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RESEARCH ARTICLE

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# EFFECT OF NATURAL ADMIXTURE ON COMPRESSIVE STRENGTH, FLEXURAL STRENGTH AND BOND STENGTH OF CLASS C FLY ASH BLENDED CONCRETE

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**ABSTRACT**

This research work focus on Compressive strength, flexural strength and Bond strength of Conventional Concrete (CC) and Class C fly ash blended concrete incorporation with Natural Admixture. Broiler hen egg was used as Natural admixture (NAD) to study the effect of NAD on strength properties. The Class C fly ash was replaced to cement at various levels and NAD was replaced to liquid and identified the optimum replacement level of Class C fly ash and optimum dosage of NAD by maintaining the constant liquid constant 0.55 to achieved M20 grade concrete. The compressive strength, flexural strength and bond strength of concrete for both CC and FA concrete. The studies reveal that the optimum replacement of Class C fly ash is 25% and optimum dosage of NAD is 0.25% based on strength results.

**Keywords:** Natural admixture; Class C fly ash; compressive strength; Flexural strength and bond strength.



## 1. INTRODUCTION

The rapid development of constructional activities lead to increase in cement usage. The major problem in usage of cement in bulk quanity, that leads to liberation of green house gas ($CO_2$). The $CO_2$ causes to global warming and continues mining and extraction of lime stone leads to unnecessary problems to environment. Therefore researches are concentrates on sustainable materials. In this scenario chemical and mineral admixtures were introduced.

Before invention of chemical and mineral admixtures our ancients were use some more natural products like surkhi, burnt coconut shells, mud, clay, starch, jaggrey, lime and egg. Amount those products broiler hen egg was chosen as one of the admixture in this research.

## 2. LITERATURE REVIEW

Ramesh Babu and Neeraja [1] had revealed that NAD was acting as accelerator when added to binder and also concluded that the 0.25% was optimum dosage of NAD. Class C fly ash with 0.25% NAD was attained higher strength than that of all FA replaced mixes. Ramesh Babu et al [2] had concluded that all mechanical properties of conventional and Class C fly ash blended concrete exhibits same trend like compressive strength at optimum dosage. Hanifi Binici et al. [3] concluded that replacement of egg shell powder in sand leads to decrease in compressive strength and flexural

strength, but it exhibits resistance against radiation effect.

## 3. EXPERIMENTAL STUDY

### 3.1 Materials

This research concentrates on the study of NAD effect on compressive strength, flexural strength and bond strength of CC and Class C fly ash blended concrete. Class C fly ash was replaced to cement by its weight 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% and 1.5% to the weight of cementitious material, by maintaining the liquid to binder ratio at 0.55. This study concentrates on Unit weight, compressive strength, flexural strength and bond strength of convention concrete (CC) and Class C fly ash (FA) blended concrete.

### 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 [4]. 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 $C_3A>5.0$<br>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), Egg white albumen and yellow yolk was thoroughly mixed and added to concrete. The NAD was replaced to water at various replacement levels 0%, 0.25%, 0.5%, 1.00% and 1.5% of cementitious material weight by maintaining the liquid to binder ratio (0.55).

#### 3.2.3 Mineral admixture

Class C fly ash (FA) was used as an additive according to ASTM C 618 [5]. 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 |

**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 [6]. Fig. 1 and 2 shows the gradation of 20 mm and 10 mm respectively. The coarse aggregate was blended with 20mm (60%) and 10mm (40%) to its total weight of coarse aggregate.

**3.2.5 Fine aggregate**

The Swarnamuki river sand was used as fine aggregate. The specific gravity was 2.62 and water absorption of the fine aggregate was 0.325%. Sieve analysis was conducted as per IS 383:1970 [6] and gradation of fine aggregate is shown in Fig. 3 and confirmed to zone - III sand [6].

**3.2.6 Water**

The ordinary tap water was used in present study which satisfies water standards as per IS 456 – 2000 [7].

