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Conventional Concrete Mix Design for Producing the Low and High Volume of Fly Ash Based Fiber Reinforced Concrete

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Abstract: ***The present research work analysis the conceptual concrete mix design regarding the packing unit density concept for multi initial trial and error perfect shaped methodologies. In initial, a high strength based concrete with desired target compressive strength of M40 Graded concrete was shaped for various mixing proportion and Also, a stabilized standard chart has been developed for the various packing constituents (percentage) in various parameters, where the aggregates (F/c) ratio 0.5 to 0.8, Binder-Total aggregate (B/Ta) ratio 0.27 to 0.24 and water-binder content (w/b) ratio 0.30. The laboratory experimental research work results contain fly ash percentage replacement level at 25 and 50% in Portland cement and inclusion of both ends hooked type of steel fibers along with 1.50% of superplasticizers by weight of binder content for the various mix produced for the good tracking of the UPV values by using fabricating Plexiglas moulds, Pozzolanic Activity Index (PAI), if the compressive strength increases automatically less volumetric shrinkage takes place.***

Keywords: Drying Shrinkage, Fly ash, Rapid chloride test, Setting properties, Strength.

I. INTRODUCTION

The fastest production increase in the fly ash offers a wide range of substitutions in building concrete which is attributed to the enormous positive effects on the mechanical properties of cementing available composites. It is a well-applicable document from the earlier studies that the usage of fly ash as a partial replacement to a particular level for cement in combination with superplasticizers which provides a significant satisfaction by increasing the fresh and hardened properties of concrete and also the workability of the fresh concrete will stay more for a period of time to work with the specially designed concrete [1, 2].

More ever, a higher amount of addition of fly ash is restricted for owing to its poor pozzolanic reaction at the early ages of concrete setting properties [3]. Previous work focused on the beneficial setting properties of fly ash available in concrete, which can be realized in terms of improving the setting properties due to a longer curing period [4-7]. It was also reported that the mix design, materials characteristics and curing techniques which leads to the improvement of setting properties in hardened concrete [8, 9]. The reacting efficiency of fly ash presents in concrete more than 30% is affected by the low water-cement ratio and also hydration process can lead to the poor binder to aggregate proportioning [10]. Previous research work has shown that the proper selecting the materials and usage of mineral/chemical admixtures and tailoring the concrete ingredients to meet requirements in fly ash based concrete [11-14]. The quality of concrete can be monitored by ultrasonic pulse velocity test (in-situ concrete) by a non-destructive method. Also, it was noted that the permeability of concrete that is indirectly to assess the parameter like water-binder content ratio, porosity and voids [15]. An enormous range of research study work indicates that the fly ash replaced in cement up to 30% by weight of binder content showed better pozzolanic reactivity in conventional concrete. However, the inclusion of chemical admixtures at low water to binder content ratio shows relaxing performance levels of high volume fly ash addition in construction building materials in concrete mixes [16]. It was noted that the previous studies related to the faster reaction in early age hardening of concrete which can substantially design the concrete performance level of fly ash addition for various mixes 17]. Also, it was observed that the different type of waste by-product to utilize in the concrete with the help of curing techniques methods thus producing the setting properties in the hydration process in concrete [18]. Several experimental studies that much not focused on how to improve the early age hardening while usage of waste by-products. Therefore, the present research works have taken into a good account of how to improve the pozzolanic reactivity of fly ash with the addition of a liquid type of accelerator. Also, the impact influences have been focused how to improve the bending stress in hardened concrete while usage of steel fiber addition and also a careful selection of materials proportioning ratio depending upon the packing density concept has been studied systematically for various mixes. Further, a keen study is needed on how to evaluate the various properties of fly ash with low and high volume addition in concrete.

