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Self compacting self curing concrete

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ABSTRACT

Self compacting self curing concrete is a new type of concrete which have the properties of self compaction as well as self curing. Self compacting concrete requires no external vibration to achieve consolidation and generally results in saving labour and time, improved workability, improved quality, higher durability and better surface finish. The strength and durability of concrete will be fully developed only if it is cured properly. To achieve good cure, excessive evaporation of water from fresh concrete should be avoided. Curing operations should ensure that adequate amount of water is available for cement hydration to occur. Concrete incorporating self-curing agents will represent a new trend in the concrete construction in the new millennium. Better understanding of the self-curing agents and the self compacting nature of concrete will definitely result in a new generation of concrete, which will be stronger, more durable, will have the desired stress-strain behavior and, possibly, with the whole range of newly introduced self curing self compacting properties. Curing compounds can be effectively used with improved strength and sustainability of water. Currently, one of the most active research areas dealing with cement and concrete is the understanding of the hydration of cement particles and achieving the optimum cure of concrete without the need for external curing methods.

Introduction

Curing is the maintaining of a satisfactory moisture content and temperature in concrete during its early stages so that the desired properties may develop. Inorder to achieve the most beneficial properties of a concrete, it is necessary for it to be cured properly. When concrete is left in air, water evaporates from its surface. A number of factors influence the rate of evaporation such as air temperature, wind speed, relative humidity, type of cement, w/c ratio and the initial temperature of the concrete. Curing methods involve either the introduction of additional water to the concrete surface for a period of time after placing or the reduction in the rate of evaporation from the surface. Ponding and spraying are the most effective curing techniques, although they present a number of practical problems. The use of coverings is an expensive technique both in terms of the materials used and labour. An internal curing system has several advantages, primarily the production of a better quality concrete surface, greater turnover and the reduction in costs of operatives. Internal curing system is obtained by the mixing of self curing agents which act as barriers to evaporation to water from the concrete.

What is self compacting concrete?

The Self Compacting Concrete (SCC) is an engineered material consisting of cement, aggregates, water and admixtures with several new constituents like colloidal silica, pozzolanic materials, portland flyash (PFA), ground granulated blast furnace slag (GGBS), microsilica, metakaolin, chemical admixtures, etc., to take care of specific requirements, such as, high-flowability, compressive strength, high workability, enhanced resistances to chemical or mechanical stresses, lower permeability, durability, resistance against segregation, and passibility under dense reinforcement conditions. The properties, such as, fluidity and high resistance to segregation enables the placement of concrete without vibrations and with reduced labour, noise and much less wear and tear of equipment. Use of SCC overcomes the problem of concrete placement in heavily reinforced sections and it helps to shorten construction period. Self compacting concrete was made in Japan in the year 1986. Okamura (1993)[1] proposed a mix design method for self compacting concrete. The standard mix design method of self compacting concrete proposed by Japanese Ready-Mixed Concrete Association[2] (JRMCA) is a simplified version of Okamura's method. Nan Su, et al. (2001)[3], developed a simple mix design method for self compacting concrete. Since then many investigators are carrying out extensive research on self compacting concrete.

What is self curing concrete?

Concrete that is capable of retaining greater quantities of water than ordinary concrete when cured in air is called self-cure concrete. This can be achieved by the addition of water soluble polymeric glycol which acts as a self-curing agent. Some specific water soluble chemicals added during the mixing can reduce water evaporation from and within the set concrete, making it 'self-curing'. Self-curing agent is a chemical that reduces the evaporation of water from its surface, primarily by reducing the vapour pressure at the concrete pore solution surface. Curing concrete means creating conditions such that water is not lost from the surface i.e., curing is taken to happen 'from the outside to inside'. In contrast, 'self-curing' otherwise termed as internal curing is allowing for curing 'from the inside

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to outside'. This is mainly due to the enhanced water retention in concrete. Water retention is best achieved by the application of self curing agents that act as a barrier to evaporation.

What is self compacting self curing concrete?

