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Study of the reinforcement of limestone mortars by polypropylene fibers waste

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Abstract

The first objective of this study is the valorisation of limestone waste produced from the crushing stations by using it as fine sand for mortars mixes and hence replaces the river sand. The second objective is the reinforcement of mortars by polypropylene fibers waste coming from the fabrication of domestic brushes and sweeps.
In this paper we presented the results of physical and mechanical properties of reinforced mortars prepared with limestone sand which is in abundance in the city of Laghouat situated in 400km in the South of Algiers. The fibers dosages used are: 0.5, 1, 2 and 4wt% with length of 10, 20 and 30mm. The results of this investigation put in evidence the efficiency of the reinforcement of limestone mortars by polypropylene fibers waste in the improvement of their flexural tensile and compression strength.

Keywords: Valorisation; Fibers reinforced Concrete; Waste; polypropylene fibers; Workability; Tensile strength; Compressive strength.

1. Introduction

The concrete is the most used material in construction; nevertheless its low behaviour in tension constitutes always a handicap in its history. This handicap is the main cause of cracking which can damage its durability and its appearance; one of the solutions proposed to stop these cracking is the reinforcement of concrete by fibers, it's about fibers reinforced concrete. Adding fibers to a matrix increases the energy absorbing capability of hardened concrete, makes it more suitable for use in structures subjected to impacts and earthquake loads Boulekbache et al. [1].

Fibers play a beneficial role in improving the strength and have an effect of sewing of cracks after fracture of the matrix and give a better distribution of these cracks. The uniform distribution of fibers in the matrix of the concrete offers it isotropic properties, which can't be obtained in the traditional concrete.

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The cost of fibers constitutes an importing disadvantage in fibers concretes, but the use of fibers waste as reinforcement of concrete is going to reduce its cost price. According to Youjiang [2] each year, a large amount of fibrous waste is disposed of in landfills; this not only poses economical and environmental concerns to the society, but also represents a waste for resources.

The reinforcement used in this study is assured by polypropylene fibers waste resulting from the industry of brushes and sweeps. Due to their low weight, high deformation rate and does not react with cement elements, the polypropylene fibers are among the most used one for the reinforcement of concretes. Polypropylene fibers are also hydrophobic and do not absorb water or bond chemically to cement paste Sugi et al. [3].

In the present research we studied the effect of polypropylene fibers on the physical and mechanical behaviour of mortars prepared based on limestone sand. The results obtained show that the adding of polypropylene fibers into the limestone mortar decreases its workability but it confers it a significant increment of its flexural tensile and compressive strength.

2. Materials and experimental methods

2.1. Materials

The sand used was limestone crushing sand with a maximum particle size of 2mm; it has a specific gravity of 2.52, a fineness modulus of 1.8 and a sand equivalent of 63. The Portland cement used consisted of class 42.5 with a density of $3g/cm^3$ and a specific area of $3200cm^2/g$. The chemical analyses of cement revealed the following composition: 65.9%CaO, 21.94%SiO_2, 4.82%Al_2O_3, 3.94%Fe_2O_3, 1.65%MgO, 0.98%SiO_3, 0.6%K_2O and 0.1%NaO_2. Polypropylene fibers have a diameter of 0,62mm, a ratio l/d between 16, 32 and 48, a specific gravity near to 1.00, a deformation of 58%, a tensile strength of 86MPa and a nil absorption.

2.2. Mix proportions, and Tests

Sand/cement and water/cement ratio were equal to 3 and 0.78 respectively. Content percentages of fibers were 0.5, 1, 2 and 4wt%. The measure of workability was made according to the French Standard NFP 18-452. Specimens 4x4x16cm were prepared, demoulded after 24 hours of casting and then cured in water in 20C° until testing. The flexural tensile strength through a three points and compressive strength were determined according to the French Standard EN196-1.

3. Tests results and discussions

3.1. Workability

According to the Fig. 1, the incorporation of polypropylene fibers was a negative effect on the workability of mortars.

