Journal of Building Engineering 20 (2018) 1–7

Contents lists available at ScienceDirect

Journal of Building Engineering

journal homepage: www.elsevier.com/locate/jobe

Thermal effect of marble and tile fillers on self-compacting concrete behavior in the fresh state and at early age

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

[a] Université de Tunis El Manar, Ecole Nationale d'Ingénieurs de Tunis, LR03ES05 Laboratoire de Génie Civil, 1002 Tunis, Tunisia
[b] Direction Générale des Etudes Technologiques, Institut Supérieur des Etudes Technologiques de Radès, BP 172, 2098 Radès Médina, Tunisia
[c] Prince Sattam Bin Abdulaziz University, College of Engineering, Civil Engineering Department, BP 655, 11942 Al-Kharj, Saudi Arabia

ARTICLE INFO

Keywords:
Self-Compacting Concrete (SCC)
Waste of marble
Wastes of tile
Shrinkages of SCC
Resistance to cracking

ABSTRACT

This paper mainly focuses on studying the effects of industrials wastes from marble and tiles factories on the cracking of self-compacting concrete (SCC) due to shrinkages in the fresh state and at early age.

In this study, the effect of industrial wastes of marble and tiles on setting of the cement is studied by testing different pastes (cement alone or combined with each normalized limestone filler or the industrial wastes). In a second part of this research, a study of the effect of these industrial wastes on the hydration reaction in early age is carried out on different self-compacting concretes made with industrials wastes from marble and tiles factories (SCCWs).

Furthermore, in this work, the resistance to cracking of different concretes at the fresh state is evaluated against the variation of the two factors favoring the cracking due to the plastic shrinkage (temperature at 25 °C and 40 °C both with and without presence of ventilation).

The behaviors of the SCCWs are compared to those of a reference self-compacting concrete (SCCR) made with standard or normalized limestone filler and an ordinary vibrated concrete (OVC).

The testing results of the setting of cement show that the marble and tiles wastes have a positive effect on the fresh state of concrete and the setting period by reducing the critical phase of concrete in the face of shrinkages. At the same time, these industrial wastes fillers reduce the heat in the exothermic hydration reactions of cement in SCCWs and limit their cracking due to thermal shrinkage. Moreover, the testing results show that SCCWs, exposed to heat and ventilated environment, have satisfactory strength to cracking due to the plastic shrinkage.

1. Introduction

The self-compacting concretes (SCCs) are considered a new family of concrete in the world. Initially, these SCCs were used only for big projects such as bridges, and thereafter, they were used even for the construction of buildings. The advantages of the use of these SCCs, are mainly the combination of stability to segregation and great fluidity they offer in the fresh state.

Under certain climatic and environmental conditions (heat and blowing wind), the use of self-compacting concrete (SCC) to horizontal applications with large surfaces can compromise the aesthetic, performance and durability of buildings in service since these large surfaces are more fragile for cracking of the surface due to plastic shrinkage. This phenomenon is even more distinct in SCC because of the high volume of paste present in its composition. It is now recognized as the amplitude of plastic shrinkage of self-compacting concrete is much greater than that of ordinary vibrated concrete (OVC) [1–4].

Also, the hydration reaction of the cement is exothermic and thermally activated, for large structure elements; the temperature of the concrete can reach very high values. As a result of cooling, thermal shrinkage is added to the autogenous shrinkage due to the hydration reaction. For large structure elements, it is necessary to take precautions with regard to these phenomena.

Holt and Leivo have shown that to limit the plastic shrinkage, companies must use cure products that are pulverized on the surface of the horizontal elements after concreting [5]. Once the risks of plastic shrinkage are eliminated, the maturation of the concrete is necessary to reduce the amplitude of the autogenous shrinkage; the best way is to cover the surface of the SCC with hessian or geotextile soaked in water. The same can be used for new admixture (admixture shrinkage reducer).

The use of these products with SCC increases its cost compared to the OVC; also these cure products present a real risk for security at the site. The ideal approach is to optimize the composition of the SCC to

* Corresponding author.
E-mail address: mongi.benouezdou@enit.rnu.tn (M.B. Ouezdou).

https://doi.org/10.1016/j.jobe.2018.06.015
Received 4 March 2018; Received in revised form 28 June 2018; Accepted 28 June 2018

Table 1
Chemical and physical properties of cement and fillers.

Chemical composition (%)		C (Cement)	LF (Limestone)	W1 (Marble)	W2 (Marble tile)	W3 (Gravel tile)
Calcium oxide (lime): CaO		64.86	55.44	49.46	47.09	53.08
Aluminum oxide (alumina): Al_2O_3		**3.80**	**0.02**	**0.46**	**0.58**	**0.66**
Iron oxide: Fe2O3		4.52	0.01	0.66	0.06	0.10
Silicon dioxide (silica): SiO2		20.52	1.09	7.36	3.78	4.28
Magnesium oxide: MgO		1.35	0.38	0.23	4.62	0.10
Sulfur trioxide: SO3		3.22	0.07	0.08	0.41	0.29
Potassium oxide: K2O		0.53	0.02	0.11	0.09	0.08
Mineralogical composition of cement (%)		Physical properties				
C_3S	61.00	Ignition Loss (%)				
C_2S	11.85	0.72	42.85	40.23	42.44	41.32
C_3A	2.42	Blaine surface (m^2/kg)				
C_4AF	13.75	440.0	720.0	652.6	621.4	563.1

