An Experimental Investigation of Natural Admixture Effect on Durability Studies of High Silica Fly Ash

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Abstract: The research work focused on durability studies of high silica fly ash i.e. class f fly ash (fa) replaced concrete with natural admixture (nad) incorporation with binder. broiler hen egg selected as natural admixture in this experimental investigation. fa was replaced to cement at different replacement levels from 0 to 35% of replacement by its weight and nad was used as supplementary material admixture in fa replaced concrete at different replacement dosages from 0% to 1.00% by its weight of water content and 0.5 was maintained as liquid to binder ratio. the durability studies (i.e. water absorption and acid attack) of fa replaced concrete mix were examined at different ages of curing for all fa replaced mixes with nad. the research revealed that the optimal dosage of nad was considered as 0.25% for all fa replaced concrete, witnessed from the compressive strength, unit weight, water absorption and acid resistance studies. the studies evidenced that 35% high silica fa replaced concrete mix with optimal nad dosage having lower water absorption and also it shown that the % of loss in compressive strength reduced when soaked in HCL and H2SO4 water sample.

Keywords: Natural Admixture; High Silica Fly Ash, Compressive Strength, Unit weight, water Absorption and Acid Resistance.

1. Introduction
The quick growth of construction industry primes to huge consumption of cement causes emission of greenhouse gas (CO2) into environment and that causes the global warming. To reduce the emission of CO2, the supplementary cementious material was introduced and vast investigation is going on over those materials. The supreme of the research was stated that the 35% fly ash as optimum replacement that can be replaced to cement to attain the designed strength with reducing the emission of CO2 percentage. It evident that further reduction of cement utilization by introducing the supplementary materials like pozzolanic materials and by products, additives or admixtures.

This research concentrates on durability studies i.e. water absorption and acid attack illustrates with percentage loss of concrete compressive strength soaked in HCL and H2SO4 of concrete with high
silica fly ash replaced mixes and with Natural Admixture incorporation and also identified optimal replacement of FA to enhance the durability action with optimum dosage of NAD.

2. Literature Review
Ramesh Babu and Neeraja [1] discovered that addition of NAD to binder enhances the strength of high calcium FA, it performances as an accelerator. The binder fresh and mechanical properties were considered to optimize the NAD dosage of conventional and high calcium FA concrete and reported that 0.25% NAD replacement dosage as optimal dosage for all replacement of FA. Due to more viscous property of NAD and fly ash concrete setting and the workability of concrete was dropped. Ramesh Babu et al [2&3] recounted that the conventional and high calcium FA replaced concrete mechanical properties will improved at optimal dosage of NAD. 25% replacement of high calcium FA concrete with optimal dosage achieved designed M25 concrete strength with optimal NAD dosage.

3. Experimental Work
3.1 Ingradients
The research is dedicated to study the Natural Admixture (NAD) effect on compressive strength unit weight and durability studies of conventional and high silica fly ash (i.e. Class F) blended concrete. The high silica FA was replaced to OPC cement by considering its weight to replacement levels from 0%, to 35%. NAD was mixed with water at different dosages levels of 0% to 1.00% to the cementitious material weight and the fixed liquid (vs) binder ratio (i.e. 0.5) was retained. Concrete compressive strength was considered to optimize FA replacement level. The durability studies were explained with water absorption and acid resistance of conventional and FA replaced concrete. The optimal replacement dosage of FA with NAD was fixed by considering the M25 grade concrete target strength.

4. Experimental Procedure
4.1 Mix design
The Conventional Concrete (CC) was designed for M25 grade was conforming to IS 10262-2009 [4] and IS 456:2000 [5] and its target strength was pinned as 32.6 MPa. The different replacement levels of high silica FA was considered from 0% to 45% to weight of cementitious materials calculated for M25 grade CC concrete mix weight. CC and FA replaced concrete, NAD replaced to water at different replacement dosages from 0% to 1.00% and maintained constant liquid-binder ratio as 0.5. Liquid stated that water with and without NAD, binder stated that cementitious material (i.e. cement and fly ash). The mix proportions of ingredients were shown in Table 01.

| Sample Notation | Cement (Kg) | Fly Ash (Kg) | Fine aggregate (Kg) | Course aggregate (Kg) | Water (lts) | % of NAD | Pquette 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                |
4.2 Test Methods

4.2.1 Compressive Strength

According to Bureau of Indian Standards (IS : 516) [6], the specimen compressive strength was calculated. 150 mm cubical specimens of three samples were cast and that were used for determination of compressive strength at 7, 28 & 56 for each designed mix.

