EVOLUTION OF THE SURFACE ROUGHNESS OF A COARSE SAND AFTER A BEACH NOURISHMENT

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Abstract – Beach nourishment with material from quarries is an increasingly common practice. These materials are usually coarse sands or fine gravels, and the particles show a very angular and rough surface. In this work, research on the evolution of the surface roughness of coarse sand particles that were dumped in January 2020 at Los Locos beach in Torrevieja (Alicante, Spain) is conducted. This sample came from a quarry and presented a high angularity and roughness on the surface of its particles. Samples were taken monthly for a year and a half (from January 2020 to June 2021), always at the same sampling point. Due to restrictions caused by the Covid-19 pandemic, samples could not be collected for 6 months. Once the samples were collected they were taken to the laboratory where the grain-size analysis of the complete sample was performed, and 108 particles of each of the most significant sieves (1.60 mm, 1.25 mm and 1.00 mm) of the coarse sand (from a quarry) were photographed. The contras, angular second moment (also known as energy), inverse difference moment, correlation and entropy were obtained (for each particle) from the photographs. Also, the swell that occurred throughout the study period was obtained from the SIMAR point 2077096 (the closest point to the study area). The significant wave height, period and direction of the waves affecting the sampling point were analyzed. The results show a decreasing trend in all the parameters studied (median sediment size, contrast, entropy, etc.). Some increases are observed due to the swell that moves the sediments from the backshore to the swash zone. These variations are first observed in the median size but are not seen until the following month in the textural parameters (contrast and entropy). When relating the parameters obtained from the photographs to the particles (contrast, entropy) with the surface texture of the particles, it is observed that they cannot be analyzed separately but must all be considered together. Thus the decrease in contrast and entropy shows a decrease in the superficial roughness of the particles, but the greater the difference between these two parameters, the greater the smoothness of the surface. After a year and a half of dumping the quarry material on the beach, a high degree of decrease in the roughness of the particles is observed; however, to reach the degree of polishing that the particles of a natural beach have, a longer period is necessary.

Introduction

When the coastline undergoes a continuous process of erosion, beach nourishment is a regular process [6]. To mitigate erosion processes, it is common to use artificial structures (breakwaters, groins, etc.) and to dump natural (dredged) or artificial (quarried) sand along the beach [7]. The incorporation of new sediments (different from the original ones) to

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beaches requires a thorough understanding of the processes to obtain the required response of the morphodynamic systems [1]. Since natural materials, mainly fine sands, are scarce, nourishment is currently conducted with coarse sands from quarries. Due to these, it is important to analyze the development of borrowed sand over time [10].

The main studies conducted on borrow sand focus on the evolution of the size and sorting of the dumped sediment [4, 5]. Most of these studies conclude that approximately one year after nourishment, both the size and sorting of the sediment is usually similar to the original material [10]. This is the case when the dumped material is relatively similar (median sediment size equal to or slightly larger) to the original. However, what happens when the median sediment size is significantly larger than the original sand? Does a quarried sand behave in the same way?

This work studies the evolution of coarse sand from a quarry dumped on an originally sandy beach. The evolution of the median size of the sediment, the surface roughness of the particles (since quarry material is usually quite rough and angular) and finally the influence of waves on this evolution will be studied.

Materials and Methods

Study area

This work is based on samples collected at Los Locos beach in Torrevieja, Alicante, in southeastern Spain (Figure 1). At the study area, the temperate climate is Mediterranean, with a semi-warm subtropical sea temperature regime (mean value of 20.5 °C). The local wave regime is strongly dependent on the seasonal nature of the area. It is a beach of 470 m length protected by the NE swells by the cape "Punta del Salaret", and in the south, it is supported by an artificial breakwater, recording 0.64 m mean significant height and 3.7 s mean period. The area is a micromareal zone, the maximum value reaches 75 cm when the astronomical tide (30 cm) is affected by meteorological factors. A small rocky step causes undertow currents that cause a loss of sand that cannot be recovered due to the characteristics of the bathymetry. This originally sandy beach (median sediment size of 0.193 mm and 22 m average width) was nourished (35 m average width) in January 2020 with material from a quarry with a median sediment size of 1.19 mm (Figure 2).