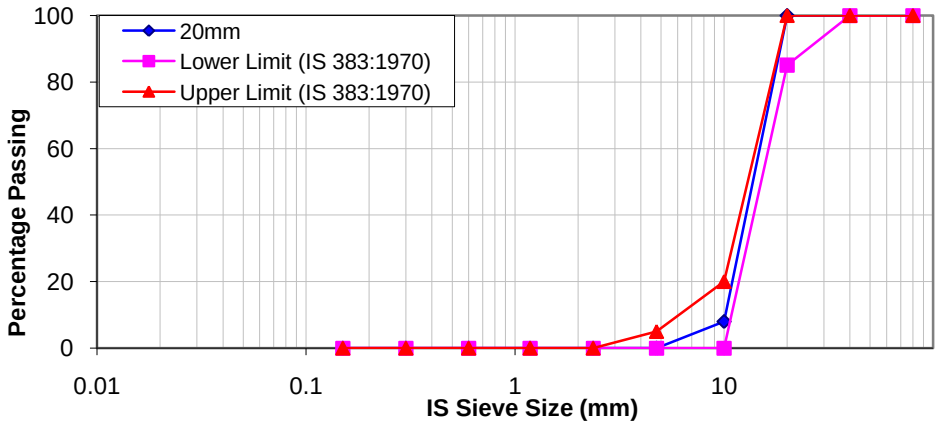


Figure 1. Grading curve of 20 mm coarse aggregate

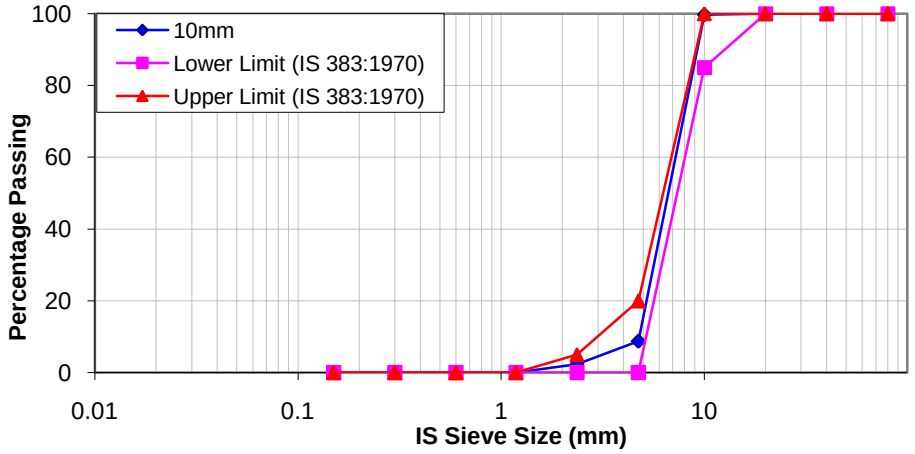


Figure 2. Grading curve of 10 mm coarse aggregate

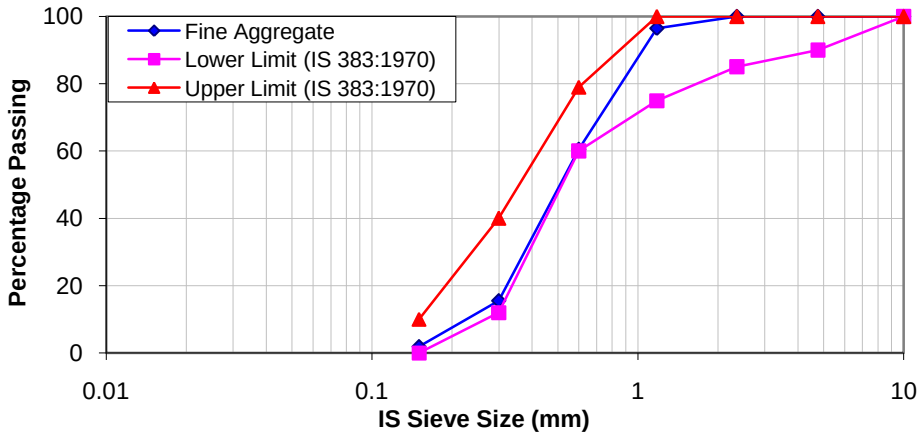


Figure 3. Grading curve of fine aggregate

**4. EXPERIMENTAL PROCEDURE**

**4.1 Mix design**

M 20 grade of conventional concrete (CC) was designed as per IS 10262-2009 [8] and IS 456-2000 [7]. The desired strength of M 20 grade of CC was about 26.6 MPa after 28 days of curing. Class C fly ash blended mixes were prepared using the designed M 20 grade of CC by replacing the cement with FA at various levels of 0%, 25%, 35% and 45% of CC cement weight. In both CC and FA blended concrete, NAD was replaced in water at various dosages of 0%, 0.25%, 0.5%, 1.0% and 1.5% of cementitious material weight by maintaining constant liquid – binder ratio (0.55) which affects the compressive strength [7]. Here, liquid refers to water content with or without egg replacement and binder refers to cementitious content. The design mix proportions are shown in Table 4.

