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Technical Note

Influence of Different Sieving Methods on Estimation of Sand Size Parameters

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Abstract: Sieving is one of the most used operational methods to determine sand size parameters which are essential to analyze coastal dynamics. However, the influence of hand versus mechanical shaking methods has not yet been studied. Herein, samples were taken from inside the hopper of a trailing suction dredger and sieved by hand with sieves of 10 and 20 cm diameters on board the dredger. Afterwards, these same samples were sieved with a mechanical shaker in the laboratory on land. The results showed differences for the main size parameters D_{50}, standard deviation, skewness, and kurtosis. Amongst the main results, it should be noted that the highest values for D_{50} and kurtosis were given by the small sieves method. On the other hand, the lowest values were given by the mechanical shaker method in the laboratory. Furthermore, standard deviation and skewness did not seem to be affected by the sieving method which means that all the grainsize distribution was shifted but the shape remained unchanged. The few samples that do not follow these patterns have a higher percentage of shells. Finally and definitely, the small sieves should be rejected as a sieving method aboard.

Keywords: D_{50}; sieving; sand size; sand parameters; coastal dynamics

1. Introduction

Sand-size parameters are essential to study the coastal dynamics and other geomorphological behaviours of beaches [1–3]. Main parameters must include measure of: average grain size (D_{50}), spread of the size around the average (Standard Deviation, σ, or Sorting), degree of asymmetry (Skewness) and degree of peakedness (Kurtosis). Parameters such as D_{50} and sorting (σ) are necessary for calculating equilibrium profiles or estimating sediment transport [4,5], to check if the borrowed sand is suitable to substitute the native sand eroded from the beach [6,7] or to calculate the required amount of sand for beach nourishment [8]. Analysis of sand-size distribution also gives essential hints to the origin, depositional environment and movement history [9]. Moreover, sand-size analysis is an indispensable mechanism to subdivide facies and environments [10] and it also makes possible to see how a beach reacts to storms [11]. Different methods to analyse sand-size particles and some comparisons between them were studied by some researchers, such as; laser diffraction [12], laser granulometer and sedigraph [13], microtac [14], comparison of laser grain size with pipette and sieve [15], image analysis [16] and sieving [17]. Due to the simplicity use and economy, the sieving method was chosen to be the method to perform the analysis of sand-size inside a dredger because of the special circumstances on board a ship.

In particular, in order to make decisions about the landfill area, the coastal manager needs to know the size parameters of the dredged sand before it gets dumped onto the beach. This means that the analysis must be done on board the dredger. Therefore, due to the usual shortage of space inside the dredger and the consequent absence of an adequate laboratory, sieving is usually done by hand. However different sieving methods can influence not only the D_{50} but also all other parameters.

Thus, due to the already established importance of sand size determination, the aim of this paper is to find out the influence of using different sieving methods on the results obtained for sand size parameters. The sieving methods were by hand (shaking manually) with 10-cm diameter sieves versus 20-cm sieves, and mechanical sieving (shaking machine) with 20-cm sieves.

2. Area of Study

The samples were taken from inside the hopper of a trailing suction dredger used for two beach nourishments (Costa Ballena and Punta Candor). Sand had been borrowed from the Meca sandbank, located in the Gulf of Cadiz close to the Strait of Gibraltar (Figure 1a). It has a depth of approximately 15–20 m and contains up to 25 millions of m^3 of sand that can be used for beach nourishments (further data can be found in reference [18]). A previous study demonstrated that there was no serious impact to the environment of the area as a result of the sand removal [19].

