International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 04 | Apr 2020 www.irjet.net p-ISSN: 2395-0072

STUDY OF PROPERTIES OF POLYPROPYLENE REINFORCED CONCRETE

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Abstract - An enormous increase in constructions activities has resulted in a large-scale consumption of basic materials for making concrete. Performance of conventional concrete is enhanced by the addition of fiber to it. The brittleness of concrete is reduced and its ductility is adequately improved by the addition of fiber to it. In the present work concrete cube, cylinders and prisms of M25 grade concrete were cast designated as per relevant Indian standard. The polypropylene fibers were used individually in various proportions i.e. 0.5%, 1%, 1.65%,1.85%, 2% by weight of cement in the preparation of concrete mixes, equal amount of cement was replaced with fiber. The test result show that use of fiber in concrete, resulting product called fiber Reinforced Concrete (FRC), improves compressive strength, split tensile strength and flexural performance compared to conventional concrete.

In this experimental investigation concrete cube, beams and cylinders were caste and reinforced with polypropylene fibers with varying percentages of fibers by the weight of cement to study improvements in the strength properties.

The workability of the specimens decreased as the amount of fibers was increased, which states that at higher percentages of fiber the mix harsh. Some plasticizers need to be added to overcome this difficulty.

The also presents results of an experimental investigation carried out on concrete beams, of size 100mm x 100mm x 500mm. the beams were tested under two-point bending. The outcome indicated that the flexural properties of solid grid are essentially improved by the expansion of polypropylene filaments. Out of the various sorts of strands utilized right now, filaments with 1.65% of cement indicated better productivity in improving the flexural reaction. Specimens of polypropylene fiber Reinforced Concrete containing these fibers individually in various proportions along with conventional concrete as a reference wre cast and tested. Based on the method of mix design presented in the Indian standard, proportions of different ingredients were obtained to get M25 grade of concrete. Samples were prepared without admixture. The aim of this thesis is to compare the properties of concrete beams in which different percentages of fibers were added individually.

This also present resulted of an experimental investigation carried out on cylinder and cubes, of size 150mm x 300mm and 150mm x 150mm x 150mm respectively. These specimens were tested on UTM. The results show that there was not considerable change in case of compressive strength of cubes at 1.65% of fibers there was considerable change in strength after which it started decreasing, but in case of cylinders there was a moderate change in strength as compared to controlled specimen, 1.65% of fiber specimen was the optimum percentages of fiber at which strength was increased to a considerable value.

Different parameters, for example, load conveying limit, usefulness of fiber Reinforced Concrete Beams were contrasted and that of regular solid bars. The controlled examples were cast and tried to examine quality properties and afterward the outcomes were analyzed. Results of the experiments programmed were compared with theoretical predictions. Based on the results of the experimental programmed. It can be concluded that the addition of polypropylene fibers by 1.65% by weight of cement has the effect on the flexural strength and split tensile strength of specimens. It is concluded that addition of fiber to concrete enhances its properties and this concrete establishes its supremacy over conventional concrete in many respects.

***Key Words*: Polypropylene Fiber, FRC (Fiber Reinforced Concrete), Compressive Strength, Split Tensile Strength, Flexural Strength,**

1. INTRODUCTION

In modern years Fibers reinforced concrete, a cement based composite material, has been developed. It has been effectively utilized in development with its exceptional flexural quality, protection from parting, sway obstruction and remarkable porousness and ice opposition. It is a fruitful method to raise strength, stun obstruction and protection from plastic shrinkage breaking of the mortar. Fiber is included as a strengthening material having certain trademark properties. They can be roundabout, triangular or level in cross-section. The fiber is often described by convenient parameters called- aspect ratio. The aspect ratio of the fiber is the ratio of its length to its lateral dimension. The fundamental purpose behind fusing strands into a concrete framework is to expand the durability and elasticity and improve the opposition against breaking twisting attributes of the resultant composite. For fiber Reinforced Concrete to be a possible construction material, it must be able to complete economically with existing reinforcing system.

