Thermal activation of ordinary Portland cement–slag mortars

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Temperature variation caused by the heat of hydration, in mass concrete or the change of external environment, has a large influence on the mechanical properties of early-age concrete. Mechanical properties, such as compressive strength, are factors to be considered in the design and construction of concrete structures. Therefore, effects of temperature and aging, on the mechanical properties, should be studied and quantified.

According to the experimental results, concrete subjected to high temperatures at early ages, attains a higher early-age compressive and splitting tensile strength but lower later age compressive and splitting tensile strength than concretes subjected to normal temperatures [1]. Mortar and concrete are the most important elements of infrastructures and, if well-designed, they can be durable construction materials. One effective way to reduce the environmental impact is to use mineral admixtures, as a partial cement replacement. This strategy has the potential to reduce costs, conserve energy, and reduce waste volumes. Mineral admixtures are silica-based materials, such as ground granulated blast furnace slag (GGBFS), fly ash and silica fume. Mineral admixtures have been used more and more for concrete because of their strength and durability [2]. The presence of some mineral admixtures, such as GGBFS in the cement, can modify the kinetics of hydration, reduce the heat evolution and produce additional calcium silicate hydrates (CSH) gel. These admixtures result in a noticeable performance increase to the concrete, in hot climates, in which the negative effect of the temperature is partly reduced by the pozzolanic reaction, their weak hydration heat and their great activation energies.

Several researchers reported that a high temperature improves strengths at early ages [1–3]. At a later age, the important number of formed hydrates had no time to arrange suitably, and this engendered a loss of ultimate strengths; this behavior had been called the crossover effect [4]. For ordinary Portland cement (OPC), it appears that the ultimate strength decreases, nearly linearly, with curing temperature [5]. Since GGBFS itself is nothing more than a latent hydraulic binder, it must be activated to react and provide the desirable mechanical properties. One of these activation methods is the thermal method [6]. The objective of this study is to produce a data inventory of the early-age behavior, of some mechanical properties, such as compressive strength of mortars with temperature. In addition, to investigate the relationship between compressive strength with temperature, and the relationship between the compressive strength of specimens, cured in air and water, at 3 and 7 days, for 40% and 50% levels of slag replacement.

2. Research significance

It is known that a lot of slag is produced in the steel–iron industry every year, throughout the entire world. If a means of consumption for these materials is found, it would help in terms of being environment friendly and also provide significant economic benefits. Moreover, several researches have shown that the use of the replacement materials in mortars and concretes has improved durability, which has vital significance for the structures built in aggressive environments, such as those in marine structures, big tunnels, and bridges with long life spans. However, there is a problem in using the materials; initial hydration is lower than that for OPC, and then the mortars and concretes have low early-strengths. Hence, there are several ways of resolving this problem; one of the most common methods is using thermal activation, which is precisely the main purpose of this study.

3. Experimental procedure

3.1. Mix proportions and curing

Table 1 represents the mix designs for different mortars. In all mixes W/B = 0.33, S/B = 2.25. Silica sand was used in the mixes. At first, based on Particle size analysis (PSA), five groups of silica sands were mixed. One minute after that, cement and replacement–slag were put into the mixture, followed by 1 min of mixing.

Mixing water was then added to the mix, and mixing was continued for 2 min, after which the required amount of super plasticizer (SP) was added. Mixing was continued for 2 min before finally, filling the moulds with fresh mortar at two layers. Each layer was compacted with 10 impacts by a rod with 16 mm diameter. 24 h after casting, the specimens were demoulded and heated in water at 60 _C, for the required time, as mentioned in Table 1, and then cured in air room temperature (27 ± 3 _C) with 65 ± 18% relative humidity (RH) and water with 23 ± 3 _C until the test day.

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