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Effect of Steel and Polypropylene Fibres on the Strength Characteristics of a Cement Concrete Overlay

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Abstract: In developing countries like India, it is not always feasible to lay a new road every time when an existing road deteriorates. So an overlay is laid over the existing road either to rehabilitate a damaged road or to increase the load carrying capacity or both. In the present study, an attempt is made through laboratory investigations to examine the strength characteristics of concrete reinforced with different types of fibers for the purpose of providing a thin overlay capable of resisting stresses of higher intensity.
Key words: Fibre, overlay, rehabilitation, compressive strength.

Introduction:

Whenever an existing road pavement deteriorates due to excessive loading, changed climatic condition an overlay is preferred as a rehabilitation measure. In our country, bituminous overlays are normally constructed in the past because of the availability of bitumen, considerably lesser initial cost, and flexible methods for engineers to construct. But nowadays, concrete overlays are preferred because of their increased service life, improved structural capacity, less maintenance requirements and lower life cycle costs as compared to that of bituminous overlays. In the present study an attempt is made through laboratory investigations to examine the strength characteristics of concrete reinforced with different types of fibers for the purpose of providing a thin overlay capable of resisting stresses of higher intensity. As part of our experimental program, all the basic properties of cement such as consistency, setting time, etc. are found in the lab and M 50 grade concrete mix is designed as per IRC 44 2008 guidelines. Subsequently compressive strength, split tensile strength and flexural strength characteristics of control concrete as well as concrete reinforced with varying proportions of steel and polypropylene fibers at various curing periods are determined.

Literature Review:

It was found from the experimental studies[1] that microfibers offer more resistance to initial crack formation especially in case of thin concrete overlays and also concluded from this study that Steel and carbon microfibers perform better than polypropylene fibres with a few limitations of developing transverse cracks in thin overlays.

A new overlay design procedure was developed [2] by them and they have also found that there is a reduction in slab thickness of about 20% due to reinforcement of the fibres in the concrete. From the experiments conducted [3], the compressive strength of polypropylene fibre reinforced concrete was observed to increase between 10 per cent and 18 per cent for 7 and 28 days. Corresponding values for Hybrid concrete was found to be increased by 3 per cent to 22 per cent for 7 to 28 days as compared to that of conventional concrete.

Material Properties:

Cement:

Fly ash based Portland pozzolana cement (PPC - Dalmia Vajram) was used which satisfies the requirement of IS:1489, Part I[4]. The properties of the cement are shown below:

1. Specific Gravity of = 3.10
2. Consistency = 29%
3. Soundness = 1mm
4. Initial Setting Time = 30 minutes
5. Final Setting Time = 280 minutes
6. Compression test on cement mortar cubes:

No. of days of curing	Strength (MPa)
7	15.62
14	26.23
28	35.46

Fine Aggregate

Locally available sand was used. The sand was conforming to Grading Zone II as per IS: 383-1970[5]. The properties of fine aggregate are as shown below.

Specific Gravity = 2.62.

Maximum nominal size = 4.75mm

Coarse Aggregate

Locally available crushed aggregate which was complying with IS:383[5] was used. The properties of coarse aggregate are shown below.

Specific Gravity of Coarse Aggregate = 2.80.

Maximum nominal size = 20mm.

Silica Fume

The silica fume was used in these experiments conforms to IS 15388:2003[6]. The silica fume is an extremely fine particle, which exists in the form of white color powder. The properties of silica fume is shown below.

Specific gravity = 2.20

Super Plasticizer

Cera Hyperplast x40, a super plasticizer used in these experiments conforms to IS:9103[7]

Super plasticizer of 0.4% by weight of cementitious material was added.

Specific gravity = 1.10.

Fibres

Following fibres were added to concrete in the present work.

