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Effect of Using Different Fibers on Slab on Grades

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ABSTRACT

Slab on grade, also called floors on ground, are different from other structural members. First, they are supported directly by soil, and their success or failure may depend more on the soil qualities than on the slab construction. Second, they carry equipment and floor finishes, and any defect in the slab's integrity or moisture resistance affects those elements. A floor slab undergoing drying shrinkage may not only crack, but also break the brittle ceramic tile it carries. Failure may also occur due to overloading. For reducing cracks propagation, control or contraction joints are used. In this research, 225 specimens by fifteen-mix design with different dosage of polypropylene and steel fibers were prepared for evaluating compressive, impact and flexural testing at the ages of 7 and 28 days. As a result, the optimum dosage of polypropylene fibers was 1.6 kg/m3 and at this dosage, impact resistance enhanced about 460% and flexural strength enhanced about 70% in comparison with control specimens. Steel fibers improved impact resistance and flexural strength about 312% and 58% respectively, at the dosage of 30 kg/m3. Results also showed that the compressive strengths of specimens are not significantly increased by using fibers.

Keywords: slab on grade, polypropylene fibers, steel fibers, cracking

1. INTRODUCTION

Resistance to crack propagation is achieved by fiber-reinforced concrete (FRC) that contain coarse aggregate, and the existence of coarse aggregate in the matrix, brings some difficulties for fiber distribution or dispersion. Thus the volume fraction is highly limited. For fiber reinforced concrete used in practice, the applicable fiber volume fraction range from 0.4 to 2% for steel fiber and 0.06 to 0.5% for polypropylene. Slab on grades are the most important element in industrial projects. Considering to the use of floors are subjected to the damages and with repair and retrofitting need expenditure. The design and construction of a durable concrete floor in the storage, saloon and platforms are important [1]. The industrial floors have two functions; one bearing operational loadings, storages of material, the dynamic load from lift truck wheels and transferring them to the subgrades, secondly, providing a smooth surface for ease of use and safety [2]. It is necessary to enhance the quality of the concrete. Normal concrete is weak in tension about 1/10 of the compressive strength.

It is brittle against the impact loadings. Reinforcement with steel rebar cannot prevent their resistance against cracking, therefore the fibers is introduced. These fibers are separated and are distributed in concrete randomly. The precedence of the use of fibers is backed to the old Egyptians that they used fibers in mud walls. Also, rock wools fibers for reinforcement of clay is used about 5000 years ago [3]. From different kinds of fibers used in concrete the steel and polypropylene are mostly used. This research tried to evaluate two kinds of fibers. The flexural and impact resistance are the most important parameters. Base on this, six prisms specimens were prepared for testing flexural strength, six concrete disks for impact testing and nine cubes for compressive strength tests. In general, slab on grade problems can be categorized as cracking, surface deterioration, curling, settlement or heave, failure of joints, delamination of finishes, water penetration, chemical attack and wearing out [4].

