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STATISTICAL ANALYSIS OF POLYPROPYLENE FIBRE REINFORCED CONCRETE

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ABSTRACT: The capability of durable structure to resist weathering action and other degradation processes during its service life with the minimal maintenance is equally important as the capacity of a structure to resist the loads applied on it. Although concrete offers many advantages regarding mechanical characteristics, the brittle behavior of the material remains a larger handicap for the seismic and other applications where flexible behavior is essentially required. Reinforcement with randomly distributed short fibers presents an effective approach to the stabilization of the crack and improving the ductility and tensile strength of concrete. Poly Propylene (PP) fiber reinforcement is considered to be an effective method for improving the shrinkage cracking characteristics, toughness, and impact resistance of concrete materials. In the present study, we are carrying out the statistical analysis of Poly Propylene fiber reinforced concrete by comparing various properties such as compressive strength, tensile strength, workability properties with various content of fiber (0%, 0.5%, 1% and 1.5%).

I. INTRODUCTION

The fibre reinforced concrete (FRC) contains randomly distributed short discrete fibres which act as internal reinforcement so as to enhance the properties of the cementitious composite (concrete). The principal reason for incorporating short discrete fibres into a cement matrix is to increase the toughness and tensile strength, and to improve the cracking deformation characteristics of the resultant composite. These properties of FRC primarily depend upon the type of the fibres used in the concrete. The polypropylene fibre reinforced concrete (PPFRC) has seen limited applications in several structures including parking areas, drive ways, industrial floorings, water and other chemical storage tanks, walkways, pavements, roof screeds, mosaic flooring, structural concrete and also in pre-cast slabs. The applications are primarily to inhibit the cracking. However due to the lack of awareness, design guidelines and construction specifications, its uses are limited by the local construction industry. Therefore there is a need to develop information on the properties of Polypropylene Fibre Reinforced Concrete (PPFRC) in which indigenous polypropylene fibres are used.

Objective

1. Conducting experimental investigation for measurement of workability, compressive strength and split tensile strength of Polypropylene Fibre Reinforced Concrete (PPFRC).
2. For the measurement of workability of the PPFRC, standard method is used for characterizing workability in terms of consolidation, however; four standard test methods are used to characterize the flow property of PPFRC.

3. For the properties, the following tests are conducted to study the effect of amount of fibres and the length of fibres on the compressive, tensile strength and the associated straining capacity.

Research Significance

The use of PPFRC in the local construction industry is limited. The purpose of this work is to develop evidence of the engineering properties of PPFRC in which polypropylene fibres are used. This includes the properties of PPFRC such as workability in fresh state, free shrinkage and other properties in hardened state. The results of this work will be useful for the local construction industry and could be used for developing specification guidelines for the use of PPPFC in the local construction.

II. METHODOLOGY

The research methodology was to conduct a literature review of the studies on FRC and PPFRC that have been conducted in the past two decades. On the basis of the literature review, knowledge gaps were identified. It was realized that mechanical properties of Polypropylene fibre reinforced concrete have been studied by many researchers in different areas of world. However there still a need to provide experimental and knowledge ground for the use of PPFRC in the local construction industry. An experimental program was developed to study the properties of PPFRC. The experimental program included number of variables such as the length of the PPF, amount of PPF, test age etc. Concrete mixture proportions for plain and PPRC concrete were developed to maintain a target slump. Using these PPFRC concrete mixes, test specimens were cast, cured and tested as per the experimental matrix. The results of the plain and PPFRC concrete test specimens were compared to quantify the beneficial effects of PPF on concrete. The results are discussed and presented along with an analytical equation for characterizing the stress-strain curve of PPFRC in compression.

