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Valorization of port dredged sediments in cement mortars

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Abstract

The objective of this work is to study the influence of the partial replacement of sand and cement by *dredged sediments* from Ports of Tangier and Larache (Morocco) on the mechanical behavior of cement mortars. Firstly, the characterization of the studied *dredged sediments* was carried out by using several techniques. Chemical analysis were conducted in order to assess the composition of sediments namely major elements, heavy metals, organic matter, and PAHs (polycyclic aromatic hydrocarbons). The physical properties such as particle size distribution, and absolute density were measured. The mineralogy of these sediments was carried out by the X-ray diffraction method. The results showed that the studied sediments have high content of organic matter, important fine particles and the absence of metal and organic pollution .The main minerals observed are calcite, quartz, kaolinite, and muscovite. Secondly, the sediments were introduced into the mortar mixture by replacing 20% mass content of the standard sand, and 20% mass content of cement by *dredged sediments*. Partial replacement of cement by sediments leads to a decrease of compressive strength with 45% in comparison with control mortar. This result is explained by the reduction of the quantity of cement in mortars. Partial substitution of sand by studied sediments is satisfactory, but with a rate of compressive strength reduction with 30%. With such resistances, the potential uses relate to masonry mortars or manufactured blocks. For these products we can accept a partial replacement of the standard sand by these sediments.

1. Introduction

Dredged port sediments are a product of extraction sediments that are deposited on the bottom of port. They consist of mineral phases, organic and liquid. The sustainable management of *dredged sediments* today remains an important issue, the annually volumes of *dredged sediments* are considerable. The quantities of sediments extracted from ports are a real environmental problem. Therefore it is important to suggest solutions for using sediments as building materials. A study on substitution rate of sand and cement in mortar formulation by port dredged sediments of Tangier and Larache (north of Morocco) was carried out. The first way of valorization as a construction material concerned the fired bricks by replacing clay (raw material) with *dredged sediments* [1].
The present work deals with the possibility to value the studied *dredged sediments* in cement mortars by a partial substitution of sand and cement. The mortar is a construction material which contains cement, water, sand, optionally adjuvants and additives. Several studies showed the possibility to use *dredged sediments* as a sand or cement in the composition of building materials based on cement matrix [2-11].

2. Material and Methods

2.1. Characterization of collected sediments

Complete characterization of dredged port sediments of Tangier and Larache was performed: chemical analysis (major elements, heavy metals, organic matter, and PAHs), physical (size distribution, and absolute density), and mineralogical (DRX).

2.2. Preparation of mortars mixtures

The aim of this work is to study the behavior of sediments in mortars by partially replacing on one hand 20% of the standard sand and on the other hand 20% of cement by two sediments (Tangier and Larache). The formulation of the control mortar is: standard sand = 1350 g; cement = 450 g; water = 225 g (W/C of the report is 0.50). The cement used is a Moroccan cement CPJ 45, with a water to cement ratio (W/C) of 0.5. The dosages selected are 1350 kg of sand per 450 kg of cement.

Prismatic mortar specimens (4×4×16 cm3) were prepared according to EN 196-1 [10] for the study of compressive and flexural strength. Specimens were cast in steel molds and kept in a moist room at 20+2°C for 24h. Demoulding took place after 24h and specimens were placed in water at 20+2 °C for a curing period of 7 and 28 days.

The flexural Rf and compressive strength Rc were measured at 7 days and 28 days.

Each compressive strength value was calculated as the average of the results from three specimens. The reference values correspond to the control mortar. All the average values of resistance are summarized in fig. 2, 3, 4 and 5.

3. Results and discussion

3.1. Characterization of studied sediments

The characterization of the sediments allowed us to measure the potential pollutant, we noticed an absence of metal pollution. The content of trace elements in *dredged sediments* (Table 1) was compared to the reference levels N1 and N2 given by GEODE (Group of Studies and Observations on Dredging and the Environment) [13]. All concentrations obtained are bellow N2. The results given in table 2 show that the sediments have high content of organic matter. The values of total PAHs remain below the values of the landfill threshold (50 mg/kg) [14]. So, there is an absence of organic pollution PAHs. Particle size analysis was performed by wet sieve of 63 µm in order to separate the fine fraction and the coarse fraction (> 63 m). The results indicate that these sediments are generally fine materials. Their principal constituents are clay, silt and fine sand. The absolute density for both sediments are nearly similar (Table 2). Table 3 shows that the silica percentages are almost equal for the two sediments.