Most structural failure in slabs on grade are caused by point loading, wheel loading of cranes and other construction equipment, and heavy stacks of material. Quite often, structural cracking can be traced to loading that was applied too early, before concrete could gain its full strength [5,6]. The industrial floors are kind of slabs on grade and are very important elements. The slabs on grade are supported by ground and their performance is more depend on soil qualities and they are noticeable by employers [7]. Mirmiran, A et al. (2014) [8] saying that FRC is known to provide good resistance to plastic shrinkage and has a proven record in the building industry, particularly with slab-on-grade application. However, the current specification does not address the use of FRC in civil infrastructure. Results indicated that both polyethylene and nylon fibers provided the best resistance to early-age shrinkage. However, balling was a problem for nylon fiber reinforced concrete. Short fibers (< 1-in.) also had the best performance in resisting early-age shrinkage, while long fibers (> 1-in.) provided additional post-cracking capacity. For replacement slab, it is recommended that a short polyethylene fiber be used to eliminate uncontrolled cracking. In conclusion, adding a fiber to concrete can increase the early age compressive strength by up to 48%. Furthermore, the age at cracking can be more than doubled by just adding 0.3% volume of polypropylene fibers and the crack width is reduced to a fourth. Other fiber can also be used for intermediary effects. Steel fibers are found to provide residual strength. However, they are also prone to deterioration due to corrosion. The steel fibers used were found to be rusted even under laboratory conditions. Gharehbaghil et al. (2017) [9] were mentioned that FRC can also significantly improve flexural strength when compared to traditional Concrete. This improvement in flexural strength can be varied depending on the actual fibers used. Although not new, FRC is gradually gaining popularity in the construction industry, in particular for high rise structures. This included the involvement of additional structural reinforcement, particularly for demanding areas such as seismic areas. Moreover, FRC was thus utilized for non-load bearing structural component, predominantly for seismic areas.Grija et al. (2016) [10], work on the martial called Hypo sludge. This sludge was added at a dosage of 25%, 50% and recon 3s fibers has to be added at a dosage of 0.5%, 1% by weight of cement. In this paper, studies shall be conducted on a mix and tests like compression test, split tensile test, flexural test, capillary and porosity shall be conducted. Finally, the results of fiber reinforced concrete shall be compared with the conventional concrete. Industrial waste materials were found to be performing better than normal concrete, in properties such as workability, durability, permeability and compressive strength. Utilization of these wastes in concrete will not only provide economy but also help in reducing disposal problems. Silawat and Kumar (2016) [11], were investigated the properties of steel fiber reinforced concrete like flexure and compressive strength. Tests were conducted to study the flexural and compressive strength of steel fiber reinforced concrete with varying aspects and varying percentages of fiber. In the experiments conducted four aspect ratio were selected i.e. 40,50,60,70 and percentage of steel in each case varied from 0.5% to 2.5% at interval of 0.5%. The various strength parameters studied are compressive strength and flexural strength as per the relevant IS standards. From load deflection curve, it is observed that as the percentage of fiber increases with constant aspect ratio, the deflection of the beam is also increased before failure. The maximum deflection is observed with 2.5% fibers and aspect ratio of 70 and it was 3.2mm. Abbas Zaidi et al. (2016) [12] presented a paper that reviews the literature related to the utilization of waste material and its various effects on compressive strength, split tensile strength, flexural strength and workability of concrete. The steel powder, empty tins, soft drink bottle caps were deformed into the rectangular strips of 3mm width and 10mm length. This included that fiber addition improves ductility of concrete and its post-cracking load-carrying capacity. Ragavendra et al. (2017) [13] Fiber Reinforced Concrete (FRC) is gaining attention as an effective way to improve the performance of concrete. Fibers are currently being specified in tunneling, bridge decks, pavements, loading docks, thin unbounded overlays, concrete pads, and concretes slabs. These applications of fiber reinforced concrete are becoming increasingly popular and are exhibiting excellent performance. Fiber-reinforced concrete pavements prove to be more efficient than conventional RC pavements. In several aspects, compressive strength for fiber-reinforced concrete is seen to be improved. It can be clearly seen that strength at 28 days for CSFRC 1% is better than other cases hence recommended.

2. MATERIALS AND METHODS

The main materials used in this research work is polypropylene fibers (PP) their specification is given in Table 1 and steel fibers (SF) specification is given in Table 2, these are described more as follows; the PP fibers made in different shapes and sizes. The integrity of PP fibers to concrete is weak chemically, but the mechanical adhesion is suitable; these fibers are possible to have tensile failure. Polypropylene material is obtained from a raw hydrocarbon C_3H_6. Their production process is similar to Nylon and Rayon fibers. PP fibers in alkali environment of concrete have a high resistivity. PP fibers with ratio is used for pedestrian overlays, slab on grades, floors system and tunnel linings, canals, reservoirs for preventing crack the range of use is between 0.05-0.3 percent [14]. The PP fibers have elastic modulus of 3-5GPa. Also, these fibers prevent initial shrinkage in plastic state of concrete. After casting, at the time cracks occurred, the PP fibers are exerted a low displacement load for preventing crack propagation. Also, due to strip shapes of PP fibers, better bonding is occurred at interface with concrete. As concrete is hardened, the effect of PP fibers is reduced [15]. Other properties of PP fibers are their effect on the fire. Due to fire, PP fibers are disappeared (the fibers are melted) and exerted from concrete porosity. The steam of water is come out from the ducts that produced by burning PP fibers. Therefore, not only PP fibers have not negative effect but for a certain time preventing concrete failures. The characteristics of the PP fibers used in this research, is given in Table 1. And Figure 1 shows the Polypropylene fibers used in this research and Figure 2 shows stress-strain curves of Polypropylene fiber reinforced concrete with different percentage of used.

