BEACH SEDIMENT SAMPLING AND PROCESSING GUIDELINES

JUNE OF 2012

Beach sedimentary characterization: guidelines for sediment sampling and processing (Beach Sand Code project)

Beach sedimentary characterization seems to be an easy and straightforward task when compared with the morphological and oceanographic forcing characterization. In most studies the sediment is described by a single parameter, disregarding either the spatial and temporal variability. However, results obtained in the scope of Beach Sand Code project show that sedimentary variability has strong implications in sediment transport estimates, either based on field data or on numerical computations. This implies that sediment sampling should account for this variability.

The main objective of this technical note is to develop guidelines for sediment sampling and processing that take into account spatial and temporal scales of beach sediment variability.

As sampling and sediment processing guidelines depend on the study objectives in this document specific guidelines were developed for the following purposes: 1 - beach sediment textural description; 2 – modeling the sediment transport; 3 - beach nourishment and monitoring; 4 - beach environmental reconstruction.

Beach sediment sampling and processing guidelines

BEACH SEDIMENTARY CHARACTERIZATION: GUIDELINES FOR SEDIMENT SAMPLING AND PROCESSING (BEACH SAND CODE PROJECT)

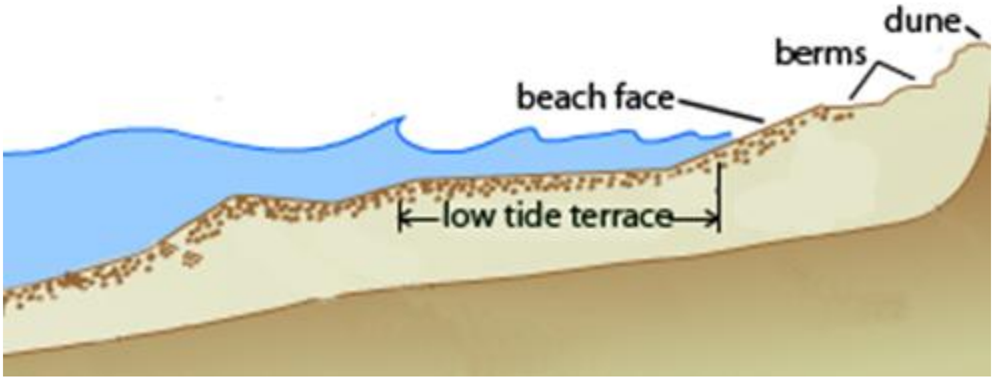
1. INTRODUCTION

Using the terminology adopted by Komar (1998) a beach can be defined "as an accumulation of unconsolidated sediment (sand, gravel, cobbles and boulders) extending from the mean low-tide to some physiographic change such as a sea cliff or dune field or to the point where the permanent vegetation is established". From this definition we can deduce that the beach sediments are normally composed by a wide variety of particles with different sizes. The relative abundance of any kind of particle in a beach is dependent from the source and from the sedimentary processes acting on the beach environment. Along a cross-shore transect, mean grain size usually decrease both shoreward and seaward from the plunge point at the base of the swash zone and a secondary coarsening of sediments may be observed at the offshore bar, where wave breaking is initiated.

1.1. Beach units

In order to define the sediment sampling and processing guidelines according to different objectives of the work the main beach units must be proper acknowledged (figure 1).

Figure 1 – Typical beach units used on this technical note



1.2. Beach sedimentary variability

On most beach environments, a simple visual inspection of the superficial sediments reveals large grain size contrasts. For example, at the North beach (located on the Nazaré coast, west of Portugal) where sand median grain size is highly variable, ranging from - 2.60 to 1.79 ϕ.

The sediment textural variability at this beach 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 (figure 2).

