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Self-curing concrete types; water retention and durability

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Abstract Internal curing of concrete by the use of pre-saturated lightweight aggregates or polyethylene-glycol is well established method of counteracting self-desiccation and autogenous shrinkage.

This study was carried out to compare among concretes without or with silica fume (SF) along with chemical type of shrinkage reducing admixture, polyethylene-glycol (Ch), and leca as self-curing agents for water retention even at elevated temperature (50 °C) and their durability. The cement content of 400 kg/m^3, silica fume of 15% by weight of cement, polyethylene-glycol of 2% by weight of cement, pre-saturated lightweight aggregate (leca) 15% by volume of sand and water with Ch/binder ratio of 0.4 were selected in this study. Some of the physical and mechanical properties were determined periodically up to 28 days in case of exposure to air curing in temperature of (25 °C) and (50 °C) while up to 6 months of exposure to 5% of carbon dioxide and wet/dry cycles in 8% of sodium chloride for durability study. The concrete mass loss and the volumetric water absorption were measured, to evaluate the water retention of the investigated concretes. Silica fume concrete either without or with Ch gave the best results under all curing regimes; significant water retention and good durability properties.

1. Introduction

The recent trend in concrete technology toward the so-called high-performance, or low water/solid binder mass ratio (w/b), concretes encountered some problems. One of the major problems with such a mixture is its increased tendency to undergo early-age cracking. While this cracking may or may not compromise the (higher) compressive strength of these concretes, it likely does compromise their long-term durability. The phenomenon of early-age cracking is complex and depends on thermal effects, autogenous strains and stresses, drying, stress relaxation, and structural detailing and execution. In concretes with low w/binder ratio, a major contributor to early-age cracking can be the autogenous shrinkage induced by the self-desiccation that occurs during hydration under sealed or partially saturated conditions [1]. As the cementitious

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materials hydrate under sealed conditions, empty porosity is created within the "set" microstructure, because the hydration products occupy less volume than the reacting materials. The water menisci created by these empty pores in turn induce compressive stresses in the three-dimensional microstructure. The magnitude of these stresses is influenced by both the surface tension of the pore solution [2] and the meniscus radius of the largest water-filled pore within the microstructure [1]. Concrete incorporating self-curing agents will represent a new trend in the concrete construction in the new millennium, due to the increased use of high-performance concrete. Several techniques may, potentially, be used for incorporation of internal curing water in concrete [3]. Several researchers have proposed the use of saturated light weight aggregates to provide "internal" curing for concrete [4–9]. On the other hand, other researchers used poly-glycol products in concrete mixes as self-curing agent [10,11].

In this paper, three engineering methods for reducing autogenous stresses and strains by internal water supply for internal curing are compared under air-curing regime in normal temperature (25 °C) and high temperature (50 °C) and are examined for their effect on the concrete resistance to carbon dioxide (5%) and wet/dry cycles in saline water (8% sodium chloride). These three methods are the replacement of sand by saturated low-density fine aggregates (leca) which provides the cement paste by store water in saturated Leca particles [12] thereby mitigate the effects of self-desiccation in low w/b concrete mixture [6], adding polyethylene-glycol by weight of cement which reduces the water evaporation from concrete, and hence increase the water retention capacity of the concrete [13], and the addition of silica fume by weight of cement which retains water and causes continuation of the cement hydration and to conversion of the calcium hydroxide, which tends to form on the surface of aggregate particles into calcium silicate hydrate (C-S-H) and strengthening the aggregate matrix transition zone, which becomes less porous and more compact [3,14,15].

2. Scope and objectives

A comprehensive experimental investigation has been undertaken to study the effects of self-curing agents such as pre-soaked (in water) lightweight aggregate (leca), polyethylene-glycol and the addition of SF on the mechanical and non-mechanical properties of concrete and its durability. The considered concrete properties are compressive, tensile strength, volumetric water absorption, Ph value and mass loss. The test program was performed on concretes containing cement content (400 kg/m^3), water (including Ch)-cement ratio (0.4) cured in air (25 °C) and elevated temperature (50 °C). The research aimed to examine the resistance of the aforementioned concretes to carbon dioxide (5%) and wet/dry cycles in saline water (8% sodium chloride). Special attention was given to the enhancement in self-curing concrete properties cured in normal (25 °C) and elevated temperature (50 °C), as well as its durability to carbon dioxide and wet/dry cycles in saline water as affected by the type and doses of self-curing agent (SCUA) along with the addition of silica fume.

3. Experimental program

3.1. Material and mix proportion

The ordinary Portland cement and silica fume with chemical composition illustrated in Table 1, siliceous sand as a fine aggregate with fineness modulus of 2.79, and gravel coarse aggregate of nominal maximum size (20 mm) from Suez quarry were used throughout the program for producing concrete. The superplasticizer (SP) used was of the sulphated naphthalene formaldehyde condensate type. The superplasticizer dosage was adjusted to produce concretes with the same slump of 120 ± 10 mm and do not show visual signs of segregation during the normal casting of concrete in the molds. Leca which is brand name for an expanded clay clinker and burned in a rotary kiln at approximately 1200 °C was used as self-curing agent of light weight aggregate type, while polyethylene-glycol characteristics as produced by the manufacturer indicated in Table 2 was used as self-curing agent of chemical type. The proportions of concrete batches are given in Table 3.

3.2. Experimental procedure

Mixing of concrete components was achieved by using a horizontal mixer. The Leca was oven-dried at 105 °C for 24 h, air cooled and then submerged in water for 24 h before mixing. All the dry constituents were placed in the mixer and mixed for 2 min to ensure uniformity of the mix. Half of the mixing water was added gradually during mixing and followed by the

Table 1 Chemical composition of Portland cement and silica fume.

Chemical composition (%)	Portland cement	Silica fume
Loss on ignition	1.36	1.0
SiO_2	19.49	95
Al_2O_3	7.36	0.4
Fe_2O_3	2.68	0.6
CaO	62.51	0.2
MgO	3.7	0.4
SO_3	2.4	0.3
Specific weight (g/cm^3)	3.12	2.2
Specific surface (cm^2/g)	3000	150,000
Mineralogical components (%)		
C3S	37.17	–
C2S	33.65	–
C3A	11.73	–
C4AF	8.15	–

Table 2 Characteristics of polyethylene-glycol.

Type	Molecular weight	Maximum solubility at 20 °C (mass fraction%)	Functional group	
			Hydroxyl	Ether
Synthetic	200	100	Yes	Yes

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