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Improving the Performance of Cement Concrete Pavement by using Polypropylene Fibers

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***Abstract*: India is a leading country in terms of infrastructure development in the world. In future use of high-performance concrete which are durable is required for construction of roadways. Polypropylene Reinforced Concrete is concrete containing polypropylene fibers which increases the structural integrity. The characteristics of Polypropylene Reinforced Concrete changes with varying fiber geometrics, distribution, orientation and densities. Polypropylene fiber is a light weight synthetic fiber. It is expected that if the addition of polypropylene in concrete mix in a right proportion can help enhancing the concrete properties like strength, water resistance etc. Roadways being backbone of the transportation system it is very important that they are designed to last long should be able to resist wear and tear for longer period. If the Polypropylene Reinforced Concrete mix is used in the construction of Rigid pavement it will allow us to design high performance Rigid pavements which can last longer than regular concrete mix pavements at a same or less construction cost and the maintenance cost is also expected to be reduced.**

***Keywords*: Concrete, Polypropylene fiber, Property enhancing, Performance, Rigid pavement.**

1. Introduction

Concrete is a man-made material, comprising a matrix of cementitious binder cement paste and a dispersed particles or filler of aggregates (typically a rocky material, loose stones, and sand). The binder "glues" the filler together to form a synthetic conglomerate. Many of concrete are available, determined by the formulations of binders and the types of aggregate used to suit the application of the engineered material. These variables determine strength and density, as well as chemical and thermal resistance of the finished product.

Aggregates contains large chunks of material in a concrete mix, generally a rough gravel or crushed rocks like limestone, or granite, alongside finer materials like sand.

Cement paste, most ordinarily made from portland cement, is the most prevalent kind of concrete binder. For cementitious binders, water is mixed with the dry cement powder and aggregate, which produces a semi-liquid slurry (paste) that can be shaped, typically by pouring it into a form. The concrete solidifies and hardens through a chemical change called hydration. The water reacts with the cement, which bonds the opposite components together, creating a strong, stone-like material.

Our project revolves around concrete pavements and its design, where we have tried to improve the physical properties of the pavement using PP (Polypropylene) fibers. Properties such as compressive strength, water absorption and flexural strength were attempted to be enhanced with the help of these fibers.

The characteristics of Polypropylene Reinforced Concrete changes with varying fiber geometry, distribution and densities. It is expected that the addition of polypropylene in concrete mix in a right proportion can help enhancing the concrete properties like strength, water resistance etc. When the Polypropylene Reinforced Concrete mix is used in the construction of Rigid pavement, it will allow us to achieve higher performance. Rigid pavements which can last longer than conventional concrete mix pavements, at a equal or less construction and the maintenance cost.

Concrete is the most used construction material in the world. It can be used in almost each and every aspect of the construction industry. Concrete can add beauty and sturdiness to several residential and commercial projects. It works great on highways, patios, parking lots, walkways, roads, and so much more, and it creates a timeless look.

While concrete offers many benefits, it's not always perfect. Improper processes and maintenance, as well as certain weather conditions, can cause a few common concrete problems that can affect the aesthetics or durability and various problems related to pavements such as the higher cost incurred for maintenance and most important is the down time required for competing repair works affecting people's commute. Work needs to be done in the field of pavement design and improving its properties with the help of new age materials such as polypropylene which are cost effective and easy to use.

A. Scope and Objectives

- The objective is to study the effect of polypropylene fiber in concrete.
- To conduct a comparative study on fiber in concrete and conventional concrete.
- Improving the strength and performance of pavement.

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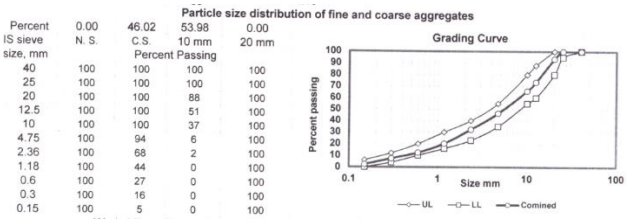
2. Methodology

- Testing on material and concrete – Materials were procured and tested to maintain the quality of project.
- Testing of cement – Field test and laboratory test were carried out on cement of OPC 53 Grade.
- Testing of aggregates – Various types of tests such as crushing test and sieve analysis of test were done on the aggregates.

The aggregates were clean natural river aggregates.

