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RESEARCH AND MANUFACTURE OF POLYPROPYLENE FIBRE REINFORCED CONCRETE

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ABSTRACT

Concrete made with ordinary Portland cement is relatively strong in compression but weak in tension and tends to be brittle. This weakness causes the concrete to the poor performance under flexure behavior. Another fundamental weakness of concrete is that due to its shrinkage, cracks start to form as soon as concrete is placed and before it has properly hardened. These cracks are major cause of weakness in concrete when particularly in large onsite applications that leading to subsequent fracture, failure and general lack in durability. The weakness in tension can be overcome by the use of conventional reinforcement rods and to some extent by the inclusion of a sufficient volume of certain fibers. Natural Fiber Composites (NFCs) and Wood Polymer Composites (WPCs) based on polypropylene (PP) have gained increasing interest over the past two decades, both in the scientific community and in industry. Meanwhile, a large number of publications is available, but yet the actual market penetration of such materials is rather limited. To close the existing gap between scientific and technical knowledge, on the one hand, and actual market applications, on the other, it is the purpose of this paper to analyze the current state of knowledge on mechanical performance profiles of injection molded NFCs and WPCs. As the composite properties are a result of the constituent properties and their interactions, special attention is also given to mechanical fiber/filler properties. Moreover, considering that NFCs and WPCs for a variety of potential applications compete with mineral reinforced (mr; represented in this study by talc), short glass fiber (sgf), long glass fiber (lgf) and short carbon fiber (scf) reinforced PP, property profiles of the latter materials are included in the analysis. To visualize the performance characteristics of the various materials in a comparative manner, the data were compiled and illustrated in so-called Ashby plots. Based on these comparisons, an assessment of the substitution potential of NFCs and WPCs is finally performed, along with a discussion of still open issues, which may help in guiding future material development and market application efforts.

I. INTRODUCTION

Concrete is a construction material composed of cement, fine aggregates (sand) and coarse aggregates mixed with water which hardens with time. Portland cement is the commonly used type of cement for production of concrete. Concrete technology deals with study of properties of concrete and its practical applications. In a building construction, concrete is used for the construction of foundations, columns, beams, slabs and other load bearing elements. There are different types of binding material is used other than cement such as lime for lime concrete and bitumen for asphalt

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concrete which is used for road construction. Various types of cements are used for concrete works which have different properties and applications. Some of the type of cement is Portland Pozzolana Cement (PPC), rapid hardening cement, sulphate resistant cement etc. Materials are mixed in specific proportions to obtain the required strength. Strength of mix is specified as M5, M10, M15, M20, M25, M30 etc, where M signifies Mix and 5, 10, 15 etc. as their strength in kN/m^2.

Water cement plays an important role which influences various properties such as workability, strength and durability. Adequate water cement ratio is required for production of workable concrete. When water is mixed with materials, cement reacts with water and hydration reaction starts. This reaction helps ingredients to form a hard matrix that binds the materials together into a durable stone-like material. Concrete can be casted in any shape. Since it is a plastic material in fresh state, various shapes and sizes of forms or formworks are used to provide different shapes such as rectangular, circular etc. Various structural members such as beams, slabs, footings, columns, lintels etc. are constructed with concrete. Components of concrete are cement, sand, aggregates and water. Mixture of Portland cement and water is called as paste. So, concrete can be called as a mixture of paste, sand and aggregates. Sometimes rocks are used instead of aggregates. The cement paste coats the surface of the fine and coarse aggregates when mixed thoroughly and binds them. Soon after mixing the components, hydration reaction starts which provides strength and a rock solid concrete is obtained.

Objectives of the research

1] To reduce the consumption of fine aggregate and thereby increase the fire load strength

2] To develop the polypropylene fiber reinforced concrete of M30 grade

3] To enhance the concrete's flexural tensile strength, crack arresting system and post cracking ductile behavior of basic matrix.

II. MANUFACTURING PROCESS

Polypropylene chips can be converted to fiber/filament by traditional melt spinning, though the operating parameters need to be adjusted depending on the final products. Spun bonded and melt blown processes are also very important fiber producing techniques for nonwovens. The process is explained below,

1. Extrusion: L/D=30, compression ratio=1:3.5
2. Metering: one or more spinning gear pumps receives the molten polymer and sends it through the spinning pack to homogenize the product, feed the spinning pack at a constant rate, and prevent fluctuation due to screw extruder.
3. Spinning: the spinning pack consists of three parts-filters, distributor (which distributes the molten polymer over to die surface) and the die. The diameter of the die varies from 0.5 to 1.5mm, depending on the denier required.
4. Quenching: newly extruded filaments are cooled in a good "box" which will distribute 3 m3/min of cool air without damaging the filaments.
5. Finishing: to improve antistatic and reduce abrasion.
6. Hot Stretching: to enhance the physico-mechanical properties.
7. Crimping: to improve the bulk.

