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Effect of Natural Admixture on Durability Properties of Conventional and Class C Fly Ash Blended Concrete

T.S. Ramesh Babu[a*], D. Neeraja[b], Mulugeta Daniel [a], Utino Warabo[a]
[a] *Department of Civil Engineering, Wachemo University, Hossana, Ethiopia.*
[b] *School of Civil and Chemical Engineering, Vellore Institute Of Technology, Vellore – 632 014, Tamilnadu, India.*

ABSTRACT: *The research work concentrated on durability study of Conventional Concrete (CC) and Class C Fly Ash(FA) blended concrete with and without Natural admixture (NAD). Broiler hen egg white albumen and yellow yolk was used as Natural Admixture. Cement was replaced by Class C fly ash at various levels of 0%, 25%, 35% and 45% by its mass and NAD was added to concrete at different replacement dosages of 0%, 0.25%, 0.5% and 1.00% by its volume to water content and liquid to binder ratio was maintained as 0.5. For all replacement levels of FA and NAD, the compressive strength and durability studies viz water absorption, porosity and acid attack of CC and Class C fly ash (FA) were studied at 7, 28 and 56 days. It was concluded that 0.25% of NAD dosage was considered as optimum dosage for both CC and Class C fly ash blended concrete from the compressive strength and durability tests. The studies revealed that 25% Class C fly ash blended concrete mix with 0.25% NAD having less water absorption and porosity. And also it has less percentage loss of compressive strength when immersed in HCL and H_2SO_4.*

Keywords: *Natural Admixture; Class C fly ash, Compressive Strength, Water absorption, Porosity, and Acid attack.*

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I. INTRODUCTION

The rapid development of construction industry lead to hug utilization of cement, this leads to emission of greenhouse gas (CO_2) into environment and that causes the global warming. To reduce the emission of CO_2, the supplementary cementiousmaterial was introduced and vast investigation is going on over those materials. The most of the research was concluded that the 25% fly ash can be replaced to cement the get the designed strength thatwill reduce percentage of CO_2 emission. So that there is necessity again reduce utilization of cement again by increasing the supplementary and pozzolanic materials by adding additives or admixtures.

Ravina Dan and Mehta [1]was concluded that 40 to 50% Class F or Class C fly ashes can be replaced to cement, but it requires 180 days of curing. They were proposed the high volume fly ash concrete by replacement level greater than 50% to cement. But practically curing of concrete for 180 days is not possible. So that the curing period has to reduce, and there by mix should get design strength within 28 days curing period by adding accelerators to enhance the hydration and pozzolanic action. Ramesh Babu and Neeraja [2] have concluded that the Natural Admixture (NAD) is acting as accelerator when it added to binder at optimum dosage. Malhotra and Painter [3] concluded that high volume fly ash concrete having high resistance to freezing and thawing effect.

This research is focused on study of durability propertiesvizwater absorption, porosity and acid attack explained with percentage loss of compressive strength immersed in HCL and H_2SO_4 of Conventional Concrete (CC) and Class C fly ash blended concrete incorpation with Natural Admixture and also identify optimum mix to improve the durability with optimum NAD dosage.

[*]E-mail address of the corresponding author: rams134.reddy@gmail.com (T.S. Ramesh Babu)

II. LITERATURE REVIEW

HanifiBinici et al. [4] reported that replacement of egg shell powder in sand that leads to reduction in the compressive strength and flexural strength of cement mortar. But it has high resistance to radiation effect. Ramesh Babu and Neeraja [2] revealed that when NAD added to binder, it acts as accelerator. The optimum dosage of NAD was determined by the fresh properties of binder and compressive strength CC and Class C fly ash concrete and concluded as 0.25% NAD replacement dosage as optimum dosage for CC and Class C fly ash blended concrete. Due to high viscous nature of NAD and rapid setting of concrete and the workability of concrete was decreased. Ramesh Babu et al [5] reported that the mechanical properties of CC and Class C fly ash blended concrete will increases at optimum dosage 0.25% NAD replacement. But 25% replacement of Class C fly ash with optimum dosage had attained M25 designed strength with optimum NAD dosage, and there after decreasing of compressive strength was observed with increasing FA. They were concluded that maximum replacement of Class C fly ash was 25%. Ramesh Babu and Neeraja [6] concluded that 55% Class F fly ash can be replaced to cement with 0.25% NAD to get designed strength and also 34% production can reduced.

II. EXPERIMENTAL STUDY

3.1 Materials

The aim of this research is to study the effect of Natural Admixture (NAD) on durability properties of CC and Class C fly ash blended concrete. The Class C fly ash was replaced to cement by its weight at various replacement levels of 0%, 25%, 35% and 45%. NAD was replaced to water at various dosages levels of 0%, 0.25%, 0.50%and 1.00% to the weight of cementitious material, by maintaining the liquid to binder ratio at 0.5. The durability properties viz water absorption, porosity and acid attach of convention concrete (CC) and Class C fly ash (FA) blended concrete were determined. The optimum replacement level of Class C fly ash to get designed strength of M25 with optimum dosage of NAD was determined.

