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RESEARCH ARTICLE

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AN EXPERIMENTAL INVESTIGATION ON THE STRENGTH AND WORKABILITY CHARACTERISTICS OF POLYMER BASED FLYASH CONCRETE

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ABSTRACT

The polymer concrete is a composite material in which aggregates are bonded together with resin. Performance of polymer concrete is strongly dependent on aggregates and resins. In the present research work the effect of addition of polymer on the workability and strength characteristics of flyash concrete is studied. The polymer percentage is varied from 0% to 5% with an increment of 0.5%. The optimum percentage of polymer is found from the practical consideration point of view. The workability characteristics are found using slump, compaction factor, percentage flow and vee-bee degree. The strength characteristics such as compressive strength, tensile strength, flexural strength, shear strength and impact strength are studied for different percentage addition of polymer. Along with this the near surface characteristics such as water absorption and sorptivity are studied. The work is carried out on M30 grade of concrete. 30% and 40% of cement is replaced by flyash in all the experimental work.

Key Words: Polymer concrete, Flyash, SBR Latex, Strength properties, Water absorption and Sorptivity.

INTRODUCTION

Polymer-modified cementitious materials date back more than 70 years. In the 1940's they were developed for use on ships decks and bridges. The history of research and development of polymer concrete composites is considerably different in various countries because of differences of background. Active research and development of the concrete polymer composites has been performed all over the world, particularly in the U.S.A and the Soviet Union (Russia). In the Japanese construction industry, the active research and development of the polymer-modified mortar and concrete have been performed for the past 50 years, and they are currently used as popular construction materials in various applications because of their high performance, multifunctionality and sustainability compared to conventional concrete. The polymer concrete (PC) is a composite material in which aggregates are bonded together with resins in polymer concrete. Performance of PC is strongly dependent on aggregates and resins. The particle size of aggregates has various types and mixed proportion of great influence on mechanical behavior of the PC and improves its physical and mechanical strengths.

Polymers are made from simple organic molecules (monomers) that combine to form more complex structures through a process called polymerization. Because the use of a polymer instead of Portland cement represents a substantial increase in cost, polymers should be used only in applications in which the higher cost can be justified by superior properties, low labor cost or low energy requirements during processing and handling. It is therefore important that architects and engineers have some knowledge of the capabilities and limitations of PC materials in order to select the most appropriate and economic product for a specific application. PC is being extensively used as a suitable substitute for cement concrete in a variety of applications such as construction and structural repairs, highway pavements, wastewater pipe lines, bridges, floors and dams. Polymer concrete has historically not been widely adopted due to the high costs and difficulty associated with traditional manufacturing techniques. However, recent progress has led to significant reductions in cost, meaning that the use of polymer concrete is gradually becoming more widespread.

Fly ash is an industrial by-product, generated from combustion of coal in the thermal power plants. The increasing scarcity of raw materials and an urgent need to protect the environment against pollution has accentuated the significance of developing new building materials based on industrial waste generated from coal fired thermal power station which creates unmanageable disposal problems due to its potential to pollute the environment. In the era of advances in technology, one of the concepts is to use waste materials in the production of concrete.

The growing awareness of environmental problems, particularly with regard to energy efficiency and greenhouse gas emissions, the construction and the cement industry has had a prominent place, the later being responsible for about 7% of CO_2 emissions into the atmosphere. Knowing that cement production contributes about one tonne of CO_2 for every tonne produced, it remains paradoxical that concrete, the product most consumed by humans, exceeded only by water, cannot find a credible more efficient and greener replacement material for Portland cement.

MATERIALS USED FOR THE EXPERIMENT

Cement	: Ordinary Portland cement of 53 grade was used in this experiment conforming to IS12269:1987
Coarse aggregates	: Locally available, maximum size 20 mm, specific gravity 2.60
Sand	: Locally available sand zone-I with specific gravity 2.60, water absorption 1% conforming to IS – 383-1970.
Water	: Potable water was used for the experiment.
Chemical admixture	: Styrene Butadiene Rubber (SBR) Latex Polymer.
Flyash	: Low calcium, class F dry fly ash from the silos of Raichur thermal power plant conforming to IS: 3812 (Part 1) – 2003 was used.

EXPERIMENTAL RESULTS

The concrete mix M30 investigated in this study is prepared with standard 53 grade Portland cement and polymers which conform to Indian standards. Mix design was carried out according the IS 10262: 2009. The concrete mixed used for casting the cube, cylinder, beam, L-shape and impact specimen is 1: 1.47: 2.48 by weight and a water cement ratio as 0.45.

