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THE EFFICACY ON STRENGTH OF STEELFIBER AND POLYPROPYLENE FIBER ON HIGH PERFORMANCE CONCRETE

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Abstract: In this paper, the investigation regarding the effect of reinforcing steel fiber as well as polypropylene fibers over the normal high-performance concrete is done. The effect is examined over the slump, compressive strength as well as flexural strength. The combination of M40 (OPC 53 Vasavadatta) along with steel fiber and polypropylene fiber separately is used for study. Workability of fiber mixed concrete is tested at the time interval of initial stage, 60 min, 120 min and 180 min. Total 36 Cubes of size (150*150*150 mm) and 9 beams of size (700*150*150 mm) are casted to inspect. Cubes are tested at the age of 3 days, 7 days and 28 days. Flexural strength is determined on the 28th day. Based on experimental studies, the paper identifies the fibers combination indicates maximum compressive strength and flexural strength of concrete. Specimens were tested over the different age levels for mechanical properties of concrete. A detailed study was carried out of curing conditions over the compressive strength. The behavior of flexural load-deformation, compressive strength of conventional concrete is briefly compared with fiber reinforced cementitious composites. Eventually the result derives that the addition of fibers to concrete resulted in increase in compressive strength as well as flexural strength compared to mixture of plain concrete.

Index Terms: OPC (Ordinary Portland Cement), Polypropylene fiber, Steel fiber, mix design, strength, flexure, slump, compressive, high performance.

I. INTRODUCTION

In construction industry concrete is one of the most widely used material in developed and developing countries. Performance of concrete is dependent over the ingredients used. The materials have inherently brittle nature and have some dramatic disadvantages like poor deformability and weak crack resistance in the practical usage. Brittle nature of concrete is one of the objectionable characteristics resulting in its low strength. Reinforcement is necessary in order to be used over worldwide. In conventional method steel bars are used for reinforcement in appropriate position in concrete structure where used to withstand the imposed tensile and shear stresses. For more efficient practices short, discontinuous fibers are used. It is randomly distributed in the entire concrete member to produce a composite construction material known as fiber reinforcement concrete (FRC). The considerable superiority of fibre reinforced concrete is to convert a brittle concrete into pseudo ductile material. [2] Micro cracks can be avoided by using fibre reinforced concrete. [7] Different fibres like steel, polypropylene etc. has been incorporated in concrete and mechanical properties of such concrete were studied. But still it is ongoing process to improve properties of concrete. In fiber reinforced concrete thousands of small fibers are distributed randomly in concrete during mixing and thus improve the concrete properties in all directions [4].

In recent years, cement based composite materials that has been developed called fiber reinforced concrete. It has been successfully used in construction with its all mechanical properties like flexural-tensile strength. It is an effective way to increase toughness, shock resistance and avoid plastic shrinkage cracking of concrete. [3] A small piece of reinforcing material possessing certain characteristics properties is known as fiber. They are of any shape or size like circular, triangular, flat or linear in cross section. For fiber reinforced concrete to be a viable construction material, it must be able to compete economically with exiting reinforcing system. Polypropylene fibers also one of the main types of fibres used in market just like steel fibers. Regardless of properties their elastic strength varies significantly. Polypropylene fibers are more cost-effective. Polypropylene interpose the prospect of a high-performance concrete to the globe. It has better durability due to anti-rust property. It is flexible for handling due to light weight. Due to its improved mechanical properties of Fiber reinforced concrete is becoming an increasingly popular construction material over unreinforced concrete. to alter the brittle nature of pain concrete fiber reinforcement is one of the best modifications.

In this paper experimental study is made on the utilization of steel fibers and polypropylene fiber in the concrete cube. Polypropylene fiber is the synthetic fiber with low density, low modulus of elasticity with fine diameter. It has special characteristics such as high strength, ductility and durability, abundant resources, low cost and easily physical and chemical reformation according to certain demands. It can be wildly utilized in the field of concrete products. Steel fibers are filaments of wire, deformed and cut to length, for reinforcement concrete, mortar and other composite materials. It is cold drawn wire fiber with corrugated and flatted shape. In this study the influence of different types of fibers like steel and polypropylene in concrete, properties were investigated by measuring compressive strength and flexural strength. [9].

