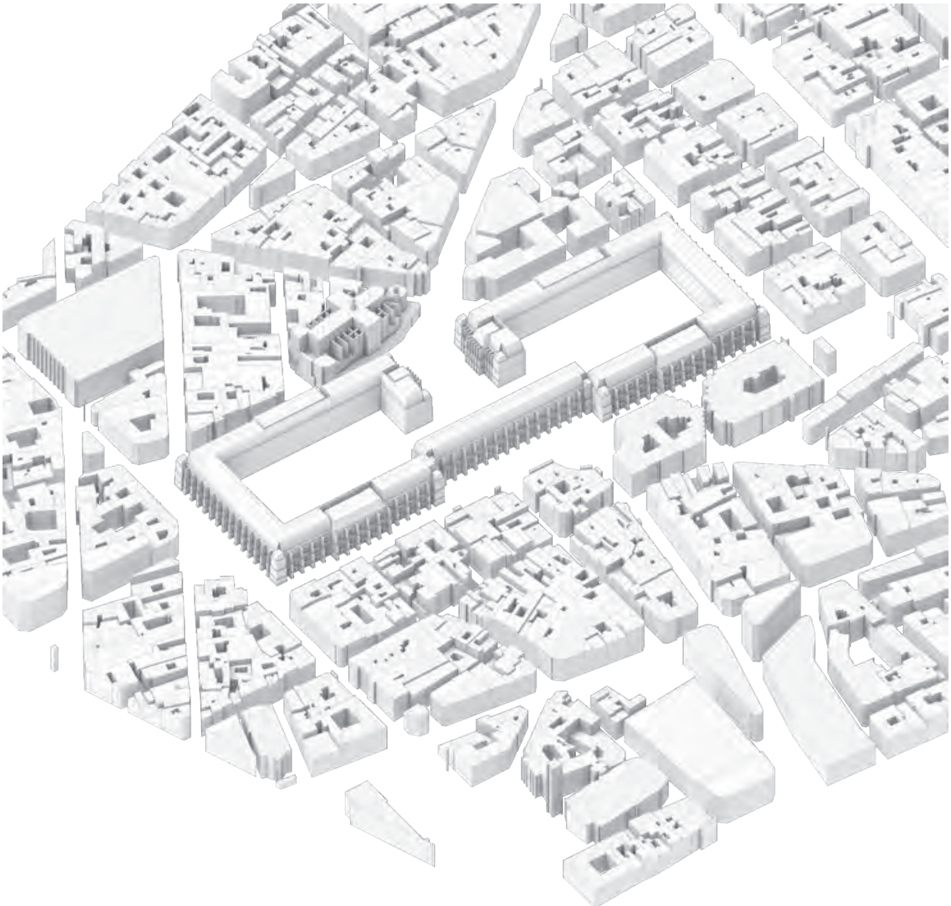
18-32-1 Typological experimentation in urban spaces. Case Study Blücherplatz, Aachen. Linear Palace 07.

18-32-2 Typological experimentation in urban spaces. Case Study Blücherplatz, Aachen. Linear Palace 07.

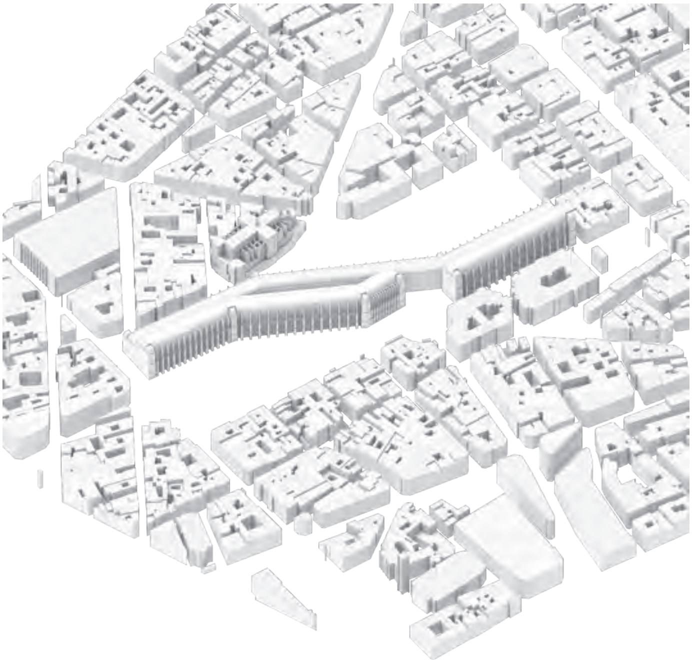
18-32-3 Typological experimentation in urban spaces. Case Study Les Halles, Paris. Linear Palace 09.



