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Effect of Calcium Nitrate on the Pozzolanic Properties of High Early Strength Concrete

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Abstract: Flyash based concrete poses constraint on the early strength gain and resulted in restriction for large scale utilization. The effect of accelerator on the improvement of setting properties is of much concern in recent years. In the present study the effect of calcium nitrate on setting properties of flyash concrete was investigated. Effect of accelerators on compressive, split tensile strength and flexural behavior of various concrete mixes was studied. For this purpose, four different variables of concrete mixes were considered namely F/C ratio (0.4, 0.5, 0.6 and 0.7), w/c ratio (0.3 and 0.4), replacement levels of flyash (5, 10, 15, 20, 25 and 30%), respectively and accelerator dosage (0.5 and 1%). The experimental studies showed that the effect of calcium nitrate on the setting properties was greatly improved due to increased reactivity. Further the results on the experimental investigation carried out in the laboratory on the performance indicated that high strength of concrete (52.1 MPa at 28 days) was obtained for F/C ratio of 0.6 at w/c ratio of 0.3 and an accelerator dosage of 1%. It can be also concluded that 20% of flyash with a w/c of 0.4 the strength gain results improved remarkably. Also, the water absorption test results showed a considerable reduction for the flyash based concrete specimens compared to reference concrete.

Keywords: Accelerator, flyash, flexural strength and water absorption, high strength

INTRODUCTION

A special concrete which can overcome certain limitations of setting properties of reference concretes can be referred as High Early Strength Concrete (HESC). It may include concrete which provides either substantially improved resistance to environmental influences (durability in service) or substantially increased structural capacity while maintaining adequate durability. It may also include concrete which significantly reduces construction time to permit rapid opening or reopening of roads to traffic, without compromising long-term serviceability. Therefore, it can be reinstated that HESC satisfies the performance requirements of the intended use of the concrete. A concrete made with appropriate materials combined according to a selected mix design and properly mixed, transported, placed, consolidated and cured so that the resulting concrete will give excellent performance in the structure in which it will be exposed and with the loads to which it will be subjected for its design life. In practical application of HESC the emphasis has in many cases gradually shifted from the compressive strength to other properties of the material, such as a high modulus of elasticity, high density, low permeability and resistance to some forms of attack. Generally the most common application of high strength concrete is the one with high density, high strength and high workability. Most HESC’s have high cementitious content and a w/c ratio of 0.40 or less. Concretes with low water to cement ratio, have a lower permeability than reference concrete. A rapid freezing and thawing rate may induce additional damage to concretes with low w/c ratio simply due to the lower permeability. Malhotra and Painter (1989) in this research studies concluded a very low w/c ratio, for an adequately cured concrete, can reduce or even eliminate the amount of freezable water in the pores for practical temperature ranges. These mixes will also dramatically reduce the ingress of water during the test, therefore reducing the amount of damage due to physically freezing water in the concrete. Bharatkumar *et al*. (2001) showed that cracks due to plastic shrinkage were rare. It was concluded that concrete was apparently gaining strength faster than it shrink. But since most HPC's are paste rich with low water content, bleeding is typically very low. Therefore, it is necessary to cure adequately or take other precautionary measures to reduce evaporation as soon as possible for slabs or members with large exposed surfaces. Rafat (2004) their research studies showed that various level of replacement of flyash with cement reduced the setting properties earlier. But there was a continuous and significant improvement of strength properties after 28 days. It was also concluded that the optimum level of flyash based concrete improved the strength properties as well as abrasion resistance was found to increase with the increase in age for all reference concrete

