

## EVALUATING THE PERFORMANCE OF POLYMER CONCRETE DOSED WITH LOW-COST STEEL FIBERS & SBR LATEX

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### ABSTRACT

Fiber Reinforced Polymer Cement Concrete (FRPCC) is a relatively modern approach towards the conventional concreting techniques. It possesses excellent strength and durability properties. Looking into the various advantages of Polymer Cement Concrete (PCC) and Fiber Reinforced Concrete (FRC), an exhaustive literature survey was carried out to study their uses and effect on the various properties of conventional concrete. An attempt has been made to present review on polymer modified concrete dosed with Styrene Butadiene Rubber (SBR) Latex polymer & Low cost Steel fibers. The fibers used in this study are ordinary stapler pins (Kangaro No. 10 - 1M). The objective of this study is to find out the optimum quantities of the steel fibers and SBR polymers in the concrete mix, which is able to achieve the maximum compressive and flexural strength for M30 grade concrete. In PCC, use of two or more fiber in a suitable combination may potentially not only improve the overall property of PCC but may also result in performance synergy.

**KEYWORDS:** FRPCC, SBR Latex, Low-cost Steel Fibers, FRC, PCC

Concrete is among some of the oldest used construction materials in the world. It is reputable for providing great versatility and economic efficiency in comparison to other construction materials. However, it must also be noted that concrete is discredited for its brittleness and strength-to-weight ratio [2]. The biggest drawback of concrete is that it can act only as a compression member as the tensile strength of concrete is only approximately one tenth of its compressive strength. Hence, concrete members are unable to support flexural loads and stresses that are usually applied on concrete beams and slabs. In recent times the lower tensile strength of concrete is rectified by utilizing intrinsic fibers as a form of reinforcement in the concrete matrix [5]. The use of natural fibers such as sisal, banana, coconut or jute fibers in fiber reinforced concrete (FRC) can affect the overall properties of fresh and hardened concrete. However, the exact influence of fiber length and volumetric content of these fibers still remain unknown. The fibers in concrete provide a crack arresting property, particularly improving the ductility and durability by mitigating cracking due to shrinkage."The role of fibers is essential in arresting the advance of cracks by applying pinching forces at the crack tips, thereby delaying their propagation across the matrix and creating a slow stage of crack propagation" [3]. In the words of Sakai, 1995, "The introduction of small, closely spaced, randomly oriented fibers transfers an inherently brittle material with low tensile strength and impact resistance into a strong composite material with superior crack resistance and

improved ductility". Modification of concrete with a polymer latex (colloidal dispersion of polymer particles in water) results in greatly improved properties, at a reasonable cost. Therefore, a great variety of latexes is now available for use in polymer cement concrete products and mortars. The most common latexes are based on poly (methyl methacrylate) also called acrylic latex, poly (vinyl acetate), vinyl chloride copolymers, poly (vinylidene chloride), (styrene-butadiene) copolymer, nitrile rubber and natural rubber. Each polymer produces characteristic physical properties. The acrylic latex provides a very good water-resistant bond between the modifying polymer and the concrete components, whereas use of latexes of styrene-based polymers results in a high compressive strength.

### PROBLEM STATEMENT

We have studied the concept of Fiber reinforced concrete (FRC) and Polymer Cement Concrete (PCC) separately but here we are trying to incorporate the properties of steel fibers by adding them to PCC mix (dosed with SBR Latex polymer). To optimize the results and check the accuracy of mix design, twelve separate mixes are to be made and tests are to be carried out to determine the efficiency of the batch. Further analysis is to be done to calculate the cost effectiveness of the structures. Thus, 12 batches of concrete were made of M30 grade with a constant W/C ratio, by varying the proportions of SBR polymers & Steel fibers. They are designated as follows:

