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EFFECT OF NATURAL ADMIXTURE ON FRESH PROPERTIES AND COMPRESSIVE STRENGTH OF CLASS C FLY ASH BLENDED CONCRETE

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ABSTRACT

In this investigation, broiler hen egg was used as natural admixture (NAD) to study the effect on fresh properties and compressive strength of Conventional Concrete (CC) and class C Fly Ash (FA) blended concrete. Cement was replaced by fly ash at various levels of 0%, 25%, 35% and 45% and broiler hen egg mixed sample (white albumen and yellow yolk) was added to concrete at different replacement dosages of 0%, 0.25%, 0.5%, 1.00%, 1.5% and 2.0% in water content and liquid to binder ratio was maintained at 0.5. For all replacement levels of NAD and FA, the fresh properties and compressive strength of mixes were studied at 7, 28 and 56 days. From the results, it was concluded that 0.25% of NAD dosage was considered as optimum dosage for both CC and class C fly ash blended concrete.

Keywords: Natural admixture; broiler hen egg; class C fly ash; fresh properties and compressive strength.

1. INTRODUCTION

Ancient structures were constructed using lime, mud, clay, jaggery, sugar, wood, surkhi, burnt coconut shells, egg etc. Among those materials, egg white was used to enhance the binding property of mortar [1]. In 1824, cement was invented and thereafter it is being used widely as binder in the construction industry. But the production of cement releases green house gas (CO_2) emissions into environment and causes global warming. To protect environment against land deposits and global warming, fly ash has been used as Supplementary Cementitious Material (SCM) in various construction works. The compressive strength of concrete depends on mix proportions, water – cement ratio (W/C), curing conditions and age of concrete [2].

In this work, broiler hen egg was used as natural admixture (NAD) to study the effect of

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NAD on the fresh properties and compressive strength of CC and class C fly ash blended concrete. SEM analysis was also carried out to examine the microlevel properties of concrete, which has ceramic-like properties.

2. EXPERIMENTAL STUDY

2.1 Materials

The prime motive of this study is to introduce the utilization of egg as natural admixture (NAD) in conventional concrete and fly ash blended concrete. In this study, class C fly ash was replaced in cement at various replacement levels of 0%, 25%, 35% and 45%. NAD was replaced in water at various dosages of 0%, 0.25%, 0.5%, 1%, 1.5 % and 2% by maintaining the liquid to binder ratio at 0.5. This study concentrates on fresh properties and compressive strength of concrete with and without fly ash blending.

2. 2. Material properties

This section describes the proprieties of ingredients used in this study as per American Society for Testing and Materials (ASTM) and Bureau of Indian Standards (BIS).

2.2.1 Cement

Ultra tech 53 grade ordinary Portland cement was used corresponding to IS 12269:1987 [3]. The properties of cement are shown in Tables 1and 2.

Table 1: Chemical properties of cement

Particulars	Test result	Requirement as per IS:12269-1987
Chemical composition		
% Silica (SiO_2)	19.29	
% Alumina (Al_2O_3)	5.75	
% Iron oxide (Fe_2O_3)	4.78	
% Lime (CaO)	62.81	
% Magnesia (MgO)	0.84	Not more than 6.0%
% Sulphuric anhydride (SO_3)	2.48	Max. 3.0% when $C_3A>5.0$ Max. 2.5% when $C_3A<5.0$
% Chloride content	0.003	Max. 0.1%
Lime saturation factor CaO $0.7SO_3/2.8SiO_2+1.2Al_2O_3+0.65Fe_2O_3$	0.92	0.80 to 1.02
Ratio of Alumina/Iron Oxide	1.21	Min. 0.66

Table 2: Physical properties of cement

Particulars	Test result	Requirement as per IS:12269-1987
Physical properties		
Specific gravity	3.15	
Fineness (m^2/kg)	315.4	Min. 225 m^2/kg
Soundness		
Lechatlier expansion (mm)	0.8	Max. 10mm