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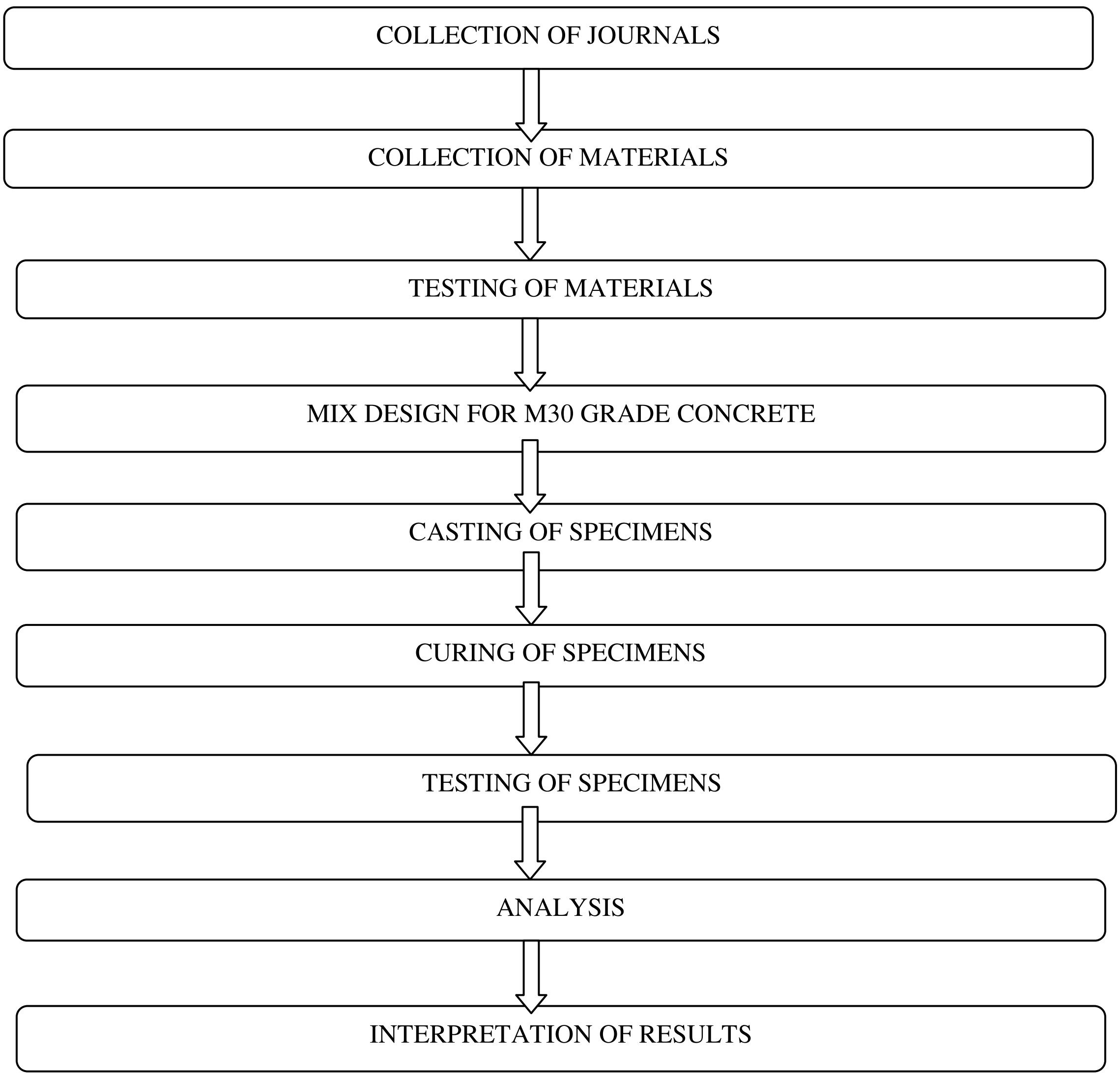
8. Thermosetting: it is a treatment in hot air or steam that removes the internal stresses and relaxes fibers. The resultant fibers are heat-set with increased denier.
9. Cutting: fibers are cut into 20 to 120 mm length depending on whether they are intended for cotton or woolen system

