Beach sediment grain size variability based on image analysis

J. Cascalho (1, 4), I. Bosnic (2, 3), R. Taborda (3), M. Ribeiro (2, 3), C. Lira (4) e M. Carapuço (3)

(1) Museu Nacional de História Natural e da Ciência (UL) e Centro de Geologia da FCUL, Campo Grande, 1749-016 Lisboa, Rua da Escola Politécnica 56/58, 1250-102 Lisboa, jpcascalho@fc.ul.pt
(2) Instituto Hidrográfico, Rua das Trinas, 49, 1249-093 Lisboa
(3) Instituto Dom Luiz, Universidade de Lisboa, Campo Grande, 1749-016 Lisboa
(4) Centro de Geologia da FCUL, Campo Grande, 1749-016 Lisboa

Abstract: Sediment grain size variability is fundamental to understand the processes and direction of sediment transport on littoral systems. The aim of this work is the characterization of the grain size variability and the implications on the definition of adequate sampling strategies. The work was developed at Norte beach, a high energetic and heterometric sandy beach located at Nazaré (west coast of Portugal). The beach sediment was digitally photographed in order to compute the median grain size using the image analysis based on the autocorrelation method. A total of 1498 images were taken covering the beach face superficial and sub-superficial sediment and also some beach face representative cores. Results question the representativeness of surficial sampling as systematic deviation from the beach "typical" grain size was detected.

Keywords: textural, digital, sand, sampling, beach face

1. INTRODUCTION

Grain size is a very important physical property of the sediment particles, because it affects the sediment entrainment, transport and deposition (Folk and Ward, 1957; Friedman, 1979). On many beach environments a simple visual inspection of the superficial sediments in a cross-shore profile can reveal large grain size contrasts, for example, between fine and very coarse sand. If we aim to do an accurate study of the beach grain size variability based on traditional methods (e.g. sieving or laser-diffraction analysis) it is necessary to collect hundreds of samples which would imply an unreasonable need of personal, equipment and funding. Alternatively, if this characterization is based on sediment image analysis (IA) the above limitations could be overcome.

This work aims to demonstrate the usefulness of the IA to describe the grain size variability of a beach with large grain size contrasts – the North beach (Nazaré) - and to support the definition of a suitable sampling methodology that characterizes the overall system grain-size.

2. METHODS

Fieldwork was conducted at Norte beach (Nazaré) on July, 20th, 2011. This beach is located at the Portuguese west coast, at about 2 km north of Nazaré and at approximately 120 km north of Lisbon (Fig. 1).This coastal stretch is fully exposed to the north Atlantic swell and has a semi-diurnal mesotidal regime.

Sediment textural variability was accessed through the acquisition of in-situ high resolution digital images. A total of 1498 digital samples were acquired from which 215 refer to the superficial sediment, 215 to sub-superficial sediment (obtained by removing the uppermost sediment layer with 1 centimeter thick) and 1068 represent 1 cm thick cores sections, from a total of 38 cores (Fig. 2). The images were processed through an autocorrelation-based algorithm developed by Bosnic (2011) and Bosnic *et al.* (*this volume*) which is based on Barnard *et al.* (2007) work.

Beach topographic survey and sampling location was performed using a DGPS, in RTK mode. A representative cross-shore profile shows a steep beach face and the presence of several berms (Fig. 3). The elevation of the active berm crest was 4 m.

All data was assembled and processed in a GIS environment.

Fig. 1.Norte beach location.

