

Deflection Control in Rigid Pavements

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Abstract. The need for modern transportation systems together with the high demand for perpetual pavements under the drastically increasing applied loads has led to a great deal of research on concrete as a pavement material worldwide. This research indeed instigated many modifications in concrete aiming for improving the concrete properties. Pavement Quality Concrete requires higher flexural strength and fewer deflections in hardened state. Fiber reinforcement and latex modification are two reliable approaches serving the required purposes. The concrete made with these two modifications is called Polymer-modified Fiber-reinforced concrete. The present study deals with the usage of polypropylene as fiber and SBR (Styrene Butadiene Rubber) Latex as polymer. M30 grade concrete was modified by replacing cement with two different percentages of fiber (0.5%, 1.0% of weight of cement) and with three different percentages of SBR latex (10%, 15% & 20% of weight of cement).

1. Introduction

1.1. General

Transportation is one of the fastest growing and highly demanded fields since the start of the now-a-day modern era. Roadway, the most preferred and agile among all the modes of transport has the highest need for sophisticated improvements and modifications. So, as a part of these techniques, developing pavements with high service life and little or no maintenance requirement has been in highest demand which are otherwise called perpetual pavements. These are been in use to cope up with the drastically increasing modernization as well as to serve longer and better [1]. Rigid pavements are a better option when compared to flexible pavements for the design of perpetual pavements as the former has higher service life [1,2]. Besides, rigid pavements in spite of their high initial cost, are proven to be more economic than flexible type pavements when due considerations are made to life cycle cost and all types of maintenance costs [1-3]. Since almost all rigid pavements are laid with cement concrete as the material, our focus needs to be shifted to concrete. Further, there is a high potential for research on concrete because concrete, originally has some undesirable properties like excessive brittleness, shrinkage cracking etc., In order to overcome these flaws and make concrete, a more useful material several modifications are being proposed. Polymer modification and fiber reinforcement are two of the most effective modifications done to concrete as they concentrate on serious problems of concrete (especially when it is used as a pavement material) like low tensile strength and high shrinkage [5].



1.2. Fiber Reinforced Concrete (FRC)

Reinforcing concrete with fiber is found to be finer reinforcement when compared to all other ways of reinforcing. Fiber reinforcing in concrete, found to be improving many of the desirable properties of concrete like tensile strength, impact resistance, fracture strength, toughness, load carrying capacity, fatigue performance, etc., [4-10] and also to reduce undesirable properties like plastic shrinkage and permeability. However, these advantages can be observed in the concrete mix only when the fiber percentages are well designed in the mix. Besides, enough mixing has to be done while casting as it is difficult for the fibers to be spread uniform and enough dispersion only can help the fiber to improve the properties of concrete in desirable way.

1.3. Polymer Modified Concrete (PMC)

Synthetic polymers have been in use for many decades to modify concrete mixes. The mostly used polymers are the styrene-butadiene copolymers (SBR), styrene-acrylic copolymers (SA), acrylic polymers (PA), vinyl acetate copolymers, and vinyl acetate homopolymer [11]. Modified systems have always been formulated considering the well-known association and combination of cement, fine aggregate, coarse aggregate, water and latex combined with a polymer/cement ratio (generally ranging from 5 to 20%), depending on the weight of cementitious materials in the mix [11-18]. The most widely proven and accepted fact about these modified systems is that because of the interpenetration of cement hydrates and polymer, which in turn is a result of many physicochemical reactions within the compounds, there is a formation of a strong network structure after the curing process. The cement paste and the aggregates showed improved values of cohesion at the interface due to the above mentioned reason and this is one of the main reasons the mix shows increased compactness in its hardened state. As an outcome of all these processes, these modified systems have been showing improved tensile and flexural strengths, adhesive and durability properties while showing a considerable reduction in permeability.

1.4. Polymer Modified Fiber Reinforced Concrete (PM-FRC)

For Pavement Quality Concrete (PQC), improving the strength properties is not merely sufficient. Instead, the performance characteristics are to be focused more on PQC to make concrete a better material for pavements. One such attempt is controlling the deflections in rigid pavements which cannot be achieved by modifying the concrete using only polymer or by simply reinforcing it. Polymer modification and fiber reinforcement individually are found to be giving satisfactory results in improving the flexural strength and plastic shrinkage properties of concrete, but have no considerable effect in controlling the deflections in PQC. These two techniques, when combined and used together in the same mix was proved to be better than using them individually as the latter shows advantages of both the modifications resulting in a superior mix [19,20].

2. Materials

2.1. Cement

In the present study, Ordinary Portland Cement (OPC) of 43 grade was used. The cement was tested as per IS 4031-1988 [21].