III. METHODOLOGY

The experimental program consists of laboratory tests on plain concrete an polypropylene fiber reinforced concrete to characterize the strength. For this purpose total of four concrete mixtures were casted including control mix. The different volume fractions of the fibers were 0%, 10%, 20% and 30%. Tests were carried out on cubes of size 150x150x150 mm cylinder of diameter and height 300 mm and beams of size 500x100x100 mm. The materials, mix design, casting, curing, test methods and procedures for mechanical properties of hardened concrete are described in detailed respective sections.



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IV. EXPERIMENTAL PROGRAMME

CEMENT

The following tests were conducted in accordance with IS codes

- Specific gravity (IS : 4031-1988 PART 11)
- Fineness (IS :4031-1996 PART 1)
- Standard consistency (IS :4031-1988 PART 4)
- Initial setting time (IS:4031-1988 PART 5)
- Final setting time (IS:4031-1988 PART 5)

The results of the tests on cement sample are listed in the table

TABLE I ROPERTIES OF CEMENT

S.NO	SPECIFICATION	RESULT
1	Type	PPC
2	Specific gravity	3.16
3	Initial setting time	35 MINUTES
4	Final setting time	420 MINUTES
5	fineness	10

FINE AGGREGATE

The fine aggregate used in this investigation was M sand and the following tests were carried out on sand as per IS: 2386-1968 (1&2)

- Specific gravity
- Sieve analysis and fine modulus

SI.NO	SPECIFICATION	RESULTS
1	Type	M SAND
2	Specific gravity	2.46
3	Fineness modulus	2.74
4	Grading zone	Zone 3

TABLE II PROPERTIES OF FINE AGGREGATE

COARSE AGGREGATE: - Typically, coarse aggregate sizes are larger than 4.75 mm (5 mm in British code), while fine aggregates form the portion below 4.75 mm. A maximum size up to 40 mm is used for coarse aggregate in most structural applications, while for mass concreting purposes such as dams, sizes up to 150 mm

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may be used. The tests conducted are sieve analysis, specific gravity etc as per IS codes .Specific gravity of specimen is 2.77 and aggregate confirms to Table 2 of IS 383

POLYPROPELENE FIBRE: - Fibrillated polypropylene fibers with 20 mm length were used in different volume fractions. The fibrillated polypropylene fibers are composed of film sheets which are cross linked by fine fiber along their length. These fibers manufactured in chicken mesh form and then cut into desired length.

REINFORCEMENT :- Reinforced concrete, concrete in which steel is embedded in such a manner that the two materials act together in resisting forces. The reinforcing steel—rods, bars, or meshes—absorbs the tensile, shear, and sometimes the compressive stresses in a concrete structure. If a material with high strength in tension, such as steel, is placed in concrete, then the composite material, reinforced concrete, resists not only compression but also bending and other direct tensile actions. The yield strength of steel reinforcements used in this experiment program was 415 N/mm^2

V. MIX DESIGN

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. Concrete mix design is the process of finding right proportions of cement, sand and aggregates for concrete to achieve target strength in structures. The concrete mix design involves various steps, calculations and laboratory testing to find right mix proportions. This process is usually adopted for structures which require higher grades of concrete such as M25 and above and large construction projects where quantity of concrete consumption is huge. Benefits of concrete mix design is that it provides the right proportions of materials, thus making the concrete construction economical in achieving required strength of structural members. As, the quantity of concrete required for large constructions are huge, economy in quantity of materials such as cement makes the project construction economical.

Design stipulations for proportioning

a) Grade of concrete
   = M_{30}
b) Type of cement
   = OPC 53 JSW
c) Max nominal size of aggregate
   = 20 mm
d) Workability
   = 50 mm slump
e) Type of aggregate
   = crushed angular aggregate

TEST DATA FOR MATERIALS

i. Specific gravity of cement = 3.16

ii. Specific gravity of
   a. Coarse aggregate = 2.77
   b. Fine aggregate = 2.46

iii. **Sieve analysis**
   a. Coarse aggregate = 40 mm
   b. Fine aggregate = 4.75 mm