III. MATERIALS

a) Cement

The cement used was 53 grade Ordinary Portland cement (OPC). It has specific gravity of 3.13 with initial and final setting times of cement were 45 and 185 mins respectively. The physical properties are confirming to IS: 12269-1987.

b) Aggregates

The material whose particles are of size as are retained on I.S

Sieve No.480 (4.75mm) is termed as coarse aggregate. The size of coarse aggregate depends upon the nature of work. The coarse aggregate used in this experimental investigation are of 12.5mm size crushed angular in shape. The aggregates are free from dust before used in the concrete. Good quality sand is used as fine aggregate.

c) Water
The water causes the hardening of concrete through a process called hydration. It is a chemical reaction in which the major compounds in cement form chemical bonds with water molecules and become hydrates or hydration products. According to IS: 456-2000, water for concrete should be of portable quality (PH- 6.8 to 8.0). Ordinary tap water, which is fit for drinking has been used in preparing all concrete mixes and curing in this investigation.

d) Fibre
Fibrillated polypropylene fibres (PPF) with two different lengths were used in different volume percentage. The fibre and the material specifications were provided by the Reliance Company. The polypropylene fibres are composed of film sheets which are cross linked by fine fibre along their length. These fibres are manufactured in chicken mesh form and then cut into desired length. It was manufactured by the name Recron 3s by Reliance Industry Limited (RIL). The fibres are available in 3 different sizes i.e. 6mm, 12mm, and 24mm. In this project, 12mm fibre is used.

IV. MIX DESIGN

A suitable concrete mix design was established on the basis of preliminary testing of mortar cubes having cement to sand ratio of 1:2.75 and w/c ratio of 0.48. Twelve number of 2"x2" cubes were cast and cured in water tank and then tested under compression using Universal Testing Machine at a loading rate of 60 psi/min. The strength- time curve was developed for 28 days of curing. Each point on strength-time curve is an average of three replicate cube specimens. Note that the 28 day strength is in excess of 3000 psi.

a) Tests for Workability of Fresh PPFRC
Standard test methods were used to study the workability of PPFRC in terms of flow ability. Slump test was performed on the batch of concrete for the purpose of homogeneity and the results obtained thus were compared and calibrated. The complete experimental matrix for workability tests is given.

i) Standard Slump Test
The slump test is the most well-known and widely used test method to characterize the workability of fresh concrete. The inexpensive test, which measures consistency, is used on job sites to determine rapidly whether a concrete batch should be accepted or rejected.
The apparatus consists of a mould in the shape of a frustum of a cone with a base diameter of 200 mm, a top diameter of 100 mm , and a height of 300 mm. During this test, the mould is filled with concrete in three layers of equal volume. Each layer is compacted with 25 strokes of a tamping rod. The slump cone mould is lifted vertically upward and the change in height of the concrete is measured.

ii) Compacting Factor Test
The compaction factor test measures the degree of compaction resulting from the application of a standard amount of work. The test was developed in Britain in the late 1940s and has been standardized as British Standard 1881-103 [Eric et al (2003), BS 1881-103 (1993)].
The apparatus, which is commercially available, consist of a rigid frame that supports two conical hoppers vertically aligned above each other and mounted above a cylinder. The top hopper is slightly larger than the bottom hopper, while the cylinder is smaller in volume than both hoppers. To perform the test, the top hopper is filled with concrete but not compacted. The door on the bottom of the top hopper is opened and the concrete is allowed to drop into the lower hopper. Once all of the concrete has fallen from the top hopper, the door on the lower hopper is opened to allow the concrete to fall to the bottom cylinder. A tamping rod can be used to force especially cohesive concretes through the hoppers. The excess concrete is carefully struck off the top of the cylinder and the mass of the concrete in the cylinder is recorded. This mass is compared to the mass of fully compacted concrete in the same cylinder achieved with hand rodding or vibration. The compaction factor is defined as the ratio of the mass of the concrete compacted in the compaction factor apparatus to the mass of the fully compacted concrete.

b) Tests for Mechanical Properties of Hardened PPFRC
Some of the mechanical properties of PPFRC are considered in this study. These include Compressive strength, splitting tensile strength. Standard methods of test for each of the property are described in the following sections.

i) Compressive Stress-Strain Curve
This test method covers the determination of cylindrical compressive strength of concrete specimen. The specimens are prepared by pouring freshly mixed concrete into lubricated cylinders. The mixing procedure is the same as described of this report. Consolidation is done externally over vibrating table for 3-5 minutes. After vibration and finishing, the moulds are kept at normal atmospheric conditions for 23 ½ ± ½ hours after which de moulding is done. The specimens are then cured in water tank.