Auto Clave expansion (%)	0.01	Max. 0.08%
Setting time (Minutes)		
Initial	45	Min 30 mints
Final	230	Max. 600 mints

2.2.2 Natural admixture

Broiler hen egg was used as natural admixture (NAD). Egg structure with key ingredients is shown in Fig. 1. White albumen and yellow yolk of broiler egg were thoroughly mixed and added to concrete. The replacement dosages were kept at 0%, 0.25%, 0.5%, 1.00%, 1.5% and 2.0% in water content by maintaining the liquid to binder ratio (0.5).

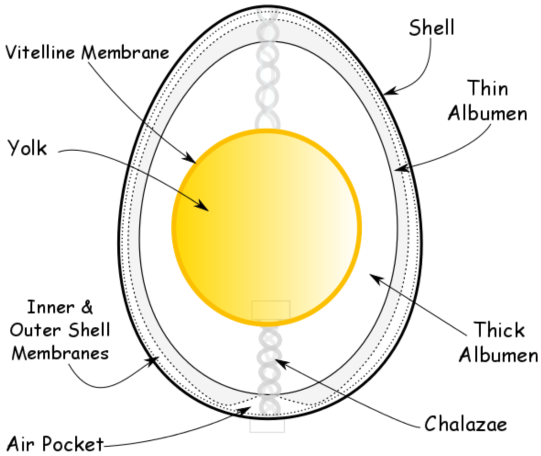

Figure 1. Egg structure with key ingredients

2.1.3 Mineral admixture

Class C fly ash (FA) was used as an additive according to ASTM C 618 [4]. Table 3 shows the properties of class C fly ash.

Table 3: Properties of fly ash

Physical properties	**Test results**
Specific gravity	2.15
pH	11.36
Moisture content	0.85%
Chemical properties	
Element	**%**
CaO	15.02
SiO_2	49.45
Al_2O_3	22.78
Fe_2O_3	5.62
$SiO_2 + Al_2O_3 + Fe_2O_3$	77.85
SO_3	1.28
MgO	2.15
Loss on ignition	1.45

2.2.4 Coarse aggregate

20 mm and 10 mm crushed granite stones were used as coarse aggregate. The specific gravity was 2.62 and water absorption of the coarse aggregate was 0.3%. Sieve analysis was conducted as per IS: 383-1970 [5]. Fig. 2 and 3 shows the gradation of 20 mm and 10 mm respectively.

2.2.5 Fine aggregate

The river sand was used as fine aggregate. The specific gravity was 2.6 and water absorption of the fine aggregate was 0.32%. Sieve analysis was conducted as per IS 383:1970 [5] and gradation of fine aggregate is shown in Fig. 4 and confirmed to zone - III sand [5].

2.2.6 Water

The ordinary tap water was used in present study which satisfies water standards as per IS 456 – 2000 [6].

