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Prediction of high strength concrete: Creep and shrinkage

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ABSTRACT

The rapid expansion of high-strength concrete applications in construction and bridges. When using high strength concrete, all methods of building can benefit from the beneficial benefits of reduced member sizes and strengthening. Bridges, on the other hand, are often built with long lengths, resulting in considerable dead weight, which, when combined with the creep and shrinkage properties of concrete, results in significant dead weight. In the long run, this results in major deformation and prestressing force depletion. The effects of creep and shrinkage on prestressed concrete bridge girders were studied in this report. The aim is to measure prestress failure in high-strength concrete bridges and to find justifications for expanding the use of high-strength concrete in bridge construction. The aim of this report is to forecast concrete's long-term creep and shrinkage activity. The development of generic prediction approaches that a design engineer can use when precise experimental data is unavailable. A literature review was also carried out as part of this research. It implies that high-strength concrete necessitates a change in current creep and shrinkage behavior. As a result, the first part of this research focuses on determining the correct creep and shrinkage code. The bridge case is then subjected to a finite element analysis. The findings show that the complex the complex effects of high strength concrete strength, creep, and shrinkage behavior on girder size and prestressing volume are controlled by the complex effects of high strength concrete strength, creep, and shrinkage behavior.

Index Terms: Creep, High Strength Concrete, Shrinkage.

INTRODUCTION

The popularity of high-strength concrete (HSC) has been steadily increasing and it is now a widely used building medium. High-strength concrete is described as having a 28-day compressive strength of at least 41.4 MPa (6000 psi). Higher compressive strengths are obtained by reducing the water-to-cementations materials ratio, which necessitates the use of water-reducing admixtures to ensure sufficient workability. Since more slender members can be built, high-strength concrete has a range of cost advantages over standard-strength concrete in terms of content and shipping costs. Deflection becomes more important as structural elements become slenderer, making long-term creep and shrinkage deformations particularly important in HSC systems.

Creep and shrinkage are time-dependent deformations that occur in all concrete systems. Creep is characterized as the deformation of a viscoelastic material over time, in excess of the initial elastic strain, caused by a sustained stress. Shrinkage is a time-dependent deformation that happens when there is no load added. As a result, the average strain of a concrete specimen is equal to the number of the

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original elastic, creep, and shrinkage strains at any given moment [1-5].

Concrete creep can be divided into two types: simple creep and drying creep. Basic creep happens where the concrete is sealed and there is no water exchange between the concrete and its surroundings. Drying creep involves water movement to the surrounding environment. The creep experienced by the innermost region of a large concrete member is predominantly basic creep, since very little water is lost to the outside environment.

Shrinkage consists of three different mechanisms, known as drying shrinkage, autogenously shrinkage, and carbonation. When excess water not absorbed during hydration diffuses into the surrounding atmosphere, drying shrinkage occurs, resulting in a net volume loss. The water depletion caused by the cement's continued hydration is known as autogenously shrinkage. In the presence of moisture, CO2 in the atmosphere reacts with Ca (OH)2 in the cement paste to cause carbonation shrinkage.

CHARACTERISTICS OF HSC

- Excellent abrasion resistance
- High elasticity modulus
- High longevity and long life in environmental service.
- Permeability and diffusion are poor.
- Chemical attack resistance

ADVANTAGES AND DISADVATAGES

Advantages

- Reduce amount of steel
- Reduce dead load
- Reduces space occupied by columns
- Increases rental spaces
- High compressive strength
- To use the concrete service at early stage
- High rise buildings be built by reduced columns

Disadvantages

- Harmed at hot pressures, i.e., less fire resistance
- Experience in ingredient selection is needed

LONG TERM DEFLECION

Several deformations occur as concrete is loaded. Upon loading, the initial deformation, also known as instantaneous elastic strain, occurs. It is determined by the concrete's elastic properties and the amount of tension added. Additional long-term deformation will occur if motion will occur if the stress is constantly applied to the concrete. The results of shrinkage and creep properties of the concrete are the primary causes of long-term deformation [6-10].

Creep

Under long-term stress, when a continuous strain is applied. Although the symptoms of creep have been referred to by a variety of names (such as plastic drift, plastic deformations, and so on), the term creep is generally accepted as the most accurate definition of the phenomena. In certain cases, the creep strains in concrete are greater than the elastic strains that arise during loading. As a result, determining a material's creep properties is highly important. While most analyses of these properties believe that creep is a protrusion that is added to shrinkage deformation, and that creep and shrinkage are also additive deformations. are interrelated properties. The origin of creep is a contentious topic. One theory regarding creep is that it is caused by absorbed water being drawn into the capillaries of hardened concrete. The precise method of crawl, however, remains unclear due to evidence that contradicts this theory. What is understood is that applying a continuous compressive force to concrete can cause it to crack.

