International Journal of Advanced Technology in Civil Engineering

Volume 1 | Issue 4 Article 8

October 2012

EFFECT OF ADDITION OF FLY ASH ON SHRINKAGE CHARACTERISTICS IN HIGH STRENGTH CONCRETE

GUNAVANT K. KATE
Baramati, India, kategk16@rediffmail.com

PRANESH B. MURNAL
Govt .College of Egg. Aurangabad, pmurnal@yahoo.com

EFFECT OF ADDITION OF FLY ASH ON SHRINKAGE CHARACTERISTICS IN HIGH STRENGTH CONCRETE

GUNAVANT K. KATE[1], PRANESH B. MURNAL[2]

[1]Department of Civil Engg.,Malegaon(Bk), Asst.prof., Baramati, India
[2]Department of Applied Mechanics, SVPM's,College of Engg, Govt .College of Egg. Aurangabad, Head of Dept., Aurangabad, Maharashtra India
Email: kategk16@rediffmail.com, pmurnal@yahoo.com

Abstract: This paper presents the results of an experimental investigation carried out to evaluate the shrinkage of High Strength Concrete. High Strength Concrete is made by partial replacement of cement by fly ash. The shrinkage of High Strength Concrete has been studied using the different mixes from a minimum of 10% to maximum of 70 %. From the test results of the above investigation it can be concluded that the shrinkage strain of High Strength Concrete increases with increase in fly ash content. The rate of increase in shrinkage with time is uniform for low fly ash content, whereas it generally increases after 28 days for high volume of fly ash and the high volume fly ash concrete yields slow strength development at an early age.

Keywords*: high strength concrete, fly ash, HVFAC, shrinkage, shrinkage strain, super plasticizers*

I. INTRODUCTION

It is generally assumed that increasing the strength of concrete automatically corresponds to an increase in long-term durability; however this may not necessarily always be true. In recent years, long-term strength and quality has become major concern in the design and specification of concrete structures. Due to ever increasing urbanization, structures like sky-scrapers and other huge structures are increasing day by day. As a result, high strength concrete (HSC) has achieved widespread use in the world. The Indian Standard IS: 456:2000 specifies percentage of fly ash as no more than 15%-25% of total cementitious content. The use of fly ash (Grade 1) as part replacement of ordinary Portland cement (having total alkali content as Na_2O equivalent not more than 0.6 percent), is at least 20 percent or slag content is at least 50 percent. ACI 318, till recently, allowed up to 25% fly ash for all concrete, but the latest ACI 318, just off the presses has since withdrawn this limit. The high-volume fly ash concrete is one specific type of fly ash concrete with higher fly ash contents, lower water-to-cementitious materials ratio (W/CM), and lower cement contents[8].

Shrinkage is the decrease of concrete volume with time. This decrease is due to change in moisture content of the concrete, which occurs without stress attributable to actions external to the concrete. Swelling is the increase of concrete volume with time. Shrinkage and Swelling are usually expressed as dimensionless strain (in/in. or mm/mm). Under given conditions of room temperature, shrinkage is primarily a function of the paste, but is significantly influenced by the stiffness of the coarse aggregate. While it is commonly assumed that lower w/c concrete exhibits less shrinkage than higher w/c mixtures, this general rule may be misleading and should be qualified. While it is true that concrete made using a low w/c typically exhibits lower drying shrinkage, these mixtures can exhibit a substantial increase in autogenous shrinkage, especially during the first 24 hours of material development. Autogenous shrinkage describes length changes that are not attributed to mass loss (water loss) or temperature change. Autogenous shrinkage occurs as a result of self-desiccation (internal water consumption) in low w/c mixtures where sufficient water is not provided to complete the reaction with the cement. Although self-desiccation was originally described over sixty years ago, it was not perceived to be a problem in concrete for many years since high w/c ratios (>0.42) were used to insure workability. However, widespread use of water-reducing agents (and high-range water reducing agents) have made it possible to utilize low w/c mixtures more routinely and, as a result, autogenous shrinkage must be considered in these mixtures. While it is important that cement-based materials exhibit volumetric stability with moisture fluctuations, the true goal of limiting volumetric change is to reduce the potential for cracking [5]. Determining if concrete will shrinkage in service is difficult however, due to complex interaction of several factors including the materials ability to permit stress relief through creep or micro-cracking [1], shrinkage rate, and the rate of material property development. In addition, factors such as specimen geometry, curing conditions, and restraint conditions further complicate predicting the potential for cracking.