Table 4 Mix design

| 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 | 198.00 | 0.00 | 0.00 |
| | | | | | 197.10 | 0.25 | 0.90 |
| | | | | | 196.20 | 0.5 | 1.80 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | 194.40 | 1.00 | 3.60 |
| | | | | | 192.60 | 1.50 | 5.40 |
| | | | | | 198.00 | 0.00 | 0.00 |
| | | | | | 197.10 | 0.25 | 0.90 |
| C-75_FA-25 | 270 (75%) | 90 (25%) | 745 | 1150 | 196.20 | 0.50 | 1.80 |
| | | | | | 194.40 | 1.00 | 3.60 |
| | | | | | 192.60 | 1.50 | 5.40 |
| | | | | | 198.00 | 0.00 | 0.00 |
| | | | | | 197.10 | 0.25 | 0.90 |
| C-65_FA-35 | 234 (65%) | 126 (35%) | 745 | 1150 | 196.20 | 0.50 | 1.80 |
| | | | | | 194.40 | 1.00 | 3.60 |
| | | | | | 192.60 | 1.50 | 5.40 |
| | | | | | 198.00 | 0.00 | 0.00 |
| | | | | | 197.10 | 0.25 | 0.90 |
| C-55_FA-45 | 198 (55%) | 162 (45%) | 745 | 1150 | 196.20 | 0.50 | 1.80 |
| | | | | | 194.40 | 1.00 | 3.60 |
| | | | | | 192.60 | 1.50 | 5.40 |

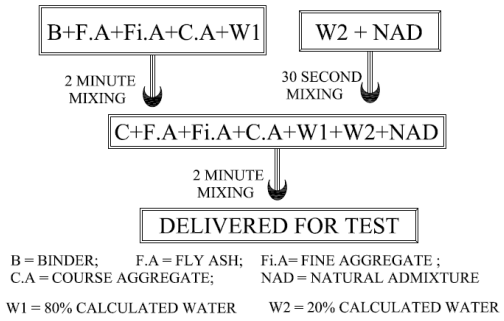


Figure 4. Mixing process of concrete ingredients

**4.2 Testing hardened properties of concrete**

Three cubes size 150 mm were cast and tested for unit weight and compressive strength for each age and each mix [9]. Three beams of size 700 mm × 150mm × 150 mm were cast and tested for flexural strength [10] and three cylinders of size 150mm dia and 300 mm height were casted by inserting the reinforcement to test the bond strength [11] as shown in Fig.7 for each age and each mix. The average of three samples was calculated respectively for each property. The weight and volume of cylindrical specimens were measured before compression test and from that unit weight of concrete ($\gamma_c$) was determined for 7, 28 and 56 days of curing. The failue samples were showed in Fig. 5, Fig. 6 and Fig 7.

The bond strength of designed mix was calculated from following formula

$$\sigma_b = \frac{P}{\pi DL}$$

Where $\sigma_b$ = Bond strength of concrete;

P= Load

D = diameter of the rod

L= Inserted length of the rod

Figure 5. Compression Failure of cube


Figure 6. Beam flexural test

Figure 7. Bond strength set up

**5. Results and Discussion**

**5.1. Unit weight of hardened concrete**

The calculated unit weight of CC and FA mixes are shown in Table 5. The unit weight of Conventional Concrete (CC) have been significantly increased from 0.00% to 0.25% of NAD replacement at all curing periods shown in Table 5, thereby NAD the decrease in unit weight was observed. The increment of compressive strength lead to increase in unit weight of concrete.

In fly ash (FA) blended mixes, the unit weight of concrete at all replacement levels of fly ash, was increased gradually up to 35% fly ash replacement without NAD. Thereby decrease in unit weight was observed by increase in fly ash replacment at all ages. The decrease in unit weight was observed by adding NAD to FA mixes at 7 and 28 days for all the mixes. After 28 days the increase in unit weight was observed in FA mixes at 0.25% NAD than that of without NAD. Thereby increaseing the NAD dosage decreasing in unit weight was observed. C-65_FA-35 mix attained highest unit weight after 28 days with 0.25% NAD dosage. This shows NAD has significant effect to increase unit weight at 0.25% NAD dosage with 35% FA replacement mix after 28 days curing. From the unit weight, 0.25% NAD can be consider as optimum dosage, because the increase in NAD dosage decrease in unit weight indicates formation of voids due to excess dosage of NAD.

