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Strength study of high volume fly ash concrete with fibres

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Abstract: High Volume Fly Ash concrete system addresses all the major sustainability issues. It is recommended over the ordinary concrete as it considerably saves cement and also prevents environmental pollution. The use of fibres improves specific material properties of the concrete, impact resistance, flexural strength, toughness, fatigue resistance, and ductility. In this paper an attempt is made to study the mechanical properties of High Volume Fly-Ash Concrete with addition of fibres at 0.1, 0.2, and 0.3% of cement and with 60% fly ash replacement with cement. It is found that fibre additions have increased its strength characteristics considerably over the ordinary cement concrete. A mathematical model was developed using SPSS 20 for the strength parameters of HVFAC with fibres. The major parameter that affected strength was total binders and water-binder ratio.

Keywords: *High volume fly ash, OPC Cement, Poly propylene fibres, SPSS Modelling, 90 day strength*

Introduction:

Concrete is the most extensively used material in civil engineering construction so that considerable attention is taken for improving the properties of concrete with respect to strength and durability. India's total installed capacity of cement stood at 320 million tonnes per annum (mtpa). Carbon concentration in cement spans from approximately 5% in cement structures to 8% in the case of roads in cement. The cement industry produces about 5% of global man-made CO_2 emissions, of which 50% is from the chemical process, and 40% from burning fuel. The amount of CO_2 emitted by the cement industry is nearly 900 kg of CO_2 for every 1000 kg of cement produced.

Use of industry waste like fly ash to partly replace cementing material in concrete system addresses the sustainability issues and its adoption will enable the concrete construction industry to become more sustainable.

Fibre reinforced concrete is considered as a material of improved properties and not as reinforced cement concrete wherein reinforcement is provided for local strengthening of concrete in tension region. Since in Fibre reinforced concrete, fibres are distributed uniformly in concrete, it has better properties to resist internal stresses due to shrinkage. Fibres improve specific material properties of the concrete, impact resistance, flexural strength, toughness, fatigue resistance, and ductility. Fibres generally used in cement concrete pavements are steel fibres and organic polymer fibres such as polypropylene and polyester.

2. Experimental investigation:

2.1 Materials used:

The following materials were used in the study.

Cement: Ordinary Portland Cement, 53 Grade conforming to IS 12269 – 1987.

Fine aggregate: Locally available river sand conforming to Grading zone II of IS 383 –1970.

Coarse aggregate: Locally available crushed blue granite stones conforming to graded aggregate of nominal size 12.5 mm as per IS 383 – 1970.

Fly Ash: Fly ash class F obtained from Mettur Thermal Power Plant which confines as per IS 3812-2000.

Fibres: Poly propylene recron 3S fibre was used. Properties of the fibre are given in table 1.1.

Super plasticizer: A commercially available sulphonated naphthalene formaldehyde based super plasticizer (CONPLAST SP 430) was used as chemical admixture to enhance the workability of the concrete. The properties are given in table 1.2.

Water: Potable water.

Table 1.1 Properties of RECRON -3S

Property	**Values**
Cut length	6mm, 12mm
Aspect ratio (L/d)	300
Specific gravity	0.91
Tensile Strength	6000 kg/cm^2
Melting point	> 250ºC
Dispersion	Excellent
Acid resistance	Excellent
Alkali resistance	Good

Table 1.2 Properties of Super Plasticizer

Colour	Brown
Specific Gravity	1.22 to 1.225
Chloride Content	Nil
Solid Contents	40%

Table 2 Mix Proportion of all the mixes used

Constituents (kg/m^3)	0 % fly ash (M0)	0 % fibre addition (M1)	0.1 % fibre addition (M2)	0.2 % fibre addition (M3)	0.3 % fibre addition (M4)
Cement	416	183	183	183	183
Fly ash	0	275	275	275	275
Fine aggregate	668	602	602	602	602
Coarse aggregate	1242	1170	1170	1170	1170
Water	158	158	158	158	158
Fibres	0	0	0.186	0.366	0.549
Super plasticizer	8.32	3.66	3.66	3.66	3.66

2.2 Mix design:

The mix design has been adopted as per IRC: 44-2008.The concrete used in this study was proportioned to attain strength of 40 MPa. The mix proportions for various mixes are shown in table 2.