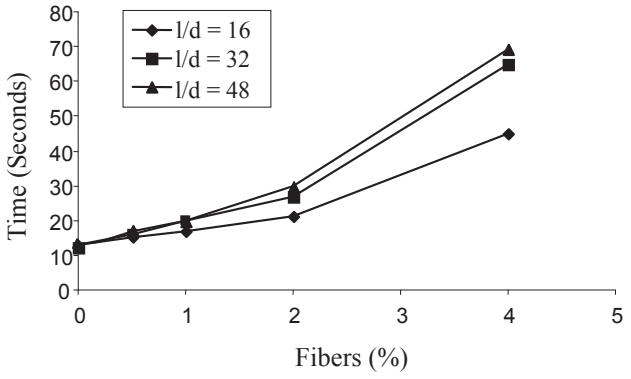

Fig. 1. Effect of fibers addition in workability of limestone mortars

This result was confirmed by the majority of reinforced concrete researches Hashem et al. [4]. It can also notice that the addition of more than 1% of polypropylene fibers in mortar present a large reduction in the workability, while Edgington et al. [5] recommend 2% maximum steel fibers content. Results from Chemrouk et al. [6] indicate that a volume of 1% of steel fibers seemed to be a reasonable one for high performance concrete reinforced. We can also remake that the workability of mortars decreases by increasing of the ratio l/d of polypropylene fibers. But the effect of the ratio l/d of fibers is less important than the effect of their content percentage.

3.2. Flexural tensile strength

The Fig. 2 shows that the flexural tensile strength evolves with the content percentage and with the ratio l/d of polypropylene fibers.

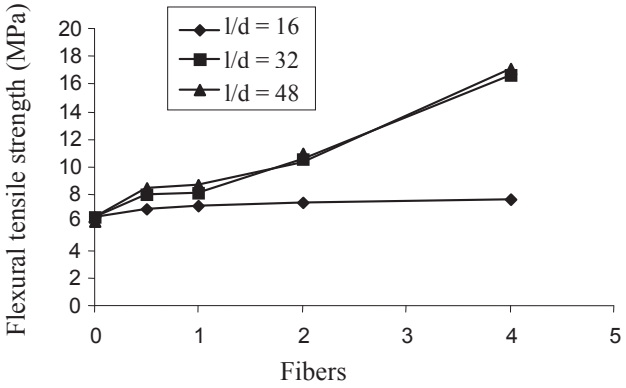

Fig. 2. Behaviour to the flexural tensile strength of polypropylene fibers mortars

This evolution is much more appreciated beyond 2% of fibers; this is justified by the beneficial role of fibers to prevent cracks, below 2%, the effect is insignificant. From the study elaborated by Zhijian et al [7], the fiber content by weight is the main factor affecting the mechanical properties of hemp fiber concrete and the optimal fiber content necessary to increase the flexural strength was approximately 0.6%.

According to the Fig. 3, introduction of polypropylene fibers with ratio l/d=16 into mortars offers a small improvement in their flexural strength.

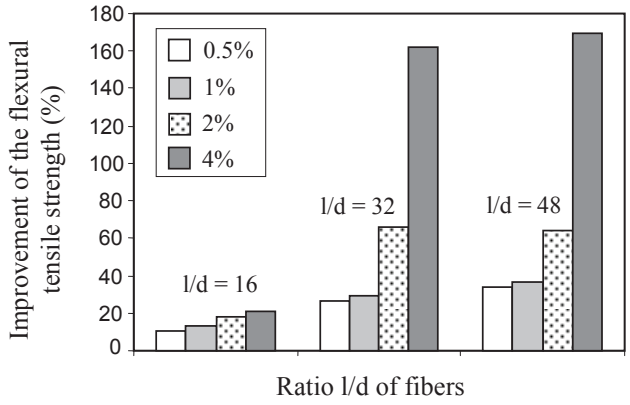

Fig. 3. The improvement of the flexural tensile strength of of polypropylene fibers mortars compared to that of mortars without fibers

But fibers with ratio l/d=32 and 48 confers them the same improvement witch possess between 26% for 0.5% of fibers and 162% for 4% of fibers with l/d=32 and between 34% for 0.5% of fibers and 170% for 4% of fibers with l/d=48. Sugi et al. [3] indicate that the presence of polypropylene fibers had a little influence on the flexural strength for volume fraction of fibers between 0.1, 0.2 and 0.3%.