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II. MATERIALS DETAILS AND PROCEDURE

The Ordinary Portland cement which conforms to 53 Grade of cement following IS 12269-1987 [19] is used for producing the concrete. The specific gravity of cement was found to be 3.15. The River sand with a specific gravity of 2.71 and fineness modulus of 2.55 has been used as a fine aggregate in the research work for making a specially designed concrete and the Coarse aggregates of size 12 mm and down and of specific gravity 2.72 were used. Also, to improve fresh concrete workability the constant dosage level of superplasticizer up to 1.5% along with 0-1% accelerator were added and also an inclusion of steel fiber at a different percentage of 0 – 1.5% by Vf. An overall sixteen different designed concrete mixtures were prepared by the proportions based on the Binder-Total aggregate ratio (0.24, 0.26), water/binding materials ratio 0.30, fine/coarse aggregate ratio (0.60, 0.80) and steel fiber 0 to 1.5% by Vf. The concrete mixtures were mixed using a 40 liters capacity vertical type of drum mixer was used. The desirable mechanical properties of concrete such as compressive strength, split tensile strength and flexural strength and also durability studies on the rapid chloride permeability test conducted and standard specimen size details are represented in Table I. Before testing the samples are required for necessary potable water curing. Finally, the best mix proportions were identified based on the trial and error methods in conceptual concrete mix design. From the various experimental test results, it is proved that the best combination for F/c ratio 0.6 and 0.8, B/Ta ratio 0.24 and 0.26 accordingly arrived for various mixture proportions are represented in Table II.

Table- I: Various standard specimen size details

Specification details	**Size of sample (mm)**	**Formula/type**	**Testing (days)**	**Code details**
Plex glass mould by UPV	100 x 100 x 100	Path length/time taken (km/sec)	Duration (minutes)	-
Pozzolanic Index (PAI)	70.6x 70.6 x 70.6	Reference strength/obtained strength	7 & 28	IS 1727-1981 [20]
Compressive strength	100 x 100 x 100	Load/Area (MPa)	1,7,28 & 56	IS 516:1959 (Reaffirmed 2004) [21]
Flexural strength (Third point loading method)	100 x 100 x 100	Pl/bd^2 (MPa)	7 & 28	
Rapid chloride permeability test (RCPT)	100 diameter x 50 height	Q=900*(I0+2(I30+I60-----+I330) +I360) /1000 (Coulombs)	28, 56 & 90	ASTM C 1202 [22]
Drying shrinkage	75 x 75 x 285	Digital length comparator (Microseconds)	1 to 56	ASTM C 157 [23]

Table- II: Concrete mixture proportions

Mix Id	**w/b**	**F/c**	**B/Ta**	**Steel Fiber(V_f)**	**Acl**	**Fly ash**	**Cement**	**Fly ash**	**Fine Aggregate**	**Coarse Aggregate**	**Water**
	ratio			**(%)**			**(kg/m^3)**				
M-C1	0.3	0.60	0.26	0	0	0	473	0	672	1113	142
M-C1A				0	1	0	473	0			
M-SF1				0.5	1	25	355	118			
M-SF2				1	1	25	355	118			
M-SF3				1.5	1	25	355	118			
M-SF7				0.5	1	50	237	236			
M-SF8				1	1	50	237	236			
M-SF9				1.5	1	50	237	236			
M-D1		0.80	0.24	0	0	0	473	0	815	1019	
M-D1A				0	1	0	473	0			
M-SF4				0.5	1	25	355	118			
M-SF5				1	1	25	355	118			
M-SF6				1.5	1	25	355	118			
M-SF10				0.5	1	50	237	236			
M-SF11				1	1	50	237	236			
M-SF12				1.5	1	50	237	236			

III. CONCEPTUAL CONCRETE MIX DESIGN

Initially, a high strength concrete with desired target strength of M40 Grade of concrete was designed for various proportions. The standard chart was developed for various packing constituents (%), such as Fine aggregate-coarse aggregate materials (F/c) ratio (0.5 to 0.8) and Binder/Total aggregate materials ratio (0.24 to 0.26) as shown in Figure 1. High strength concrete mixtures were obtained which had high fine to coarse aggregate ratio (F/c >0.6) with water/binder materials ratio of 0.3. Based on several trial studies conducted the various mixture proportions adopted in this study.

