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Physics Procedia 21 (2011) 28 – 34

Physics Procedia

Conference Title

Effect of limestone fillers the physic-mechanical properties of limestone concrete

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Abstract

This work focuses on the exploitation of local industrial wastes and their use in the formulation of new concretes which can be used in local constructions. The valorised materials are limestone crushing sand (0/5mm) and limestone fillers (80µm). The two materials are extracted from local aggregate crushing wastes. Thus, and since the used gravels are also of limestone nature, the formulated composite is a limestone concrete. So this study constitutes an experimental work that aims at the study of the effect of the addition of limestone fillers on the physico-mechanical behaviour of limestone concrete. To carry out this study, different proportions of fillers ranging from 0 to 40% were considered. Very important results have been achieved on the workability and strength. By increasing the amount of limestone filler in concrete, the first one improves, but the second one increases then decreases passing by an optimal content of fillers which gives a maximum mechanical strength. Finally, and concerning the dimensional variations, it is noteworthy that they decrease at the beginning till an optimal value of fillers content, but beyond this optimum, they start increasing without exceeding recommended values.

Key-words: Crushing limestone sand, Limestone fillers, workability, Mechanical strength, Dimensional Variations.

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 doi:10.1016/j.phpro.2011.10.005

1. INTRODUCTION

The majority of buildings in Algeria have been made with alluvial sands. At Laghouat, it's the same case; almost all buildings are made of alluvial sands. But, in the 2000s, a new law came to prohibit the extraction of sand and river beaches. Moreover, in some areas, we are currently facing a progressive exhaustion and sometimes a total absence of siliceous materials intended for the formulation of concretes. To overcome this sands needs, mostly generated by the ban on sand extraction rivers, the state has proposed various mine sites across the country for the production of crushed sand. It should be noted that there are very large deposits of untapped limestone massive rocks. These facts have guided researchers to reflect on the formulation of new concretes, in which the siliceous materials will be replaced by limestone materials. These concretes are called "limestone concrete" [1]. It should be noted that a limestone concrete is defined as a concrete whose all aggregates are of limestone nature.
In addition, wastes resulting from the crushing of aggregates constitute an environmental nuisance that's difficult to overcome. Therefore, the reuse of these wastes in the field of construction can solve a threefold problem: environmental, technical and economic problems. Several applications have been conducted in this direction and have allowed the developing of new building materials comparable to the usual materials or even better [2]. It's in this context therefore that we undertook this study. Its objective is to promote local materials and to reuse industrial wastes in building construction. It aims at the study of the effect of adding limestone fillers on the physico-mechanical properties of limestone concrete. The proposed contents of fillers vary from 0% to 40% by mass relative to the sand.

2. USED MATERIALS

2.1. Sand

The used sand is a white crushed sand (0 / 5 mm) extracted from the area of the city of Laghouat (Algeria). Its physical characteristics are summarized in Table I and its particle size distribution is shown in Figure 1.

Table 1: Physical Characteristics of used sand

Apparent density (kg/m^3)	Specific density (kg/m^3)	Compactness	Porosity	Fineness Modulus	Sand equivalent	
					ES piston	ES Visuel
1541	2660	*0,58*	*0,42*	*2,21*	*69*	*68*

2. 2. Gravel

The used gravels are extracted also from the areas of the city of Laghouat. They are mainly composed of limestone. Two fractions are selected for the production of the studied concrete: 3/8 and 8/15mm. Their physical characteristics are shown in Table II and their particle size distribution is shown in Figure 1.