Shrinkage

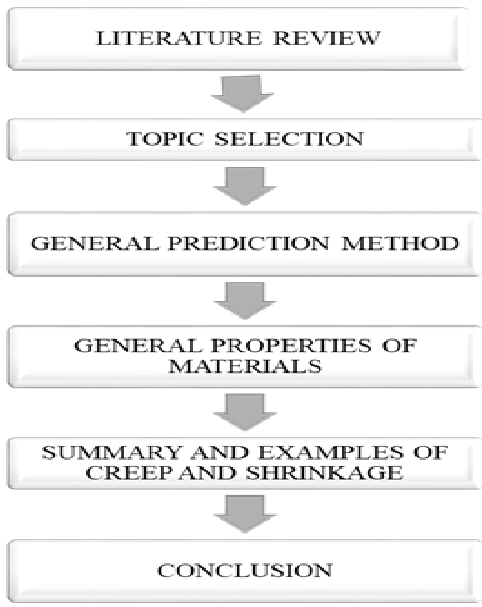
The lack of moisture leads to a change in concrete thickness. This loss of moisture will happen when the concrete is still wet, which is known as "plastic shrinkage," or after it has dried, which is known as "drying shrinkage." These deformations are caused by shrinkage. The drying shrinkage of the high-performance concrete used in this study is the sole focus of this research. Since the lack of water not used in the hydration of the cement in concrete causes drying shrinkage, the difference in volume does not match the volume of water lost. The concrete would not shrink as a result of the water leakage from the capillaries. When the capilla is fully dry [11-15].

"Carbonation shrinkage" is another form of shrinkage. The carbon dioxide in the air reacts with the hardened cement paste, creating a volume loss. CaC03 and free water are formed as Ca (OH) carbonates. As in drying shrinkage, this water will escape, causing concrete shrinkage.

AIM AND OBJECTIVES

- The key goal of this research is to look at how a high-strength concrete mixture deforms over time.
- Another goal is to equate observed creep and shrinkage malformations to seven existing predictions and determine which one is the most accurate predictions creep and shrinkage strains for this combination.

METHODOLOGY



Literature Review

Many articles have been written on the subject of creep and shrinkage in high-strength concrete. These papers demonstrate varying natures in concrete based on the conditions causing creep and shrinkage. Some publications have mentioned the study of creep and shrinkage in high-strength concrete, but these studies used other admixtures and other varieties of materials, as well as a different w/c ratio, to reduce creep and shrinkage deformation while still increasing the concrete's strength [16-18].

Altho Sagaraa, Ivindra Paneb, 2015, The effects of creep and shrinkage on high-strength concrete used in prestressed concrete bridge girders was studied in this research. The aim is to measure prestress failure in high-strength concrete bridges and to find justifications for expanding the use of high-strength concrete in bridge construction. As a case study, a continuous-span bridge constructed using the span-by-span process (movable scaffold system) was selected. The strength of concrete is examined in three grades: 40 MPa, 80 MPa, and 100 MPa, which reflect standard, medium high and high strength concrete, respectively. There are grades that can be manufactured on a regular basis by the concrete industry without requiring major changes to existing production/process technology. A literature review was also carried out as part of this research. It implies that high-strength concrete necessitates a change in the existing creep and shrinkage code (applicable only for normal con-crete). As a result, the first part of this research focuses on determining the correct creep and shrinkage code. The bridge case is then subjected to a finite element analysis.

Coutinho, A.S., (1959) He performed an experimental research programme to determine the effect of cement form on cracking tendency, and he concluded that (a) Natural cement, as well as the concrete made with it, have an exceedingly low cracking tendency due to the strong creep (or high relaxation) of this cement, and (b) Natural cement has a high early strength. Because of its mild creep (or relaxation), Portland cement has a strong cracking propensity. Concrete made with it has a greater propensity to break than concrete made with regular Portland cement (c) Because of its extremely limited creep and wide initial shrinkage, aluminous cement has the highest cracking tendency of all the cements tested.