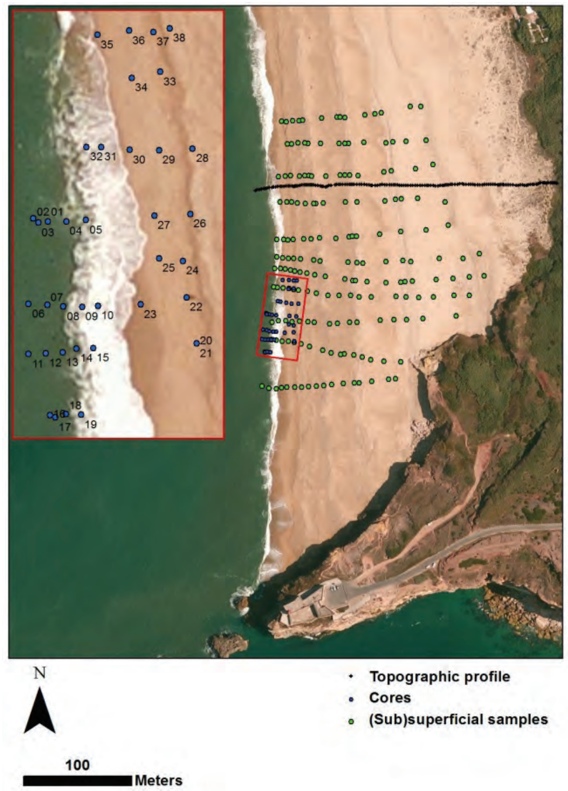

Fig. 2.Sampling location (green dots represent the location of the superficial and sub-superficial samples; blue dots represent the cores location).The location of the cross-shore topographic profile is represented by the black line. The inset represents the coring area. The orthophoto date does not match with the fieldwork date.

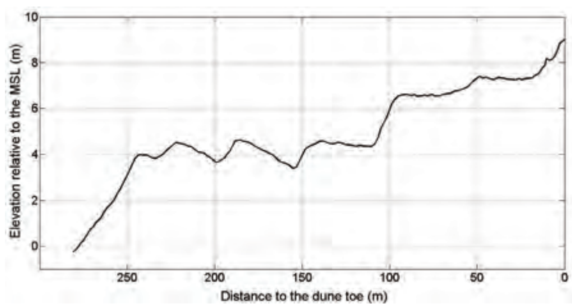

Fig. 3.Beach cross-shore topographic profile (the location is represented on figure 2).

3. RESULTS

3.1.Beach textural variability

Results show that the median grain size of the North beach sand is highly variable, ranging from -2.60 to 1.79 Φ. The statistical parameters that describe median grain size variability across the beach are summarized on table I.

Table I. Statistical parameters of the median grain size according to the main sample groups: ALL- all samples, CORES – cores, SUP –superficial, SUB-SUP – sub-superficial for the entire beach sampled area; SUP_C – superficial, SUBSUP_C – sub-superficial for the coring area. On the first table line: # - number of samples, min – minimum value, max – maximum value, std – standard deviation (all values in Φ units).

Sample group		#	mean	min	Max	std
ALL		**1498**	**0.18**	**-2.60**	**1.79**	**0.63**
BEACH AREA	CORES	1068	0.18	-1.50	1.49	0.47
	SUP	215	-0.08	-2.60	1.77	0.97
	SUBSUP	215	0.44	-2.35	1.79	0.78
CORING AREA	SUP_C	23	0.48	-0.55	1.16	0.40
	SUBSUP_C	23	0.76	-0.10	1.28	0.38

The superficial sediments (represented by the SUP group) are the coarser ones with a mean grain size of -0.08 Φ, ranging from -2.60 to 1.77 Φ; and the finer ones are represented by the SUBSUP group with a mean of 0.44 Φ, ranging from -2.35 to 1.79 Φ.

3.2. Cores textural variability

Along each of the 38 collected cores the difference between the median grain size maximum and minimum rarely exceeds 2 Φ. Most of the cores (23) show a sedimentary positive sequence (the sediment became progressively finer from the base to the top) and the other 15 show an undefined sedimentary sequence. The occurrence of these two types of sequences(positive or undefined) is apparently not correlated with the beach morphology. The same is true if we represent the spatial distribution of each core median grain size (Fig.4). Additionally, if we represent the mean, minimum and maximum of the correspondent core levels it is possible to confirm the dominance of the positive sequence with an average difference of about 0.5 Φ between the lower and the upper levels (Fig.5).

