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Physical characterization of sea shell for a concrete formulation

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Abstract

This paper investigates the feasibility of using shells from marine coasts of the Souss Massa region in Agadir (Morocco), as aggregates in the production of a composite material called ecological concrete. Different steps were conducted: Firstly, a prospecting phase carried out on various sites of the concerned region in order to identify and quantify the different types of waste shells available in sites and also to establish a regional maritime waste cartography. Then a sort was done, followed by a thermal treatment to eliminate any kind of impurities, and then a crushing was made to the collected shells. Secondly, physical characterizations of different aggregates, including shells, to more particularly determine the measurement of bulk density, the apparent particle density and compactness of shells. A geometric characterization through a particle size analysis was also performed. The obtained parameters were compared to those of the sand dune and quarry sand. Furthermore, a study on the chemical characterization on these shells must be conducted.

1. Introduction

The concrete remains and will remain the most widely used material in construction around the world. Its use is even more interesting when combined with steel to define what is known as reinforced concrete or pre-stressed concrete.

In Morocco, with the current explosion in the construction and public works sector, demand for building materials is growing rapidly. These materials mainly concern the aggregates of different classes obtained generally following the crushing of the massive rocks extracted from quarries with a high energy cost and environmental problems related to pollution. However, enormous quantities of shell waste are illegally abandoned on maritime coasts, or are incinerated in factories, which also cause pollution and destruction of the environment. As a result, it becomes essential to have recourse to the recovery of this waste. Several studies have been carried out to investigate the feasibility of reuse of shell waste in the field of civil engineering as a partial or total alternative to aggregates, sand or cement [1-19]. It is the framework of our present work. The first step is to prospect the maritime coasts of the Souss Massa region in southern of Morocco in order to identify the different types of molluscs existing and to establish a local map corresponding to these species. After grinding these shells, we performed a physical characterization of the aggregates obtained for a concrete formulation.

2. Prospecting and collection of shell waste

Morocco has shores on the Mediterranean Sea on one side and on the Atlantic Ocean on the other with a very important maritime richness. At the national level, Morocco has several shellfish harvesting sites from north to south [20].

The harvesting sites are divided into two types: natural harvest sites and packaging sites. We focused our study on the region of Souss Massa given the richness of these different sites. Although the region does not have any breeding sites, it does have several sites where shells are harvested by traditional methods. Among the main sites, we quote: Cap Ghir, Imsouane, Ait Tamer, Tigrt, Tiflt, Tifnit, Massa, Aglou and Mirleft. The molluscs available on these sites are mainly mussels with more than 95% and snails in small quantity. The collection takes place throughout the month during low tides; the massive harvest is carried out during the nights of the full moon. Figure 1 shows a regional mapping of natural harvest sites [21].

Figure 1: Shellfish harvesting sites in the Souss Massa region.

For our prospective study, we chose the best known site in the region of Agadir, namely the Cap Ghir site (Coordinates: 30 ° 38 'North 9 ° 53' West). Cap Ghir is a promontory of the Moroccan coast, on the Atlantic Ocean. It is about forty kilometers north-west of Agadir. On the spot, we observe the establishment of the encampments of shellfish-collecting fishermen as well as enormous quantities of waste shells abandoned in nature, figure 2. The harvesting of the molluscs is done either directly by hand, or with a hammer to be able to extract them out of the ratchets.

Figure 2: Shell waste site

At the end of the collection, the shells are heated on low heat to cause the shells to open and thus to extract the pulpit (fruit) which is sold either fresh or dried. The shells are then left to the abandonment on the site and following the accumulation of the successive deposits, they have been able to constitute shells layers of certain thicknesses. This led us to conclude that the crops on this site had existed for some time. A geological study would make it possible to go back to the exact age of the formation of these sedimentary layers, figure 3. The shells harvested in the region of Cap Ghir are mainly mussels but also sea snails in small quantity.

Figure 3: Sedimentary shell layers

3. Experimental study

The formulation of concrete rests on two aspects: the choice of constituents and the determination of their proportions. To do this, we were interested in the characteristics of some conventional constituents used in the making of concrete to compare them with those of shells. These characteristics are determined from several tests, as particle size analysis, bulk density and absolute density of two types of sand, in particular dune sand and quarry sand, and shells of mussels grinded.