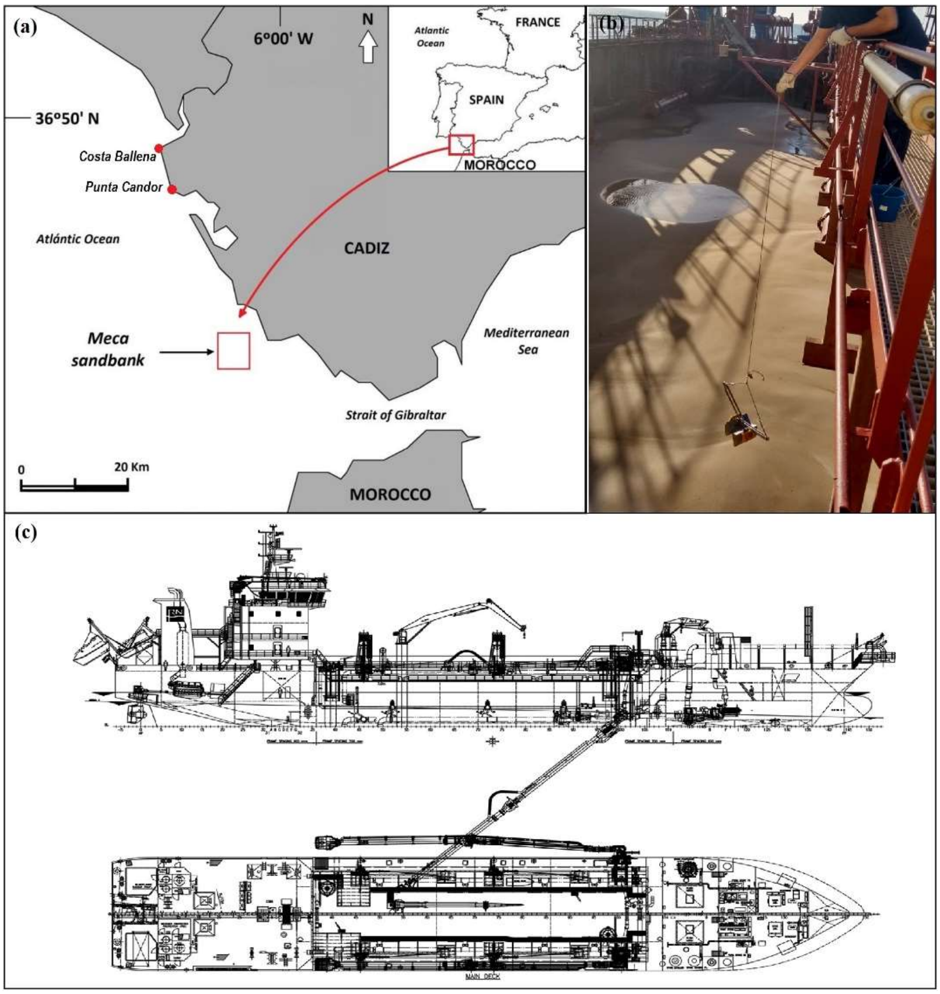

Figure 1. (**a**) Location of Costa Ballena and Punta Candor nourished beaches and the borrow site named "Placer de Meca" (Meca sandbank) (SW Spain); (**b**) sampling method aboard the dredger; (**c**) scheme of Njord dredger (https://rohde-nielsen.com).

Moreover, the effects of the turbidity are also negligible due to the limited percentage of fines [10]. Tidal range is mesotidal, varying between 1.10 m and 3.22 m, and has a semidiurnal periodicity. The beaches considered in this study were composed of fine-medium sand, very similar to the borrowed sediment. The average D_{50} is about 0.25 mm, consisting of 90% quartz and 10% calcium carbonate [20].

3. Materials and Methods

Nineteen samples were taken (Figure 1b) from the hopper of the Njord dredger (Figure 1c) on different days once the dredging operations were finished (for security measures). The same sample was sieved on board, by hand, with two different kinds of sieves—small (10 cm diameter) and large (20 cm diameter)—with the same sieving time (10 min in all cases) and saved. Afterwards, the samples were sieved at the laboratory inland with a mechanical shaker and the big sieves. The last method of sieving, the results of which will be taken as a reference, cannot always be performed on the dredger due to several reasons. First of all, a stable energy supply is not easy to get onto the dredger. Moreover, the machine performing the sieving has to deal with the instability and the vertical acceleration induced by waves.