Maritime climate

Puertos del Estado (http://www.puertos.es) provided the data from SIMAR point 2077096 (-0.583 E; 38.000 N; Figure 1c), which was used to obtain the swell. The SIMAR series is the most complete database for the Mediterranean with data since 1958.

The wave height, period and direction of the waves produced during the study period were analysed. The swell data refer only to the swells that impact directly on the study point, from N111ºE to N204ºE (Figure 1d). The rest of the swells are considered calm at this point of the beach.

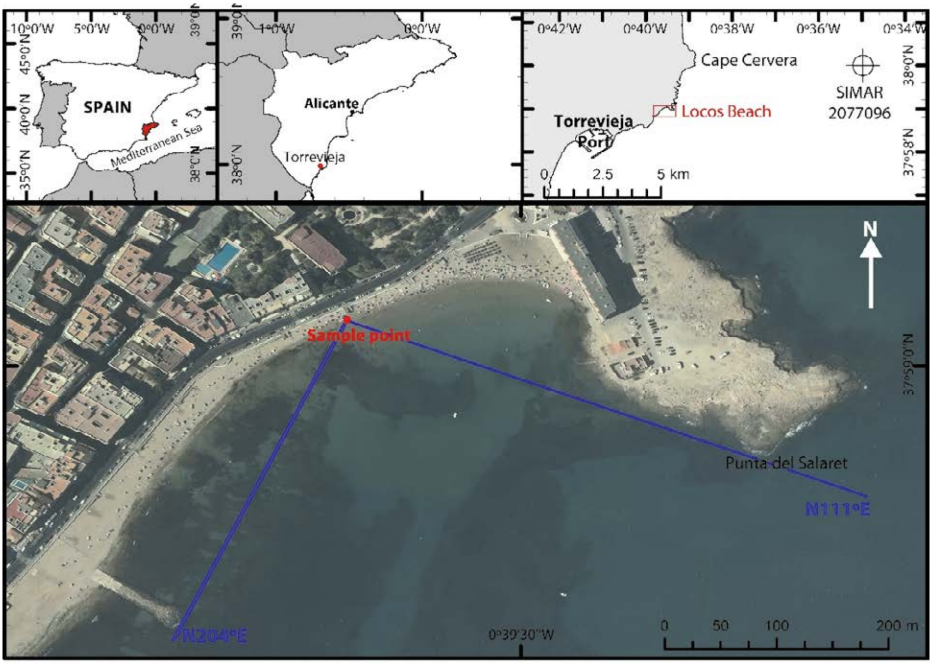

Figure 1 – a) Study area located in Spain, b) in the province of Alicante and (c) in Torrevieja town, with the location of the SIMAR node used for wave data. d) Location of sample point at Los Locos beach.

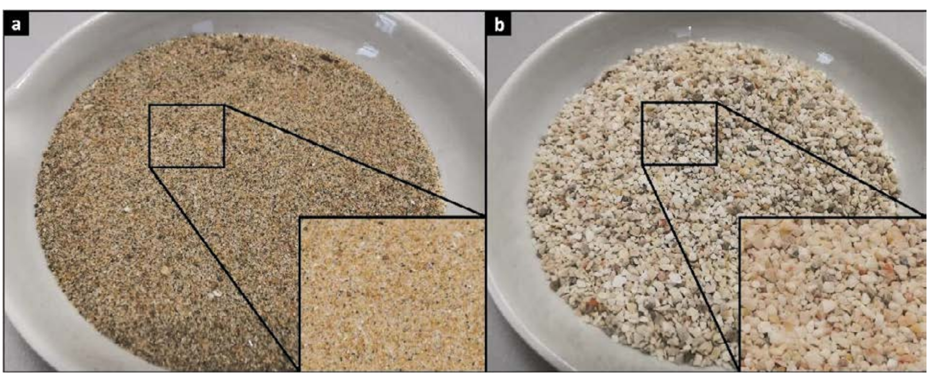

Figure 2 – a) Sample of the original beach (median sediment size of 0.193 mm). b) Sample of the material of the nourished beach (median sediment size of 1.19 mm).

