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Effects of Polypropylene on the M30 and M40 Concrete Material

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ABSTRACT
This research aims to explore the effects of using polypropylene fibers to produce concrete with certain strength characteristics, The purpose of this study was to investigate the effect of polypropylene fibers in PCC mixtures on material properties such as compressive strength, tensile strength, flexural strength, bond, toughness, and fatigue strength. The results of this investigation are used to develop recommended mixture proportions, construction procedures, and quality control methods. The study includes an evaluation of current practice regarding the use of steel fibers in pavements as they pertain to the use of polypropylene fibers.

KEYWORDS: *Concrete, Polypropylene Fiber (PFRC), Compressive strength, Tensile Strength / Flexural Strength*

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OBJECTIVE:
This study aims to contribute to the following areas of research

- To conduct experimental investigation for measurement of compressive strength, split tensile strength and flexural strength of polypropylene fiber reinforced concrete.
- To investigate and compare the properties of hardened concrete and various PFRC mixes.

INTRODUCTION:
Concrete material is strong in compression while it is very weak in tension so, it tends to be brittle material. Using steel reinforcement and/or a sufficient amount of fibers, the weakness in tension can be resolved. Using fibers also leads to change the behaviour of concrete members after it has been cracked, thereby improving its toughness. Nowadays, many types of fiber, such as carbon, glass, steel and polypropylene fibers are frequently used in many projects such as high buildings, prestressed and precast concrete elements, bridges, dams, etc. The fibers can influence the properties of concrete both in fresh and hardened forms. The addition of various types of fibres to mechanically improve or modify the performance of Portland cement concrete (PCC) results in what is called fibre reinforced concrete (FRC).

Historically, the use of fibers as reinforcement in building materials dates back thousands of years and includes the use of asbestos fibers to construct clay pots, straw in making bricks, and hair in construction mortars. The use of fibers as reinforcement in concrete precedes the use of conventionally reinforced concrete. The modern use of fibers for reinforcing concrete dates from the 1950's to the present. Steel fibers have had the widest usage of any fibers in the paving industry due to their ability to provide increased tensile and flexural strength and fatigue loadings. The steel fibers, because of their high modulus or strength values, provide primary reinforcement similar in effect to steel bars in reinforced concrete. The improvement in material properties which enable the steel fibers to provide primary reinforcement was initially used to justify larger slab sizes and thinner pavement sections. Problems encountered in the field after construction with excessive curling and corner cracking led to the use of more conventional slab dimensions and thickness designs that considered the type of base course material on which the slab was constructed.

Polypropylene fibers can not provide the primary reinforcement in a concrete pavement because of relatively low modulus and strength values when compared with steel fibers. Polypropylene fibers are used to provide what is termed secondary reinforcement, or the encouragement of a desired material behaviour such as decreased plastic and shrinkage cracking and improved toughness. Polypropylene fibers have been widely used in structural applications since the late 1950's and more recently in paving applications. The predominant paving type of application for polypropylene fibers has been in slab on grade and parking lot construction. Several manufacturers have been selling the fibers to improve the concrete's resistance to the formation of plastic shrinkage cracking and as secondary reinforcement as a replacement for welded wire fabric (WWF). Polypropylene fibers have had limited use in thick airfield pavements or as overlays on existing PCC pavement.

KEY POINTS:

1. Polypropylene fibers play a crucial role in reducing crack formation and propagation in concrete, enhancing its durability and longevity.
2. The addition of polypropylene fibers improves the toughness of concrete, making it more resistant to impact and abrasion.
3. These fibers help control shrinkage in concrete, mitigating plastic shrinkage cracking, especially in hot and dry conditions.
4. Polypropylene fibers enhance the workability of concrete mixtures, facilitating easier handling and placement during construction.
5. Concrete containing polypropylene fibers exhibits increased fire resistance by reducing spalling, which occurs at high temperatures.
6. The permeability of concrete is reduced with the incorporation of polypropylene fibers, making it less susceptible to water penetration and chemical attacks.
7. Polypropylene fibers also improve the resistance of concrete to damage caused by freeze-thaw cycles, minimising the ingress of water into the concrete matrix.