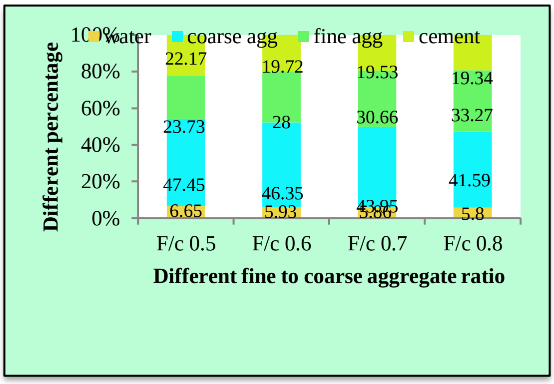

Fig. 1: Standard chart developed for various percentages in packing constituents

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IV. TEST RESULTS AND DISCUSSIONS

A. Monitoring Rate of Setting characteristics of Fresh Cementing System

The setting properties of fresh cementitious systems were tested in a fabricated Plexiglas mould size of 100 x 100 x 100 mm and continuously monitored by using the UPV techniques in parallel method. The noted velocity values for various fresh cementitious mixtures are represented in Figures 2 to 4. It was identified that the ordinary Portland cement with 25% of partially replacing of fly ash with increased accelerator dosage showed a gradual increase in the pulse velocity which represents the steady increase in the setting properties (as shown in Figure 4).