The mesh sizes of the eight sieves required by the Spanish Coastal Administration were: 2 mm, 1 mm, 710 μm, 500 μm, 355 μm, 250 μm, 125 μm and 62.5 μm. Thus, the same sample, about 100 g, was sieved by the three different methods. The amount of sediment is important because, obviously, a large volume of sediment means a lower chance for the grain to pass through the net.

After the initial weighting, the samples were put in the upper sieve and the sieves were shaken by hand. It should be noted that finger pressing was not allowed. After weighting the sand accumulated in each sieve, required values (D_{16}, D_{50} and D_{84}) were obtained (Table 1) as well as the other main parameters [21] as sorting, skewness and kurtosis (though these last two parameters are not used for beach nourishment projects) (Figure 2). They were calculated by using the corresponding equations (see Table 2, [21,22]) which are based on the phi unit scale (Equation (1)), and where to convert from phi units to millimetres, the inverse equation (Equation (2)) is used:

$$\varphi = -\log_2 D \tag{1}$$

$$D = 2^{-\varphi} \tag{2}$$

Table 1. Values of the parameters D_{16}, D_{50} and D_{84}, obtained by three different methods, for the 19 samples taken from the dredger hopper.

	Manual Shaking						Mechanical Shaking		
	Small Sieves			Large Sieves			Laboratory		
Sample	D_{16}	D_{50}	D_{84}	D_{16}	D_{50}	D_{84}	D_{16}	D_{50}	D_{84}
1	0.217	0.300	0.379	0.201	0.291	0.35	0.177	0.274	0.346
2	0.218	0.300	0.375	0.203	0.297	0.384	0.143	0.281	0.347
3	0.261	0.314	0.418	0.229	0.307	0.422	0.149	0.296	0.383
4	0.220	0.301	0.383	0.179	0.278	0.349	0.138	0.256	0.343
5	0.194	0.290	0.354	0.174	0.269	0.339	0.139	0.263	0.335
6	0.204	0.297	0.385	0.192	0.29	0.377	0.178	0.277	0.35
7	0.179	0.280	0.358	0.171	0.267	0.349	0.171	0.265	0.346
8	0.177	0.280	0.407	0.168	0.261	0.38	0.177	0.277	0.354
9	0.186	0.284	0.351	0.182	0.278	0.344	0.17	0.261	0.335
10	0.193	0.301	0.539	0.177	0.285	0.571	0.141	0.281	0.549
11	0.257	0.314	0.440	0.206	0.298	0.409	0.164	0.307	0.417
12	0.220	0.295	0.349	0.179	0.278	0.348	0.14	0.272	0.346
13	0.255	0.315	0.497	0.205	0.305	0.499	0.151	0.306	0.491
14	0.181	0.284	0.385	0.211	0.297	0.363	0.187	0.286	0.354
15	0.199	0.292	0.354	0.187	0.28	0.339	0.25	0.307	0.417
16	0.182	0.280	0.350	0.163	0.244	0.326	0.137	0.247	0.327
17	0.186	0.288	0.395	0.165	0.251	0.339	0.16	0.235	0.337
18	0.240	0.306	0.448	0.24	0.306	0.448	0.239	0.306	0.45
19	0.226	0.303	0.394	0.141	0.272	0.342	0.17	0.263	0.339