This paper presents the results of an experimental investigation carried out to evaluate the shrinkage of

High Strength Concrete. In the present investigation an attempt has been made to study the behavior of the high strength concrete using component materials and fly ash.

II. MATERIAL COMPOSITION

This paper summarizes recent studies that illustrate the influence of pozzolanic materials like fly ash on the properties of concrete. The cement was partially replaced by different amount of fly ash and was used to describe concrete performance. In the present investigation the parameters varied were:

(i) Fine aggregate (Krishna River)
(ii) Coarse aggregate of sizes 20 mm and 12.5 mm.
(iii) Supplementary cementitious material replacement of 0, 10, 25, 40, 55, 70% cement materials by different amount of F .A.

The water to cement plus binder ratio was varied from 0.23 to 0.35. To get the required degree of workability at lower water-cement ratios, superlasticizer was added at the rate of 1.5% by weight of cement [6]. These low W/C ratios are only attainable with quite large doses of superplasticizer confirming to ASTM C-494 type F or G fly ash. The physical properties of fine aggregate; coarse aggregate and fly ash are given in Table 1-3.

Table 1: Physical properties of Fine aggregate

Sr. No.	Properties	Observed Values of Fine aggregate
1.	Bulk density	1950 kg/ m3
2.	% of voids	5.33 %
3.	% of water absorption	2.51 %
4.	Specific gravity	2. 60
5.	Fineness Modulus	3.26

Table 2: Physical properties of Coarse aggregate

Sr. No.	Properties	Observed Values of coarse aggregate
1.	Bulk density	1733 kg/ m3
2.	% of voids	40.65 %
3.	% of water absorption	0.66 %
4.	Specific gravity	2.71

Table3: Physical properties of Fly Ash (Class C)

Sr. No.	Properties	Test Results
1	Particle shape	Fineness
2	Colour	Grayish white
3	Specific gravity	1.8 - 2.4

Table 4. Chemical properties of Fly Ash (Class C)

Sr. No.	Properties	Test Results (As per available from supplier)
1.	$SiO_2+ Al_2O_3 + Fe_2O_3$ (%)	93.0
2.	SiO_2(%)	77.0
3.	MgO, (%)	0.9
4.	SO_3(%)	2.2
5	Na_2O(%)	0.8
6	Loss on ignition (LOI), (%)	5.0
7	Total chlorides, % by mass, max	0.05

III. EXPERIMENTAL PROGRAMME

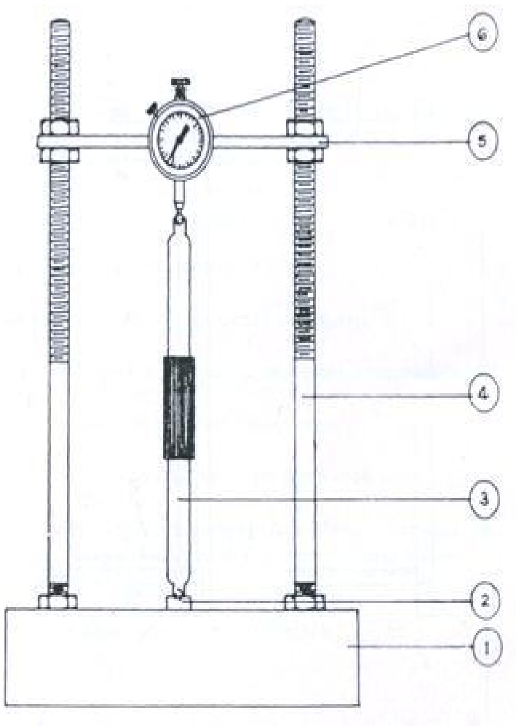
To investigate the influence of binder composition all mixtures used in this study maintained a constant aggregate volume of 65% that was composed of equal proportions of fine aggregate. Table 1, 2 and 3 provide a summary of the material proportions used; however further details of the mixture proportions, materials, and casting processes are available elsewhere in literature. The mixture proportions that will be used in this study were chosen to describe the influence of the water-to-cement ratio (w/c), fly ash replacement.

