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Evaluation of the performance of polymer concrete dosed with low-cost steel fibers & SBR latex

Jyoti Patel

PG Scholar; Deptt. of Civil Engineering
SIS Tec-R
Bhopal (M.P.),India

Abhishek Tiwari

Asst. Professor; Deptt. Of Civil Engineering
SIS Tec-R
Bhopal (M.P.), India

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*

I. INTRODUCTION

Concrete is recognized as the most prevalent used construction material in the world. It is reputable that concrete provides notable mechanical performance, great versatility, and economic efficiency in comparison to other construction materials. However, it must be noted that concrete is discredited for its brittleness and strength-to-weight ratio. Also the tensile strength of concrete is only approximately one tenth of its compressive strength. As a result, concrete members are unable to support such loads and stresses that usually take place 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. The use of natural fibers such as banana, sisal, jute or coconut fibers in fiber reinforced concrete (FRC) can affect the overall properties of hardened concrete. However, the exact influence of fiber length and volumetric content remains unknown. The fibers in concrete aims to produce a stronger and tougher concrete, particularly improving the ductility and durability and 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. The ultimate cracking strain of the composite mix is thus increased by many times compared to that of unreinforced matrix. 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 fibres 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

II. 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).

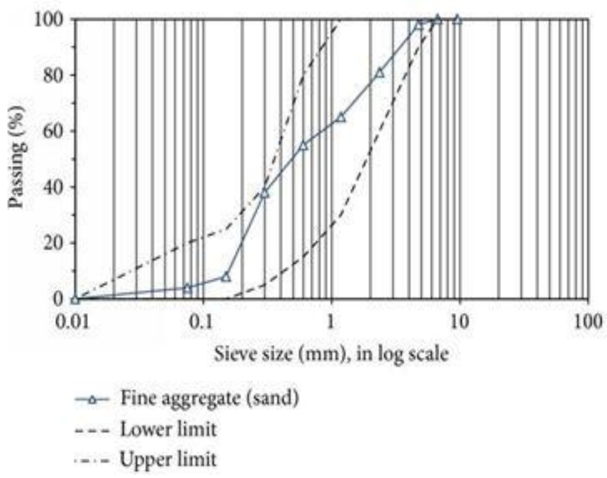

Fig.1. Fine Aggregate Grading Curve

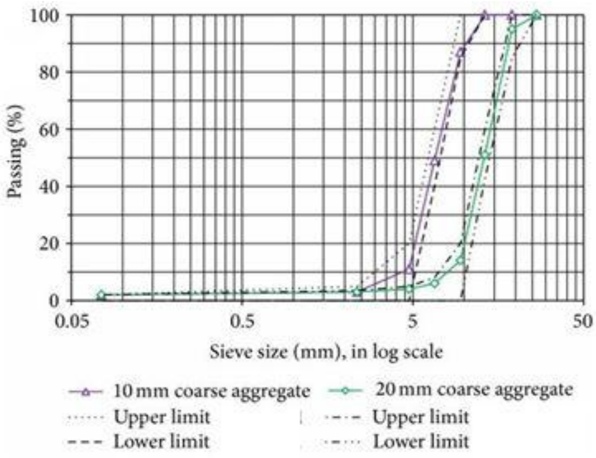

Fig.2. Coarse Aggregate Grading Curve

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 ± 2°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.

Fig.3. Lost-cost Steel Fiber used in the study

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

Table 2. Properties of Polymer Used (SBR)

Type	Styrene Butadiene Rubber
Form	White Liquid
Density	1 kg/L at 25 ^{0}C
Solid Content	50 %
Chloride Content	50 %

Fig. 4 - Cemseal Cementone SBR Latex Polymer

Mix Design-

Table 3 - Adopted Proportions of Cement, Sand & Aggregate

Materials	**Proportions**
Water (kg/m^3)	160
Cement (kg/m^3)	380
Fine Aggregate (kg/m^3)	711
Coarse Aggregate (kg/m^3)	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 Testing & Consultancy Cell, Department of Civil Engineering, Shri Shankaracharya Group of Institutions, Shri Shankaracharya Technical Campus, Junwani, Bhilai (Chhattisgarh - India)

Testing-

Slump and compacting factor 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 × 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 70mm was casted and loaded at a rate of 180 kg/min until fracture. Flexural strength was determined at the age of 28 days.