The test is conducted at surface dry condition. The specimens are capped, placed and seated in the testing machine as described by section 7 of ASTM C39. The specimens are tested at the age of 7, 14 and 28 days of curing under the Universal Testing Machine. This machine applies compressive stress on the cylinder due to the downward movement of the platen at a constant displacement rate of 0.1 mm/sec. The load and stroke measurements are noted from which stress and longitudinal strain values are computed and plotted for each set. The strength-time curves for plain concrete and PPFRC were also obtained for an average of three values and then compared to each other.

ii) Split Tensile Strength of Concrete Cylinders
This test method covers the determination of splitting tensile strength of concrete cylinders. The procedure for preparation of specimens for split cylinder testing.
This test method consists of applying a diametric compressive force along the length of a cylindrical concrete specimen at a rate that is within a prescribed range until failure occurs. This loading induces tensile stresses on the plane containing the applied load and relatively high compressive stresses in the area immediately around the applied load. Tensile failure occurs rather than compressive failure because the areas of load application are in a state of multi axial compression, thereby having a much higher resistance as compared to uniaxial compressive strength test result.

The test was performed in the Universal Testing Machine. The load and stroke values are recorded by the test machine and the split tensile stresses were calculated.

V. RESULTS

a) Workability of Fresh PPFRC
For the workability of fresh concrete, tests used were traditional Slump Cone Test, Compacting Factor, Compressive Test and Tensile Strength. These tests were performed on concrete without polypropylene fibres (PPF) termed as "control" specimens and on polypropylene fibre reinforced concrete (PPFRC) specimens.

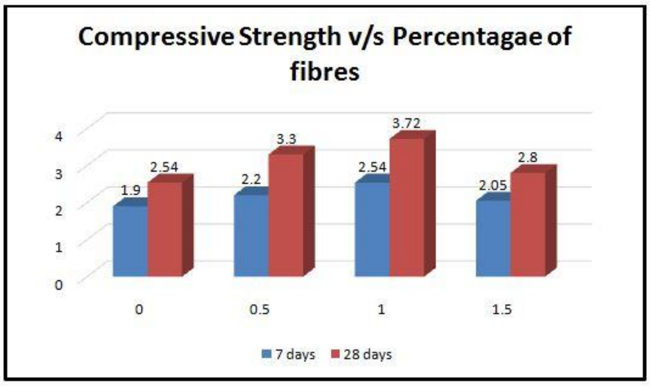
The tests results of various fresh properties tests of Plain Concrete (PC) and polypropylene fibre reinforced concrete (PPFRC) with different volume fraction (V_f) and length of fibre (L_f) are presented.

The PPFRC mixtures were proportioned to give slump values which are needed to ascertain adequate workability of the fresh concrete to be placed and finished. For all the concrete mixes having different fibre contents and with different lengths of fibres, the measured slump is greater than 3 in. (76 mm), which is an acceptable slump values for the ease of construction and finish ability. For the PPFRC mixtures, in order to maintain reasonable slump, and approximately similar w/c, the quantity of cement was increased with increase in amount of chemical admixture as segregation was observed to occur when only water content was increased in order to increase the workability of the PPFRC mixtures.

b) Plastic Shrinkage of Fresh PPFRC
The results of the shrinkage tests performed on the control specimen PC and four different PPFRC mixtures are shown. The length measurement was done using a digital caliper and then the results were computed. The results were then plotted against time and then compared. The graphical representation of the results is given. In general it can be noted that the shrinkage of both PC and PPFRC mixtures varies greatly in the initial 24 hours and then gradually reduces with the passage of time. It is evident that the shrinkage of PC specimens is larger than shrinkage of PPFRC specimens and that addition of PPF reduces the early age plastic shrinkage of concrete. Among the four PPFRC mixtures, the PPFRC 0.4-25 is found to be the most efficient in controlling early age shrinkage as it showed the maximum average shrinkage of 0.106% at 72 hours.

