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Fiber Reinforced High Volume Fly Ash Concrete for Rigid Pavement

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ABSTRACT- The most popular man-made construction material in use today is concrete. It is made by combining cementitious ingredients, water, aggregate, and occasionally admixtures, in the proper ratios. Fresh concrete, also referred to as plastic concrete, is newly mixed material that may be moulded into any shape before hardening into the substance known as concrete. A long-lasting chemical interaction between water and cement causes the hardening, which makes concrete stronger over time. The practicality, beauty, and durability of concrete structures built during the first half of the 20th century with plain round mild steel bars and ordinary portland cement (OPC), as well as the ease of obtaining the constituent materials (whatever their qualities), contributed to the widespread use of concrete.

KEYWORDS- Compressive Strength, Fiber Reinforced, Strength, Stabilization.

I. INTRODUCTION

The most popular man-made building material worldwide is concrete. It is made by combining the right amounts of cementitious ingredients, water, aggregate, and occasionally admixtures. Fresh concrete, sometimes known as plastic concrete, is a material that has just been mixed, is moldable into any shape, and hardens into a mass resembling rock[1]. As concrete ages, it becomes stronger due to the chemical reaction between water and cement that causes the hardening. Condemnation has been bred by the usefulness, beauty, and durability of concrete structures built during the first half of the 20th century with plain round mild steel bars and ordinary Portland cement (OPC), as well as by the accessibility of the constituent materials (whatever their qualities may be) and the understanding that almost any combination of the constituents results in a mass of concrete. There is no substitute for Ordinary Portland Cement (OPC), one of the primary components of concrete, in the civil construction sector[2]. Unfortunately, the process of making cement results in significant carbon dioxide gas emissions.

II. MATERIALS

A. Cement

In the present research work ordinary Portland cement of 43 grade UltraTech cement is used. The tests on cement are conducted in accordance with Indian standards confirming to IS: 8112 - 1989. The physical properties of cement are presented in table 1.

Table 1: Physical properties of cement

SI. No	Particulars	Result	Permissible Limits[60]
1	Fineness of cement (%)	5	Should not be more 10
2	Normal consistency(%)	30	
3	Initial setting time (minutes)	110	Should not be less than 30
4	Final setting time (minutes)	335	Should not be more than 600
5	Soundness (mm)	1.5	Shall not have an expansion of more than 10
6	Compressive strength of mortar cubes (N/mm²)		
	i. 3 days	23.66	Should not be less than 23 N/mm²
	ii. 7 days	36.33	Should not be less than 33 N/mm²
	iii. 28 days	45.16	Should not be less than 43 N/mm²

B. Fly Ash

The fly ash used in the present study is taken from Raichur Thermal Power Station The physical and chemical properties of the fly ash used are reported in table 2 and 3

Table 2: Physical properties of fly ash

SI. No.	Test conducted	Results	Requirement as per IS:3812:2003(61]	
			Part I	Part 2
1	Specific gravity	2.5		
2	Fineness-Specific surface in m^2/kg by Blaine's Air-permeability method, (Minimum)	469	320	200
3	Lime reactivity -Average compressive strength in N/mm^2, (Minimum).	4.6	4.5	--
4	Comparative compressive strength at 28 days, percent, (Minimum)	90	Not less than 80% of the strength to plain cement mortar cubes	
5	Soundness by autoclave test Expansion of specimens in percentage, (Maximum)	0.0025	0.8	0.8
6	Residue on 45 micron sieve, percent, (Maximum)	28.5	34	50

Table 3: Chemical composition of fly ash

SI. No.	Test conducted	Results	Requirement as per IS:3812:2003 [61)			
			Part 1		Part2	
			Siliceous pulveriz ed fuel ash%	Calcareous pulverized fuel ash%	Siliceous pulverized fuel ash%	Calcareous pulverized fuel ash%
1	Silicon dioxide (SiO) plus aluminium oxide (Al2O2) plus iron oxide (Fe), percent by mass, (Minimum)	94.68%	70%	50%	70%	50%
2	Silicon dioxide (SiO), percent by mass, (Minimum)	61.90%	35%	25%	35%	25%
3	Magnesium oxide (MgO) percent by mass, (Maximum)	0.79%	5%	5%	5%	5%
4	Total sulphur as sulphurtrioxide (SO3), percent bymass, (Maximum)	0.13%	3%	3%	5%	5%
5	Loss on ignition, percent bymass, (Maximum)	0.47%	5%	5%	5%	5%

C. Fine Aggregate

The fine aggregates used in this experimental program is procured locally from Tungabhadra River bed near Harihar. Properties of the fine aggregate used in the experimental work are tabulated in table 4.