3. 2. Material properties

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

3.2.1 Cement

Ultra tech 53 grade ordinary Portland cement was used corresponding to IS 12269:1987 [7]. The chemical and physical properties of cement are shown in Tables 1 and 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 C3A>5.0 Max. 2.5% when C3A<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

3.2.2 Natural admixture

Broiler hen egg was used as Natural admixture (NAD). The key elements of egg structure areshown in Fig 1. Both egg white albumen and yellow yolk was thoroughly mixed and added to concrete as NAD. The NAD was replaced to water as 0%, 0.25%, 0.50% and 1.00% of cementitious material weight by maintaining the liquid to binder ratio (0.5).

3.2.3 Mineral admixture

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

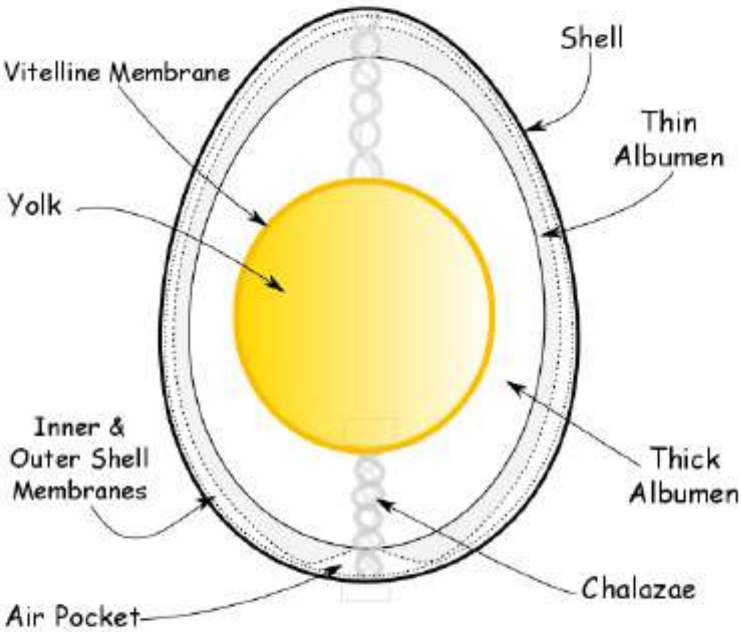

Figure 1. Egg structure with key ingredients

Table 3: Properties of Class C fly ash

Physical properties	**Test results**
Specific gravity	2.15
pH	11.36
Moisture content	0.85%
Chemical properties	
Element	**Weight %**
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

3.2.4 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 [8]. The coarse aggregate was blended with 20mm (60%) and 10mm (40%) to its total weight of coarse aggregate.

3.2.5 Fine aggregate
The river sand was used as fine aggregate. The specific gravity was 2.73 and water absorption of the fine aggregate was 0.31%. Sieve analysis was conducted as per IS 383:1970 [8].
3.2.6 Water
The ordinary tap water was used in present study which satisfies water standards as per IS 456 – 2000 [9].

IV. EXPERIMENTAL PROCEDURE

4.1 Mix design
The Conventional concrete (CC) M 25 was designed as per IS 10262-2009 [10] and IS 456-2000 [9] and the designed target strength was fixed as 32Mpa after 28 days of curing. The designed M25 CC mix was used to prepare Class C fly ash blended mixes by replacing the FA at various levels of 0%, 25%, 35%, and 45% of CC by cement weight. The NAD was replaced in water at various replacement dosages of 0.00%, 0.25%, 0.50%and 1.00% of cementitious material weight by maintaining constant liquid – binder ratio (0.5) which affects the compressive strength [9]. Here, liquid refers to water content with or without egg replacement and binder refers to cementitious content the mixing process was showed in Fig 2. The design mix proportions are shown in Table 4.

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
C-75_FA-25	270 (75%)	90 (25%)	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
C-65_FA-35	234 (65%)	126 (35%)	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
C-55_FA-45	198 (55%)	162 (45%)	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

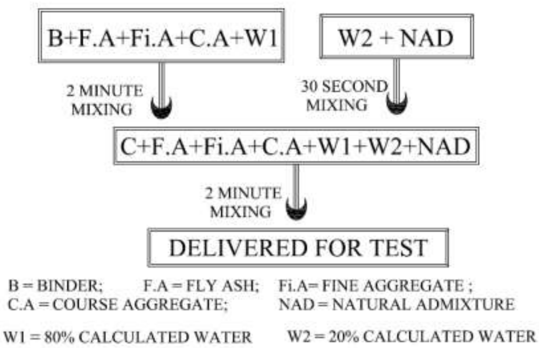

Figure 2. Mixing process of concrete ingredients

4.2 Testing of compressive strength

The compressive strength of concrete mixes was calculated as per IS 516 [11]. Three cubes of size 150 mm were cast and tested for compressive strength at 7, 28 and 56 days for each mix. The compressive strength of hardened concrete (f_{ck}) was determined after 7, 28 and 56 of curing for all the mixes. The failure of the concrete cube is Fig 3.

