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STUDY OF THE MECHANICAL PERFORMANCE OF THERMALLY TREATED MARINE SEDIMENTS ON CEMENTITIOUS PRODUCTS

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ABSTRACT

The objective of this inquiry is twofold: firstly, the harnessing of this prodigious quantity of refuse, and secondly, to assess the mechanical efficacy of these sediments in cementitious formulations. The valorization of marine sediments treated at temperature 700°C in cementitious products was carried out in order to evaluate the behavior of cement mortar during the substitution of cement by different concentrations of marine sediments. During the mortar preparation process, marine sediments treated with three different substitution rates (10%, 20%, 30%) of CEM I 52.5 Portland cement were used to replace an equivalent volume of cement. The experimental results show that calcination at a temperature of 700°C with a concentration of 10% gives better results and gives a cement compound with better mechanical properties.

Keywords: Dredging; marine sediments; cementitious products; mechanical performance; recovery.

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1. INTRODUCTION

The management of dredged sediment has emerged as a significant global concern, posing both economic and environmental challenges. France generates around 50 million cubic meters of sediment from harbors on an annual basis, whereas China dredges approximately 400 million cubic meters of sediment each year [1]. The management of dredged sediments is crucial for ensuring sustainable reuse and minimizing the impact on the environment. Various options for the beneficial use of sediments have been explored, including their use in construction, agriculture, and the production of bricks and ceramics [2]. Additionally, the characterization of sediments is essential to identify potential recycling paths and determine their suitability for different applications [3]. Proper treatment and disposal strategies are necessary, taking into account the contamination status and relevant standards [4]. Certain researchers explored the feasibility of utilizing sediments as a substitute for sand in cement-based materials [5,6,7]. Concrete, being the first material ever utilized, requires significant quantities of cement, aggregate, and water [8,9].

Couvidat et al. (2016) proposed that the utilization the coarse fraction marine sediment could be considered for incorporation into cement mortars, serving as an alternative to conventional sand specifically for non-structural applications [18].

The sediments analysed were obtained by the use of a mechanical dredge, which is essentially a mechanical shovel affixed to a pontoon, in the "Bethioua" region which is dedicated exclusively to oil activities. A number of identification tests were carried out on the samples collected. The study encompasses a collection of physical and chemical characteristics. Upon calcination marine sediments at a temperature of 700°C, marine sediments were incorporated into cementitious products to assess the comportment of cement mortar amidst the substitution of cement by varying concentrations of sediments (10%, 20%, 30%).

2. MATERIALS AND METHODS

The objective of this part of the study is to know the behavior of cement mortars when replacing cement with raw and treated (thermal) marine sediments from the port of Bethioua at calcination temperature (700°) with the different percentages of additions (10%, 20% and

30%). The portland cement used is a Matine type CEM I 52.5 /grey. This type of portland cement contains 97% clinker and 3% gypsum. Four mixtures were prepared, Four combinations were created and their compositions, together with their identification codes, are shown in Table 1.

Table 1. The percentages used for the formulation of the test tubes

		Marine sediment	Cement
Formulation	(F1)	0	100
Formulation	(F2)	10	90
Formulation	(F3)	20	80
Formulation	(F4)	30	70

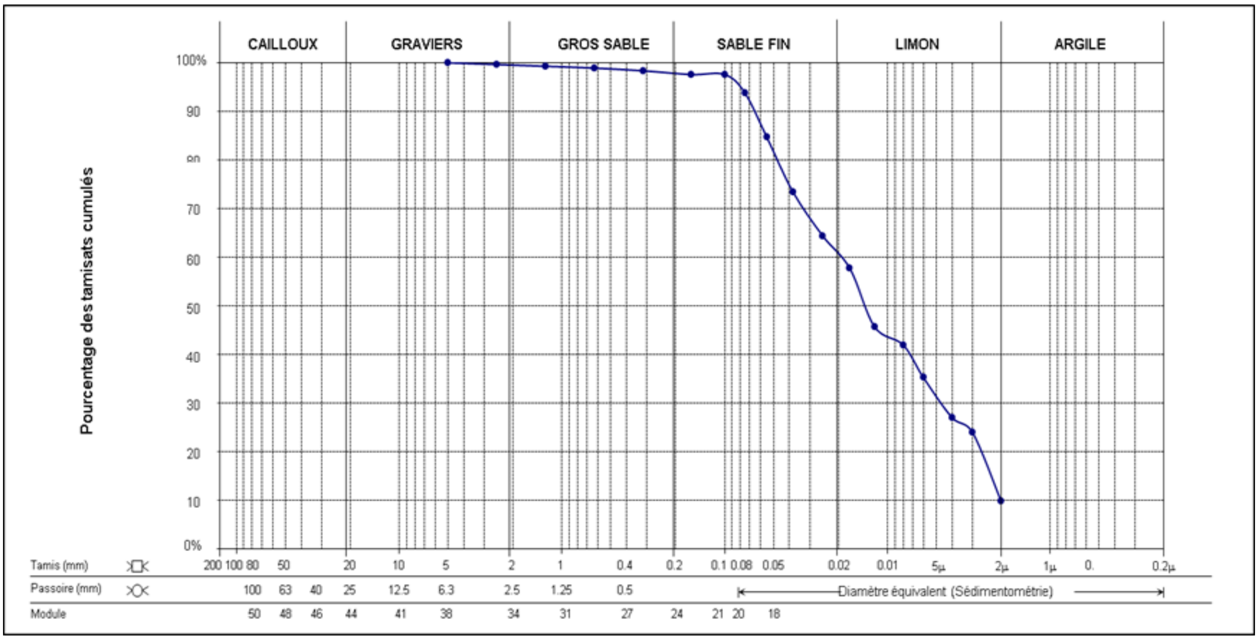
Fig.1. Formulations prepared from raw and treated (thermal) sediments