METHODOLOGY:

The study involves the preparation of concrete mixtures with M40 and M30 grades according to standard procedures. Polypropylene fibers are added to the mixtures at varying dosages to assess their effect on mechanical properties such as compression strength, flexural strength and modulus of elasticity. Durability tests, including water absorption, permeability and resistance to freeze-thaw cycles, are conducted to evaluate the long term performance of polypropylene fiber reinforced concrete.

1. Material Selection and Preparation:

The materials for concrete mixtures, including cement, aggregates, water, and polypropylene fibers, are selected based on standard specifications. The aggregates are carefully graded to meet the requirements of M40 and M30 grade concrete. Polypropylene fibers of suitable length and diameter are chosen to ensure proper dispersion and reinforcement within the concrete matrix. Properties of Cement (Table 01), Fine Aggregates (Table 03), Coarse Aggregate (Table 02) and Polypropylene (Table 04) are shown in the table below.

TABLE 01. SPECIFICATIONS OF CEMENT

SL. NO	CHARACTERS	TEST RESULTS
01.	Specific gravity	3.15
02.	Normal Uniformity	28.5%
03.	Early setting time	40 mins
04.	Last setting time	230 mins
05.	Compressive Strength 07 days 28 days	23.5 N/mm^2 35.8 N/mm^2
06.	Fineness of Cement	1.2%

TABLE 02. SPECIFICATION OF COARSE AGGREGATES

SL NO.	PROPERTIES	TEST RESULTS
01.	Shape of Coarse Aggregate	Angular
02.	Specific Gravity	2.74
03.	Fineness Modulus	7.09
04.	Water Absorption	1.16%
05.	Bulk Density Compacted Condition Loose Condition	1.49 1.34
06.	Crushing Strength	25.93%

TABLE 03. SPECIFICATIONS OF FINE AGGREGATES

SL NO.	PROPERTIES	TEST RESULTS
01.	Specific Gravity	2.65
02.	Fineness Modulus	3.25
03.	Water Absorption	2.83%
04.	Bulk Density Compacted Condition Loose Condition	1.614 1.381

TABLE 04. PROPERTIES OF POLYPROPYLENE

SL NO.	PROPERTIES	TEST RESULTS
01.	Aspect Ratio	1800
02.	Tensile Strength (MPa)	2.56×10^3
03.	Elastic Modulus	8×10^3
04.	Length of PP Fibers (mm)	12

2. Mix Design:

Concrete mix designs for both M40 and M30 grades are prepared according to relevant standards and guidelines. The mix proportions are determined to achieve the desired strength and workability while considering the incorporation of polypropylene fibers. Various dosages of polypropylene fibers are considered to evaluate their effects on concrete properties. Mix design for M30 concrete and M40 concrete is shown below in Table 05.

SL NO.	MATERIALS	MIX PROPORTION (M30)	MIX PROPORTION (M40)
01.	Cement (Kg/m³)	350	400
02.	Fine Aggregates (Kg/m³)	750	700
03.	Coarse Aggregates (Kg/m³)	1100	1050
04.	Water (Kg/m³)	180	160
05.	Polypropylene (%)	1.5	2.0
06.	Water/Cement Ratio	0.51	0.40
07.	Superplasticizer (%)	2.5	2.0

3. Mixing Procedure:

The concrete mixtures are prepared using a mechanical mixer to ensure uniform distribution of materials. Polypropylene fibers are added to the mix in predetermined quantities and mixed thoroughly to achieve proper dispersion. Care is taken to avoid fiber clumping and ensure homogeneous distribution throughout the mixture.

4. Specimen Casting:

Specimens for testing are cast using the prepared concrete mixtures. Standard moulds and procedures are followed to cast cylinders for compressive strength testing, beams for flexural strength testing, and prisms for durability testing. The casting process is conducted under controlled conditions to minimise variations and ensure consistency.