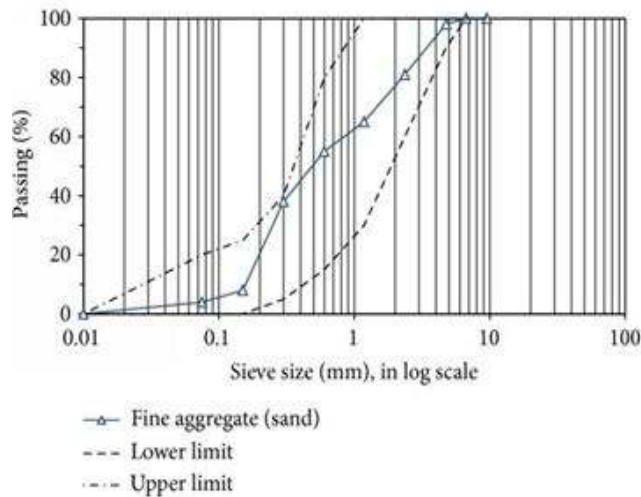
**Table 1: Batch Description**

SN	Batch Designation		Grade of Concrete	Adopted Mix Proportions	Steel Fiber (%)	SBR Polymer (%)
	Title	Description				
1	S1	Conventional	M30	1 : 2 : 3.5	0	0
2	S2	FRC			1	0
3	S3	PC			0	15
4	S4	FRPCC			2.5	15
5	S5				2.5	20
6	S6				2.5	25
7	S7				5.0	15
8	S8				5.0	20
9	S9				5.0	25
10	S10				7.5	15
11	S11				7.5	20
12	S12				7.5	25

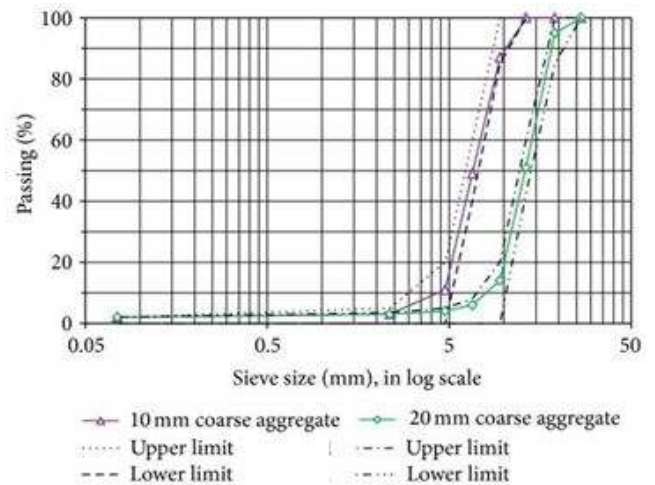
**EXPERIMENTAL WORK**

**Materials**

Twelve sets of concrete mixes were prepared using the raw materials shown in Table 1. Ordinary Portland Cement (43 grade) was used. A maximum nominal size of 20 mm aggregate was used in all mixes. All aggregates used in mix design were sourced from Rasmara, Chhattisgarh (India), which include 50/50 blended fine/coarse manufactured sand and 10 mm and 20 mm crushed gravel. The grading of all aggregates used in this study are taken from Indian Standards IS: 383-1970 specifications and limits (Figures 1 and 2).



**Figure 1: Fine Aggregate Grading Curve**



**Figure 2: Coarse Aggregate Grading Curve**

The aggregate was prepared to saturated surface dry condition prior to mixing. Drinkable grade tap water was used for the mixes after conditioning the water to room temperature ( $23 \pm 2^\circ\text{C}$ ). Furthermore, in order to improve the workability, a polycarboxylic ether based high range water reducing admixture (HWR) was used. Low-cost Steel fiber, with graphical illustration shown in Figure 4, was used in all FRC & FRPCC mixes.



Figure 3: Lost-cost Steel Fiber used in the study

Locally available polymer ‘Cemseal Cementone’ was investigated in this study. It is a type of Styrene butadiene rubber (SBR) latex. The composition of the Cemseal Cementone used as polymer is given in Table 5. Cemseal Cementone SBR is based on Styrene Butadiene rubber, special adhesive and bonding chemicals along with hydrophilic agents. Cemseal Cementone SBR gives a versatile performance in many civil engineering applications.