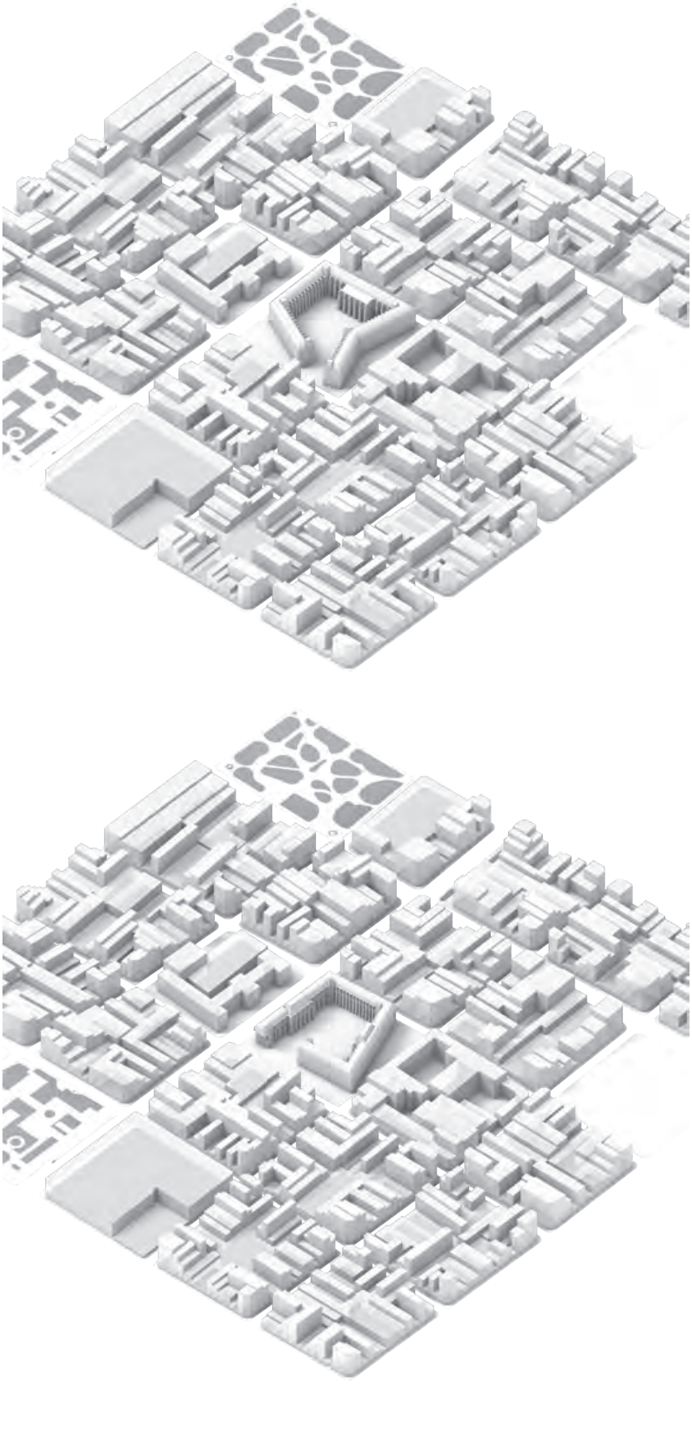
18-32-4 Typological experimentation in urban spaces. Case Study Les Halles, Paris. Linear Palace 09.



18-32-5 Typological experimentation in urban spaces. Case Study Les Halles, Paris. Linear Palace 15.



18-32-6 Typological experimentation in urban spaces. Case Study Les Halles, Paris. Linear Palace 16.



18-32-7 Typological experimentation in urban spaces. Case Study Buenos Aires. Linear Palace 11-12.

CHAPTER 19

- *Conclusions*

The general purpose of an architectural research is two-fold; on one hand to visualize (and render visible) problems that were not yet noticed and on the other, to offer answers in the shape of architectural knowledge. It needs to deliver unknown responses to new and unnoticed issues.