Table 5: Unit weight of concrete (Kg/M$^3$)

| **NAD Quantity C-100 _ FA-0** | **0%** | 0.25% | **0.50%** | **1.00%** | **1.50%** |
|---|---|---|---|---|---|
| **7 Days** | 2314.147 | 2354.842 | 2349.466 | 2343.907 | 2342.122 |
| **28Days** | 2328.278 | 2377.392 | 2367.274 | 2361.235 | 2349.283 |

| | | | | | |
|---|---|---|---|---|---|
| **56Days** | 2345.232 | 2379.955 | 2376.317 | 2368.858 | 2358.566 |
| **C-75 _ FA-25** | | | | | |
| **7 Days** | 2322.653 | 2305.334 | 2302.906 | 2295.725 | 2289.254 |
| **28Days** | 2332.56 | 2314.992 | 2311.152 | 2307.523 | 2301.936 |
| **56Days** | 2339.99 | 2350.061 | 2344.867 | 2335.171 | 2322.547 |
| **C-65 _ FA-35** | | | | | |
| **7 Days** | 2326.531 | 2301.619 | 2293.891 | 2286.211 | 2277.552 |
| **28Days** | 2336.227 | 2308.522 | 2301.552 | 2296.752 | 2286.355 |
| **56Days** | 2339.28 | 2345.885 | 2339.789 | 2326.762 | 2316.144 |
| **C-55 _ FA-45** | | | | | |
| **7 Days** | 2329.901 | 2286.384 | 2276.765 | 2269.613 | 2267.251 |
| **28Days** | 2332.042 | 2300.592 | 2296.675 | 2291.29 | 2280.461 |
| **56Days** | 2335.469 | 2341.2 | 2331.11 | 2322.595 | 2307.475 |

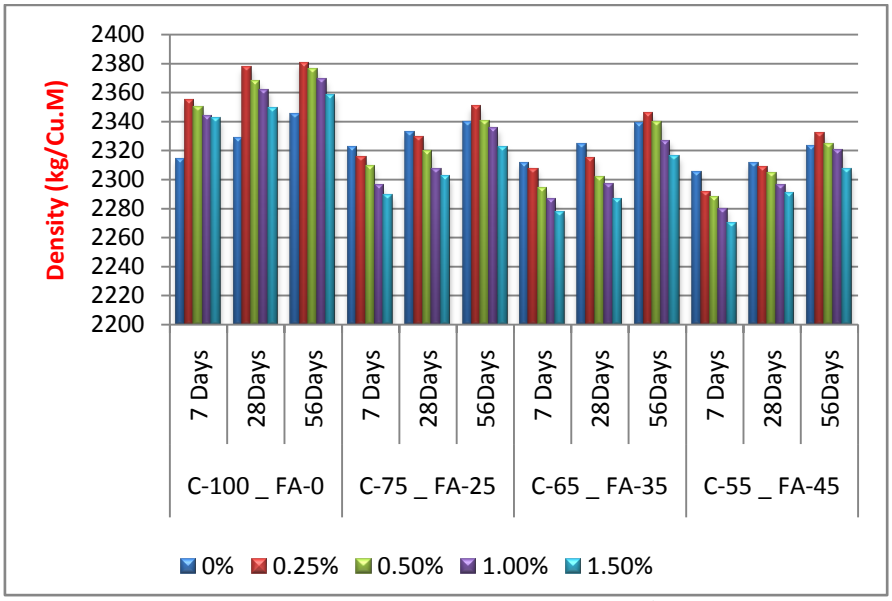


Figure 8. Unit weight of concrete (kg/m$^3$)

**5.2. Compressive strength**

The compressive strength of the concrete cubes was showed in Table 6 and showed in Fig 9. From the results it is observed, increase in compressive strength with increase in Class C fly ash up to 35% fly ash replacement at 7 days of curing, thereby increasing the FA beyond 35% decrease in compressive was observed without NAD. The Class C fly ash contains high calcium content that leads to development of early strength in Class C fly ash mixes than that of CC mixes [12-14].

In CC mixes the compressive strength was significantly increased at 0.25% NAD at all the ages when compared with 0.00% NAD dosage mix. The 7 days compressive strength of CC with 0.25% is greater than 28 days designed strength. It shows that the NAD acts as accelerator to get designed 28 days strength of CC at 7 days of curing. Thereby increasing the NAD dosage decreasing the strength was observed. This is due to excess dosage of NAD leads to formation air voids and porous in concrete, it can be concluded from decreasing in unit weight.