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mixtures (Poon *et al*., 2000). It was reported that at lower water to binder ratios with optimum level of flyash content, higher strength of 80 MPa could be obtained at w/b of 0.24 and was better than normal concrete. However, it was noted that higher dosage of superplasticizer was required for the mix with 45% flyash and also higher volume fraction of fine particles in the mix had improved the interfacial bond between the paste and the aggregate in the concrete. Such concrete has lower heat of hydration and chloride diffusivity than the equivalent plain cement concrete or concrete prepared with lower flyash contents (Megat Johari *et al*., 2011). This study deals with an investigation into the influence of supplementary cementitious materials on the engineering properties of high strength concrete with 28 days cube compressive strength in excess of 80 MPa. Similarly the significant reduction in volume of macro pores as a result of the inclusion of the blended content could be attributed to the pozzolanic reaction and possibly the filler effect of the binder materials. As a result of the pozzolanic reaction, the calcium hydroxide is transformed into secondary gel. Megat Johari *et al*. (2011) reported that the mechanical as well as durability properties of concrete was greatly improved due to effect of chemical admixture as well as binary materials had showed better performance than reference concrete. Thereby higher dosage level of water to binder ratio with higher replacement level mineral admixture had less water absorption and volume reduction also less compared to normal one, therefore the effect setting properties due to effect hydration process (Mahmoud and Salehi, 2010). Their research studies investigated the effects of supplementary cementitious materials on the temperature profile, heat evolution and early age strength development of medium and high strength concrete. It was observed to exhibit low heat liberation corresponding to the specimen containing flyash at 15% which is able to develop sufficient tensile strength to resist thermal cracking potential in massive high strength concrete. Tokyay (1999) several curing techniques were adopted and predicted the strength of concretes containing high lime and low lime flyash as partial cement replacement were proportioned to keep the slump of 80-100mm, the standard strength of the flyash concrete can be predicted with sufficient reliability by using the proposed relationship, the test result indicated that 93.8% increased for warm water curing and 85% increased for boiling water curing and compared to normal concrete. However, it is more dependable on the type of curing either warm water curing or boiling water curing.

Table 1: Chemical composition of fly ash

Component	Flyash (class F)
SiO_2 (%)	20-60
Al_2O_3 (%)	5-35
Fe_2O_3 (%)	10-40
CaO (%)	1-12
LOI (%)	0-15

EXPERMENTAL METHODOLOGY AND INVESTIGATIONS

Constituent materials:

Cement: An Ordinary Portland Cement (OPC) 53 grade available in local market is used in the investigations. The cement used has been tested for various properties as per IS 4031-1988 and found to be conforming to various specification of IS 12269-1987.

Fine aggregate: Locally available river sand conforming to zone II with specific gravity of 2.59and fineness modulus of 2.73

Coarse aggregate: Crushed blue metal from a local source was used as coarse aggregates with a specific gravity of 2.93, flakiness index of 4.58% and fineness modulus of 7.12.

Admixture: To improve the workability of fresh concrete of the mix, a high range water reducing agent of superplasticiser with calcium nitrate solution was used with a dosage level of 0.5 and 1% by weight of cement.

Supplementary cementitious material: The class F flyash is one of the residues generated in the combustion of coal. Fly ash used is generally captured from the chimneys of coal-fired thermal power plants obtained from Ennore thermal power station, Tamilnadu and passing through 90-micron fraction was used for the experimentation; the chemical composition of flyash is given in Table 1.

Mix proportions: The concrete mixture proportions used in the study were provided in Table 2. A Total of fourteen different concrete mixes M1 to M14 were proportioned based on the water to cement ratio (w/c) 0.3 and 0.4 and the replacement level of flyash was kept at 0, 5, 10, 15, 20, 25 and 30% by weight of binder material and fine to coarse aggregate (F/C) ratio of 0.4, 0.5, 0.6 and 0.7. The design of the reference mix (M1) is carried out according to absolute volume method.

Casting: The concrete mixtures were mixed using a 25L capacity of tilting drum type mixer, the size

Table 2: Various concrete mixture proportions adopted in the present study

Mix Id	Constituents							
	Cement	Fly ash	Fine aggregate	Coarse aggregate	water	Acl (%)	F/C ratio	w/c ratio
	Kg/m^3							
M1	473	-	520	1277	142	0.5	0.4	0.4
M2	473	-	567	1135	142	0.5	0.5	0.4
M3	473	-	672	1113	142	0.5	0.6	0.4
M4	473	-	733	1040	142	0.5	0.7	0.4
M5	473	-	520	1277	142	1	0.6	0.3
M6	473	-	567	1135	142	1	0.6	0.3
M7	473	-	672	1113	142	1	0.6	0.3
M8	473	-	733	1040	142	1	0.6	0.3
M9	473	5	672	1113	142	1	0.6	0.4
M10	473	10	672	1113	142	1	0.6	0.4
M11	473	15	672	1113	142	1	0.6	0.4
M12	473	20	672	1113	142	1	0.6	0.4
M13	473	25	672	1113	142	1	0.6	0.4
M14	473	30	672	1113	142	1	0.6	0.4