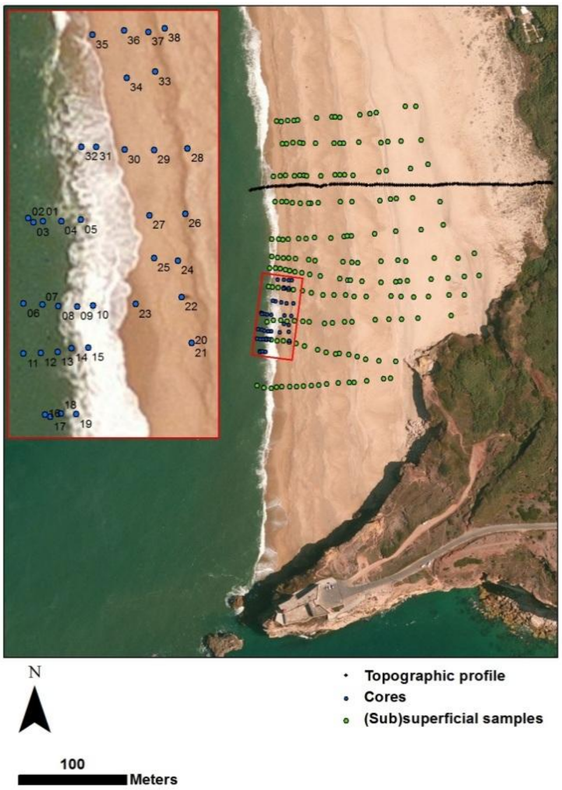


Figure 3 - Sampling location (green dots represent the location of the superficial and sub-superficial samples; blue dots represent the cores location). The location of the cross-shore topographic profile is represented by the black line. The inset represents the coring area. The orthophoto date does not match with the fieldwork date (from Cascalho et al. 2012).

The images were processed through an autocorrelation-based algorithm developed by Bosnic (2011) based on Barnard et al. (2007) work. These algorithm and numerical implementations are available at http://sandcode.fc.ul.pt/ImageAnalysis.html.

The superficial sediments are the coarser ones with a mean grain size of -0.08 ϕ, ranging from -2.60 to 1.77 ϕ; while the sub-superficial are finer with a mean of 0.44 ϕ, ranging from -2.35 to 1.79 ϕ (table1).

Table 1 - 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). From Cascalho et al. 2012.

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

Vertical variability was accessed along each of the 38 collected cores, where 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 (figure 3). 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 (figure 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 (figure 5).