4.3 Testing of durability properties

4.3.1 Water absorption

Cylindrical samples of size 100 mm dia with 50mm thick were cast and soaked in water for the designed period of all mixes. After designed period the samples were removed from curing tank and it kept in oven for 24 hour at 100° C temperature to escaping the moisture, until the mass of the specimens becomes constant and then the corresponding weight is noted as (W1). Then the samples were transferred into hot water at 85oC for 210 mints. After cooling of specimens, it was removed and wiped out the surface water and noted the corresponding weight as (W2). The equation 0.1 illustrates the percentage of water absorption.

\[
\% \text{ water absorption} = \left( \frac{W_2 - W_1}{W_1} \right) \times 100 \quad \text{(Eq.01)}
\]

4.3.2 Acid Resistance Test

Acid resistance of concrete specimens was determined. 150mm concrete cubes were cast and allowed for curing in water up to designed soaking period. After curing in water, the specimens were transferred from water to testing platform and allowed for drying preferably up to 24 hours. The 5% of HCL acid water sample was prepared and another acid water sample 5% of H2SO4 was prepared. After preparation of acid water samples, the cube specimens were separately soaked in prepared acid water samples in HCL and H2SO4. The pH of acid water sample was maintained constant by regularly changing the acid water sample. After completion of design soaking period in acid water sample, the specimens were removed and the specimen surfaces were cleaned with dry cloth. After evaporation of adsorbed water the specimens were used to calculate the % loss of compressive strength.

5. Results and Discussions

5.1 Compressive Strength of Concrete

The compressive strength of cubical specimens (fc) of CC and high silica FA replaced concrete were presented in Figure 1. The concrete strength decreased with increase in Class F FA replacement levels at its early curing period (i.e. at 7 days). In conventional concrete with 0.25% NAD significantly improved the compressive strength, it witnesses that at all period of curing when compared that to without NAD (i.e. 0%) dosage, as illustrated in Figure 1. The strength of CC, at 7 days of curing 72.04% of strength was increased (i.e. from 20.57 MPa to 35.66 MPa) with collaboration with 0.25% NAD dosage. The strength increment was due to incorporation of calcium present in NAD enhanced the hydration to develop C-S-H(gel) in CC mix. It perceived that the 28 days target strength of M25 grade CC (i.e. 32.6 MPa) was attained in 7 days of curing with 0.25% NAD. Hence, it can be resolved that NAD acts as accelerator, when it is added to the binder. The strength increment was continuous with increasing of the curing age, but the strength increment percentage was compact with increase in curing age.
The strength increments in C-100_FA-0 mixes (i.e. CC) were 72.14%, 30.83% and 22.64% with 0.25% NAD dosages at 7, 28 & 56 respectively. It was chiefly due to existence of calcium in NAD, that speed up the hydration in conventional concrete at all curing ages. Hence, it witnesses that 0.25% NAD dosage amended the bonding between the ingredients that boosted the strength of conventional concrete.

On further increase in NAD dosage, lowering the strength was observed. Addition of complex dosage leads to disruption of hydration that created an obstacle between the ingredients. Hence, 0.25% NAD dosage deliberated as optimum NAD dosage for CC mixes.

Further, it inferred that increase of FA replacement levels dropping of strength at 7 & 28 days of curing. This was due to insufficient quantity of Ca(OH)2 progress that slow downing pozzolanic action in FA replaced concrete at initial curing periods than that of conventional concrete mixes. The strength attainment of high silica FA replaced mixes was superior in 0.25% to 0.75% of NAD dosages, than that of without NAD quantity mixes at all curing ages. It was primarily due to attribution of the enhanced reaction between the Calcium present in NAD and Silica present in FA and that prime to the progress of Calcium-Silicate-Hydroxide (C-S-H) gel in high silica FA replaced concrete. It shows that the influence of 0.25%NAD exhibits superior performance in improving the strength in FA blended mixes. Further increase in NAD dose greaterthan0.25%, declined in FA blended mixes strength at all curing ages. This is due to establishment of voids in concrete, due to surplus NAD dosage leads to increase in entrapped air bubbles.

35% replacement of high silica FA mix attained superior strength than that of other FA replacement mixes at 56 days of curing. It was due to superior pozzolanic action at later ages without NAD dosage. It perceived that the strength improvement was superior performance 0.25%NADforsame FA replacement. Strength improved from 40.32 to 46.52 MPa and at 56 days of curing. Guru Jawahar et al. [7] stated that the fly ash concrete attained higher strength at later ages it is due to pozzolanic action. Zareei et al. [8] resolved that compressive strength can be improved with addition of pozzolanic materials and also it dropped the penetration of chloride ions. The authors also perceived that the mechanical properties of high silica FA concrete were increased than that of
conventional concrete with 0.25% NAD.