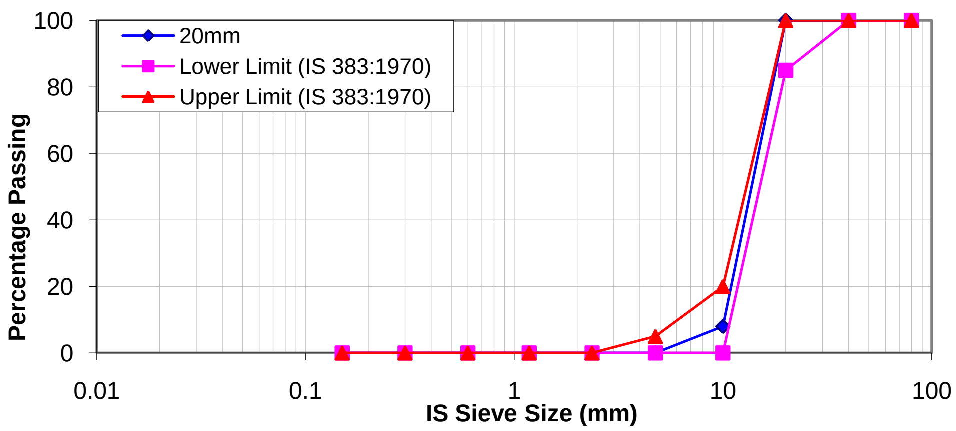

Figure 2. Grading curve of 20 mm coarse aggregate

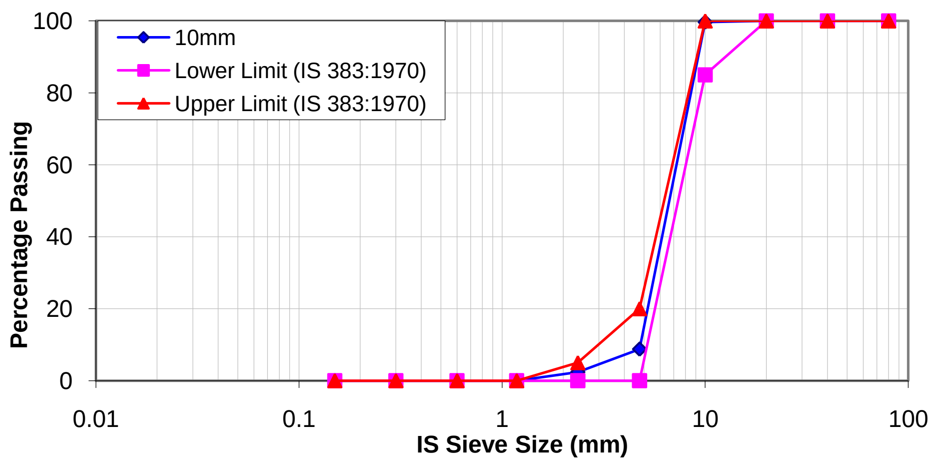

Figure 3. Grading curve of 10 mm coarse aggregate

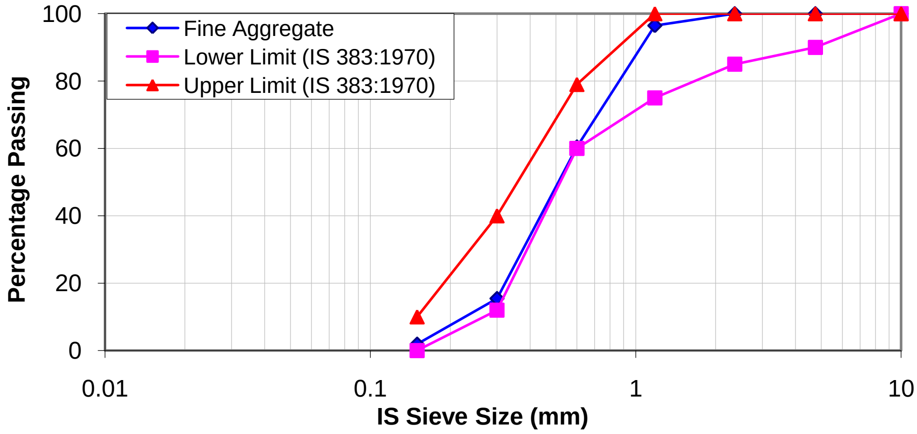

Figure 4. Grading curve of fine aggregate

3. EXPERIMENTAL PROCEDURE

3.1 Mix design

The Conventional Concrete (CC) of M 25 grade was designed as per IS 10262-2009 [7] and IS 456-2000 [6]. The cement was replaced by class C fly ash to the designed conventional concrete mix by various replacement levels of 0%, 25%, 35% and 45%. The NAD was replaced in water at various dosages of 0% to 2.0 % by maintaining liquid to binder ratio at 0.5. Liquid refers to water content with or without egg replacement and cementitious materials are considered as binder. 20 mm and 10 mm coarse aggregates were blended in 60:40 proportions (by weight). The design mix proportions are shown in Table 4.

