Strength and Workability Characteristics of High Volume FlyAsh Concrete

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Abstract— Concrete is the most versatile construction material mainly because of moulding ability & high compressive strength. Concrete requires large amounts of cement. The cement industry consumes lots of natural resources & moreover the production of cement causes air pollution. Flyash is a by-product from thermal power stations which is generated in massive quantities & its disposal is a great issue. If this is used in concrete as a replacement of cement, the issue of its disposal can be addressed to a certain extent. The pozzolanic properties of flyash enhance the properties of concrete in it's fresh as well as hardened state. High volume flyash concrete (HVFAC) is the concrete with high volumes of flyash (50% or more) of cement content. In the present paper, an attempt has been made to highlight the fresh properties of concrete such as workability and compressive strength by replacing cement at replacement levels of 40%, 60% & 80% by weight with flyash and a comparison is made with the available literature.

Key words: HVFAC, Concrete, Flyash, Workability, Compressive Strength

I. Introduction

Concrete is one of the most widely used construction materials in the world. The importance of concrete in modern society cannot be overestimated. Concrete structures are everywhere such as buildings, roads, bridges, and dams. There is no escape to the impact concrete makes on our everyday life.

Cement is one of the ingredients of concrete. It is a binder, a substance that sets and hardens and can bind other materials together. Cements used in construction can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to be used in the presence of water.

Supplementary Cementitious Material (SCM) has been used since a few decades in the production of Portland cement concrete. A supplementary cementitious material, when used in conjunction with Portland cement, contributes to the properties of the hardened concrete through hydraulic or pozzolanic activity, or both. As such, SCM's include both pozzolans and hydraulic materials. Pozzolans that are commonly used in concrete include flyash, silica fume and a variety of natural pozzolans such as calcined clay and shale, and volcanic ash. SCM's that are hydraulic in behavior include ground granulated blast furnace slag and flyash with high calcium contents (such flyash display both pozzolanic and hydraulic behavior).

Experiments on Hardening & Setting Time of flyash concrete has been conducted by Tarun R. Naik and Shiw S.Singh (1997) on concrete which included the 28 days strength of 35MPa. The findings of the experiment work includes,

1) Initial & final setting time was influenced by both the source & the amount of flyash.
2) The settling time retarded proportionally to the percentage of the flyash used but after 60% a reverse trend in the settling time was noted.
3) The inclusion of 60% of cementitious material replacement, the strength was appropriate for most construction applications.

P.Kumar Mehta (1999) made a study on high-volume flyash concrete for sustainable development, where concrete mixtures containing more than 50% flyash by mass of the cementitious material and found the HVFAC showed reduced water demand, improved workability, minimized cracking due to thermal and drying shrinkage, and enhanced durability to reinforcement corrosion, sulphate attack, and alkali-silica expansion.

When concrete mixes with 300 to 500 kg/cum cementitious material at 20%, 30%, 40% and 50% replacement levels, the following highlights were shown by Amit Mittal, M.B. Kaisare and Rajendra Kumar Shetty (2011) while studying use of flyash in concrete.

1) The workability was improved which helped to reduce the unit water content and also reduce admixture dosage.
2) The setting time was retarded.
3) Bleeding was significantly reduced, other properties like cohesiveness, pumping characteristics & surface finish were improved.
4) The flyash reduced the compressive strength at earlier ages as compared to later ages.
5) Rate of strength development at various ages is related to the W/Cm (Water to Cementitious material) and percentage of flyash in concrete mix.
6) Shrinkage remained same to that of the control concrete mixes.
7) The concrete were found more durable as compared to OPC concrete & significant reduction in the RCPT (Rapid Chloride Permeability Test) at 56 days & 90 days which indicate much lower permeability of flyash compared to OPC concrete.

S L Patil and J N Kale (2012) found that when flyash was introduced at replacement levels of 5% to 25% by steps of 5% the compressive strength of concrete was reduced as well as delaying the process of hardening but giving it some amazing properties that outnumbered its disadvantages in use of HVFAC.

P. R. Wankhede and V. A. Fulari (2014) in their study on "the effect of flyash on the properties of concrete‖ for nominal mix of M25" concluded the followings

1) Slump loss of concrete increases with increase in w/c ratio of concrete.
2) For w/c ratio 0.35 without any admixtures, initial

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3) slump cannot be measured by slump cone test as it is very less.
4) Ultimate compressive strength of concrete goes on decreasing with increase in w/c ratio of concrete.
5) Slump loss of concrete goes on increasing with
6) increase of quantity of fly ash.
7) Concrete with 10% and 20% replacement of cement with fly ash shows good compressive strength for 28 days than normal concrete for 0.35 w/c ratio.
8) But in the case of 30% replacement of cement with fly ash ultimate compressive strength of concrete decreases.