Table1: Trace elements contents (mg/kg) of *dredged sediments* compared to limit values of GEODE [13]

Element (mg/kg)	Tangier	Larache	N1	N2
As	35.09	21.01	25	50
Cd	1.85	1.23	1.2	2.4
Cr	113.03	125.17	90	180
Cu	80.14	46.22	45	90
Pb	87.91	27.13	100	200
Ni	55.04	56.90	37	74
Zn	380.45	187.32	276	552

Results of XRD analysis of two sediments are shown in the figure 1. Both diffraction patterns are identical, we note the presence ni the two spectrums the following main phases :Kaolinite (K), Calcite (C), Muscovite (M), and Quartz (Q).

3.2. Compressive tests of mortars

Figures 2 and 3 show the evolution of the flexural strength Rf and compressive strength Rc values of mortars obtained for a substitution of 20% of sand versus curing time. The values of compressive strength are below the values of normal mortars (control) with a reduction of about 30%. This decrease of the resistance is explained by the presence of organic matter in the sediment introduced. However, the sediment from the port of Larache gives a stronger mortar than the sediment of Tangier because of the high rate of organic matter present in the sediment of Tangier.

Table 2: Characterization of studied sediments

	Tangier	Larache
Organic matter (%)	7.00	4.20
Total HAP (mg/kg)	0.17	$5.40\ 10^{-2}$
Fraction < 63 µm (%)	41	94
Fraction > 63 µm (%)	59	6
Absolute density (g/cm^3)	2.28	2.20

Table 3: Chemical composition (%) of studied sediments

Major elements (%)	Tangier	Larache
SiO_2	48.5	49.6
Al_2O_3	11.9	14.5
Fe_2O_3	7.4	9.1
CaO	11.7	11.2
MgO	1.2	0.5
Na_2O	2.0	2.1
K_2O	1.7	1.7
Loss on ignition (LOI)	15.9	14.5

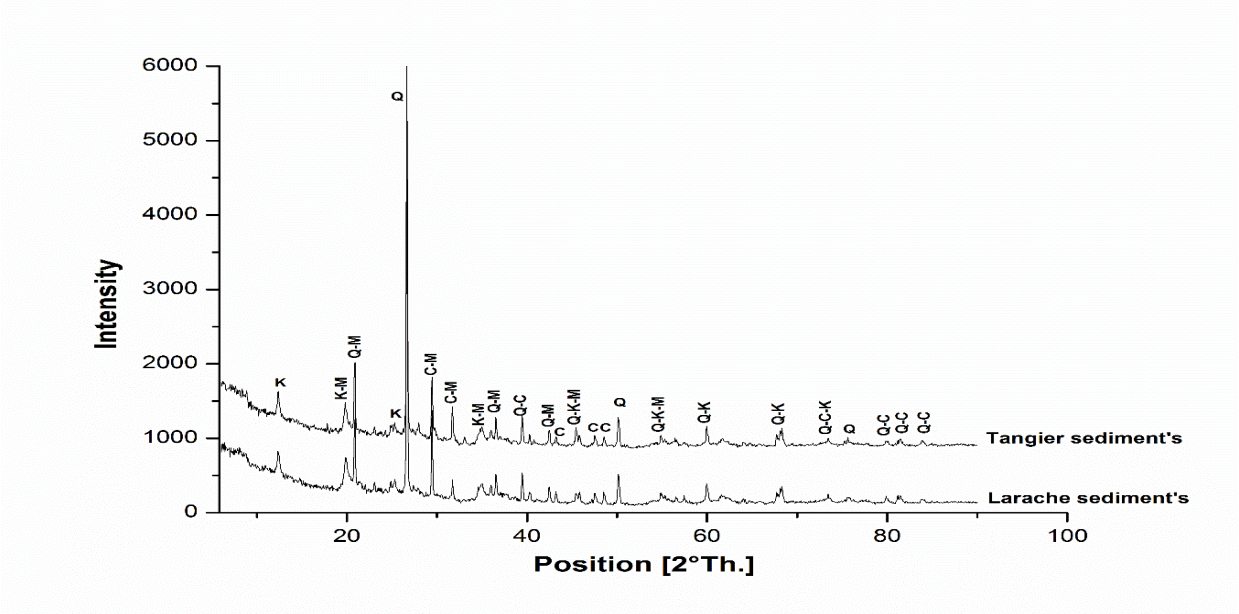

Figure 1: XRD of studied sediments

The presence of high organic matter in cement-based materials affect the mechanical strength of these materials [15] and the setting time of the cement paste [16-17]. Organic matter would capture calcium ions released by the cement during the hydration and would no longer form hydrates needed to manufacture strong bonds between particles [18-19], therefore the mechanical strength decreases.