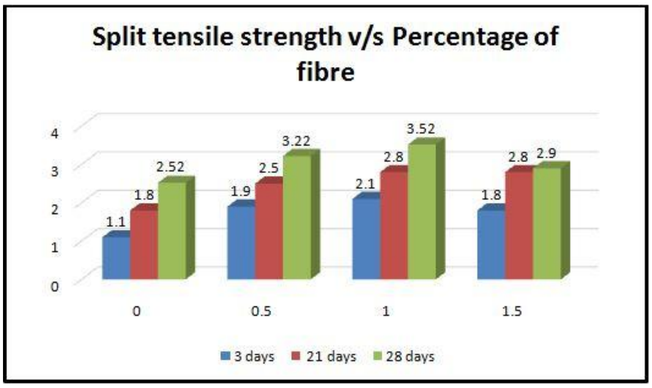
c) PFRC
The addition of the PPF to the concrete mixtures has beneficial effects on the mechanical properties of hardened concrete. The effect of volume of fibres (V_f) and the length of fibres (L_f) on the mechanical properties such as compressive strength, split cylinder tensile strength, flexural tensile strength at different test ages are reported.

d) Compression Strength Test Results
The compressive strength tests were performed on one plain concrete mixture "Control" concrete polypropylene fibre reinforced concrete (PPFRC) mixtures. These were tested at the ages of 7 and 28 days. Three replicate specimens were tested at each test age for each type of mixture. At each of the test age, three (3) specimen were taken out from curing, dried and then caped with sulphur and were tested to get the load-stroke data. From the load-stroke data, stress-strain data was computed. From the stress-strain data of each of the 3 specimens, an average stress-strain data was obtained, which was plotted.



e) Split Tensile Strength Test Results
The splitting cylinder tensile tests were performed on one plain concrete mixture "Control" concrete and polypropylene fibre reinforced concrete (PPFRC). The seven different mixtures. These were tested at the ages of 7 and 28 days. Three replicate specimens were tested at each test age for each type of mixture.
At each of the test age, the specimens were tested and the load-stroke data was obtained from which stress-displacement data was computed. From the stress displacement data of each of the 3 specimens, an average stress-displacement data was obtained, which was plotted.
The average stress-displacement behavior of PC shows a linear trend up to the cracking. After the first crack occurs, the strength of the PC reduces immediately and the crack widening leads to the splitting of the cylinder.
The average stress-displacement behavior of PC and PPFRC with different V_f and L_f at different test ages. From these, it can be seen that the stress-displacement behavior up to first crack is almost the similar for both PC and PPFRC; however the post-peak behavior is different and the addition of PP

fibres to concrete helps in increasing the post peak deformation capacity and enhancing the post-cracking strength of PPFRC in tension.
In the case of PPFRC, the PP fibres come into action after the first crack. The PP fibres bridge these cracks and restrain them from further opening and hence improve the load-carrying capacity of structural member beyond cracking. After the first crack, a drop in the stress is noted which shows the stress transfer from concrete to the randomly distributer fibres, which further take the applied load by elongating. The failure or the splitting on the cylinder occurred when the fibres elongation exceed the allowable i.e. the breaking of the fibres under axial tension.



f) Applications of Fibre

- Hydraulic structures
- Residential roads and driveways
- Tennis courts
- Foundations/floors for greenhouses
- concrete pavements
- Well linings
- Sidewalks
- Pathways

Type of Work	Fibre Length (mm)	Minimum Dosage (gms/50 Kg cement bag)
Plaster Works (Including Colour Crete)	6	100
External Plaster Works, Precast Concrete and Repair of Plaster Works	13	100
Residential and Commercial Roof Screed and Roof Slab, Industrial Flooring and Pavement, RCC Structure for Water Tank, Basement Walls, Manhole and Canal Lining	25+13	300
Water Reservoir, Sewerage Drain, Storm Water Drain and Residential Roof Screed (Over Flexible Insulation Base)	25+13	450
Heavy Duty Industrial Floor, Hanger Floor, Runway, Quay Wall, Sea Block, Bridge Deck Screed, Expansion Joint and	25	600

VI. CONCLUSIONS

1. Polypropylene fibers reduce the water permeability, plastic, shrinkage and settlement and carbonation depth.
2. Workability of concrete decreases with increase in polypropylene fiber volume fraction. However, higher workability can be achieved with the addition of HRWR admixtures even with w/c ratio of 0.3.
3. Polypropylene fibers enhance the strength of concrete, without causing the well known problems, normally associated with steel fibers.
4. The problem of low tensile strength of concrete can be overcome by addition of polypropylene fibers to concrete. Notable increase in compressive strength is reported with addition of polypropylene fibers.
5. The durability of concrete improves and addition of polypropylene fibers greatly improves the fracture parameters of concrete.
6. The compressive strength, split tensile strength, flexural strength and modulus of elasticity increase with the addition of fiber content as compared with conventional concrete.

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