Target strength for mix proportioning

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f 'ck = fck+ts

From table 1 standard deviation, s = 5 N/mm^2

Therefore target strength = 30=1.65x5=38.25 N/mm^2

Selection of w/c ratio

From table 5 of IS 456:2000,

Maximum water cement ratio = 0.50

From the graph in IS 10262-2009,

Maximum water content = 186 liters

Calculation of cement content

Water cement ratio = 0.41

Cement content = 149/0.41= 362.93 kg/m^3

From table 5 of IS 456,

Minimum cement content for severe exposure condition =300 kg/m^3

Hence ok

Proportion of volume of coarse aggregate and fine aggregate content in total aggregate

From table 3 of IS 10262-2009

Volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate (ZONE 2) for water cement ratio of 0.5 = 0.64

Correction required in coarse aggregate content for water cement ratio reduction of 0.09 = 0.018

Volume of coarse aggregate = 0.64+0.018

Volume of fine aggregate = 0.342

Mix calculation

The mix calculations per unit volume of concrete shall be as follows

a) Volume of concrete
   = 1 m^3
b) Volume of cement
   =(mass/sp. Gravity) x 1/1000
c) Volume of water
   =0.149m^3
d) Volume of all aggregates
   =0.738 m^3
e) Volume and weight of coarse aggregates

Volume

= 0.738x0.658

= 0.486 m^3

Weight

= volume x sp.gravity x 1000

= 1345.49 kg

f) Volume and weight of fine aggregates

Volume = 0.735 x 0.342

= 0.251 m^3

Weight = volume x sp.gravity x 1000=621.06 kg

Mix proportions

- Cement = 362.93 kg/m^3
- Water = 149 lit/m^3
- Fine aggregate = 621.06 kg/m^3
- Coarse aggregate = 1345.49 kg/m^3
- Water cement ratio = 0.41

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TABLE III CASTING OF SPECIMEN WITH DIFFERENT VOLUME FRACTION OF PP FIBRE

S.NO:	DESCRIPTION	
1	PPF 0	Using 0% ppf in ordinary concrete
2	PPF 10	Using 10% volume fraction of ppf in ordinary concrete
3	PPF 20	Using 20% volume fraction of ppf in ordinary concrete
4	PPF 30	Using 30% volume fraction of ppf in ordinary concrete

VI. RESULTS AND DISCUSSIONS

Compressive strength of concrete cube test provides an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. Concrete compressive strength for general construction varies from 15 MPa (2200 psi) to 30 MPa (4400 psi) and higher in commercial and industrial structures. Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, and quality control during production of concrete etc.

For cube test two types of specimens either cubes of 15cm X 15cm X 15cm or 10cm X 10cm x 10cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15cm x 15cm x 15cm are commonly used. This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of this specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen. These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Mix the cement and fine aggregate on a water tight none-absorbent platform until the mixture is thoroughly blended and is of uniform color. Add the coarse aggregate and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch. Add water and mix it until the concrete appears to be homogeneous and of the desired consistency

Compressive strength was calculated as follows

Compressive strength = P/A×1000

Where, P= Load in KN, A=Area of cube surface=150×150mm^2

Compressive Strength of Concrete at Various Ages

The strength of concrete increases with age. Table shows the strength of concrete at different ages in comparison with the strength at 28 days after casting.

TABLE IV COMPRESSIVE STRENGTH OF CEMENT AT VARIOUS AGES

Age	Strength percentage
7 days	65%
14 days	90%
28 days	99%

TENSILE STRENGTH OF CYLINDER

The tensile strength of concrete is one of the basic and important properties which greatly affect the extent and size of cracking in structures. Moreover, the concrete is very weak in tension due to its brittle nature. Hence. it is not expected to resist the direct tension. So, concrete develops cracks when tensile forces exceed its tensile strength. Therefore, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. Finally, different aspects split cylinder test of concrete specimen will be discussed in the following sections. Computation of the split tensile strength was as follows.

Split tensile strength = $2P/\pi dL\times1000$

where,

P = Load in KN and

$\pi = 3.142$

d = Diameter of cylinder = 150 mm

L = Length of cylinder = 300 mm

Apparatus for Splitting Tensile Test of Concrete

Firstly, it shall conform to the requirements of Test Method C 39/C 39M. Secondly, testing machine should be able to apply the load continuously and without shock. Thirdly, it should be able to apply loads at a constant rate within the range 0.7 to 1.4 MPa/min (1.2 to 2.4 MPa/min based on IS 5816 1999) splitting tensile stress until the specimen fails. It is employed when the diameter or the largest dimension of the upper bearing face or the lower bearing block is less than the length of the cylinder to be tested. Plate width is 50mm, it shall be used in such manner that the load will be applied over the entire length of the specimen.