3.2 Testing fresh properties

3.2.1 Normal consistency and initial setting time of binder

The Vicat's needle penetration test was conducted to determine the normal consistency of the paste for various paste proportions as per ASTM C187 – 11 [8]. Then initial setting times of these proportions were determined as per ASTM C 191 [9]. The preparation process of binder paste is shown in Fig. 5.

Table 4: Mix proportions of constituent materials

Sample Notation	Cement (Kg)	Fly Ash (Kg)	Fine aggregate (Kg)	Course aggregate (Kg)	Water (lts)	% of NAD	Quantity of NAD (lts)
C-100_FA-0	360 (100%)	0.00 (0%)	745	1150	180.00	0.00	0.00
					179.10	0.25	0.90
					178.20	0.50	1.80
					176.40	1.00	3.60
					174.60	1.50	5.40
					172.80	2.00	7.20
C-75_FA-25	270	90 (25%)	745	1150	180.00	0.00	0.00

	(75%)				179.10	0.25	0.90
					178.20	0.50	1.80
					176.40	1.00	3.60
					174.60	1.50	5.40
					172.80	2.00	7.20
					180.00	0.00	0.00
					179.10	0.25	0.90
C-65_FA-35	234 (65%)	126 (35%)	745	1150	178.20	0.50	1.80
					176.40	1.00	3.60
					174.60	1.50	5.40
					172.80	2.00	7.20
					180.00	0.00	0.00
					179.10	0.25	0.90
C-55_FA-45	198 (55%)	162 (45%)	745	1150	178.20	0.50	1.80
					176.40	1.00	3.60
					174.60	1.50	5.40
					172.80	2.00	7.20

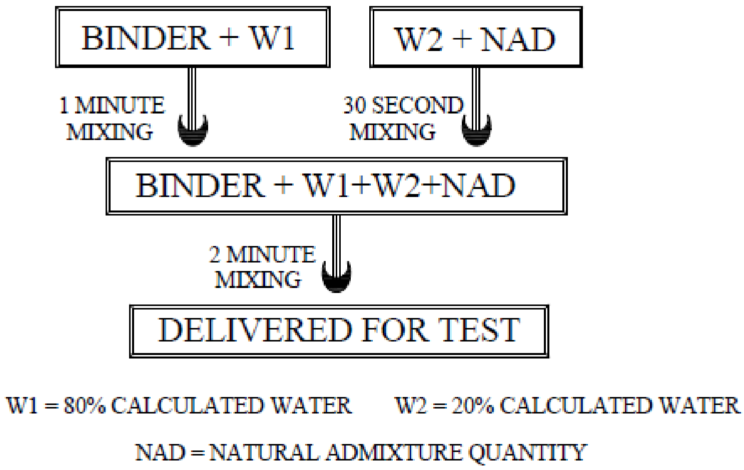

Figure 5. Mixing process of binder paste for normal consistency

3.2.2 Slump test

The workability of fresh concrete was determined by slump test as per ASTM C143 [10]. Neville [11] described that internal energy is required to overcome the formation of voids in concrete. As per ACI Committee 116 [12], workability is defined as the property of concrete that exhibits homogeneity, mobility and finishablity of concrete. The workability of fresh concrete was determined by slump test as per ASTM C143 [10].

3.3 Compressive strength test

The compressive strength values of hardened concrete mixes were calculated as per IS 516[13] after 7, 28 and 56 days of curing. Three cubical specimens of size 150 mm × 150 mm × 150 mm were caste for each mix proportion and curing period. The average of three samples of each mix and curing period was calculated to determine the compressive strength of concrete.