Where as in FA mixes the decrease in compressive strength was observed with increasing fly ash at 7 and 28 days with addition of NAD. After 28 days a rapid increase in compressive strength was observed at 0.25% NAD dosages for all FA mixes that is greater than without NAD dosage FA mixes. This shows that NAD involves developing the strength in FA mixes after 28 days curing. The mix C-75_FA-25 mix

attained higher compressive strength at 0.25% NAD dosage than that of remaining FA mixes at 56 days, which is greater CC mixes.

Table 6. Compressive strength of concrete cube

| NAD Quantity | 0.00% | 0.25% | 0.50% | 1.00% | 1.50% |
|---|---|---|---|---|---|
| | | | **C-100_FA-0** | | |
| **7 Days** | 17.11 | 29.87 | 25.03 | 21.23 | 16.02 |
| **28Days** | 28.56 | 35.92 | 30.81 | 27.39 | 20.16 |
| **56Days** | 32.04 | 38.09 | 35.69 | 32.95 | 26.03 |
| | | | **C-75_FA-25** | | |
| 7 Days | 18.56 | 15.94 | 15.69 | 12.07 | 11.09 |
| 28Days | 27.36 | 25.96 | 22.22 | 18.22 | 16.89 |
| 56Days | 29.91 | 34.06 | 32.087 | 30.57 | 20.16 |
| | | | **C-65_FA-35** | | |
| 7 Days | 20.41 | 15.45 | 14.94 | 11.78 | 10.74 |
| 28Days | 24.44 | 22.47 | 18.96 | 16.26 | 15.54 |
| 56Days | 26.47 | 28.12 | 26.79 | 19.93 | 18.04 |
| | | | **C-55_FA-45** | | |
| 7 Days | 19.57 | 13.42 | 12.64 | 10.09 | 10.14 |
| 28Days | 22.67 | 22.03 | 17.96 | 14.78 | 14.18 |
| 56Days | 24.22 | 26.67 | 25.96 | 21.91 | 20.4 |