Figure 3. Compression Failure of cube

4.3 Testing of durability properties

4.3.1 Water absorption and porosity

Three specimens of size 100 mm diameter and 50mm height were cast and immersed in water for 7, 28 and 56 days for each mix. Then the specimens were oven dried for 24 hours at temperature 100°C until the mass becomes constant and then weighed as (W_1). Then the specimens were kept in hot water at 85°C for 3 hours and 30 mints. Then the specimens were removed from water and wiped out the surface water and weighted the weight of specimens and noted as (W_2). The percentage of water absorption was calculated as follows. The Fig 4 shows the schematic representation of specimen for water absorption.

$$\% \text{ water absorption} = \frac{(W_2 - W_1)}{W_1} \times 100$$

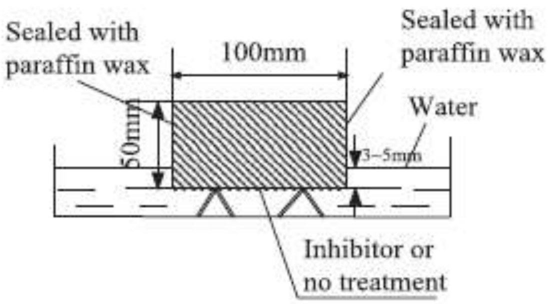

Figure 4. Water absorption test setup

4.3.2 Acid attach test

The concrete cubes of size 150mm were cast and allowed for curing in water for 28days. After 28days of water curing the specimes were removed from curing tank and allowed for drying for 24 hours. The acid water sample was prepared by adding 5% of HCL and another acid water sample was prepared by adingg 5% H_2SO_4 by its weigth of water. Then the cubes were immersed in prepared acid water samples seperately for HCL and H_2SO_4 the pH of sample was maintained constant by periodically changing the sample water. After 7, 28 and 56 days of immersion in acid water samples, specimens were removed form acid water and cleaned the surface of cubes by dry cloth and tested the compressive strength of the samples and calculated the % loss in compressive strength.

V. RESULTS AND DISCUSSION

5.1. Compressive strength

The compressive strength of concrete mixes is shown in shown in Fig. 5. 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 [13-14]. 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.

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 Fig 5. 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 - 19].

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 during periods when compared to those of 0% NAD replaced mixes as shown in Fig. 5. 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.

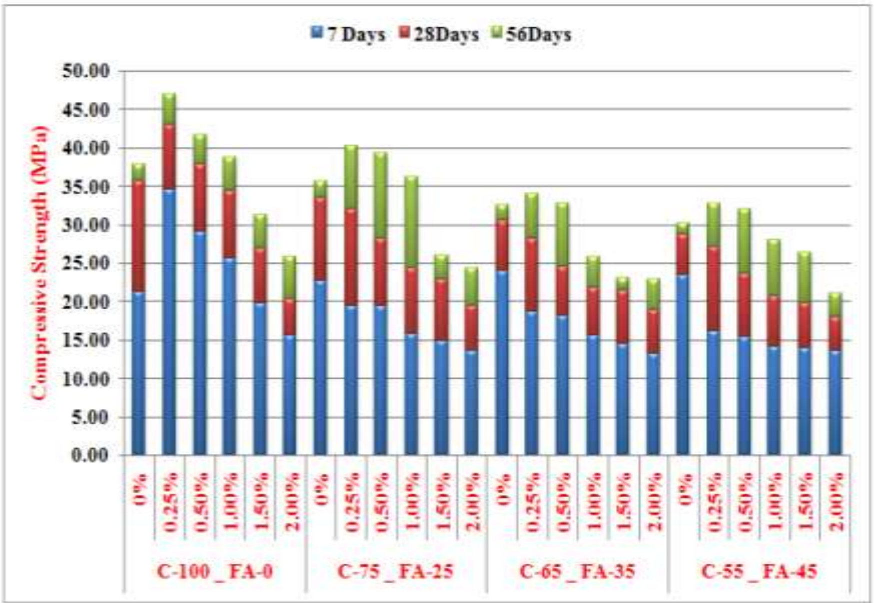

Figure 5. Compressive strength of concrete

5.2. Water absorptionof concrete

The water absorption and porosity of CC and FA concrete were showned in Fig6.A to 6.C. The Water absorption was decresed with increase in curing priod. At 0.25% NAD dosage has achieved the lower water absorption in all the mixes at all the ages. At 7 days C-75_FA-25 mix has lower water absorption at 0.00% NAD dosage, because the Class C fly ash has higher lower strength that influnces to reduciton in water absorption shown in Fig 6.B. The C-100_FA-0 has lower absorption at 28days curing with 0.25% NAD dosage. The decrease in water absorption is due to formation of crystals of calcite in voids. Pei et al. [20] also reported similar results of reduction in water absorption of concrete on use of B. Subtilis. At 56 days of curing the mix C-75_FA-0 with 0.25% NAD dosage has achived lowest water absorption 1.39% among all the mixes with remaining dosages. This is due to the fromation of crystalls has enhanced with NAD that leads to reduction in water absorption. The water absorption of C-65_FA-35 is shown in Fig 6. C. It has achived higher water absorption at all ages than that of reamining mixes with lesser percentage of FA replacement. It indicates that, increase in FA replacement levels higher than 25% replacement increase in water absorption. Water absorption can be reduced by adding 0.25% NAD dosage in C-65_FA-35 mix also.