4. RESULTS AND DISCUSSION

4.1 Fresh properties

4.1.1 Normal consistency of binder

Normal consistency of binder for all paste proportions are shown in Table 5 and Fig. 6. From the results, it can be seen that the normal consistency value has been increased with the increasing replacement levels of FA and NAD till 1% as shown in Fig. 6. For NAD replacement levels 1.5% and 2%, the consistency value has been increased till the 35% FA replacement and later decreased at 45% FA replacement.

Table 5: Normal consistency of binder

NAD quantity	C-100 _ FA-0	C-75 _ FA-25	C-65 _ FA-35	C-55 _ FA-45
0.00%	29	30	30	32
0.25%	30[a]	32	32	33
0.50%	31	32	34	35
1.00%	32	34	35	36
1.50%	31	34	35	34
2.00%	30	32	33	32

[a] C-100_FA-0 : C- represents cement percentage, FA represents class C fly ash percentage.

The normal consistency of mix C-100_FA-0 at 0.25% dosage of NAD is 30% i.e., 90 ml liquid (89.25 ml water and 0.75 ml NAD) for 300gms of binder.

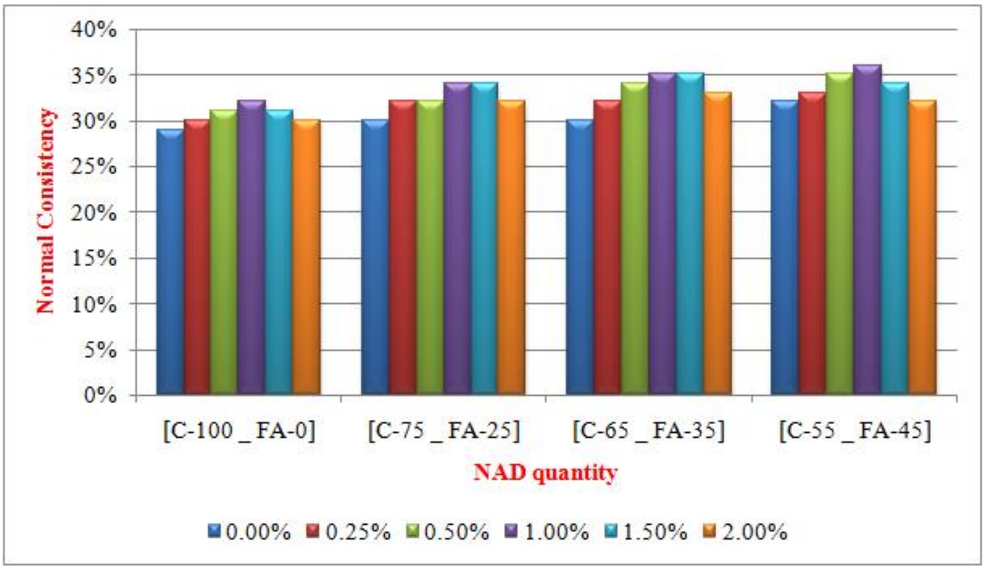

Figure 6. Normal consistency of binder

4.1.2 Initial setting time of binder

Fig. 7 shows the initial setting time of binder for all paste proportions. From Fig. 7, for the 0% NAD paste, it is observed that initial setting time value has been increased with the increasing FA replacement levels. It is already known that the inclusion of class C fly ash increases the setting time due to less heat of hydration. At 0.25% NAD, the paste has been set rapidly at 0% FA than that of other FA replacement levels.

The rapid setting could be due to the formation of thin film over the binder particles and the chemical action between binder and NAD and leads to faster hydration. For other dosages after 0.25% NAD, it is clearly observed that setting time of paste has been increased with the increasing NAD dosage for all FA replacement levels. It may be due to the increase in NAD dosage increases the thickness of the film over the binder particles which retards the hydration and thus leads to slower setting. Hence, it is concluded that by increasing of NAD dosage, the thickness of NAD film increases that reduces the hydration and thereby increase in setting time was observed.