2.2. Fine Aggregate

Locally available river sand was used as a fine aggregate. The sand was screened at the site to remove deleterious materials and it was made sure that sand contained no or negligible water content before it was used for the mixing process.

2.3. Coarse Aggregate

Coarse aggregate is the strongest and least porous constituent of concrete. Moisture movement is a considerably serious problem in concrete mixes causing drying shrinkage along with other dimensional changes. These ill effects due to the moisture movement can be effectively controlled by

use of coarse aggregate in the mix. When properly graded, the use of coarse aggregate is even found to check down the permeability of concrete. Two sizes of crushed, angular shaped coarse aggregate: 20mm and 10mm were used in the study.

2.4. SBR Latex

Latex type polymer is selected as a modifier in this study which has styrene butadiene emulsion as its main component along with some special admixtures in it. Latexes have been showing outstanding bonding properties in mortar and concrete mixes. SBR Latexes have a typical composition of flexible butadiene monomers and rigid styrene monomers which shows many desirable features in the overall mix. The physical properties of SBR Latex are given in the below table.

Table 1. Properties of S.B.R latex	
Property	Value
Specific Gravity	1.02
pH value	9-11
Solid Content	48%

2.5. Polypropylene Fiber

Fiber reinforcing in concrete has been a reliable approach to improve the tensile and flexural properties of the mixes even better than the traditional bar type reinforcement. This is mainly because of the ability of the fibers to reach out and spread throughout the mix. This is a sort of disadvantage in case of polypropylene fibers. Because their hydrophobic nature, polypropylene fibers need to be mixed for long time so that the fiber disperses well throughout the mix. This mixing time should not even be too long because longer mixing times may result shredding of the fibers. The physical properties of the polypropylene fibers are shown in the following table.

Table 2. Properties of Polypropylene fiber	
Property	Value
Specific Gravity	0.9
Young's Modulus	5500-7000MPa
Tensile Strength	360 MPa
Melting Point	160°C
Fiber Length	12mm

3. Present Study

This study deals with seven different mixes out of which six are Polymer modified Fiber reinforced concrete and one is for nominal M30 grade concrete. The six PM-FRC mixes dealt with 3 different percentages of SBR latex (10, 15 & 20%) and also with 2 different percentages of polypropylene fiber (0.5% & 1%). A total of nine prism specimens were casted for each mix and were tested for flexural strength as well as maximum deflection value. The samples were named as per the latex and fiber percentage in their respective mixes where Lx-PPy means the sample contains x% of SBR Latex and y% of Polypropylene fiber by weight of cement in the mix.

(Example: L15-PP1 means the mix contains 15% SBR Latex and 1% Polypropylene fiber)

4. Mix Proportioning

The mix proportions, in the present study were calculated based on the design guidelines given by IS 10262:2009[22]

Table 3. Mix Proportions

Specimen ID	Cement (kg/m ³)	Fine aggregate (kg/m ³)	Coarse aggregate 20 mm (kg/m ³)	Coarse aggregate 10 mm (kg/m ³)	Water (kg/m ³)	S.B.R Latex (Kg/m ³)	P.P Fiber (Kg/m ³)
L0-PP0	442.8	628.37	655.36	436.9	191.6	0	0
L10-PP0.5	428.2	628.37	655.36	436.9	191.6	14.38	0.635
L15-PP0.5	421.22	628.37	655.36	436.9	191.6	21.57	0.635
L20-PP0.5	414.03	628.37	655.36	436.9	191.6	28.76	0.635
L10-PP1	428.42	628.37	655.36	436.9	191.6	14.38	1.27
L15-PP1	421.22	628.37	655.36	436.9	191.6	21.57	1.27
L20-PP1	414.03	628.37	655.36	436.9	191.6	28.76	1.27