Fig. 1: Typical picture for compression testing in progress

Fig. 2: Typical picture for two points loading by flexural testing machine

specimens 100×100×100 mm were produced for the compressive strength and size of the beam mould specimens with dimensions of 100×100×500 mm specimens were produced for the flexural strength test. Cement and sand are taken in concrete mixture and made to mix uniformly. Now, the coarse aggregate is poured in concrete mixture and the mixture is allowed to run for 30 sec to attain uniformity. Meanwhile the required amount of water is taken and accelerator is mixed according to the given calculations. Now, the water is poured into the concrete mixture and the mixture is allowed to run for 2 min. After mixing for 2 min the concrete is taken out and collected. The concrete is then poured into the cubes and beams which were previously coated with grease or oil. For uniform compaction first the concrete is manually compacted upto one third height of concrete using tamping rod after that followed by Vibration in a mechanical Vibrator. After the concrete is fully compacted the moulds are allowed to set for 24 h. After 24 h the cubes and beams are taken out from mould and kept in a water tank for curing for 7, 14 and 28 days, respectively.

Testing methodology: The specimens were taken for testing after required curing in water ponding and the specimens were weighed initially after initial drying. The specimens were then tested in a Compression Testing Machine (CTM) as shown in Fig. 1 and the beam is tested for flexural strength and is expressed as modulus of rupture in MPa and is determined by standard test methods ASTM C 78 (third-point loading) as shown in Fig. 2.

EXPERIMENTAL TEST RESULTS AND DISCUSSIONS

Compressive strength: It is the common basis for design for most structures, other than pavements and even then is the common method of routine quality testing. Compressive strength is the capacity of a material to withstand axially directed pushing forces. When the limit of compressive strength is reached, materials are crushed and Compression Testing Machine (CTM) is used to calculate the Compressive strength. The compressive test results of different concrete mixtures as shown in Table 3 to 5 and test results value plotted the graph. It can be observed that reference concrete compared to 1% of accelerator with F/C ratio 0.6 showed higher strength 44.5 MPa for 7days, 50.5 MPa for 14 days and 52.1 MPa for 28 days.

Table 3: Compressive strength results of different mixture proportions of concrete at 0.5% accelerator

Mix Id	w/c ratio	F/C ratio	Compressive strength (7 days) (N/mm^2)	Compressive strength (14 days) (N/mm^2)	Compressive strength (28 days) (N/mm^2)
M1	0.4	0.4	36.4	38	40.5
M2	0.4	0.5	37.7	40.3	41.2
M3	0.4	0.6	40.8	43	45
M4	0.4	0.7	28	32.5	36

Table 4: Compressive strength results of different mixture proportions of concrete at 1% accelerator

Mix Id	w/c ratio	F/C ratio	Compressive strength (7 days) (N/mm^2)	Compressive strength (14 days) (N/mm^2)	Compressive strength (28 days) (N/mm^2)
M5	0.3	0.6	41.2	44	46.4
M6	0.3	0.6	47.4	49.2	50
M7	0.3	0.6	44.5	50.5	52.1
M8	0.3	0.6	44.8	46.7	48.5

Table 5: Compressive strength results of different mixture proportions of Fly ash based concrete at 1% accelerator

Mix Id	Fly ash replacement (%)	Compressive strength (7 days) (N/mm^2)	Compressive strength (14 days) (N/mm^2)	Compressive strength (28 days) (N/mm^2)
M9	5	36	38.8	40.2
M10	10	35.2	38.1	40.1
M11	15	33.6	35.4	37.6
M12	20	37.4	40.2	42.5
M13	25	34.2	36.9	39
M14	30	32.8	35.3	38.1