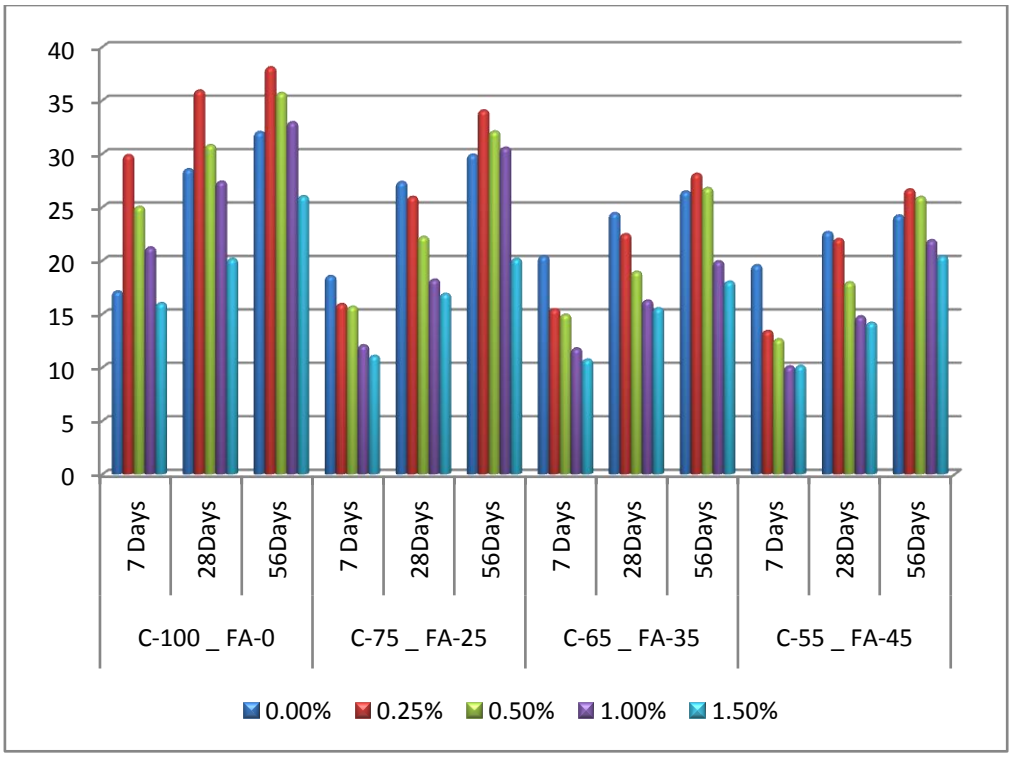


Figure 9. Compressive strength of concrete

**5.3 Flexural strength**

The flexural strength of CC and FA blended mixes were showed in Table 7 and Fig 10. The flexural strength of CC concrete was increased with increase in age with and without NAD. The flexural strength of CC mix with 0.25% NAD achieved higher flexural strength than that of without NAD, which is similar to compressive strength. The compressive strength is main function of all properties of concrete. The increases in Class C fly ash dosage increases in flexural strength was observed up to 35% fly ash replacement without NAD dosage at 7 days, that is greater than CC strength. This is due to Class C fly ash effect, it having early strength gaining capacity [14]. The decrease in strength was observed with addition of NAD to FA mixes at 7 and 28 days. After 28 days all the FA mixes at 0.25% NAD dosage achieved highest strengths than that of remaining dosages. The mix C-75_FA-25 with 0.25% NAD mix attained highest strength than that of CC mix without NAD mix and also it is the highest among remaining FA mixes. The increase in NAD dosage more than 0.25% NAD decrease in strength was observed in all mixes after 28 days.

At 56 days the CC mixes achieved highest flexural strength than that of remaining FA blended mixes without NAD. From 0.00% NAD to 0.25% NAD dosage all the mixes flexural strength was increases there by increasing the NAD dosage decrease in strength was observed. Among all the mixes the CC with 0.25% NAD mix achieved higher strengths than that of remaining mixes and remaining NAD dosages.

Studies concluded that addition of NAD improves the flexural strength of concrete. Addition of admixtures or higher finer materials has higher influence on flexural strength of concrete [15].

The relationship between compressive strength and flexural strength was showed in Fig 11. From the result and Fig 11 the flexural strength increases with increase in compressive strength.

Table 7. Flexural strength of concrete (MPa)

| NAD Quantity | 0% | 0.25% | 0.50% | 1.00% | 1.50% |
|---|---|---|---|---|---|
| **C-100_FA-0** | | | | | |
| **7 Days** | 3.08 | 4.09 | 3.67 | 3.31 | 2.79 |
| **28Days** | 4.17 | 4.49 | 4.18 | 3.99 | 3.52 |
| **56Days** | 4.23 | 4.72 | 4.44 | 4.26 | 3.79 |
| **C-75_FA-25** | | | | | |
| **7 Days** | 3.19 | 2.97 | 2.92 | 2.63 | 2.49 |
| **28Days** | 3.91 | 3.82 | 3.53 | 3.29 | 3.19 |
| **56Days** | 4.07 | 4.39 | 4.31 | 4.09 | 3.39 |
| **C-65_FA-35** | | | | | |
| **7 Days** | 3.29 | 2.87 | 2.79 | 2.57 | 2.51 |
| **28Days** | 3.77 | 3.62 | 3.41 | 3.07 | 2.97 |
| **56Days** | 3.82 | 3.96 | 3.89 | 3.42 | 3.21 |
| **C-55_FA-45** | | | | | |
| **7 Days** | 3.21 | 2.63 | 2.57 | 2.39 | 2.29 |
| **28Days** | 3.67 | 3.49 | 3.28 | 3.07 | 2.81 |
| **56Days** | 3.75 | 3.92 | 3.82 | 3.57 | 3.31 |