II. MATERIALS USED

The materials used in this experimental work are cement, fine aggregate, coarse aggregate, steel fibers and polypropylene fibers. Properties of materials are specified in Table 1 as follows:

table 1: properties of c.a. and f.a.

Property	C. A.	Sand
Specific Gravity	2.7	2.62
Fineness modulus	6.446	2.70
Max aggregate size (mm)	20	4.75
% Absorption	0.95	1.88

2.1. Steel Fibers

In replacement of traditional reinforcement such as rebar, wire mesh steel fibers are used [1]. They are nothing but short, discrete lengths of steel fibers with aspect ratio about 20 to 100 along with varying cross sections also efficiently tiny enough for random dispersion in unhardened concrete mixture just like nominal mixing process. The addition of steel fibers improvises the resistance to cracking, impact, fatigue, bending, tenacity, durability etc. It can replace steel mesh and reduce the pouring thickness of concrete by 15-25%. Helps to improve construction conditions and shorten the construction period by 30%. It facilitates continuous and rapid pouring of concrete. Savings on labor, total fiber cost, construction convenience allows shortening the construction period. Steel fibers used as reinforcement, reinforce in three dimensions throughout the entire concrete [7]. These distributed steel fibers restrain micro-cracking and redistribute accumulated stress caused by applied loads and shrinkage. As soon as the crack is intercepted and its growth is inhibited, the less chance the crack will occur. Fiber orientation has a crucial effect on tensile strength. The primary purpose of addition steel fiber is to increase toughness and ductility Fiber family 3D, Tensile strength: 1.225 N/mm^2 Young's modulus: 21.00N/mm^2, Length 60 mm, Diameter 0.75 mm, Aspect ratio 80. Steel fiber transforms the concrete which is brittle in to ductile, robust, durable and resistant composite materials. This transformation from a brittle to a ductile type of material would increase substantially the energy absorption characteristics of the fiber composite and its ability to withstand repeatedly applied, shock or impact loadings.

fig: steel fiber.

2.2. Polypropylene

Polypropylene is one of the cheapest and abundantly available polymers. Manufacturing of polypropylene fibers is done in various shapes and different properties. At present it is used as discontinuous fibrillated material. In past ages polypropylene used in relatively low contents just like a secondary reinforcement. Polypropylene Increases the energy absorption capacity. Dynamic modulus of elasticity of polypropylene fibers is higher. Polypropylene has melting point 1650c which strengthen the concrete to withstand elevated temperatures for some time interval. Mainly it is used to arrest cracking due to effects like temperature variations as well as moisture differences [3]. Polypropylene strands are hydrophobic, surface repairing. It also provides support to material behavior like reduction in plastic behavior, shrinkage and increases toughness. Nature of polypropylene is inert that means any chemical if damages the polypropylene will be surely quite harmful to concrete mix as well [8]. It enhances the mix quality over a long duration. Strengthen the structural strength. Lowering the requirement of steel reinforcement. It increases resistance towards explosive spalling in cease of fire.

In every structure the quality of concrete plays an important role. Imperviousness of concrete retard the corrosion of steel reinforcement. Main cause of reduction in quality of concrete is cracks. Which can result in making structure out of service. It is important to reduce crack width and this can be achieved by addition of fibers to concrete. The use of fibers in the concrete fills the crack efficiently and resists its further propagation. Fibers are tiny in nature that allows them exposure to more area of surface resulting in strengthening of concrete. Thus, an extra amount of load and energies will be required for more deflection. This improves the load carrying capacity of structural member beyond cracking also preserving concrete integrity. Plastic shrinkage, plastic settlement, freeze thaw damage, fire damage are the main causes for the formation of crack.

Fig: Polypropylene.