3.1 Preparation of samples

We first started our study by carrying out three successive washes with water of the mussels shells collected to eliminate any trace of impurity [1], [4], [11], [12], [14]. Then, after crushing the shells, dehydration in an oven at 110 ° C. ± 5 ° C. is necessary for 24 h, [4], [5], then grinding and sieving are carried out in order to obtain the size required. The figure 4 shows an illustration of the crushed shells. Each of these aggregates has undergone a sampling by the method of quarting to obtain a representative sample of one or more characteristic properties of the assembly.

Figure 4: Crushed mussel shells

3.*2 Particle size analysis*

The tests involved shell samples and two types of sands in order to carry out a comparative study. These tests consist of sieving the aggregates on a series of square mesh sieves of decreasing opening size and weighing the rejection on each sieve. The square openings of the sieves are standardized. The granulometric curve expresses the cumulative percentages of grains weight passing through successive sieves nested one over the other. On the lower part, a sealed bottom is placed to recover the fillers for further analysis. A lid will be placed at the top of the column to prevent any loss of material during sieving. The figure 5 shows the electrical screening device used.

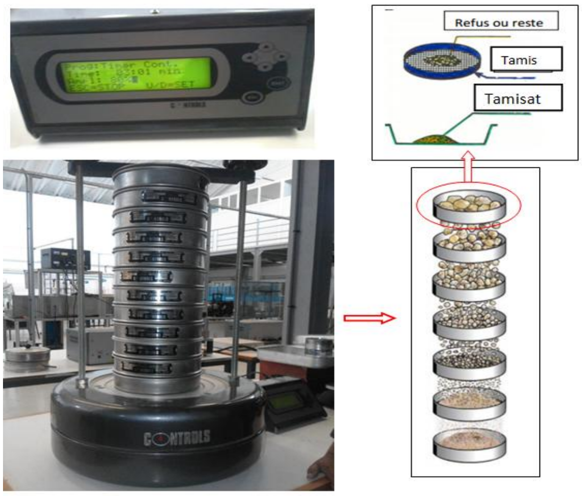

Figure 5: Electrical sieve shaker

The granulometric curves of the three samples are represented by carrying the grain size on the abscissa and the percentages of the passing sieve on the ordinate on an arithmetic scale. A sieving of 4 minutes and amplitude of 80% was carried out. The three granulometric curves of the various aggregates (dune sand, quarry sand and crushed shells) from the tests are presented in figure 6. The table 2 summarizes the results obtained from the calculation of the coefficients of uniformity and curvature.

The figure 6 shows that the granulometric curve of the crushed shells lies between the two granulometric curves of the dune sand and quarry sand. The calculation of the two coefficients of uniformity and curvature confirmed this type of behavior. Indeed, we observe that the crushed shells have both a wide grading corresponding to the characteristic of the quarry sand and a distribution poorly graded corresponding to that of the dune sand.