COMPRESSIVE STRENGTH OF CUBES

TABLE V COMPRESSIVE STRENGTH OF CUBES

PERCENTAGE	7 DAYS (N/mm^2)	14 DAYS (N/mm^2)	28 DAYS (N/mm^2)
Conventional	8.88	13.33	15.73
PPF 10%	9.6	13.73	20.83
PPF 20%	13.78	16.9	22.3

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PPF 30%	14.67	19.6	26.3

TENSILE STRENGTH OF CYLINDER

TABLE VI TENSILE STRENGTH OF CYLINDERS

PERCENTAGE	7 DAYS (N/mm^2)	14 DAYS (N/mm^2)	28 DAYS (N/mm^2)
Conventional	1.27	1.6	1.96
PPF 10%	1.9	2.2	2.46
PPF 20%	2.1	2.8	3.26
PPF 30%	2.6	2.96	3.6

FLEXURAL STRENGTH OF BEAM

S.NO	LOAD (KN)	DIVISION	DEFLECTION(mm)
1	5	1	0.01
2	10	8	0.02
3	15	16	0.04
4	20	23	0.16
5	25	36	0.38
6	30	42	0.86
7	35	1	0.98
8	40	46	1.2
9	45	50	1.8
10	50	54	1.9
11	55	59	2.6
12	60	65	2.8
13	65	72	3.6

FLEXURAL STRENGTH OF BEAM

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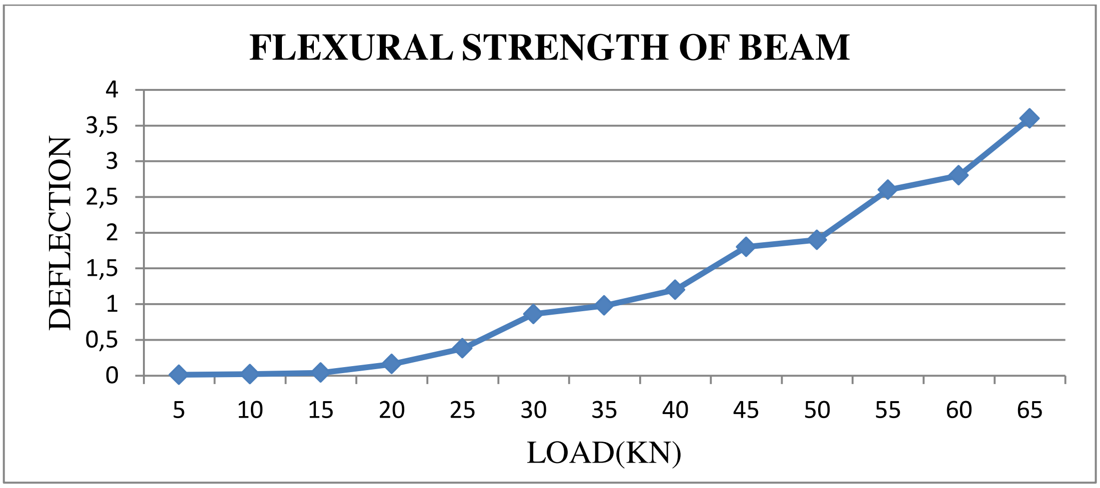

VII. CONCLUSION

Innovations in engineering design and construction, which often call for new building materials, have made polypropylene fiber-reinforced concrete applications. In the past several years, an increasing number of constructions have been taken place with concrete containing polypropylene fibers such as foundation piles, prestressed piles, piers, highways, industrial floors, bridge decks, facing panels, flotation units for walkways, heavyweight coatings for underwater pipe etc. This has also been used for controlling shrinkage & temperature cracking.

Due to enhance performances and effective cost-benefit ratio, the use of polypropylene fibers is often recommended for concrete structures recently. PFRC is easy to place, compact, finish, pump and it reduces the rebound effect in sprayed concrete applications by increasing cohesiveness of wet concrete. Being wholly synthetic there is no corrosion risk. PFRC shows improved impact resistance as compared to conventionally reinforced brittle concrete. The use of PFRC provides a safer working environment and improves abrasion resistance in concrete floors by controlling the bleeding while the concrete is in plastic stage. The possibility of increased tensile strength and impact resistance offers potential reductions in the weight and thickness of structural components and should also reduce the damage resulting from shipping and handling.

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