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Incorporation of fillers from marble and tile wastes in the composition of self-compacting concretes

Mohsen Tennich [a,b], Abderrazek Kallel [a,c], Mongi Ben Ouezdou [a,d,*]

[a] University of Tunis El Manar, National Engineering School of Tunis, Civil Engineering Laboratory (LGC-ENIT), LR03ES05, BP37, 1002 Tunis, Tunisia
[b] Direction Générale des Etudes Technologiques, Institut Supérieur des Etudes Technologiques de Radès, BP 172, 2098 Radès Médina, Tunisia
[c] Salman bin Abdulaziz University, College of Engineering, Civil Engineering Department, BP 655, 11942 Al-Kharj, Saudi Arabia
[d] Civil Eng. Dept., American University of Sharjah, PO Box 26666, Sharjah, United Arab Emirates

HIGHLIGHTS

- Study the influence of the wastes from marbles and tiles factories on the behavior of SCC modified withy these wastes.
- Results of show that incorporation of these wastes gives a satisfactory fluidity to the SCC.
- The mechanical properties of the tested SCC with these wastes were satisfactory.

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ABSTRACT

The objective of this paper is to evaluate the incorporation of wastes from marbles and tiles factories as mineral additives to self-compacting concrete (SCC) and to substitute at 100% the known additions (limestone filler, fly ash, ...). The use of these wastes can help produce economical self-compacting concretes (SCCW) and reduce the amount of wastes dumped into landfills. The influence of these wastes on the behavior of SCC in the fresh state is highlighted in comparison to a reference self-compacting concrete (SCCR) made with limestone filler while their effects on mechanical strength and ultrasonic testing are evaluated in the hardened state in comparison to the properties of both SCCR and an ordinary vibrated concrete (OVC). The compositions of the different concretes considered in the present study were formulated and optimized using the "Concrete LabPro2" software.

The results of testing carried out on fresh concretes (slump flow test, V-funnel test, L-Box test and sieve stability test) show that the incorporation of wastes from marbles and tiles factories gives a satisfactory fluidity to the SCCW and their resistance to segregation, approaching those of SCCR. The mechanical properties of the tested concretes were evaluated by ultrasonic testing and by simple compressive testing and tensile splitting of cylindrical specimens (160 mm × 320 mm) at the curing ages of 3, 7, 14 and 28 days. The results show that the speed of wave propagation through the concrete and the compressive and tensile strengths are clearly sufficient for the self-compacting concretes incorporating wastes from marbles and tiles factories compared to those of SCCR and OVC.

1. Introduction

The use of self-compacting concrete (SCC) in the construction became a routine activity to achieve the desired performance in terms of ease of placing, eliminating the need of vibration with a smooth surface, obtaining a perfect wall of the structural member and to achieve the casting according to the rules of the art regardless of the complexity of the formwork. The preparation of concrete requires the use of admixtures and additives (fillers, silica powder, ...) that are relatively expensive but greatly influence the performance of the SCC.

Various studies were conducted to evaluate the behavior of SCC in the fresh and hardened states under the influence of the addition of fillers, pozzolanic or not, the Portland cement [1–3] and the effect of the fineness of fillers [4]. Other researchers have focused their interest on the incorporation of industrial wastes into SCC. Hebboub et al. [5] showed the possibility of using marble waste to replace natural aggregates for the production of hydraulic

* Corresponding author. Tel.: +216 71 874 700x449.
E-mail address: mongi.benouezdou@enit.rnu.tn (M. Ben Ouezdou).

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concrete. Furthermore, Belaidi et al. [6] examined the effect of substitution of cement powder by natural pozzolana and marble powder on the rheological and mechanical properties of SCC. Tayeb et al. [7] studied also the effect of marble powder on the proprieties of sand concrete (SCSC) in fresh and hardened state. Shirule et al. [8] partially replaced cement by marble powder. Corinaldesi et al. [9] used marble powder as mineral addition to mortars and concretes. Alyamaç and Ince [10] have investigated the relationship between the properties of fresh and hardened state SCC containing marble powder. Herbudimana and Mulyawan Saptaji [11] studied the use of marble powder traditional roof tile powder in self-compacting concrete; this research is an effort to recycle waste and new development in environmental friendly concrete material technology.

Topcu et al. [12] have integrated marble dust combined with the fly ash in the formulation of SCC, the dosage of the fly ash varies from 7.69% to 50% of the amount of additions (marble dust + fly ash). In their paper, the authors have replaced binder of SCC by the marble dust at certain contents of 0, 50, 100, 150, 200, 250 and 300 kg/m^3. Therefore, they have changed the cement content of 475 to 225 kg for the different compositions. Recently, Gesoglu et al. [13] have studied the effect of additions (marble filler and limestone filler) with or without fly ash on the fresh and hardened properties of SCC. In their paper, the authors studied the effect of marble filler on SCC's properties with a change in its quantity of 26, 52 and 104 kg and the dosage of fly ash is fixed at 156 kg. They varied the dosage of cement to maintain the amount of the binder at 520 kg in the composition of the SCC.

