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An Experimental Investigation on the Properties and Effects of Polypropylene Fibre Reinforced Concrete

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ABSTRACT

The paper deals with the effects of addition of various proportions of polypropylene fibres on the properties of concrete. An experimental program was carried out to explore its effects on compressive, tensile, flexural strength under different curing condition. The main aim of the investigation program is to study the effect of Polypropylene fiber mix by varying content such as 0.25%, 0.50%, 0.75, 2%, and 2.5% and finding the optimum Polypropylene fibre content. The concrete specimens were tested at different age level for mechanical properties of concrete, namely, cube compressive strength, split tensile strength, flexural strength. A detailed study was carried out for curing conditions. Half of the concrete specimens were left exposed to the surrounding to cure by themselves and the remaining half were cured in a curing tank. Initially the concrete specimen's shows appreciable strength for irregular curing but as the days advances the curing specimens gave satisfactory strength. A notable increase in the compressive, tensile and flexural strength was observed. However, further investigations were highly recommended and should be carried out to understand more mechanical properties of fibre reinforced concrete. The interest in the use of fibres for the reinforcement of composites has increased during the last several years. A combination of high strength, stiffness and thermal resistance favourably characterizes the fibres. In this study, the results of the Strength properties of Polypropylene fibre reinforced concrete have been presented. The compressive strength, splitting tensile strength of concrete samples made with different fibres amounts varies from 0.25%, 0.50%, 0.75, 2%, and 2.5% were studied. The samples with added Polypropylene fibres of 1.5 % showed better results in comparison with the others.

Keywords : Compressive, Flexure, Compaction, Optimum, Polypropylene, etc.

I. INTRODUCTION

The advancement and latest development of major construction is largely associated with improving the efficiency of the building under seismic effect, reducing cost, economic use of new materials etc., concrete is one such material, which is consumed in construction industry next to water consumption in the world. This marvellous material is strong in compression but very weak in tension. Use of dispersed reinforcement in the cement based matrix/concrete attains promising new material and eliminates certain drawbacks and entrances certain property. In 1910, porter put the idea that concrete can be strengthened by the inclusion of fibers. Till 1963; there was only slow progress on fiber reinforced concrete (FRC). Romualdi and Batson gave rise to FRC by conducting numerous experimental works to determine the basic engineering properties such as compressive, tensile strength FRC. Typical types of fibers used are steel, acrylic asbestons, glass, xylon, polyster, polyethylene, polypropylene, rayon, rock wool and so on. Steel fibers are available in round, flat, reimped, deformed forms. Steel fibers were used in different structural elements in various zones and investigated its performance. Now-a-days synthetic fibers have become more attractive and used for the reinforcement of cementitious materials. 'Fiber Reinforced Cement' as a material made from hydraulic cement and discrete, discontinuous fibers (containing no aggregate). "Fiber reinforced concrete" (FRC) is made with hydraulic cement, aggregates of various sizes, in corporating discrete, discontinuous fibers. Both are firmly established as a new construction material.

Steel fibers and synthetic fibers find applications in civil engineering on a larger scale by virtue of their inherent advantages; it is of interest to note that the performance of concrete can be enhanced through the employment of these micro-reinforcements in a hybrid form. The volume of data available on the performance studies of hybrid fiber reinforced concrete appears to be inadequate for a better understanding the investigation, it is proposed to combine these fibers at different proportions in the beam structural elements and engineering properties and performance are being investigated. The necessity for the addition of fibers in structural material is to increase the strength of the concrete and mortar and also to reduce the crack propagation that mainly depends on the following parameters.

- Strength characteristics of fiber
- Bond at fiber matrix interface
- Ductility of fibers
- Volume of fiber reinforcement
- Spacing, dispersion, orientation, shape and aspect ratio of fiber.

High strength fibers, favorable orientation large volume, fiber length and diameter of fiber have been found independently to improve the strength of composites. The steel fiber is known to have possessed high tensile strength and ductility.