3.3. Compressive strength

By examining the Fig. 4, we notice that the compressive strength is an increasing function with the amount of polypropylene fibers and with the ratio l/d also.

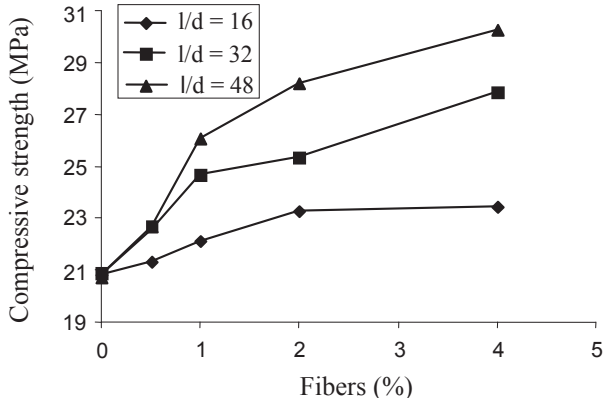

Fig. 4. Behaviour to compressive strength of of polypropylene fibers mortars

According to the Fig. 5 we can see that the improvement of the compressive strength compared to that of mortars without fibers is much weaker than this found in the flexural tensile strength. In mortars reinforced by 0.5% of fibers with l/d = 48 for example, the compressive strength is improved by more than 7%, while the introduction of 4% of fibers with the same ratio l/d increases this rate beyond 45%. From the experimental results found by Song et al. [8], the compressive strength of the nylon fiber concrete and the polypropylene fiber concrete was improved by 12.4% and 5.8% respectively for a fibers's concentration of 0.6kg/m^3. Nevertheless that the majority of the researches realized on reinforced concretes indicated that had no or a small evolution of the compressive strength such the studies from García-Santo et al. [9] and Sugi et al. [3] realized in polypropylene fibered composite. The possible reason for this behaviour is the bad homogeneity of the concrete, the high ratio of water or the weak compactness of the concrete caused by the excess of fibers.

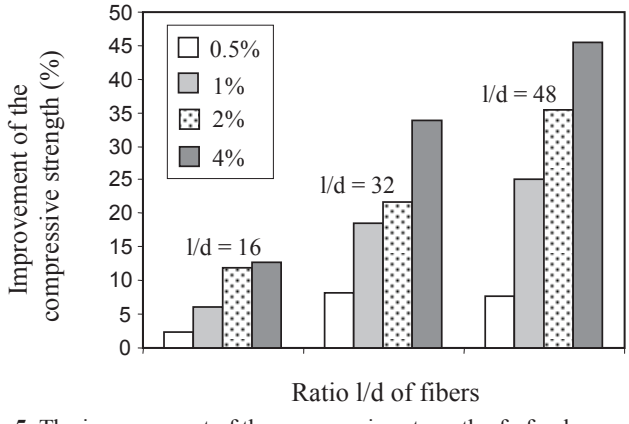

Fig. 5. The improvement of the compressive strength of of polypropylene fibers mortars compared to that of mortars without fibers

4. Conclusion

From this study, the following conclusions can be drawn:

- Addition of polypropylene fibers in limestone mortars decreases their workability. Beyond 1% of polypropylene fibers, the used of a Superplasticizer is a necessity.
- The role of the ratio l/d of the polypropylene fibers on the workability of mortars has only a secondary role with regard to the role of their content percentage.
- Using polypropylene fibers as element of reinforcement into limestone mortars produces a significant increment of their flexural tensile strength and confers them a small improvement of their compressive strength.
- Polypropylene fibers presented a high strength to the tearing of the matrix. Beyond 2% fibres, the test specimens crushed with flexion remained just fissured.

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