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# EXPERIMENTAL STUDIES ON THE EFFECT OF FINENESS OF FLYASH PARTICLES ON THE ACCELERATED CONCRETE PROPERTIES

V. M. Sounthararajan and A. Sivakumar
Structural Engineering Division, VIT University, Vellore, Tamil Nadu, India
E-Mail: soundar.vm@vit.ac.in

**ABSTRACT**

The growing concern over the use of high volume of flyash use in concrete necessitates the improvement on the reactivity of flyash owing to poor pozzolanic action. The present study focuses on the evaluation of the influence of fineness of flyash particle for producing accelerated rate of hardening at early ages in flyash mixed concrete. Experimental tests were conducted on the concrete mixtures containing different fineness of flyash consisting of particles passing through 300 microns; 150 microns and their performance were compared with raw flyash obtained from the source directly. The test results indicated that with higher replacement level upto 30% fine flyash (passing through 90 microns) showed an increased rate of hardening and compressive strength (43.9 MPa) at 7 days compared to coarser flyash 28 days compressive strength of concrete. It can also be noted that all the flyash concrete mixes showed a consistent strength increase compared to controlled concrete however, the rate of strength development is higher for finer varieties of flyash.

**Keywords:** concrete, flyash, compressive strength, ultrasonic pulse velocity, dynamic modulus.

## 1. INTRODUCTION

The need for a quality concrete and improved strength property is increasing due to its long term performance characteristics. However, the properties of concrete depend on the careful proportioning of its ingredients and further addition of admixtures. Among all these ingredients, cement is the most important binder components of concrete and plays a key role in the strength development and durability of concrete. Therefore its selection and proper use lead to play an important role for construction purpose. On the other hand, cement is one of the most cost effective binders. Ordinary Portland cement is the most popular cement used by concrete purpose. However, some applications require the use of other cements to exhibit some special properties like an invention of blended cements is mostly used for construction purpose. This new blend also attracts the green environmental condition. Flyash can be considered a valuable resource and needs to be studied, in order to facilitate the application of flyash to new and innovative areas of economic interest.

(Kraiwood Kiattikomol *et al*., 2001) developed many mixes of cement mortar with different percentage level of finer particle of flyash gave a better compressive strength than that without flyash and one the coarser flyash decreased the compressive strength and no significant difference was found between mortars containing classified and ground coarse flyash with similar median particle size. (Slanicka and Paya *et al*., 1991) observed from different sources of flyash into various finenesses showed that the concrete with finer particle of flyash gave an excellent improvement of the compressive strength compare to normal concrete strength. Therefore, the coarse flyash exhibited medium pozzolanic activity because it contained a high proportion of crystalline phases and thus resulted affected the slight variation of the compressive strength. (Naik TR and Ramme BW *et al*., 1989) conclude that normal flyash do not have much effect on the chemical composition of flyash and using large quantity of flyash and obtained higher compressive strength. The finer flyash obtained by more silica content and loss of ignition has no relation to increase the carbon content. It has been observed that the compressive strength of concrete with finer particle of flyash can be improved. (Toutanji H and Delatte N *et al*., 2003). Also found that addition of flyash has been used in the production of high strength concrete when it is cured for long period of time after 90 days exceed the control concrete strength because of slow pozzolanic reaction of flyash. (McCarthy M.J. and Dhir. R.K., 2004) in their research studies it is observed that at higher replacements of cement with fine varieties of flyash, a highly durable concrete was obtained. Their test results showed that compressive strength of concrete increased with the addition of flyash was upto 50 percent. The test results also confirmed that the high volume flyash concrete showed low permeability as well as good resistance to freezing and thawing. (Ondova a M and Stevulova N *et al*., 2012) in their research used an air classifier to remove coarse flyash particles from bulky flyash particles. The grading with various particle size distributions was made by them. Air classification is an approximate technique for separation of flyash into various size fractions. By removing the coarse size fractions from flyash, a significant improvement of concrete properties was achieved. (Gregor Trtnik and Marko Ivanvalic *et al*., 2009) Ultra sonic pulse velocity test (UPV) is a non-destructive testing method used to assess the quality of concrete in terms of density, uniformity, homogeneity, etc.; this method consists of measuring the time taken for the ultra sonic pulse to pass through the concrete. The velocity of the ultrasonic pulse passing through the solid material depends on the density and elastic properties of that related to its quality. Comparative higher velocity is obtained when the quality of the concrete is good.