The following workability tests are conducted on fresh concrete.

- Slump cone test.
- Compaction factor test.
- Vee-Bee consistometer test.
- Flow table test.

The following strength tests are conducted after 28 days of curing

- Compressive strength test on 150mmX150mmX150mm cube.
- Tensile strength test on 150mmϕ X300mmL cylinder.
- Flexural strength test on 100mmX100mmX500mm beam.
- Impact strength test on 150mmϕ X60mmL cylinder.
- Shear strength test on L shaped specimens

Workability and near surface characteristics test results: - Following tables give the slump test, compaction factor, Vee-Bee degree, flow table, water absorption and sorptivity test results for polymer based flyash concrete produced by different dosage of polymer addition. The variations in the workability are depicted in the forms of graphs.

Table 1 Slump tests results for polymer based flyash concrete produced by different dosage of polymer addition.

Percentage of polymer addition	Slump (mm)	
	Polymer concrete produced by replacing 30% cement by flyash	Polymer concrete produced by replacing 40% cement by flyash
0% (ref. mix)	35	28
0.5%	41	35
1.0%	48	42
1.5%	55	48
2.0%	60	55
2.5%	65	64
3.0%	72	70
3.5%	83	78
4.0%	77	76
4.5%	66	68
5.0%	63	65

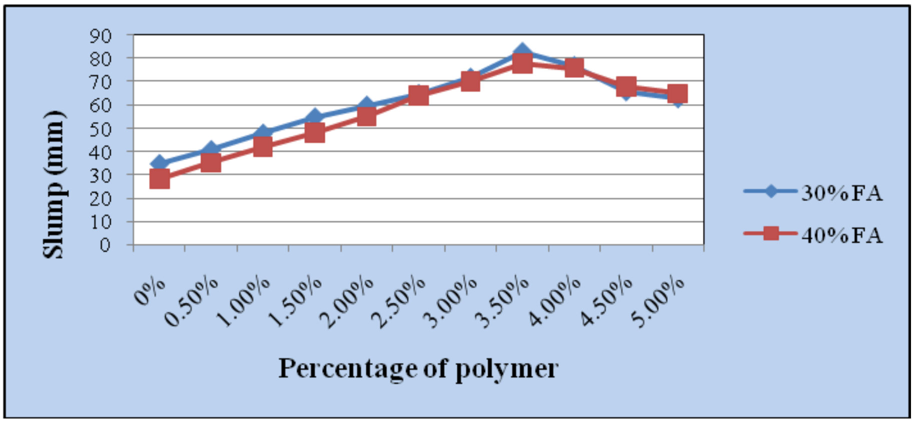

Fig. 1 Variation of slump

Table 2 Compaction factor tests results for polymer based flyash concrete produced by different dosage of polymer addition.

Percentage of polymer addition	Compaction factor	
	Polymer concrete produced by replacing 30% cement by flyash	Polymer concrete produced by replacing 40% cement by flyash
0% (ref. mix)	0.900	0.900
0.5%	0.920	0.910
1.0%	0.940	0.930
1.5%	0.960	0.940
2.0%	0.972	0.942
2.5%	0.981	0.949
3.0%	0.986	0.958
3.5%	0.995	0.974
4.0%	0.975	0.960
4.5%	0.960	0.945
5.0%	0.955	0.930

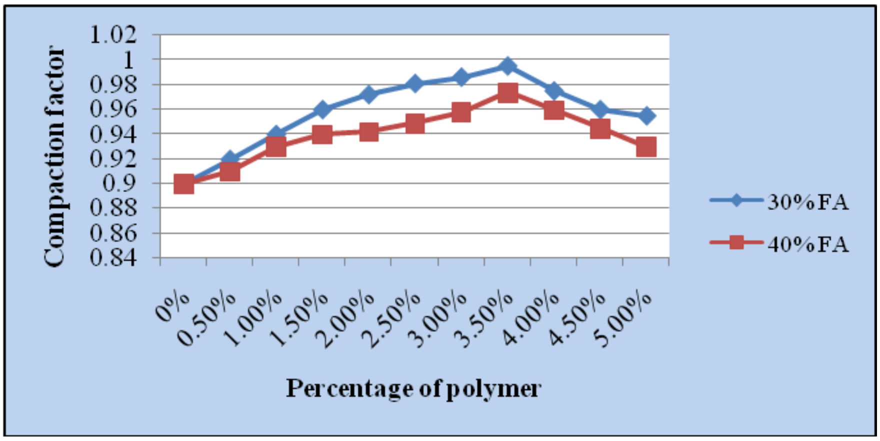

Fig. 2 Variation of compaction factor

Table 3 Vee-Bee consistometer test results for polymer based flyash concrete produced by different dosage of polymer addition.