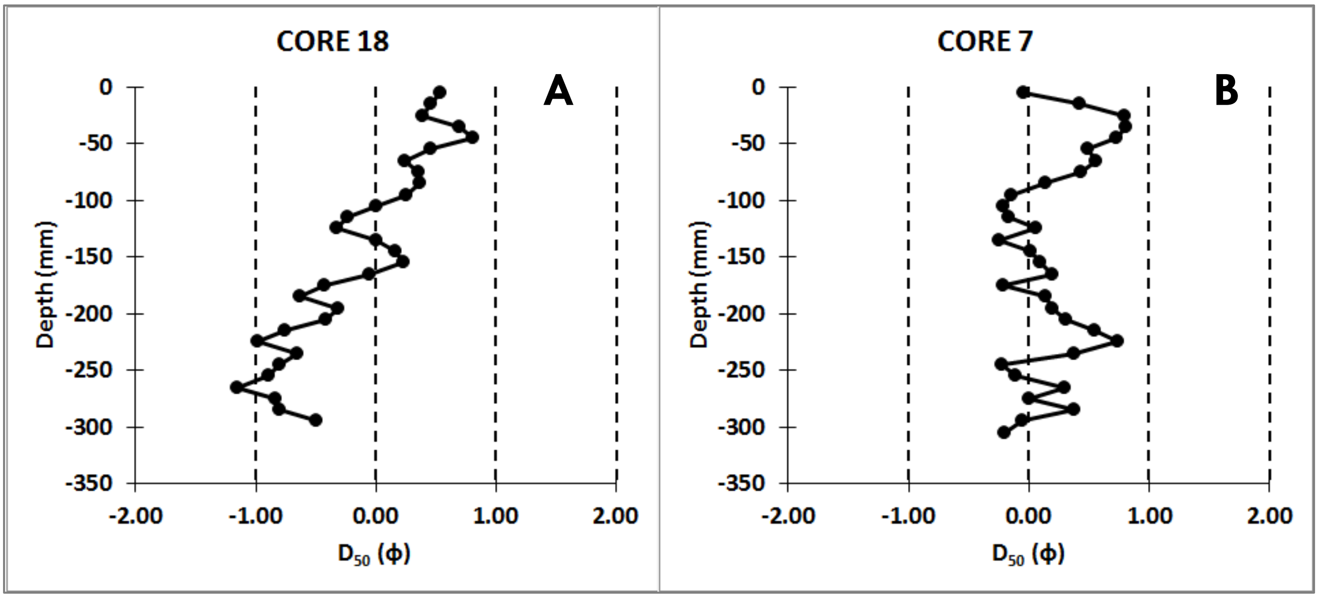


Figure 3 – Typical sedimentary sequences: (A) positive (B) undefined.

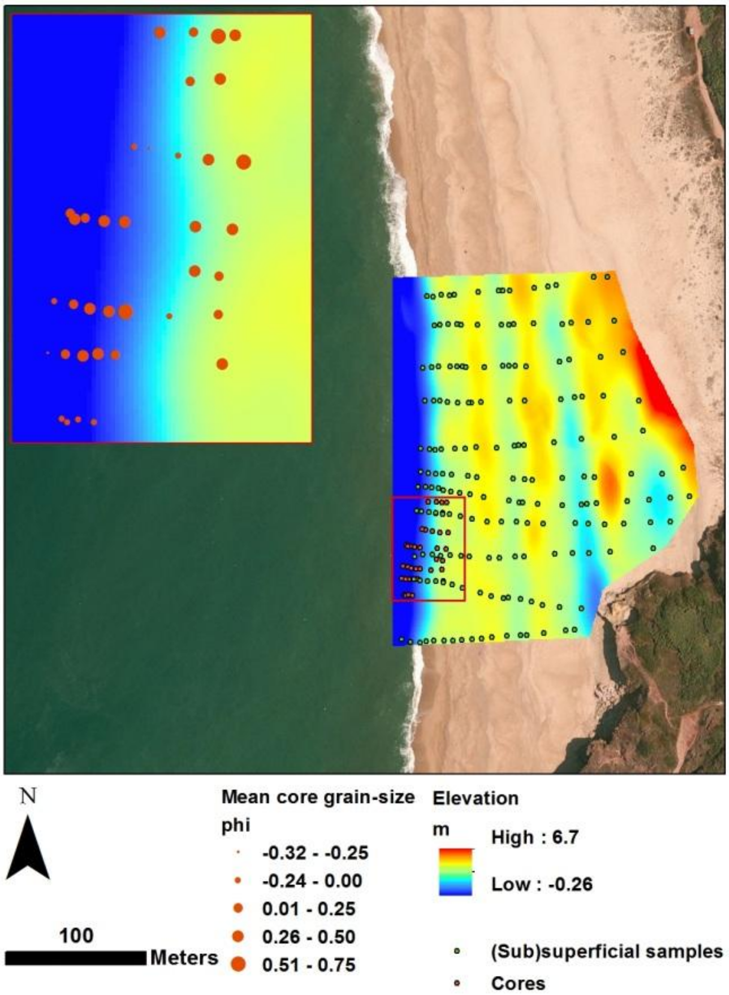


Figure 4 - Distribution of the mean core grain size according to the beach topography (from Cascalho et al., 2012).