This paper reports on the comprehensive investigation on the strength properties of various flyash based concrete mixtures consisting of varying fineness of flyash (passing through 90 microns, passing through 150 microns and passing through 300 microns) and compared to that of raw flyash obtained from the source. Additionally, a comparison between the compressive strength values with that of ultrasonic pulse velocity test values was made for the various flyash concrete mixtures.

## 2. EXPERIMENTAL INVESTIGATION

### 2.1. Materials used

**Cement**

An ordinary Portland cement was used (53 grade) as per IS 4031-1988 and found to be conforming to various specifications as per IS 12269-1987. The composition of cementitious material is provided in Table-1.

**Coarse aggregate**

Crushed angular granite aggregate less than 12.5mm was used. The properties of coarse aggregates are: Specific gravity = 2.64, Dry rodded unit weight = 15560 Kg/m$^3$, Water absorption = 0.5% of the weight of the aggregates.

**Fine aggregate**

River sand confirming to zone II as per IS 383-1987 was used as a fine aggregate passing through 4.75 mm IS sieve. The specific gravity and fineness modulus 2.55 and 2.67, respectively and compacted bulk density values of sand is 1456 Kg/m$^3$.

**Super plasticizer**

A sulphonated naphthalene formaldehyde type super plasticizer in a liquid form (CONPLAST 420) was used in all the concrete mixtures and this is high range of water reduction with good workability.

**Flyash**

Flyash (Type F) collected from thermal power plant near Chennai, India. The main characteristics of flyash are given in Table-1. Investigations were carried for different percentage of fineness of flyash 10, 20 and 30% of cement replacement by mass of flyash.

**Table-1.** Chemical composition of cementitious materials.

| **Properties** (%) | **Fly ash class F** | **Cement** |
|---|---|---|
| $SiO_2$ | 59.3 | 20.81 |
| $Al_2O_3$ | 34.6 | 4.79 |
| $Fe_2O_3$ | 5.87 | 3.2 |
| CaO | 1.02 | 63.9 |
| MgO | 0.38 | 2.61 |
| $SO_3$ | 0.1 | 1.39 |
| $Na_2O$ | 1.28 | 0.18 |
| $K_2O$ | 0.01 | 0.79 |
| $Cl^-$ | 0.49 | 0.002 |
| Loss on ignition | 1.9 | 0.98 |
| Insoluble residue | - | 0.12 |
| Moisture content | 0.73 | - |
| Specific gravity | 3.13 | 2.24 |

### 2.2. Concrete mixture proportions

The various proportions of cementitious mixes were arrived based on flyash dosage levels which is provided in Table-2. The conceptual mix design was adopted for arriving different with a target slump of 75 mm and a w/c ratio of 0.3. The water content for reference mix and various mix proportions was found to be 142 Kg/m3 were established by keeping the fine aggregate to coarse aggregate ratio (F/C = 0.6) and w/c ratio of 0.3. Flyash sieved through 300, 150 and 90 microns were used in the study and compared with that of raw flyash. The corresponding mixes were denoted by $C_0$ - raw flyash, $F_1$ - 300microns, $F_2$ - 150 microns, $F_3$ - 90 microns and M refers to controlled concrete without flyash.

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**Table-2.** Mixture proportions of various concretes.