Percentage of polymer addition	Vee-Bee degree (sec)	
	Polymer concrete produced by replacing 30% cement by flyash	Polymer concrete produced by replacing 40% cement by flyash
0% (ref. mix)	25	28
0.5%	24	26
1.0%	22	25
1.5%	21	23
2.0%	20	22
2.5%	18	20
3.0%	17	19
3.5%	16	17
4.0%	18	19
4.5%	19	21
5.0%	21	22

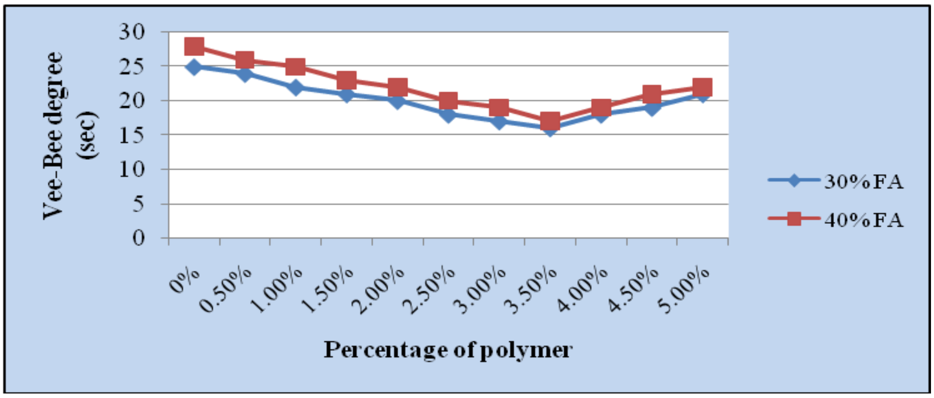

Fig. 3 Variation of Vee-Bee degree

Table 4 Flow table test results for polymer based flyash concrete produced by different dosage of polymer addition

Percentage of polymer addition	Percentage flow	
	Polymer concrete produced by replacing 30% cement by flyash	Polymer concrete produced by replacing 40% cement by flyash
0% (ref. mix)	38.64	39.80
0.5%	36.66	37.30
1.0%	35.28	36.58
1.5%	33.85	35.05
2.0%	32.50	33.56
2.5%	31.28	32.28
3.0%	28.07	30.45
3.5%	26.90	28.35
4.0%	29.60	31.56
4.5%	30.95	32.85
5.0%	32.56	34.65

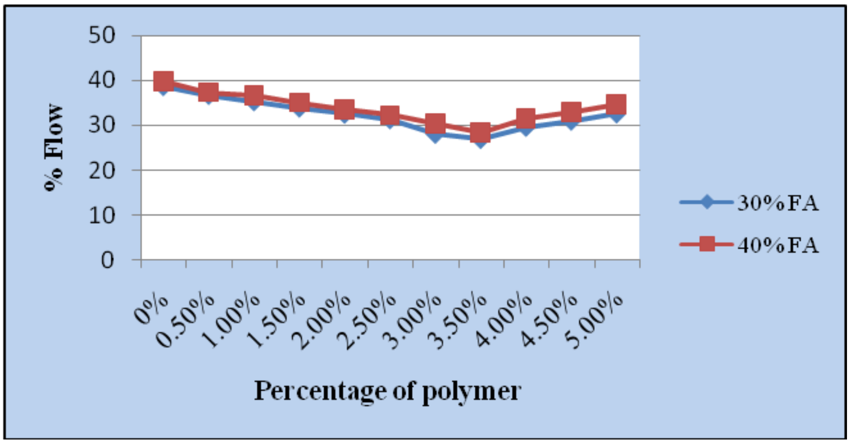

Fig. 4 Variation of percentage flow

Table 5 Water absorption test results for polymer based flyash concrete produced by different dosage of polymer addition.