III. FIBER MECHANISM

Spacing mechanism and crack bridging mechanism are the two mechanisms which fiber utilizes while working with concrete. Spacing mechanism requires a large amount of fibers well dispersed within the matrix of concrete to restrain any existing micro-crack which may potentially expand and create a bigger crack. For typical volume fractions of fiber, using small diameter fibers to ensure the required number of fibers for micro crack arrest.

Crack bridging mechanism need large straight fibers with adequate bond to the concrete. The prime example for this is a steel fiber which is commonly referred as large diameter fiber or micro fiber. Impact resistance, flexure and tensile strengths, ductility and fracture toughness are the benefits of using larger fibers.

IV. EXPERIMENTAL STUDY

Concrete mix M40 is examined in this study of grade 53 Ordinary Portland Cement. Materials were weighted accurately using digital weighing instrument for plane concrete, fine aggregate, coarse aggregate, cement and water were added and were mixed thoroughly. Steel fibers and polypropylene fibers were manually added into concrete mix after through mixing of ingredients.

Fig: Cubes casted.

V. MIX PROPORTIONS

Four mixes of concrete were produced to cast a series of test specimen from mix M1 to M4.for this research work M1 stands for normal plain M40 concrete, mix design M2 contains steel fibers along with normal M 40 concrete, M3 represents the M40 concrete with addition of polypropylene fibers, M4 represents the M40 concrete with addition of fly ash. 9 cubes of each mixture are casted for compressive test while 3 beams of M1, M2, M3 mixture are casted for flexural testing.

Table 2: Mix design.

Mix Design	**Dry wt. per Cum (in kg)**				
	cement	**Fibres**	**C.A. 20mm**	**C.A. 10mm**	**FA**
M40	365	0	665	455	806
M40 Steel fibres	365	10	665	455	806
M40 Polypropylene	365	0.9	670	461	806
M40 Fly ash	370	90	605	494	790

VI. EXPERIMENTAL METHODOLOGY

6.1. Slump cone test

We have performed a slump cone test on polypropylene fiber reinforced concrete (PPF), steel fiber reinforced concrete and conventional M40 grade concrete. Slump cone test is performed to determine workability of freshly prepared concrete before it sets. Filling of mould done in three stages. A bar of 16 mm diameter is used for tamping. At each stage tamping is done 25 times. At 3rd stage concrete is stuck off flush with top of mould. The slump values taken at initial point, after 16 min, after 120 min and after 180 min. as given in table 1. The comparative bar graph of polypropylene fiber reinforced concrete (PPF), steel fiber reinforced concrete and conventional M40 grade concrete has given in graph 1.

Fig: Slump cone test.

6.2 Compression strength test

For the testing of compression test, specimens of the dimension 150X150X150 mm were casted of mix designs M1, M2, M3, M4. Before mixing the concrete, the molds were kept ready. Oil was applied to the inner surface of moulds for easy removal. Cubes were poured with concrete, after pouring of concrete into the mold, tamping rod is used to compact the concrete and then the top surface was given a smooth finish [2]. Demoulding was done after 24 hrs. Specimens were shifted to curing tank for curing process. Testing was done at the age of 3 days, 7 days, 28 days of concrete. For each reading 3 cubes were tested and average value is considered.

Fig: ACTM Machine.

6.3 Flexural strength test

As flexural strength is a material property, which defines the stress in concrete material just before it yields. Stress at failure in bending was measured. For study of flexural strength, the beams of dimensions 700X100X100 mm were casted. Total 9 beams were examined. The specimens were demoulded after 24 hrs. and shifted to curing tank for curing process. Specimens were tested at the age of 28 days. Testing was done on Flexural strength machine and flexural strength is derived. Average values are reported for further analysis. Graph was plotted for time v/s strength parameters. The loads were applied as shown in the figure. The stress was noted down when the beam failed. We have done central point load test to calculate the flexural strength. The distance between the line of fracture and the support was 200.33mm so we know that if a is greater than 170mm for 150mm specimen, or less than 133.33mm but greater than 110mm for 100mm specimen. As the line of fracture was at 200.33mm, the formula used for calculating the flexural strength, according to which the flexural strength is given in table 3.1