5. Results and Discussions

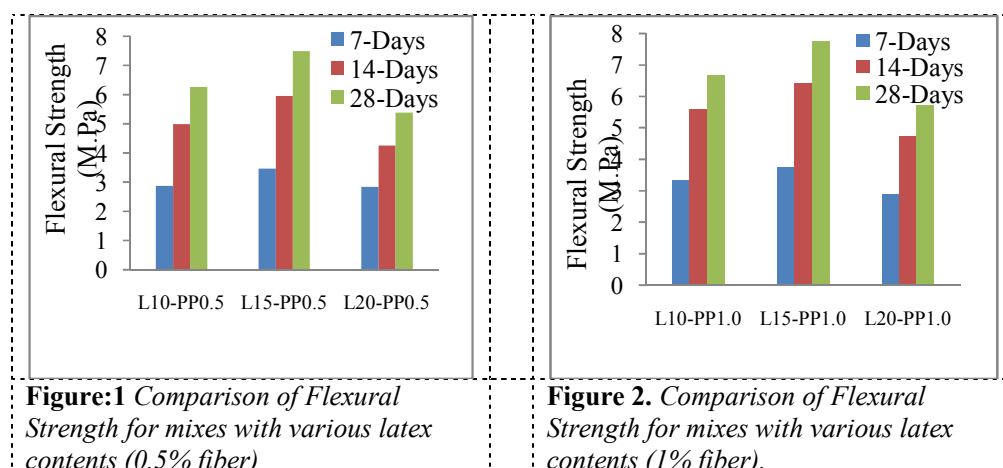
5.1. Flexural Strength

Prism specimens of dimensions 100 mm x 100 mm x 500 mm were cast and tested according to IS:516 (1959) [23]. The specimens were taken out of the curing tank well before the testing process and dried because water has shown high reluctance in escaping from the concrete matrix as a result of the use of polymer and fiber in it. All the mixes were tested at 7, 14 & 28 days in order to monitor the rate of strength gain in the specimens. The results of the flexural strength tests are given in Table 4.

Table 4. Flexural Strength of various mixes

MIX	Flexural Strength (MPa)		
	7-Days	14-Days	28-Days
L0-PP0	3.42	4.85	5.45
L10-PP0.5	2.87	4.99	6.26
L15-PP0.5	3.46	5.95	7.48
L20-PP0.5	2.83	4.26	5.38
L10-PP1.0	3.31	5.6	6.66
L15-PP1.0	3.75	6.41	7.75
L20-PP1.0	2.87	4.72	5.72

The results show that there was an increase in flexural strength for the modified concrete irrespective of the polymer and fiber percentages. The comparisons of the flexural strength results are shown below:



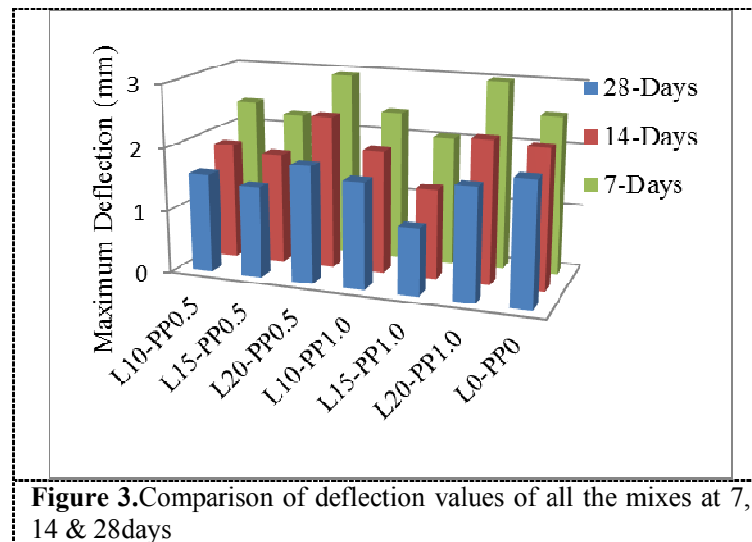
5.2. Deflection Studies

The maximum value of deflections obtained for each mix at 7, 14 and 28 days are tabulated in the Table 5 below:

Table 5. Deflections of Various mixes

MIX - ID	7-Days	14-Days	28-Days
L10-PP0.5	2.41	1.86	1.57
L15-PP0.5	2.24	1.76	1.44
L20-PP0.5	2.95	2.43	1.85
L10-PP1.0	2.39	1.95	1.68
L15-PP1.0	2.05	1.42	1.05
L20-PP1.0	3	2.27	1.76
L0-PP0	2.51	2.21	1.95

Mixes with polymer and fiber percentage had shown lesser deflection values when compared to normal mix except for the mix with 20% Latex and 1% fiber. The deflections reduced with increase in latex content up to 15% and then reached a higher value. This shows that 20% latex content is too high for the mixes. Out of all the mixes used, 15% latex and 1% fiber showed the least deflections and the mixes with 15% latex showed lesser deflections than the other specimens of its kind for both the fiber contents. This difference is much larger for the fiber content of 1% which is recommended as the optimum combination of polymer and fiber.



6. Conclusions

The following conclusions were drawn out of the present study:

- Concrete, when modified with latex and fiber had shown improved properties of flexural strength and lesser deflections.
- The increase in flexural strength when compared to the conventional concrete varied from a minimum of 5.6% to a maximum of nearly 45%.
- By increasing the fiber content from 0.5-1%, the flexural strength and resistance to deformation have increased slightly.

- Latex content of 15% is found to be giving the best results in terms of deflection and flexural strength. This is because of the sufficiency of latex at 15% and increase of latex beyond that point, resulted in disturbance of the latex-fiber structure.

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