The type of results that this thesis produces as a consequence of architectural experimentation is difficult to evaluate on a positivist base, yet its argumentation is not. Each lesson extracted from the experimentations remains singular and subscribed to its own formal medium, and however difficult their instrumentalization and universalization may be, they may remain possible -and reproducible- outside the scope of this research. Many of the experiments described on this work can be applied to actual architectural problems; as a jumpstart or preliminary sketches on some cases or as production drawings on the last stages of design on other ones.

In the same way on the educational field, a geometrical understanding of architectural typologies or composition techniques might help a novel perception and critique of both historical and contemporary design strategies. Similarly, the operative character of some experiments renders them as a powerful tool in the field of Project Research. On all fields, academic, research or professional, this set of tools (and digital tools in general) requires a thoughtful process of instrumentalization in order to produce a significant and reliable outcome; the uncritical use will most certainly produce ineffective results and turn the whole exercise counterproductive.

Sarquis states that there are two types of architectural innovation from the identification of architectural problems and their resolution: a transferable instrumental one and a non-instrumental one, which creates a whole new set of problems and ´scenarios´ to build up from. This thesis is an example of the latter; it has produced a series of experiments, proto-projects ´finalizable´ or embryonic projects (like Eliaschev´s definition) proposing new problems and paths to walk through them. It foresees new problems, proposes a set of tools to tackle them and provides a theoretical framework to evaluate its results.

As both Sarquis stated, a Project Research thesis does not seek a scientific validity but intends to enhance the discipline´s capacity to identify and construct architectural problems; a narrative encompassing History, Theory, Context, Methodologies and Techniques in a coherent manner.

The use of digital tools and methodologies to investigate on disciplinary and historical topics such as typological variation, spatial articulation and formal experimentation, among many others has proven useful and its potentiality is still untapped. The work at the Poiesis Centre, the collaboration projects with

Rokokorelevanz and the experiments depicted on this thesis are evidence of the potential of such methodologies and the possibilities that these tools and their creative use unleash.

As Merx´s projects testify, a critical understanding of historical methodologies and tools, embodied in the concept of design strategies is still a fertile field of research in view of the crescent influence of digital tools in our practices. A fresh perception of their evolution is required in order to avoid common or familiar answers to novel problems, particularly when interwoven with construction and fabrication techniques, design strategies or historical information.

This ´digital approach´ to historic architectural features intends not only to fuel further digital research but also to reframe our understanding of architectural history and several of its topics and tools, such as formal analysis or close reading. The use of digital tools in order to analyze and produce architectural features other than just the production of visual exuberance is still an interesting and untapped field of research on our discipline. The confluence of historical topics and digital design tools still raises questions and demands further investigations, particularly in view of the new developments in the field of artificial intelligence and machine learning.

This research has also produced several outcomes apart from this thesis, such as the collaboration projects with Rokokorelevanz, conference papers and several collaborations within RWTH in Aachen. All of them revolved around the influence of digital tools and architectural production; the exploration of quality, detail and overall architectural value.

Considering the growing influence of digital tools in our practices, the importance of this thesis rests on the study and development of such tools and how can they be framed within the architectural discipline. This thesis is then attached to the numerous Rokokorelevanz and Poiesis projects on these topics, updating their vast knowledge base as well as producing new problems and questions.

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This research began with a very simple question: how do architects deal with the history of their discipline in the age of digital tools? How can we design, and at the same time learn from the past now that we have an arsenal of impressive tools to our disposal?

The role of architectural history, although variable throughout different periods, is still central to our discipline. Construction technologies, building aesthetics and architectural programs are historically grounded concepts that require a continuous consideration, particularly in the digital turn.

The research deals with a pressing question about our discipline and its design strategies combining historical information and the ubiquity of digital tools. Design strategies in architecture are historically defined, they rely on geometry, context, history, human requirements, building technologies and representational tools. The study of Architecture´s own history, particularly in the verge of technological advancements such as the introduction of new materials or tools may shed some light on how to tackle new challenges in a rapidly shifting context. The development of new design strategies capable of metabolizing these advancements is crucial to our discipline.

On this regard, the role of digital tools in architectural design processes has been growing steadily in relevance for the last twenty years, yet their function has shifted from a representational instrument to a concrete design and manufacturing tool.

This design research aims to illustrate the importance of detail, quality and overall freedom that the study of design and production tools reveals; both historical ones (such as the introduction of iron or ceramics) to contemporary resources, as the use of complex design software and novel fabrication tools have become ubiquitous in our field.

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