Steel fibres :

Steel fibres have equivalent diameters of 0.15mm to 2mm and length from 7mm to 75mm. Aspect ratio varies between 20 to 100. Aspect ratio is the ratio between fibre length and its equivalent diameter. Steel fibres have tensile strength ranging from 0.5 - 2.0 GPa and modulus of elasticity of 200 GPa.

Polypropylene fibres :

Polypropylene fibres, a synthetic carbon polymer, are produced as continuous mono – filaments, with circular cross section that can be cut to required length of rectangular cross section. Polypropylene fibres are tough but they have low tensile strength and modulus of elasticity and their ability to cause interference with the capillary forces by which water bleeds to the surface of concrete reduces the risk of plastic settlement due to evaporation of water.

Table 1 Properties of fibres

Fibre Type	Length(mm)	Equivalent diameter(mm)	Tensile Strength(Mpa)
Steel fibre	42	1.0	1100
Polypropylene	50	0.6	550

Mix Design: Mix design is done using IRC 44-2008[8]

Stipulation for Proportioning

Grade designation: M50
Type of cement: Portland Pozzolana Cement
Silica Fumes: Conforming to IS:15388
Maximum nominal size of aggregate: 20mm
Chemical admixture type: Super Plasticizer

The proportion of materials for control concrete is given below

Table 2 Mix Proportions

Material	Proportion
Cement	1
Fine Aggregate	1.914
Coarse Aggregate	3.971
Silica Fumes	0.111
Super Plasticizer	0.00444
Water	0.34

For fibre reinforced concrete fibres of 0.5%, 1.0%, 1.5% of cement content is taken and the proportion of the all other materials remains the same.

Compressive Strength:

Cube specimens of dimensions 150 mm × 150 mm × 150 mm were cast using the mix proportions given in Table 2, by reinforcing with varying proportions of steel, polypropylene and combining both the above fibres, Compressive strength test was carried out for all the specimens and the results are presented graphically in figures 1,2, and 3.

Table 3 Compressive strength of concrete cubes

Compressive strength	Cube 1 (MPa)			Cube 2 (MPa)		
Curing (days)	**7**	**14**	**28**	**7**	**14**	**28**
Control concrete	32.16	40.24	51.02	32.62	38.46	51.68
Concrete + 0.5% steel	34.96	44.98	54.26	34.52	42.94	53.46
Concrete + 1.0% steel	37.86	48.56	57.92	36.24	45.44	56.80
Concrete + 1.5% steel	36.12	45.16	54.00	35.32	43.38	53.98
Concrete + 0.5% polypropylene	35.72	48.78	56.34	36.24	45.46	57.18
Concrete + 1.0% polypropylene	38.08	49.20	58.48	37.16	48.32	57.26
Concrete + 1.5% polypropylene	38.56	47.28	59.24	38.12	47.16	58.64
Concrete + 0.5% steel & polypropylene	34.48	42.72	53.04	34.66	43.48	52.36
Concrete + 1.0% steel & polypropylene	33.98	40.28	51.12	33.02	41.50	50.96

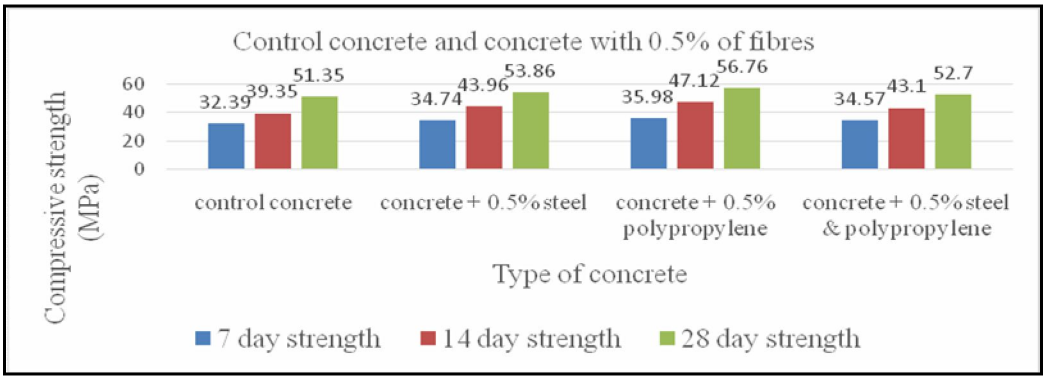

Figure 1 Compressive strength of control concrete and concrete with 0.5% of fibre