Percentage of polymer addition	Percentage of water absorption for Polymer concrete produced by replacing 30% cement by flyash	Polymer concrete produced by replacing 40% cement by flyash
0% (ref. mix)	0.93	0.96
0.5%	0.89	0.92
1.0%	0.85	0.88
1.5%	0.80	0.85
2.0%	0.78	0.81
2.5%	0.75	0.77
3.0%	0.71	0.73
3.5%	0.68	0.71
4.0%	0.76	0.79
4.5%	0.80	0.82
5.0%	0.83	0.86

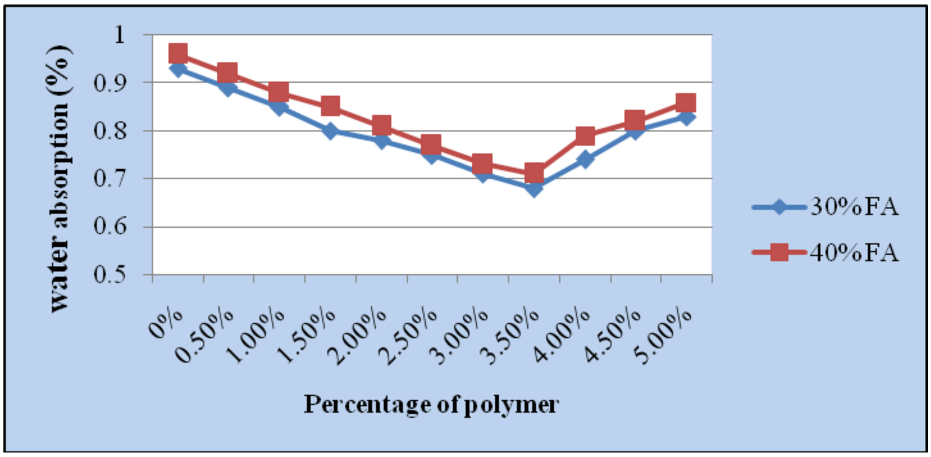

Fig. 5 Water absorption test results

Table 6 Sorptivity test results for polymer based flyash concrete produced by different dosage of polymer addition.

Percentage of polymer addition	Sorptivity values for (mm/mm$^{0.5}$) Polymer concrete produced by replacing 30% cement by flyash	Polymer concrete produced by replacing 40% cement by flyash
0% (ref. mix)	5.50	5.81
0.5%	5.34	5.56
1.0%	5.25	5.35
1.5%	5.13	5.16
2.0%	4.95	4.98
2.5%	4.72	4.83
3.0%	4.48	4.70
3.5%	4.31	4.56
4.0%	4.85	4.96
4.5%	4.97	5.10
5.0%	5.20	5.26

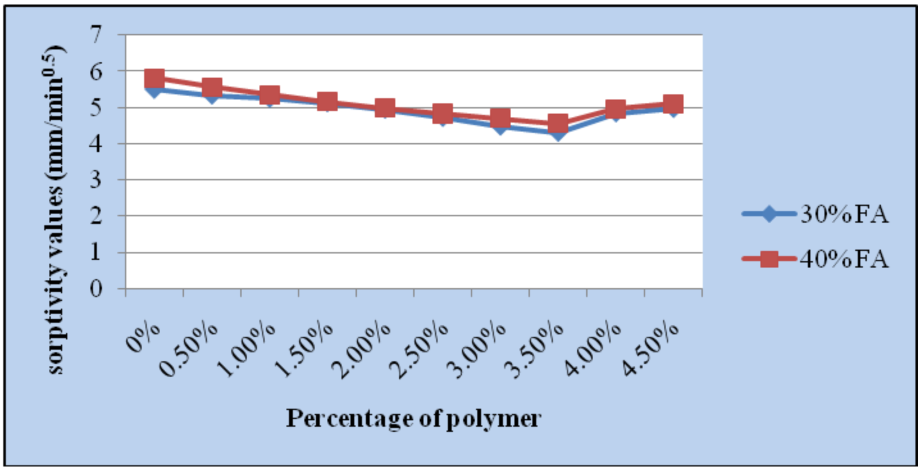

Fig. 6 Variation of sorptivity values

STRENGTH TEST RESULTS

Following tables give the overall results of compressive strength, tensile strength, flexural strength, shear strength and impact strength of polymer based flyash concrete produced by different dosage of polymer addition with 28days of curing. Also it gives the percentage increase or decrease of compressive strength with respect to reference mix. The variation in the strength is depicted in the form of graph.