Table 1. Details of polypropylene fibers in use

Material	Polypropylene
Length	8 mm
Diameter	20 μm
Aspect ratio (l/d)	400
Density	0/9 gr/cm3
Tensile strength	350 MPa

Figure 1. Polypropylene fibers used in this research

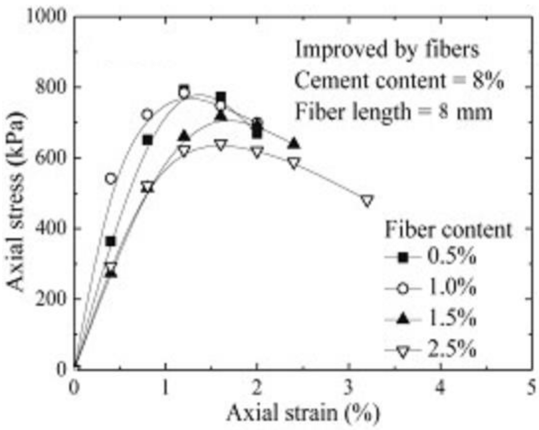

Figure 2. Stress-Strain curves of Polypropylene fiber reinforced concrete [19]

2.1. STEEL FIBERS

The industrial floors and overlaying are used mostly steel fibers [16]. The E value is about 200GPa with a high tensile strength of 800-2500MPa. At the early age of concrete, it is possible that very fine cracks due to shrinkage have appeared. Also, in this duration, the fibers are not adhered to concrete. Based on this, steel fibers are not effective in early age, but at hardened state, their effects are increased and crack propagation is reduced. Due to using steel fibers, corrosion may occur mostly near to surface and causes discoloration of concrete but not effected on load-bearing capacity. Corrosion potential in steel fibers is reduced by two methods:

- Optimization of the fiber concrete ingredient
- Use of galvanize or stainless fibers

- Another reason for the importance of using steel fibers is their strength against fire. Steel fibers have not specific character against fire but have the worse behavior against fire in comparison with normal concrete [15]. In Table 2, the characteristic of steel fibers, used in this research, is given. Figure 3 shows the steel fiber used in this research.
- Steel Fibers do little to enhance the static compressive strength of concrete, with increases in strength ranging from essential nil to perhaps 25%. Even in members that contain conventional reinforcement in addition to the steel fibers, the fibers have little effect on compressive strength. However, the fibers do substantially increase the post-cracking ductility, or energy absorption of the material. This is shown graphically in the compressive

stress-strain curves of steel fiber reinforced concrete in Figure 4.

Table 2. Details of steel fibers in use

Material	Steel
Length	25 mm
Diameter	1 mm
aspect ratio (l/d)	25
Tensile strength	100 MPa

Figure 3. Steel fibers used in this research

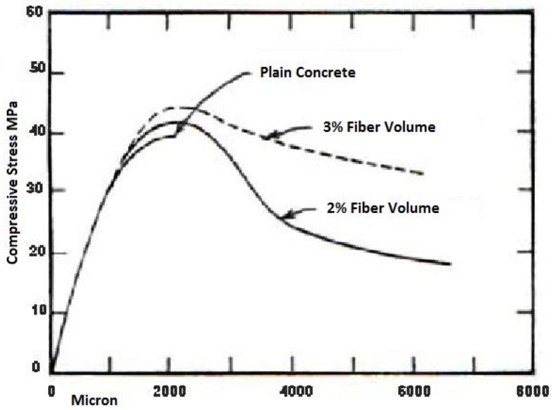

Figure 4. Stress-Strain curves in compression for steel fiber reinforced concrete [20]

The normal amount of the use of steel fibers is 20-40 kg/m^3 of concrete. As the amount is increased, the flexural strength increases. Those mixes that used conveyor belts for transporting concrete usually the fibers are mixed with aggregates and are entered into the mixer. If l/d is less than 50 the gathering fibers are not causes of concern. However, if l/d is more than 50 care should be taken to prevent fibers gathering.

2.2. EXPERIMENTAL PROGRAM

In this research, 225 specimens in fifteen different mix designs were provided to evaluate the properties of concrete. 90 specimens were tested at the age of 7 days and 135 specimens were tested at the age of 28 days. Two types of specimens with different dosage of steel and polypropylene fibers and one type as control were prepared. Compressive strength, impact loading and flexural strength tests were undertaken. For compressive test, 150 mm concrete cubes based on ASTM C39 [17], for impact loading test, disks with dimension of 6" diameter and 1.5" thickness based on ACI 544-2R[18] and for flexural strength, beams with dimension of 600*125*75 mm based on ASTM C293-02 [16] were provided. Figure 5 shows the method to exert flexural load to beams that used in this research. Figure 6 shows constructed beam under one-point flexural loading.