Table 4: Fine aggregate physical characteristics

SI No	Property	Result
1	Specific gravity	2.66
2	Fineness modulus	2.65
4	Water absorption	0.91%

D. Coarse Aggregate

Locally available crushed granite coarse aggregates having the maximum size of 20 mm are used in the present work[3]. The results of various tests conducted on coarse aggregate are presented in table 5.

Table 5: Physical properties of coarse aggregate

SlNo.	Property	Result
1	Fineness modulus	6.53
2	Specific gravity	2.72
3	Water absorption percentage	0.94%
4	Crushing valu e, percentage	26.33%
5	Impact value, percentage	25.16%
6	Abrasion valu e, percentage	24.42%
7	Flakiness index, percentage	13.60%
8	Elongation index , percentage	10.36%

E. Superplasticizer

Conplast- SP430, a concrete superplasticizer based on Sulphonated Naphthalene Polymer is used as a water-reducing admixture and to improve the workability of fly ash concrete[4]. Conplast SP430 has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability y. Conplast SP430 is non-toxic. CONPLAST SP430 is marketed by Mis Fosroc Chemicals, Bangaluru is used in the present investigation as superplasticizer with a dosage of 1.1% by weight of binder content (cement + fly ash).

F. Water

Given that it actively contributes to the chemical interaction with cement, water is a crucial component of concrete. The quantity and quality of water must be carefully considered since it aids in the formation of the cement gel that gives construction materials their strength. In general, potable water is regarded as adequate. Tap water is employed in the current inquiry for both mixing and curing.

III. TESTING METHODS

A. Compressive Strength

For the purpose of determining the compressive strength of FRHVFAC, concrete cubes with dimensions of 150 mm x 150 mm x 150 mm are utilised as specimen preparation. According to Indian Standard Specifications IS: 516 -1959, all specimens are created. All of the moulds had been thoroughly cleaned and lubricated. Before casting, these are firmly tightened to the proper size.It is carefully ensured that there are no spaces left where slurry could leak. The specimens are stripped and preserved for curing after being cast for 24 hours. The specimens are taken out of the tank and put through a compression test on a machine with a 2000kN capacity.

B. Split Tensile Strength

For testing the split tensile strength of FRHVFAC, concrete cylindrical specimens with dimensions of 150 mm in diameter and 300 mm in height are cast. According to Indian Standard Specifications IS: 5816 -1999, all specimens are created. All of the moulds have been thoroughly cleaned and lubricated. Before casting, these are firmly tightened to the proper size. It is carefully ensured that there are no openings left for the possibility of sludge leakage[5]. The specimens are stripped and preserved for curing after being cast for 24 hours. The specimens are taken out of the tank and put through a 2000 kN compressive testing equipment to measure their split tensile strength. The specimen is positioned horizontally between the compression testing machine's loading surfaces, and load is applied until failure.

C. Flexural Strength

For testing the FRHVFAC's flexural strength, concrete beam specimens measuring 100 mm by 100 mm by 500 mm are cast. Each specimen is prepared in compliance with IS: 516 -1959, the Indian Standard Specifications[6]. Every mould has been professionally cleaned and lubricated. Before casting, these are properly sized and tightly tightened. The precaution of making sure there are no openings left for slurry leakage is taken. The specimens are stripped and preserved for curing after the first 24-hour casting period. Following the necessary time for flexural testing, the specimens are removed from the curing tank. On a universal testing device with a 600kN capacity, the test is performed. Test specimens are placed in water and kept there for 48 hours at a temperature between 24 and 30 °C. They are then removed and examined right away.

D. Impact Strength

This is the simplest test for evaluating impact resistance proposed by ACI Committee-544. This test method does not yield quantitative results; rather the test is designed to obtain the relative performance of plain concrete and FRC containing different types and amounts of fibers[7]. A disc 150 mm in diameter, 64 mm in thickness is subjected to repeated blows by dropping a 4.54 kg hammer (w) from a height of 460 mm (h). The load is transferred from the hammer to the specimen through a steel ball 64 mm in diameter. The number of blows to cause the specimen failure, that is the specimen opens up so that it touches three of the four positioning lungs, are noted. Number of blows (n) to cause the failure of the specimen is recorded as the ultimate strength.