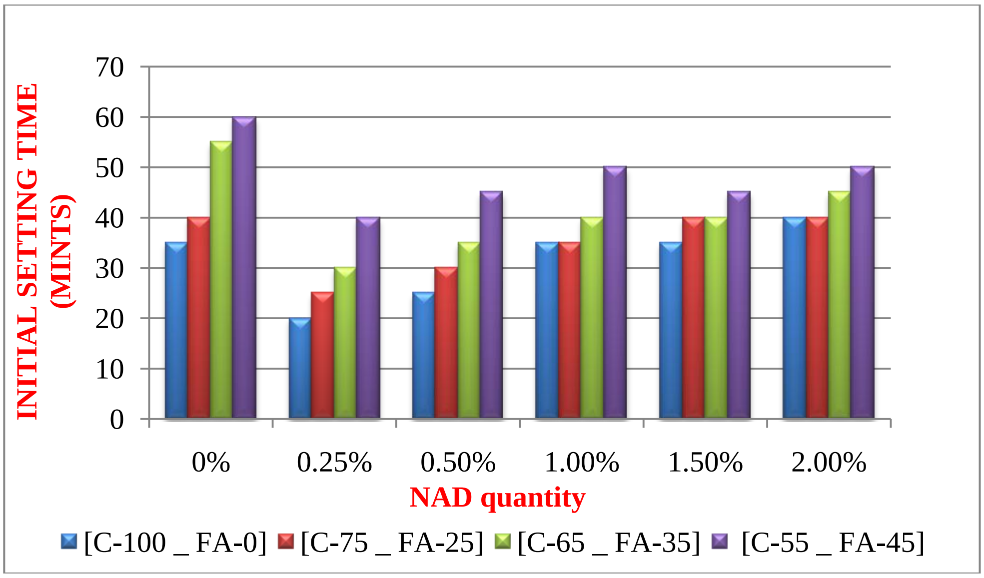

Figure 7. Initial setting time of binder

4.1.3 Slump test of concrete

The slump values of all concrete mixes are shown in Fig. 8. From the results, it is observed that the slump values of the 0% NAD mixes have been increased with the increasing replacement levels of FA. It is well known that the slump value increases with the increased FA replacement [14]. Megat Johari [15] also concluded that increasing the quantity of FA by maintaining the same binder quantity increased the slump values. At each FA replacement level, the increase in NAD dosage caused the reduction of slump value as shown in Fig. 8. This reduction is due to increase in the viscosity of mix and adhesion between the ingredients with the incorporation of NAD dosage. Adel Kaikea et. al. [16] reported slump loss of concrete occurs due to the addition of viscous material. Hence, it can be said that the percentage of NAD dosage in CC and FA blended concrete mixes affects the workability of concrete.