3. CHARACTERIZATION OF SEDIMENT

3.1. Physical properties

The water content is measured by subjecting the sample to heat at a temperature of 105°C, following the guidelines outlined in the NF P 94-050 standard. Marine sediments have an average water content value of around 24.20%. The density of solid particles of marine sediments using a pycnometer according to standard NF P94-054.

The marine sediment has an average value of around 2.31 g/cm^3. The sand equivalent test is carried out according to standard NF P18-598 for marine sediments. The sand equivalent values measured on the sediments of the port of Bethioua were of the order of 55.32% which makes it possible to identify the type of sand (clay sand). The determination of the liquidity limit was carried out using the Casagrande apparatus according to French standard NF P94-051. The liquidity limit value is of the order of 31.28%. The plastic limit is determined by the roller method. Sticks 10 to 15 mm long and 3 mm thick are formed and then put in a tare and oven direction for 24 hours so that we can then do the calculations. The plasticity limit value is of the order of 22.67%. The plasticity index Ip of marine sediments is 8.61%. These results show that the sediments of the port of Bethioua are not very plastic and have a very firm consistency. The particle size analysis carried out on the sediments gave the particle size curve shown in Figure 2, These sediments are composed of 27.79% coarse sand,33.33% fine sand, 33.33% silt and 5.55% clay. The particle size indices express the position and dispersion of the particle size distribution. Those that are generally the coefficients of uniformity that characterize the slope of the particle size curve, which are also called the coefficient of uniformity Cu is 10 mm and the coefficient of curvature Cc is 6.25 mm of the



particle size curve. The median diameter (D50) of the sediments is of the order of 0.002 mm and the diameter through which 95% of the particles pass is equal to 0.06mm.

Fig.2. Particle size curve of marine sediments from the port of Bethioua

3.2. Chemical properties

The pH values were assessed in accordance with the NF X31-103 standard, revealing that the marine sediments exhibit alkaline characteristics. The measurement of electrical conductivity was conducted using a calibrated conductivity cell following the NF ISO 11625 standard. According to the results of the test, the conductivity value is of the order of 342 ms. The organic matter of the materials studied was determined according to standard XP P94-047. According to the test results, the value of organic matter (OM) is of the order of 5.78%. After (2% ≤% MO ≤ 6), it can be said that the sediments of the Port of Bethioua are weakly organic. The determination of methylene blue was carried out following the NF P 94 068 standard. The results of the test indicate a methylene blue value approximately around 1.15%. This falls within the range of (0.2 < VBS < 2), it is found that the sediments of the Port of Bethioua are silty soils (poorly plastic soil). The calcium carbonate (CaCO3) content of the soil was determined by a calcimeter according to the standard (ASTM D4373-96). According to the results of the calcium carbonate test, a value of the order of 25.70% is obtained. After (10% < %CaCO3 < 30%), indicating that we are in the presence of a slightly marly and low-limestone clay. The results of the X-ray fluorescence analyses of the materials studied are given in Table 2. In order to assess the environmental impact of marine sediments, a study was carried out by Dr BENYEROU for the measurement of trace elements such as (Lead, Mercury, Cadmium, Arsenic, Tin, Nitrite, Phenol and Total Hydrocarbon). Measurements carried out on the sediments of the port of Bethioua show that the proportion of trace elements is lower than the N1 level and the N2 level. These analyses were determined by direct spectrometric analysis on solid materials. These analyses were carried out at the AFAK laboratory. The results of the environmental analyses are summarized in Table 3.

Table 2. Chemical analysis of marine sediments and different formulations.