$$\text{Flexural strength, } f_r = \frac{3pa}{bd^2}$$

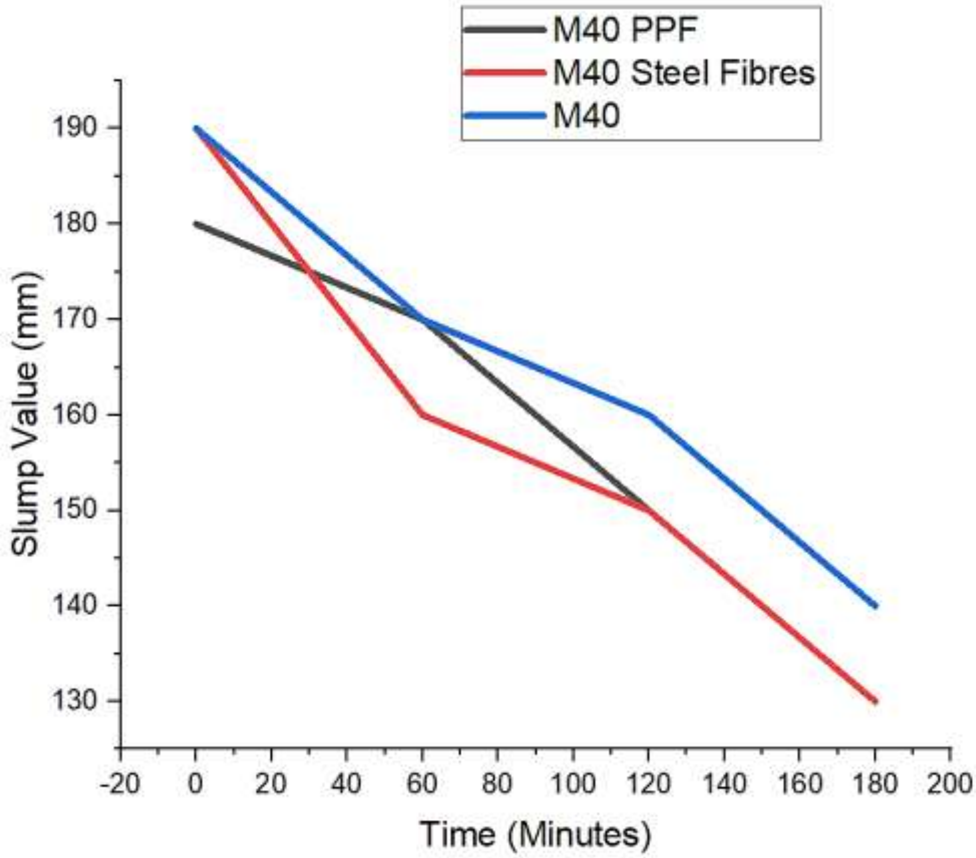
VII. RESULTS

The result of all the tests conducted is interpreted as follows

7.1 Slump cone test

Table 7.1: Slump cone values with varying time

Slump/Flow	M40: PPF	M40: Steel Fibre	M40
Initial	180	190	190
60 min	170	160	170
120 min	150	150	160
180 min	130	130	140



Graph 7.1: time v/s slump value.

8.2 Compressive strength test

Table 8.2.1: M40 concrete along with Polypropylene Fibers.

Date of Test	Age (Days)	Size (in mm)	Weight in kg	Density kg/m^3	Load in KN	Strength N/m^2	
							Average
19/4/2022	3	150	8.76	2596	540	24	24.6
19/4/2022	3	150	8.74	2590	564.8	25.1	
19/4/2022	3	150	8.71	2581	558	24.8	
23/4/2022	7	150	8.69	2575	762.8	33.9	34.6
23/4/2022	7	150	8.75	2593	776.3	34.5	
23/4/2022	7	150	8.71	2581	769.5	35.4	
14/5/2022	28	150	8.77	2591	1212.8	53.9	53.6
14/5/2022	28	150	8.72	2584	1185.8	52.7	
14/5/2022	28	150	8.73	2587	1221.8	54.3	

Table 8.2.2. M40 concrete along with Steel Fibers.