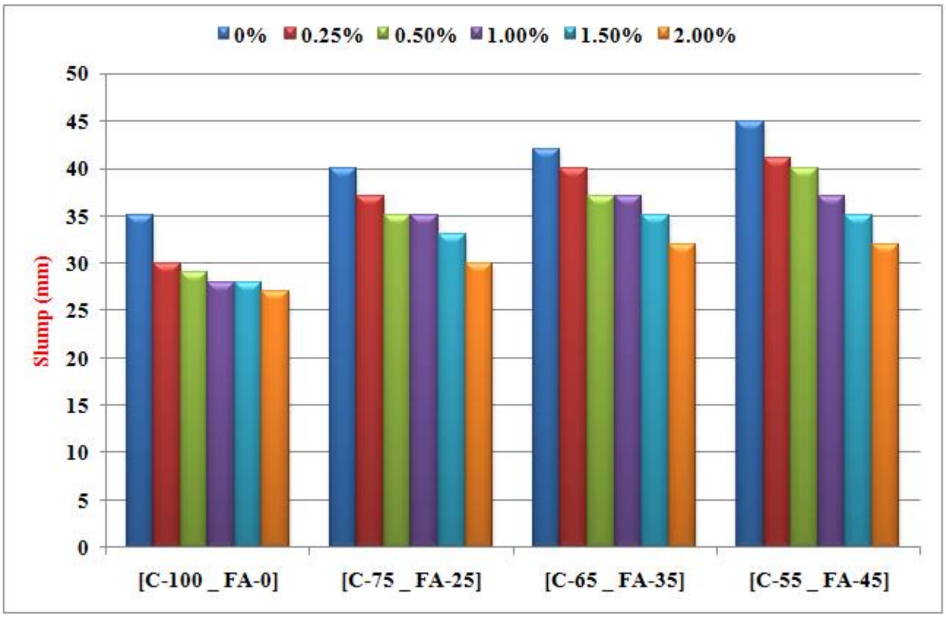

Figure. 8 Slump of concrete

4.4. Compressive strength of concrete

The compressive strength of concrete mixes are shown in Table 6 and graphically shown in Fig. 9. From the results, it is noted that at 0% NAD replacement level and after 7 days of curing, compressive strength values of concrete have been increased with the increasing percentage of FA replacement level up to 35%. It is particularly due to the self cementing properties of high calcium class C fly ash which accelerates the hydration at early ages, beyond this level (at 45% FA), early age strength was reduced [17]. Whereas at 0% NAD and 0% FA replacement levels, compressive strength values of CC (C-100_FA-0) were higher than those of fly ash blended mixes after 28 days and 56 days of curing. It is observed that both 0% and 25% FA replaced mixes have attained the desired 28 days strength of CC after 28 days of curing at 0% NAD dosage.

Table 6: Compressive strength of concrete cubes (MPa)

NAD	0%	0.25%	0.50%	1.00%	1.50%	2.00%
			C-100 _ FA-0			
7 Days	21.11	34.44	29.11	25.56	19.73	15.60
28Days	35.56	42.89	37.78	34.42	26.91	20.29
56Days	37.78	46.89	41.56	38.67	31.20	25.78
			C-75 _ FA-25			
7 Days	22.75	19.47	19.29	15.78	14.89	13.56
28Days	33.36	31.96	28.22	24.22	22.89	19.33
56Days	35.56	40.22	39.33	36.22	26.00	24.22
			C-65 _ FA-35			
7 Days	24.02	18.69	18.13	15.58	14.53	13.11
28Days	30.44	28.22	24.44	21.82	21.47	18.89

56Days	32.44	34.00	32.67	25.78	23.11	22.89
			C-55 _ FA-45			
7 Days	23.45	16.16	15.33	14.09	13.89	13.62
28Days	28.67	27.11	23.56	20.67	19.78	18.00
56Days	30.22	32.67	31.96	27.91	26.40	21.09

At the ages of 7 and 28 days, the dosage of NAD has reduced the compressive strength of FA blended concrete mixes as shown in Table 6. It is because of excess calcium content with the addition of NAD which disturbs the hydration of FA blended concrete. Whereas, all fly ash blended mixes have attained higher values of compressive strength after 56 days of curing at all NAD dosages. It is due to pozzolanic action of FA at later ages [17 - 22].

From the results, it was observed that the compressive strength values of 25% FA blended mix at 0.25% NAD are comparable to those of CC. Hence, it is revealed that 0.25% NAD can be taken as optimum dosage for 25% FA replacement. The effect of 0.25 % NAD dosage in class C fly ash blended concrete is very much significant after 56 days in all FA replacement levels to get higher compressive strengths than that of 0% NAD dosage.