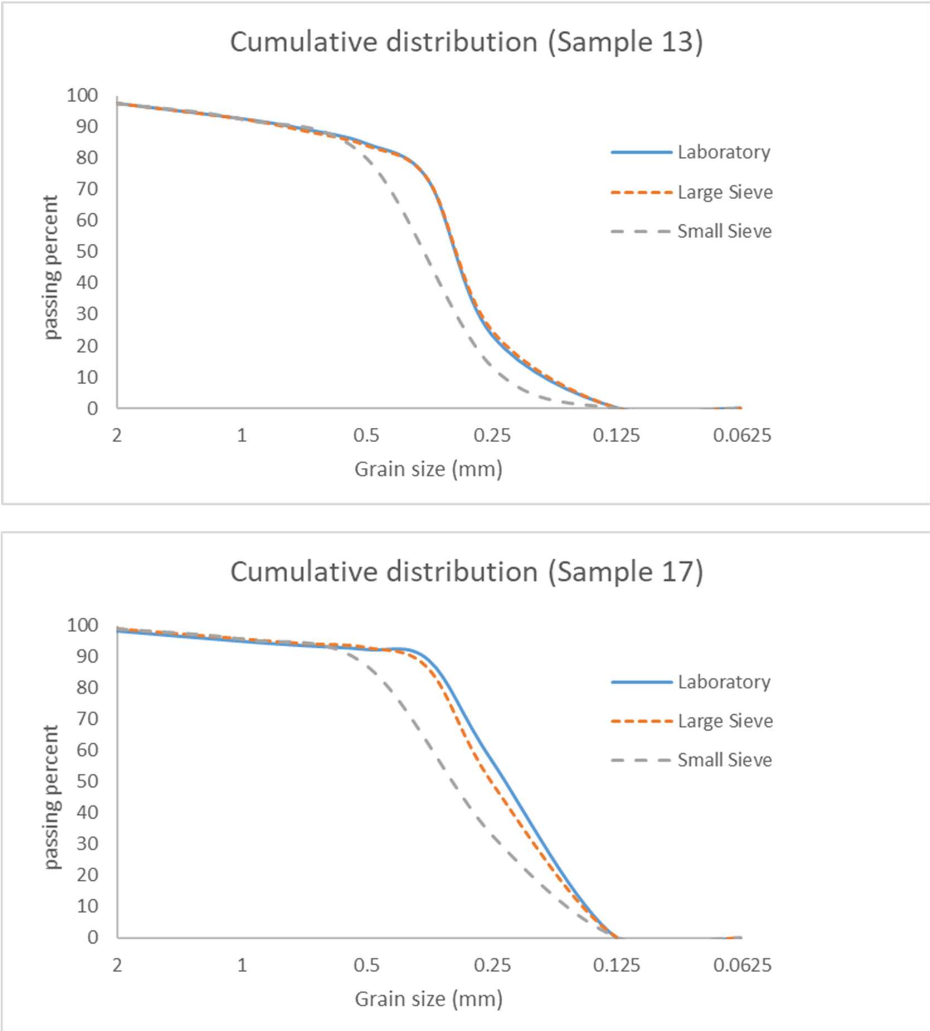

Figure 2. Cumulative distribution of the passing percentage of samples 13 and 17 for the three sieving methods.

Table 2. Formulae used for calculation of the main granulometric parameters, according to Folk and Ward graphical measures [21,22].

Mean	Standard Deviation or Sorting	Skewness	Kurtosis
$M_\varphi = \frac{\varphi_{16}+\varphi_{50}+\varphi_{84}}{3}$	$\sigma_\varphi = \frac{\varphi_{84}-\varphi_{16}}{4} + \frac{\varphi_{95}-\varphi_5}{6}$	$Sk_\varphi = \frac{\varphi_{16}+\varphi_{84}-2\varphi_{50}}{2(\varphi_{84}-\varphi_{16})} + \frac{\varphi_5+\varphi_{95}-2\varphi_{50}}{2(\varphi_{95}-\varphi_5)}$	$K_\varphi = \frac{\varphi_{95}-\varphi_5}{2.44(\varphi_{75}-\varphi_{25})}$

4. Results and Discussion

4.1. D_{50} (Median Grain Diameter)

A comparison of the cumulative distribution of the passing percentage for the three methods is shown in Figure 2. Only two samples (13 and 17) have been presented to show an example of the results. Though the 19 samples are not shown, this figure gives a real image of the differences among the methods.

