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DRYING SHRINKAGE PROPERTIES OF ACCELERATED FLYASH CEMENT CONCRETE REINFORCED WITH HOOKED STEEL FIBRES

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ABSTRACT

Shrinkage of concrete during the process of drying is an inherent property which is accompanied with volume reduction and typically a very serious problem for mass concreting works. This volumetric reduction of concrete needs to be addressed at the outset since any restrained dimensional changes leads to cracking. The present study focuses on the influence of concrete with accelerated strength properties and the effect of steel fibres on the overall shrinkage characteristics of concrete. The effect of shrinkage was studied for the various design concrete mixtures containing different percentage of flyash (20 and 40%); steel fibres (0.5 and 1%) and accelerator (1%, 2% and 3%) and the performances were compared with plain concrete. The test results showed that for concretes containing 20 % flyash replacement, 1% steel fibre and a 1% accelerator dosage showed a consistent reduction in the drying shrinkage value (174 micro strains) compared to plain concrete tested at 28 days. It can also be noted that the drying shrinkage value was found to be lower in the case of fibre concretes compared to controlled concrete. However, the concretes with accelerator showed higher drying shrinkage compared to controlled concrete due to increased rate of hardening. From the experimental results it is suggested that, low calcium flyash, steel fibres and accelerator can be effectively utilized for producing high early strength concrete without showing any appreciable volume reduction.

Keywords: accelerator, flyash, steel fibre, drying shrinkage.

1. INTRODUCTION

Recycling of fly ash has become an increasing concern due to its various factors. Till recently utilization of fly ash in construction industry has been gaining popularity. Most of research studies use fly ash as one of the additive material for producing a high performance concrete. However, limited studies done on studying the effect of steel fibre and accelerator in concrete to improve the properties. The long term durability of concrete depends primarily on the 3dimentional shrinkage of concrete as restrained shrinkage accompanied by cracking. The improvement in the concrete properties as lead to emergence of high early strength concrete which incorporate accelerator as one of the primary chemical admixture also the high early strength development can result in pneumonia shrinkage which as to be addressed with the addition of supplementary reinforcement this necessitate the use steel fibre in concrete to give additional strengthening during voluminous shrinkage. Flyash addition in concrete also found to be beneficial reducing the cement content as well as reduce cracks cause by heat hydration. Present study will focus on pertinent issues for improving the setting and shrinkage properties of fly ash concrete along with steel fibers and accelerator, which mainly influence the rate of hydration of alite phase in OPC resulting in an increase in heat evolution and C-S-H gel formation at an early age due to calcium nitrate.