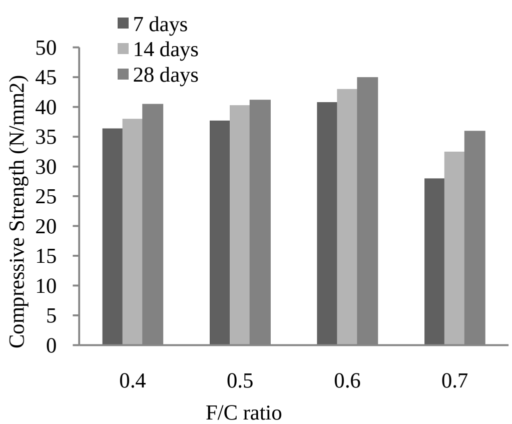

Fig. 3: Variation in compressive strength by varying F/C ratio for sand with 0.5% accelerator

It can also be noted that the variables such as fine to coarse aggregate ratio affected the compressive properties greatly when the w/c ratio is 0.3 as observed in Fig. 3. Similarly it can be seen from Fig. 4 that compared to 0.3 w/c ratio, 0.4 w/c showed higher strength due to F/C ratio 0.6 with 1% accelerator. Also, the same trend was observed for the reference concrete mix which resulted in marginal increase in the

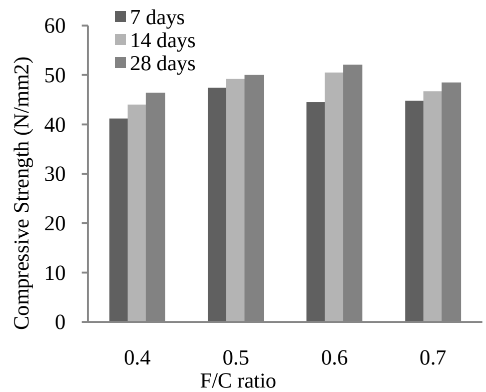

Fig. 4: Variation in compressive strength by varying F/C ratio with 1% accelerator

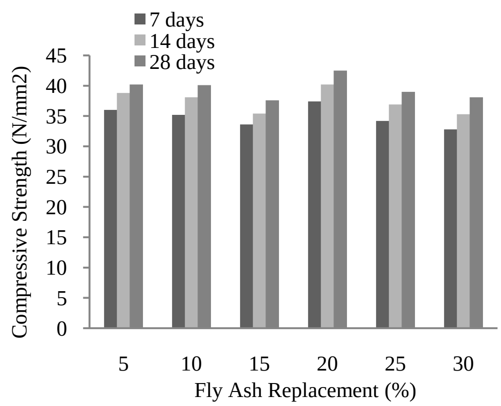

Fig. 5: Variation in compressive strength of flyash based concrete with1% accelerator

Table 6: Flexural strength results of different mixture proportions of concrete at 0.5% accelerator

Mix Id	F/C ratio	Flexural strength (7 days) (N/mm^2)	Flexural strength (28 days) (N/mm^2)
M1	0.4	4.21	4.42
M2	0.5	4.27	4.46
M3	0.6	4.47	4.58
M4	0.7	3.62	4.11

compressive strength for w/c and F/C ratio. Also it can be well noted that at F/C ratio 0.6, 20% flyash with 1% accelerator concrete showed in higher strength 37.4, 40.2 and 42.5 Mpa, respectively with different curing age of 7, 14 and 28 days, respectively and plotted the graph as showed in Fig. 5. This can lead to delayed cracking in concrete upon loading.

Flexural strength: Flexural strength is a measure of the resistance of material against flexural tensile stress developed upon loading. The experimental test results are shown in Table 6 to 8. It is observed that the

Table 7: Flexural strength results of different mixture proportions of concrete at 1% accelerator

Mix Id	F/C ratio	Flexural strength (7 days) (N/mm^2)	Flexural strength (28 days) (N/mm^2)
M5	0.4	4.42	4.75
M6	0.5	4.80	4.94
M7	0.6	4.64	5.03
M8	0.7	4.66	4.84

Table 8: Flexural strength results of different mixture proportions of flyash based concrete at 1% accelerator

Mix Id	Flyash replacement (%)	Flexural strength 7 days (N/mm^2)	Flexural strength 28 days (N/mm^2)
M9	5	4.10	4.39
M10	10	3.97	4.37
M11	15	3.83	4.25
M12	20	4.21	4.55
M13	25	4.02	4.33
M14	30	4.00	4.31