Table 2: Physical Characteristics of used gravels

Specific density (kg/m^3)	Absorption Capacity of water (%)	Porosity (%)
2660	1,4	3,66

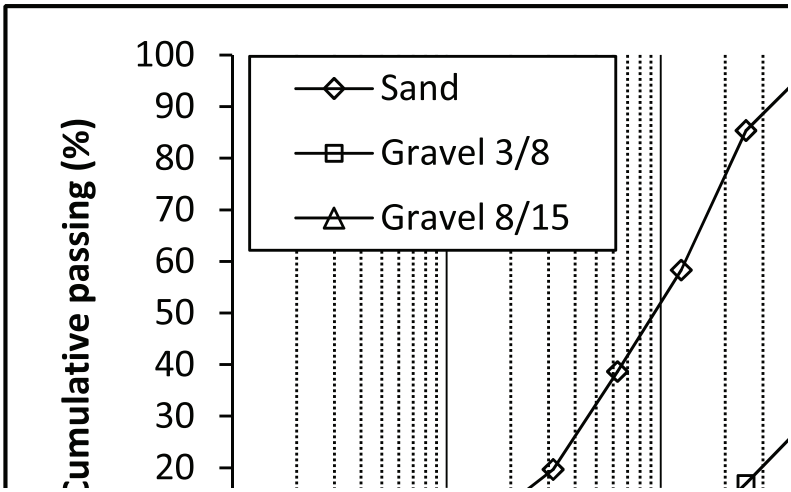

Fig. 1 : Particle size distribution of the different aggregates used

2 .3. Fillers

The fillers used have been obtained by sifting (to a sieve opening of 80 μm) crushing waste generated in Laghouat region. They are mainly composed of limestone (97.5 mass% of CaCO3). The EDX analysis has highlighted the calcareous nature of these fillers. Their physical characteristics are summarized in Table III. Let's note that the limestone fillers are best suited for concrete (high reactivity with cement) and offer the best performances to the concrete [3].

2.4. Cement

The cement used is a CPJ-CEM II/A 42.5; its physical characteristics are given in Tables III and IV.

Table 3: Physical Characteristics of used fillers and cement

	Apparent density (kg/m^3)	Specific density (kg/m^3)	Blaine specific surface area m^2/kg
Fillers	1026	2715	322,9
Cement	1038	3010	320

Table 4 : Setting time of used cement

	At cold weather	At hot weather
Initial set	2h 45mn	30mn
Final set	5h 28mn	1h 15mn

3. PREPARATION OF THE STUDIED CONCRETE

3.1. Composition

The compositions of the studied concrete and the different considered proportions are shown in table V.

Table 5: Different compositions of the studied limestone concrete

Composition	Content (kg/m^3)						
Cement (C)	400						
Sand (S)	730						
Gravel 3/8 (G1)	194						
Gravel 8/15 (G2)	912						
W	202 (l/m^3)						
Fillers (F) (% comparing to the mass of sand)	0	5	10	15	20	30	40

3.2. Mixing and conservation

Gravel 8 / 15, the gravel 3 / 8, sand, cement and fillers are introduced into a mixer and firstly mixed at dry state, then in adding gradually water until the proper homogenization of the material. The samples are made in cubic forms (10x10x10 cm) for measuring the compressive strength and prismatic forms (7x7x28 cm) for measuring the flexural strength and shrinkage. After demoulding, 24 hours after casting, the specimens are kept in water at a temperature of 20 ± 5 ° C for 72 hours before being returned to the air in laboratory conditions until the day of test.

4. EXPERIMENTAL RESULTS ET DISCUSSIONS

Three different properties are studied in this work: the workability, the mechanical strength and the shrinkage.

4.1. Workability

This test was performed according to standard NFP 18-45 [4] using the Abram's cone, also called "Slump test". The results obtained are shown in Figure 2.