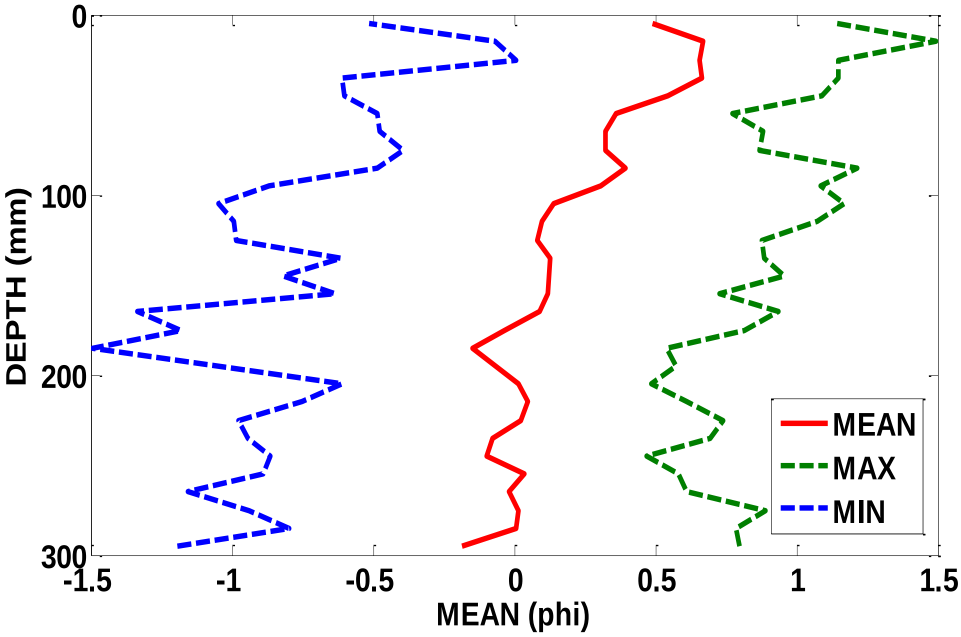


Figure 5 - Mean, maximum and minimum of the sediment media along the 38 collected cores (from Cascalho et al., 2012).

2. SEDIMENT SAMPLING AND PROCESSING TECHNIQUES

To do an high resolution 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. During the period of the "beach sand code" project implementation (between March, 2009 and June, 2012) several sampling and sediment treatment techniques were tested. One of the main achievements of this project was the development of a sediment grain size analysis methodology based on digital sediment images acquired in situ. This technique prove to be the best way for the acquisition of massive sediment textural data avoiding the problem of carrying thousands of samples and the correspondent time consuming in their laboratory treatment. Additionally, this technique allows the acquisition high resolution textural data based on a unique descriptor – the sediment median. The usefulness of this methodology in measure the grain size variation of the beach mixture layer or in the characterization of the beach textural variability is demonstrated by the works of Bosnic et al. (2011) and Cascalho et al. (2012). The method validation revealed an excellent correlation between the image analysis and sieving results, with a determination coefficient (R^2) of 0.90 and a standard error of the estimate (SEE) of 0.2 Φ.

The main beach sampling techniques and methods for the beach sediment processing (in order to characterize the grain size) are summarized on tables 2 and 3. Table 1describes the sampling techniques using during the field work of the beach sand code project and table 3 describes the main advantages and disadvantages of the current methodologies of sediment grain size analysis based on digital images and on some common laboratory procedures.

Figure 4. Scatterplot of 169 median grain sizes obtained throught image analysis and sieving (R2 = 0.90).