Table 7 Overall results of compressive strength

Percentage of Polymer addition	Compressive strength of polymer concrete with 30% replacement of cement by flyash (MPa)	Percentage increase or decrease of compressive strength w.r.t reference mix	Compressive strength of polymer concrete with 40% replacement of cement by flyash (MPa)	Percentage increase or decrease of compressive strength w.r.t reference mix	Percentage increase of compressive strength for 30% replacement as compared to 40% replacement
0% (ref. mix)	28.03	0	26.03	0	+8
0.5%	28.92	+3	27.36	+5	+6
1.0%	29.59	+6	28.48	+9	+4
1.5%	30.10	+10	28.92	+11	+4
2.0%	30.56	+2	29.37	+13	+3
2.5%	31.05	+8	30.26	+16	+3
3.0%	32.48	+16	30.70	+18	+6
3.5%	33.82	+21	31.59	+21	+7
4.0%	29.37	+5	28.92	+11	+2
4.5%	28.48	+2	26.30	+1	+8
5.0%	26.70	-5	26.10	+0.5	+2

Table 8 Overall results of tensile strength

Percentage of Polymer addition	Tensile strength of polymer concrete with 30% replacement of cement by flyash (MPa)	Percentage increase or decrease of tensile strength w.r.t reference mix	Tensile strength of polymer concrete with 40% replacement of cement by flyash (MPa)	Percentage increase or decrease of tensile strength w.r.t reference mix	Percentage increase of tensile strength for 30% replacement as compared to 40% replacement
0% (ref. mix)	1.46	0	1.45	0	+1
0.5%	1.41	-3	1.37	-6	+3
1.0%	1.46	+13	1.37	-3	+2
1.5%	1.50	+4	1.36	-7	+1
2.0%	1.64	+13	1.46	0	+1
2.5%	1.84	+27	1.64	+12	+1
3.0%	1.98	+37	1.84	+26	+7
3.5%	2.41	+66	2.12	+45	+12
4.0%	2.26	+56	1.92	+32	+15
4.5%	1.73	+19	1.46	0	+16
5.0%	1.42	-2	1.42	-3	0

Table 9 Overall results of flexure strength

Percentage of Polymer addition	Flexure strength of polymer concrete with 30% replacement of cement by flyash (MPa)	Percentage increase or decrease of flexure strength w.r.t reference mix	Flexure strength of polymer concrete with 40% replacement of cement by flyash (MPa)	Percentage increase or decrease of flexure strength w.r.t reference mix	Percentage increase of flexure strength for 30% replacement as compared to 40% replacement
0% (ref. mix)	2.86	0	2.74	0	+4
0.5%	3.00	+5	2.78	+1	+7
1.0%	3.18	+11	2.86	+4	+10
1.5%	3.26	+14	2.98	+9	+9
2.0%	3.42	+20	3.07	+12	+10
2.5%	3.40	+19	3.14	+15	+8
3.0%	3.58	+25	3.22	+18	+10
3.5%	3.80	+33	3.38	+23	+11
4.0%	3.29	15	2.99	+9	+9
4.5%	2.94	+3	2.62	-5	+10
5.0%	2.58	-10	2.06	-25	+20

Table 10 Overall results of shear strength

Percentage of polymer addition	Shear strength of polymer concrete with 30% replacement of cement by flyash (MPa)	Percentage increase or decrease of shear strength w.r.t reference mix	Shear strength of polymer concrete with 40% replacement of cement by flyash (MPa)	Percentage increase or decrease of shear strength w.r.t reference mix	Percentage increase of shear strength for 30% replacement as compared to 40% replacement
0% (ref. mix)	5.37	0	4.22	0	+21
0.5%	5.45	+11	4.34	+3	+20
1.0%	6.00	+11	4.61	+9	+23
1.5%	6.52	+11	4.73	+12	+27
2.0%	6.95	+12	4.83	+14	+31
2.5%	7.35	+12	4.83	+14	+34
3.0%	7.79	+34	5.17	+23	+34
3.5%	8.15	+63	6.39	+51	+22
4.0%	7.00	+54	5.17	+23	+26
4.5%	6.80	+32	3.67	-13	+46
5.0%	4.85	+6	2.56	-39.33	+47