Table 5- Mix propotions

Mix Ratio				
Material	Water	Cement	Sand	Coarse Agg.
Mix 1	0.3	1	1.05	3.08
Mix 2	0.3	1	0.65	1.91

IV. EXPERIMENTAL PROCEDURE

For determination of shrinkage, a concrete shrinkage measuring apparatus was used in this study as shown in fig.1.

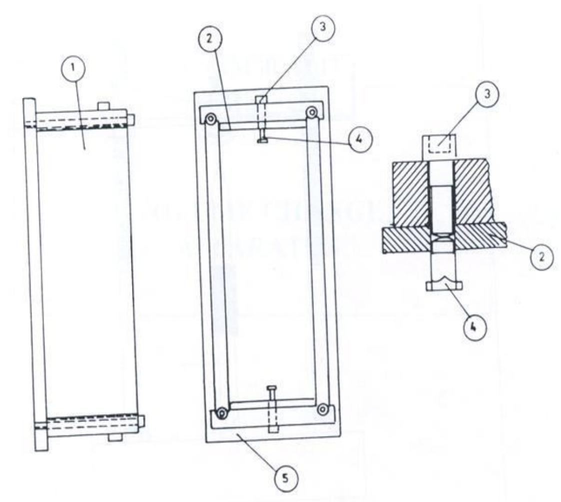


1. Base, 4.Pillars,
2. Recessed Seating, 5. Cross Plate,
3. Standardization Bar, 6. Dial Gauge.

Figure .1: Shrinkage Apparatus

In this experimental work, rectangular concrete specimens of 100mm × 100 mm in cross section and 250mm length were cast with various concrete mixes. Pins were embedded at both ends of the specimens to hold them in the shrinkage apparatus as shown in fig.2. Specimens were cured in water for 7 days before testing for shrinkage. Initial readings of the specimens were taken with the help of dial gauge attached to the apparatus. Then the specimens were air dried for 7, 28 and 56 days. Again the final reading of each specimen was taken after the specified period of air-drying. The change in length of each specimen was calculated from the difference of final and initial dial gauge readings. Then the shrinkage strain was calculated [11].

Immediately after 7 days moist curing period, all the specimens were taken for shrinkage measurement. After noting down the shrinkage values these specimens were stored in the laboratory for air dry curing period of 7, 28 and 56 days. Care was taken to keep a minimum 5 mm clearance between individual concrete specimens to permit for free air circulation.



1.Mould,	3. Allen Bolt,
2. Detachable End Plate,	
4. Reference Points/ Pins,	5. Base Plate.

Fig.2: Concrete Mould

V. DISCUSSION OF EXPERIMENTAL RESULTS

A) Effect of Fly Ash Content on Shrinkage Characteristics:

The test results of various concrete mixes without and with replacement of 0, 10, 25, 40, 55, 70% amounts of fly ash respectively is reported. The shrinkage results of various concrete mixes were observed during the course of this investigation. The drying shrinkage of high strength concrete and high volume fly ash high strength concrete are obtained on rectangular specimens prepared and tested under specified conditions. The test results of shrinkage and shrinkage strain of concrete Mix-1 and Mix-2 containing different quantities of fly ash are represented in Table 5 to 6 and Figures 3 to 6 respectively. In addition this, compressive strength of hardened concrete was also tested. All the results of compressive strength were based on 15 cm cube test specimens, which were cured under the standard condition. The specimens were made for each concrete mix separately and tested for 7, 28 and 56 days. The compressive strength developments for mix-1 and mix-2 are shown in Table 7 and 8 which represents the compressive strength of concrete containing different quantities of fly ash.

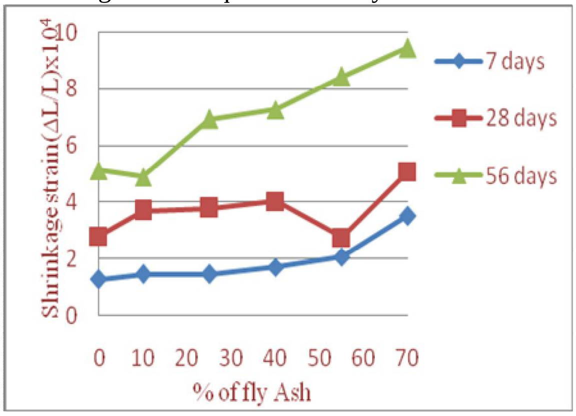


Figure 3. Variation of Shrinkage Strain of Concrete Mix-1 with different fly ash quantities with age.