Degree of sediment calcination	Sediment addition rate	Substances							
		Silicon dioxide	Al2O3	Fe2O3	CaO	MgO	SO3	K2O	Na2O

Raw Sediment	10%	16.72	5,70	3.14	60.65	3.63	2.47	0.65	0,20
	20%	16.86	5.63	3.45	58.77	3.62	2.25	0.66	0,20
	30%	17.00	6.30	3.77	56.81	3.58	2.05	0.66	0,20
700°C	10%	16.74	5.16	3.19	61.09	3.74	2.46	0.65	0,20
	20%	16.91	5.72	3.47	58 / 71	3.74	2.24	0.66	0,20
	30%	17.13	6.60	3.94	55,63	3.75	1.91	0.66	0,20

Table 3. Concentrations of trace elements, measured in (mg/kg) of dry materials analyzed within the fraction less than 2 mm, are defined by GEODE (METL & MATE) in the year 2000.

Regulatory threshold Recommended by the MATE (1999)	Level 2	Level 1	Marine sediment	Units	Metals
250	200	100	<0.01	mg/kg	Lead (Pb)
1.5	0.8	0.4	<0.01	mg/kg	Mercury (Hg)
180	180	90	<0.005	mg/kg	Chrome (Cr)
3	2.4	1.2	<0.01	mg/kg	Cadmium (Cd)
/	50	25	< 0.05	mg/kg	Arsenic (As)
/	/	/	<0.01	mg/kg	Tin
/	74	37	0.00	mg/kg	Nitrite
/	/	/	0.017	mg/kg	Phenol
300	/	/	1.010	mg/kg	Total hydrocarbons

These findings allow us to infer that when comparing the heavy metal concentrations in the examined sediments with the reference levels (MATE, 1999), it becomes evident that the sediments in the Port of Bethioua are devoid of pollution. Consequently, these sediments extracted from the Bethioua port possess the potential for reuse in the development of new materials in civil engineering, presenting significant economic and ecological benefits.

4. RESULTS AND DISCUSSION

The primary characteristic of cement that holds utmost significance is the progression of compressive strength. In a cement plant, the precision and accuracy of a test specimen for evaluating compressive strength are crucial. The resistance classes of cements are defined by ENV 197-1 and NFP 15-301 based on their strength at 2 (or 7 days) and 28 days. These specific timeframes are essential for confirming the conformity of a cement. The tabulated results of compressive strength can be found in Table 4.

Table 4. Result of compressive strength.

Degree of sediment calcination	Sediment addition rate	Compressive strength in MPA		
		2 days	7 days	28 days
Raw Sediment	10%	26.9	39.5	47.7
	20%	23.3	38	40.1
	30%	19.4	30.3	34.8
700°C	10%	29	44.5	52.4
	20%	25.2	40.8	49.6
	30%	20.95	34.3	44.3
CEM I reference		29.1	47.5	52.5

Comparison with the mechanical characteristics from the tests at 2, 7 and 28 days on the same formulation of 10% calcined marine sediments at a temperature of 700°C, shows that the results at 2 and 28 days give identical values to that of the reference formulation. The mechanical strengths increase according to the age of hardening for this concentration. This may be due to the variation in the hydration kinetics of the mineral C3S (tricalcium silicate) and C2S (dicalcium silicate) because the latter are the two main minerals that ensure the development of mechanical strengths as well as the pozolanic reactions that react in the long term.

Compressive strength decreases with increasing percentage of addition. This decrease in resistance is considerable especially at a young age and decreases as the percentage of addition increases. It can be concluded that the substitution of cement by marine sediments treated (thermal) at a temperature of 700°C is the most suitable for recovery in cement mortars with a concentration of 10% (RC = 52.4 MPA).

5. CONCLUSION

This study concluded that:

• Physical analyses have shown that these sediments are of the clay sand type. They are classified as poorly plastic materials with a percentage of 3.8% in clays, tests have shown the existence of a low organic matter content of 5.78% and a percentage of $CaCO_3$ is of the order of 25.70%.

• Compressive strength decreases with increasing percentage of addition. This decrease in resistance is considerable especially at a young age and decreases as the percentage of addition increases.

• The mechanical strengths increase according to the age of hardening for this concentration. This may be due to the variation in the hydration kinetics of the mineral C_3S (tricalcium silicate) and C_2S (dicalcium silicate) because the latter are the two main minerals that ensure the development of mechanical strengths as well as the pozolanic reactions that react in the long term.

• Experimental results show that for formulations of 10% marine sediments, the resistance is systematically closer than that obtained for the reference formulation (CEM I).

• The compressive strength decreases as the percentage of addition increases and it increases as the shelf life increases. It reaches the value of 52.4 MPa for 28 days and 10% of addition it is equivalent to the value of the CEM I reference cement (52.5 MPa).

• It can be concluded that the substitution of cement by marine sediments treated (thermal) at a temperature of 700°C is the most suitable for recovery in cement mortars with a concentration of 10% (RC = 52.4 MPA).

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