Fig. 1. Crushing test conducted on aggregates



Percent	0.00	46.02	53.98	0.00
IS sieve size, mm	N. S.	C.S.	10 mm	20 mm
		Percent Passing		
40	100	100	100	100
25	100	100	100	100
20	100	100	88	100
12.5	100	100	51	100
10	100	100	37	100
4.75	100	94	6	100
2.36	100	68	2	100
1.18	100	44	0	100
0.6	100	27	0	100
0.3	100	16	0	100
0.15	100	5	0	100

Fig. 2. Sieve analysis

Testing of sand - Sieve analysis of sand was performed.

Testing of concrete - Vivid varieties of test such as compressive test, flexural test, slump cone test and water absorption test were performed on concrete. [3]

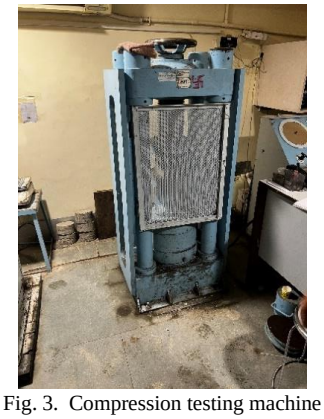


Fig. 3. Compression testing machine

Fig. 4. Flexure test

Fig. 5. Slump cone test

Design comparison - The rigid pavement was designed according to IRC 58 -2002 [5]

One with conventional concrete and one with PP (polypropylene) concrete.

Wheel load stress was found out using,

Load stress at interior (S_i)

$$S_i = \frac{0.316 \times p}{h^2}\left(4\log_{10}\left(\frac{1}{b}\right) + 1.069\right)$$

Stress at edge (S_e)

$$S_e = \frac{0.572 \times P}{h^2} \times \left(4\log_{10}\left(\frac{1}{b}\right) + 0.359\right)$$

Stress at corner (S_c)

$$S_c = \frac{3P}{h^2} \times \left(2 - \left(\frac{aV2}{l}\right)^{0.6}\right)$$

Where,
P= wheel load

h= thickness of slab in cm

Si, Se, Sc = Maximum Stress at interior, edge, and corner due to loading

E = Modulus of elasticity of concrete

Warping Stress was found out using

Interior Warping Stress

$$St_i = \frac{Eet}{2}\frac{(c_x + \mu c_y)}{1-\mu^2}$$

Stress at edge

$$= \frac{c_x \times E \times e \times t}{2}$$

Stress at corner

$$S_c = \frac{E \times e \times t}{3(1-\mu)} \times \left(\frac{V_a}{l}\right))$$

Where,

E= Modulus of elasticity of concrete

e = thermal coefficient of concrete

t = temperature difference at top and bottom of slab

c_x= coeffifcient based on $\frac{l_x}{1}$ in desired direction

C_y=coefficient based on $\frac{l_y}{1}$ in desired direction

μ= 0.15 Poisson's ratio

Frictional stress was found out using,

Frictional Stress

$$S = \frac{W.l.F}{2\times 10^4}$$

Where,

f = coefficient of subgrade restraint

L= slab length in meters

B= slab width in meters

Now the critical combination of stresses is found out and FOS (factor of safety) is determined.

By using,

$$FOS = \frac{\text{Strength of concrete}}{\text{Critical combination of stresses}}$$

3. Results and Discussion

A. Compressive Strength

Concrete cubes of two types of mixture one of conventional concrete and other of PP concrete were casted and compressive test on both were done at 14 and 28 days respectively. [3]

It was found out that the compressive strength of concrete was found maximum for 0.2% mix of concrete.

Following is the graph displaying the results for the same.

Table 1
Compressive strength

Type	14 Day Compressive strength (N/mm^2)	28 Day Compressive strength (N/mm^2)
Conventional Concrete	35.5	49.1
0.2 % proportion	42.8	53.6
0.4 % proportion	40.8	52.8
0.6 % proportion	37.2	49.4

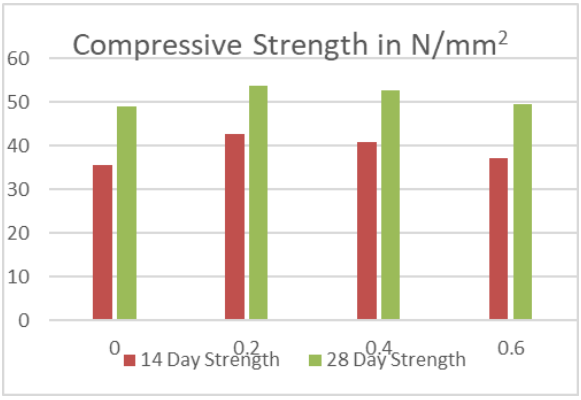


Fig. 6. Compressive strength graph

B. Flexural Strength

To determine the flexural strength of the concrete beams were cast for the concrete mixes and flexural test was done for the same on the UTM.