| Mix ID | Cement | Flyash | | | | Fine aggregate | Coarse aggregate | water | Super plasticizer | F/C ratio | W/C Ratio | Cement to Total aggregate ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $C_o$ | $F_1$ | $F_2$ | $F_3$ | | | | | | | |
| | Kg/m$^3$ | | | | | | | | | | | |
| M | 473 | - | - | - | - | 672 | 1113 | 142 | 47.3 | 0.6 | 0.3 | 0.26 |
| M1A1 | 425 | 47.0 | | - | - | 672 | 1113 | 142 | 47.3 | 0.6 | 0.3 | 0.26 |
| M1A2 | 425 | - | 47.0 | | - | 672 | 1113 | 142 | 47.3 | 0.6 | 0.3 | 0.26 |
| M1A3 | 425 | - | - | 47.3 | | 672 | 1113 | 142 | 47.3 | 0.6 | 0.3 | 0.26 |
| M1A4 | 425 | - | - | - | 47.3 | 672 | 1113 | 142 | 47.3 | 0.6 | 0.3 | 0.26 |
| M2B1 | 378 | 94.6 | | - | - | 672 | 1113 | 142 | 94.6 | 0.6 | 0.3 | 0.26 |
| M2B2 | 378 | - | 94.6 | | - | 672 | 1113 | 142 | 94.6 | 0.6 | 0.3 | 0.26 |
| M2B3 | 378 | - | - | 94.6 | | 672 | 1113 | 142 | 94.6 | 0.6 | 0.3 | 0.26 |
| M2B4 | 378 | - | - | - | 94.6 | 672 | 1113 | 142 | 94.6 | 0.6 | 0.3 | 0.26 |
| M3C1 | 331 | 142 | | - | - | 672 | 1113 | 142 | 141.9 | 0.6 | 0.3 | 0.26 |
| M3C2 | 331 | - | 142 | | - | 672 | 1113 | 142 | 141.9 | 0.6 | 0.3 | 0.26 |
| M3C3 | 331 | - | - | 142 | - | 672 | 1113 | 142 | 141.9 | 0.6 | 0.3 | 0.26 |
| M3C4 | 331 | - | - | - | 142 | 672 | 1113 | 142 | 141.9 | 0.6 | 0.3 | 0.26 |

**2.3. Preparation of test specimens**

In the present study a total of 13 different concrete mixtures were proportioned based on the Cement to Total Aggregate ratio (C/TA) 0.26, Water to Cement ratio (W/C) 0.3 and Fine to Coarse aggregate ratio (F/C) 0.6. The concrete mixtures were mixed using a 40 liters capacity with tilting drum type mixer and specimens were cast using steel mould, the standard size of cube (100 x 100 x 100 mm) moulds and cylinders (100 mm diameter x 200 mm height) and compacted with table vibrator. For each mix at least three specimens cast from that Specimen were demoulded 24 hours after casting and water cured at 27±2$^o$C until the age of testing at 7, 28 and 90 days. All the specimens were cured in the same curing tank to maintain the uniformity for all the specimens.

**3. EXPERIMENTAL TEST RESULTS AND DISCUSSIONS**

The compressive test results for various mix proportions of the concrete are presented in Table-3 and represented graphically in Figures 1 to 3). It can be observed that addition of flyash in ordinary Portland cement showed good increase in the compressive strength upto 30% of flyash. A highest compressive strength (46.70 MPa was obtained for a flyash (passing through 90 microns) concrete containing W/C 0.3 and F/C ratio 0.6 for the mix id of M3C4 and the rate of strength gain was found to be higher than OPC (as observed in Figures 4 to 6). In the case of Ordinary Portland cement with effect of F/C ratio 0.6 and W/C ratio 0.3 had shown strength of (40.80 MPa). Whereas in the case of OPC mixed with raw flyash level of 20% had recorded a maximum strength of (40.50 MPa). It can be noted from the test results that the finer varieties of flyash a remarkable improvement in the compressive strength gain was noticed due to increased pozzolanic reaction. The reactivity of flyash is known to improve due to increased surface area of particles and leads to earlier pozzolanic reaction with the hydration products of cement particles. This is evident from the test results that the rate of hardening is increased with the increase in the fineness of flyash. Also, it can be observed from the test results that compared to raw flyash, the addition of finer flyash showed a consistent increase in the compressive strength values. The test results on the split tensile strength were further showing similar trend as that of compressive strength. A highest split tensile strength of 3.6 MPa was obtained for finer flyash passing through 90 microns. The relationship between compressive strength and ultra sonic pulse velocity were plotted (shown in Figures 7 to 9) for all the concrete mixtures and found to be showing a increasing trend as that of compressive strength which satisfies the codal provision (IS 13311 part 1). In general it can be concluded that the reactivity of flyash is pronounced with the increase in the fineness of flyash which leads to early hardening and faster pozzolanic reaction.