Even though literature suggests the use of flyash upto 60-65% is optimum for strength gain & durability, however at places where high early strength and/or high strength is not a primary criteria, the replacement levels of 80% can be made use of. Hence in this paper it is planned to focus the compressive strength at 40%, 60% & 80% replacement level & check the compressive strength in cubes, flexure for Beams, split tensile strength in cylinders with the following objectives.

II. Objective

1) To Study the fresh properties of the (High Volume Flyash Concrete) HVFAC with replacement levels of 40%, 60% & 80% by weight of cement.
2) To study the compressive strength of HVFAC at 7days & 28days.
3) To study the Split Tensile Strength in Cylinders & Flexural Strength in Beams subjective to pure Bending conditions.

III. Materials and Methods

Standard mix of M30 grade concrete with varying w/c ratio starting with 0.4 with flyash 40%, 60%, and 80% replacement by mass of cement was carried out. The effects of different w/c ratio on the fresh properties of HVFAC concrete was studied. The compressive strength of the 7 days & 28 days HVFAC concrete was also measured. To produce good quality concrete the following steps were involved in concrete preparation.

1) Batching of materials.
2) Mixing
3) Compaction.
4) Finishing.
5) Curing and Demoulding.
6) Cube testing.

A. Materials Used

The materials used for the experimental work are as follows.

1) Cement - Ordinary Portland cement, Brand corresponding to Jaypee Cement of 43 Grade was utilised for the Project. The specific gravity of cement was found out using Le Chatelier's flask.
2) Coarse Aggregate - The Coarse Aggregate comprised of 60% passing through 20 mm size IS sieve & remaining 40% passing through 12mm size IS sieve as per IS 383-1970.
3) Fine Aggregate - Fine aggregate passing through 4.5 mm IS sieve was used.
4) Flyash - Class F Flyash was used. This flyash was procured from Raichur Thermal Power Station (RTPS), Raichur, India.
5) Chemical Admixture - Superplasticizer Fosroc Conplast SP430 DIS.

B. Mix Proportion

Mix Calculation for making Control Cubes was done according to the guideline mentioned in IS 10262: 2009. Mix proportion adopted for control concrete and subsequent replacement levels is 1:2.08:2.58 with a water cement ratio of 0.4 for control mix. Water to cementitious materials ratio for various replacement levels are as shown in Table 1.

Mix id	Flyash Replacement level (%)	Water-cementitious material ratio
M-0	0	0.42
M-40	40	0.382
M-60	60	0.364
M-80	80	0.351

Table 1: Water to cementitious material ratios for various mixes.

C. Mixing, Casting and Curing

The concrete ingredients for various mixes were weigh batched, mixed in a concrete mixer and poured into moulds of size 100mm x 100mm x 100mm. After 24 hours the concrete cubes were demoulded and cured for 28 days under water.

IV. Results and Discussion

A. Fresh Properties of concrete with and without Flyash

As the water content increased the mixture became more workable & this what was observed when the Mix Design was made with a W/C ratio of 0.4 for the first trial & was increased to 0.42 keeping the amount of cementitious material constant for the 2nd trial which was used for making the Mix Design for the Control Units. During the trial mixes it has been observed that, after exceeding W/C ratio 0.42, bleeding occurred when the mix was adequately workable. So the W/C ratio had to be restricted to 0.42 instead. Slump of all the mixes were noted and are tabulated in Table 2

Replacement Levels With Flyash	Slump in (mm)
Control Units	90
40% Replacement	110
60% Replacement	140
80% Replacement	165

Table 2: Slump of various mixes.

Fresh properties of concrete have been observed to improve drastically with the use of high volumes of flyash as a replacement of cement. Reduced bleeding is yet another advantage of use of high volumes of flyash. Mixes with high volumes of flyash have been observed to be more cohesive compared to control concrete mix. All these properties enable the mix to be handled, transported and placed easily without much external effort.