Sediment analysis

Sampling was performed always at the same point (705536.22; 4206585.76;30) of the swash zone (Figure 1d) from January 2020 to June 2021 between the 15th and 20th of each month. Due to the Covid-19 pandemic and the mobility restrictions it caused, samples could not be collected between March and August 2020.

Once the samples were collected, they were taken to the laboratory where they were washed and grain-size analysis was performed. Then from each sample and sieve (1.60 mm, 1.25 mm and 1.00 mm as they retained the highest percentage of the sample), 108 particles were photographed with a microscope with a wide resolution and a magnification of at least 50x.

The subsequent image processing (texture measures) and statistical treatment were performed using ImageJ. In ImageJ, this is accomplished using Julio Cabrera's plugin GLCM (grey level cooccurrence matrix) Texture Analyzer [3]. The distance – offset – between two pixels was established on 1 (size of the step) and their spatial relationship was calculated for direction of the step of 0, 90, 180 and 270 degree angle). The outputs were: contrast, angular second moment (also known as energy), inverse difference moment, correlation and entropy were obtained. Finally, the average for 0, 90, 180 and 270 was conducted.

Results

First, the results concerning the evolution of the median sediment size are shown (Figure 3). The median sediment size (D_{50}) of quarry material originally (18/01/2020 describes filling sediment parameters during the nourishment) had a value of 1.19 mm, but due to waves it is mixed with the original beach material (D_{50} = 0.193 mm) and in April 2021 the D_{50} was 0.344 mm with only 43 % of the sample being quarry material (> 0.4 mm). The sediment size at the sampling point and the percentage of quarry material varies throughout the study period, the increases in both parameters are mainly due to waves (Figure 4). After events with wave heights greater than 1.5 m, these parameters increase, because the swell picks up material from the backshore and deposits it on the shoreline.

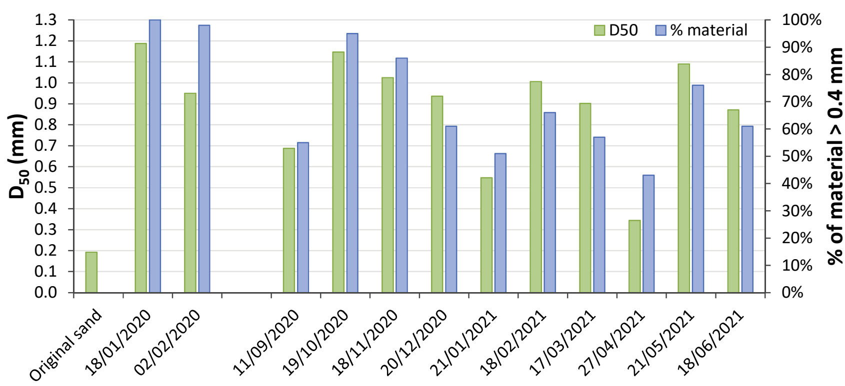

Figure 3 – Evolution of the median sediment size (D_{50}) and the percentage of material larger than 0.4 mm.