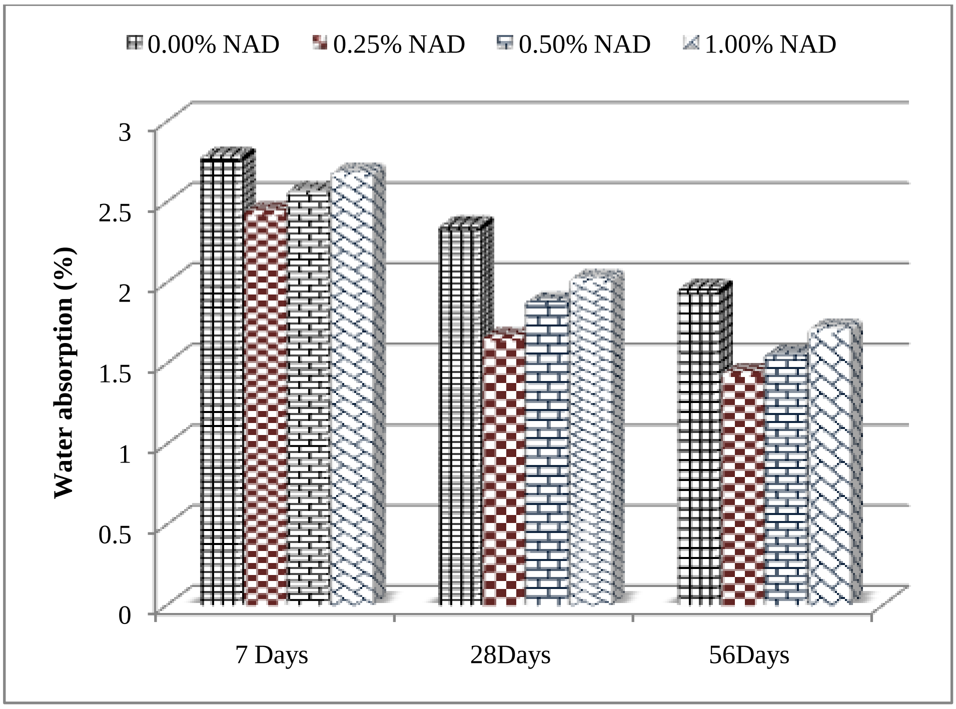

Figure 6.A. Water absorption of C-100_FA-0

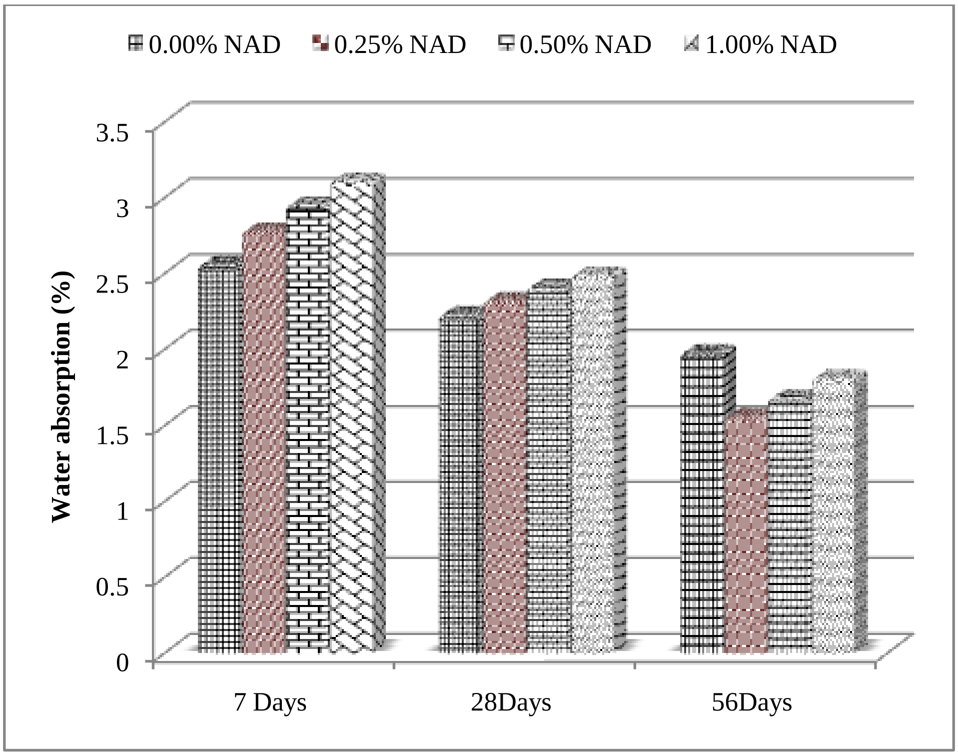

Figure 6.B. Water absorption of C-75_FA-25

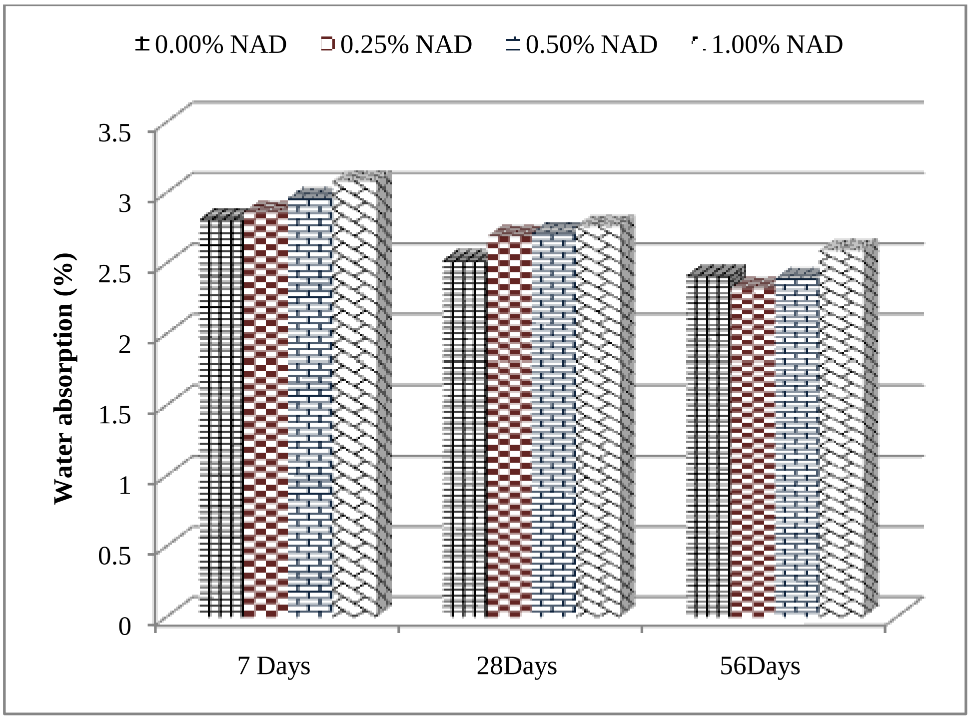

Figure 6.C. Water absorption of C-65_FA-35

5.3. Porosity of concrete

Porosity results were shown in Table 5 and shown graphically in Fig. 7.A and 7.B. At 7 days, the C-75_FA-0 mix 0.00% NAD has 5.75% porosity. Which is the lowest porosity among all the mixes at 7 days. Similar result to the water absorption. There by increase in the age at 28 days the C-100_FA-0 has 4.23% porosity with 0.25% NAD that is lower than remaining mixes with other NAD dosages. This is due to addition of NAD enhances the compressive strength that leads to filling of pores voids caused reduction in porosity. Ramesh and Neeraja [5-6] had reported that the addition of 0.25% NAD to CC mix has adversed effection on mechanical properities at early ages. At 56 days, C-75_FA-25 mix had achived lowest porosity (i.e 3.87)with 0.25% NAD. The formation of crystalls are enhanced by NAD, that leads to reduction in pore voids due to disrupting the connectivity of pores similar to the water absorption.

Table 5. Porosity of concrete

		0.00% NAD	**0.25% NAD**	**0.50% NAD**	**1.00% NAD**
C-100 _ FA-0	**7 Days**	6.15	5.57	5.84	5.96
	28Days	4.59	4.23	4.39	4.47
	56Days	4.24	3.95	4.06	4.15
C-75 _ FA-25	**7 Days**	5.75	6.11	6.18	6.25
	28Days	5.36	5.42	5.51	5.6
	56Days	4.35	4.12	4.28	4.33
C-65 _ FA-35	**7 Days**	5.89	6.19	6.23	6.32
	28Days	5.45	5.59	5.67	5.79
	56Days	4.56	4.23	4.42	4.53