The most significant factor affecting resistance to crack propagation and strength of the fibrous concrete and mortar are

- Shape and bond at fiber matrix interface
- Volume fraction of fibers
- Fiber aspect ratio and Orientation of fibers
- Workability and Compaction of Concrete
- Size of Coarse Aggregate
- Mixing

A) SHAPE AND BOND AT FIBER MATRIX INTERFACE

The modulus of elasticity of matrix must be much lower than that of fiber for efficient stress transfer. Low modulus of fibers such as nylon and polypropylene are therefore unlikely to give strength improvement, but they help in the absorption of large energy and therefore impart greater degree of toughness and resistance to impact. High modulus fibers such as steel, glass and carbon impart strength and stiffness to the composite. Interfacial bond between the matrix and the fibers also determine the effectiveness of stress transfer, from the matrix to the fiber. A good bond is essential for improving tensile strength of the composite. The interfacial bond could be improved by larger area of contact, improving the frictional properties and degree of gripping and treating the steel fibers with sodium hydroxide or acetone.

B) VOLUME FRACTION OF FIBER

The strength of the composite largely on the quantity of fibers used in it. The increase in the volume of fibers, increase approximately linearly, the tensile strength and toughness of the composite. Use of higher percentage of fiber is likely to cause segregation and hardness of concrete and mortar.

C) FIBER ASPECT RATIO

Fiber aspect ratio is defined as the ratio of fiber length to the equivalent fiber diameter. In order to utilize fracture strength of fibers fully, adequate bond between the matrix and the fiber has to be developed. This depends on the shape of the fibers viz., straight, crimped, hooked end and its aspect ratio. An aspect ratio 60 to 100 is commonly used.

D) ORIENTATION OF FIBERS

One of the differences between conventional reinforcement and fiber reinforcement is that in conventional reinforcement bars are oriented in the direction desired while fibers are randomly oriented. It was observed that in fiber reinforced mortar the fibers aligned parallel to the applied load offered more tensile strength and toughness than randomly distributed or perpendicular.

E) WORKABILITY AND COMPACTION OF CONCRETE

Incorporation of steel fiber decreases the workability considerably and even prolonged external vibration fails to compact the concrete. This situation adversely affects the consolidation of fresh mix. The fiber volume at which this situation is reached depends on the length and diameter of the fiber and non-uniform distribution of the fibers. Generally, the workability and compaction standard of the mix are improved through increased water/cement ratio or by the use of water reducing admixtures. The overall workability of fresh fibrous mixes was found to be largely independent of the fiber type. Crimped fibers produce slightly higher slumps, and hooked fibers were found to be more effective than straight and crimped ones.

F) SIZE OF COARSE AGGREGATE

Several investigators recommended that the maximum size of the coarse aggregate should be restricted to 10mm, to avoid appreciable reduction in strength of the composite. A fiber in effect, as aggregate having a simple geometry, their influence on the properties of fresh concrete is complex. The inter-particle friction between fibers and between fibers and aggregates controls the orientation and distribution of the fibers and consequently the properties of the composite. Friction reducing admixtures and admixtures that improve the cohesiveness of the mix can significantly improve the mix.

G) MIXING

Mixing of fiber reinforced concrete needs careful conditions to avoid balling of fibers, segregation, and difficulty of mixing the materials uniformly. Increase in the aspect ratio, volume percentage and size and quantity of coarse aggregate intensify the difficulties and balling tendencies. It is important that the fibers are dispersed uniformly throughout the mix. This can be done by adding fibers before adding water. When mixing in a laboratory mixer, introducing the fibers through a wire mesh basket will help even distribution of fibers.

II. PROPERTIES OF MATERIALS

2.1 PROPERTIES OF CEMENT

The properties of ordinary Portland cement as shown in the table.