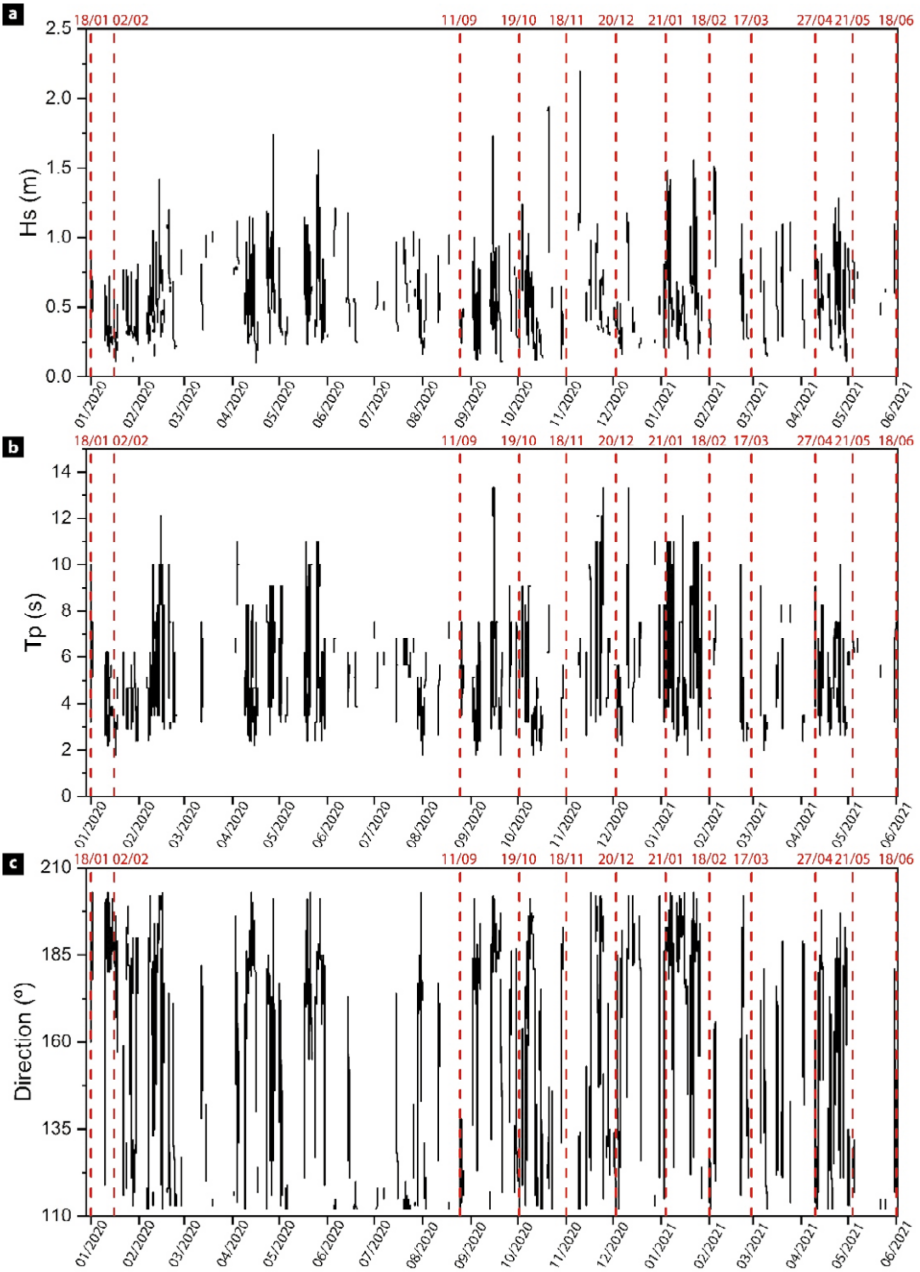

Figure 4 – Wave data that impact the study point during the monitoring time and sampling dates (marked vertically). a) Significant wave height (in meters). b) Wave period (in seconds). c) Wave direction (in degrees, 0 is north, 90 is east, 180 is south, and 270 is west).

Secondly, the results of the evolution of contrast (C), entropy (E), and the difference between contrast and entropy are shown (Figure 5 and Figure 6). Of the five parameters studied on the particle photographs, only these parameters are shown since they show the greatest relationship with particle surface roughness. As with D_{50}, it is observed that all parameters tend to decrease during the study period. However, when D_{50} increases this is not represented in the textural parameters until the following month, for example, the increase in D_{50} that occurs in February 2021 is not represented in the entropy until March 2021. This could be because the increase in median size in February was due to a loss of the finer material and did not affect the coarse material of the nourishment. Whereas the increase in entropy the following month may be due to a storm that moved material from the foreshore to the swash zone a few weeks before the sample was collected.