Table 11 Overall results of impact strength for 30% FA

Percentage of polymer addition	Initial crack impact strength of polymer concrete with 30% replacement of cement by flyash (N-m)	Percentage increase or decrease of initial impact strength w.r.t reference mix	Final crack impact strength of polymer concrete with 30% replacement of cement by flyash (N-m)	Percentage increase or decrease of final impact strength w.r.t reference mix
0% (ref. mix)	246.78	0	286.50	0
0.5%	267.35	+8	329.50	+13
1.0%	308.48	+20	371.50	+23
1.5%	329.04	+25	410.20	+30
2.0%	373	+34	431.80	+34
2.5%	411.30	+40	452.43	+37
3.0%	431.86	+43	476	+40
3.5%	494	+50	534.70	+46
4.0%	308.48	+20	352.02	+19
4.5%	226.23	-9	280.55	-2
5.0%	145.01	-7	185.00	-6

Table 12 Overall results of impact strength for 40% FA

Percentage of Polymer addition	Initial crack impact strength of polymer concrete with 40% replacement of cement by flyash (N-m)	Percentage increase or decrease of initial impact strength w.r.t reference mix	Final crack impact strength of polymer concrete with 40% replacement of cement by flyash (N-m)	Percentage increase or decrease of final impact strength w.r.t reference mix
0% (ref. mix)	180	0	240.59	0
0.5%	235.56	+24	280.05	+14
1.0%	267.35	+33	308.60	+22
1.5%	287.91	+37	329.05	+27
2.0%	329.04	+45	380.75	+37
2.5%	370.17	+51	395.50	+39
3.0%	411.30	+56	452.42	+47
3.5%	431.86	+58	480.70	+50
4.0%	329.04	+45	370.17	+35
4.5%	210.05	+14	265.70	+10
5.0%	123.89	-5	150.70	-6