This is a type of concrete which has in it the properties of both self compaction and self curing ability. This type of concrete is neither subjected to external consolidation nor external curing. This reduces the construction period since no time is spent on consolidating the fresh concrete and curing the set concrete. This is achieved mainly due to the mixing of self-curing agents in the fresh concrete in the mixing stage. The use of self curing admixtures is very important from the point of view that water resources are depleting everyday and water has become a scarce commodity. Approximately $1m^3$ of concrete requires $3m^3$ of water most of which is for curing. The benefit of self-curing admixtures is more significant in desert areas where adequate water is not available and in areas where there is shortage of labour force.

Importance of Curing

Poor curing practices adversely affect the desirable properties of high-performance concrete, just as they do any concrete. Proper curing of concrete is essential to obtain maximum durability, especially if the concrete is exposed to severe conditions where the surface will be subjected to excessive wear, aggressive solutions, or severe environmental conditions (such as cyclic freezing and thawing). Likewise, proper curing is necessary to assure that design strengths are attained. Even when good quality concrete is placed on the job site, curing is necessary to ensure the concrete provides good service over the life of the structure. Good concrete can be ruined by the lack of proper curing practices. Curing is even more important today than ever before for at least three reasons:

- Today's cements gain strength earlier and allow contractors to remove formwork soon after concrete placement. This encourages discontinuing curing operations prematurely.
- The lower water-cement ratios being used with modern concretes tend to cause self-desiccation. Ingress of water from proper curing is necessary to control this phenomenon.
- Many modern concrete mixtures contain mineral admixtures, such as fly ash and ground granulated blast furnace slag that have slower reaction rates. Curing over longer periods of time is needed for proper development of the properties of these mixtures.

Curing has a major impact on the permeability of a given concrete. The surface zone will be seriously weakened by increased permeability due to improper curing. The importance of adequate curing is very evident in its effect on the permeability of the "skin" (surface) of the concrete. The idea of making self compacting self curing concrete is of recent origin. An attempt has been made in this paper to review the state-of-the-art of this concept.

State-of-the-art:-

Self curing concrete can be made by adopting one of the following methods.

- By using an internal curing agent.
- By using an absorbent material at the time of mixing.
- By covering the surface with a thin membrane.

Self curing concrete using an internal curing agent

R. K. Dhir, et al., (1994)[4] carried out an investigation on the feasibility of curing concrete by adding water-soluble chemicals during mixing that reduce evaporation in the set concrete, making it 'self-curing'. The degree of hydration was measured using x-ray powder diffraction (XRD) and thermogravimetry (TG) methods. Initial surface absorption tests and compressive strength measurements were made to determine surface permeability and strength measurements. The Scanning Electron Microscope (SEM) was used to do a study on the cement paste microstructure. It was found that two of the six chemicals studied had a significant 'self-curing' effect. The two chemicals suitable for self curing were water-soluble polymers possessing either hydroxyl (-OH) or ether (-O-) functional groups. The authors reported that the lower molecular weight polymers exhibit hygroscopic properties which further prevent moisture loss from the capillaries or pores.

R. K. Dhir, et al., (1995)[5] reported the results of several durability tests conducted on self-cured concrete specimens. It was found that initial surface absorption, chloride ingress, carbonation, corrosion potential and freeze/thaw resistance characteristics were all better self-cured concrete than in the air cured control. The authors found that the improvements in concrete durability properties were dependent on dosage of admixture. Although the durability properties obtained were not as good as the film cured concrete, the authors suggested that it might be possible to achieve such properties with higher quantities of self-cure chemical. The self-cure chemical used in the study was a water-soluble polymeric glycol.

Ravindra K. Dhir, et al., (1996)[6] made an attempt to explain the observations at a micro structural level. This paper attempts to explain the physical properties and powder x-ray diffraction characteristics using a scanning electron microscope, and by computer-modeling the formation of cement microstructure. They found out that, water retention was induced by the addition of a water-soluble polymeric glycol admixture (polyethylene glycol with an average molecular weight of 200) and led to an improvement in strength and permeability properties in concrete specimens cured in air due to an increase in the cement hydration achieved. The authors observed that, at low dosages, good strength and improved permeability characteristics were attained. The authors suggest that although a lowering of strength does occur at high dosage, a much lower permeability for a given strength can be obtained.