3.3. Superficial spatial variability

For the superficial sediment it can be seen the existence of a longshore band with an approximate 50 m width where the sediment has a median grain size coarser than 0 Φ. This coarser sediment band is approximately located in the beach berm (Fig. 6).

3.4. Sub-superficial spatial variability

For the sub-superficial sediments a similar grain size distribution pattern is observed. However, the median values are considerable lower than the precedent ones (approximately 0.5 Φ)(Fig. 6).

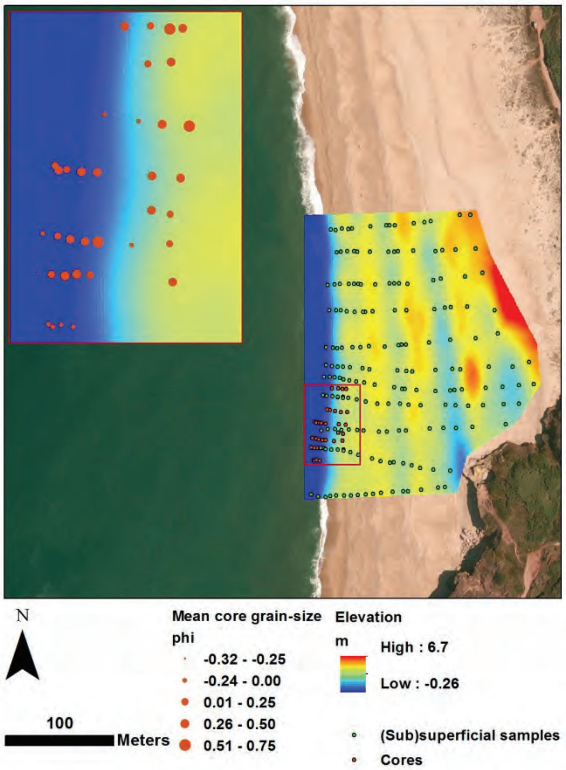

Fig. 4.Distribution of the mean core grain size according to the beach topography.

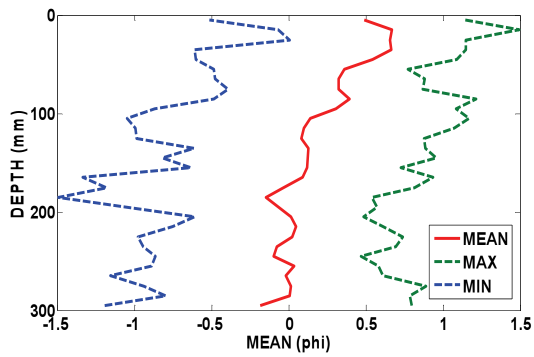

Fig. 5. Mean, maximum and minimum of the sediment media along the 38 collected cores.

4. DISCUSSION

The extensive grain size database collected at North beach allowed, for the first time, the detailed description of spatial (horizontal and vertical) textural variability of a sandy beach.

The magnitude of this variability, higher than 4 Φ, arises two main questions: What is the beach representative grain size? How can we sample it? From the present study it became clear that a random sample collected from the beach topographic surface does not represent the typical beach grain size sediment (Fig 7).