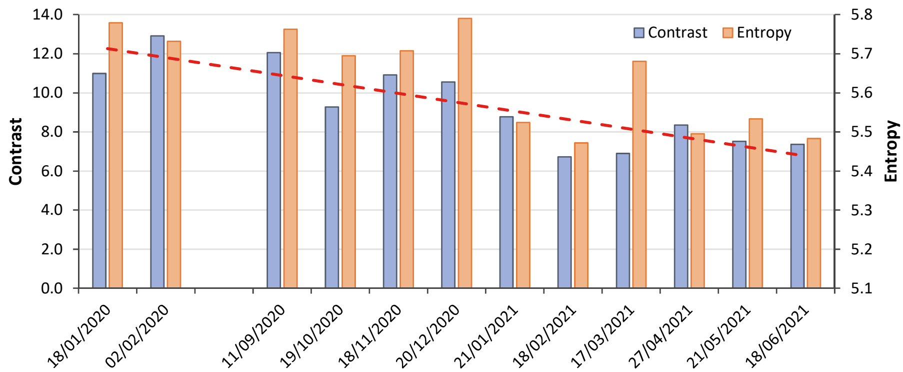

Figure 5 – Evolution of contrast and entropy of analyzed particles from beach nourishment.

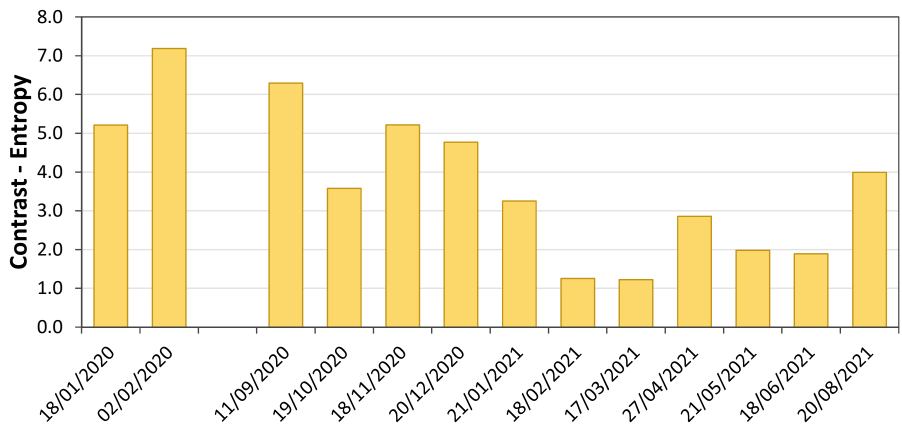

Figure 6 – Evolution of the difference between contrast and entropy (contrast minus entropy) since beach nourishment.

Nevertheless, although the textural parameters (contrast and entropy) show a decrease over time, when these values are related to the image of the particles (Figure 7) it is observed that to determine the evolution of the surface roughness of the particles, the textural parameters cannot be considered individually, but must all be considered together. Thus it is observed that the lower the contrast and entropy the less rough the surface is, but the higher the ratio between contrast and entropy (C-E) the higher the smoothness of the particle.

Finally, it is observed that after a year and a half of wave action on the particles they reach a level of surface roughness similar to those of a natural beach. Although a longer period is still necessary to reach the level of polishing that natural particles have (Figure 7b), the quarry particles reach a high degree of rounding and surface smoothness (Figure 7e,f) concerning their original state (dumping time, Figure 7a).

Figure 7 – a) Particles dumped on the beach in January 2020. b) Particles of a natural beach (Playa del Triador, Castellón, Spain). c-f) Particles with the maximum and minimum values of contrast (C), entropy (E) and contrast-entropy (C-E).