Table 2: Properties of Polymer Used (SBR)

Type	Styrene Butadiene Rubber
Form	White Liquid
Density	1 kg/L at 25 °C
Solid Content	50 %
Chloride Content	50 %



Figure 4: Cemseal Cementone SBR Latex Polymer  
Mix Design

Table 3: Adopted Proportions of Cement, Sand & Aggregate

Materials	Proportions
Water (kg/m <sup>3</sup> )	160
Cement (kg/m <sup>3</sup> )	380
Fine Aggregate (kg/m <sup>3</sup> )	711
Coarse Aggregate (kg/m <sup>3</sup> )	1283
Calculated Proportions	1 : 1.871 : 3.376
Suggested Proportions	1 : 2 : 3.5

NOTE : The above readings are shown for one frequency of M30 grade concrete, as tested & reported by T&C Cell, SSGI, Bhilai (C.G.)

#### Testing

Slump, Compaction factor and Vee-Bee test were carried out to determine the consistency. In addition, air content and mass per unit volume were measured to study the effect of SBR & Steel fibers on the properties of concrete in its plastic state. The behavior of the concrete under compressive load has also been assessed by conducting compressive strength testing. Cubical specimens of 150mm x 150mm x 150 mm were tested under constant load rate. Compressive strength was determined at ages of 7 and 28 days. To assess the behavior

of concrete subjected to flexural loadings, three-point loading was carried out. A beam of size 150mm x 150mm x 700mm was casted and loaded at a rate of 180 kg/min until fracture. Flexural strength was determined at the age of 28 days.

**RESULTS AND DISCUSSION**

Fig. 5 shows that the value of Slump fluctuates randomly with increase in the overall fiber content and polymer dosage in the mix. This effect cannot be generalized. However for 7.5% fiber & 15% polymer dosage, the value of slump was minimum. This leads us to believe that with increase in the fiber content, the workability will decrease accordingly. Similarly, with increase in the polymer content, the workability will increase accordingly. The same trend was observed in case of Compaction Factor also as shown in Fig. 6. Vee Bee time also tells that the all mixes are in plastic state.