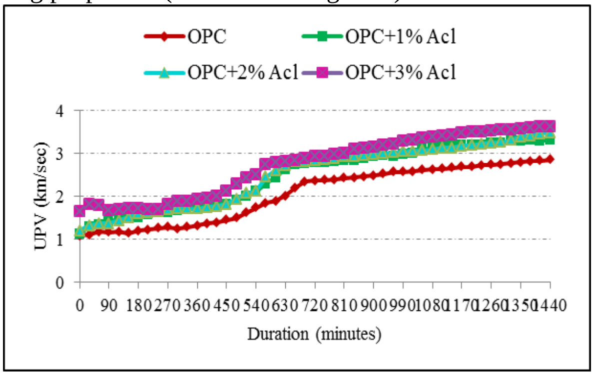

Fig. 2. UPV for various mixture proportions of fresh cementitious system

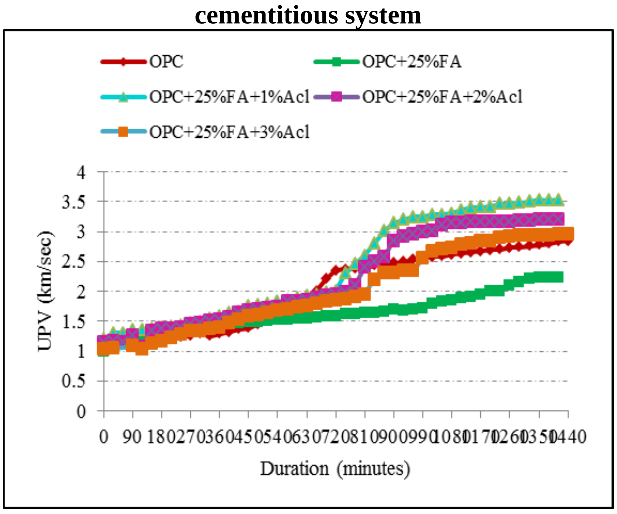

Fig. 3. UPV test values for various mixes in fresh cementitious system

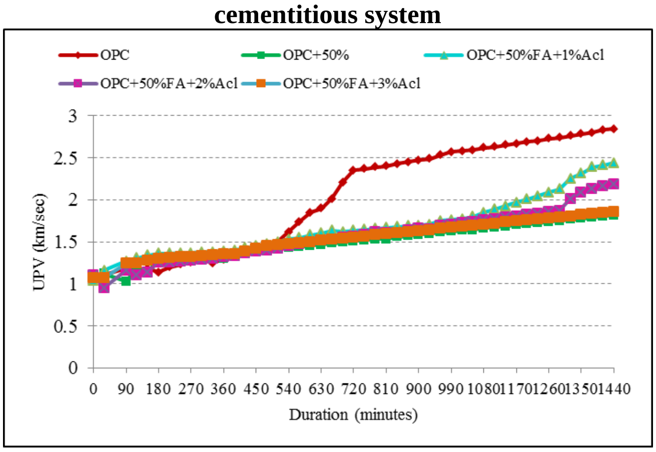

Fig. 4. UPV test values for various mixes in fresh cementitious system

B. Pozzolanic Activity Index (PAI)

The addition of fly ash makes a considerable effect in the cementitious system were more assessed in the case of pozzolanic activity index values are provided in Table III. The efficiency of fly ash reaction with cement was better noticed with the addition of accelerating admixture. This is a better improvement on the pozzolanic activity index for 25% of fly ash at 7 days. The effect of chemical accelerator type of admixtures resulted in an increase in the pozzolanic reactivity up to13% compared to normal mixes.

Table- III: PAI for cement mortar (1:3) test for with and without fly ash

Fly ash	Cement	Acl	Comp. Strength (MPa) at 7 days	Comp. Strength (MPa) at 28 days	PAI Index at 7 days	PAI Index at 28 days
	%					
0	100	0	34.67	51.05	-	-
25	75	0	28.08	45.35	80.99	88.83
25	75	1	35.81	52.16	103.29	102.17
50	50	0	24.95	38.23	71.96	74.89
50	50	1	29.12	43.28	83.99	84.78

Note: Normal mix water required up to 115 ml

C. Compressive Strength of Concrete

Figure 5 shows the experimental trends for the up and downs in compressive strength for different fine aggregate to coarse aggregate ratio of 0.5 to 0.8 for plain cement concrete. It was observed that the F/c-ratio 0.6 produced the one-day maximum strength of 26.10 MPa was achieved for plain concrete. Whereas, the fly ash substituted with concrete mixes reported maximum 1-day strength of 23.75 MPa for 25% fly ash substitution and 18.01 MPa for 50% fly ash substitution as shown in Figure 6. However, the target M40 grade was achieved with the effect of accelerated curing for 25% fly ash substituted concretes as seen in Figure 7. Similarly, M30 grade was obtained for 50% fly ash substituted concrete mixes as seen in Figure 8.

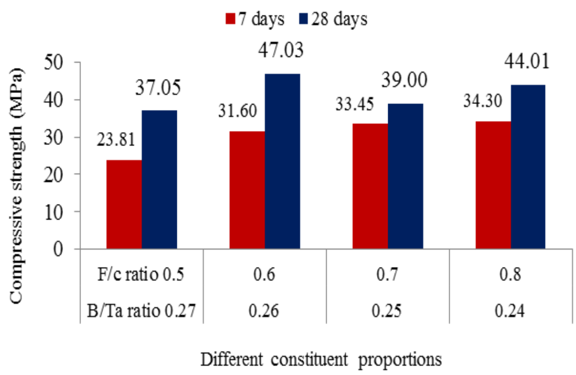

Fig. 5. OPC-compressive strength of concrete for different constituent proportions

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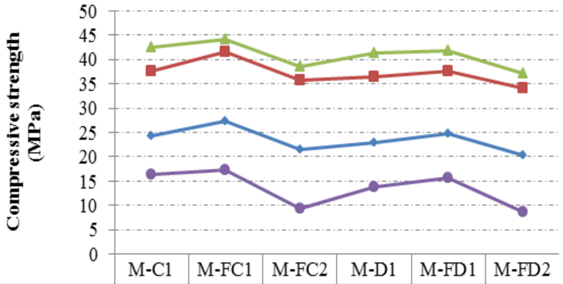
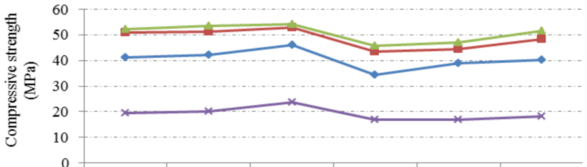