2.3 Preparation, Casting and Testing of Specimens

The 150 mm cubes were cast for compressive strength, 150mm X 300mm cylinders for split tensile strength and 100mm X 100mm X 500mm beams for flexural strength. All the test specimens were stored at room temperature and demoulded after 24 hours and kept in curing tanks. The strength tests were done at 7, 28 day and 90 days.

3. Results and discussions:

3.1 Workability studies:

3.1.1 Slump cone test:

For a pavement slab workability required is in the ratio of 20 to 25mm. In this experiment water binder ratio has been kept constant. From the table 3.1 and fig 3.1 it is clear that slump is more mix M1. On fibre additions (M2, M3, M4) a nominal decrease in workability is observed.

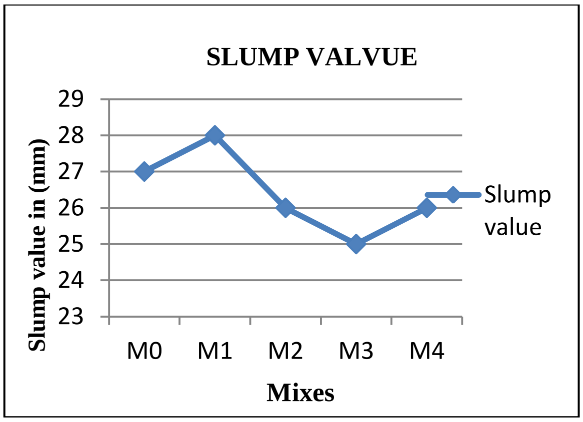

Fig 3.1 Slump Values

3.1.2 Compaction factor test:

The compaction factor values for different mixes are shown in table 3.1 and fig 3.2. The compaction factor test also determines the workability of the concrete mix. It is observed that for a fixed water – binder ratio, compaction factor increases when cement is increasingly replaced with fly ash (M1). It is also observed that with fibre addition (M2, M3, M4), compaction factor decreases.

Table 3.1 Slump and Compaction factor Values

Mix	Fly Ash (%)	Fibre %	Slump Value (mm)	Compaction factor (%)
M0	0	0	27	0.754
M1	60	0	28	0.762
M2	60	0.1	26	0.747
M3	60	0.2	25	0.735
M4	60	0.3	26	0.752

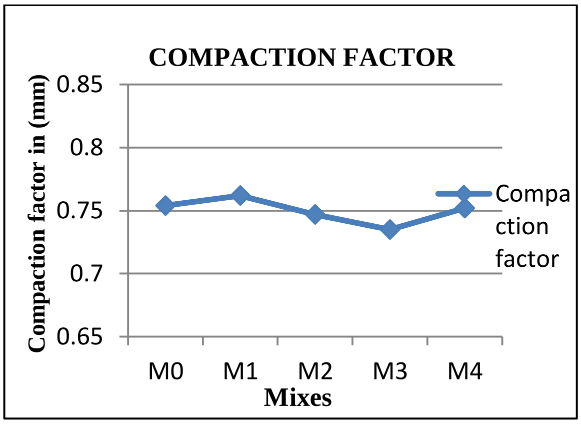

Fig 3.1 Compaction Factor Values

3.2 Strength results:

3.2.1 Compressive strength test:

The results of the compressive tests of various mixes at the age of 28 and 90 days are given in Table 3.2 and fig 3.3. The influence of fly ash replacement of cement at 60% and varying percentages of fibre additions at 0.1, 0.2 and 0.3% and the control mix are shown. Though the 28 day compressive strength is more for control mix, ie M0 the 90 day compressive strength is more for M3. In the long time period fly ash based fibre added concrete gains more strength than fibreless fly ash less concrete. M1 mix values are higher than M0 by 6.7%. With the use of fibres, compressive strength shows further increase, the maximum being for (M3) 0.2% fibre added fly ash concrete. The increase over control mix is 12.5%.