control their shrinkages especially the volume of paste. Various studies were conducted to evaluate the behavior of SCC in regards to shrinkages cracking in the fresh state and early age under hydration reaction and the influence of different components. Puentes et al. studied the performance of a SCC with fibers, during the cement hydration process and the evolution in the hardened state [6]. Esping studied the effect of limestone fillers with different specific area on plastic cracking [7]. Güneyisi et al. compared the effects of different additives (fly ash, ground granulated blast furnace slag, silica fume and metakaolin) combined with the Portland cement on the drying shrinkage properties of self-compacting concretes [8]. Topçu et al. studied of drying shrinkage cracking of composite mortars incorporating crushed tile fine aggregate [9]. This study has showed that cracks depend on physical and mechanical properties of fine aggregate. Moreover, Topçu et al. showed that shrinkage cracking decrease because of the porous structure of mortar specimens [10,11]. Leemann et al. have studied the impact of admixtures on the plastic shrinkage cracking of self-compacting concrete [12]. Girotto et al. have studied the effects of the superplasticizer and the additives (silica fume and basaltic filler) on the plastic shrinkage and cracking of self-compacting concrete mortars [13]. Briffaut et al. have developed restrained shrinkage ring test to follow the early age concrete behavior [14]. This test was used to study cracking due to restrained thermal shrinkage of massive structures. Boulay designed a test rig for autogenous shrinkage measurements of concrete at early age [15]. The test rig allows the measurement of this shrinkage after a fixed age of the concrete or setting time. Recently, Bilir et al. have studied properties of mortars with fly ash as fine aggregate and they have showed that the free drying shrinkage increases with a fly ash addition. But, crack width shows a decreasing trend and crack formation is delayed [16]. Furthermore, Bilir et al. have developed drying crack width prediction model to help designers and producers to consider precautions before mortar or concrete production without losing time and money [17].

According to these researches, the results show that despite some additives (fly ash) to reduce drying shrinkage, different shrinkages at fresh state and early age remain high. As part of the objective of valorizing the Tunisian industrial wastes (W1: Waste of marble, W2: Waste of marble tile and W3: Waste of gravel tile) in the SCC; the behavior of SCC made with these industrial wastes (SCCWs) were studied at fresh and hardened states in a previous paper [18]. This research was undertaken to evaluate the effect of these industrial wastes on shrinkages (plastic, thermal,…) of self-compacting concretes at fresh state and early age and their relationship to the hydration reaction of the cement in the critical phase of these fresh concretes where they are exposed to climatic variation that can be either heat or the bellows of the wind.

In this paper, the work is presented in three parts: in the first one, the effect of these industrial wastes on the setting of cement paste was studied using the penetration of the Vickat device. In the second part, their effects on the phase of hydration of the cement at early age of the SCCWs were analyzed by using a semi-adiabatic calorimeter. Finally, the plastic shrinkage and cracking in the fresh state of the SCCWs were studied in a hot climate with bellows of the wind by using a concrete cracking device. These three SCCWs were compared to a reference selfcompacting concrete made using referenced limestone filler (SCCR) and a reference ordinary vibrated concrete (OVC).

The aim of this paper is to investigate the effect of the use of the marble and tiles wastes in SCC on the setting period and on the heat released during process of cement hydration.

2. Experimental procedures

2.1. Materials

The major materials used in this study were:

- A Portland cement CEM I 42.5 noted (C) and according to NT47.01 [19] standard type, it has a Blaine specific surface of 346.6 m^2/kg.
- Aggregates were defined in the standard NT 21.30 [20]. Those were essentially an alluvial silica sand (0/4) and a crushed gravel (4/16). The sand has a fine content of 2% and his sand equivalent of 72%.
- Additives that were normalized limestone filler (R) and industrial wastes fillers (W1: Waste of marble, W2: Waste of marble tile and W3: Waste of gravel tile. Their chemical and physical properties are given in Table 1.
- A superplasticiper, high water reducer polyvalent (SIKA VISCOCRETE TEMPO 12).

The observations of cement and the various fillers SEM are illustrated below in Fig. 1 at a magnification of 3500.

The properties of concretes at fresh and hardened state are presented in Table 2. These properties were extracted from our previous paper study [18].

Also, the behavior of the concrete made with marble and tile waste against different forms of external sulfate attack were studied in our second paper [21].

2.2. Mixture proportions

A total of five concretes or paste mixes were prepared of which three SCC mixes made with industrials wastes (W1, W2 and W3) and two a reference concretes that one is ordinary vibrated concrete (OVC) and the second mix is a self-compacting concrete made with normalized limestone filler (SCCR). All these mixes of concretes were designed with a fixed dosage of cement of 350 kg/m^3. So, the cement was not replaced. Instead, the limestone filler (expensive additive to production the SCC) was replaced with 100% of these industrial wastes.

The "Concrete Lab Pro2" software [22] has been used to formulate these concrete mixes and they were adjusted by tests in the fresh state to have characteristics within standard EFNARC [23] and are in good