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Formulation of low cost eco-repair mortar based on dune sand and Stipa tenacissima microfibers plant

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HIGHLIGHTS

- The use of Alfa micro-fiber increases compressive and flexural strengths and decreases shrinkage.
- Mortar with 0.75% fibers present a very good resistance to gas permeability and lower sorptivity.
- Mortar with fibers has a bond strength higher than that of ordinary mortar.

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ABSTRACT

Mortar for patch repair of damaged concrete elements by corrosion or honeycombing are extensively used. However, they are quite expensive and they frequently incorporate low volume of synthetic fibers. This paper presents an experimental study on the development of an eco-repair mortar based on dune sand and microfibers plant. The vegetable fibers are 3–5 mm long Alfa microfibers plant (Stipa tenacissima L.) and are used with different volume ratios. The physical and mechanical properties investigated are compressive strength, flexural strength, shrinkage and bonding strength. The durability of mortar was evaluated through gas permeability and capillary water absorption tests. The results obtained show an enhancement of the mechanical and physical properties of mortars with natural microfibers compared to those of mortars without natural fibers. A lower sorptivity and a lower gas permeability were also obtained for the repair mortar reinforced with microfibers plant.

1. Introduction

Construction industry consumes large amounts of natural resources and energy and there is a need for using local and natural renewable materials such as natural fibers and recycled materials. In addition, reinforced concrete infrastructures deteriorate with age and under aggressive environments such as hot climate. Hence, there is need to rehabilitate and repair old reinforced concrete structures such as historical buildings, wharfs and bridges. The repair mortar used for corroded concrete structures is usually a cement based mortar with and without fibers. In North Africa region, the repair mortar is costly as it is mainly imported from Europe and there is a need for formulating mortar using local materials such as dune sand and natural fibers to reduce cost. Natural fibers are cheap and readily available and require low energy for their production as compared to synthetic fibers.

Dune sand is available in large quantities in the Sahara and is covering over 60% of the area of Algeria. Recently, there has been a growing interest in sand dune as construction material [1–4]. Dune sand is used as a replacement to manufactured sand river and river sand which its use is restricted for environmental reasons and hence help preserving natural resources.

In fiber-reinforced mortars, fibers are usually synthetic polyethylene or polypropylene fibers and are discontinuous and randomly distributed throughout the composite. Random dispersion of fibers delay cracks and limits their openings through the effects of bridging transmitted to the fracture surfaces [5–9]. However, to produce ecofriendly mortar, the use of recycled fibers such as foamed recycled fibers, recycled steel fibers from waste tires or

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lathe metal workshop, waste polypropylene fibers from storage bags and recycled nylon fibers have been used to get more sustainable cement mortar composites [10–14] or vegetable fibers as reinforcement is a viable way for achieving a more sustainable construction [15,16]. Vegetable fibers are considered as a renewable resource, stronger than synthetic fibers, less costly and environment friendly. Natural fibers include among others coconut, sisal, jute, Hibiscus cannabinus, eucalyptus grandis pulp, malva, ramie bast, pineapple leaf, kenaf bast, sansevieria leaf, abaca leaf, vakka, date, bamboo, palm, banana, hemp, flax, cotton and sugarcane fibers [17]. The incorporation of fibers into cementitious materials can effectively improve their toughness and can control drying plastic shrinkage cracks [18–23]. Other advantages of vegetable fibers in cement composites include increased flexural strength, post-crack load bearing capacity, increased impact toughness and improved bending strength, cost reduction and benefits associated with processing, compared to synthetic fibers [24–26]. Vegetable fibers are eco-friendly materials as they are obtained from renewable sources. However, they are considered as biodegradable [27]. Natural fibers, recycled PET fibers and wood fibers have been reported to degrade when embedded in cement matrix [28,29].

Alfa grass (Stipa tenacissima L.) is a tussock grass widely distributed in semi-arid and arid regions, in North Africa and southern Spain. This perennial grass, also named Esparto grass, is used as a main source of fiber for paper making. Algeria has an area of more than 3 million hectares of Alfa fibers. Currently, Alfa is well known for paper applications as a raw material but it is not used in cement composite applications. In this paper, the effect of adding simultaneously this local vegetable fibers and dune sand to produce a sustainable and economical patch repair mortar is investigated. Fibers are added to reduce the shrinkage cracking of the repair mortar and reduce the risk of its carbonation and therefore reduce the risk of corrosion.

The most important characteristics of a patch repair mortar are its flowability, bond strength, mechanical strength, low shrinkage and protection from aggressive environments. The protection of repair mortar to concrete could be assessed by water absorption by capillary and gas permeability which could be a good indicators for resistance to water penetration and carbonation. The experimental work presented in this paper analyzes the effect of incorporation of Alfa vegetable fibers on physical and mechanical characteristics of dune sand repair mortar as well as its durability through gas permeability and water absorption by capillary tests. The adhesion characteristics of repair mortars on concrete substrate is also evaluated by means of pull-off tests.