Shrinkage of concrete is an important role in which the water from the concrete system evaporates and leads to volume change and occurs in almost all types of concretes. The shrinkage of concrete leads to the shrinkage cracks therefore this type of volume change either autogenously or induced is to be considered for most detrimental properties of concrete, which affects the long-term strength and durability. (Bai. Y *et al.*, 2005) this research study concluded that the strength and drying shrinkage of concretes with the natural sand replaced with furnace bottom ash, the test showed that strength and volume reduction decreased with the increase of the furnace bottom ash it could be concluded that 30% of the natural sand can be beneficially replaced with the furnace of bottom ash sand to produce high strength concrete and drying shrinkage properties of the structural concrete. (Benoit Bissonnette *et al.*, 1999) this paper deals with influences of different parameters that evaluated the deformation and obtain a better understanding of the behaviour of concrete under drying conditions, the test results showed that shrinkage deformation range from 48 to 100% also concluded that the drying shrinkage is approximately inversely proportional to the relative humidity of the surrounding atmosphere. (Pu-woei Chen and Chung D.D.L, 1995) reported that use of carbon fibers dominate the silica fume in lowering the drying shrinkage (free strain 1.9×10^{-5} at 14 days) and increasing the flexural strength, toughness and freezing thawing durability properties and also concluded that the fibers decrease while the silica fume increases the compressive strength and chemical associated with an air content increase. (Jenn-Chuan Chern *et al.*, 1989) this paper deals with concrete specimens containing higher volume fraction of fibres yield less shrinkage curve is similar for steel fibre reinforced concrete and plain concrete, creep tests were performed in the moist room called as basic creep as observed that less values compare to plain concrete and less total deformation in a drying condition. (Gholamreza Fathifazl *et al.*, 2011) investigated the effects of a new method of mixture proportioning method on the creep and shrinkage of concrete produced with recycled coarse aggregate was quite noticeable, the volume reduction. It is well known that when concrete dries, it loses water and a volumetric change occurs. When water gets started the hardening with cementitious materials of the concrete, contraction will major role for drying shrinkage properties. Another study also focusing on influence of drying properties that is important factors that contribute to the cracks in concrete particularly in floors and pavements is that due to drying shrinkage. (Haque M.N 1996) concluded that the term shrinkage is used to describe the various aspects of volume changes in concrete due to loss of moisture at different stages. The magnitude of shrinkage is an inherent property of the concrete; it demands higher understanding of the various properties of concrete and made with 5 and 10% condensed silica fume resulted in the least loss of strength and drying shrinkage and had a superior quality cover concrete. (Tam CM *et al.*, 2012) examines the influences of water to binder ratio and super plasticizer dosage was experimented. It was found the reactive powder concrete (RPC) generally exhibits relatively low drying shrinkage due to the reduction of the pore size and connectivity of the voids which results from the high packing density of RPC and higher dosage of super plasticizer causes the more shrink in concrete.

1.1. Research objectives

The main objective of this study is to focus on the influence of concrete constituents on the drying shrinkage properties of flyash concrete. The influence of steel fibres dosage at 0.5% and 1%, fly ash substitution at 20 and 40% and accelerator dosage at 1%, 2% and 3% were studied for different concrete mixes at various curing ages.

2. EXPERMENTAL METHODOLOGY

An ordinary Portland cement (OPC-53) which complies with Indian Standards and has a 28-day mortar compressive strength of 57 MPa was used as binder material and the specific gravity was found to be 3.12. The initial and final setting time of cement was found to be 65 min and 260 min, respectively. The size of the coarse aggregate used was 12.5 mm (passing) crushed angular granite with a fineness modulus of 4.85. A river sand was used as fine aggregate with a fineness modulus of 2.20 and conforms to zone II as per IS 383 1970. The mineral admixture used was class F flyash obtained from Ennore thermal power station in Tamil Nadu, India. An accelerating chemical admixture consisting of calcium nitrate was used as set accelerators with different dosage levels of 1%, 2% and 3% by weight of binder and dosage level of steel fiber 0.5% and 1.0% by volume fraction of concrete. The steel fibres used were having a size of 30 x 0.5mm with aspect ratio of 60.

2.1. Concrete mix preparations

In this research paper a total of 26 various concrete mixture proportions were prepared. A controlled concrete mix without (flyash, accelerator and steel fibres) was proportioned as per Indian standard specifications IS: 10262-1982 and the other 25 mixes contained various compositions of mixtures are shown in Table-1. The concrete mixtures were designed using conceptual method by keeping the fine aggregate to coarse aggregate ratio of 0.6, cement to total aggregate and w/c ratio of 0.3.

2.2. Casting of specimen

The ingredients were mixed in a rotating mixer of capacity 25 Kg for a period of 3 minutes. The Accelerator was then mixed thoroughly with the mixing water and added to the mixer and casted in steel prism moulds of standard size 75 x 75 x 285 mm and compacted on a Table vibrator. The surface finishing was done very carefully to obtain a uniform smooth surface. All the specimens were cured in the same curing tank to maintain the uniformity of the specimens. Tests were performed at 7 and 28 days of curing period and at different curing ages. Then the specimen is tested under length comparator of least count 0.01mm to monitor the volume change by drying shrinkage as shown in Figure-1.