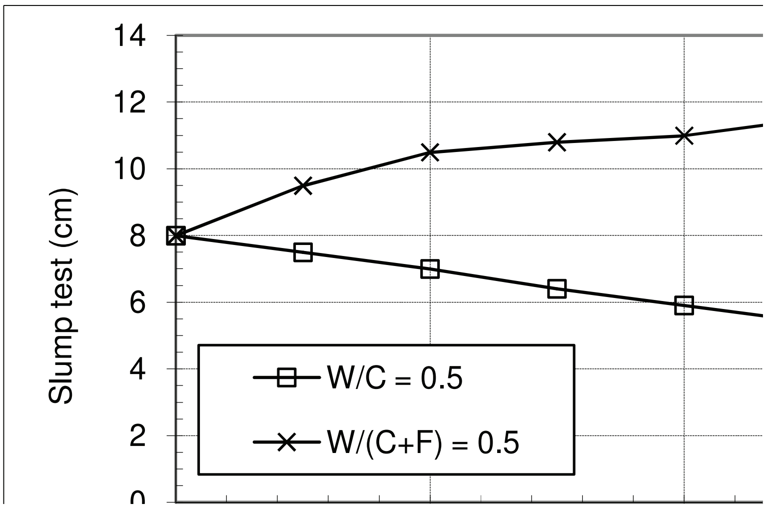

Fig. 2: Evolution of the workability according to fillers content

From this figure, it is clear that, in the case of " W/C=constant ", the workability slightly decreases when the fillers content increases. This is due to the fact that, although the specific surface of aggregates was increased, the water content did not change and the mixture required more water. But when the evolution is studied with " W/(C+F)=constant ", we can see that the workability improves with increasing fillers content. So, when the volume of the paste of cement and fillers increases, the aggregate grains find a facility of movement during the casting.

4.2. Mechanical strength

4.2.1. *Compressive strength*

This test was performed according to standard NFP 18-406 [5]. The compressive strength was measured by compression using a universal press on 10x10x10 cm cubic samples. The obtained results are illustrated by Figure 3.

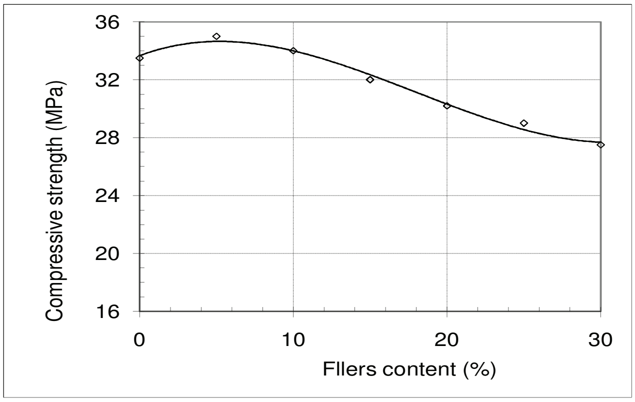

Fig. 3: Evolution in compressive strength vs. fillers content

It is obvious that after 28 days, the compressive strength reaches its maximum value at a rate of about 5% of fillers [6]. Beyond this quantity, the compressive strength decreases with the increase of filler. We can, therefore, infer that for this optimum proportion of fillers giving the maximum strength, the compactness is also maximum, since a profit in compactness is almost generally accompanied by a profit in strength.

On the other hand, and below the optimum content of fillers, the fillers merely fill the inter-granular voids, which increase the compactness of the material and consequently its mechanical strength. But once these voids are completely filled, the additional portion of fillers begins to take the place of main aggregates grain, which reduces the stiffness of the granular skeleton and hence the mechanical strength of the composite.

4.2.2. *Flexural strength*

For each composition, flexural strength was determined (using three points test) on six 7x7x28 cm prismatic samples.

It appears that the flexural strength according to the rate of fillers evolves in the same manner as the compressive strength. It has been also recorded an optimal rate of fillers that gives a maximum value of flexural strength. This optimum rate of fillers is almost similar to that recorded in the case of compressive strength (5%). Beyond this value, it has been observed a marked decrease in flexural strength. This may be due to the same reasons cited in the case of the compressive strength.

Figure 4 shows the relationship between the rate of fillers and flexural strength.

