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Technical Report

The effect of heat treatment on the compressive strength of cement-slag mortars

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ABSTRACT

Thirty-eight mix proportions of ordinary Portland cement-slag mortars (OSMs) were used to study the effects of temperature and relative humidity on strength. Three levels of slag (0%, 40%, and 50%) and different temperatures were used; the 50% level and heat curing of 60 °C for duration of 20 h were found to be the optimum. The optimum mortar's strength at 3 and 7 days for the specimens cured in air were 55.0 and 62.0 MPa, respectively. The results show that for durations of 4–26 h, the strength of specimens cured in air is greater than those cured in water. This is a novelty with major advantages in arid areas. It was proved that more ettringite production at early ages resulted in higher early strengths. Comparison of curing regimes with different temperatures and the same relative humidity or different relative humidity and the same temperatures showed that higher strengths are attributed to higher temperatures and lower relative humidity, respectively.

1. Introduction

Temperature variation caused by the heat of hydration in mass concrete or the change of external environment, has a considerable 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, the 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 higher early-age compressive and splitting tensile strengths but has lower later-age compressive and splitting tensile strengths than concrete subjected to normal temperatures [1]. Mortar and concrete are the most important elements of structures and, if well-designed, 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 the volume of waste. Mineral admixtures are silica-based materials such as ground granulated blast furnace slag (GGBFS), fly ash, and silica fume. Mineral admixtures are being 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 (C–S–H) gel. These admixtures result in a noticeable performance increase in the concrete in hot climates as the negative effect of the temperature is partly reduced by the pozzolanic reaction, their weak hydration heat, and their great activation energy. The use of pozzolans as supplementary cementing materials has been found to provide noticeable enhancement to the mechanical properties of concrete and mitigate the damage, which is of particular concern for durability. Based on various studies on the effects of heat curing on cementitious systems, heat treatment of concrete has become a regulated practice in the precast concrete industry. In the 1980s Germany introduced heat curing regulatory particles specifying the parameters of the curing cycle including a maximum temperature of 60 °C. Presently, certain countries including Canada, the United States, South Africa, and most European countries have developed similar specifications for the regulation of heat curing for precast concrete. The maximum curing temperature imposed is often 60–70 °C. The length of heat exposure is not usually included in these specifications as this can be adjusted without adversely affecting performance [3]. Several researchers [1,2,4–6] reported that a high temperature improves strength at early ages. At a later age, the important numbers of formed hydrates have no time to arrange suitably and this causes a loss of ultimate strength; this behaviour has been called the crossover effect [7,8]. For ordinary Portland cement (OPC), it appears that the ultimate strength decreases with curing temperature nearly linearly [9]. 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 [10]. The objective of this study is to produce a data inventory of the early-age behaviour of some mechanical properties, such as the compressive strength of mortars with temperature, as well as to investigate the relationship between compressive strength with temperature and the relationship between the compressive strength of specimens cured in air under room temperature and water at 3 and 7 days, for 40% and 50% levels of replacement slag.

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