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Table-1. Concrete mixture proportions adopted in the present study.

Mix Id	Constituents								
	Cement	Fly ash	Fine aggregate	Coarse aggregate	water	Acl (%)	Steel fibres Vf (%)	F/C ratio	W/C ratio
	Kg/m^3								
OP	473	-	672	1113	142	0	0.0	0.6	0.3
OP1	473	-	672	1113	142	1	0.0	0.6	0.3
OP2	473	-	672	1113	142	2	0.0	0.6	0.3
OP3	473	-	672	1113	142	3	0.0	0.6	0.3
OP4	473	-	672	1113	142	0	0.5	0.6	0.3
OP5	473	-	672	1113	142	0	1.0	0.6	0.3
OP6	473	-	672	1113	142	1	0.5	0.6	0.3
OP7	473	-	672	1113	142	1	1.0	0.6	0.3
OP8	473	-	672	1113	142	2	0.5	0.6	0.3
OP9	473	-	672	1113	142	2	1.0	0.6	0.3
OP10	473	-	672	1113	142	3	0.5	0.6	0.3
OP11	473	-	672	1113	142	3	1.0	0.6	0.3
B0	378	95	672	1113	142	0	0.0	0.6	0.3
B1	378	95	672	1113	142	1	0.5	0.6	0.3
B2	378	95	672	1113	142	1	1.0	0.6	0.3
B3	378	95	672	1113	142	2	0.5	0.6	0.3
B4	378	95	672	1113	142	2	1.0	0.6	0.3
B5	378	95	672	1113	142	3	0.5	0.6	0.3
B6	378	95	672	1113	142	3	1.0	0.6	0.3
D0	284	189	672	1113	142	0	0.0	0.6	0.3
D1	284	189	672	1113	142	1	0.5	0.6	0.3
D2	284	189	672	1113	142	1	1.0	0.6	0.3
D3	284	189	672	1113	142	2	0.5	0.6	0.3
D4	284	189	672	1113	142	2	1.0	0.6	0.3
D5	284	189	672	1113	142	3	0.5	0.6	0.3
D6	284	189	672	1113	142	3	1.0	0.6	0.3

Figure-1. Typical picture showing for digital length comparator.

3. EXPERIMENTAL TEST RESULTS AND DISCUSSIONS

The drying shrinkage test results for the various concrete mixtures are given in Table-2 and represented in Figures 2 to 13. It can be noted from the experimental trends that the free shrinkage of all concrete was marginally lesser than that of controlled concrete (OP). However, the shrinkage strain was higher during the initial drying period and the values for all concrete mixtures were observed to be constantly varying over different curing days. It can be noted from the test results that the drying shrinkage values for plain concrete was found to be higher than all other concrete mixes. However the addition of accelerator at higher dosage levels showed the increased shrinkage strain values. With the addition of 3% accelerator there was an increase in the drying shrinkage strain value of 382 and 1178 micro strains at 7 and 28 days respectively. However, the addition of steel fibre concrete mixes had shown a reduction in shrinkage and the value was found to be lower (821 micro strains) at 1% of steel fibres compared to 0.5% steel fibres addition. The shrinkage trend was slightly different in the case of concrete mixes containing fibres and accelerator, wherein the shrinkage strains value was found to be between the plain concrete with accelerator and plain concrete with fibre concrete mixes. It can be concluded that the drying shrinkage of concrete mixes were found to consistently reduced with addition of steel fibre and accelerator, the drying shrinkage was found to be higher due to increase in the early setting property and subsequently the volume changes occurred much before than the plain concrete. The percentage increases in shrinkage strain for various concrete mixes with reference to control concrete mix are shown in Figures 14 and 15. It is clearly evident from the results that in the case of accelerated concrete mixes the shrinkage strain was found to be higher than the control due to faster setting and subsequently with addition of fibre the shrinkage strain was found to be reduced. As well as, the addition of steel fibres in accelerator concrete had shown remarkable reduction in shrinkage strain and this can be anticipated that the free shrinkage strain are relatively controlled by fibres. However, a good effect can be observed when the shrinkage is restrained at the boundary of the structural element were the shrinkage tensile stresses created is shared by the fibres which can be provided with adequate reinforcement index by the steel fibres in concrete. Also the higher replacement of cement with flyash had shown consistent reduction in shrinkage, the real synergistic effect due to flyash and steel fibre addition can lead to phenomenal reduction in shrinkage.