IV. RESULTS & DISCUSSION

M40 concrete mix is designed in accordance with the guidelines of CANMET handbook with 50% replacement of cement by fly ash. The mix proportion arrived is 1:1.17:2.54 (BC: FA: CA) with water binder ratio of 0.3 and superplasticizer dosage of 1.1% by weight of binder content (cement + fly ash). Fibers are added at varying percentages of 0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6 and 1.8 % by volume fraction.The specimens are cast for compressive strength, split tensile strength, flexural strength and impact strength tests. To study strength characteristics under normal condition the specimens were cured in water for 7, 28 and 90 days and tested for respective strengths. The detailed experimental procedures are explained in chapter 4. The test results are tabulated and shown in graphs for analysis.

A. Compressive Strength Test Results

Following tables give the compressive strength test results of FRHVFAC for different percentages of fibers and for different days of curing in table 6.

Table 6: Overall results of compressive strength for FRHVFAC

Percentage of fiber	7 days compressive strength (MPa)	Percentage increase or decrease of 7 days compressive strength with respect to reference mix.	28 days compressive strength (MPa)	Percentage increase or decrease of 28 days compressive strength with respect to reference mix.	90 days compressive strength (MPa)	Percentage increase or decrease of 90 days compressive strength with respect to reference mix.
0.00 (Reference mix)	19.56	-	43.33	-	51.11	-
0.20	20.00	2	44.74	3	52.74	3
0.40	20.78	6	46.07	6	54.37	6
0.60	21.33	9	47.41	9	56.00	10
0.80	22.26	14	49.19	14	58.22	14
1.00	22.74	16	50.37	16	59.41	16
1.20	22.89	17	50.37	16	59.70	17
1.40	22.96	17	50.96	18	60.00	17
1.60	22.67	16	50.37	16	59.41	16
1.80	22.59	16	50.22	16	59.26	16

B. Split Tensile Strength Test Results

Following table 7 gives the overall results of tensile strength of FRHVFAC. Also, it gives the percentage increase or decrease of tensile strength with respect to reference mix.

Table 7: Overall results of tensile strength for FRHVFAC

Percentage of fiber	7 days tensile strength (MPa)	Percentage increase or decrease of 7 days tensile strength with respect to reference mix.	28 days tensile strength (MPa)	Percentage increase or decrease of 28 days tensile strength with respect to reference mi x.	90 days tensile strength (MPa)	Percentage increase or decrease of 90 days tensile strength with respect to reference mix.
0.00 (Reference *mi x)*	1.74	-	2.35	-	3.30	-
0.20	1.86	7	2.65	13	3.30	0
0.40	1.91	9	2.74	17	3.37	2
0.60	2.02	16	2.83	21	3.54	7
0.80	2.09	20	3.02	29	3.57	8
1.00	2.22	27	3.17	35	3.62	10
1.20	2.32	33	3.27	39	3.86	17
1.40	2.41	38	3.30	41	3.94	19
1.60	2.38	36	3.28	40	3.87	17
1.80	2.31	32	3.21	37	3.82	16

C. Flexural Strength Test Results

Following table 8 gives the overall results of flexural strength of FRHVFAC. Also, it gives the percentage increase or decrease of flexural strength with respect to reference mix.

Table 8: Overall results of flexural strength for FRHVFAC

Percentage of fiber	7 days flexural strength (MPa)	Percentage increase or decrease of 7 days flexural strength with respect to reference mix.	28 days flexural strength (MPa)	Percentage increase or decrease of 28 days flexural strength with respect to reference mix.	90 days flexural strength (MPa)	Percentage increase or decrease of 90 days flexural strength with respect to reference mix.
0.00 (Reference mix)	2.21	-	3.37	-	5.77	-
0.20	2.77	25	4.20	25	6.29	9
0.40	3.07	39	4.63	38	6.64	15
0.60	3.15	42	4.96	47	7.05	22
0.80	3.43	55	5.18	54	7.11	23
1.00	3.81	72	5.77	71	7.13	24
1.20	3.84	73	5.87	74	7.32	27
1.40	3.97	80	5.99	78	7.44	29
1.60	3.93	78	5.94	76	7.40	28
1.80	3.87	75	5.91	76	7.37	28

D. Impact Strength Test Results

Following table 9 gives the overall results of impact strength of FRHVFAC. Also, it gives the percentage increase or decrease of impact strength with respect to reference mix. Variation in the impact strength.