It was found out that the flexural strength was maximum for the mix with 0.4% of PP fibers

Here is a graph displaying the results for the same:

Table 2
Flexural strength

Type	Flexural Strength (N/mm^2)
Conventional Concrete	5.7
0.2% proportion	5.7
0.4% proportion	6.1
0.6% proportion	5.1

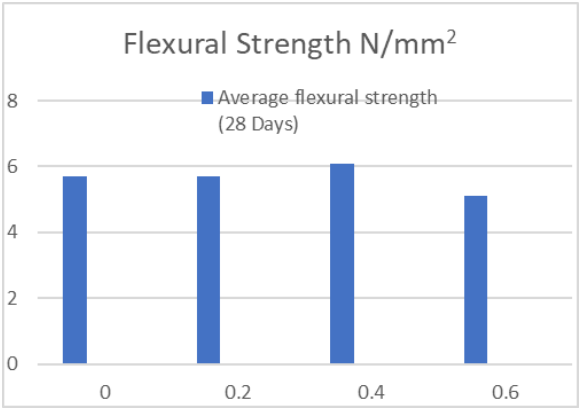


Fig. 7. Flexural strength graph

C. Water Absorption Test

Core cutting was done on the beam to cut out a cylindrical section and water absorption test was done for the same.

Water absorption was found to be minimum for 0.6% mix.

Table 3
Water absorption

Type	Average water absorption (%)
Conventional Concrete	2.88
0.2 % Proportion	2.5
0.4 % Proportion	2.53
0.6% Proportion	2.38

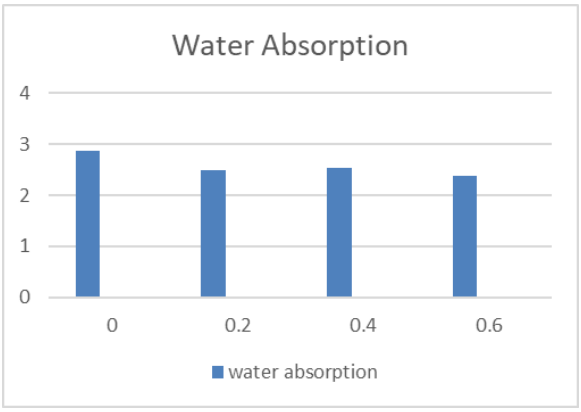


Fig. 8. Water absorption graph

D. Pavement Design Comparison

Design comparison of rigid pavement using both concrete (conventional and polypropylene) were done, the data required for the comparison were assumed

Here the critical combination of stresses was found out to be 49.368 kg/cm^2

FOS was calculated using,

$$\text{FOS} = \frac{\text{strength of concrete}}{\text{Critical combination of stresses}}$$

$$= 0.7\sqrt{f_{ck}}/49.368$$
$$= 0.7\sqrt{49.1}/49.368$$
$$= 0.98$$

Now according to IRC the FOS should be more than or equal to 1 for the pavement to be safe but the pavement here is failing

But when we use PP concrete,

$$\text{FOS} = 0.7\sqrt{f_{ck}}/49.368$$
$$= 0.7\sqrt{53.6}/49.368$$
$$= 1.03$$

Here we find out that when PP concrete is used the FOS > 1 Hence the Pavement is safe and there is no need to increase the thickness of the pavement.

(Note: The concrete used for both the comparison is of M40 grade, the properties of the concrete is enhanced by PP fibers).

4. Conclusion

Innovations in concrete are on a rise in this modern era PP (Polypropylene) concrete being on the forefront of it. Its popularity has increased because it enhances the properties of concrete with minimum increase in its cost.

When used in pavements the PP concrete was found to increase the FOS (factor of safety) of the pavement which in turn increases the serviceability of the pavement. PP concrete can be used for the construction of rigid pavements where the imposed load may increase in the future, under such circumstances PP concrete may be used.

We can conclude that future research can be done on this topic with varying sizes of PP fibers and material combinations to enhance the results.

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