Table-2. Free shrinkage test results of various concretes.

Mix Id	**Free shrinkage strain at 7 days** (µs)	**Free shrinkage strain at 28 days** (µs)	**Strain at 7 days** (%)	**Strain at 28 days** (%)
OP	301	1091	0.032	0.109
OP1	340	1146	0.034	0.115
OP2	367	1153	0.037	0.115
OP3	382	1178	0.038	0.118
OP4	274	935	0.027	0.094
OP5	223	821	0.022	0.082
OP6	323	1235	0.032	0.124
OP7	423	1376	0.042	0.138
OP8	409	1341	0.041	0.134
OP9	498	1532	0.050	0.153
OP10	521	1521	0.052	0.152
OP11	585	1689	0.059	0.169
B0	235	923	0.024	0.092
B1	203	913	0.020	0.091
B2	174	746	0.017	0.075
B3	192	800	0.019	0.080
B4	294	1078	0.029	0.108
B5	212	891	0.021	0.089
B6	285	1045	0.029	0.105
D0	289	982	0.029	0.098
D1	241	1032	0.024	0.103
D2	237	1019	0.024	0.102
D3	278	1032	0.028	0.103
D4	267	1019	0.027	0.102
D5	278	1039	0.028	0.104
D6	280	1054	0.028	0.105

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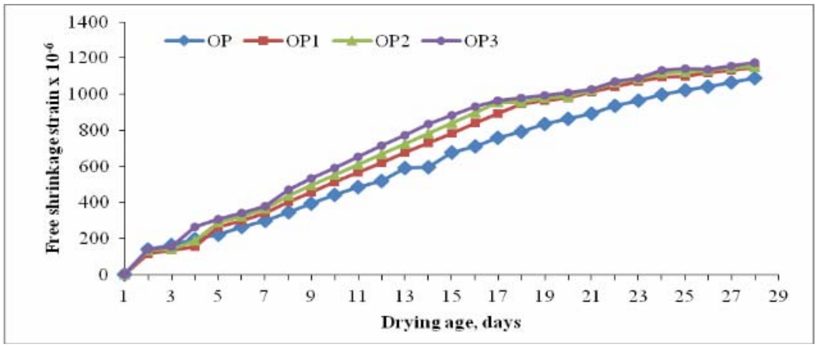

Figure-2. Drying shrinkage results for concrete containing OPC and various dosage of accelerator at 28 days.

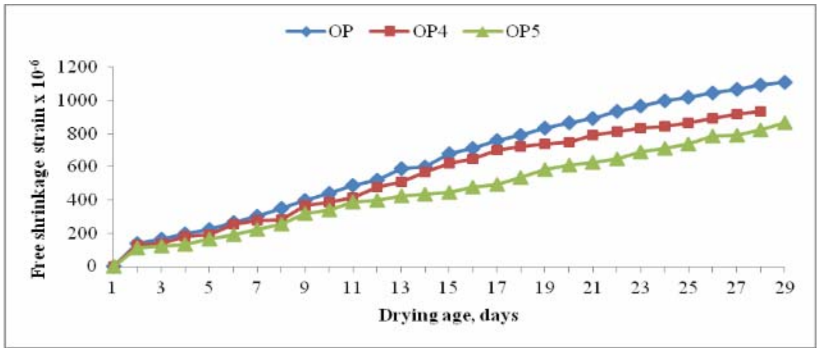

Figure-3. Drying shrinkage results for concrete containing OPC and various dosage of steel fibre at 28 days