R. K. Dhir, et al., (1998)[7] developed a self-curing agent which produced an alteration in the microstructure of the hydration product, and it was considered that it might also contribute to the improved water retention properties. Weight loss measurements were conducted on both self-cure and ordinary pastes exposed to controlled ambient conditions, while the thermogravimetric analysis was carried out on identical specimens. It was found that, while the evolution of heat of hydration rendered the early stages of drying very complex, it was possible to examine the diffusion dependent stage of drying. The diffusion coefficients observed for water vapour passing through the dry region of the self-cure paste surface were much lower than those observed for the control. The authors explained that, this has been attributed to two mechanisms: the lower vapour pressure above the pore solution leading to a smaller difference across the dried portion of the paste and lower relative humidities in the cement pores, and the change in microstructure which reduced permeability.

A.S.El-Dieb (2007)[8] carried out experimental investigations on water retention and hydration of concrete containing self-curing agents and the results were compared to conventional concrete. Water transport through the concrete was evaluated and was compared with conventional concrete continuously moist-cured and air-cured. Concrete weight loss and internal relative humidity measurements with time were carried out in order to evaluate the water retention ability. Non-evaporable water at different ages was measured to evaluate the hydration of self-curing concrete. The water transport, as durability index was evaluated by measuring water absorption %, permeable voids%, water sorptivity and water permeability. The self-curing agent used in this study was water soluble polymeric glycol (i.e., polyethylene-glycol). The dosage of the self-curing agent was kept constant for all the self-curing mixes. The dosage was 0.02% by weight of cement. From the results obtained the authors have concluded the following compared to conventional concrete: water retention for the concrete mixes incorporating self-curing agent is higher, as found by the weight loss with time, self-curing concrete suffered less self-desiccation under sealed conditions, self-curing concrete resulted in better hydration with time under drying condition, water transport through self-curing concrete is lower, and, water sorptivity and water permeability values for self-curing concrete decreased with age which indicated lower permeable pores% as a result of the continuation of the cement hydration.

Self curing concrete with an absorbent material at the time of mixing

Light weight aggregate as an absorbent material

John W. Roberts, P.E. (2004)[9] explained that most expanded shale lightweight aggregates have the ability to absorb 15 % or more by weight of water, and the absorbed water, when incorporated in a low water-cement (w/c) ratio concrete mixture, was immediately available to hydrate the cement particles deprived of mixing water. The author carried out investigation about the characteristics of light weight aggregates needed for effective internal curing.

Dale P. Bentz, et al., (2006)[10] carried out experimental investigation using three-dimensional x-ray microtomography with a voxel. In this paper, the authors studied the water movement during the internal curing of a high-performance mortar containing saturated lightweight aggregate. Clear evidence was observed that many of the initially water-filled pores within the supersaturated light weight aggregate particles empty during the first day of hydration. The observations were compared with conventional measures of hydration and compressive strength development of companion mortar specimens. The authors suggested that x-ray microtomography technique can be equally applicable to other internal curing materials such as, super absorbent polymers or water absorptive fibers.

Super absorbing polymers as an absorbent material

Bart Craeye, et al.,(2011)[11] demonstrated that by adding super absorbing polymers (SAP) into the high performance concrete as an internal curing agent, and by adding additional curing water to the concrete mixture, the chemical shrinkage and the self-desiccation during hydration of the concrete was counteracted and thus the autogenous shrinkage of the high performance concrete (HPC) can be significantly reduced. An extensive experimental investigation was performed on HPC using different degrees of internal curing processes. Several thermal and mechanical tests and finite element calculations were performed to evaluate the effect of internal curing on the HPC properties nad cracking behavior. In addition, the authors indicated the effectiveness of SAP as an internal curing agent to prevent early-age cracking of bridge decks of HPC.