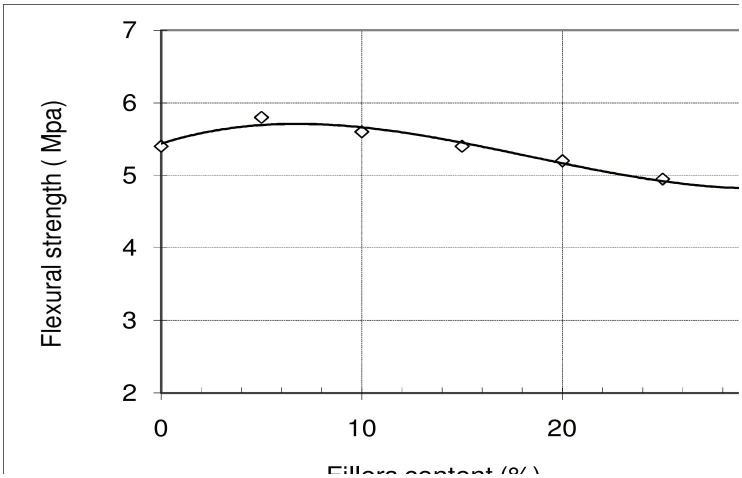

Fig. 4: Evolution in flexural strength vs. fillers content

4.3. Dimensional variations

This property was studied using the shrinkage test. Let's note that the shrinkage does not only depend on conditions of conservation (humidity, temperature, etc.), but also the constituents of concrete. The increased dosage of cement, for example, generally increases the shrinkage of concrete [7].
Is it the same case for the fillers?
To appreciate this phenomenon in the case of fillers, shrinkage measures were carried out on 7x7x28 cm prismatic samples according to standard NFP 15-433 [8]. The conservation of specimens was made in the open air at room temperature in the laboratory. The shrinkage was measured with a retractometer with a digital dial. The results obtained are shown in Figure 5.

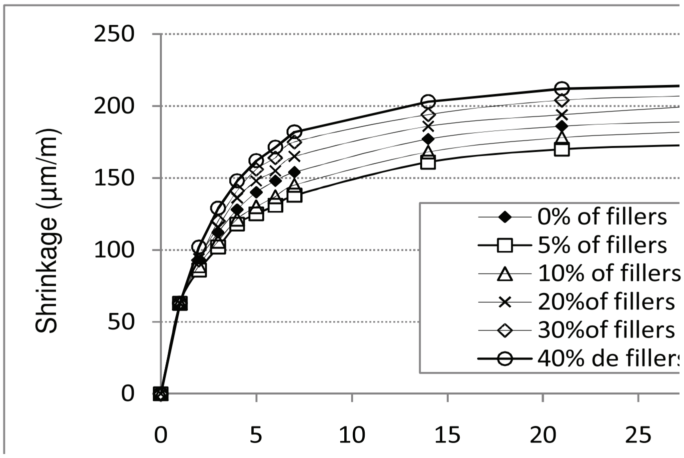

Fig. 5 : Evolution in shrinkage vs. fillers content

In observing the curves shown in Figure 5, we can see that the shrinkage of the limestone concrete decreases at low contents of fillers, but beyond a certain percentage of fillers, an increase is recorded: the higher the quantity of fillers in concrete is, the greater the shrinkage is. It is clear, therefore, that there is an optimum filler content of about

5%. It is the same rate as that which gave the best mechanical properties. The rheological properties at this optimum are also better comparing with those obtained without fillers.
Let's note that it's possible that the increase of the fineness of the filler increases the requirement of filler content and the optimum content will be slightly higher [9]. It should be noted finally that, for all contemplated rates of fillers, the shrinkage of limestone concretes is acceptable and does not exceed the recommended values for current concretes.

5. Conclusion

The main objective of this experimental work is to valorise local materials and industrial wastes by using them in construction. It aims at the study of the effect of the addition of limestone fillers on the physico-mechanical properties of limestone concrete. Starting from the test results, it can be concluded:

- Adding limestone fillers improves the workability of concrete limestone;
- It also improves its mechanical strength (in compressive and in flexural);
- And it reduces its dimensional variations.

The best values of mechanical strength and shrinkage were obtained by using an optimum content of fillers which were about 5%. It could be noted, finally, that it is possible to formulate limestone concretes having good physico-mechanical properties by using fillers and aggregates extracted from wastes of local careers.

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