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Effect of curing methods on strength and durability of concrete under hot weather conditions

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ABSTRACT

This paper reports the results of a research study conducted to evaluate the effect of curing methods on the mechanical properties of ordinary Portland cement (OPC) and Silica Fume Cement (SFC) concretes. Slab and beam specimens were prepared and cured by covering them with wet burlap or applying a curing compound under field conditions. Four types of curing compounds, namely water-, acrylic-, and bitumen-based and coal tar epoxy, were applied on the concrete specimens. The curing compounds were applied immediately after casting or after an initial period of burlap curing. The effect of the selected curing regime on the properties of OPC and SFC concrete specimens was evaluated by measuring compressive strength, water-absorption and chloride permeability. The strength and durability characteristics of both OPC and SFC concrete specimens cured by applying the selected curing compounds were similar or better than that of concrete specimens cured by covering with wet burlap. Though no significant change in strength could be noted due to the curing methodology; however, its effect was noticeable on the durability. The best performance was shown by concrete specimens cured by applying the bitumen-based curing compound followed by those cured by applying coal tar epoxy, acrylic-based or water-based curing compound. The initial period of water curing, prior to the application of the curing compound, was also noted to be beneficial in increasing the durability of concrete.

1. Introduction

The hot weather conditions in many parts of the world create several problems for both the fresh and hardened concrete. Reduced durability is one of the major problems in concrete prepared under hot weather conditions. Under hot weather conditions, concrete has to be cured for an extended period of time compared to normal weather conditions in order to achieve acceptable strength and durability. Rasheeduzzafar et al. [1] indicated that the protection provided by concrete against corrosion of steel by migration of chlorides into the concrete is greatly dependent upon the duration of curing. With increasing use of supplementary cementing materials, proper curing of concrete becomes all the more important. Many problems of cracking of silica fume cement concrete have been reported from the field due to inadequate curing. Curing is also essential for the pozzolanic cement concretes as water is required for the pozzolanic reaction to take place in the later stages of hydration of cement [2]. Concrete is cured either by water ponding, covering with wet hessian, or by the application of a curing compound. The first two methods have been preferred over the third one. However, due to shortage of water there is an increasing tendency to cure concrete by applying a curing compound. This is particularly true in regions with severe water shortage.

Some studies have been conducted on the efficiency of curing compounds. Wang et al. [3] evaluated the performance of a membrane curing compound and the experimental results showed that the effectiveness of membrane curing was dependent markedly on the time of its application. Among the curing compounds studied, chlorinated rubber was reported to be the most effective one, followed by the solvent-based curing compound, and the least effective was the water-based type. However, concretes moist cured for only 2 days exhibited significant improvement in strength and other characteristics, compared with concrete without any curing [4].

Austin and Robins [5] indicated that wet burlap curing was the most effective and air curing was the least effective between 7 and 28 days in the hot climatic conditions. Moist cured blast furnace slag cement concrete exhibited a greater increase in the pulse velocity than similarly cured OPC concrete. Wang and Black [6] reported that the curing efficiency index (CEI) correlated well with the capability of the curing membranes in retaining moisture within concrete.

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Experiments conducted by Grafe and Grube [7] on the influence of curing on the gas permeability of concrete prepared with different types of cement indicated that GGBFS and PFA cement concrete had greater permeability than OPC concrete, when specimens were cured only for 1 day. However, they concluded that with prolonged sealed curing, mixes prepared with blended cements performed better than OPC with the same water–cement ratio and cement content.

According to Khan and Ayers [8], the minimum period of curing should be optimized in terms of several properties, such as strength, permeability and the movement of aggressive gases and/or liquids from the environment. Their results show that the minimum period of curing required for OPC, FA and the SFC concrete mixtures were 3, 3.75, and 6.5 days, respectively. In general, it has been shown that concretes prepared with mineral admixtures are more sensitive to water curing than OPC concretes.

The effect of curing period and curing delay on the properties of concrete in hot weather was studied by Al-Ani et al. [9]. They reported that wet burlap curing method was an effective technique for maintaining the moisture in concrete for curing. However, they recommended a minimum of 3 days of wet burlap curing for rich mixes whereas 7 days for lean mixes.

The effect of curing on the strength development in both OPC and fly ash cement concretes was investigated by Haque [10]. The 90-day compressive strength of OPC and fly ash cement concrete was reported to be 67% and 50% of continuously fog cured concrete specimens. However, 7 days prior curing improved these values to 95% and 82% of the fully cured concrete.