B. Compressive Strength of Concrete

Uni-axial compressive strength testing has been done on 150 x 150 x 150 mm cubes. The procedure is the same as given in IS 516-1959. All the cubes were wet cured up to the day of testing. The cubes were subjected to axial compressive load until crushing. The crushing load divided by the surface area of load application gives the compressive stress that the concrete can resist. This gives measure of the strength and its confirmation with acceptance criteria. The compressive strength of concrete cube was calculated from the values of maximum load each cube bears before failure, obtained from the digital compressive strength testing machine.

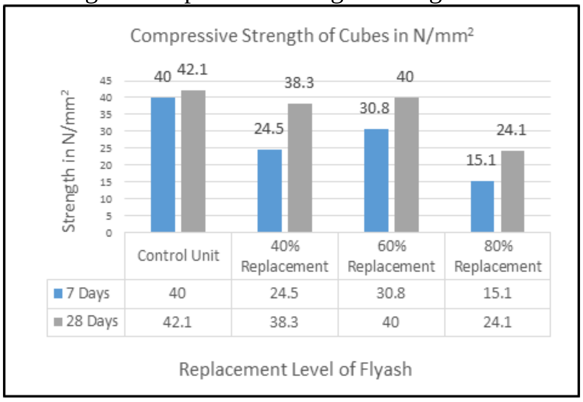

Fig. 1: Compressive strength of concrete at various replacement levels

Fig 1 shows the compressive strength of concrete for various replacement levels after 7 and 28 days of curing. Amount of strength gain after 7 days has been observed to be higher For HVFAC. This shows that for HVFAC initial strength gain is lower. However it gains strength at later stages and even beyond 28 days.

Fig 2 represents the plot of replacement levels v/s strength obtained at 7 and 28 days. It has been observed that upto 60% replacement of flyash 35 to 40MPa of strength can be obtained. This is the range of strength that is generally used as structural concrete for general construction purpose.

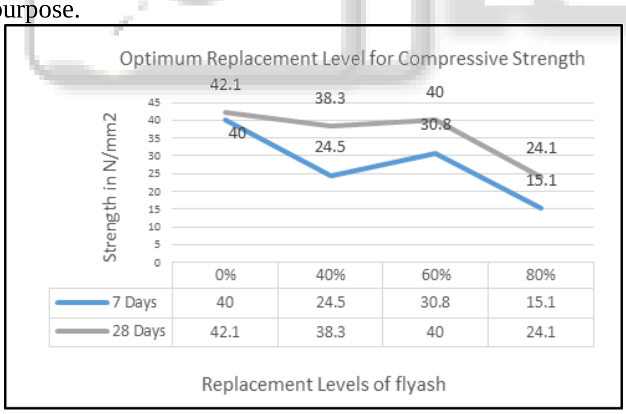

Fig. 2: Optimum replacement levels for compressive strength

C. Splitting Tensile Strength of Concrete

The Splitting tensile strength of concrete was done on concrete cylinders of size 150mm diameter x 300mm height was subjected to compression near the loaded region and the length of the cylinder is subjected to uniform tensile stress. The tensile strength of concrete cube was calculated from the values of maximum load each cube bears before splitting into failure, obtained from the digital compressive strength testing machine.

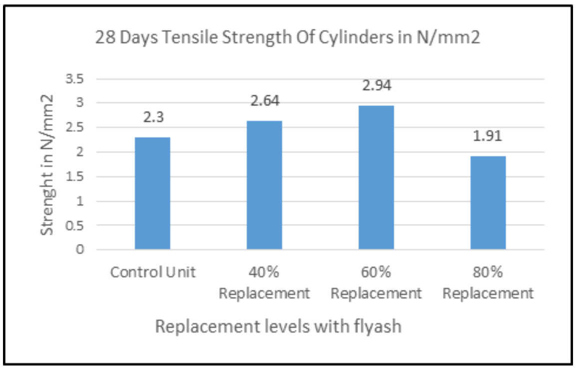

Fig. 3: 28 Days Tensile Strength of Cylinders at various replacement levels.

Fig 3 depicts the strength variation that was obtained from the different replacement levels of flyash through splitting tensile strength test on 28 days curing of HVFAC.

Fig 4 shows that the optimum level for replacement of cement with flyash could be done upto 60% to get considerable tensile strength of concrete.