Bloom, R., (1995) A graded the concrete was measured using aggregate with a total nominal aggregate dimension of 7 mm. Because of the narrow cross section, a smaller aggregate size was needed to obtain a representative sample. Shrinkage measurements were performed on prism specimens measuring 40 x 40 x 1000 mm. The specimens were either sealed or exposed to 40°C and 45 percent relative humidity. As opposed to a reference Port-land cement concrete with the same water to binder ratio, silica fume significantly improved the free shrinkage of the concrete. Regardless of the presence of silica fume in the mix, concrete with a poor water to binder ratio of 0.33 fractured due to plastic shrinkage. Concrete with a water to binder ratio of 0.50 did not break, but mixes with a water to binder ratio of 0.25 did.

Tazawa, E., (1991) looked at how mortar and asphalt shrink and crawl. Concrete drying shrinkage was measured using prism specimens measuring 100 x 100 x 400 mm. The specimens were held in a stable atmosphere with a temperature of 20°C and a relative humidity of 50%. The drying shrinkage of the silica fume concrete mixes was less than that of the same style mixes without the silica fume.

Li, H., et al, (2002) the effects of silica fume (SF), ground granulated blast-furnace slag (GGBS), and their variations on early age creep and shrinkage were investigated. The drying and autogenous shrinkage of six concrete mixtures were studied using prism specimens measuring 100 mm x 100 mm x 400 mm. The prepared specimens were analyzed after 3 days in a stable environment of 30°C and 65 percent relative humidity. It was discovered that blended cement concrete containing SF, GGBS, or both had lower drying shrinkage, particularly after 60 days, but greater autoge-nous shrinkage than ordinary Portland cement alone.

EQUATION AND PROCEDURE BASED ON IS 1343-2012

Shrinkage

The representatives of concrete assess the concrete's total shrinkage, the height of the individual, and the surrounding atmosphere. The overall shrinkage of concrete is most determined by the total volume of water contained in the concrete at the time of mixing, and to a lesser degree, by the cement material, for a given humidity and temperature. The total shrinkage strain is composed of two components, the autogenously shrinkage strain and the drying shrinkage strain

$$\varepsilon_{cs} = \varepsilon_{cd} + \varepsilon_{ca}$$

Where, ε_{cs} = total shrinkage strain ε_{cd} = drying shrinkage strain ε_{ca} = autogenously shrinkage strain. In the absence of precise field/laboratory results, the following values in design table 1 can be used.

Table 1: Grade of concrete with autogenous shrinkage

Concrete grade	Autogenous shrinkage (ε_{ca} x 10^6)
M30	35
M35	45
M45	65
M50	75
M60	95

Since it is a function of water migration via hardened concrete, drying shrinkage strain grows slowly.
The drying shrinkage strain's final worth,

$\varepsilon_{cd} = k_h . \varepsilon_{cd}$

For reference, the value of cd can be found in the table below. These are the predicted mean values, with a 30 percent coefficient of variance.

Table 2: Unrestrained drying shrinkage values

f_{ck} MPa	For relative humidity, unrestricted drying shrinkage values (cd x 10^6) for concrete with PC	
1	50%	80%
	2	3
25	535	300
50	420	240
75	330	190

Table 3: Kh is a function that is proportional to the total outstanding value h0.

h_0	k_h
100	1.0
200	0.85
300	0.75
≥500	0.70

The development of autogenous shrinkage with time may be taken as:

$\varepsilon_{ca}(t) = \beta_{as}(t). \varepsilon_{ca}$

where, $\beta_{as}(t) = 1 - \exp(-0.2\sqrt{t})$, where t is in days.

The development of the drying shrinkage strain in time may be taken as:

$\varepsilon_{cd}(t) = \beta_{ds}(t,t_s). k_h.\varepsilon_{cd}$

$\beta_{ds}(t,t_s)$=((t-t_s))/((t-t_s)+0.04√(h_0^3))

where, t = age of the concrete at the moment considered, in days.

t_s = age of the concrete at the beginning of drying shrinkage, in days; normally this is at the end of curing.

h_0 = notional size of the cross- section, in mm= $2A_c/u$,

where A_c the concrete cross sectional area and u is the perimeter of that part of cross section which is exposed to drying.

Creep

In addition, concrete creep is affected by the age of the concrete at the time of loading. Creep may be considered to be equal to stress as long as the stress in concrete does not surpass one-third of the characteristic compressive power.

The creep coefficient φt,to = $\varepsilon cc(t) / \varepsilon ci(t0)$

Where εcc(t) = creep strain at time t > t0

h0 kh 100 1.0 200 0.85 300 0.75 ≥500 0.70

εci(t0) = initial strain at loading

t0 = initial time of loading.