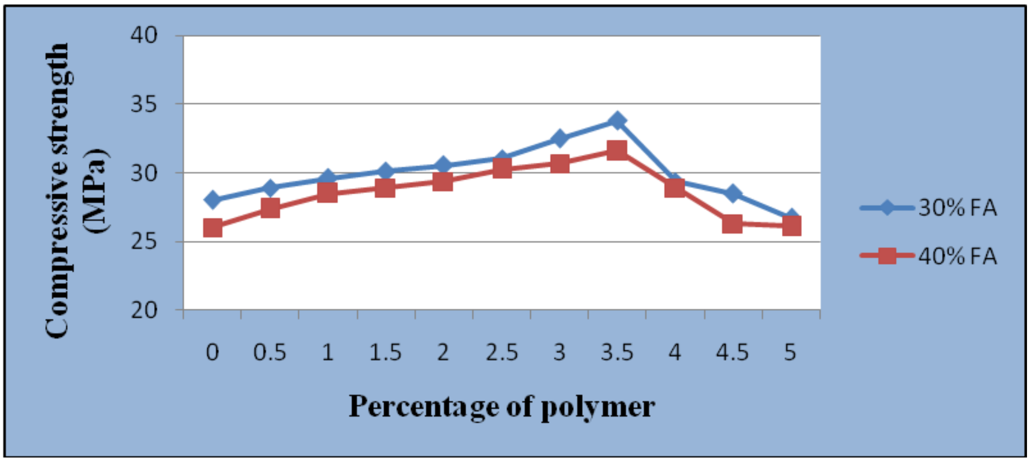

Fig. 7 Variation of compressive strength

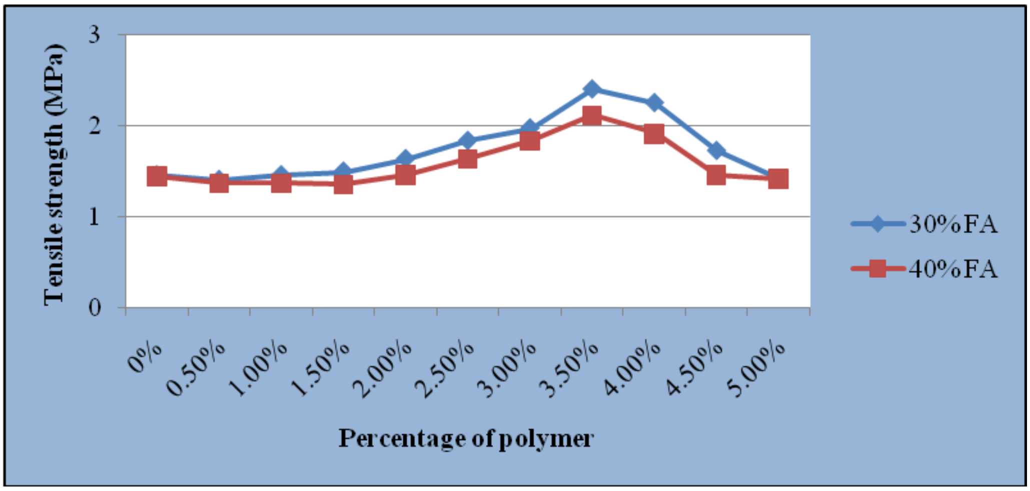

Fig. 8 Variation of tensile strength

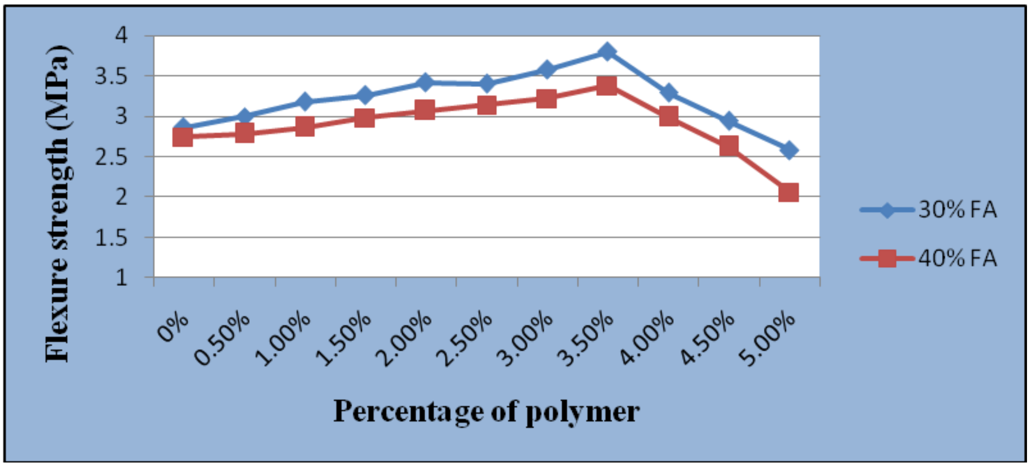

Fig. 9 Variation of flexural strength

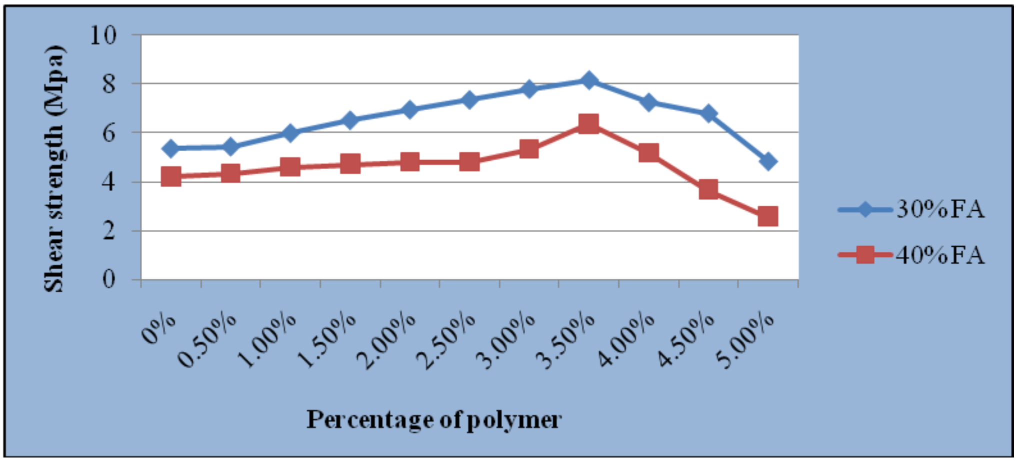

Fig. 10 Variation of Shear strength

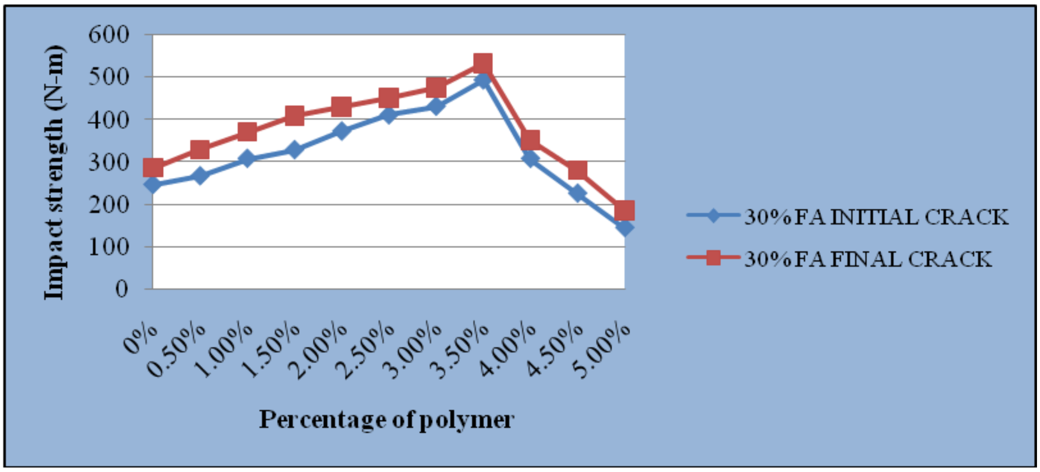

Fig. 11 Variation of impact strength for initial crack and final crack of 30% FA

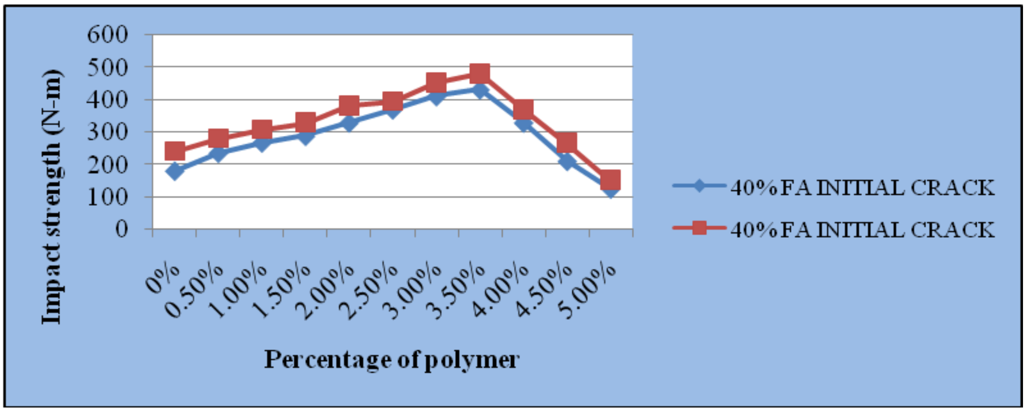

Fig. 12 Variation of impact strength for initial crack and final crack of 40% FA

CONCLUSIONS

Following conclusions can be drawn based on the experiments conducted on the strength and workability characteristics of polymer based flyash concrete.

1. Higher workability may be achieved by adding 3.5% polymer in flyash concrete. Also the polymer concrete produced by replacing 30% cement by flyash show higher workability as compared to 40% replacement.

2. Better water absorption and sorptivity values may be achieved by adding 3.5% polymer in flyash concrete. Also the polymer concrete produced by replacing 30% cement by flyash show better water absorption and sorptivity values as compared to 40% replacement.
3. Compressive strength of polymer based flyash concrete is higher at 3.5% addition of polymer. Also, it can be concluded that the compressive strength of polymer concrete with 30% replacement of cement by flyash is higher as compared to 40% replacement.
4. Tensile strength of polymer based flyash concrete is higher at 3.5% addition of polymer. Also, it can be concluded that the tensile strength of polymer concrete with 30% replacement of cement by flyash is higher as compared to 40% replacement.
5. Flexure strength of polymer based flyash concrete is higher at 3.5% addition of polymer. Also, it can be concluded that the flexure strength of polymer concrete with 30% replacement of cement by flyash is higher as compared to 40% replacement.
6. Shear strength of polymer based flyash concrete is higher at 3.5% addition of polymer. Also, it can be concluded that the shear strength of polymer concrete with 30% replacement of cement by flyash is higher as compared to 40% replacement.
7. Impact strength of polymer based flyash concrete is higher at 3.5% addition of polymer. Also, it can be concluded that the impact strength of polymer concrete with 30% replacement of cement by flyash is higher as compared to 40% replacement.

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