Date of Test	Age Days	Size (in mm)	Weight in kg	Density kg/m^3	Load in kN	Strength N/mm^2	
							Average
19/4/2022	3	150	8.75	2593	594	26.4	26.5
19/4/2022	3	150	8.77	2599	609.8	27.1	
19/4/2022	3	150	8.73	2587	585	26	
23/4/2022	7	150	8.69	2575	828	36.8	36.3
23/4/2022	7	150	8.76	2596	776.3	34.5	
23/4/2022	7	150	8.72	2584	846	37.6	
14/5/2022	28	150	8.77	2599	1248.8	55.5	54.4
14/5/2022	28	150	8.78	2601	1221.8	54.3	
14/5/2022	28	150	8.72	2584	1269	56.4	

Table 8.2.3: Plain M40 concrete.

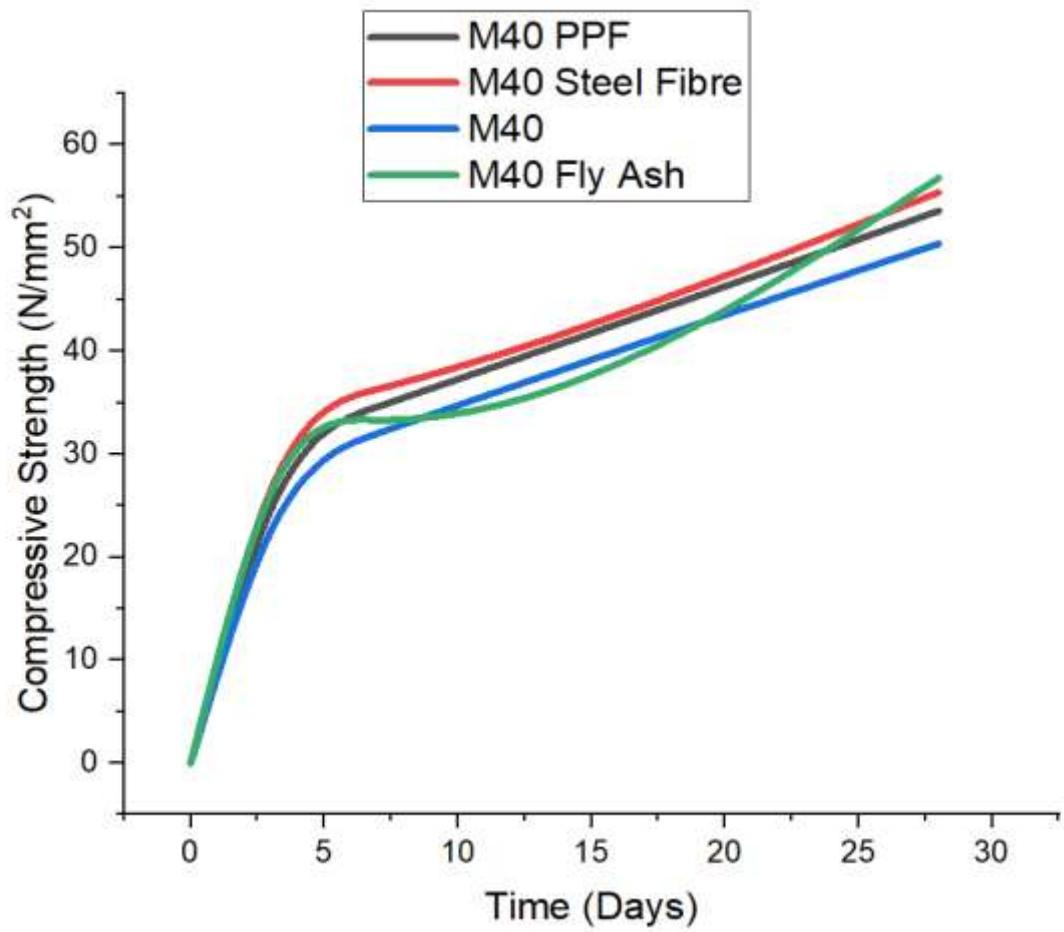
Date of Test	Age Days	Size (in mm)	Weight in kg	Density kg/m^3	Load in kN	Strength N/mm^2	
							Average
19/4/2022	3	150	8.75	2593	531	23.6	22.5
19/4/2022	3	150	8.77	2599	504	22.4	
19/4/2022	3	150	8.73	2587	486	21.6	
23/4/2022	7	150	8.69	2575	711	31.6	32
23/4/2022	7	150	8.76	2596	729	32.4	
23/4/2022	7	150	8.72	2584	720	32	
14/5/2022	28	150	8.77	2599	1129.5	50.2	50.4
14/5/2022	28	150	8.78	2601	1120.5	49.8	
14/5/2022	28	150	8.72	2584	1154.3	51.3	