The creep coefficient φ(t,t0) is given by:

φ(t,t0) = φ0 β(t,t0)

where ϕ 0 = notional creep coefficent to which the creep coefficient reaches asymptotically with time (this can be taken as value reached in 70 years) β (t,t0) = coefficient desicribing development of creep with time (see 4.2.2.2) The notional creep coefficient φ0 is given by:

Φ0 = φRHβ(fcm)β(t0)

Where φRH = a factor to allow for the effect of relative humidity on the notional creep coefficient.

= [1 + 1−RH/100 0.1 √ho 3 α1] α2 for fc> 45 MPa (RH = relative humidity of the ambient environment in %. h0 = notional size of the member, in mm = 2Ac/u Ac = cross sectional area u = perimeter of the member in contact with the atmosphere) β(fcm) = a factor to alow for the effect ofconcrete strength on the notional creep coefficient = 16.8 √$f ck$ +8 (t0) = a dimension to account for the influence of the notional creep coefficient on the concrete age of loading = 1 (0.1+ t0 0.20). Where end results are unaffected by exact values determined as described above, the values mentioned in the table below can be used as the final creep coefficient for design of normal weight concrete grades between M30 and M60 subjected to condition that the compressive stress does not exceed 0.36fck at the age of loading and mean temperature of concrete is between 100 C and 200 C with seasonal variation between -200C to 400C. for temperature greater than 400C the coefiicient given may be increased by 10%, in the absence of accurate data.

Table 4: Creep coefficent of an ordinary structural concrete after 70yrs of loading

Age at loading t_0 (days)	**Under dry atmospheric condition (RH 50%) Notional size ($2A_c/u$)**			**Under humid atmospheric condition (outdoor) (RH 80%) Notional size ($2A_c/u$)**		
	50 mm	150 mm	600 mm	50 mm	150 mm	600 mm
1	5.8	4.8	3.9	3.8	3.4	3.0
7	4.1	3.3	2.7	2.7	2.4	2.1
28	3.1	2.6	2.1	2.0	1.8	1.6
90	2.5	2.1	1.7	1.6	1.5	1.3
365	1.9	1.6	1.3	1.2	1.1	1.0

(t,t0) = (t,t0) = (t,t0) = (t,t0) = (t,t0) = (t,t0) = (t,t0) = (t,t0) [tt0 H+(t t0)] 0(t,t0) = [tt0 H+(t t0)] 0.3, where t is the age of the concrete at the time of loading in days, t0 is the age of the concrete at loadings in days, and (t – t0) is the period of loading in days. H is a coefficient that depends on the relative humidity (in percent) and the size of the hypothetical member (h0 in mm) = 1.5 [1+ (1.2 *RH RH*0)18]h0 + 250≤1500 For fck ≤ 45 MPa = 1.5 [1+ (1.2 *RH RH*0)18]h0 +250α3 ≤ 1500α3

For fck > 45 MPa RH = relative humidity expressed as % RH0 = 100 (that is , 100 % relative humidity) α1, α2, α3 = coefficient to consider the influence of the concrete strength,
α1 =[45 *f c k* +8]0.7 , α2 = [45 *f c k* +8]0.2
α3 = [45 *f c k* +8]0.5

CONCLUSION AND FUTURE SCOPE

Compressive strength modification considerations should be used in creep and shrinkage models. In this analysis, models with certain adjustment variables projected much more reliably than models that did not take compressive strength into account. In this study the 7 model of prediction are studied and compared with the Indian standard to find which shows the accurate values for the creep and shrinkage. The effect of curing temperature, loading age, and relative humidity level is investigated. The final value is then compared with the standard value obtained in ACI 209. Finally proved IS 1343-2012 is giving the most accurate values when comparing to the ACI 209 model.

FUTURE SCOPE

- Experimental studies must be produced in the area out of the same batches of concrete as the research experiments girders wherever possible, so that the specimens are of the same substance as the girders. This would minimize major structural properties differences between laboratory and girder concrete.
- The Indian norm was used, but it overestimates prestress losses due to creep and shrinkage in high-strength concrete. It can be replaced with a model that works with high-strength concrete.