The effect of 10 to 70 % replacement of cement with fly ash on shrinkage strains of 7 days cured rectangular concrete specimens was studied under the air dried condition. The results were compared to the shrinkage strains of different quantities of concrete and specific days (7, 28, and 56) to the same experimental condition. Fig.3 shows the variation of shrinkage strain with increase in percentage of fly ash for concrete Mix-1 at different curing periods. The strain calculated at every age is the average of three measurements, one from a specimen of each of the three batches of the concrete mixtures. From Fig 3, it is observed that there is a general trend of increase of shrinkage strain with increase in percentage of fly ash for all curing periods. It is also observed that the rate of increase of shrinkage strain with increase in fly ash content relatively more at 56 days than 7 and 28 days.

Table 6- Test Results of Shrinkage of Concrete Mix-1, Length of Specimen: L=275mm

SN	Mix Design	% of FA	Change in Length (ΔL) in mm after days			Shrinkage Strain (ΔL/L) x 10^4 after days		
			7	28	56	7	28	56
1	Mix 1-1	0	0.035	0.077	0.141	1.27	2.80	5.12
2	Mix 1-2	10	0.040	0.102	0.135	1.45	3.70	4.90
3	Mix 1-3	25	0.040	0.104	0.191	1.45	3.78	6.94
4	Mix 1-4	40	0.047	0.111	0.200	1.70	4.03	7.27
5	Mix 1-5	55	0.057	0.076	0.232	2.07	2.76	8.43
6	Mix 1-6	70	0.097	0.140	0.260	3.52	5.09	9.45

Table 7- Test Results of Shrinkage of Concrete Mix-2, Length of Specimen: L=275mm

SN	Mix Design	% of FA	Change in Length (ΔL) in mm after days			Shrinkage Strain (ΔL/L) x 10^4 after days		
			7	28	56	7	28	56
1	Mix 2-1	0	0.031	0.219	0.310	1.12	7.96	11.2
2	Mix 2-2	10	0.079	0.170	0.308	2.87	6.18	10.9
3	Mix 2-3	25	0.069	0.190	0.330	2.50	6.90	12.0
4	Mix 2-4	40	0.066	0.251	0.280	2.40	9.12	10.1
5	Mix 2-5	55	0.087	0.104	0.295	3.16	3.78	10.2
6	Mix 2-6	70	0.094	0.236	0.325	3.41	8.58	11.8

Fig. 4 shows the variation of shrinkage strain with % of fly ash content for concrete Mix-2. The results of concrete Mix-2 are similar to those of concrete Mix-1. However the rate of increase of shrinkage strain with % of fly ash is little lower than that of concrete Mix-1. But the magnitude of shrinkage strain for concrete Mix-2 is significantly higher than concrete Mix-1.

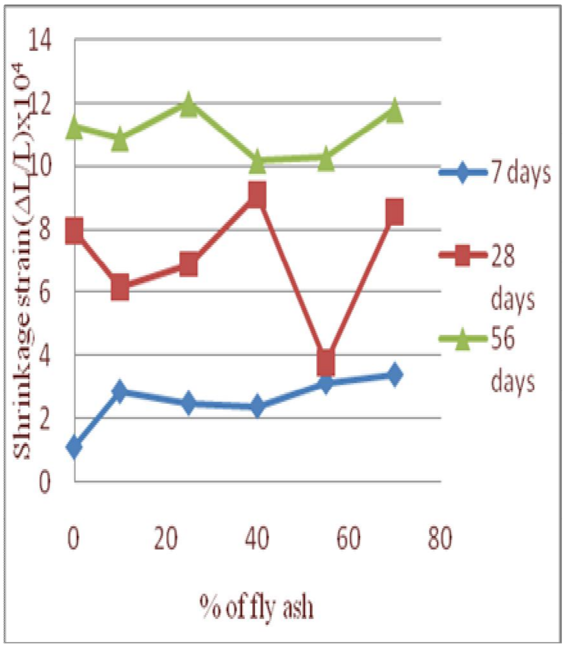


Figure 4. Variation of Shrinkage Strain of Concrete Mix- 2 with different fly ash quantities with age.