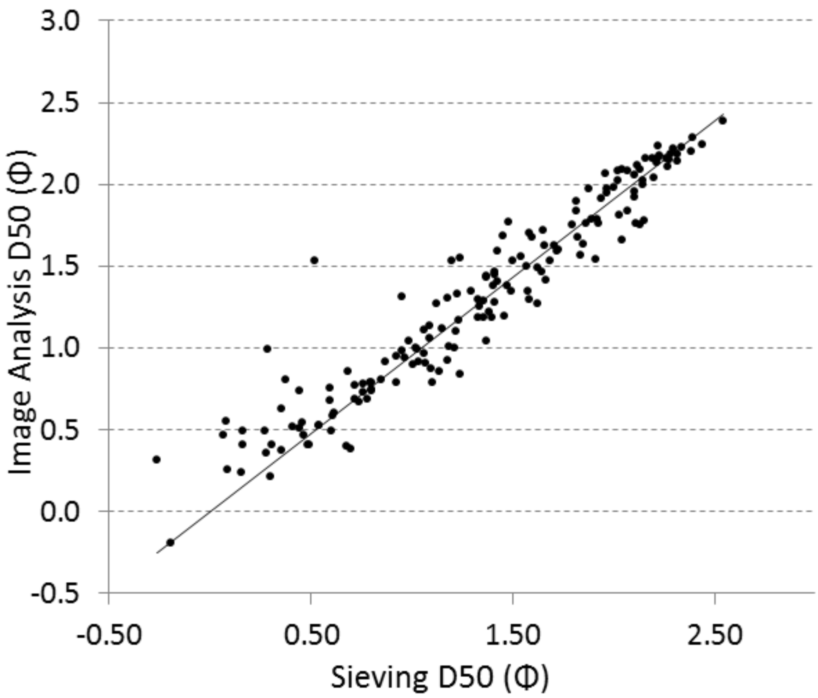


Table 2- Main beach sampling techniques

Sample type		Sampling method	Explanation	Data output
Selective	Beach surface	Image/Manual	Collect manually at the beach surface or take a photo of sediment surface layer	Sedimentary characterization of the superficial sediment
	Single layer	Image/ Manual	Collect manually at a trench or take a photo of a specific sediment layer in a core or trench	Sedimentary characterization of a specific sediment layer
	Suspension	Sediment trap/Pump	Collect sediment from suspension in water column using sediment traps or a pump	Sedimentary characterization of the suspended sediment
Composite	Vertical average	Cores/Manual	Collect a sediment vertical sample using a core or manually	Sedimentary characterization of the deposited sediment (several tide cycles)
	Horizontal average	Image/Manual	Collect multiple sediment horizontal samples or take several photos of a sediment surface area	Sedimentary characterization of the superficial sediment (over a large beach area)

Table 3 – Main methods of sediment grain size characterization (very fine sand to medium pebble range)

Methods that allow in situ sediment grain size characterization			
Methods	Main advantages	Main disadvantages	Some references
Image analysis based on statistical methods (IAs)	Expedite method of obtaining a single textural descriptor (mean or median). Allows a high resolution textural characterization based on sediment images (especially in sedimentary vertical sequences).	Doesn't allow the representation of the sediment grain size distribution including the derived statistical parameters.	Rubin (2004); Barnard et al. (2007); Buscombe (2008); Bosnic et al. (2011); Cascalho et al. (2012)
Image analysis based on grey morphological openings (IAg)	Adequate method for obtaining the sediment grain size distribution and respective statistical parameters based on sediment images.	High time consuming on laborious and heavy computational routines	Lira (2011), Pina et al. (2011)
Main methods of grain size characterization that require laboratory facilities			
Methods	Main vantages	Main disadvantages	References
Sieving (Si)	Adequate (and easy) method for size determination in the pebble and sand ranges based on the weights of the grain size classes.	The results obtained are partly controlled by particle shape and consequently substantial deviation of particle shapes from spheres may lead to underestimation of the characteristic intermediate diameter. High time consuming especially if using high number of samples.	Krunbein and Pettijohn (1938); Folk (1974); Buller and McManus (1979)
Laser diffraction (Ld)	Adequate to perform the particle size analysis where the final results (grain size distribution and statistical parameters) are expressed in terms of equivalent spherical diameter volume basis.	It is only suitable for sediments finer than medium sand. For coarser sediments this method needs to be complemented by another technique (e.g. sieving). Highly cost equipment that needs regular calibration and maintenance.	http://www.malvern.com/
Sedimentation tube (St)	Adequate to determine the sediment grain size distribution and respective statistical parameters in accurate way, based on the particle settling velocity which is dependent on its weight, volume and shape.	Less accurate results when the sediment contains appreciable quantities of heavy minerals with densities greater than quartz and mica flakes whose shapes differ from the spherical. Sensitive equipment that needs regular calibration and maintenance.	Gibbs (1974); Komar and Cui (1984)