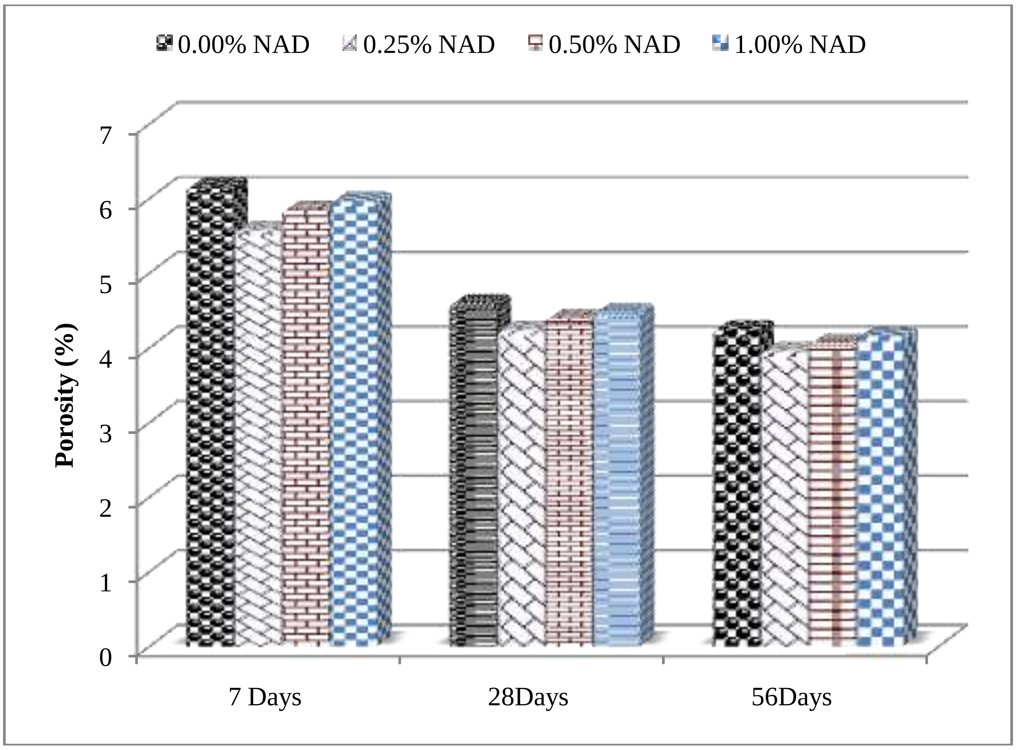

Figure 7.A. Porosity of C-100_FA-0

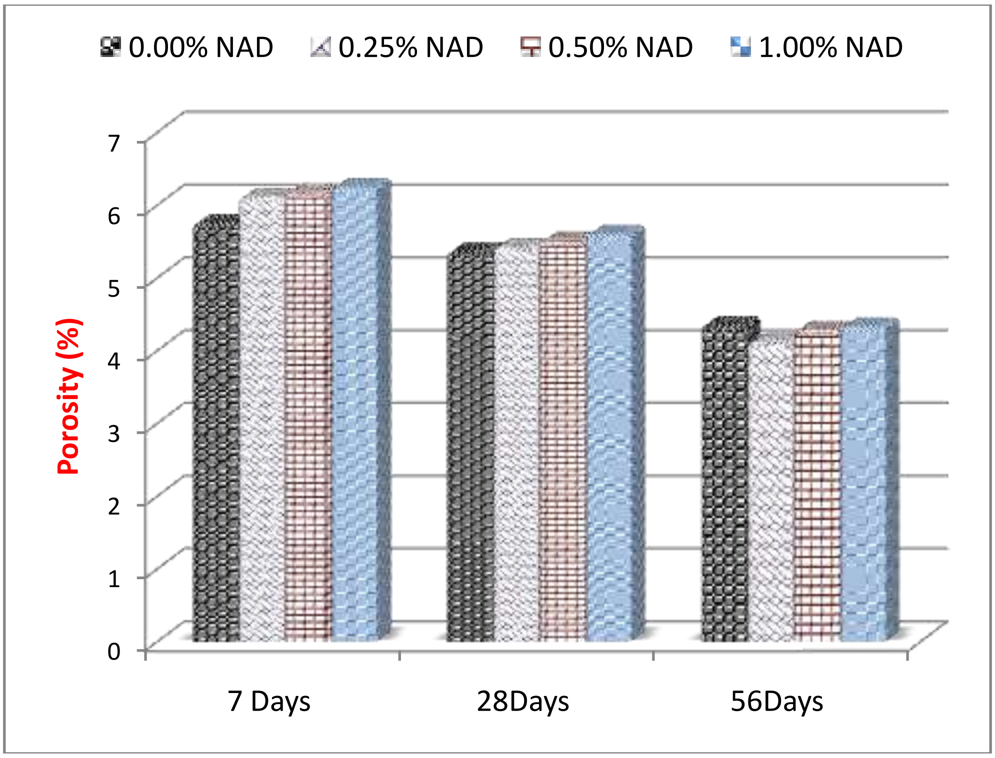

Figure 7.B. Porosity of C-75_FA-25

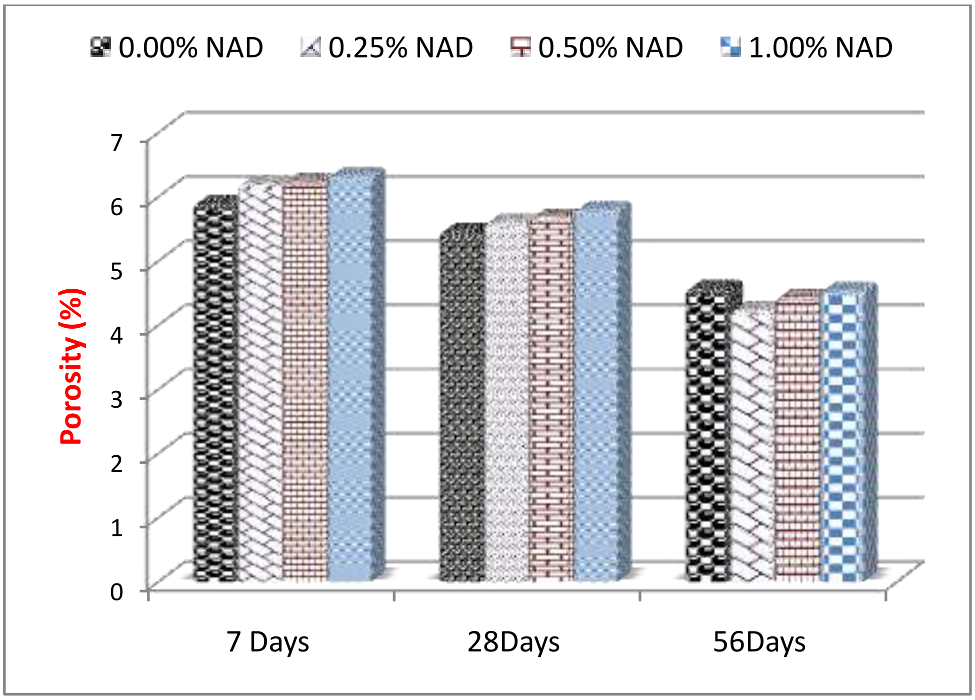

Figure 7.C. Porosity of C-65_FA-35

5.4. Acid attack of concrete

The compressive strength of concrete before and after immersion in 5% HCL at 7, 28 and 56 days were shown in Table 6 of CC and FA mixes. The percentage loss in compressive strength at 7, 28 and 56 days were calculated and showed in Table 6 and Fig 8. The mix C-75_FA-25 has 2.98%, 4.72% and 7.53% at 7, 28 and 56 days respectively with 0.25% NAD dosage, which lowest than that of all the mixes. The percentage loss in compressive strength was decreases by adding 0.25% NAD in both CC and FA mixes. It was increased with increase in age in all the mixes. But the percentage increments were reduced from 7 to 28 days and 28 to 56 days.

Table 6. Percentage loss of compressive strength in 5% of HCL

	(Before immersion)		**(After immersion)**		**% loss of compressive strength**	
NAD	**0.00%**	**0.25%**	**0.00%**	**0.25%**	**0.00%**	**0.25%**
C-100 _ FA-0						