ANNEXURE - 1

Design example no: 1

Step 1: General data from is 1343-2012

- 50% of ambient relative humidity
- Moist cured concrete
- Loaded at 6 days of age
- Shrinkage considered from 7 days

Step 2: The creep coefficient

$\Phi (t, t_o) = (\varepsilon cc (t))/(\varepsilon ci (to))$

Where $t_o = 1$, $t = 7$, since $t > t_o$

$\therefore \varphi (t, t_o) = \varphi_o \beta(t,t_o)$

Where $\Phi_0 = \varphi_{RH}\beta(f_{cm})\beta(t_0)$

Since the end value using this equation is not precise the creep coeffient value is take from the table no: 1 on IS 1343-2012.

$\therefore \varphi_o = 4.1$; where $h_o = 50mm$

Step 3: the development of creep with the time

$\Phi(t,t_o) = \beta(t,t_o) \times \varphi_o$

Where $\beta(t,to) = [\ t - t\ o\ \ \beta\ H + (t - t\ o\ )\ ]^{0.3}$

$\because \beta H = 1.5\ [1+ (1.2R\ H\ \ R\ H\ o\ )18]\ ho + 250\alpha 3 \leq 1500\alpha 3$

$\alpha 3 = [\ 45\ f\ c\ k + 8\ ]0.3$

$= 0.88$

$\therefore \beta H = 295.007$

$\therefore \beta(t,to) = 0.409$

The development of creep $\Phi(t,to) = 4.1 \times 0.409 = 1.68$

Step 4: shrinkage coefficient

The total shrinkage value, $\varepsilon cs = \varepsilon cd + \varepsilon ca$

Where, $\varepsilon ca = 95 \times 10-6$

$\varepsilon cd\infty = kh.\ \varepsilon cd$

Where, εcd is obtainted from interpolation

$\therefore y = y1 + (x-x1)y2 - y\ 1\ x\ 2 - x\ 1$

$= 420 + (60-50) \times (330-420)/(75-50)$

$= 384$

$\varepsilon cd\infty = 0.85 \times 384 = 326.4 \times 10-6$

The autogenous shrinkage dependent on time is given by,

$\varepsilon ca (t) = \beta as(t).\ \varepsilon ca$

$\beta as(t) = 1- \exp(-0.2\sqrt{t}) = 1 - \exp (-0.2\sqrt{7}) = 4.753$

$\therefore \varepsilon ca (t) = 4.753 \times 95 \times 10-6 = 451.53 \times 10-6$ The drying shrinkage dependent on time is given by,

$\varepsilon cd (t) = \beta ds (t,ts).kh.\ \varepsilon cd$

where, $\beta ds (t,ts) = t - t\ s\ \ (t - t\ s\ ) + 0.04\sqrt{h}03$

$= 0.05$

$\varepsilon cd (t) = 0.05 \times 0.85 \times 326.4$

$= 13.872 \times 10-6$

$\therefore$ the total shrinkage dependent on time

$\varepsilon cs (t) = 451.53 \times 10-6 + 13.872 \times 10-6$

$= 465.402 \times 10-6$

DESIGN EXAMPLE NO: 2

Step 1: General data from is 1343-2012

- 80% of ambient relative humidity
- Moist cured concrete
- Loaded at 6 days of age
- Shrinkage considered from 7 days

Step 2: The creep coefficient

Φ (t, to) = $\varepsilon c c (t) \varepsilon c i (t o)$

Where to = 1, t = 7, since t>to

∴ φ (t, to) = φo β(t,to)

Where Φ0 = φRHβ(fcm)β(t0)

Since the end value using this equation is not precise the creep coeffient value is take from the table no: 1 on IS 1343-2012.

∴ φo = 2.7; where ho = 50mm

Step 3: the development of creep with the time

Φ(t,to) = β(t,to) x φo

Where β(t,to) = [$t - t o \ \ \beta H + (t - t o)$]0.3

∵ βH = 1.5 [1+ (1.2$R H \ \ R H o$)18] ho + 250α3 ≤ 1500α3

α3 = [45 $f c k$ +8]0.3

= 0.88

∴ βH = 290.53

∴ β(t,to) = 0.56

The development of creep Φ(t,to) = 2.7x0.56 = 1.52

Step 4: shrinkage coefficient

The total shrinkage value, εcs = εcd + εca

Where, εca = 95 x 10−6

εcd∞ = kh. εcd

Where, εcd is obtainted from interpolation

∴ y = y1 + (x-x1)y2−y 1 x 2−x 1

= 240 + (60-50) x (190-240)/(75-50)

= 220

εcd∞ = 0.85 x 220 = 187 x 10−6

The autogenous shrinkage dependent on time is given by,

εca (t) = βas(t). εca

βas(t) = 1- exp(-0.2√t) = 1 –exp (-0.2√7) = 4.753

∴ εca (t) = 4.753 x 95 x 10−6 = 451.53 x 10−6 The drying shrinkage dependent on time is given by,