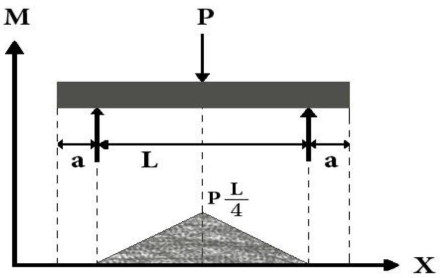

Figure 4. Schematic of flexural loading system

Figure 5. Constructed beam under one-point flexural loading

According to ACI 544-2 [18], good impact resistance (dynamic energy absorption as well as strength) is one of the important attributes of FRC. One type of tests that have been used to measure the impact resistance of FRC is drop-weight test. In this method, the number of blows in a "repeated impact" test to achieve a prescribed level of distress shows impact resistance of concrete. This number serves as a qualitative estimate of the energy absorbed by the specimen at the levels of distress specified. The test can be used to compare the relative merits of different fiber-concrete mixtures and to demonstrate the improved performance of FRC compared to conventional concrete. In this research, a standard manually operated 4.54 kg (10 lb.) compaction hammer with a 457 mm (18 in.) used to apply 20 Joules energy by impact loading (Figure 7).

$$E = mgh = 4.54*0.457*9.81 = 20 \text{ J}$$

Apparatus for impact loading test is made by a steel frame in dimension of 350*650 mm.

Figure 6. Impact loading test

Type 2 cement, crashed coarse aggregate with maximum size of 19 mm and washed sand with drinkable water were used. Superplasticizers based on poly-carboxylate ether with dosage of 0.8% cement content were used and the water-cement ratio was constant for all the mixes. Table 3 gives the amount of materials per m^3.

Table 3. Materials used in concrete (Kg/m3)

Material	Mass (kg)
Cement	400
Coarse Aggregate	985
Fine Aggregate	816
Water	132
Super Plasticizer	3.2
Water-Cement Ratio	0.33

The amount of use of PP fibers per m^3 were 0.8, 1, 1.2, 1.4, 1.6, 1.8 and 2 kg and steel fibers were 20, 22.5, 25, 27.5, 30, 32.5 and 35kg. Air temperature was 28°C and relative humidity 36%. The specimens were moistening for 24 hours in mold, then de-molded and submerged in water for curing. The tests were undertaken at the ages of 7 days and 28 days and before testing, specimens were maintained in the oven for 24 hours in 105°C temperature. For each mix design, 3 specimens made for test at each age and average amount of each test intended as a result of the test. The fibers were added to the mix by careful observation. To prevent balling phenomena, fibers added to mixture slowly and especially, for PP fibers, first fibers added to water, then added to mixture in gradual stages.

3. RESULTS AND DISCUSSION

All of the tests were carried in laboratory of Technical and Mechanical Soil in Khuzestan under standard with temperature of 36°C and relative humidity 36%. For Compressive test hydraulic jack by 300 ton capacity at loading rate 0.3 $\frac{N}{mm^2}Sec$ was used. Results are given in Table 4.

Table 4. Results of the compressive strength tests

Row	Type	Fiber content (kg)	Average Compressive Strength (kg/cm2) [Age : 7 days]	Standard Deviation	Average Compressive Strength (kg/cm2) [Age : 28 days]	Standard Deviation
1	Control	0	387	8.34	503	6.3
2	PFRC1*	0.8	395	7.25	511	5.44
3	PFRC2	1	396	9.1	514	7.41
4	PFRC3	1.2	412	6.23	523	3.98
5	PFRC4	1.4	418	5.3	530	4.7
6	PFRC5	1.6	440	7.69	538	6.36
7	PFRC6	1.8	430	4.23	528	8.45
8	PFRC7	2	402	6.3	525	5.74
9	SFRC1**	20	376	5.87	523	5.12
10	SFRC2	22.5	370	5.12	527	2.96
11	SFRC3	25	368	9.01	539	4.23
12	SFRC4	27.5	359	6.48	547	4.39
13	SFRC5	30	367	7.2	553	6.41
14	SFRC6	32.5	365	8.05	533	5.15
15	SFRC7	35	359	6.12	511	7.75
* PFRC : Polypropylene Fiber Reinforced Concrete						
** SFRC : Steel Fiber Reinforced Concrete						