5.1.1. Unit Weight of Concrete

The unit weight of C-100_FA-0 and 35% high silica FA replaced mix C-65_FA-35 with 0% and 0.25% NAD mixes was shown Figure. 2. It was witnessed that unit weight of C-100_FA-0 with 0.25% NAD achieved superior density than that of without NAD mix at all curing ages. With increasing FA replacement, the drop in density was noticed in with and without NAD mixes. It was evident that adding of lighter materials that dropping of density of concrete. But the density was improved with supplementing of 0.25% NAD in C-100_FA-0 and other FA replaced concrete mixes. It was due to progress of compressive strength enhanced by development of calcite crystals that occupies the voids in the concrete. It perceived that NAD also significantly contributed in improvement of density conventional concrete and FA replaced concrete.

![Figure 2. Density of High Silica Fly Ash Replaced Concrete](image)

35% high silica FA replacement mix with 0.25% NAD attained the 28days designed M25 grade concrete strength with lighter density. Assaedia et al. [9] reported accumulation of Nano particle increases the density and decreases the water percolation and porosity.

5.2. Durability Studies of High Silica Fly Ash Replaced Concrete

5.2.1. Water Absorption of High Silica FA Replaced Concrete

Water absorption of C-100_FA-0 and C-65_FA-35 concrete was shown graphically presented in Figure. 3. At 7 days of curing, the water absorption of C-100_FA-0 mix was 2.83% with 0% NAD dosage and it was compact to 2.45% with supplement of 0.25% NAD. It demonstrates the water absorption was dropped with supplement of 0.25% NAD.

From the Figure. 3., it was detected that water absorption reduces to 2.79% with 35% replacement of high silica FA without NAD dosage. It signifies that addition of FA decreases the water absorption. Again it was decreased to 2.35% with 0.25% NAD (i.e. optimal) dosage and this was inferior to that of C-100_FA-0 mix with 0.25% NAD mix. The drop in water absorption was due to packing of air voids with fine material (i.e. fly ash). Tasdemir (2003) revealed that particles of micro-filler materials, seals both interfaces and also grows the paste in bulk volume that drops the absorption capacity of liquid. The packing of air voids with rapid development of Calcite crystals reduces the plugs of air voids cause the reduction in capillary rise of water. Guo et al. [10] concluded about the addition of finer materials occupies the air voids reduce the permeability of water on to concrete. The addition of recycled aggregates in concrete increase in water absorption and porosity was noticed and it can be reduced by adding fine material to concrete to pack the cracks in recycled aggregates [11&12].
The increase in strength of concrete due to tougher bond between the particle and development of C-S-H (gel) leads to packing of the air voids in concrete. It perceives that NAD had major contribution in reduction of water absorption. Again increase of NAD dosage greater than 0.25%, the rise in the water absorption was witnessed.

It represents that, C-65_FA-35FA mix with optimal dosage had inferior water absorption than that of C-100_FA-0 mix with remaining NAD dosages and it reduces with increase in curing.

5.2.2. Acid Resistance Test

The loss of concrete compressive strength was presented in percentage by soaking in 5% HCL water sample for CC and 35% Class F FA and the variations in hardened concrete was presented graphically in Figure. 4. The % loss of strength in CC was 4.22, 7.42 and 9.66 respectively without NAD at 7, 28 & 56 days of dipped in 5% HCL water sample. It was detected that the % loss of strength rises with increasing in dipping period, but it was dropped from 100% to 43.13% at 0 to 7 days and again it dropped from 43.13 to 23.19% from 28 to 56 days soaking period. It shows that the rate of increment of percentage loss of strength decreases with increasing soaking period. This is due to rise in concrete strength that reduces the segregation of particle by improving its bond strength of ingredients. Again it was reduced to 2.59, 5.46 and 8.07 with addition of 0.25%NAD dosage at 7, 28 & 56 days of soaking in 5% HCL water sample. The % loss of concrete compressive strength was more in CC, because the modern Ca(OH)2 from hydration will react with HCL and that formulas Calcium chloride (CaCl2), again CaCl2 reacts with calcium aluminate generated from hydration and that reacts with water leads to formation of precipitation (3CaO.Al2O3.CaCl2.10H2O), it was shown in Eqn. 1. and Eqn. 2 The drop in percentage loss of strength was by enrichment of strength with addition of NAD.

\[
2\text{HCL} + \text{Ca(OH)}_2 \rightarrow \text{CaCl}_2 + 2\text{H}_2\text{O} \quad (1)
\]
\[
\text{CaCl}_2 + 3\text{CaO}.\text{Al}_2\text{O}_3 + 10\text{H}_2\text{O} \rightarrow 3\text{CaO}.\text{Al}_2\text{O}_3.\text{CaCl}_2.10\text{H}_2\text{O} \quad (2)
\]