7 Days	21.11	34.44	20.23	33.56	4.17	2.56
28Days	35.56	42.89	32.94	40.56	7.37	5.43
56Days	37.78	46.89	34.15	43.12	9.61	8.04
C-75 _ FA-25						
7 Days	22.75	19.47	22.05	18.89	3.08	2.98
28Days	33.36	31.96	31.17	30.45	6.56	4.72
56Days	36.12	40.22	32.95	37.19	8.78	7.53

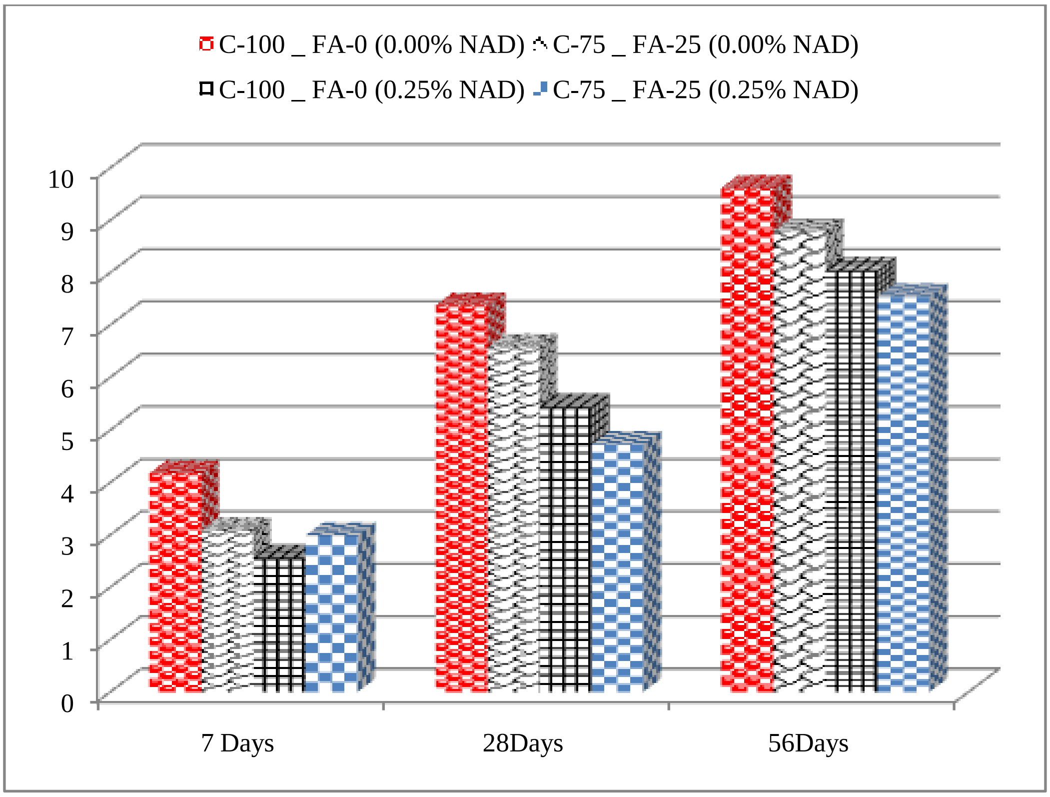

Figure 8. Percentage loss of compressive strength in 5% of HCL

Table 7.Shows the compressive strength of concrete before and after immersion in 5% H_2SO_4 at 7, 28 and 56 days. The percentage loss in compressive strength at 7, 28 and 56 days were calculated and showed in Table 7 and Fig 9. At 7 days the CC mix with 0.25% NAD has 23.20%, which is lower % loss of compressive strength than that of remaining mixes with remaining NAD dosages. It is because due to early strength in CC that has enhanced with NAD [5]. The mix C-75_FA-25 has 24.19% and 26.83% at 28 and 56 days respectively with 0.25% NAD dosage, which lowest than that of all the mixes. The percentage loss in compressive strength when immersed in $H_2SO_4$was decreases by adding 0.25% NAD in both CC and FA mixes. It was increased with increase in age in all the mixes.

