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Literature Review on Creep and Shrinkage Analysis and Comparison of High Strength Concrete

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***Abstract*- High strength concrete (HSC) has revolutionized the construction industry in the 1980's and Australian researchers, consultants and contractors have been very active in this area. However, most major codes for design and construction with concrete are applicable only to normal strength concrete (f'c < 50 MPa) and are based on research on normal strength concrete (NSC). In order to investigate the creep and shrinkage behavior of HSC, creep and shrinkage specimens were cast using concrete of strengths namely 110 MPa and creep and shrinkage strains measured. Presented herein are the experimental details and the test results. The obtained results are also compared with five published creep and shrinkage models most of which are meant for NSC. The preliminary findings indicate that they are not quite applicable to HSC and there is need for the development of new models for the prediction of creep and shrinkage in HSC.**

***Keywords*- HSC, Creep analysis, Shrinkage analysis.**

I. INTRODUCTION

An introduction about concrete, high strength concrete, creep and shrinkage. High strength concrete (HSC) has revolutionized the construction industry in the 1980's and Australian researchers, consultants and contractors have been very active in this area. However, most major codes for design and construction with concrete are applicable only to normal strength concrete (f'_c < 50 MPa) and are based on research on normal strength concrete (NSC). Shrinkage in high strength concrete is an important factor in the study of concrete. Shrinkage is the result of volume change of concrete resulting from either chemical shrinkage or environmental factors.

High strength concrete usually dries out in the surface, while the internal part of the concrete section withholds more moisture, for a longer time period. The main difference between high strength and normal strength concrete is that there is a difference in drying conditions. High strength concrete usually dries out in the surface, while the internal part of the concrete section withholds more moisture, for a long time. The creep of concrete depends on many factors such as volume content of hydrated cement paste, relative humidity, the type and volume of the aggregate, the age of the concrete at the time of loading, the stress level, the duration the concrete is stressed, and the geometry of the member. Creep in high-strength concrete is generally smaller than in normal-strength concrete loaded to a similar stress level because of the lower water-to-binder ratio of high-strength concrete. Most recent completed experimental work has been conducted on the different types of shrinkage faced and also creep (volume change of concrete with an applied load). Shrinkage and creep of high strength concrete are two of the great problems faced before the concrete can be used in a large scale. For the analysis of shrinkage of concrete there are many models related to the prediction of volume change. From a review of the literature, the most widely discussed and used shrinkage prediction models have been found to be the CEB Model [5], the B3 Model [6], the American Concrete Institute ACI 209 Model [7], GL 2000 Model [8], Sakata Model [9] and the Australian Standard AS 3600 Model [10]. Most of these models have also provisions for creep prediction. In order to investigate the creep and shrinkage behavior of HSC, creep and shrinkage specimens were cast using concrete of strengths namely 110 MPa and creep and shrinkage strains measured. Presented herein are the experimental details and the test results. The obtained results are also compared with five published creep and shrinkage models most of which are meant for NSC. The preliminary findings indicate that they are not quite applicable to HSC and there is need for the development of new models for the prediction of creep and shrinkage in HSC.

II. LITERATURE REVIEW

Wiegrink, Marikunte, and Shah reported decreasing specific creep values with increasing amounts of silica fume. There is an upper bound on the benefit of using silica fume. Shah and Ahmad13 pointed out that if silica fume is included at a dosage of over 10 per cent by weight, it can actually increase creep.

Neville pointed out that cements with high alumina content have a unique behavior. Whereas creep rate decreases over time and eventually approaches a near constant rate for most cements, high alumina cement undergoes a linear period of creep beginning at around 6 months after loading, and the time for the creep rate to reach a near constant rate is longer.

Collins studied the effect of course aggregate size on creep behavior. Mixtures with a maximum aggregate size of 1 ½ in. experienced 15 per cent less creep after 90 days than those with a ¾ in. maximum size.

Mokhtarzadeh and French studied creep of mixtures containing five different types of aggregate, and observed that the mixtures containing round river gravel had much higher specific creep values than the other mixtures.

Neville discussed the undisputed point that specific creep of concrete increases with increasing w/cm ratio. This is because with a lower w/cm ratio, the volume of hydrates is reduced along with the free water content, thereby reducing creep deformations. The low w/cm ratio of HSC concrete gives it more desirable creep characteristics**.**

Khan, Cook, and Mitchell examined the effects of air-dried curing and moist curing on creep of normal, medium, and high strength concrete. The results were significantly higher creep strains in the air-dried specimens.

Mokhtarzadeh and French reported that for the specimens that were moist cured, the differences in creep behavior due to mixture characteristics were miniscule. Moist curing caused the different mixtures to have similar microstructures, resulting in similar creep behavior.

Another conclusion from **Mokhtarzadeh's** research was that higher curing temperatures resulted in more creep. Their explanation was that higher temperatures increase porosity and internal cracking, which contribute to creep.

Smadi, Slate, and Nilson performed creep tests on high-, medium-, and low-strength concretes and investigated the response to sustained stress levels between 40 and 80 per cent. They found that the creep strain was proportional to the stress level, up to a certain proportionality limit. The limit is about 65 per cent of ultimate for HSC, and 45 per cent of ultimate for NSC and LSC. These results imply that HSC can be safely loaded to a higher fraction of its ultimate strength without experiencing excessive time-dependent deformations.

Another factor affecting creep is the concrete age when a sustained load is applied. Specimens loaded after one day of curing typically have twice the specific creep of specimens loaded after 28 days.13 If the concrete has not been given adequate time to cure, then it will not have the stiffness needed to resist creep. In particular, **Khan, Cook, and Mitchell** observed that HSC is much more sensitive to early-age loading than NSC.