The % loss of concrete compressive strength with 35% FA replacement was 2.69, 6.41, and 8.42 with 0% NAD dosage at 7, 28 & 56 respectively. It was marked that the loss of strength drops with increasing the FA replacement level of 35% and it was lower than that of C-100_FA-0 mix with 0.25% NAD. The liberated Ca(OH)2 was involved in pozzolanic action and transformed in to C-S-H (gel), that drops in development of calcium chloride. There by % loss of concrete compressive strength was noticed. The drop in percentage loss of strength was due to the drop of permeability of liquid into interior of concrete reduced in the particles segregation. With addition of optimum NAD dosage (i.e. 0.25%), the values were dropped to 2.62, 5.99 and 7.87 at 7, 28 & 56 days of soaking period respectively. It perceives that it was the lowest among as all the mixes. The drop in percentage loss of strength was
due to accumulation of NAD it increases the strength and packing of voids by calcium crystals establishment with addition of NAD. Florian et al., [13] reported that the supplementation of high-purity mineral admixture in the shotcrete binder significantly dropped the sulfate durability.

The % loss of concrete compressive strength soaked in 5% H2SO4 acid water sample. The loss of percentage of strength in CC was 26.62, 29.18 and 31.57 respectively without NAD at 7, 28 & 56 days of soaking period illustrated in Figure 5. It was noticed that the percentage loss was more in H2SO4 acid water sample soaking than that of HCL water sample results. The liberation of Ca(OH)2 from hydration that reacted with H2SO4 leads the development of CaSO4 as presented in Eqn. 3. The Tri-calcium silicate generated from hydrated concrete was reacted and caused to generation of CaSO4 with Si(OH)4 and the final products were shown in Eqn. 5.4 and Eqn.5. It was the witness that rises in loss of percentage of concrete compressive strength concrete was noticed that when soaked in H2SO4.

The same increment pattern was noticed in all FA replaced mixes with and without NAD when compared with HCL sample soaking. It was reduced to 23.65, 27.14 and 29.98% with addition of optimum NAD dosage at 7, 28 & 56 days of soaking period. The ionic concentration of H2SO4 would react quicker with materials that lead to segregation of particles when compared with other acid water samples. The drop in percentage loss of strength was due to the lesser magnitude of Ca(OH)2 liberation in FA blended concrete.
The same increment pattern was noticed in all FA replaced mixes with and without NAD when compared with HCL sample soaking. The ionic concentration of H$_2$SO$_4$ would react quicker with materials that lead to segregation of particles when compared with other acid water samples. The drop in percentage loss of strength was due to minor magnitude of Ca(OH)$_2$ liberation in FA blended concrete.

$$\text{Ca(OH)}_2 + \text{H}_2\text{SO}_4 \rightarrow \text{CaSO}_4.2\text{H}_2\text{O} \quad (3)$$

$$3\text{CaO}.2\text{SiO}_2.3\text{H}_2\text{O} + \text{H}_2\text{SO}_4 \rightarrow \text{CaSO}_4.2\text{H}_2\text{O} + \text{Si(OH)}_4 \quad (4)$$

$$3\text{CaSO}_4 + 3\text{Ca.Al}_2\text{O}_3.3\text{H}_2\text{O} + 25\text{H}_2\text{O} \rightarrow 3\text{CaO.Al}_2\text{O}_3.3\text{CaSO}_4 + 31\text{H}_2\text{O} \quad (5)$$

The % loss of concrete compressive strength was reduced to 24.05, 27.27 and 30.54% with addition of optimal dosage of NAD in CC. It shows that NAD reduces the dropping the % loss of concrete compressive strength when soaked in H$_2$SO$_4$ water sample. Pei et al. [25] stated that fly ash replaced concrete reduces the loss of strength of concrete with increase in fly ash content.

6. Conclusions
1. The compressive strength and durability studies of conventional and high silica fly ash replaced mixes were very much significantly improved with 0.25% NAD dosage. So that it resolved as 0.25% NAD is optimum dosage for conventional and high silica fly ash replaced mixes.
2. Conventional concrete optimal NAD dosage attained 28 days target strength within 7 days of curing, it concluded that NAD is acting as accelerator.
3. The construction time can be reduced with optimal NAD dosage in conventional concrete.
4. The 35% FA replacement mix attained M25 grade target strength at 28 days, so that 35% high silica fly ash can be deliberated as optimum replacement level.
5. The C-65_FA-35 mix with optimal dosage of NAD has reduced the % loss of concrete compressive strength.
6. 35% of high silica FA replacement concrete mix achieved lower water absorption and superior resistance to acid (i.e. HCL and H$_2$SO$_4$) with optimal NAD dosage.
7. The durability of conventional and high silica FA concrete are improved with optimum dosage of NAD.
8. 35% of high silica fly ash replacement can be recommended and superior performance can be attained by adding 0.25% of NAD dosage.

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