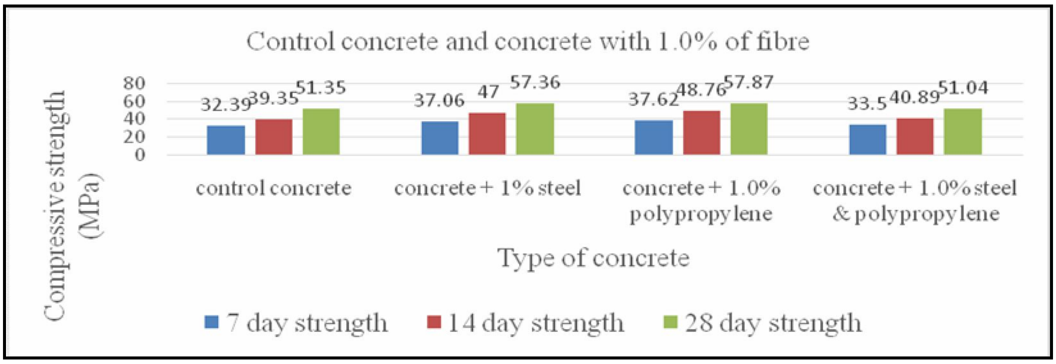

Figure 2 Compressive strength of control concrete and concrete with 1.0% of fibre

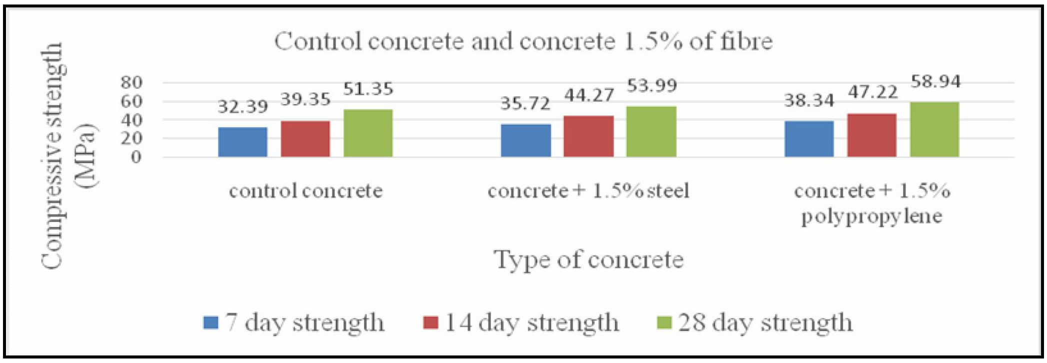

Figure 3 Compressive strength of control concrete and concrete with 1.5% of fibre

Split Tensile Strength:

Table 4 Split tensile strength of concrete cylinders

Split tensile strength	**Cylinder 1 (MPa)**			**Cylinder 2 (MPa)**		
Curing (days)	**7**	**14**	**28**	**7**	**14**	**28**
Control concrete	1.40	2.26	3.50	1.46	2.14	3.32
Concrete + 0.5% steel	2.42	3.96	5.12	2.38	4.00	4.80
Concrete + 1.0% steel	2.98	5.08	6.24	2.78	4.96	5.88
Concrete + 1.5% steel	2.56	3.84	5.18	2.64	3.98	5.02
Concrete + 0.5% polypropylene	2.74	3.66	4.22	2.52	3.48	4.16
Concrete + 1.0% polypropylene	3.04	3.98	4.68	3.12	3.86	4.82
Concrete + 1.5% polypropylene	3.28	4.12	4.94	3.48	4.32	5.06
Concrete + 0.5% steel & polypropylene	1.62	2.46	3.48	1.54	2.22	3.52
Concrete + 1.0% steel & polypropylene	1.28	2.08	2.94	1.32	1.96	2.76