**Table-3.** Compressive strength results of different mixture proportion of concretes.

| Mix Id | F/C ratio | W/C ratio | Average compressive strength (MPa) | | | % gain in 7 days strength compared to 28 days | % gain in 90 days strength compared to 28 days | Average spilt tensile strength (MPa) | Average spilt tensile strength (MPa) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 7 days | 28 days | 90 days | | | 7 days | 28 days |
| M1 | 0.6 | 0.3 | 35 | 40.8 | 43.2 | 86 | 106 | 2.4 | 3.26 |
| M1A1 | 0.6 | 0.3 | 31.3 | 39 | 40.1 | 80 | 103 | 2.12 | 3.19 |
| M1A2 | 0.6 | 0.3 | 32.2 | 39.7 | 42.4 | 81 | 107 | 2.32 | 3.53 |
| M1A3 | 0.6 | 0.3 | 30.5 | 41.9 | 43.2 | 73 | 103 | 2.5 | 3.21 |
| M1A4 | 0.6 | 0.3 | 32.9 | 42.1 | 43.5 | 78 | 103 | 2.61 | 3.24 |
| M2B1 | 0.6 | 0.3 | 31.5 | 40.5 | 41.3 | 78 | 102 | 2.05 | 3.22 |
| M2B2 | 0.6 | 0.3 | 31.7 | 41.2 | 43.9 | 77 | 107 | 2.16 | 3.25 |
| M2B3 | 0.6 | 0.3 | 34 | 43.9 | 47.8 | 77 | 109 | 2.3 | 3.26 |
| M2B4 | 0.6 | 0.3 | 34.4 | 46.3 | 49.6 | 74 | 107 | 2.74 | 3.19 |
| M3C1 | 0.6 | 0.3 | 33.5 | 41.6 | 43.7 | 81 | 105 | 2.41 | 3.36 |
| M3C2 | 0.6 | 0.3 | 34.5 | 42.9 | 44.6 | 80 | 104 | 2.45 | 3.21 |
| M3C3 | 0.6 | 0.3 | 33.2 | 43.8 | 47.2 | 76 | 108 | 2.6 | 3.3 |
| M3C4 | 0.6 | 0.3 | 34.7 | 46.7 | 50.4 | 74 | 108 | 2.81 | 3.6 |