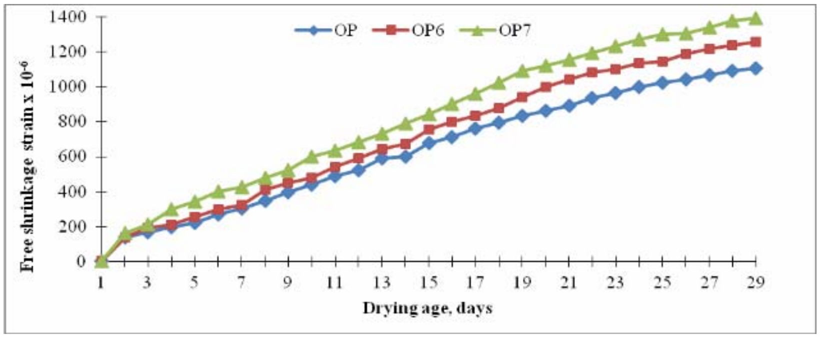

Figure-4. Drying shrinkage results for concrete containing OPC and various dosage of accelerator and steel fibre at 28 days.

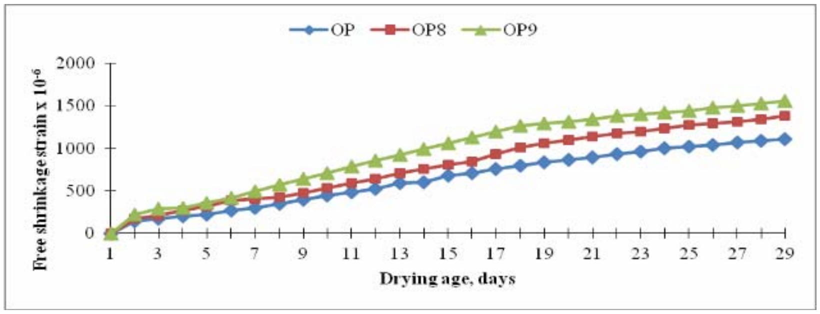

Figure-5. Drying shrinkage results for concrete containing OPC and various dosage of accelerator and steel fibre at 28 days.

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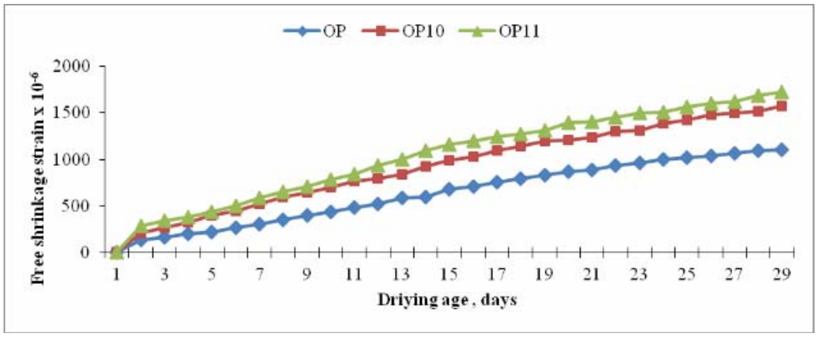

Figure-6. Drying shrinkage results for concrete containing OPC and various dosage of accelerator and steel fibre at 28 days.