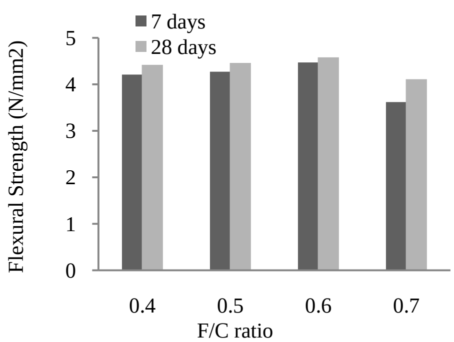

Fig. 6: Variation in flexural strength by varying F/C ratio with 0.5% accelerator

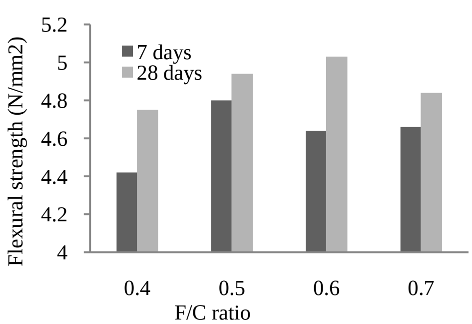

Fig. 7: Variation in flexural strength by varying F/C ratio with 1% accelerator

flexural strength increases for higher fine to coarse aggregate ratio (0.6) and thereafter a decreasing trend was noted. It can be stated that the optimum F/C ratio has direct effect on the flexural strength as well as the dosage of accelerators was dependent on the w/c ratio.

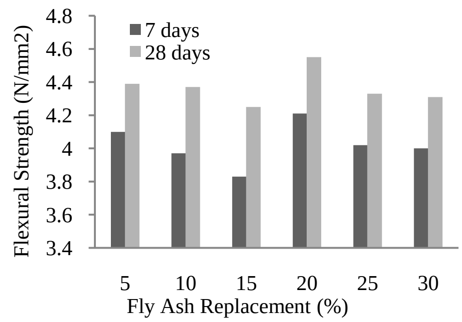

Fig. 8: Variation in flexural strength for different percentage of flyash based concrete with1% accelerator

Table 9: Water absorption with different F/C ratio and 0.5% accelerator

Mix Id	F/C Ratio	Water absorption (%) (7 days)	Water absorption (%) (14 days)	Water absorption (%) (28 days)
M1	0.4	4.12	4.45	4.53
M2	0.5	3.73	3.91	4.17
M3	0.6	3.55	3.68	3.78
M4	0.7	4.13	4.28	4.43

Table 10: Water absorption with different F/C ratio and 1% accelerator

Mix Id	F/C ratio	Water absorption (%) (7days)	Water absorption (%) (14 days)	Water absorption (%) (28 days)
M5	0.4	3.12	3.25	3.46
M6	0.5	2.79	2.91	3.14
M7	0.6	2.5	2.57	2.72
M8	0.7	3.1	3.29	3.44

It can be seen from experimental test results that high w/c ratio the requirement for accelerator was increasing i.e., for 0.4 w/c and dosage of accelerator was 0.5% and it obtained 4.47 and 4.58 MPa at 7 and 28 days, when compared to reference concrete the strength was increased upto 6.17% for 7 days and 3.62% for 28 days as shown in Fig. 6, whereas 0.3 w/c and dosage level of accelerator 1.0% obtained the strength at 7 and 28 days was 4.64 and 5.03 Mpa, respectively, when compare to reference concrete the strength was increased upto 4.97% for 7days and 5.89% for 28 days as shown in Fig. 7. In the case of flyash with higher dosage of accelerators 1%, the concrete mixes flexural strength was found to be enhanced at 7 and 28 days and was 4.21 and 4.55 Mpa, respectively, when compared to reference concrete the strength was increased upto 2.68% for 7 days and 3.64% for 28 days as shown in Fig. 8. This shows that the pozzolanic reaction is augmented with the accelerator and early hardening is anticipated.