The compressive strength values of CC have been significantly increased at 0.25% NAD replacement at all curing periods when compared to those of 0% NAD replaced mixes as shown in Table 6 and Fig. 9. It is mainly due to the calcium content of egg ingredients (NAD) that accelerates the hydration in CC at all curing periods. The strength increments of the mixes at 0% FA from 0% to 0.25% NAD dosages at 7, 28 and 56 days were observed as 63.16%, 20.63% and 24.11% respectively. That’s why, it is clearly seen that the desired 28 days strength has been achieved at 7 days itself in CC at 0.25% NAD. It is because of good bond strength and hydration of the mixes due to the incorporation of 0.25% NAD. Further dosage of NAD from 0.5% to 2% decreased compressive strength of CC at all ages. Hence, it is concluded that 0.25% NAD dosage can be taken as optimum dosage for conventional concrete mixes.

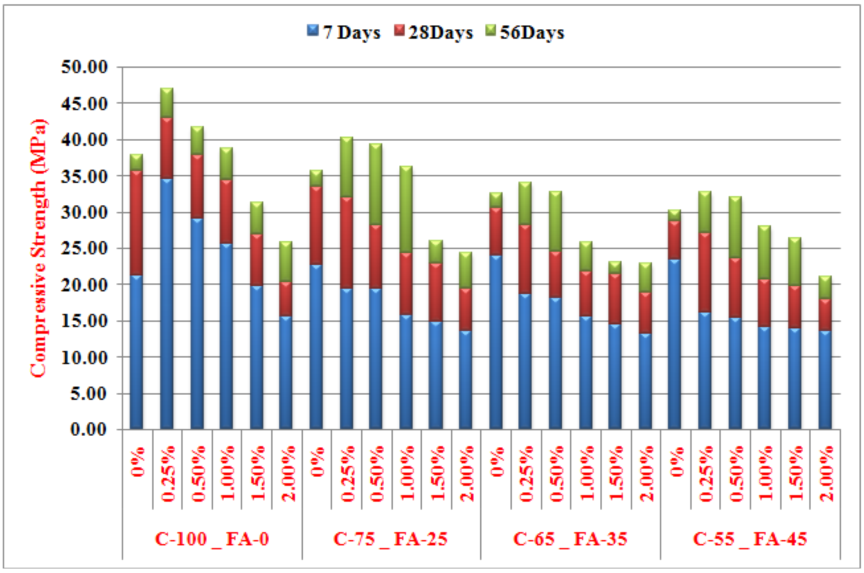

Figure 9. Compressive strength of concrete cubes

5. CONCLUSIONS

The following conclusions have been drawn based on the investigation on the effect of natural admixture (broiler hen egg) on mechanical properties of CC and FA bended concrete:

1. It is observed that the increase in NAD dosage increased the initial setting time of binder.
2. It is noted that at 0.25% NAD dosage, rapid setting was observed and can be considered as accelerator.
3. The increase in NAD dosage decreased the workability of concrete.
4. 0.25% NAD dosage has very much significant effect on compressive strength of CC at all curing periods. This is primarily due to the incorporation of NAD that accelerates the hydration in CC.
5. It is observed that CC (0% FA) has attained the 28 days strength of M 25 grade of concrete at the age of 7 days itself with the incorporation of 0.25% NAD.
6. Beyond 0.25% NAD dosage, all CC mixes exhibit lower compressive strength values as compared to those of 0.25 % NAD replaced CC mixes. Hence, 0.25% replacement of NAD can be taken as optimum dosage of NAD in conventional concrete.
7. It is observed that 25% FA blended mix has attained the desired 28 days strength of M25 grade of concrete with the incorporation of 0.25% NAD. Hence, 0.25% replacement of NAD can be taken as optimum dosage in class C fly ash blended concrete.
8. It is also observed that after 56 days of curing, the mix with 25% of FA replacement and 0.25% NAD dosage has attained more compressive strength than that of CC.
9. The usage of optimum dosage of NAD in FA blended concrete is very much significant to get higher compressive strength after 56 days in all FA replacement levels.

Hence, the present study stated that broiler hen can be used as natural admixture to increase the strength of concrete.

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