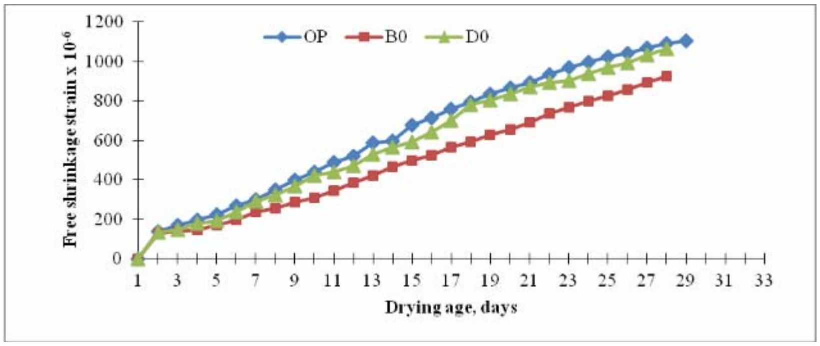

Figure-7. Drying shrinkage results for concrete containing OPC and various level of flyash at 28 days.

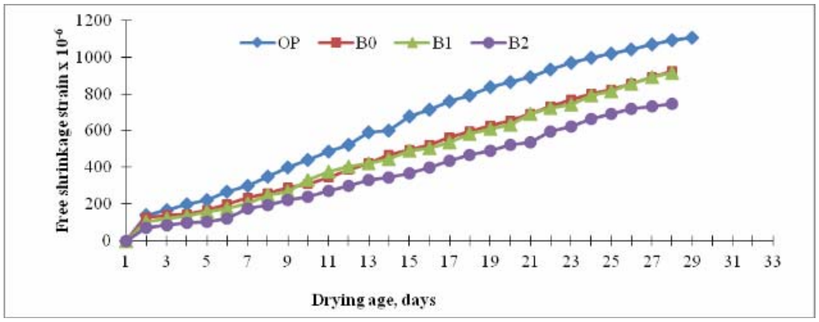

Figure-8. Drying shrinkage results for concrete containing OPC and various level of flyash, accelerator and steel fibre at 28 days.

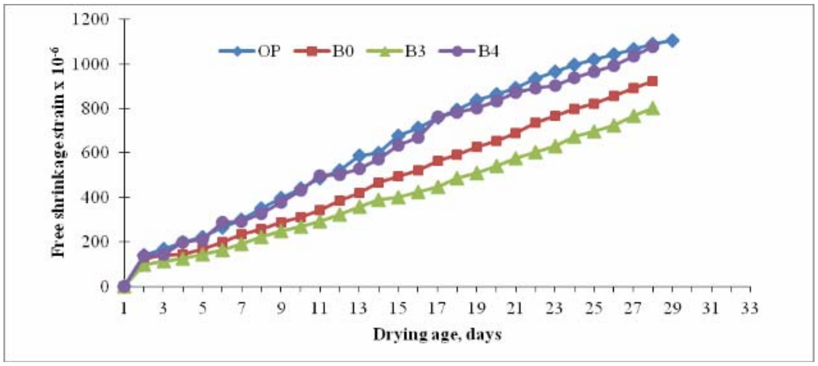

Figure-9. Drying shrinkage results for concrete containing OPC and various level of flyash, accelerator and steel fibre at 28 days.

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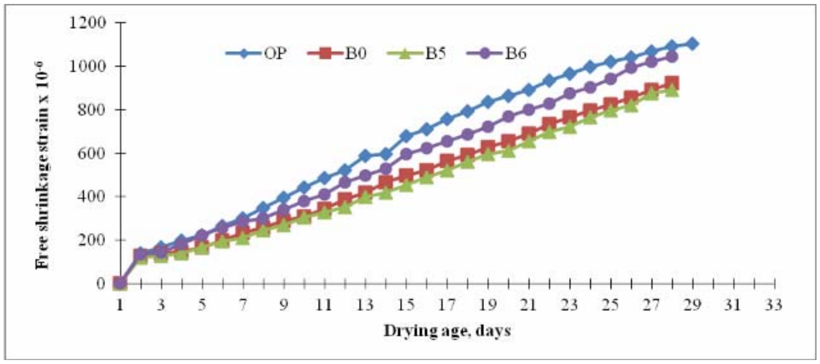

Figure-10. Drying shrinkage results for concrete containing OPC and various level of flyash, accelerator and steel fibre at 28 days.