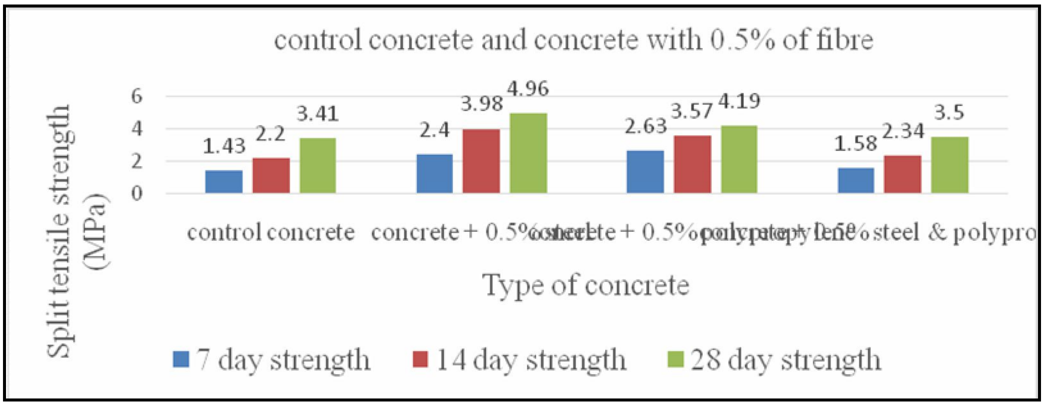

Figure 4 Split tensile strength of control concrete and concrete with 0.5% of fibre

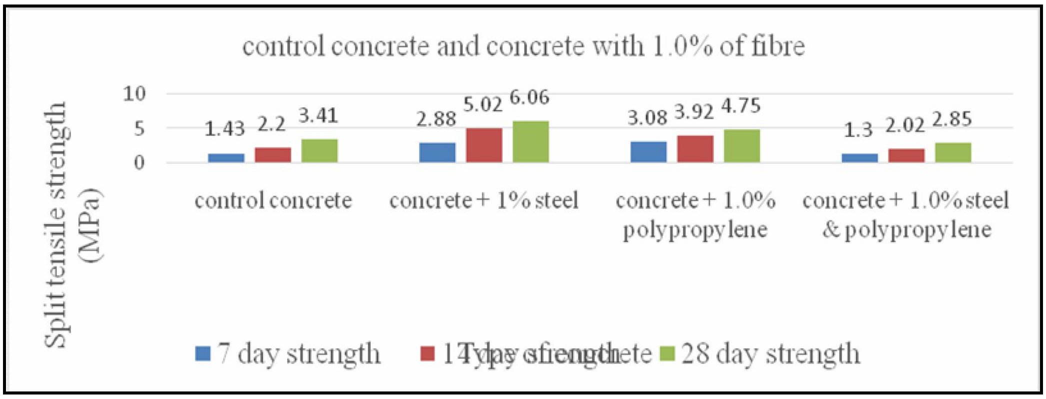

Figure 5 Split tensile strength of control concrete and concrete with 1.0% of fibre

Split tensile Strength:

Split tensile strength was found for the cylindrical specimens of control concrete as well as the fibre reinforced concrete (with similar combinations as in Compressive strength test) and the results are presented in figures 4,5 and 6.