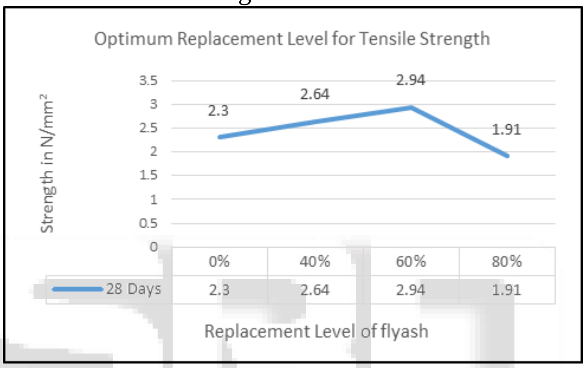

Fig. 4: Optimum Replacement Level for Tensile Strength.

D. Flexural Strength of Concrete

Concrete is very weak in tension. Direct measurement of tensile strength of concrete is difficult because no apparatus ensures uniform distribution of pull applied to the concrete. So, indirect method of flexural test is adopted to predict tensile strength properties of concrete. The flexural strength of the specimen is expressed as the modulus of rupture f_b.

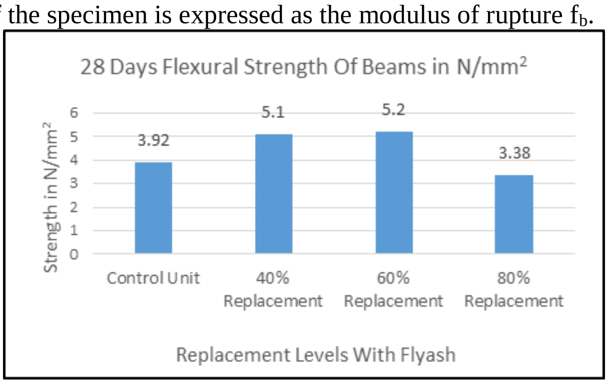

Fig 5: 28 Days Flexural Strength of Beams in various replacement levels.

Fig 5 Depicts the strength variation that was obtained from the different replacement levels of flyash through flexural strength test on 28 days curing of HVFAC.

Fig 6 Shows that the optimum level for replacement of cement with flyash lies between 40% – 60% and can be chosen based on the type of requirement.

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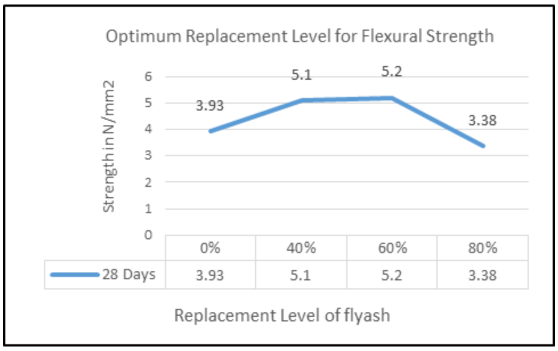

Fig. 6: Optimum Replacement Level for Flexural Strength.

The findings of the present experiment work includes

1) The Slump loss of HVFAC was increased with increase of flyash content in increasing order of 40 to 80 % by weight of cement.
2) Bleeding was significantly reduced with the addition of flyash in the increasing order of weight percentage.
3) The workability was drastically improved at a lower w/c ratio of 0.364, reducing the admixture dosage at the same time.
4) The compressive strength was reduced at the earlier ages with the introduction of flyash in comparison to the later ages increasing the setting time of the concrete.
5) The strength gain at the 28 day curing of 60% HVFAC was seen at par with the nominal strength of control units on the 28 days curing.
6) The optimum percentage of flyash was found to be 60% which could be utilised for most construction applications.

The above findings of the present work coincide with that of P.Kumar Mehta (1999), where similar reduction in water demand and improved workability was observed when concrete was made with more than 50% flyash by mass to the cementitious material. The present work also supports that of Amit Mittal (2012) who found more or less similar characteristics of HVFAC which includes workability improvements, reduced bleeding, delayed setting time & finally reduced strength at earlier ages then later ones. The strength gains at the 28 days curing came out to be very close to the work carried out by Tarun R. Naik and Shiw S.Singh (1997) who found that inclusion of 60% of cementitious material replacement, the strength was appropriate for most construction works. And finally the findings made a close resemblance to the work carried out by P. R. Wankhede and V. A. Fulari (2014) who replaced the cementitious material with flyash from 0 to 30% by weight. The strength trend graph showed an optimum percentage at 10% & gave a compressive strength value at par to the findings of this work at 60% replacement.

V. Conclusion

The Optimum level for replacement of cementitious material with flyash is possible upto 60% to get considerable compressive strength along with tensile & flexural strengths of concrete which can be utilised in general construction usages, minimising carbon emissions and also saving substantial investments on the project, making it economically viable.

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