2. Experimental details

2.1. Materials and mix proportions

Portland cement type CEM II A 42.5 according to the European standard EN 197-1 was used. The dune sand used was extracted from the Algerian desert in northern region of the city of Laghouat, 400 km South of Algiers and has a fineness modulus of 0.84 and granular size of (0/0.5). The grading curve of dune sand is presented in Fig. 1. SEM investigations reveal the relatively rounded shape grains with some irregular and angular grains of dune sand (Fig. 2). The EDX analysis demonstrates the essentially siliceous nature of dune sand (Fig. 3). A sulfated polymelamine superplasticizer (SP) admixture called Medaplast SP40 was used. The microfibers plant used are Stipa Tenacissima type (called Alfa fibers) cut by hand to 3–5 mm length and presents a dimeter of 150–250 μm. The chemical and physical properties of the cement are presented in Table 1 while the main characteristics of the Stipa

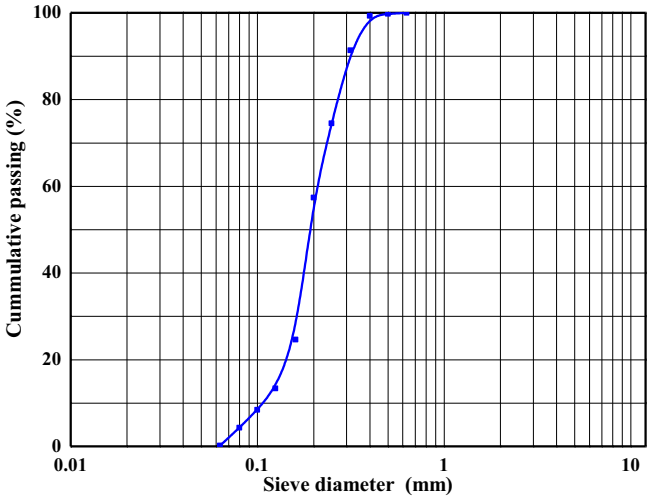

Fig. 1. Particle size distribution.

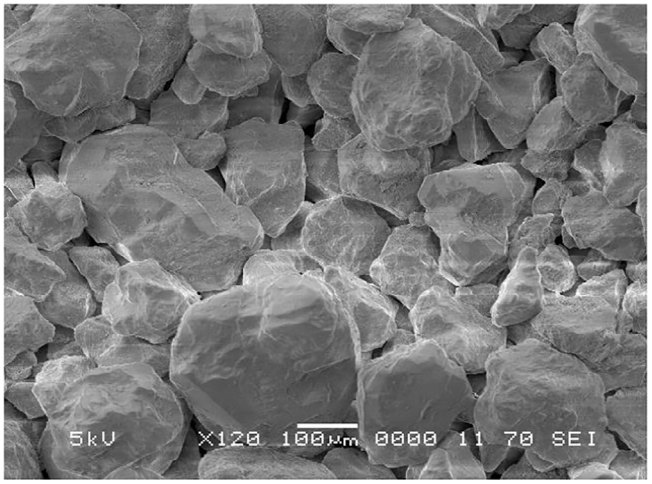

Fig. 2. Algerian desert dune sand SEM image.

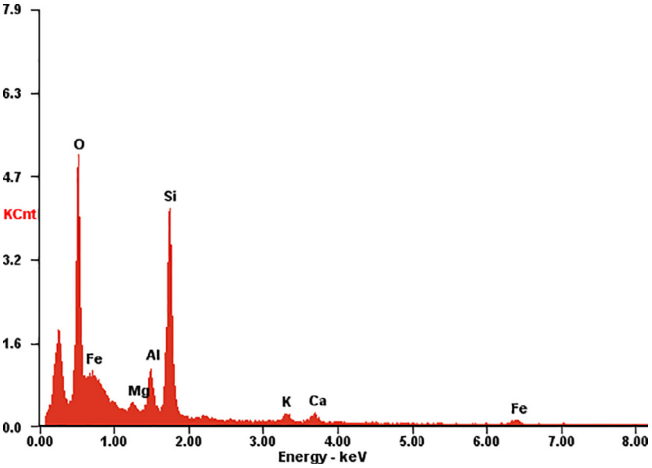

Fig. 3. Dune sand EDX analysis.

Tenacissima fibers are reported in Table 2. It can be clearly seen that the characteristics of the fibers present a large variability and hence these characteristics are given as range and not fixed