3. RECOMMENDATIONS

The Beach Sand Code project promoted the development of new methodologies for grain-size acquisition and analysis, which enabled, for the first time, a high resolution representation of beach sedimentary variability. Grounded on this knowledge new guidelines for beach grain-size characterization are presented. The recommendations for beach sedimentary sampling and grain size characterization, accounts both for beach sedimentary variability and study objective. Specific guidelines are developed for the determination of: 3.1 – average beach grain size, 3.2 - sediment transport grain size characteristics, 3.3 – spatial grain size variability, in particular the relationship between sediment texture and morphology. This characterization allow to fulfill a wide set of study objectives including beach sediment textural description, modeling the sediment transport, beach nourishment and monitoring and beach environmental reconstruction.

3.1. Average beach sediment textural description

Results question the representativeness of sampling (superficial and sub-superficial) as systematic deviation from the beach "typical" grain size was detected.

The determination of the average beach grain size should be supported by a set of composite vertical samples collected from the dune base until to the tidal terrace is adequate (according to the beach units defined on figure 1 and to the sampling techniques defined on table 1). These samples should contain at least 20 cm of the sediment upper layer in order to get the sediment particles that represent the depositional average conditions of the last tidal cycles. This sampling can be done manually or by corer craved on the beach surface (figure 6). The cores can be sub-sampled during the field work in order to be later analyzed at the laboratory. Alternatively they can be photographed in situ in order to get representative images of the collected sediment. In this case the sediment images should be obtained using a device composed by a sand box with a LED light and a diffusor adequate to take photos from sediment cores (figure 7). It should be referred that the core sampling is conditioned by the sediment saturation in water which inhibit the acquisition sediment samples at the lower beach face or at the tidal terrace.

Figure 6 – Core sampling from beach face (left), core preparation to be photographed (center), the 20 cm thick beach face upper layer (right).