Water absorption: Water absorption of concrete depends on the pore structure formation which is an important factor for durability of concrete. The test results are shown in Table 9 to 11. It is observed that

Table 11: Water absorption with different percentage of flyash and 1% accelerator

Mix Id	Flyash replacement (%)	Water absorption (%) (7 days)	Water absorption (%) (14 days)	Water absorption (%) (28 days)
M9	5	1.41	1.34	1.33
M10	10	1.35	1.32	1.32
M11	15	1.42	1.36	1.38
M12	20	1.26	1.23	1.22
M13	25	1.37	1.31	1.28
M14	30	1.32	1.29	1.31

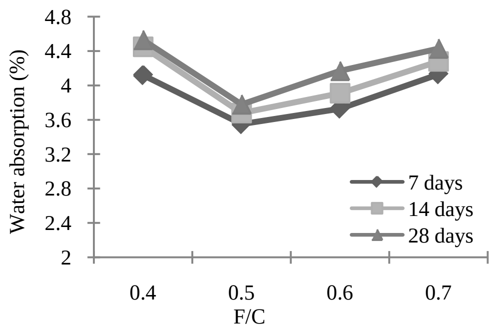

Fig. 9: Variation in water absorption by varying F/C ratio with 0.5% accelerator

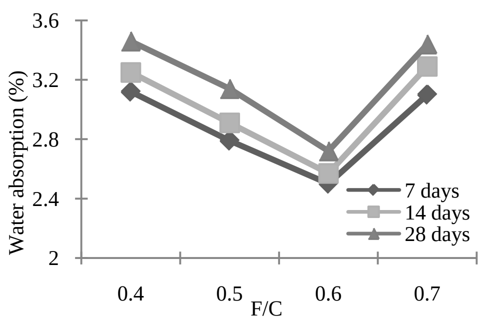

Fig. 10: Variation in water absorption by varying F/C ratio with 1% accelerator

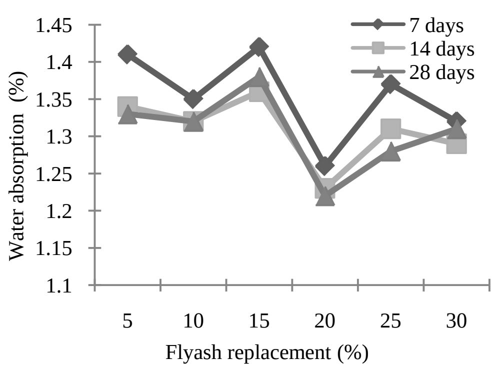

Fig. 11: Variation in water absorption for different percentage of flyash based concrete with 1% accelerator

for concrete mixes with F/C ratio 0.6 with 0.5% of accelerator obtained less absorptivity value at 28 days was 3.78%, when compared to reference concrete (4.53%) as shown in Fig. 9. It can be concluded that for concretes at w/c ratio 0.4 and 1.0% accelerator the absorption was 2.5% at 7 days and 2.72 % at 28 days and was lesser than reference concrete as shown in Fig. 10. However, w/c 0.3 and flyash replacement level at 20% with 1% of accelerator the absorption value was found to be 1.26 and 1.22% lesser than reference concrete at 7 and 28 days, respectively. In the case of flyash concrete mixes with accelerators the absorptivity was consistently reducing at all dosages compared to reference concrete as shown in Fig. 11. The additional pozzolanic property leads to increased gel formation and subsequent improvement in microstructure.

CONCLUSION

The following salient conclusions are drawn from the present study:

- The careful selection of different variables such as water to cement ratio and fine to coarse aggregate ratio has significant effect ratio which provided greater improvements in the mechanical properties of concrete.
- Among all the fine aggregates to coarse aggregate ratio (0.4, 0.5, 0.6 and 0.7) was used from that test result concluded that better performance was achieved by lower w/c ratio 0.3 and F/C ratio of 0.6 with 1% accelerator
- It was also observed the higher w/c ratio 0.4, F/C ratio 0.6 with 0.5% accelerator from that the compressive strength was achieved 45 MPa at 28 days.
- The usage of flyash as an additional ingredient has resulted in maximum compressive strength of 42.5 MPa at 28 days age of curing has been obtained from the experimental results at 20% replacement of flyash material.
- This is clearly indicates that the strength of 20% of flyash based concrete showed better strength than reference concrete at 28 days.
- The use of class F flyash showed that setting properties of concrete can be more useful where concrete pavement is required.

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