Test Particulars	Result Obtained	Requirements as per IS: 12269 1987
Specific gravity	3.15	3.10-3.15

Normal consistency (%)	31	30-35
Initial setting time (minutes)	37	30 minimum
Final setting time (minutes)	570	600 maximum
Compressive strength (MPa) a) 3 days b) 7 days c) 28 days	 28 38 44	 43 33 23

Table 2.1 : Physical properties of ordinary Portland cement

2.2 PROPERTIES OF FIBERS

STEEL FIBER (METALLIC FIBER)

Steel fiber is one of the most commonly used fibers. Generally, round fibers are used. The diameter may vary from 0.25 to 0.75 mm. The steel fiber is likely to get rusted and lose some of its strength. But investigations have shown that the rusting of the fibers takes place only at the surface. Use of steel fibers make significant improvements in flexural, impact and fatigue strength of concrete, it has been extensively used in various types of structures, particularly for overlays of roads, airfield pavements and bridge decks. Thin shells and plates have also been constructed using steel fibers.

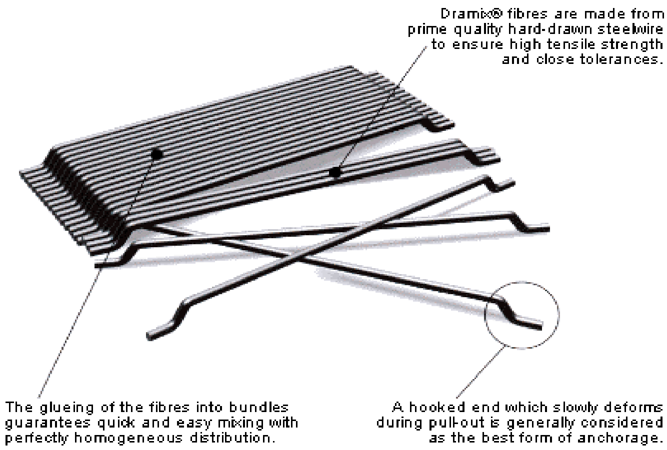

Figure 2.1 : The figure shows the general view of steel fiber

2.2.2 POLYMERIC FIBER

Synthetic polymeric fibers have been produced as a result of research and development in the petrochemical and textile industries. Fiber types that have been tired with cement matrices include arcrylic, aramid, nylon, polyester, polypropylene and polyethylene. They all have a very high tensile strength, but most of these fibers (except for aramids) have a relatively low modulus of elasticity. The quality of polymeric fibers that makes them useful in FRC is their very high length to diameter ratios, their diameters are on the order of micrometers.

A.POLYPROPYLENE FIBER (PPF)

Polypropylene fibers are synthetic types of fibers. Synthetic fibers are gradually replacing steel fibers due to the fact that are cost effective, can be used in low volume fractions and there is no risk of corrosion by there is used in concrete. Polypropylene fibers are currently manufactured in variety of geometries and configuration. These fibers are produced by drawing or stretching the synthetic fiber into film sheets which are then slit longitudinally into tapes. Polypropylene fibers are composed of crystalline and non-crystalline region. Polypropylene fibers have a softening point in the region of 150º c and a melting point at 160 to 170 º c. It is lowest thermal conductivity of all commercial fibers. It has excellent chemical resistance to acid and alkalis, high abrasion resistance.

Figure 2.2 : The figure shows the general view of polypropylene fiber

B. NYLON FIBER

Commercial available nylon fibers are made of nylon 6. They are available in varies lengths in single filament form. Since this fibers are very thin, a number of fibers per pound in the range of 35 million per pound for fiber length of 0.75 inch (19 mm).

C. POLYESTER

Polyester fibers are made of ethyl acetate monomers. Their physical and chemical properties can be changed substantially by altering manufacturing techniques. The higher modulus of elasticity and better bonding to concrete that is important for FRB application can be achieved by some of this modification.

III. EXPERIMENTAL STUDY

In order to increase the performance of concrete, many types of mineral and chemical admixtures are added. Addition of fibers may change the performance in the hardened stages. Therefore, it is very essential to evaluate the effect of fibers on mechanical properties of concrete. Thus chapter deals with the properties of materials used in this investigation, methodology, preparation of test specimens, experimental test set up and testing procedure that have been performed.

3.2 STRENGTH REQUIREMENTS

The age at is a governing criterion for selecting mixture proportions. The standard 28-day strength for normal-strength concrete penalizes high strength concrete since the later continues gaining strength after that age. One has also to consider that a structure is subjected to service load at 60 to 90 days age at the earliest.