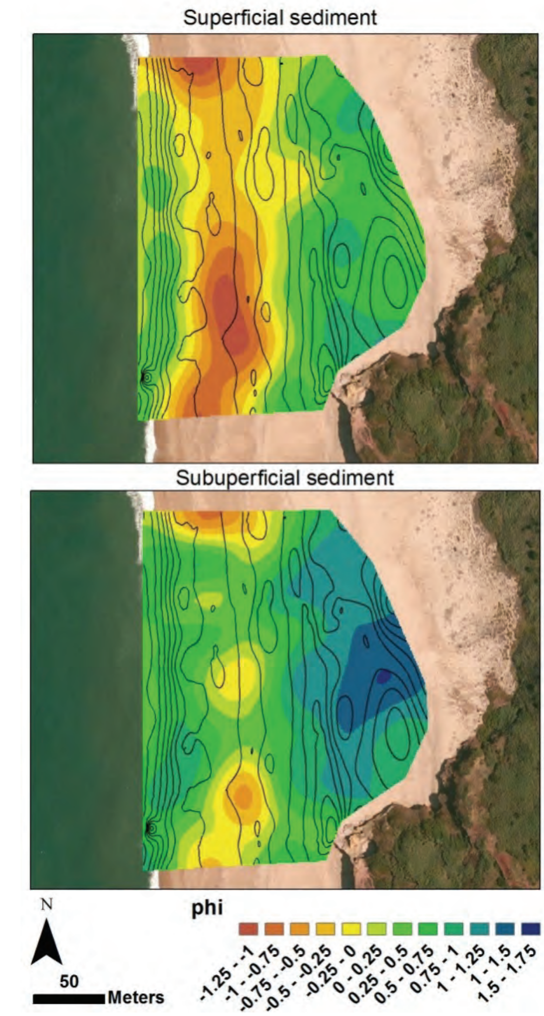

Fig.6. Median grain size distribution pattern of the superficial (top) and sub-superficial sediments (bottom).

Results of the superficial layer show that the sediments have a higher than average median-grain size, while sub-superficial one has an opposite behavior. This is because the uppermost beach layers are in equilibrium with specific hydrodynamic conditions and therefore cannot represent the average time and spatial beach conditions. This averaging is naturally represented in the sediment column which can be obtained using core sampling (Fig. 7).

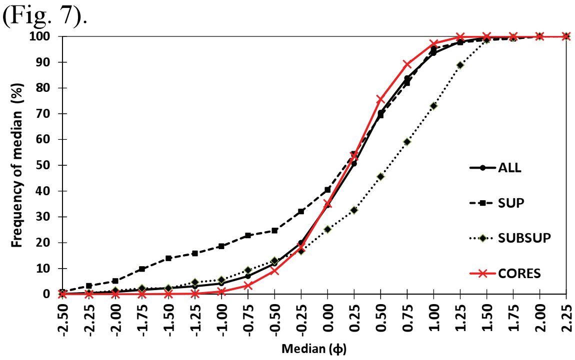

Fig.7.Cumlative frequency curves of the ALL, SUP, SUBSUP and CORES sample groups (see Table 1 for definition).

5. CONCLUSIONS

The application of image analysis techniques to the study of the beach face grain size variability proved to be a very useful tool. The data obtained in the scope of the present work show very large grain size variability both across the horizontal and vertical dimensions. Results question the representativeness of surficial sampling as systematic deviation from the beach "typical" grain size was detected.

Acknowledgements

This work is a contribution of the projects *Sand beach textural and compositional variability as indicator of sedimentary dynamics* (PTDC/CTE-GEX/64592/2006) and *Beach to Canyon Head Sedimentary Processes* (PTDC/MAR/114674/2009), both funded by Portuguese Foundation for Science and Technology (FCT).

The data processing tools are available on the "Beach Sand Code" project web page: http://sandcode.fc.ul.pt/ImageAnalysis.html.

REFERENCES

Barnard, P. L., D. M. Rubin, J. Harney, and N. Mustain (2007), Field test comparison of an autocorrelation technique for determining grain size using a digital 'beachball' camera versus traditional methods, *Sediment. Geol*., 201, 180-195

Bosnic, I., Sousa, H. , Cascalho, J., Taborda, R., Ribeiro, M. andLira, C. (this volume). New insights into image analysis applied to beach grain-size variability. *2as Jornadas de Engenharia Hidrográfica, Lisboa.*

Bosnic, I. (2011). Caracterização textural de sedimentos de praia através daanálise de imagem. *Tese de Mestrado em Geologia do Ambiente, Riscos Geológicos e Ordenamento do Território, Faculdade de Ciências da Universidade de Lisboa*, 59 p.

Folk R.L and Ward W.C. (1957). Brazos River bar: a study in the significance of grain size parameters. *Journal of Sedimentary Petrology*, 27, 3-26.

Friedman, G. M. (1979). Differences in size distributions of populations of particles among sands of various origins. *Sedimentology*,26, 3-32.