5. Curing Regime:

After casting, the specimens undergo a curing regimen to facilitate proper hydration and development of strength. Standard curing methods, such as water curing or moist curing, are employed according to established practices for the specified curing period.

6. Testing Program:

The cured specimens undergo a comprehensive testing program to evaluate various mechanical properties and durability characteristics. This includes:

- Compressive strength testing of cylindrical specimens using standard testing procedures.
- Flexural strength testing of beam specimens to assess the load-bearing capacity and resistance to bending.
- Modulus of elasticity testing to measure the stiffness and deformation behaviour of the concrete.
- Durability testing, including water absorption, permeability, and resistance to freeze-thaw cycles, to evaluate long-term performance.

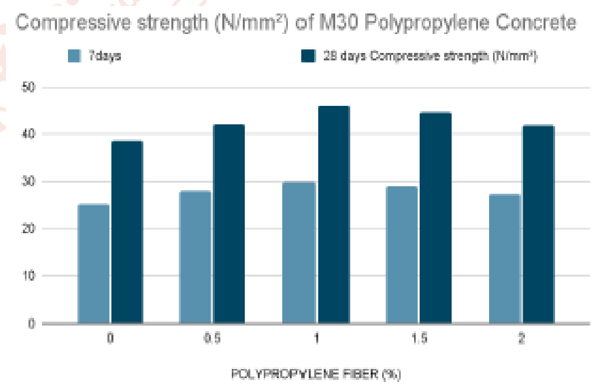
7. Data Analysis:

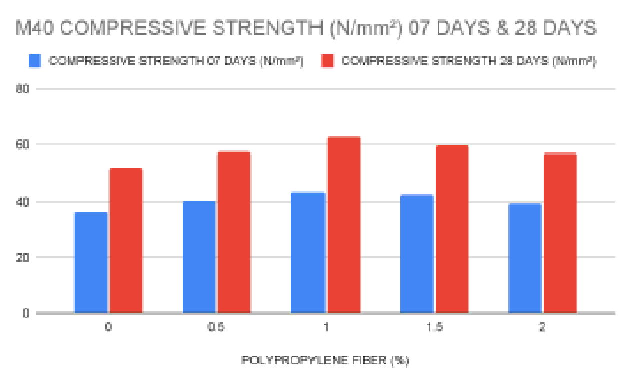
The test results are analysed to assess the effects of polypropylene fibers on concrete properties. Statistical analysis may be conducted to determine the significance of observed differences and correlations between variables. Any anomalies or inconsistencies are identified and addressed to ensure the reliability of the findings.

RESULTS

Compressive strength test results:

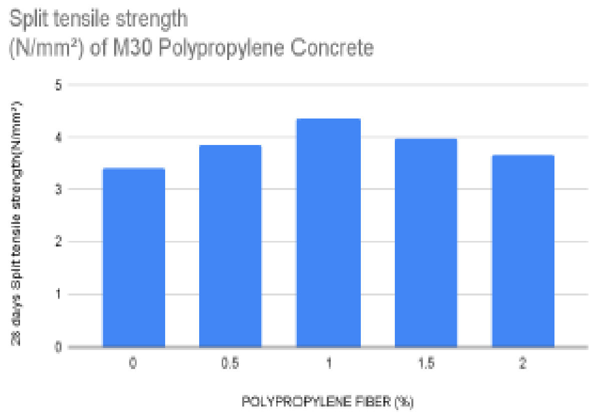
Compressive strength of concrete is tested on cubes at various percentages of polypropylene fiber content in concrete. The strength of concrete was tested on cubes at 7 days and 28 days of curing respectively, the results are furnished below in charts.