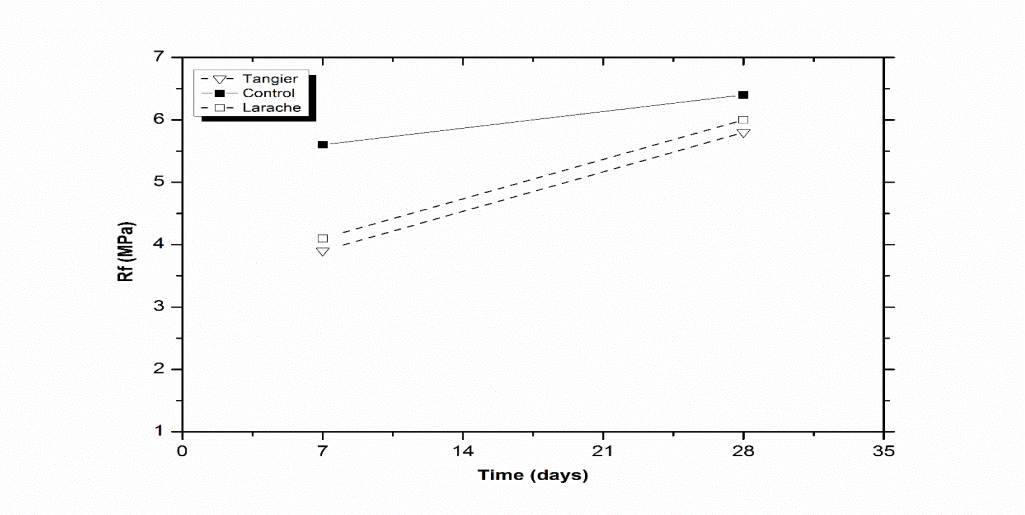

Figure 2: The flexural strength of mortars for a 20% substitution of standard sand

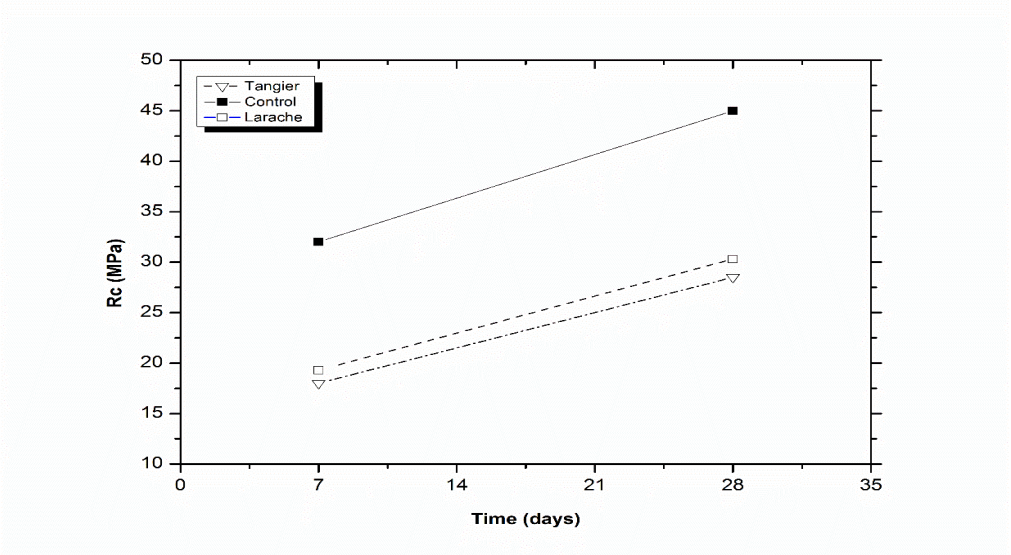

Figure 3: The compressive strength of mortars for a 20% substitution of standard sand

Results of the flexural strength Rf and compressive strength Rc at 7 days and at 28 days of mortars formed by substitution of 20% of cement are given in figures 4 and 5.