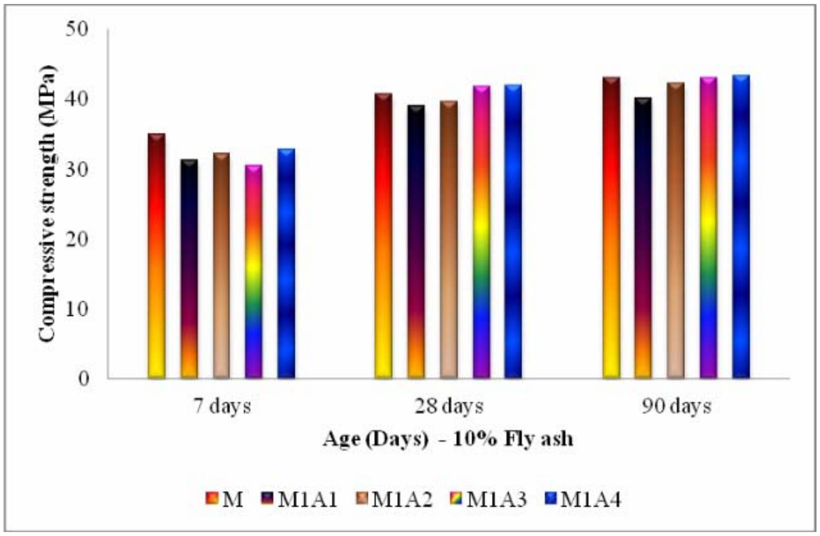


**Figure-1.** Compressive strength of concrete with 10% flyash for various mixture proportions.

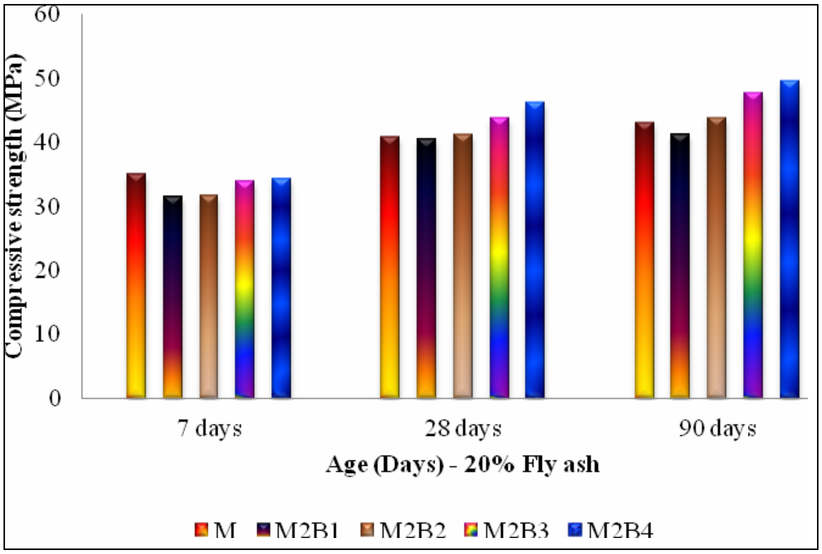


**Figure-2.** Compressive strength of concrete with 20% flyash for various mixture proportions.

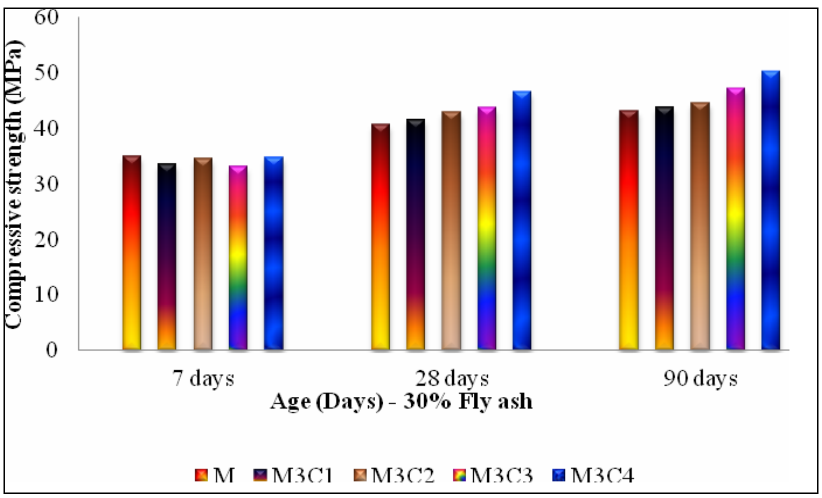


**Figure-3.** Compressive strength of concrete with 30% flyash for various mixture proportions.

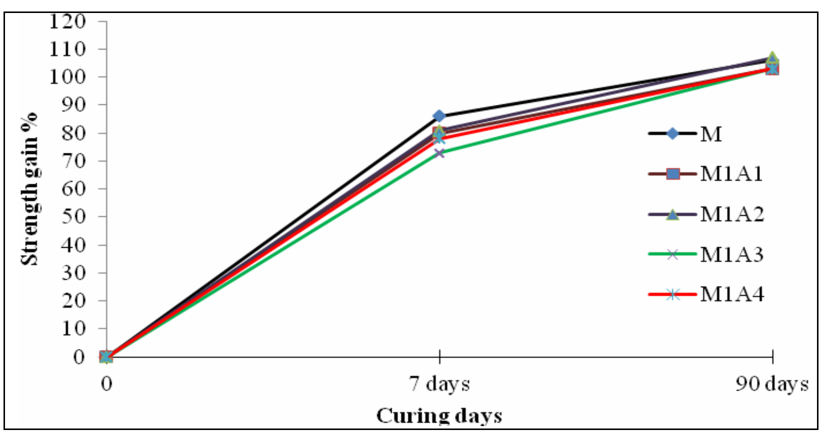


**Figure-4.** Cube strength gain for 7 and 90 days with respect to 28 days at 10% fly ash.

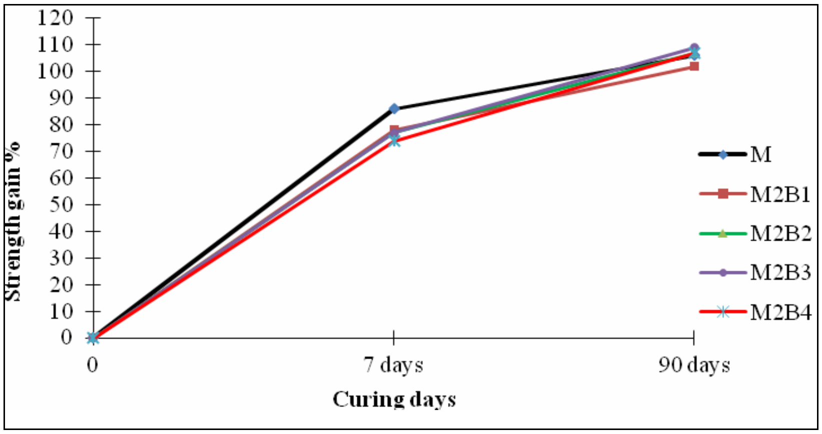


**Figure-5.** Cube strength gain for 7 and 90 days with respect to 28 days at 20% fly ash.

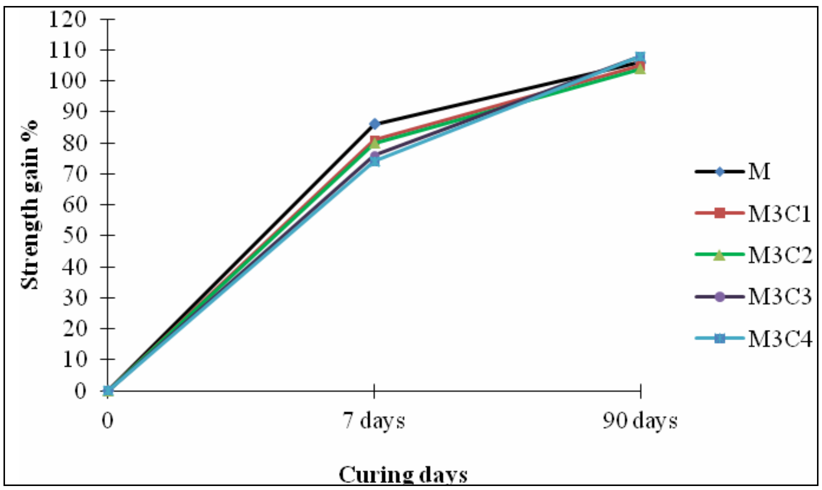


**Figure-6.** Cube strength gain for 7 and 90 days with respect to 28 days at 30% fly ash.

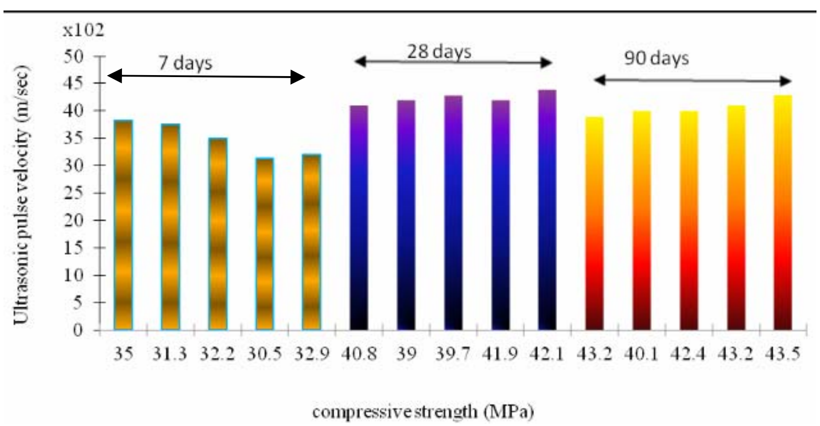


**Figure-7.** Cube strength gain for 7 and 90 days with respect to 28 days at 10% fly ash.

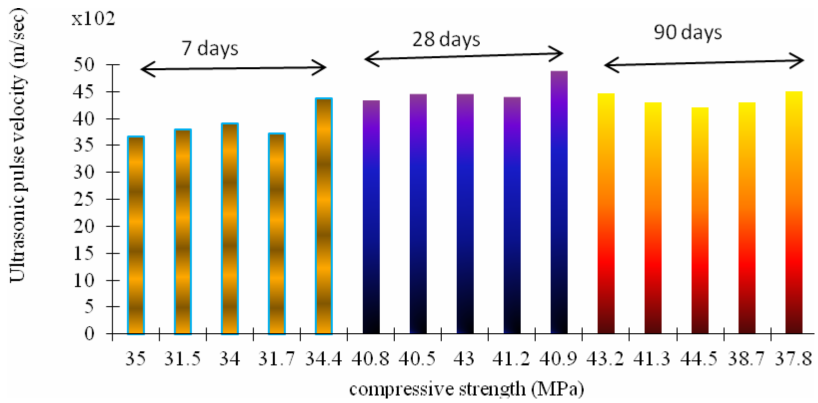