On the other hand, Figure 3a shows how D_{50} ranges from approximately 0.24 mm to 0.32 mm. The values obtained with the automatic sieving, carried out in the laboratory, are always the lowest number. On the other side, the values obtained by hand with the small sieves are always the biggest. Thus, the value of the large sieve is usually between the small sieving and the automatic shaking, values being closer to the latter. A possible explanation is that the surface in the 20 cm sieves is four times bigger than the 10 cm sieves. More holes for the grains to pass through mean more grains passing during the same sieving time (10 min in all cases). This increases the amount of sand in the lower sieves, and thus decreases the D_{50}.

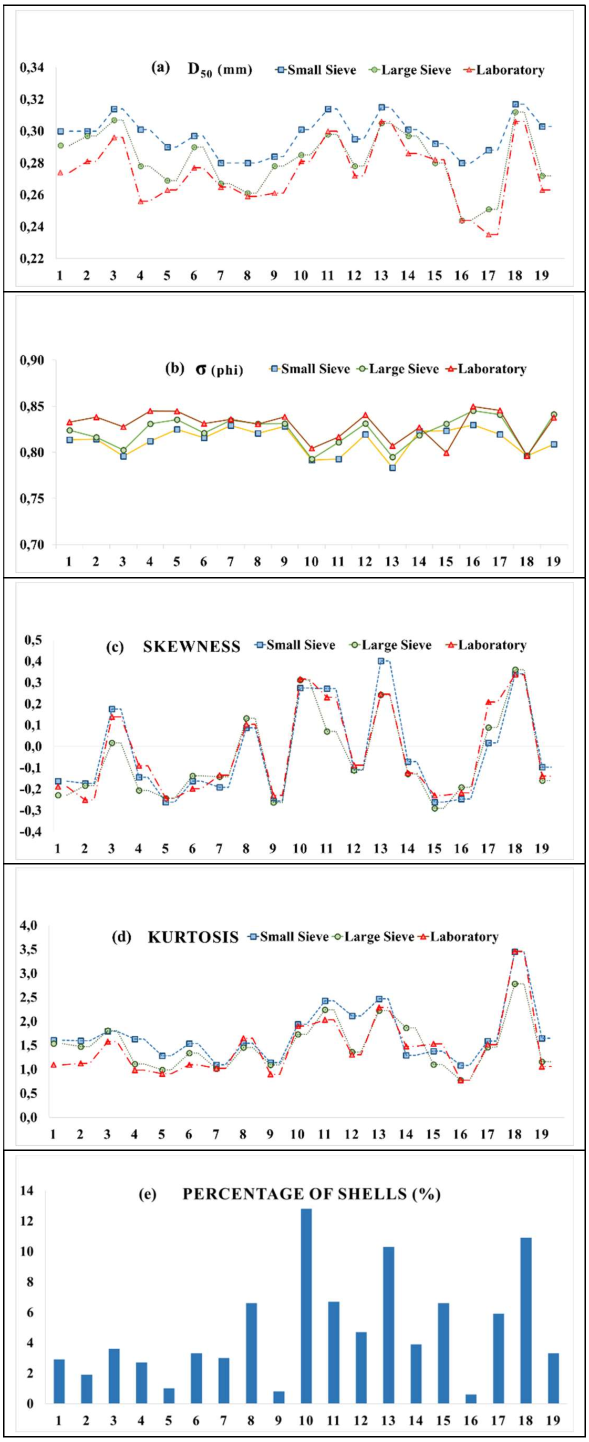

Figure 3. Values of the granulometric parameters obtained with three different types of sieving for the samples taken on board of the dredger: (**a**) D_{50}; (**b**) sorting; (**c**) skewness; (**d**) kurtosis; (**e**) percentage of shells.

Further on, we consider as reference those values obtained in the laboratory by the mechanical shaker since it is the standard procedure. Probably, the higher and constant intensity of the mechanical shaker in comparison to the manual sieving is the reason why the values of D_{50} of the former are smaller than the latter. Furthermore, though the sieving time did remain constant in all cases, the operator on board may get tired during the shaking of the sieves, which would influence the intensity of the sieving. Though the average difference was about 10%, it can be seen how the highest differences between laboratory D_{50} and small sieve D_{50}, which coincide with the finest sands (samples 4, 16, 17), can be as high as 20–25%. The manual and consequently less intensity sieving, plus the small diameter of the small sieve, could be the cause of the accumulation of fine sands in the upper sieves.