Discussion

According to different authors, approximately one year after sandy beach nourishment with borrow material, the median sediment size is very similar to the size of the original beach sediment [4, 5, 10]. However, in this case, where the size of the dumped material is 6.17 times larger than the original beach sediment this does not occur (Figure 3). The closest size to the original sand size occurs in the April 2021 sample (16 months after the dumping) with a value of 0.344 mm (1.8 times larger than the original) and 43% of new material (> 0.4 mm). However, due to the swell, which incorporates new material from the backshore, this size increases considerably in the following months. Therefore, to reach a size similar to that of the original beach, much more time must pass, so that the quarry material decreases its volume on the beach and wears out [8].

Regarding the surface roughness of the particles, few studies have been conducted [2, 9]. One of them concerns the abrasion rate on pebbles on a beach in Italy, in which the volume loss was measured and reached 61% after 13 months of dumping the material. [2]. And although in this study only the degree of rounding of the particles was measured (by weight loss and visually), whose size was much larger than those of our research (> 50 mm), the period to reach a good surface roughness agrees with that demonstrated in this work (18 months).

Conclusion

A significant increase in surface roughness is observed over time. It is observed that in a year and a half the particles found in the swash zone reach a significant surface smoothness. It should be taken into account that there is an important period of absence of samples due to Covid, during which important storms occurred, so perhaps the fact that during the first year no significant variability in surface roughness is observed may be due to the movement of the sediment by the waves. However, it can be assured that in approximately 1.5 years the quarry particles are smoothed reaching values similar to those that can be found in a natural beach, although more time is required to achieve the same level of surface polish.

References

[1] Benedet L., Finkl C.W., Campbell T., Klein A. (2004) - *Predicting the effect of beach nourishment and cross-shore sediment variation on beach morphodynamic assessment,* Coast Eng. 51 (8), 839-861.

[2] Bertoni D., Sarti G., Grottoli E., Ciavola P., Pozzebon A., Domokos G., Novák-Szabó T. (2016) - *Impressive abrasion rates of marked pebbles on a coarse-clastic beach within a 13-month timespan,* Mar Geol. 381, 175-180.

[3] Cabrera J.E. (2003) - *GLCM Texture Analyzer*; Available from: http://rsb.info.nih.gov/ij/plugins/texture.html.

[4] Campbell T., Benedet L. (2006) - *Beach nourishment magnitudes and trends in the US,* Journal of Coastal Research. 39, 57-64.

[5] Chu M.L., Guzman J.A., Muñoz-Carpena R., Kiker G.A., Linkov I. (2014) - *A simplified approach for simulating changes in beach habitat due to the combined effects of long-term sea level rise, storm erosion, and nourishment,* Environmental modelling software. 52, 111-120.

[6] Elko N., Briggs T.R., Benedet L., Robertson Q., Thomson G., Webb B.M., Garvey K. (2021) - *A century of U.S. beach nourishment,* Ocean & Coastal Management. 199, 105406.

[7] Liu G., Qi H., Cai F., Zhu J., Lei G., Liu J., Zhao S., Cao C. (2021) - *Morphodynamic Evolution of Post-Nourishment Beach Scarps in Low-Energy and Micro-Tidal Environment,* Journal of Marine Science Engineering. 9 (3), 303.

[8] López I., López M., Aragonés L., García-Barba J., López M.P., Sánchez I. (2016) - *The erosion of the beaches on the coast of Alicante: Study of the mechanisms of weathering by accelerated laboratory tests,* Science of The Total Environment. 566–567, 191 - 204.

[9] Nordstrom K.F., Pranzini E., Jackson N.L., Coli M. (2008) - *The marble beaches of Tuscany,* Geographical Review. 98 (2), 280-300.

[10] Santos-Vendoiro J.J., Muñoz-Perez J.J., Lopez-García P., Jodar J.M., Mera J., Contreras A., Contreras F., Jigena B. (2021) - *Evolution of Sediment Parameters after a Beach Nourishment,* 10 (9), 914.