**Figure-8.** Relationship between compressive strength and ultrasonic pulse velocity at 20% fly ash.

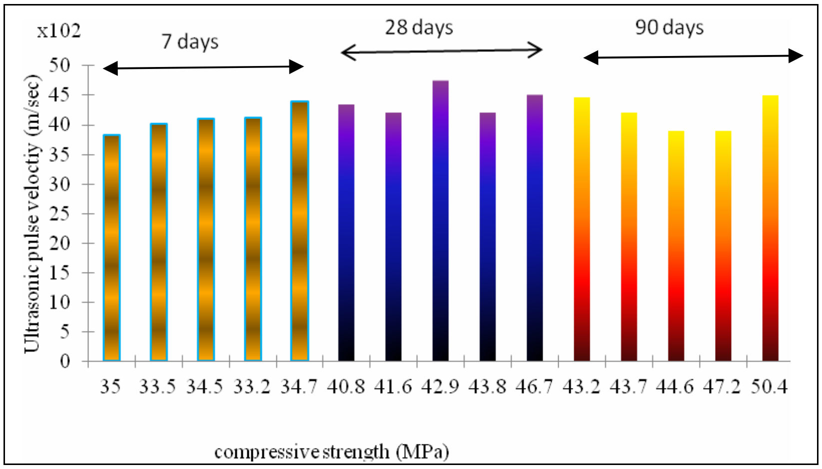


**Figure-9.** Relationship between compressive strength and ultrasonic pulse velocity at 30% fly ash.

## 4. CONCLUSIONS

Based on the experimental test results obtained in this investigation, the following important conclusions can be drawn:

a) The addition of finer flyash with suitable super plasticizers increase the compressive properties of concrete
b) An improved pozzolanic reaction is obtained with the finer particle size of flyash. The rate of hardening was found to be higher for flyash based mixes even for higher dosage of flyash upto 30%.
c) It is clearly evident from this study that finer varieties of flyash showed better performance than plain concrete and raw flyash based concrete mixes both in terms of compressive strength and split tensile strength. Hence, the higher replacement levels of flyash will provide the desired strength and early pozzolanic reaction.
d) Addition of 30% flyash (passing through 90 microns) in concrete resulted in better performance both in compression and split tension, because of more fineness which gives improved micro structural properties.
e) With the increased dosage level the improvement in setting is noticed in all the mixes, however, there was a loss in consistency observed due to increased water demand. However, the consistency can be obtained with the addition of super plasticizer.
f) Ultrasonic pulse velocity measurements were found to be an ideal tool for monitoring the early age strength gain properties of cementitious systems. Flyash replacement levels can be readily judged from the pulse velocity measurements. From the test result it can be concluded that a good agreement of pulse velocity was observed for cementitious mixes containing 20% finer flyash particles.

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