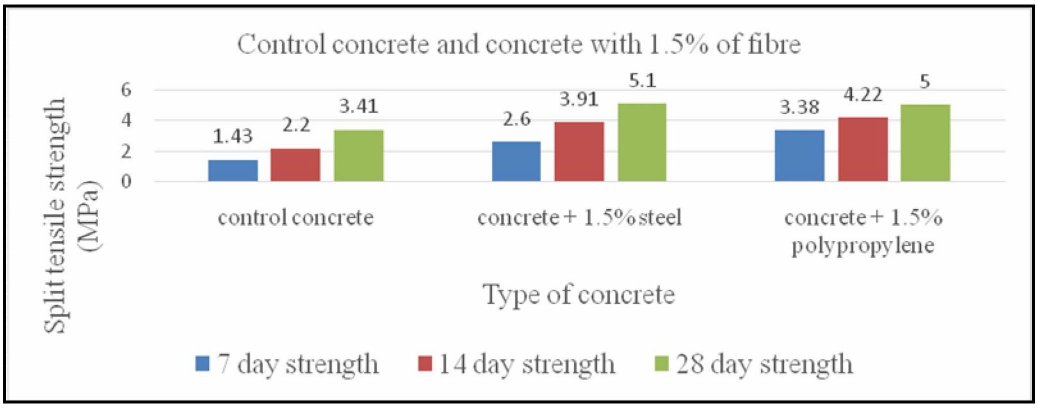

Figure 6 Split tensile strength of control concrete and concrete with 1.5% of fibre

Flexural Strength:

Table 5 Flexure strength of concrete beams

No. of days of curing (28 days)	Strength (Mpa)
Control concrete	7.45
Concrete + 1% steel	8.30
Concrete + 1.5% Polypropylene	8.96
Concrete + 0.5% steel & polypropylene	7.98

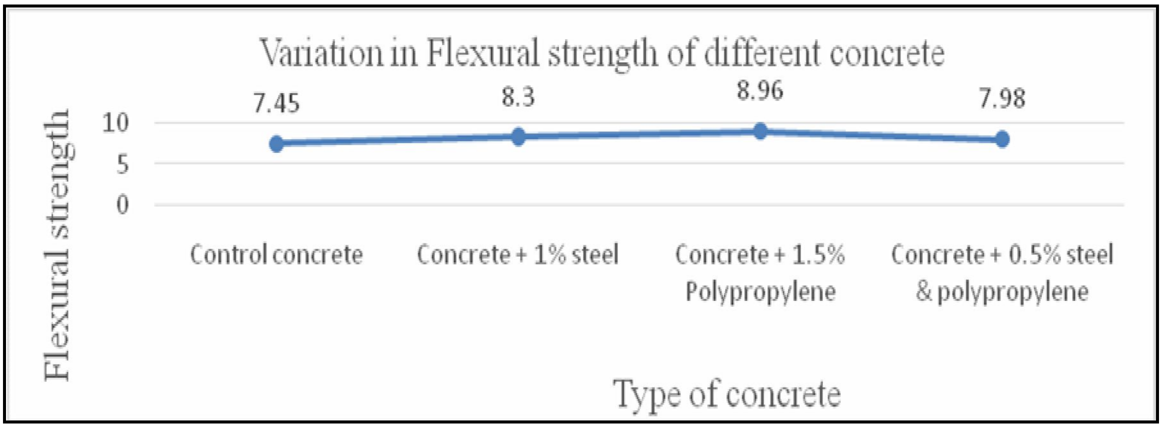

Figure 7 Variation in flexural strength of different type of concrete

Flexural Strength:

Beams of standard size were cast and flexure test was conducted for all the specimens (control as well as reinforced) and the results are presented in figure 8.

The results of compressive strength and flexural strength after 28 days of curing were compared and presented in figures 8 and 9.