4.2. Sorting or Standard Deviation

Looking at the sorting graph in Figure 3b, the results for all the sieving methods were really close to each other, values ranging from 0.79 to 0.84 phi and averaging 0.82. This information shows us that the method of sieving did not affect the sorting. Moreover, according to Folk [23], this sediment is moderately sorted, being aware that the limit for poor sorted sediment (1 phi) is not close.

4.3. Skewness

In general, the same pattern for all three sieving methods can be obtained (Figure 3c). The values of skewness for every individual sample, as in the case of the sorting, did not seem to depend on the sieving method (this means that all the grainsize distribution is shifted but the shape did not change). Most of them were between near-symmetrical (−0.1 to +0.1) and coarse-skewed (−0.3 to +0.3). Again, samples 10, 13 and 18 were the only ones that come out of the pattern, with values larger than 0.3 (very coarse-skewed). Thus, a high percentage of shells may also increase the skewness.

4.4. Kurtosis

Looking at Figure 3d, no platykurtic coefficient was observed at all. All the values ranged from mesokurtic (0.90–1.10) to leptokurtic (<1.50) and very leptokurtic (>1.50). No clear pattern could be determined.

4.5. Percentage of Shells

The amount of shells per individual sample was determined with the help of a microscope and is shown in Figure 3e. Since the particles of shells are bigger than the particles of sand, the biggest amount of shells were found in the upper sieves. The three samples (10, 13 and 18) with the highest value of shells (above 10%) were also the samples with the highest standard deviation.

4.6. Summary Table

Percent Relative Error (%) has been calculated for the main sediment parameters (mean size, sorting, skewness and kurtosis) and results are shown in Table 3. Laboratory sieve results (standard procedure) were taken as a reference to compare the results. It could be verified that the error was greater in all cases for the small sieves as discussed previously. Skewness was the only parameter without a significant difference. Thus, we can assume that the large sieve is the best way to sieve aboard and small sieves should be avoided.

Table 3. Percent Relative Error (%) calculated for granulometric parameters obtained with small and large sieves taking as a reference the laboratory sieve results (the standard procedure). σ: Standard deviation.

		D_{50}	σ	Skewness	Kurtosis
Percent Relative Error (%)	Small Sieve	8.8	2.4	28.2	26.5
	Large Sieve	3.2	1.3	29.3	14.6

5. Conclusions

The importance of the D_{50} (as well as sorting, skewness and kurtosis) in understanding the coastal dynamics and other geomorphological behaviours of beaches is well known. And, nevertheless, the influence of the method of sieving had not yet been considered in the determination of these parameters. For this reason, 19 samples were taken on board while dredging the borrow site named Placer de Meca (Meca sandbank) for a beach nourishment in the Gulf of Cadiz (SW of Spain). They were analysed with three different sieving methods (small vs. big sieves and mechanical shaker vs. manual shaking procedure).

The results showed a pattern for the D_{50} value. The biggest values were always obtained with the small sieves. The values with the machine in the laboratory always gave the lowest values.

Variance of sorting values was negligible. Thus the method of sieving does not influence the sorting and, by the way, nor the skewness either. This fact means that all the grainsize distribution was shifted but the shape remained unchanged.

The kurtosis gives a similar pattern as the D_{50} parameter: the values for the small sieves were the highest. The bigger sieves gave lower values whereas the sieving with the automatic shaker gave the lowest values in general.

The laboratory method is the standard procedure, the results of which were taken as a reference. But this sieving method cannot always be performed on the dredger. Therefore, looking at the results, we can assume that a large sieve is the best way to manually sieve aboard. Definitely, a small sieve should be rejected as a sieving method during dredging.

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