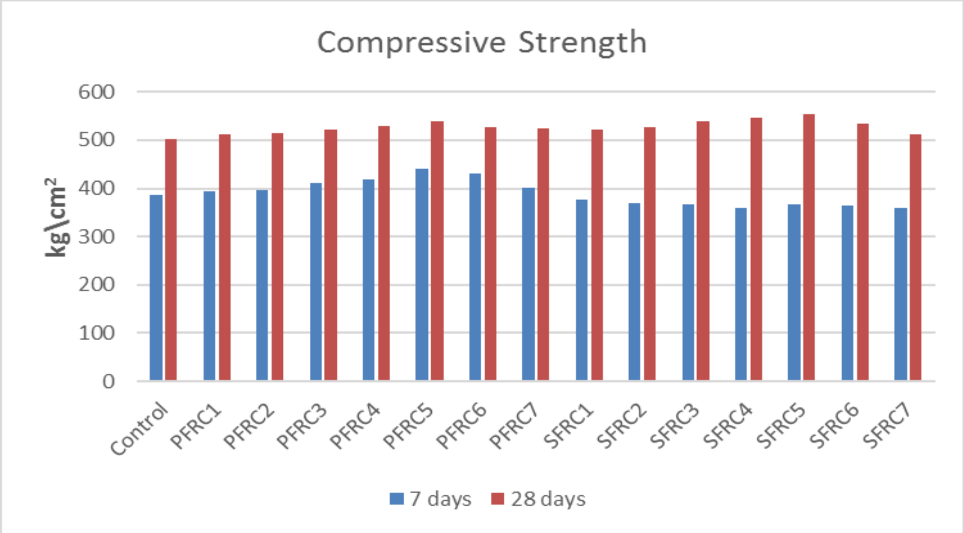

Figure 7. Compressive strength of specimens

As a result, the fibers are not so effective on compressive tests. However, results showed that in the use of steel fibers, 30kg/m^3 is optimum dosage and compressive strength increased about 10%. Also, using of polypropylene fibers cause increasing about 7% at the optimum dosage of 1.6%. The results are given in Table 5.

Table 5. Results of the impact strength tests

Row	Type	Fiber content (kg)	Average No. of impacts till first crack [Age : 7 days]	Standard Deviation	Average No. of impacts till first crack [Age : 28 days]	Standard Deviation
1	Control	0	3	1.26	8	1.18
2	PFRC1*	0.8	9	2.2	31	1.98
3	PFRC2	1	10	1.8	31	1.82
4	PFRC3	1.2	12	1.68	33	2.1
5	PFRC4	1.4	18	2.01	34	1.62
6	PFRC5	1.6	23	2.22	41	2.65
7	PFRC6	1.8	20	1.98	37	2.14
8	PFRC7	2	17	1.76	34	1.98
9	SFRC1**	20	6	2	17	1.07
10	SFRC2	22.5	8	0.89	20	1.25
11	SFRC3	25	9	1.73	22	1.78
12	SFRC4	27.5	12	1.95	23	1.65
13	SFRC5	30	15	2.3	25	1.23
14	SFRC6	32.5	13	0.78	24	2.01
15	SFRC7	35	12	1.12	24	1.8
* PFRC : Polypropylene Fiber Reinforced Concrete						
** SFRC : Steel Fiber Reinforced Concrete						