Many of the factors that affect creep behavior also influence shrinkage. As with creep, HSC tends to have more favorable shrinkage characteristics than NSC.

Chern and Chan noted that the increase in shrinkage observed with increasing slag contents might be due to greater paste volume. If Portland cement is replaced by slag on an equal-weight basis, a higher cement content results because slag has a lower specific gravity than Portland cement.

Collins investigated the effect of a high range water-reducing admixture on shrinkage, and concluded that it did not significantly affect shrinkage. Calcium chloride, which accelerates the hardening and setting of concrete, tends to increase shrinkage. Air entrainment agents have not been shown to affect shrinkage **Collins** found that shrinkage deformation is inversely proportional to moist-curing time. She observed that longer moist- curing times result in lower shrinkage deformation.

Mak, Foster, Chirgwin, and Ho observed that specimens subjected to HAC had 75 percent less shrinkage than specimens cured at standard temperature. **Mokhtarzadeh and French** varied the temperature of heat accelerated curing, and found that specimens cured at 120 F had more drying shrinkage than specimens cured at 150 F, which confirms the trend that drying shrinkage decreases with increasing curing temperature.

Altho Sagaraa, Ivindra Paneb, 2015 this study, the effects of creep and shrinkage of high strength concrete used for prestressed concrete bridge girder is investigated. The aim is to quantify the loss of prestress in high strength concrete bridge and to find justifications on increasing usage of high strength concrete for bridges. A continuous-span bridge built using span by span method (movable scaffold system) is chosen as a case study. Three grades of concrete strength are investigated, 40 MPa, 80 MPa, and 100 MPa, each representing normal, moderately high and high strength concrete. These are grades that can be routinely produced by concrete industry without significant alteration in current production/process technology. As part of this study, a literature survey has also been conducted. It suggests that high strength concrete requires modification of current creep and shrinkage code (applicable only for normal concrete). Thus, the initial part of this study deals with determination of proper creep and shrinkage code. Then, a finite element analysis of the bridge case is performed. The result indicates that reduction in girder size and amount of prestressing is not simply governed by concrete Strength, but by the complex effects of strength, creep and shrinkage behavior of high strength concrete.

Erik Wayne Farrington, Ned H. Bums, and Ramon L. Carrasquillo This study considers the creep and shrinkage properties of a high performance concrete having an ultimate strength of 90 MPa. Specifically in this study, we looked at such variables as the effects of curing temperature, age at loading, and stress level. We used strain measurements taken through 120 days, along with curve-fitting techniques, to estimate the ultimate creep coefficient and ultimate shrinkage strains of the concrete. We also compared the recorded data with predictions made using ACI Committee 209 recommendations.

Coutinho, A.S., (1959) conducted an experimental test programme to identify the influence of the type of cement on the cracking tendency and he concluded that (a) Natural cement as well as the concrete prepared with it have an extremely low cracking tendency due to the high creep (or high relaxation) of this cement, (b) High early strength Portland cement has high cracking tendency due to its slight creep (or relaxation). Concrete prepared with it has a higher cracking tendency than concrete of normal Portland cement, (c) Aluminous cement has the highest cracking tendency of all the cements studied because of its extremely small creep and the very large increase in its initial shrinkage.

Bloom, R., et al, (1995) tested concrete based on a graded aggregate with a maximum nominal aggregate size of 7 mm. This was due to the small cross section resulting in a need for smaller aggregate size to gain a representative sample. Shrinkage tests were conducted on 40 x 40 x 1000 mm prism specimens. The specimens were exposed to either 40 °C, 45% relative humidity, or they were sealed. Silica fume considerably increased the free shrinkage of the concrete compared to the reference Portland cement concrete with the same water to binder ratio. Concrete with a low water to binder ratio of 0.33 cracked due to plastic shrinkage regardless of silica fume in the mix. Concrete with a higher water to binder ratio of 0.50 did not have cracking, but the mixes with a water to binder ratio of 0.40 cracked with silica fume and no cracking was observed in the non - silica fume mixes. The shrinkage of the sealed specimens was found to be negligible.

Tazawa, E., et al, (1991) examined the shrinkage and creep of mortar and concrete. Drying shrinkage of concrete was tested using 100 x 100 x 400 mm prism specimens. The specimens were in a controlled environment of 20 °C and 50% relative humidity. The drying shrinkage of the concrete mixes with silica fume was lower than that of the same type mixes without the silica fume.

Li, H., et al, (2002) studied the early age creep and shrinkage with and without silica fume (SF), ground granulated blast-furnace slag (GGBS) and their combinations. Prism specimens of size 100 x 100 x 400 mm were used to study the drying and autogenous shrinkage of six concrete mixtures. The prepared specimens were tested after 3 days under a controlled environment of 30 ± 2 °C and 65 ± 5% relative humidity as maintained by dehumidifiers. It was concluded that the blended cement concrete incorporating SF, GGBS or both had lower drying shrinkage especially at a later age after 60 days but greater autogenous shrinkage than that containing ordinary Portland cement alone.

III. SUMMARY OF LITERATURE REVIEW

From the detailed literature review, concluded that the study of creep and shrinkage in high strength concrete done in many paper. From these papers depending upon the factors affecting the creep and shrinkage showing different nature in concrete. The study of creep and shrinkage in high strength concrete described in some journals, but these studies added another admixtures and different types of materials size, w/c ratio to decrease the creep and shrinkage deformation and also increase the strength of the concrete.

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