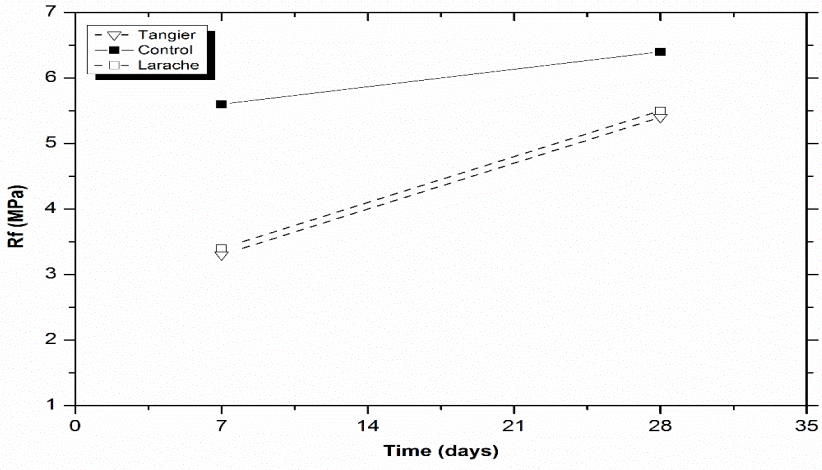

Figure 4: The flexural strength of mortars for a 20% substitution of cement

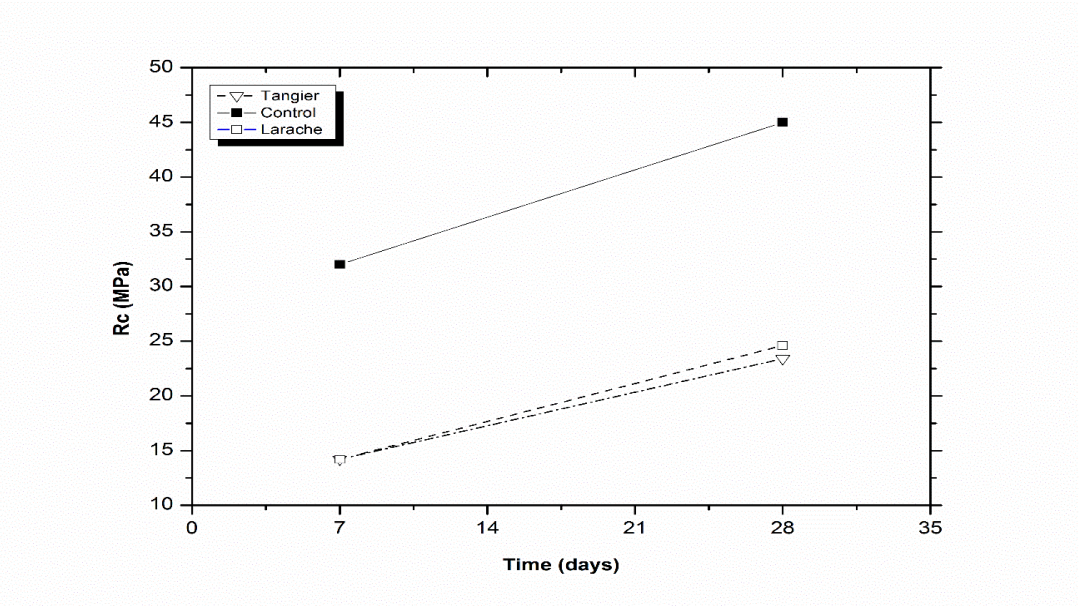

Figure 5: The compressive strength of mortars for a 20% substitution of cement

Partial replacement of cement by dredged sediments leads to a decrease of compressive strength with 45% in comparison with control mortar. This result is due to the diminution of the quantity of cement in mortars mixture, so less hydration mechanisms of C_3S and C_2S. A reduction in resistance is unavoidable. Thus, the *dredged sediments* present less performance than Moroccan cement CPJ 45 [11].

Conclusion

The characterization of *dredged sediments* from Ports of Tangier and Larache showed a high content of organic matter, important fine particles and the absence of metal and organic pollution.

The values of compressive strengths (Rc) of mortars obtained with partial substitution of sand by studied *dredged sediments*, are satisfactory with a rate of strength reduction about 30% in comparison with the control mortar. With such resistances, the potential uses relate to masonry mortars or manufactured blocks. For these products we can accept a partial replacement of the standard sand by these sediments.

In perspective, a thermal activation of *dredged sediments* (high fine content) could improve the pozzolanic properties and therefore the long-term mechanical performance. The heat treatment will transform the mineralogical composition of the material and the combination of new structures with the lime result in the formation of hydraulic binder.

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