3.2.2 Split tensile strength:

The influence of fly ash replacement of cement at 60% (M1) and varying percentages of fibre additions at 0.1% (M2), 0.2% (M3) and 0.3% (M4) and of control mix (M0) are shown in table 3.2 and fig 3.4. From the graph and table, it is found that fibre added fly ash based concrete has attained more strength compared to control mix at 90 day time period. But the reverse trend was noted for early strength at 28 days. M3 has increased its tensile strength by 4.03% compared to control mix M0 at 90 days. But the fibre less mix M1 lags behind M0 by 21%. The strength increase of fibre added mixes M2, M3 and M4 at 90 days is on an average more than 20% at 28 days. But the other two mixes M0 and M1 have only marginal increase in strength compared to their respective 28 days split tensile strength. Result follows similar trend of the compressive strength.

Table 3.2 Strength Test Results

Mix	Fly ash in % of cement	Fibre %	Compressive strength in MPa			Split tensile strength in MPa			Flexural strength in MPa		
			7 days	28 days	90 days	7 days	28 days	90 days	7 days	28 days	90 days
M0	0	0	30	36	42	3.79	4.25	4.28	3.54	4.26	4.32
M1	60	0	16	31	45	2.9	3.24	4.22	3.01	3.55	4.12
M2	60	0.1	20	32	47	3.18	3.47	4.42	3.1	3.94	4.63
M3	60	0.2	21	32	48	2.94	3.2	4.46	2.95	3.45	4.23
M4	60	0.3	21	33	45	3.34	3.75	4.16	3.24	3.56	4.34

3.2.3 Flexural strength test:

The influence of fly ash replacement of cement at 60% (M1) and varying percentages of fiber additions at 0.1% (M2), 0.2% (M3) and 0.3% (M4) along with control mix M0 are shown in table 3.2 and fig 3.5. From the results for flexural strength at 90 days, all fibre added fly ash based mix except M3 have comparatively higher strength compared to mix M0 an M1. On average fibre added mixes (M2, M3, and M4) has 2% and 6.4% increase over the control mix M0 and fibre less fly ash based concrete M1 respectively.