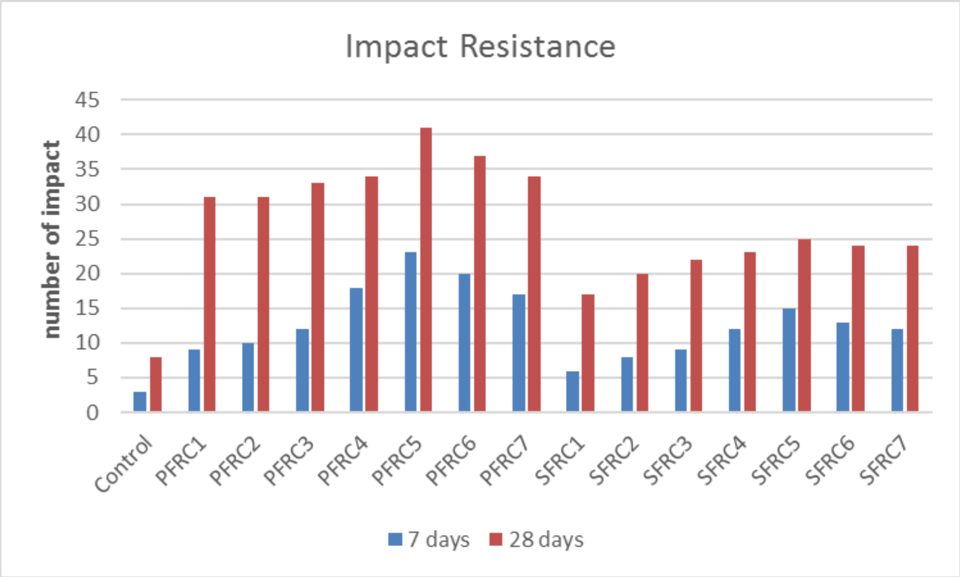

Figure 8. Impact resistance of specimens

Table 5 shows that the impact resistance of specimens with steel fibers can enhance up to 3 times bigger than control specimens. While polypropylene fibers can enhance the impact resistance up to more than 5 times bigger than control specimens. Results also showed that polypropylene fibers are more effective than steel fibers to improve impacts resistance.

Table 6. Results of the flexural strength tests

Row	Type	Fiber content (kg)	Maximum load (KN) [Age : 28 days]	Maximum flexural strength (KN.m) [Age : 28 days]
1	Control	0	24	3
2	PFRC1*	0.8	32	4
3	PFRC2	1	34	4.025
4	PFRC3	1.2	33	4.125
5	PFRC4	1.4	38	4.75
6	PFRC5	1.6	41	5.125
7	PFRC6	1.8	40	5
8	PFRC7	2	36	4.5
9	SFRC1**	20	30	3.75
10	SFRC2	22.5	32	4
11	SFRC3	25	35	4.375
12	SFRC4	27.5	36	4.5
13	SFRC5	30	38	4.75
14	SFRC6	32.5	37	4.625
15	SFRC7	35	32	4
* PFRC : Polypropylene Fiber Reinforced Concrete				
** SFRC : Steel Fiber Reinforced Concrete				

Table 6 shows that the flexural strength of specimens made by PP fibers enhanced about 70% and this amount is 58% for steel fibers in comparison with control. The maximum amount of flexural strength in corporation with PP and steel fibers earned at the dosage of 1.6 kg and 30 kg respectively. Figure 10 shows the effect of different dosages of fibers on flexural strength of concrete.

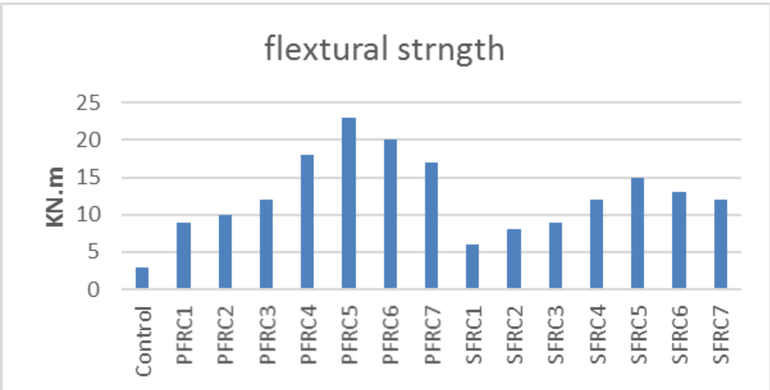

Figure 9. Flexural Strength of beams

4. CONCLUSION

The effect of steel and PP. fibers on industrial floors was evaluated in this paper. Summary of the results are given as follow:

- In construction of fiber concretes l/d ratio and optimize dosage of fiber should be controlled to prevent gathering and segregation.
- Concrete without fibers is brittle, but with fiber propagation of cracks is prevented.
- If fiber used, the control or contraction joints can be eliminated on the slab on grade.
- No significant effect was observed in compressive strength using fiber in concrete.
- Polypropylene fibers significantly increase flexural strength.
- Absorbing energy due to dropping load can be enhanced in early age while in steel fibers, effectiveness is seen at hardened concrete.
- The increase in the various mechanical properties of the concrete mixes with polypropylene fibers is not in the same league as that of the steel fibers.

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AUTHORS CONTRIBUTION

This work was carried out in collaboration among all authors.

CONFLICT OF INTEREST

The author (s) declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

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