III. RESULTS & DISCUSSIONS

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

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

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

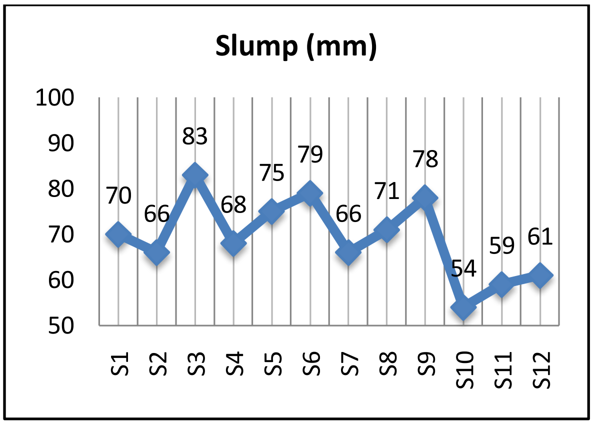

Fig. 5 - Results of Slump test

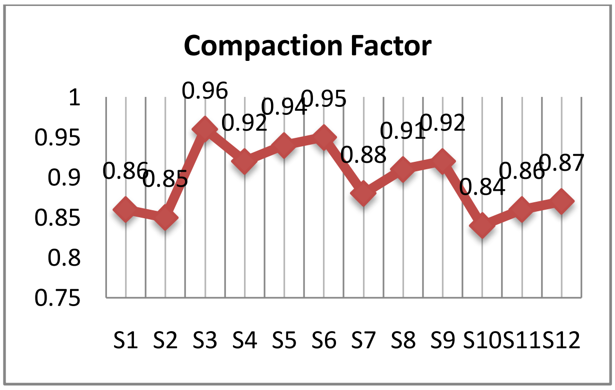

Fig. 6 - Results of Compaction Factor Test

The Characteristic Compressive Strength of concrete at 7 days and 28 days was found in N/mm2. The results of Fig. 7 & 8 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.

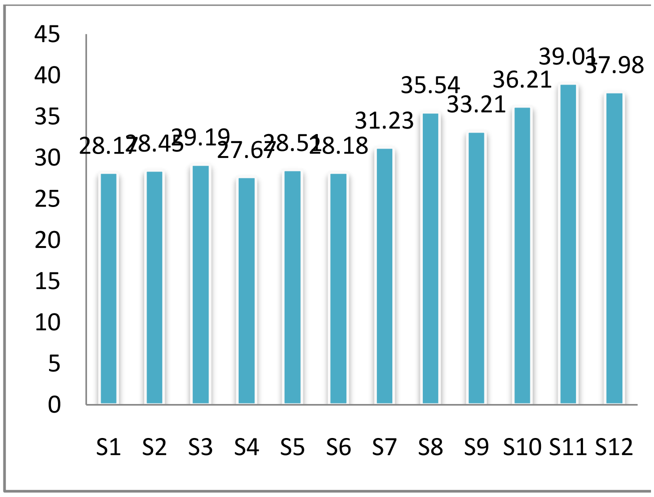

Fig. 7 - Results of 7 days Compressive Strength test

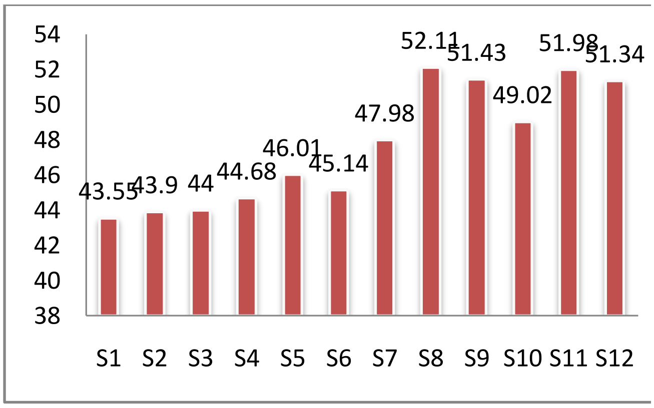

Fig. 8 - Results of 28 days Compressive Strength test

The Flexural Strength of concrete was found in N/mm^2 at 28 days. As shown in Fig. 9, 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.

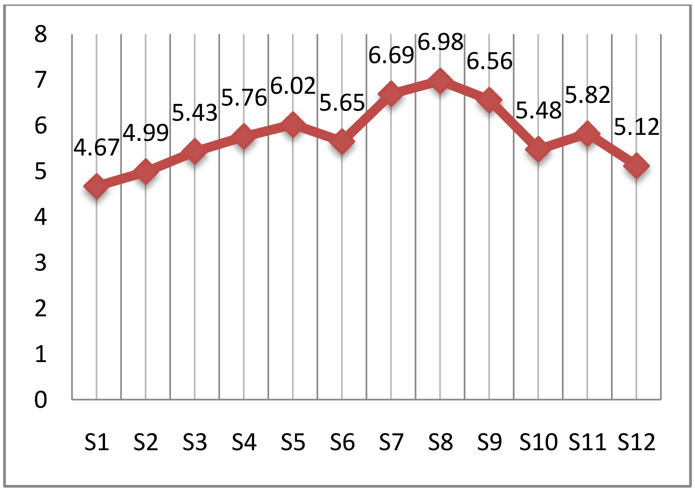

Fig. 9 - Results of Flexural Strength test

IV. SUMMARY & CONCLUSIONS

The following conclusions can be drawn from the above observations:

a) The Values of Slump and Compaction Factor generally increased with an increase in the polymer content and decreased 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.
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.