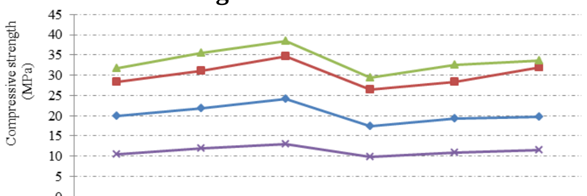
	M-C1	M-FC1	M-FC2	M-D1	M-FD1	M-FD2
1 day	16.40	17.40	9.40	13.70	15.60	8.75
7 days	24.30	27.30	21.50	22.80	24.80	20.40
28 days	37.50	41.60	35.70	36.40	37.50	34.10
56 days	42.40	44.10	38.50	41.30	41.80	37.10

Fig. 6. Variation of plain compressive strength of concrete for different age of curing



	M-SF1	M-SF2	M-SF3	M-SF4	M-SF5	M-SF6
1 day	19.60	20.05	23.75	16.94	17.04	18.31
7 days	41.20	42.30	46.10	34.50	38.90	40.30
28 days	50.90	51.20	52.90	43.40	44.50	48.30
56 days	52.30	53.40	54.00	45.80	47.10	51.40

Fig. 7. Variation of 25% of fly ash based compressive strength of concrete



	M-SF7	M-SF8	M-SF9	M-SF10	M-SF11	M-SF12
1 day	10.45	12.04	13.10	9.89	10.90	11.45
7 days	19.90	21.90	24.14	17.50	19.40	19.80
28 days	28.40	31.04	34.70	26.45	28.30	31.90
56 days	31.80	35.40	38.50	29.45	32.45	33.50

Fig. 8. Variation of 50% of fly ash based compressive strength of concrete

D. Flexural Properties Evaluation

The properties of flexural rigidity which has been calculated in accordance with IS 516-1959 [21]. It was noted that the 28 days of curing in concrete produced the higher flexural strength up to 6.98 MPa in the case of M-SF3 mix. Indeed, the effect of the accelerator has produced the early strength gain up to 34.75% as compared to plain cement concrete. It was also noted that the higher strength attainment up to 6.08 MPa at 28 days, which is consisting of fly ash 50% with 1.5% of steel fibers along with 1% of the accelerator. Further, It is well understood about the higher F/c ratio 0.8 (M-SF6) was produced the faster reaction with help of the liquid type of accelerator during the hydration process was occurred the higher flexural strength increased up to 12.93% than the plain cement concrete at 28-days of curing. Similarly, a drastic trend in the case of 50% addition of fly ash produced the little bit lower strength than compared to 25 % addition of fly ash at different curing days for various mixes as represented in Table IV.

Table- IV: Test results for Flexural strength and equivalent flexural strength of concrete

Mix Id	Flexural strength (MPa)	Residual Load (kN)	Residual Flexural Strength ratio	Flexural strength (MPa)	Residual Load (kN)	Residual Flexural Strength ratio
	7 days			28 days		
M-C1	4.05	0	0	5.18	0	0
M-C1A	4.28	0	0	5.63	0	0
M-SF1	4.23	2.60	0.28	5.85	4.80	0.37
M-SF2	4.73	4.30	0.41	6.30	7.60	0.54
M-SF3	4.95	5.70	0.52	6.98	10.50	0.68
M-SF7	4.14	2.20	0.24	5.72	4.20	0.33
M-SF8	4.28	3.30	0.35	5.85	6.20	0.48
M-SF9	4.50	4.30	0.43	6.08	7.00	0.52
M-D1	3.60	0	0	5.18	0	0
M-D1A	3.92	0	0	4.50	0	0
M-SF4	4.19	2.50	0.27	5.18	3.60	0.31
M-SF5	4.55	2.90	0.29	5.63	6.00	0.48
M-SF6	4.91	4.40	0.4	5.85	8.10	0.62
M-SF10	4.14	2.00	0.22	5.40	4.40	0.37
M-SF11	4.23	2.40	0.25	5.18	4.60	0.40
M-SF12	4.73	2.90	0.28	5.35	6.00	0.46

E. Residual load/ Residual Flexural Strength Ratio

Tables IV and V shows the test results based on the residual load which depends on the load-carrying capacity of the toughness under the limitation of cracks due to the presence of steel fiber concrete specimens. It was calculated the absolute, post crack and residual toughness up to 3 mm, which is depending on the loading, unloading the cycling process in third point loading arrangement of the flexural test machine. A maximum toughness value was obtained in the case of 25% fly ash substituted concretes containing 1.5% steel fibers. The post crack toughness and residual toughness value was also found to higher for the same mix (M-SF3); this shows the action of fibers after cracking.