B) Effect of Age on Shrinkage with different Quantities of Fly Ash of Mix-1 and Mix-2:

Due to high volume fly ash content, concrete pastes containing fly ash generally have a lower stiffness at earlier ages, making them more susceptible to increased shrinkage under standard testing conditions. The effect of age on shrinkage strain of concrete Mix-1 and concrete Mix-2 for different percentage of fly ash content are shown in fig.5 and 6.

Table 8- Test Results of Compressive Strength of Concrete Mix-1

SN	Mix Design	% of fly ash	Compressive Strength in N/mm2 after days			Concrete
			7	28	56	
1	Mix1-1	0	42.84	58.39	61.62	Low Volume Fly Ash Concrete
2	Mix 1-2	10	40.98	55.22	59.87	
3	Mix 1-3	25	28.34	36.18	59.44	
4	Mix 1-4	40	24.12	35.75	47.66	High Volume Fly Ash Concrete
5	Mix 1-5	55	16.56	23.83	34.88	
6	Mix 1-6	70	11.77	17.44	38.40	

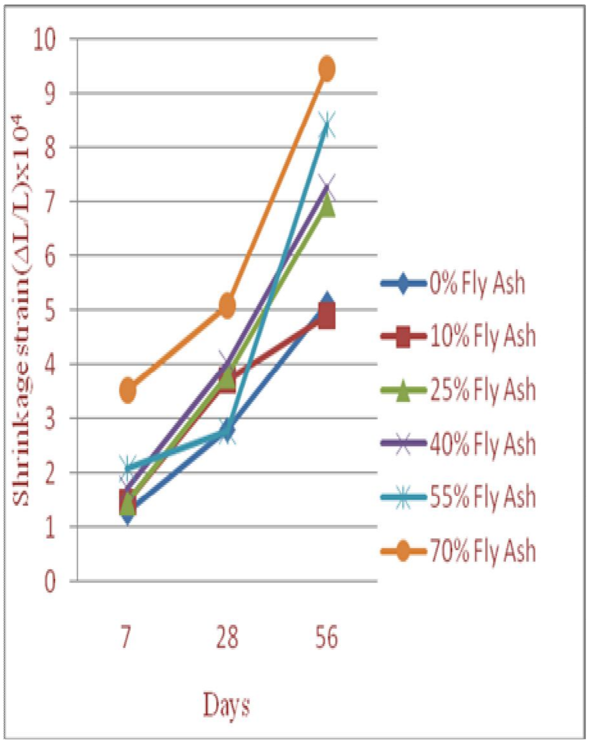


Figure 5. Effects of age on Shrinkage of diff. quantities of fly ash of Concrete Mix-1

From these figures it is seen that there is an increase in shrinkage strain with time as expected. This is true to for all contents of fly ash considered. However the rate of increasing in shrinkage at a later age (28 days to 56 days) is generally higher than for high volume fly ash concrete. This is especially significant for concrete Mix-1. The rate of increase of shrinkage strain is generally uniform for all low fly ash content.

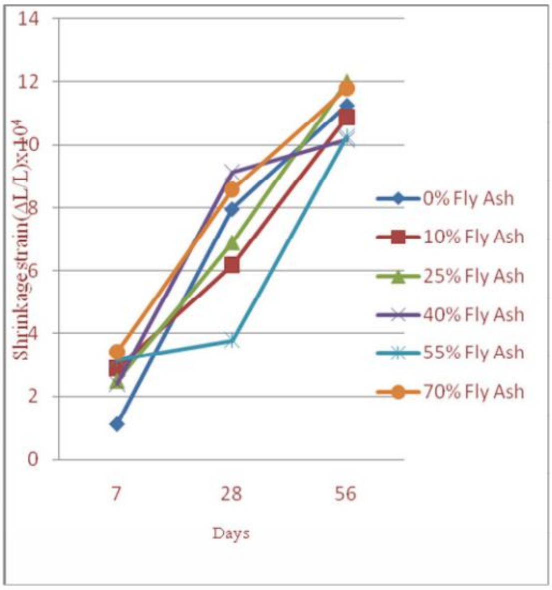


Figure 6. Effects of age on Shrinkage of diff. quantities of fly ash of Concrete Mix-2

C) Effect of Fly Ash Content on Compressive Strength:

The effect of level of cement replacement with fly ash development of the compressive strength of hardened concrete was investigated with different fly ash quantities. The results of compressive strength at 7 days, 28 days and 56 days are tabulated in Fig 7 and 8. The additional curing period of 56 days was selected because for high volume fly ash the rate of gain in strength is very slow.