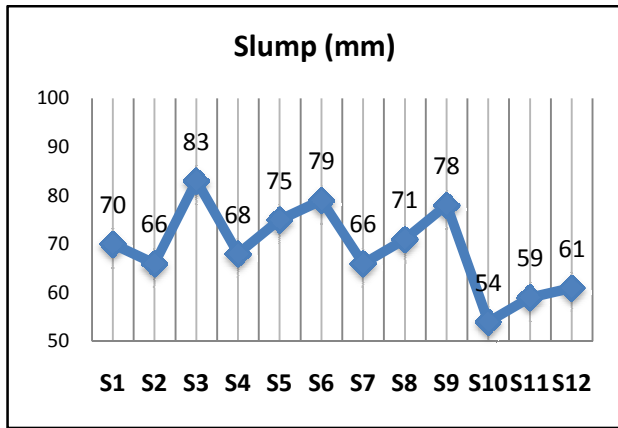


Figure 5: Results of Slump test

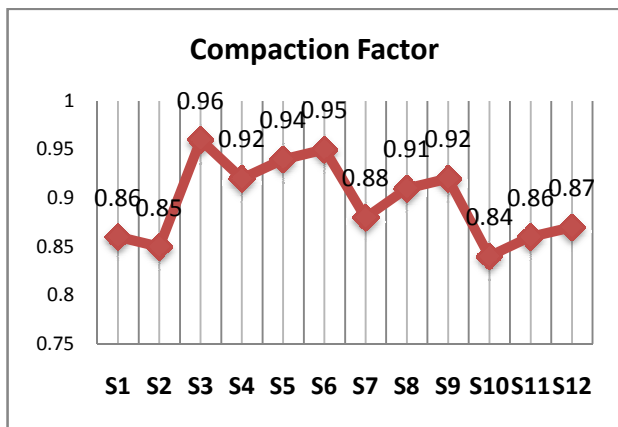
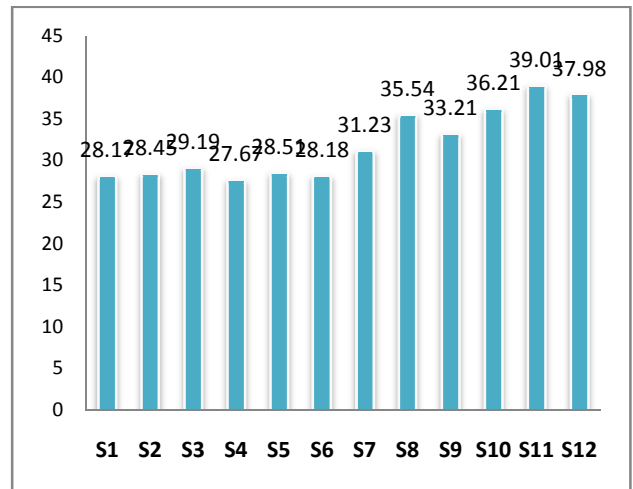
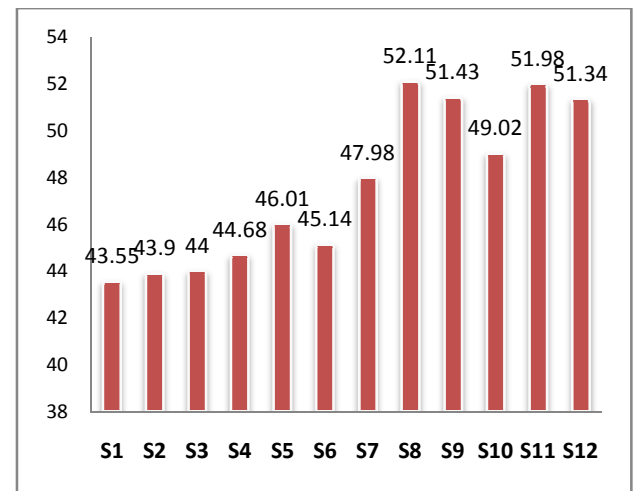


Figure 6: Results of Compaction Factor Test

The Characteristic Compressive Strength of concrete at 7 days and 28 days was found in N/mm<sup>2</sup>. The results of Fig. 7 (a) &(b) showed a moderate increase in the initial strength with addition of SBR Latex polymer & Steel fibers. However their addition increased the final strength by a large margin. It was also observed that at 25% SBR dosage, the strength slightly decreased when the mix was blended. Also at 7.5% Steel fibers, the values decreased slightly. This led us to conclude that although increasing the polymer content was advantageous, when mixed with steel fibers, the best results will be obtained for batch S8 with 5% Steel fibers & 20% SBR Latex Polymer.



(a)



(b)