Pulp fibers as an absorbent material

N.A. Johansen, et al., (2009)[12] demonstrated that the absorption capacity of internal curing materials may be determined from early age heat evolution data measured through isothermal calorimetry. Accurate assessment of absorption capacity (k) of internal curing agents is necessary to properly proportion cement-based mixtures and to measure their effectiveness in mitigating autogenous shrinkage. Standard methods for quantifying absorption capacity, such as those for coarse and fine aggregate, are not appropriate for the highly absorptive, finely divided materials often used for internal curing. The authors proposed a novel method, relying upon heat evolution with time curves generated during isothermal calorimetry, for the determination of absorption capacity of finely divided materials which may be used for internal curing in cement-based materials. The proposed method showed that the absorption capacity of a kraft pulp fiber, suitable for internal curing, was twice the anticipated value, based upon prior findings in the literature.

Shiho Kawashima and Surendra P. Shah, (2011)[13] demonstrated that the early-age shrinkage behavior of cementitious materials was affected by the addition of saturated cellulose fibers under sealed and unsealed conditions. The sealed condition simulated autogenous shrinkage exclusively while the unsealed condition introduced drying shrinkage, as well. The primary focus was to determine whether saturated cellulose fibers are suitable to mitigate autogenous shrinkage as an internal curing agent, evaluating their effect under drying conditions. At additions of 1% by mass of cement, the cellulose fibers were found to show significant drying shrinkage cracking control while providing some internal curing. In addition, early-age shrinkage test results were supplemented with a quantitative measure of fiber dispersion based on comparing theoretical and experimental values of the fiber volume fraction in hardened cementitious samples. Results indicated that improved dispersion leads to improved properties.

Self curing concrete with a covering on the surface with a thin membrane

J. Wang, et al.,(1994)[14] investigated the moisture loss from concrete, and it was revealed that the drying of concrete at early ages did not follow the “three-phase theory” and exhibited two peak rates in moisture evaporation. When curing compounds were applied, the rate of moisture loss from concrete was reduced immediately and the second peak was eliminated. It was also found that the effectiveness of membrane curing depended crucially on the time of its application and the generic type of the curing compound.

Qureshi L.A., et al. (2007)[15], compared the variation in compressive strength of high strength self compacted concrete cured by three different techniques. Three batches of concrete cylinders in each batch were cast as per ASTM standard. Mix ratio, w/cm ratio, admixture dose were kept constant. First batch was cured in a temperature controlled curing tank in the laboratory, second batch under prevailing site conditions, and the third batch was cured by the application of a curing compound (Antisole-e-white pigment from Sika complying with ASTM C309 Type II Class A was applied on the surface of cylinders @ 5 m^2/litre). From each batch, 6 cylinders were tested for compressive strength after 3 days of curing, 6 cylinders were taken after 7 days of curing and the remaining 12 cylinders were tested after 28 days of curing. Results were analyzed and graphs were drawn. The authors found that the 28 days’ compressive strength of cylinders cured under site conditions was 89% of the compressive strength of cylinders cured in water tank in the laboratory (11% less). Similarly compressive strength of cylinders cured by applying curing compound was 93% of the compressive strength of cylinders cured in the laboratory (7% less). The authors concluded that in areas with shortage of water, curing compounds can be effectively used for making self curing concrete [15].

A.S. Al-Gahtani (2010)[16] reported the result of a study conducted to investigate 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. The effect of curing methods on the properties of plain and blended cement concretes was assessed by measuring plastic and drying shrinkage, compressive strength, and pulse velocity. Results indicated 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 – and acrylic-based curing compounds. Concrete specimens cured by applying curing compounds exhibited higher efficiency in decreasing plastic and drying shrinkage strain than specimens cured by covering with wet burlap. The performance of acrylic-based curing compound was better than that of water-based curing compound. The data developed in this study indicate that curing compounds could be utilized in situations where curing with water is difficult. Among the two curing compounds investigated, acrylic-based curing compound performed better than the water-based curing compound.

Conclusions

In this paper, the recent developments in the field of self compacting and self curing concrete were discussed. The research work carried out by the various investigators in the field of self curing concrete has been grouped into three categories namely (i) self curing concrete using an internal curing agent, (ii) self curing concrete using an absorbent material at the time of mixing, and (iii) self curing concrete by covering the surface with a thin membrane and the latest findings are reported. The new generation material self compacting self curing concrete will be an innovative material that can be used in places where there is acute shortage of water and labour.

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