Table 9- Test Results of Compressive Strength of Concrete Mix-2

SN	Mix Design	% of fly ash	Compressive Strength in N/mm² after days			Concrete
			7	28	56	
1	Mix2-1	0	46.41	69.11	72.37	Low Volume Fly Ash Concrete
2	Mix 2-2	10	37.06	57.55	58.14	
3	Mix 2-3	25	32.26	41.12	62.34	
4	Mix 2-4	40	21.36	32.70	43.16	High Volume Fly Ash Concrete
5	Mix 2-5	55	18.53	29.64	39.09	
6	Mix 2-6	70	15.83	34.08	40.11	

From these test results it is seen that with increase in fly ash content the compressive strength reduces. It is also observed that target strength is not achieved for high volume fly ash. The compressive strength are also presented graphically in Fig 7 and 8. Although the target strength has not been reached by mixes with high volume of fly ash, it is seen that the rate of increase of strength has been steady even after 28 days, which is not observed for low fly ash content, so it is likely that high volume fly ash concrete may reach the target strength at a later stage. This trend is similar for both concrete Mix-1 and concrete Mix-2.

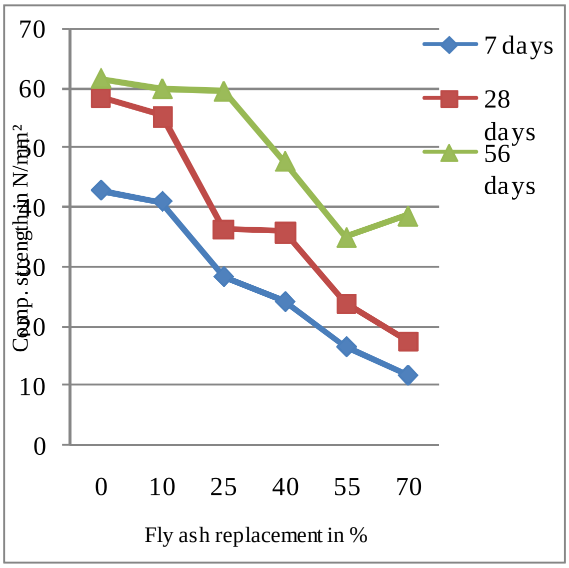


Fig. 7. Effect of % Fly ash on Compressive strength at 7,28,56 days of Concrete Mix-1

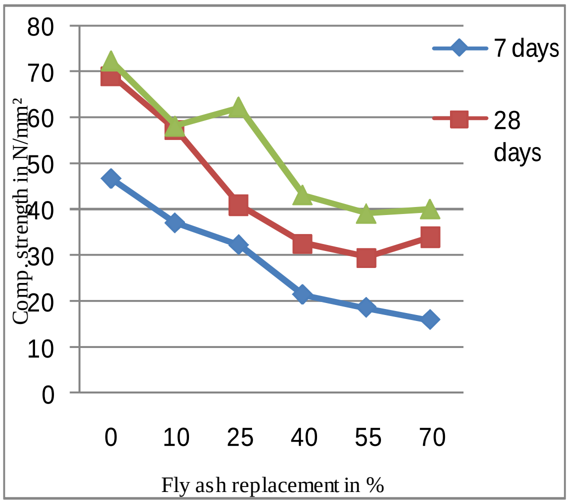


Fig. 8. Effect of % Fly ash on Compressive strength at 7, 28, 56 days of Concrete Mix-2.

VI. CONCLUSIONS

In this investigation shrinkage properties of high strength concrete with varying contents of fly ash have been studied. The study especially focuses on the effect of high volume of fly ash up to 70 %. Based on this investigation following conclusions are made.