Table- V: Flexural rigidity and toughness results for various mixes

Id	Flexural strength (MPa)	Absolute Toughness upto 3mm	Post crack Toughness upto 3mm	Residual Toughness upto 3mm	Re 3 Index
M-C1	5.18	0	0	0	0
M-C1A	5.63	0	0	0	0
M-SF1	5.85	22.833	19.921	14.2492	0.51
M-SF2	6.3	26.055	19.342	16.649	0.46
M-SF3	6.98	34.365	27.966	24.27	0.602
M-SF7	5.72	16.147	10.731	8.226	0.282
M-SF8	5.85	23.401	17.167	15.28	0.44
M-SF9	6.08	29.614	25.855	17.87	0.638
M-D1	5.18	0	0	0	0
M-D1A	4.5	0	0	0	0
M-SF4	5.18	13.454	8.661	7.521	0.269
M-SF5	5.63	21.452	16.945	15.705	0.491
M-SF6	5.85	25.503	19.245	11.922	0.493
M-SF10	5.4	14.808	8.495	7.913	0.253
M-SF11	5.18	21.917	17.608	14.879	0.51
M-SF12	5.35	25.656	19.985	15.172	0.512

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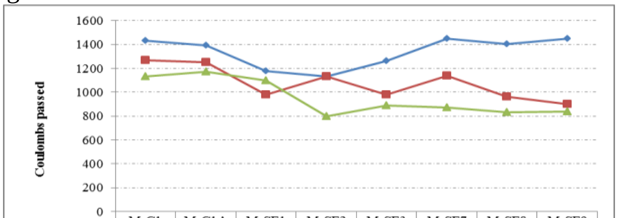
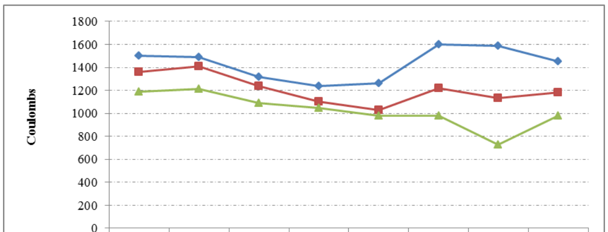
F. Rapid Chloride Permeability Test (RCPT)

The quality assessment of test in fly ash based concrete to resist the chloride ions in RCPT, which reflects the long term performance based on the refined microstructure of concrete. It was noted that the less ingress of chloride ions 800 coulombs (very low chloride permeability in accordance with ASTM C 1202) in the combination of 25% of fly ash substituted in OPC while the plain cement concrete passed average 1130 coulombs at 90 days as shown in Figure 9. Similarly, it was also exhibited that the low chloride permeability 730 coulombs consisting of 50% of fly ash with 1% of the accelerator along with 1.5% of steel fibers than compared plain cement concrete (F/c-ratio 0.8) as shown in Figure 10.



	M-C1	M-C1A	M-SF1	M-SF2	M-SF3	M-SF7	M-SF8	M-SF9
28 days	1430	1390	1180	1130	1260	1450	1405	1450
56 days	1270	1250	980	1130	980	1140	960	900
90 days	1130	1170	1100	800	890	870	830	840

Fig. 9. RCPT results for different age of curing (F/c - 0.6)



	M-D1	M-D1A	M-SF4	MSF5	M-SF6	M-SF10	M-SF11	M-SF12
28 days	1500	1490	1320	1240	1260	1600	1590	1450
56 days	1360	1410	1240	1100	1030	1220	1130	1180
90 days	1190	1210	1090	1050	980	980	730	980