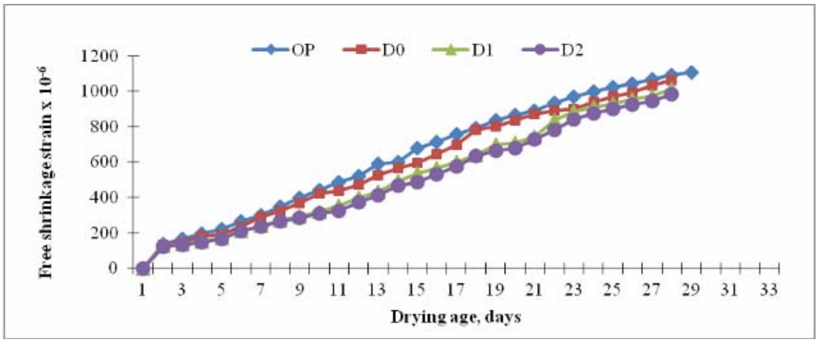

Figure-11. Drying shrinkage results for concrete containing OPC and various level of flyash, accelerator and steel fibre at 28 days.

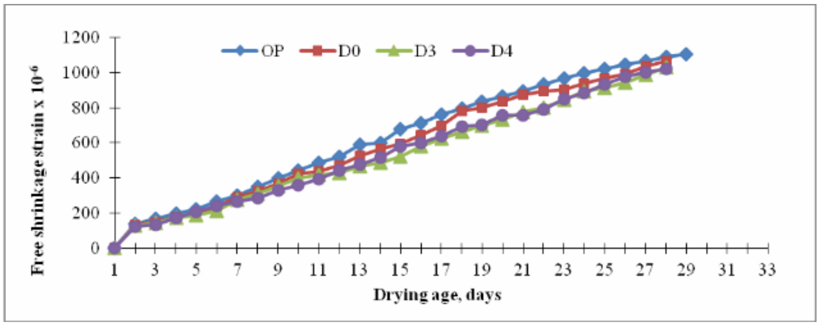

Figure-12. Drying shrinkage results for concrete containing OPC and various level of flyash, accelerator and steel fibre at 28 days.

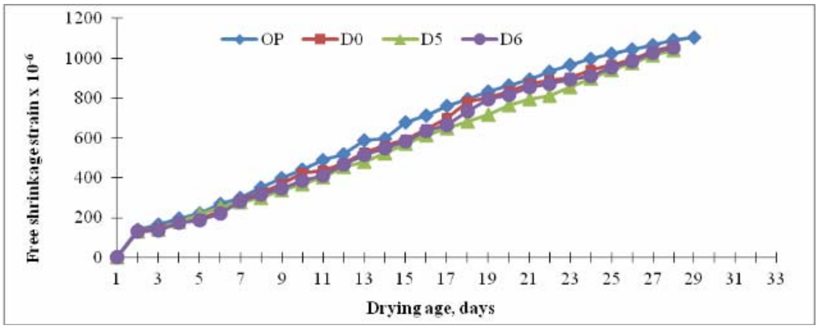

Figure-13. Drying shrinkage results for concrete containing OPC and various level of flyash, accelerator and steel fibre at 28 days.

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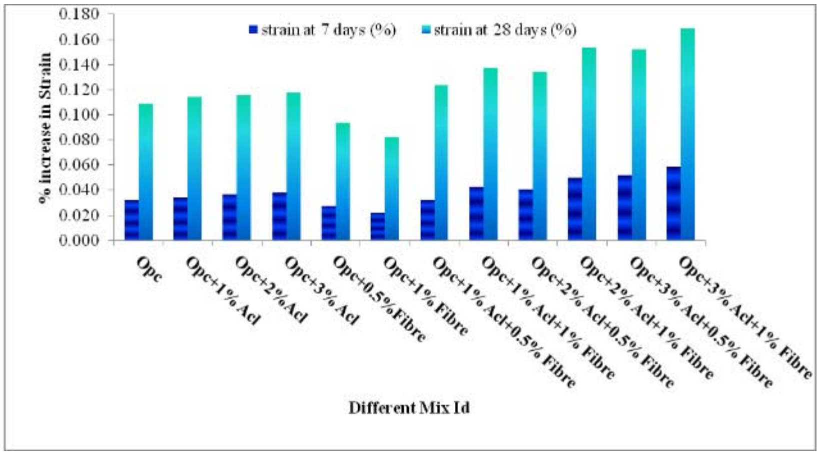