Table 7. Percentage loss of compressive strength in 5% of H_2SO_4

	(Before immersion)		**(After immersion)**		**% loss of compressive strength**	
NAD	**0.00%**	**0.25%**	**0.00%**	**0.25%**	**0.00%**	**0.25%**
			C-100 _ FA-0			
7 Days	21.11	34.44	15.69	26.45	25.68	23.20
28Days	35.56	42.89	25.54	31.56	28.18	26.42
56Days	37.78	46.89	26.23	32.97	30.57	29.69
			C-75 _ FA-25			
7 Days	22.75	19.47	17.36	13.12	23.69	32.61
28Days	33.36	31.96	24.65	24.23	26.11	24.19
56Days	36.12	40.22	26.21	29.43	27.44	26.83

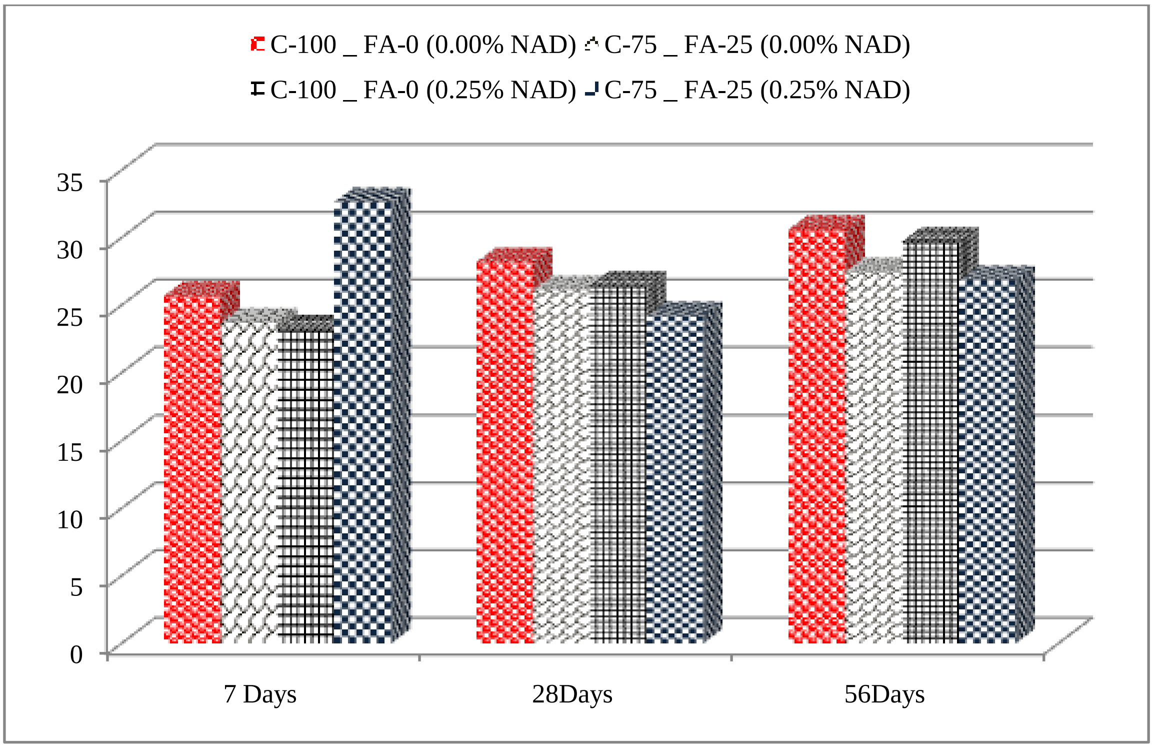

Figure 9. Percentage loss of compressive strength in 5% of H_2SO_4

V. CONCLUSIONS

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

1. The durability properties of Conventional Concrete (CC) and Class F fly ash (FA) blended mixes was very much significantly increased at 0.25% NAD dosage. So that it can be concluded as 0.25% NAD is optimum dosage for CC and FA blended mixes.
2. The 25% FA replacement mix has achieved designed compressive strength of M25, so that 25% Class C fly ash can be considered as optimum replacement level.
3. The C-75_FA-25 mix with optimum dosage has achieved higher strength at later ages.
4. 25% FA replacement of Class C fly ash achieved lower water absorption and porosity.
5. C-75_FA-0 mix has higher resistance to acid attach for both HCL and H_2SO_4 with 0.25% of NAD
6. The % loss of compressive strength is reduced by adding optimum dosage of NAD with 25% replacement of Class C fly ash.
7. The durability properties of CC and FA concrete mixes are improved with optimum dosage of NAD
8. 25% of Class C fly ash replacement can be recommended with 0.25% of NAD addition.

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