Fig. 10. RCPT results for different age of curing (F/c - 0.8)

G. Drying Shrinkage Properties

The drying shrinkage property preliminary test results for the various designed shape concrete mix are represented in Figures 11 and 12. The addition of fly ash (25%) with 1.50% of steel fibers along with 1% of the accelerator, quality of coarse aggregate and volume of binder past exhibited a reduction in the drying shrinkage values. However, when compared to 50% of fly ash with 1.5% of steel fibers containing accelerator dosage of 1% shows a better decrement on the drying shrinkage value when monitored to F/c ratio 0.8.

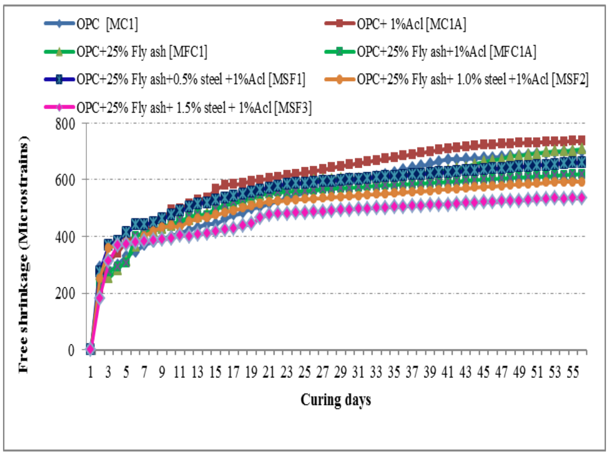


Fig. 11. Drying shrinkage of concrete for various mixes (25% fly ash

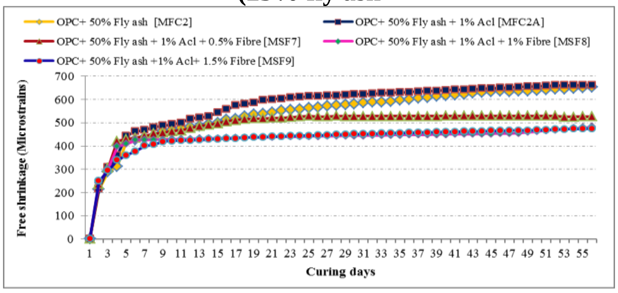


Fig. 12. Drying shrinkage of concrete for various mixes (50% fly ash)

V. Salient Conclusions

The following limitation of the conclusion can be drawn from the various experimental test results

The instrumental effects on the fly ash substituted in OPC were noted for both low and high volume of fly ash. It is proved that the lab test results for 25% of fly ash produced higher strength at 7 days up to M30 grade. Similarly, for 50% of fly ash produced the M30 grade of concrete at 28 days for various constituents of the mixes.

It is recommended based on the various stages involved for trial and error method for conceptual mix design. The best mix In the case of B/Ta-ratio 0.26 with F/c-ratio 0.6 produced the excellent improvement in the early hardening of concrete for any type of mineral admixtures replaced in OPC. Further, this study also recommended for low B/Ta ratio 0.24 with higher F/c-ratio 0.24 for any type of waste by-products which is suitable for a marginal amount of binding materials while partially replaced in OPC.

The Residual load-carrying capacity of steel fiber designed concretes are found to exhibit the incredible flexural strength bearing capacity of all fiber reinforced concrete mix designed after the initiation of the first initial cracking and subsequent reloading till the end of the failure level.

It is well understood that, from the various laboratory test results that are the higher residual flexural strength ratio (0.68) which was noticed in the combination of 25% of fly ash with 1.5% Vf of steel fiber reinforced concrete.

The drying shrinkage reduction was found to be reduced in the case of 25% of fly ash up to 23.54% and 32.06% for 50% of fly ash, which shows the inclusion of both ends hooked type of steel fibers along with 1% of the accelerator presented for various mixes.

The drying shrinkage properties with the usage of steel fiber and accelerator showed a consistent volumetric reduction from 14.89% to 23.4% than compared to plain cement concrete.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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