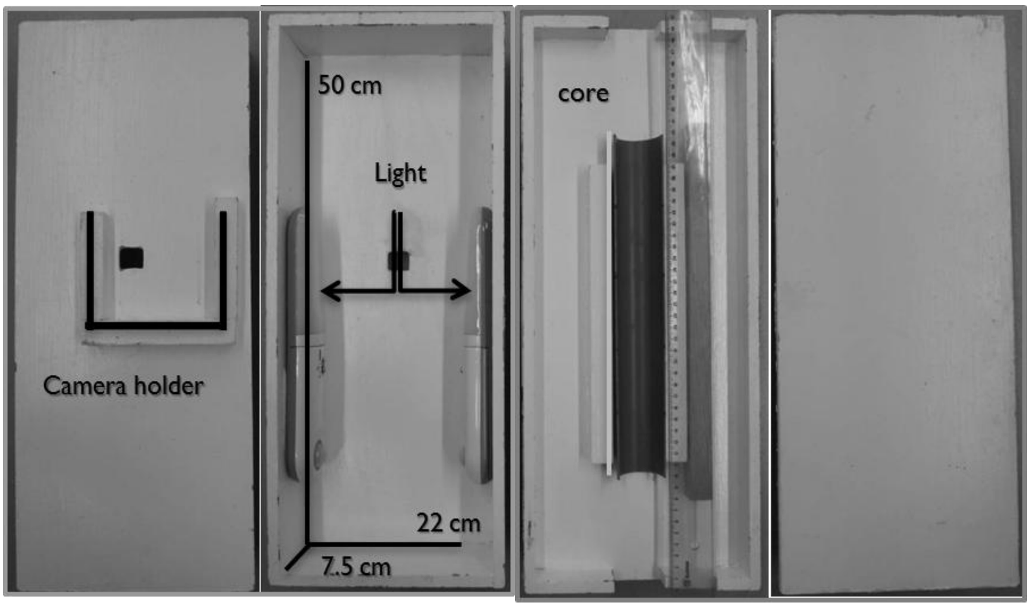


Figure 7 – Sand box suitable to take photos from sediment cores. Upper module on the left and lower module on the right (from Bosnic et al., 2012)

3.2. Sediment transport grain size characteristics

Under this objective the characterization of the sediment in suspension at the breaking wave zone is fundamental, the sampling procedure should include samples collected from suspension (selective suspension sample type - table 1). Additionally the breaking zone bottom sediment should be sampled as a "vertical average composite sample" referred on table 1.

3.3. Spatial grain size variability

Under this objective the main beach units (as defined in figure 1) must be sampled in order to characterize the textural variability of the beach system. It is recommend the development of a sampling grid that includes a set of transects from the dune toe up to the lower beach face. Composite vertical samples should be collected manually or using cores (table 1) in order to characterize the grain size average characteristics.

4. REFERENCES

Barnard, P. L., Rubin, D. M., Harney, J., Mustain, N. (2007) – Field test comparison of an autocorrelation technique for determining grain size using a digital "beachball" camera versus traditional methods. Sedimentary Geology, 180-195.

Bosnic, I., Cascalho, J., Taborda, R., Ribeiro, M., Oliveira, A., Rodrigues, A., Lira, C. (2011) - Textural Characterization of the Beach Active Layer. Journal of Coastal Research, SI 64, 40-44.

Bosnic, I., Sousa, H., Cascalho, J., Taborda, R., Ribeiro, M., Lira, C., 2012. New insights into image analysis applied to beach grain-size variability. Actas das 2.as Jornadas de Engenharia Hidrografica extended abstract book, 275-278.

Buller, A. T., McManus, J. (1979) – Sediment sampling an analysis. In: Estuarine Hydrography and Sedimentation (Ed. By K. R. Dyer), pp. 87-130.

Buscombe, D. (2008) - Estimation of grain-size distributions and associated parameters from digital images of sediment. Sedimentary Geology, 210, 1-10.

Cascalho, J., Bosnic, I., Taborda, R., Ribeiro, M., Lira C., Carapuço, M. (2012) – Beach sediment grain size variability based on image analysis. 2.as Jornadas de Engenharia Hidrográfica extended abstract book, 287-290.

Folk, R. L. (1974) - Petrology of Sedimentary Rocks. Hemphill P. 182 p.

Gibbs, R.J. (1974) - A settling tube system for sand-size analysis. Journal of Sedimentary Petrology 44, 583–588.

Komar, P. D. (1998) – Beach processes and sedimentation (second edition). Prentice Hall, 544 p.

Komar, P.D., Cui, B. (1984) - The analysis of grain-size measurements by sieving and settling-tube techniques: Journal of Sedimentary Research, 54, 603-614.

Krumbein, W. C., Pettijohn, F.J. (1938) - Manual of sedimentary petrography: Appleton-Century-Crofts, NewYork, 549 p.

Lira, C., Pina, P. (2011) - Granulometry on classified images of sand grains. Journal of Coastal Research, SI 64, 1697 -1701.

Pina, P., Lira, C., Lousada, M. (2011) - In-situ computation of granulometries of sedimentary grains – some preliminary results. Journal of Coastal Research, SI 64, 1727-1730.

Rubin, D. M., (2004) - A simple autocorrelation algorithm for determining grain size from digital images of sediment. Journal of Sedimentary Research, 74, 160-165.