Figure-14. Variation of shrinkage strain for different concrete mixes containing OPC with dosages of accelerator and steel fibre.

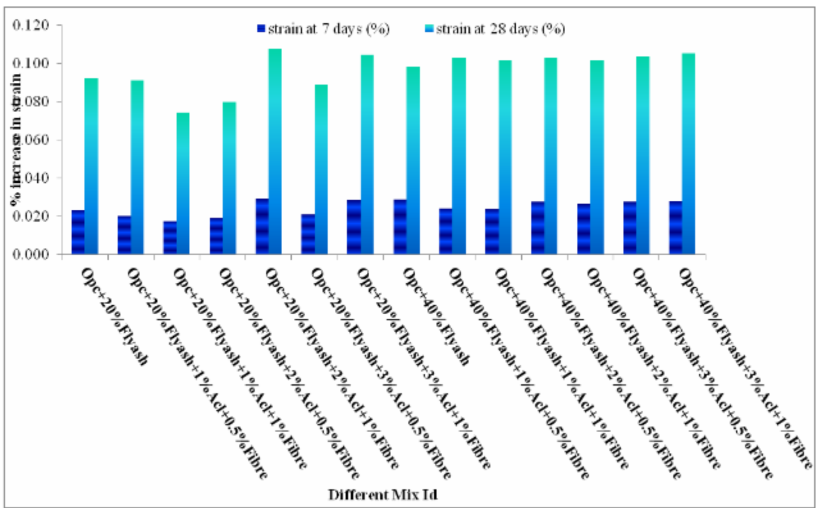

Figure-15. Variation of shrinkage strain for different concrete mixes containing OPC, flyash, accelerator and steel fibre.

4. CONCLUSIONS

Based on the experimental test results observed, the following conclusions are drawn from the study.

- Use of accelerator increased the drying shrinkage values when compared to plain concrete, and it is seen that there is no much increase in the drying shrinkage after the curing age of 14 days when compared to 28 days.
- The addition of Steel Fibres to the concrete resulted in the reduction of drying shrinkage when compared to OPC and with the increase in the percentage of steel fiber the percentage reduction of drying shrinkage was found to be increased.
- Addition of Flyash to concrete not only results in the increase of compressive strength but also resulted in the reduction of drying shrinkage; however with the increase in the flyash addition the reduction in shrinkage was found to be appreciable (746 micro strains).
- It can also be observed that the addition of flyash at 20% and 40% with cement showed a shrinkage reduction of 16% and 40% respectively, which clearly shows that with the increased addition of flyash shrinkage was found to be reduced.
- The effect of steel fibres at 0.5% of volume fraction (Vf) of concrete showed a consistent reduction upto 15% and with higher addition of steel fibres at 1% showed a good reduction of 18%.
- The effect of shrinkage with the use of accelerator was profoundly reduced with the addition of steel fibres and showed a consistent reduction from 14.89% to 23.4% when compared with OPC.
- In general the effect of steel fibre addition had shown a remarkable reduction in the shrinkage in accelerated cementitious composites. Also, the flyash substitution upto 20% had shown a good improvement in

shrinkage reduction. This exhibits that for mass concreting structural works the addition of steel fibres is inadvertently needed to improve the restrained shrinkage resistance and long term volumetric reduction of the composite.

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