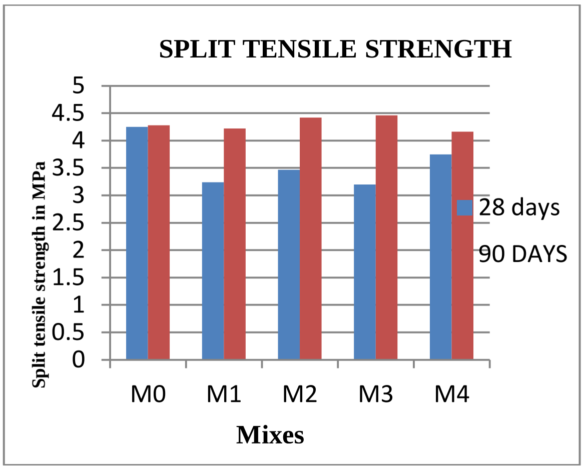

Fig 3.4 Split Tensile Strength

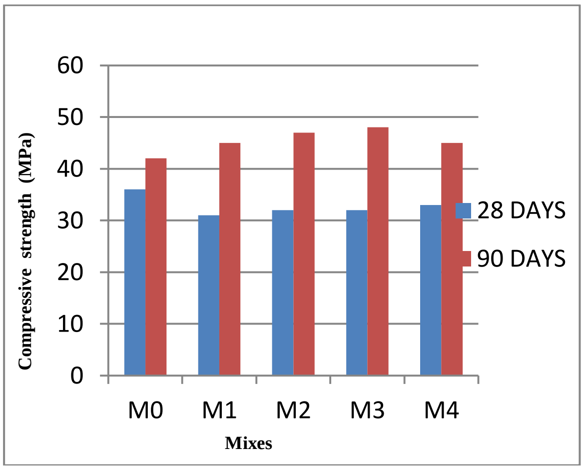

Fig 3.3 Compressive Strength

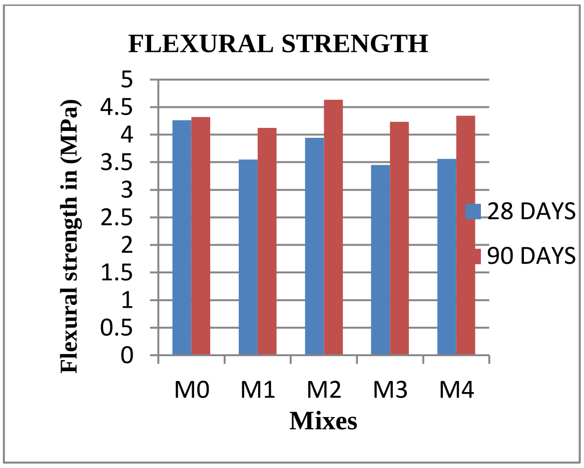

Fig 3.5 Flexural Strength

4. Mathematical model:
A mathematical model is an idealization of the real world phenomenon and it is a mathematical language to describe the behaviour of the system. The actual model is a function that describes the relation between the different variables. Advantages of mathematical modelling are that it can reflect complex physical structures and irregular geometric shapes. Convenient and flexible to use and easy to calibrate. The parameters taken into consideration for mathematical model are Fibre, (F), Total binder, (TB), Water-binder ratio, (W/B).

Table 4.1 Values of parameters

Variable	M1	M2	M3	M4
Fibre, F	-1	-0.33	0.33	1
Total binder, TB	-1	-0.33	0.33	1
Water-binder, W/B	-1	0	0.5	1

The result of equation for mathematical modelling for compressive strength, split tensile strength and flexural strength are given in table 4.2, table 4.3 and table 4.4.

4.1. Compressive strength model:
The general regression model equation for compressive strength at 90 days is obtained as,
45.317 – (7.14 X F) + (7.46 X W/B), R^2 = 0.917
With increase in the values of fibres and decrease in the water – binder ratio, the compressive strength increases.
4.2. Split tensile strength model:
The general regression model equation for split tensile strength at 90 days is obtained as,
3.781 – (2.10 X F) + (2.53 X W/B), R^2 = 0.979
With increase in the values of fibres split tensile strength increases, whereas with increase in the water – binder ratio, split tensile strength decreases.
4.3. Flexural strength model:
The general regression model equation for flexural strength at 90 days is obtained as,
4.19 – (1.07 X F) + (1.136 X W/B), R^2 = 0.875
With increase in the values of fibres flexural strength increases, whereas with increase in the water – binder ratio, flexural strength decreases.
The tabulated values of the parameters are given in table 4.1.

Table 4.2 Compressive strength values at 90 days

Mix	Predicted value	Experimental value	% difference
M1	47.89	45	6
M2	47.18	47	0.38
M3	46.46	48	-1.03
M4	45.75	45	3.2

From table 4.2, for compressive strength both the experimental and predicted value shows an average variation of 2.65%.

Table 4.3 Split Tensile strength values at 90 days

Mix	Predicted value	Experimental value	% difference
M1	4.65	4.22	9.24
M2	4.44	4.42	0.45
M3	4.23	4.46	-5.44
M4	4.02	4.16	-3.48

From table 4.3, for split tensile strength both the experimental and predicted value shows an average difference of 4.65%.

Table 4.4 Flexural strength values at 90 days

Mix	Predicted value	Experimental value	% difference
M1	4.48	4.12	8.1
M2	4.47	4.63	-3.58
M3	4.37	4.23	3.2
M4	4.26	4.34	-1.88

From table 4.4, for flexural strength both the experimental and predicted value shows an average difference of 4.2%, which is permissible.

5. Conclusion:
1. Slump and compaction factor value decrease with fibre addition
2. The strength gaining at 28 days is found to be less for fly based (M1) and fibre added (M2, M3 and M4) concrete by 13.8% and 9.7% respectively on comparing to OPC based concrete (M0).
3. The strength gaining at 90 days is higher for fibre added fly ash based concrete than OPC based concrete.
4. Fly ash based concrete performs well at later stage than at early days.
5. Fibre additions to the fly ash based mix M2, M3 and M4 has higher increase in strength over 60% fly ash added concrete M1. Fibre addition of 0.2% (M4) has the maximum compressive, and tensile strength compared to fibre less M1 mix.
6. Mathematical modelling using SPSS has been done for compressive strength, flexural strength and split tensile strength.
7. The modelling of strength shows that amount of fibres and water-binder ratios are the parameters which influences the strength.
8. Comparison of predicted and experimental values on average shows a variation of 2.65%, 4.65% and 4.2% respectively for compressive strength, split tensile strength and flexural strength.

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