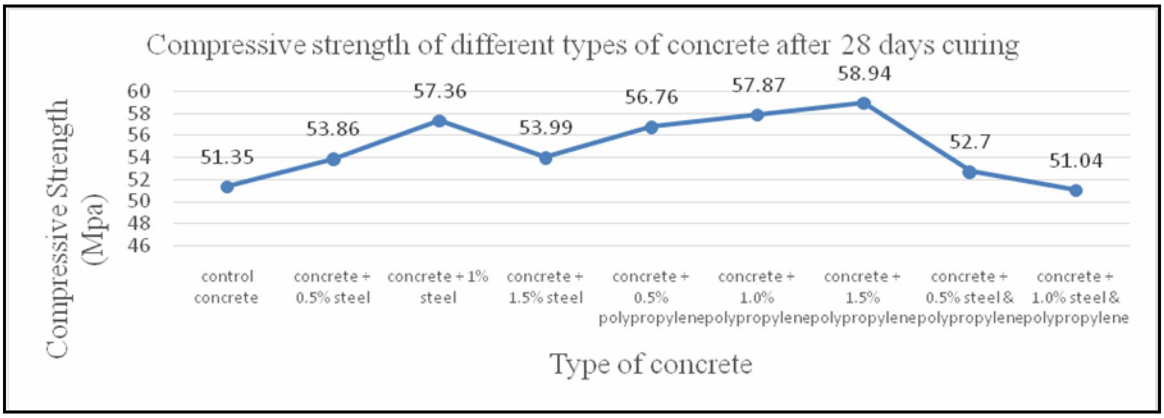

Figure 8 Compressive strength of different types of concrete after 28 days curing.

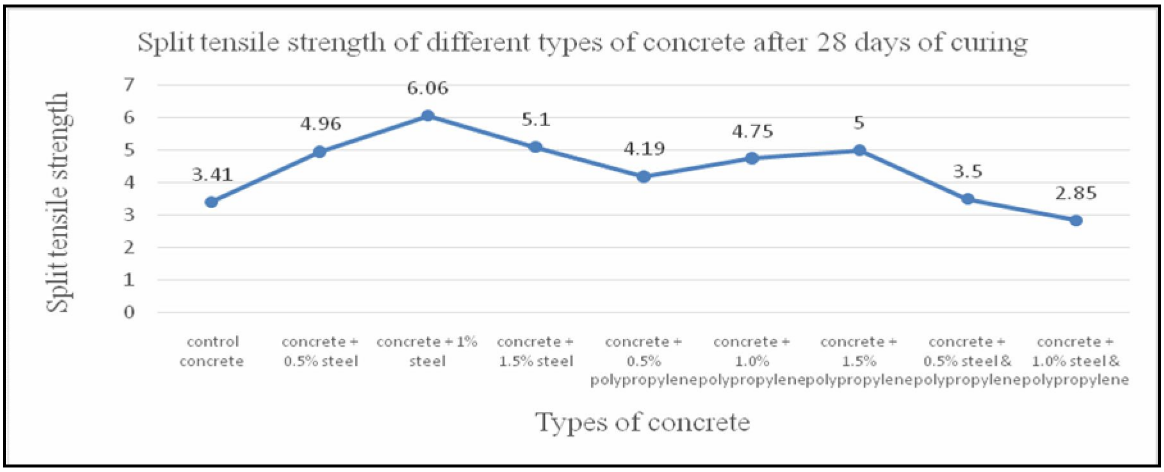

Figure 9 Split tensile strength of different types of concrete after 28 days of curing.

Conclusion

1. The Compressive strength and Split tensile strength of different proportion of all fibre reinforced concrete was higher than that of control concrete.

2. The Compressive strength of concrete with 1.5% of polypropylene fibre is higher than that of control concrete by 14.78% as compared with all other combination of fibres.
3. The Split tensile strength of concrete with 1.0% of steel fibre is higher than that of control concrete by 77.71% when compared to all other combination of fibres.
4. The Flexural strength of concrete with 1.5% of polypropylene fibre is higher than that of control concrete when compared to all other combination of fibres.
5. There was no increase in percentage of strength when both Steel and Polypropylene hybrid fibres were used.
6. From the results obtained, optimum combination of fibres and their percentage was polypropylene fibres @ 1.5%.

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