IV. TESTING OF SPECIMEN AND TEST RESULTS

4.1 COMPRESSIVE STRENGTH TEST

The compressive strength of concrete is one of the most important and useful properties of concrete. I most structure applications concrete is employed primarily to resist compressive stresses. In those case where strength in tension or in shear is of primary importance, stresses. In those cases where strength in tension or in shear is of primary importance, the compressive strength is frequently used as a measure of these properties. Therefore, the concrete making properties of varies ingredients of mix are usually measured in terms of the compressive strength. Compressive strength is also used as a qualitative measure for other properties of hardened concrete. The modulus of elasticity in this case does not follow the compressive strength. The other case where the compressive strength does not indicate the useful property of concrete is when the concrete is subjected to freezing and thawing. Concrete containing about 6 percent of entrained air which is relatively weaker is strength is found to be more durable than dense and strong concrete. The compressive strength of concrete is generally determined by testing cubes or cylinders made in laboratory or field or cores drilled from handed concrete at site or from the non-destructive testing of the specimen or actual structures. The testing of hardened concrete is discussed in the subsequent chapter. Strength of concrete is its resistance to rupture. It may be measured in a number of ways, such as, strength in compression, in tension, in shear or in flexure. In order to determine the compressive strength, a total number of 144 cubes were cast. After 24 hours of casting, the specimens were de-molded and cured under water. At the end of curing period, the above specimens were tested in a compressive testing machine as per: IS516-1989.

4.2 SPLIT TENSILE STRENGTH TEST

This is also sometimes referred as, “Brazilian Test”. This test was developed in Brazil in 1943.At about the sometime this was also independently developed in Japan. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter. When the load is applied along the generatrix, an element on the vertical diameter of the cylinder is subjected to a vertical compressive stress. In order to determine the split tensile strength of various concretes test was conducted as per IS: 5816-1999. A total number of 96 cylindrical specimens were cast and after 28 days of curing, they were tested in a compression testing machine by loading it on the longitudinal direction.

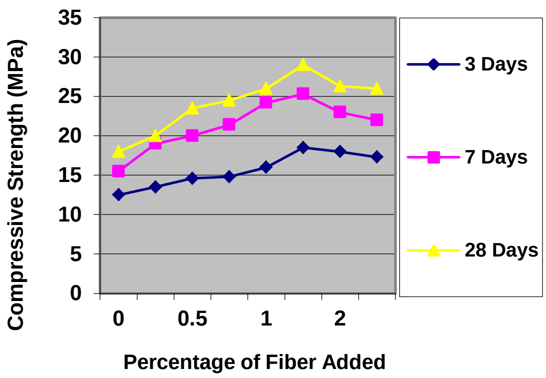

Figure 4.1 : Graph showing the compressive strength of M_{20} grade concrete with and without steel fibre

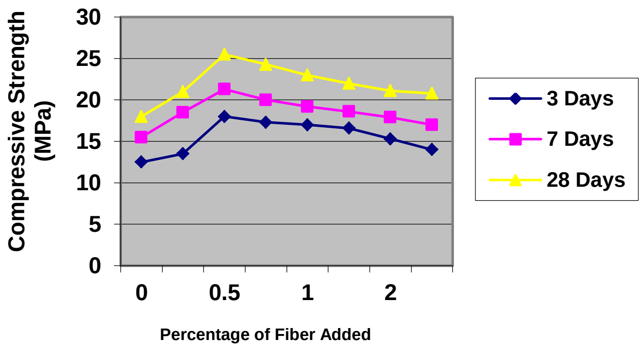

Figure 4.2: Graph shows the compressive strength of M_{20} grade concrete with and without polypropylene fibre

V. CONCLUSION

The following conclusions have been drawn based on the experimental investigation carried out on concrete mixture.

1. Higher compressive strength is obtained for 1.5 % steel fiber and 0.5% for Polypropylene Fiber added concrete.
2. Higher split tensile strength is obtained for 1.5 % steel fiber and 1% for Polypropylene Fiber added concrete.
3. Concrete attained maximum compressive and split tensile strength when mixing Minimum amount of polypropylene fiber compared to steel fiber.

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