Figure 7: Results of Compressive Strength test at (a) 7 days, (b) 28 days

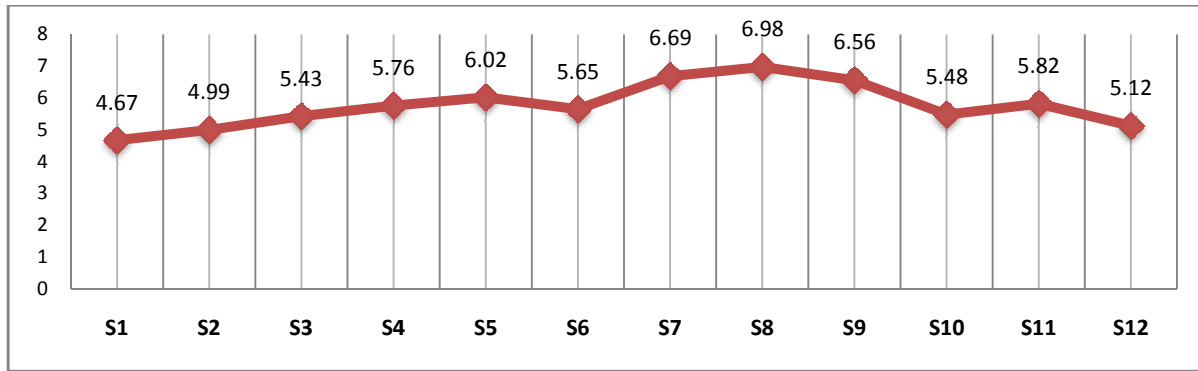


Figure 8: Results of Flexural Strength test

Table 4: Results of all the Tests performed on the Trial Batches

Mix	Steel Fiber (%)	SBR Polymer (%)	Slump (mm)	Compaction Factor	Vee-Bee Time (sec)	Compressive Strength (N/mm <sup>2</sup> )		Flexural Strength (N/mm <sup>2</sup> )
						After 7 days	After 28 days	
S1	0	0	70	0.86	6	28.17	43.55	4.67
S2	1	0	66	0.85	7	28.45	43.90	4.99
S3	0	15	83	0.96	6	29.19	44.00	5.43
S4	2.5	15	68	0.92	5	27.67	44.68	5.76
S5	2.5	20	75	0.94	4	28.51	46.01	6.02
S6	2.5	25	79	0.95	5	28.18	45.14	5.65
S7	5.0	15	66	0.88	4	31.23	47.98	6.69
S8	5.0	20	71	0.91	3	35.54	52.11	6.98
S9	5.0	25	78	0.92	3	33.21	51.43	6.56
S10	7.5	15	54	0.84	5	36.21	49.02	5.48
S11	7.5	20	59	0.86	4	39.01	51.98	5.82
S12	7.5	25	61	0.87	3	37.98	51.34	5.12

The Flexural Strength of concrete was found in N/mm<sup>2</sup> at 28 days. As shown in Fig. 8, with increase in fiber and polymer dosage, the flexural strength increased almost linearly but with polymer dosage of 7.5%, these value start to fall. Also the values fell down a little in case of batches dosed with 25% SBR Latex. This lead us to conclude that with an increase of polymer and fiber dosage, the graph climbed initially, fell down slightly at 25% polymer dosage and at 7.5 % fiber dosages both. The best results were obtained for batch S8 similar to the case of Compressive Strength.

## SUMMARY AND CONCLUSION

The following conclusions can be drawn from the above observations:

a) The Values of Slump and Compaction Factor generally decreased with an increase in the polymer content and increased with an increase in the fiber content. However the least values of Slump and Compaction factor was obtained for batch S10 with 7.5 % Steel fibers and 15% SBR Latex. Vee Bee time also tells that the all mixes are in plastic state.

b) In terms of Characteristics Compressive Strength, the optimum dosage was observed for batch S8 with 5% Steel fibers and 20% SBR Latex polymer. It showed an increase of 34.824 % in the 7 day strength and 17.887 % increase in the 28 day strength of cube specimens when compared to the Conventional concrete of batch S1.

c) In terms of Flexural Strength, the optimum dosage was again observed for batch S8 with 5% Steel fibers and 20% SBR Latex polymer. It showed an increase of 9.635 % in the 28 day flexural strength of specimens when compared to the Conventional concrete of batch S1.

It can be accurately summarized that the addition of low cost Steel Fibers, with a combination of Styrene Butadiene Rubber (SBR) Latex Polymer, is an effective way of improving the overall properties of the conventional concrete. The **FRPCC (S8) mix with 5% Steel fibers and 20% SBR Latex polymer** has shown the best workability, increased compressive strength and high resistance against flexural loads, making it suitable for use in congested spaces under high loads. Further studies need to be conducted by varying the proportions of different types of steel fibers and polymers so as to obtain the ideal mix proportions desirable to produce the best results.

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