Table 9: Overall results of Impact strength for FRHVFAC

Percentage of fiber	7 days impact energy (N-m)	Percentage increase or decrease of 7 days impact energy with respect to reference mix.	28 days impact energy (N-m)	Percentage increase or decrease of 28 days impact energy with respect to reference mix.	90 days impact energy (N-m)	Percentage increase or decrease of 90 days impact energy with respect to reference mix.
0.00 (Reference mix)	1348.61	-	2060.95	-	2458.71	-
0.20	2178.52	62	3326.56	61	3968.59	61
0.40	2558.90	90	3893.67	89	4645.15	89
0.60	3084.51	129	4682.09	127	5585.73	127
0.80	3561.71	164	5415.18	163	6460.30	163
1.00	3575.54	165	5435.92	164	6485.06	164
1.20	3969.75	194	6030.69	193	7194.62	193
1.40	4156.48	208	6293.50	205	7508.14	205
1.60	3872.92	187	5885.46	186	7021.35	186
1.80	3298.90	145	5014.05	143	5981.76	143

V. OBSERVATIONS

It is observed that the compressive strength of FRHVFAC increases as the percentage of steel fibers in it increases up to 1.4%. Thereafter the compressive strength shows a decreasing trend. Thus, the higher ':' value of compressive strength may be obtained by using 1.4% steel fibers. This is true for 7 days, 28 days and 90 days compressive strength. At 1.4% addition of steel fibers the percentage increase of 7 days, 28 days and 90 days compressive strength are found to be 17%, 18% and 17% respectively. It is also observed that a small percentage addition of fibers has improved the compressive strength of high-volume fly ash concrete.

It is observed that the tensile strength of FRHVFAC increases as the percentage of steel fibers in it increases up to 1.4%. Thereafter the tensile strength shows a decreasing trend[9]. Thus, the higher value of tensile strength may be obtained by using 1.4% steel fibers. This is true for 7 days, 28 days and 90 days tensile strength. At 1.4% addition of steel fibers the percentage increase of 7 days, 28 days and 90 days tensile strength are found to be 38%, 41% and 19% respectively. Also, it is observed that a small percentage addition of fibers has improved the tensile strength of high-volume fly ash concrete.

It is observed that the flexural strength of FRHVFAC increases as the percentage of steel fibers in it increases up to 1.4%. Thereafter the flexural strength shows a decreasing trend. Thus, the higher value of flexural strength may be obtained by using 1.4% steel fibers. This is true for 7 days, 28 days and 90 days flexural strength. At 1.4% addition of steel fibers the percentage increase of 7 days, 28 days and 90 days flexural strength are found to be 80%, 78% and 29% respectively. Also, it is observed that a small percentage addition of fibers has improved the flexural strength of high-volume fly ash concrete.

It is observed that the impact strength of FRHVFAC increases as the percentage of steel fibbers in it increases up to 1.4%. Thereafter the impact strength shows a decreasing trend. Thus the higher value of impact strength may be obtained by using l .4% steel fibbers. This is true for 7 days, 28 days and 90 days impact strength. At 1.4% addition of steel fibbers the percentage increase of 7 days, 28 days and 90 days impact strength are found to be 208%, 205% and 205% respectively. Also, it is observed that a small percentage addition of fibbers has improved the impact strength of high-volume fly ash concrete substantially.

The improvement in the strength properties of HVFAC may be due to the fact that additions of fibbers improve the stiffness of concrete[10]. Also, addition of 1.4% fibers will fill all the major voids resulting in dense mass. Addition of more than 1.4% steel fiber result in lowering the strength characteristics, since it affects the workability of concrete seriously. Mixing and compaction operations become difficult when more than 1.4% steel fibbers are added in high volume fly ash concrete. Substantial improvements are found in tensile strength, flexural strength and impact strength when 1.4% steel fibbers are added to high volume fly ash concrete, and marginal increase is found for compressive strength.

Thus, there is a clear indication that the use of steel fibbers in high volume fly ash concrete can modify the properties to suit it for rigid pavement construction.

VI. CONCLUSION

- Compressive strength of FRHVFAC shows an increasing trend up to 1.4% addition of steel fibers. Thereafter compressive strength shows a decreasing trend. The percentage increase of 7 days, 28 days and 90 days compressive strength for 1.4% addition of steel fibers are found to be 17%, 18% and 17% respectively.
- Tensile strength of FRHVFAC shows an increasing trend up to 1.4% addition of steel fibers. Thereafter tensile strength shows a decreasing trend. The percentage increase of 7 days, 28 days and 90 days tensile strength for 1.4% addition of steel fibers are found to be 38%, 41% and 19% respectively.
- Flexural strength of FRHVFAC shows an increasing trend up to 1.4% addition of steel fibers. Thereafter flexural strength shows a decreasing trend. The percentage increase of 7 days, 28 days and 90 days flexural strength for 1.4% addition of steel fibers are found to be 80%, 78% and 29% respectively.
- Impact strength of FRHVFAC shows an increasing trend up to 1.4% addition of steel fibers. Thereafter impact strength shows a decreasing trend. The percentage

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