REFERENCES

[1] "Perma Construction Aids Pvt. Ltd."(http://permaindia.com/perma-latex-sbr/)

[2] "IS:10262-2009". Recommended guidelines for concrete mix design, Bureau of Indian Standards (Reaffirmed), New Delhi, 2000.

[3] "IS:456-2000". Indian standard recommended guidelines for concrete mix design, Bureau of Indian Standards.

[4] "IS:8112-1989". Specifications for 43-Grade Portland cement, Bureau of Indian Standards, and New Delhi, India.

[5] "IS:516-1959". Method of test for strength of concrete, Bureau of Indian Standards, New Delhi, 1959.

[6] "IS:2386 (Part I, IV, VI)-1988". Indian standard Method of test for aggregate for concrte, Bureau of Indian Standards, Reaffirmed, New Delhi, 2000.

[7] "IS:1199-1959". Indian Standards Methods of Sampling and Analysis of Concrete, Bureau of Indian Standards, New Delhi, India.

[8] Afridi MUK, Ohama Y, Demura K, Iqbal MZ. "Development of polymer films by the coalescence of polymer particles in powdered and aqueous polymer modified mortars". Cement and Concrete Research No. 11, 33(2003) 1715-21.

[9] Sakai E. and J. Sugita. "Composite mechanism of polymer modified cement".Cement and Concrete Res., 25: 127–35 (1995)

[10] Ohama Y., K. Demura, K. Kobayashi, Y. Sato and M. Morikawa. "Pore size distribution and oxygen diffusion resistance of polymer-modified mortars". Cement and Concrete Res., 21: 309–15 (1991)

[11] Zhengxian Y., S. Xianming, T.C. Andrew and M.P. Marijean. "Effect of styrene butadiene rubber latex on the chloride permeability and microstructure of portland cement mortar". Construction and Building Materials, 23; 2283–2290 (2009).

[12] Makhtar, A. M. (1997). "Properties and Performance of Polymer-Modified Concrete". The University of Leeds. PhD Thesis.

[13] Chandra S and P. Flodin. "Interactions of polymer and organic admixtures on Portland cement Hydration". Cement and Concrete Res., 17: 875– 90 (1987).

[14] Baoshan H., W. Hao, S. Xiang and G. B. Edwin. "Laboratory evaluation of permeability and strength of polymer-modified pervious concrete". Construction and Building Materials, 24: 818– 823 (2010).

[15] Chandra, S. and Ohama, Y. (1994). "Polymers in Concrete". CRC Press, Boca Ration, Florida.

[16] Kardon, J. B. (1997). "Polymer-Modified Concrete: Review". Journal of Materials in Civil Engineering. 9(2): 85-92.

[17] Lewis, W. J. and Lewis, G. (1990). "The Influence of Polymer Latex Modifiers on the Properties of Concrete". Composites., 21(6), 487-494.

[18] Ohama, Y. (1984). Polymer-Modified Mortars & Concretes. "Concrete Admixtures Handbook". Properties, Science, and Technology. Park Ridge: Noyes Publication.

[19] Ohama, Y. (1997). "Recent Progress in Concrete-Polymer Composites". Advanced Cement Based Materials. New York: Elsevier Science Ltd. 31-40.

[20] Colville, J., Amde, M. A., and Miltenberger, M. (1999). "Tensile Bond Strength of Polymer Modified Mortar". Journals of Materials in Civil Engineering. 11(1): 1-5.

[21] Kuhlman, L. A. and Foor, N. C. (1984). "Chloride Permeability Versus Air Content of Latex-Modified Concrete". Cement, Concrete and Aggregates, CCAGDP. Vol.6, No.1: pp. 11-16.

[22] Silva, D. A., John, V. M., Ribeiro, J. L. D. and Roman, H. R. (2001). "Pore size distribution of hydrated cement pastes modified with polymers". Cem. Concr. Res. 31, 1177–1184.

[23] Joao A. R. and V.C.A. Marcos. "Mechanical properties of polymer-modified lightweight aggregate concrete". Cement and Concrete Res., 32; 329–334 (2002)