εcd (t) = βds (t,ts).kh. εcd

where, βds (t,ts) = $t - t s \ \ (t - t s)$+0.04√h0)= 0.05

εcd (t) = 0.05 x 0.85 x 187 = 8 x 10−6

∴ the total shrinkage dependent on time

εcs (t) = 451.53 x10−6 + 8 x10−6

= 459.53 x10−6

RESULT

The effects of many variables on creep and shrinkage are not excessive and trend to each other. Therfore, in a simplified design procedure, the only variables for which corrections must be made are humidity, age of loading, and age from which shrinkage is considered.

The results are compared to the standard value obtained from ACI 209.

Relative humidit	ACI 209		IS 1343-2012	
	creep	shrinkage	creep	shrinkage
50%	1.82	730 x 10^{-6}	1.68	465x10^{-6}
80%	1.79	595x10^{-6}	1.52	459.53x10^{-6}

Hence from the above compared results it is clear that the Indian standard code also gives the accurate values for creep and shrinkage. Hence, proved.

REFERENCE

[1]. Goodspeed, C. H., Vanikar, S., and Cook, R., Untitled memo "RE: Circulation of HPC Definition Version 1.0" University of New Hampshire, Durham, 1995.

[2]. Barrios, A., "Behavior of High Strength Concrete Pretension Girders during Transfer of Prestressing Forces," Master's Thesis, The University of Texas at Austin, 1994.

[3]. Neville, A. M., Properties of Concrete, Pitman Publishing, Inc., Marshfield, Massachusetts, 1981.

[4]. Hanson, J. A., "Prestress Loss as Affected by Type of Curing," PC! Journal, 9(2), 1964, 69-93.

[5]. ACI Committee 517, "Low Pressure Steam Curing," ACI Report, American Concrete Institute, Detroit, 60-48, 1963.

[6]. Swamy, R.N., and Anand, K. L.," Shrinkage and Creep Properties of High-Strength Structural Concrete," Civil Engineering and Public Works Review (London), 68(80), 1973, 859-868.

[7]. Mindess, S., and Young, J. F., Concrete, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1981.

[8]. Collins, T. M., "Proportioning High-Strength Concrete to Control Creep and Shrinkage," ACI Materials Journal, 86(6), 1989, 576-580.

[9]. Smadi, M. M., Slate, F. 0., and Nilson, A. H., Shrinkage and Creep of High-, Medium-, and Low-Strength Concretes, Including Overloads," ACI Materials Journal, 84(3), 1987, 224-234.

[10]. Ngab, A. S., Nilson, A. H., and Slate, F. 0., "Shrinkage and Creep of High Strength Concrete," ACI Journal, 78(4), 1981, 255-261.

[11]. ACI Committee, "Prediction of Creep, Shrinkage, and Temperature Effects in Concrete Structures," Designing for Creep and Shrinkage in Concrete Structures, SP-76, American Concrete Institute, Detroit, 209, 1971.

[12]. Parthiban, P. M. E., M. Rajalingam ME, Dr MIE, and Sunilaa George. "Comparative Study on Strength Enhancement of Concrete Using Magnetic and Normal Water." International Journal of New Technology and Research 2(5).

[13]. American Society for Testing and Materials, Annual Book of ASTM Standards, "Standard Test Method for Creep of Concrete in Compression," ASTM C512, 1987.

[14]. Sennour, M. L., and Carrasquillo, R. L., "Creep and Shrinkage Properties in Concrete Containing Fly Ash," Research Report, Center for Transportation Research, The University of Texas at Austin, 481-6, 1989.

[15]. El Hindy, E., Miao, B., Chaallal, and Aitcin, P., "Drying Shrinkage of Ready Mixed High-Performance Concrete," ACI Structural Journal, 91(3), 1994, 300-305.

[16]. Nasser, K. W., and Al-Manaseer, A. A., "Creep of Concrete Containing Fly Ash and Super plasticizer at Different Stress/Strength Ratios," ACI Journal, 83(4), 1986, 668-673.

[17]. Russell, H. G., and Larson, S. C., "Thirteen Years of Deformations in Water Tower Place," ACI Structural Journal, 86(2), 1989, 182191.

[18]. Neville, A. M., in collaboration with W. Dilger, Creep of Concrete: Plain, Reinforced, and Prestressed, North Holland Publishing Company, Amsterdam, 1970.