Tunisia factories producing tiles and marble generate by their manufacturing and shaping processes an enormous amount of industrial wastes such as sludge (about 148,000 m^3 of wastes for the greater Tunis area). These industrial wastes pose problems in terms of transportation and environmental management since they are presently dumped into landfills.

The objective of the present research is to evaluate the incorporation of these Tunisian wastes (W1: Waste of marble, W2: Waste of marble tile and W3: Waste of gravel tile) in the manufacturing of economical self-compacting concretes by using them as mineral additives to replace the limestone filler in the composition of SCC, hence lowering the cost of SCC and reducing the amount of wastes from marbles and tiles factories being rejected in the environment. In Tunisia, the additives such as the limestone fillers and fly ash are expensive or unavailable.

In this paper, we have also formulated for the first time the SCCs made from 100% of the addition of the wastes tiles (W2 and W3). Hence, we studied the characteristics of SCCs made with the industrials wastes (W1,W2, W3 and combined) without combination of known additions (limestone filler, fly ash, ...). Moreover, we used of the "Concrete LabPro2" software to formulate the SCCs that allows us to predict the properties of concretes in the fresh and hardened states and to optimize these main proprieties of SCC. Unlike former studies, in which the dosage of cement was changed, we have fixed this dosage at 350 kg/m^3. This choice aims to formulate a self-compacting concretes made with wastes fillers (SCCW) that has sufficient mechanical strength and respects the rules of the trade and standards with a minimum dosage of the binder for a reinforced concrete structure. The effect of introducing such wastes on the SCC properties would be investigated.

2. Identification of the constitutive materials

A total of six types of self-compacting concrete (SCCW) incorporating one or mixes of these three industrial wastes (W1, W2 and W3) were prepared for evaluation by testing. The performance of these SCCW were compared to a reference ordinary vibrated concrete (OVC) and a reference self-compacting concrete made using limestone filler (SCCR). The constitutive materials of all these concretes are as per the following.

2.1. Cement

Portland cement CEM I 42.5, according to NT47.01 standard type, is provided by the factory CAT – Jebel Jeloud in Tunis. The mineralogical composition is calculated using Bogue formulas: C_3S = 61%, C_2S = 11.85%, C_3A = 2.42%, C_4AF = 13.75%. The cement has a specific gravity of 3.13 and a Blaine specific surface of 346.6 m^2/kg.

2.2. Aggregates

2.2.1. Gravel

This is crushed gravel from quarry crushing Jebel Ressas in Tunis. The gravel contains 54.89% of CaO and other minerals. It has a continuous and spread granular size class 4/16 mm, it has a compactness Cg = 0.601 and an absolute density ρ_g = 2.7.

2.2.2. Sand

It is alluvial silica sand from the quarry of Borj Hfaiedh, near Tunis. The sand is composed of 98.26% of SiO_2 and other minerals. This sand has a class of granular 0/4 mm having a fine content of 2%, has sand equivalent of 72%, it has a compactness Cs = 0.665 and an absolute density ρ_s = 2.65.

The particle size distributions of the aggregates are presented in Fig. 1.

2.3. Additives

The additives used are limestone filler (LF), chosen to make the control or Reference self-compacting concrete (SCCR) and three industrial wastes fillers: W1: Waste of marble, W2: Waste of marble tile and W3: Waste of gravel tile. The particle size distributions for all four fillers are presented in Fig. 2 and their respective physical and chemical characteristics are summarized in Table 1. The compactness (with and without admixtures) of cement and the various fillers are presented in Fig. 3.

2.4. Superplasticizers

Two a new generation superplasticizers (SP1: Sika ViscoCrete Tempo 12 and SP2: CHRYSO Fluid Optima 175), which are available in the Tunisian market, were used as admixture for all tested self-compacting concretes. The SP1 is a superplasticizer, high

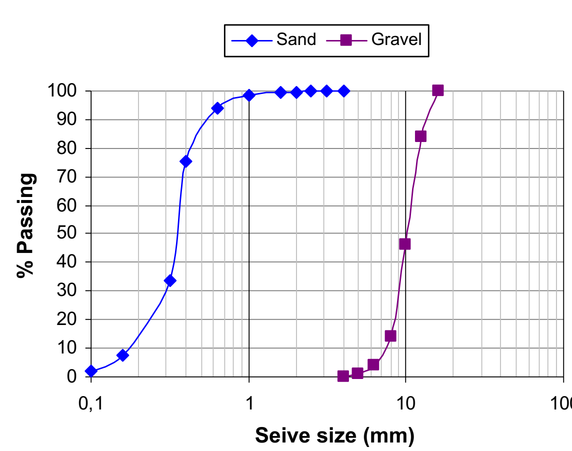

Fig. 1. Particle size distributions of the aggregates (sand and gravel).