1. Shrinkage of high strength concrete increases with increase in fly ash content.
2. The rate of increase of shrinkage with time is uniform for low fly ash content, whereas it generally increases after 28 days for high volume of fly ash.
3. The strength of concrete after a given curing period decreases with increase in fly ash content. However the increase in strength continues for a long period for concrete with high volume of fly

ash. Hence it is likely that target strength may be achieved after a long duration.

4. The workability of High Strength Concrete improves with increase in fly ash content.

REFERENCES

[1] R.L.Carrasiquillo, A.H. Nilson and F.O.Slate, “Properties of High Strength Concrete Subject To Short Term Loads”, *ACI Materials Journal*s, Title no. 78-14, May-June 1981.

[2] Ravindra Gettu, Zdenek P. Bazant, and Martha E. Karr, “Fracture Properties and Brittleness of High-Strength Concrete”, *ACI Materials Journals*, Vol. 87, No. 06, November-December 1990.

[3] S.P. Shah, M.E.Karagular, M. Sarigaphuti, “Effects of Shrinkage Reducing Admixtures on restrained shrinkage cracking of concrete”, *ACI Materials Journals*, Vol. 89, No.03, May-June 1992.

[4] Surendra P. Shah, W. Jason Weiss, and Wei Yang, “Shrinkage Cracking in High Strength Concrete”, *Proceedings of the PCI/FHWA International Symposium on High Performance Concrete*, New Orleans, Louisiana, October 20-22, 1997.

[5] .Surendra P. Shah, W. Jason Weiss, “High Performance Concrete: Strength, Permeability, And Shrinkage Cracking”, *Proceedings of the PCI/FHWA International Symposium on High Performance Concrete*, Orlando Florida, © 2000, pp. 331-340.

[6] F H Witmann, “Crack formation and fracture energy of normal and high strength Concrete”, *Sadhana*, Vol. 27, Part 4, August 2002, pp. 413–423.

[7] . Jennifer Morris, “A Comparative Study of Shrinkage and Cracking of High- Performance Concrete Mixtures for Bridge Decks” *Thesis submitted to the College of Engineering And Mineral Resources at West Virginia University*, Morgantown, West Virginia ,2002

[8] A. Camoes, P.Rocha, B.Aguiar, S.Jalali and R.Delgado, “Mechanical Properties of High-Performance Concrete with Fly Ash” *Eighth CANMET / ACI International Conference on Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete*, Las Vegas,U.S.A., May 23-29, 2004.

[9] Min-Hong Zhang, Lian Li and P.Paramasivam,“Shrinkage of High Strength Lightweight Aggregate Concrete Exposed To Dry Environment ”, *ACI Materials Journals* , Vol. 102, No. 02, March-April 2005.

[10] S.Sujjavanich, V. Sida, and P. Suwanvitaya, “Chloride Permeability and Corrosion Risk of High Volume Fly Ash Concrete with Mid-Range Water Reducer.” *ACI Materials Journals*, Vol. 102, No. 03, May-June 2005.

[11] .S.M. Gupta, P. Aggarwal and Y. Aggarwal, “Shrinkage of High Strength Concrete”, *Asian Journal of Civil Engineering (Building And Housing)* VOL. 7, NO. 2 (2006), Pages 183-194.

[12] .T. P. Earney, V. S. Gopalaratnam, and G. C. Luckenbill, “Understanding Early-Age Shrinkage of High-Performance Concrete for Bridge Deck Applications” *Dept. of Civil and Environmental Engineering*, E2509 Lafferre Hall, University of Missouri, Columbia, October 13, 2006

[13] .S. Wang and Victor C. Li, “Engineered Cementitious Composites with High Volume Fly Ash,” *ACI Materials Journals*, Vol. 104, No. 03, May-June 2007.

[14] .R.Henkensiefken, Peter Briatka, Dale P.Bentz, Tommy Nantung, Jason Weiss, “Plastic Shrinkage Cracking in Internally Cured Mixtures”, *Concrete International* Vol. 32, No.02, February 2010.

[15] .M. Suzuki, I. Maruyama, and R. Sato, “Properties of Expansive-Ultra High-Strength Concrete” SP-228—74.

◈◈◈