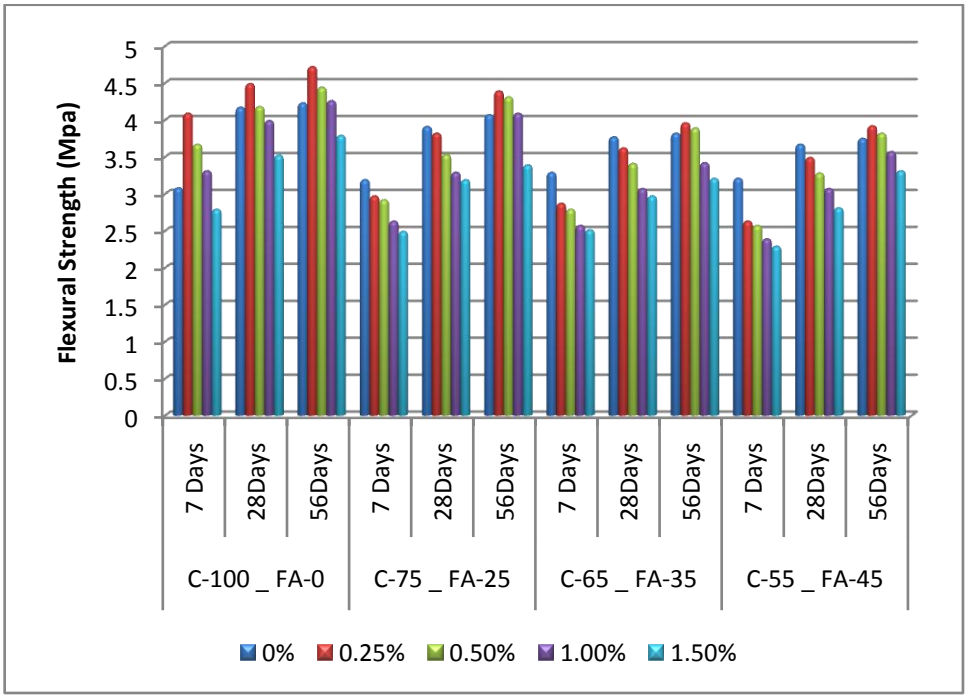


Figure 10. Flexural strength of concrete beam

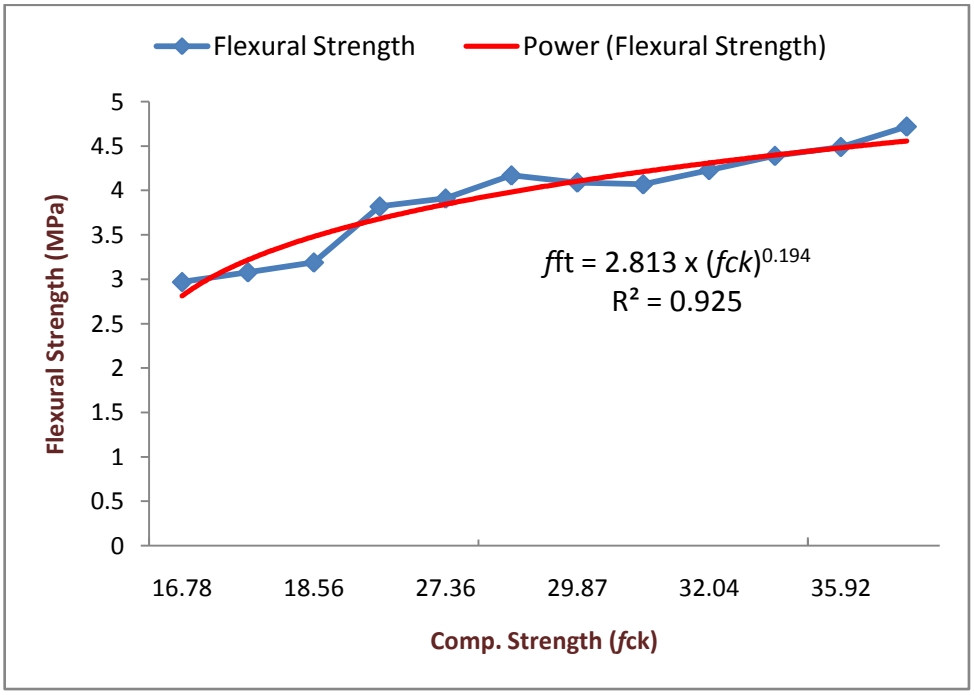


Figure 11. Relationship between compressive strength and flexural strength

**5.4. Bond strength**

The bond strength of all the mixes was showed in Table 8 and Fig 12. From the results the bond strength of CC mixes increases with increase in age for all the ages with and without NAD. The bond strength of C-100_FA-0 with 0.25% NAD achieved higher strength than that of without NAD dosage, thereby increasing the NAD dosage the decrease in bond strength was observed at all the ages. The bond strength of C-100_FA-0 mix with 0.25% NAD was 32.12%, 12.14% and 9.03% higher that of without NAD at 7, 28 and 56 days.

Where as in FA blended mixes increase in Class C fly ash bond strength increases up to 35% replacement at 7 days without NAD dosage and decrease in strength was observed with addition of NAD for all NAD dosages. At 28 days all FA mixes, 25% replacement of achieved higher strength but it is less than C-100_FA-0 mixes at 28 days. The same decrease in bond strength was observed by addition of NAD to FA mixes at 28 days also. At 56 days increase in bond strength was observed for all FA blended mixes. C-75_FA-25 mix achieved higher strength at 0.25% NAD than that of without NAD dosage. That is 6.71% higher than that of without NAD dosage. It is clearly observed that up to 28days the addition of NAD decreases the bond strength for Class C fly ash mixes, after 28 days of curing the NAD has effetely involved in development of compressive strength, flexural strength and bond strength. The same increasing trend was observed in all FA replacement mixes with 0.25% NAD after 28 days of curing.