Soroka et al. [11] studied the effect of stream curing on the later age strength of concrete with cement content raging from 150 to 400 kg/m^3. The delay in pouring the concrete was 30–60 min, the curing period varied from 2 to 5 h and the curing temperature ranged from 60 to 80 °C. The results showed that stream curing adversely affected the later age strength of concrete. However, under short curing periods and moderate temperatures this adverse effect was primarily due to lack of supplementary wet curing and due to physical factors, such as increased porosity, internal cracking and the heterogeneity of the paste.

Not much information could be found in the literature on the performance of curing compounds under hot weather conditions. Few studies that have been conducted on this aspect have indicated a beneficial effect of curing compounds in general. Whitting and Snyder [12] conducted a laboratory study to examine the effectiveness of different types of curing compounds in retaining water for hydration. The results indicated that application of curing compounds improved concrete strength and reduced permeability, relative to classic curing techniques, such as plastic sheeting and ponding and relative to the use of no curing treatment. Comparisons of moisture loss, compressive strength, permeability, and capillary porosity were made for specimens representing three high-VOC curing compounds, three low-VOC curing compounds, water curing, and plastic-sheet curing, and for specimens with no curing treatment after 3 days and 28 days of curing. The performance of the six curing compounds tested varied greatly, but none of the curing compounds performed as well as the specimens cured with water or plastic sheeting. However, it was reported that all the curing compounds performed better than specimens with no curing treatment.

Hani et al. [13] investigated the effect of curing on the elastic modulus of ternary cement concretes. Three methods of curing, namely air-dry curing, curing compound and wet curing with burlap were evaluated. The results showed that adding silica fume resulted in an increase in strength and modulus at early ages; however, there was no change in the modulus at 28 and 56 days. In addition, adding 20% fly ash with various percentage of silica fume had an adverse effect on both strength and modulus values at all ages. It was also shown that dry curing and curing compound reduced the modulus of elasticity compared to wet curing with burlap.

Recently, Al-Gahtani [14] studied the effect of curing methods on the properties of plain and blended cement concretes. The concrete specimens were prepared with Type I, silica fume, and fly ash cement concretes. They were cured either by covering with wet burlap or by applying two types of curing compounds, namely water-based and acrylic-based under a laboratory environment. The effect of curing methods was assessed by measuring plastic and drying shrinkage, compressive strength, and pulse velocity. It was reported that the strength development in the concrete specimens cured by covering with wet burlap was more than that in the specimens cured by applying water- or acrylic-based curing compounds [14]. It was reported that concrete specimens cured by applying curing compounds exhibited higher efficiency in decreasing the plastic and drying shrinkage strain than specimens cured by covering with wet burlap only. Among the two curing compounds investigated, acrylic-based curing compound was reported to perform better than the water-based curing compound.

Bushlaibi and Alshamsi [15] evaluated the efficiency of curing methods based on the strength property of the concrete. The compressive strength results of the water cured specimens were compared with the strength of concrete specimens cured under different regimes, such as indoor and outdoor environments with and without sprinkling water twice a day for 7 days. It was reported that the effect of curing regimes on strength is highly influenced by the exposure environment. Noticeable difference in the influences of the curing methods was observed for indoor specimens only. It was also reported that the strength of concrete specimens stored in the outdoor environment was less than the strength of results than those stored indoors for all curing regimes.

Austin et al. [16] reported a study conducted to compare the development of strength and permeability of ordinary OPC and GGBFS concretes that were cured in a simulated arid climate. The arid environment of Algerian Sahara was simulated inside an environment chamber to create different field conditions. It was concluded that under good curing conditions strength of the GGBFS concretes was higher than that of the OPC control concrete at all test ages. However it was reported that the GGBFS concrete was more sensitive to poor curing than OPC concrete.

With growing scarcity of water, it becomes essential to cure concrete by the application of a curing compound. Also, in certain regions curing by water ponding or by covering with wet hessian is costly as desalinated water utilized for this purpose is expensive. Further, under certain situations the wet burlap curing cannot be prolonged due to construction constraints. Under such circumstances, curing by the application of a curing compound may be preferred after initial wet burlap curing for few days. Further, there is a need to study the effect of optimum duration of wet curing prior to the application of curing compounds on the properties of concrete.

In the reported study the performance of the curing methods was evaluated under field conditions in a hot and arid environment.

2. Methodology of research

2.1. Materials and specimens

Concrete slab specimens, measuring 1 × 1 × 0.15 m, and beam specimens, measuring 0.2 × 0.2 × 1 m, were prepared. Table 1 shows the mix constituents used to prepare OPC and silica fume cement concrete specimens. The OPC and silica fume cement concrete specimens were prepared with ASTM C150 Type I cement.