Table 8.2.4: M40 concrete with fly ash.

Date of Test	Age Days	Size (in mm)	Weight in kg	Density kg/m³	Load in kN	Strength N/mm²	
							Average
10/5/2022	3	150	8.68	2571.8	580.5	25.8	26.2
10/5/2022	3	150	8.74	2589.6	591.7	26.3	
10/5/2022	3	150	8.77	2598.5	596.2	26.5	
14/5/2022	7	150	8.71	2580.7	707.9	31.4	33.3
14/5/2022	7	150	8.75	2592.5	749.4	33.3	
14/5/2022	7	150	8.69	2574.8	724.5	32.2	
06/6/2022	28	150	8.68	2571.8	1244.6	55.3	56.8
06/6/2022	28	150	8.7	2577.7	1335.3	59.3	
06/6/2022	28	150	8.73	2586.6	1260	56	

Table 8.2.5: Average Values.

Days	M40: PPF	M40: Steel Fibres	M40	M40: Fly ash
3	24.6	26.5	22.5	26.2
7	34.6	36.3	32	33.3
28	53.6	55.4	50.4	56.8

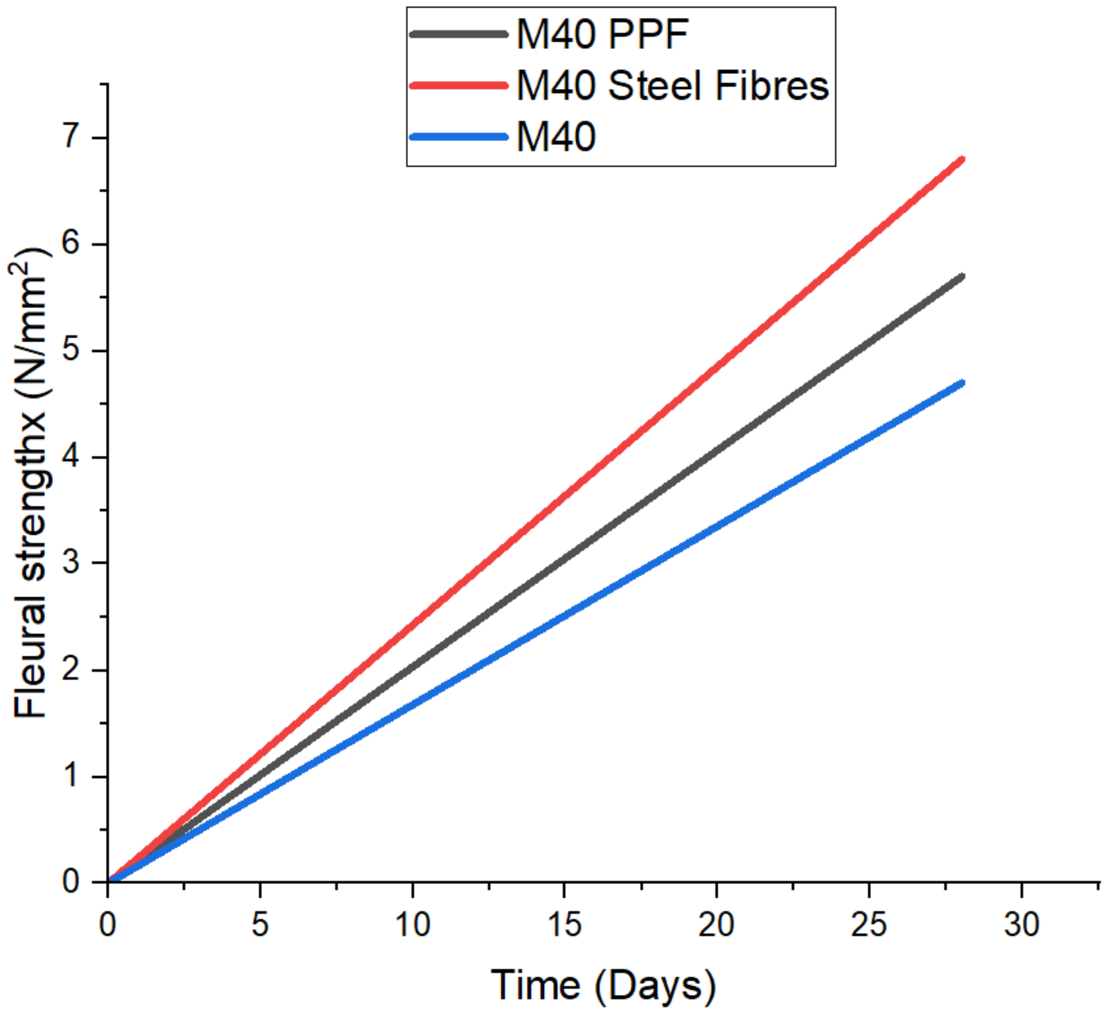


Graph 8.2: time v/s compressive strength.

8.3 Flexural strength test

Table 3.1: Flexural strengths of various harden concrete.

Date of Test	Age Days	Mix Design	Size (in mm)	Load in kN	Strength N/mm^2	
						Average
14/5/2022	28 Days	M 40 Polypropylene	700X150X150	33.8	6	5.7
			700X150X150	32.6	5.8	
			700X150X150	30	5.4	
		M 40 Steel Fibres	700X150X150	33.3	7	6.8
			700X150X150	38.1	6.9	
			700X150X150	36.5	6.5	
		M 40	700X150X150	27.5	4.9	4.7
			700X150X150	24.2	4.3	
			700X150X150	27.5	4.8	



Graph 8.3: time v/s flexural strength

VIII. CONCLUSION

Based on experimental results presented in paper, the main conclusion are as follows

(i) The slump value of plain concrete and steel fiber is more at initial stages. As time passes the slump of plain concrete is more than that of fiber reinforced concrete. Hence workability of plain concrete is more.

(ii) The slump cone test was carried out over plain M40 concrete which gives higher slump than that of slump of mixes of fiber reinforced concrete. Workability of concrete will be more if the slump is higher.

(iii) The use of fibres affects the major parameters of concrete structures such as compressive & tensile strength enhancement which reflects that the load carrying capacity has improved, when small amount of steel fibers were added up to 0.47% by weight of concrete.

(iv) Overall it has seen that it is advantageous to use 0.04% of polypropylene fibres to the weight of concrete which gives adequate results in all conducted tests for concrete Grade M40 without making lumps / bunches of fibres.

(v) The addition of 3.83% of fly ash increases the compressive strength of concrete by 12.69 % in comparison to normal M40 plain concrete.

(vi) 0.47% addition of steel fibers improvise the compressive strength by 9.92% and flexural strength by 44.68 %.

(vii) 0.04% addition of polypropylene fibers increases the compressive strength by 6.37% and flexural strength by 21.27 %.

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