Table 8. Bond strength of concrete (GPa)

| NAD Quantity | 0.00% | 0.25% | 0.50% | 1.00% | 1.50% |
|---|---|---|---|---|---|
| | | | **C-100_FA-0** | | |
| **7 Days** | 6.20 | 8.20 | 7.50 | 6.91 | 6.00 |
| **28Days** | 8.02 | 8.99 | 8.33 | 7.85 | 6.73 |
| **56Days** | 8.49 | 9.26 | 8.96 | 8.61 | 7.65 |
| | | | **C-75_FA-25** | | |
| **7 Days** | 6.46 | 5.99 | 5.94 | 5.21 | 5.00 |
| **28Days** | 7.85 | 7.64 | 7.07 | 6.40 | 6.16 |
| **56Days** | 8.20 | 8.75 | 8.50 | 8.29 | 6.73 |
| | | | **C-65_FA-35** | | |
| **7 Days** | 6.78 | 5.90 | 5.80 | 5.15 | 4.92 |
| **28Days** | 7.42 | 7.11 | 6.53 | 6.05 | 5.91 |
| **56Days** | 7.72 | 7.95 | 7.76 | 6.70 | 6.37 |
| | | | **C-55_FA-45** | | |
| **7 Days** | 6.64 | 5.49 | 5.33 | 4.76 | 4.78 |
| **28Days** | 7.14 | 7.04 | 6.36 | 5.77 | 5.65 |
| **56Days** | 7.38 | 7.75 | 7.64 | 7.02 | 6.77 |

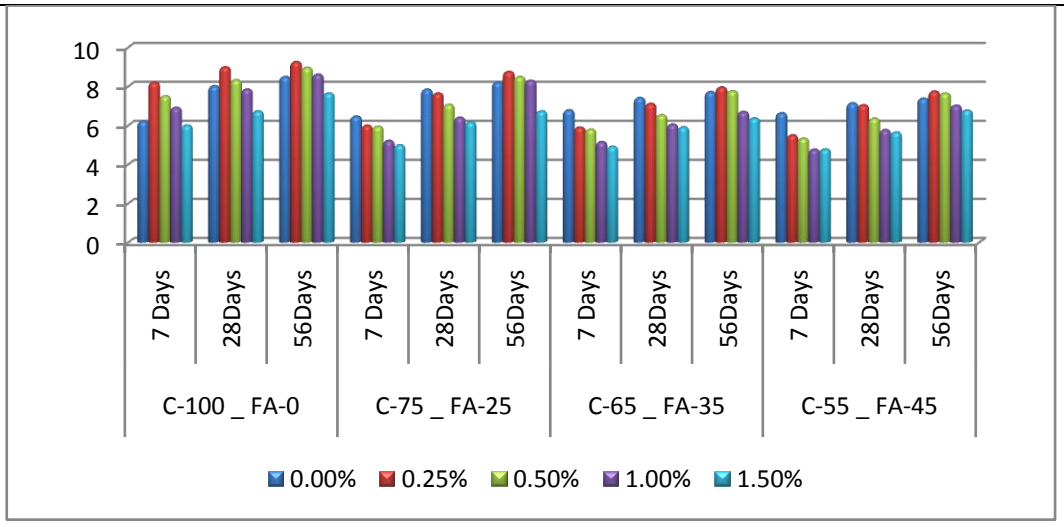


Figure 12. Bond strength of concrete

**5. Conclusions**

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

1. The unit weight of CC and FA mixer were high at 0.25% NAD, so it can be concluded as optimum doasge.
2. NAD effectively involved to achived 28 days designed strength of M20 grade concrete mix at 7 days of curing with 0.25% NAD doasage.
3. So that NAD can be used as accelerator to enhance the hydration.
4. The flexural strength of CC and FA was increased with 0.25% NAD dosage. The flexural strength of C-75_FA-25 mix attained higher strength than that of remaining FA blended mixes.
5. The bond strength of CC and FA also increases with increase in NAD dosage up to 0.25%, thereby decrease in bond strength indicates 0.25% NAD is optimum dosage based on all the strength properties.
6. The 25% Class C fly ash can be recommended to get design strength of M20 grade concrete.
7. The NAD also increases the flexural strength and bond strength of the both CC and FA concrete.

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