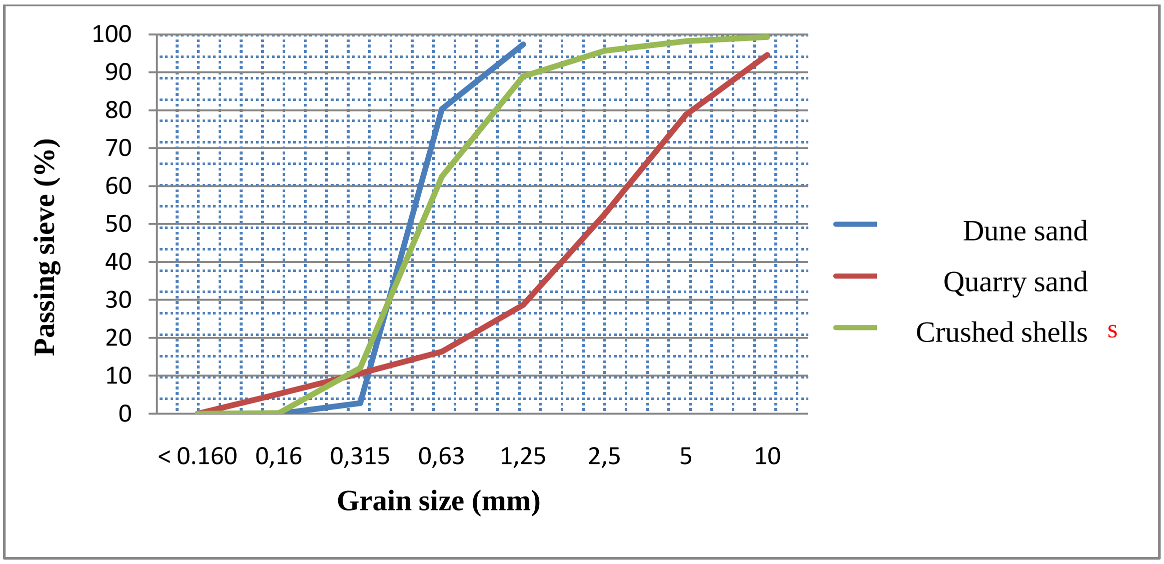

Figure 6: Granulometric curves of the three samples

Table 2: Summary table of particle size analysis

Types	Equation	Interpretations
Dune sand	$C_u = \frac{0.55}{0.38} = 1.45$ $C_c = \frac{0.4^2}{0.55*0.38} = 0.76$	$C_u < 2$: Uniformly graded $C_c < 1$: Poorly graded material
Quarry sand	$C_u = \frac{3.25}{0.315} = 10.32$ $C_c = \frac{1.37^2}{3.25*0.315} = 1.83$	$C_u > 2$: Wide grading $1 < C_c < 3$: Well graded material (continuity is well distributed)
Crushed shells	$C_u = \frac{0.624}{0.29} = 2.15$ $C_c = \frac{0.4^2}{0.624*0.29} = 0.88$	$C_u > 2$: Wide grading $C_c < 1$: Poorly graded material (continuity is bad distributed)

3.3 Apparent density

The bulk density of a material is the density of one cubic meter of material taken in a heap, including both permeable and impermeable voids of the particle as well as voids between particles. It is given by the ratio between the mass of the material and the volume. Table 3 presents the results of the tests concerning the apparent density of the three types of aggregates studied. The apparent density of the crushed shells is similar to that of the lightweight aggregates (1200 kg / m^3) used for the manufacture of "light" concretes. These concretes have particular characteristics that make them interesting materials in more ways than one.

Table 3: Bulk density of the aggregates studied

	Sample type		
	Dune sand	Quarry sand	Crushed shells
Apparent density Kg/m^3	1489	1574	1241

3.4 Absolute density

Absolute density is the mass per unit volume of the material that constitutes the aggregate, regardless of the voids that may exist in or between the grains. It is calculated by the method of the graduated cylinder:

- Fill a graduated cylinder with one volume of water (V_1)
- Take a sample of aggregates and weigh it, ie Ms
- Introduce this mass into the specimen by removing all air bubbles (vibrate, shake slightly)
- Read the new volume (V_2).

The absolute density is obtained according to the relation:

$$\frac{Ms}{V_2 - V_1}$$

Table 4 summarizes the results of calculations of absolute densities. From the analysis of these results, it emerges that the absolute density of the crushed shells is close to those of the two sands studied.

Table 4: Absolute density of the aggregates studied

	Sample type		
	Dune sand	Quarry sand	Crushed shells
Absolute density Kg/m^3	2616.4	2626.9	2597.2

Conclusion

The objective of this study is the physical characterization of aggregates, in particular those resulting from sea shell-type waste from the Agadir region, with a view to developing a concrete formulation. In this framework, we examined the characteristics of the different conventional constituents of concrete (two types of sand) and those of crushed shells. In advance, we conducted a survey in the region of Souss Massa on the site of Cap Ghir. After exploration of the site, it appears that only shells of mussels are strongly present, hence the choice of study for these shells. After a few tests (particle size analysis, bulk volume and absolute mass), we were able to conclude that the shells of crushed mussels can be candidates as constituents of lightweight concrete. The results obtained by calculating the percentage of vacuum showed that the crushed shells have a low compactness compared to the sands studied.

As a perspective, it would be necessary to study the preparation of a concrete based partially or totally on the aggregates resulting from the crushed shells with different granulometric sizes while seeking the best compromise between the physical and mechanical properties.

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