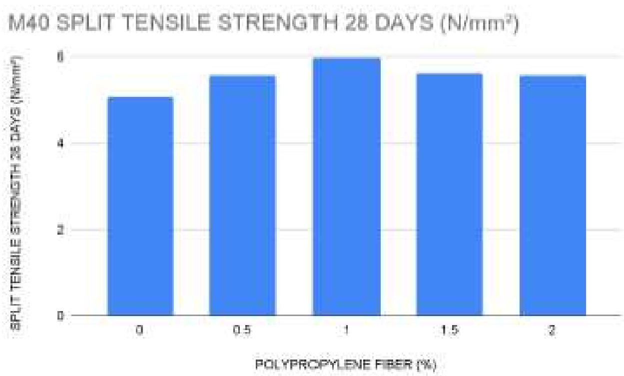




Split Tensile Strength test results:

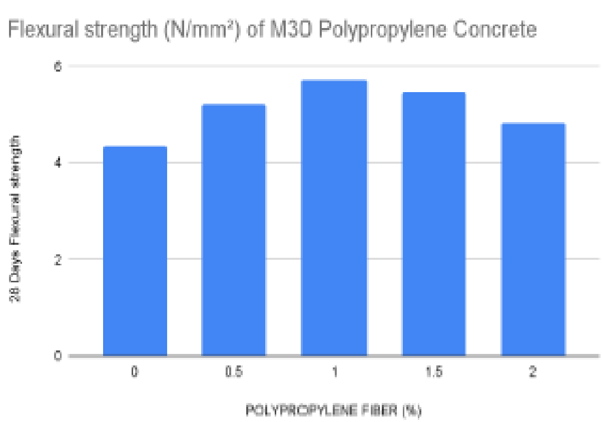
Split tensile strength of concrete is tested on cylinders at various percentages of polypropylene fiber content in concrete. The split tensile strength of concrete was tested on cylinders at 28 days of curing respectively, the results are furnished below in charts.

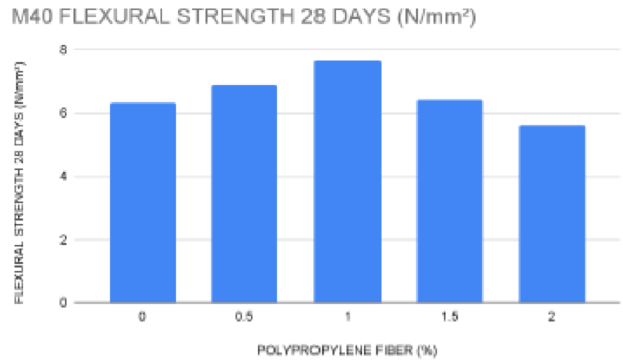




Flexural Strength Test on Cylinders:

Flexural strength of concrete is tested on beams at various percentages of polypropylene fiber content in concrete. The flexural strength of concrete was tested on beam at 28 days of curing respectively, the results are furnished below in charts.





CONCLUSION:

The study concludes that the incorporation of polypropylene fibers positively influences the performance of concrete mixtures with M40 and M30 grades. Polypropylene fiber-reinforced concrete demonstrates improved mechanical properties, durability, and resistance to environmental factors compared to conventional concrete. The addition of polypropylene fibers offers a multitude of benefits for concrete material, ranging from enhanced mechanical properties to improved durability. These following findings highlight the potential of polypropylene fibers as an effective additive for enhancing concrete performance in construction applications, providing engineers and construction professionals with valuable insights for optimising concrete mix designs.

- In this investigation program we conclude that there was an increase in compressive strength, split tensile strength, and flexural strength up-to 1% of fiber content and thereafter there was decrease in strength on further increase in fiber content.
- At 1% of addition of polypropylene fibers to concrete the compressive strength is increased by 19.84% for 28 days.
- At 1.5% of replacement of cement with polypropylene fibers the split tensile strength is increased by17.9% for 28 days.
- Fiber reinforcement significantly increases the tensile strength of lightweight aggregate concrete. The higher tensile strength along with the higher flexural strength is believed to be effective in reducing shrinkage in lightweight aggregate concrete.

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