Fiber reinforced concrete is concrete reinforced with fiber by adding discrete short fibers randomly in concrete. It exhibits several sustainable and improved engineering properties such as compressive strength, tensile strength, flexural strength etc. The fiber can forestall surface breaking through restricting activity prompting better effect opposition of the solid. The mix of at least two unique sorts of filaments is turning out to be increasingly basic these days with the goal of upgrading the general conduct of the framework. The aim is that the performance of these hybrid systems would exceed that induced by fiber of each type alone.

Hybrid is in view of the fiber constitutive reaction, in which one fiber is more grounded and stiffer and gives quality, while the other is progressively pliable and gives durability at high strains. Hybrids are based on fiber size, where one fiber is little and it gives smaller scale control at beginning times of stacking and the other fiber is bigger, gives a crossing over component across full scale splits. Hybrid are also based on the function of fiber, where one sort of fiber gives quality or sturdiness in the solidified composite, while the subsequent kind gives new blend properties reasonable to preparing.

1.1 Types of fiber in concrete Application

According to ACI 544, IR-96, state of the Art-Report of Fiber Reinforced Concrete, a wide variety of fibers has been incorporated into concrete. The basic fiber categories are steel, glass, synthetic and natural fiber materials. For each application it needs to be determined which type of fiber is optimal for concrete application. The selection of the type is guided by the properties of the fiber such as diameter, specific gravity, young's modulus, tensile strength and the extent these fibers affect the properties of the cement matrix.

Steel Fibers

The introduction of steel fiber in concrete can increase the resistance to fatigue, impact, blast or seismic events. The main advantage of using steel fibers in concrete is to increase the post-peak load carrying capacity of concrete after initial cracking. Steel fibers proposed for fortifying cement are characterized as short, discrete lengths of steel having a viewpoint proportion from around 20 to 100 and that are adequately little to be haphazardly scattered in an unhardened solid blend utilizing normal blending methodology (ACI 544, IR-96). Steel fibers have a moderately high quality and modulus of versatility, and their attach to solid grid can be upgraded by mechanical safe haven and surface roughness. Therefore, the fibers were modified to various types including hooked end, crimped deformed and enlarge-end fibers. Tensile strength of steel fibers in the range of 345-1200 MPa and the ultimate elongation in the range of 0.5 – 3.5% (ACI 544. IR-96)

Carbon fibers

Carbon fibers is termed as a fiber containing at least 92wt percent carbons. Carbon fibers are extremely thin fibers which are 0.005 – 0.010mm in diameter and are generally used in shorter lengths. The density of carbon fiber is very low compared to steel (chung DDL, 1992). Carbon fibers have high tensile strength, low thermal expansion, good abrasion resistance and stability at high temperature with relatively high stiffness which makes them a popular material in enterprises, for example, aviation, civil engineering, and military (Huang X, 2009). However, this type of fiber is expensive compared to other types of fiber such as glass or synthetic.

Glass Fibers

Glass fibers are created in a procedure where liquid glass is attracted the type of fibers, through the base of a warmed platinum or bushing. The structure of the reinforcing glass fibers has required the development of special technologies to incorporate the fibers into the matrix (Bentur and Mindness, 2007). The elastic modulus of glass fiber is found to be approximately one third of steel. However, when compared to carbon fiber, glass fiber longest much more before failure. The main disadvantages of glass fibers is their sensitivity to an alkaline environment. In recent years, attempts have been made to improve the alkali resistance of glass fibers. These are called AR-glass.

Synthetic fibers

The synthetic polymeric fibers used in the construction industry include acrylic, aramid, carbon, nylon, polyester, polyethylene, and polypropylene fibers. All these fibers have a high tensile strength, but most of these fibers have a moderately low modulus of elasticity. As the diameters of polymeric fibers are of the order of micrometers, their high-length-to-diameter ratios are useful in fiber reinforced concrete. The major disadvantages of polymeric fibers are a low modulus of versatility, poor bond with concrete grid, and a low liquefying point. Their cling to the concrete grid can be improved by twisting fibers together or by treating the fiber surface.

Natural fiber

Fibers produced by plants, animals and geological processes are known as natural fibers researches have used natural fibers as an alternative for steel or synthetic fibers in composites including cement paste, mortar and concrete to increase their strength properties. Some of the best-known natural fibers are sisal, coconut, sugarcane, plantain, jute, bamboo, palm, banana, hemp, flax, and cotton. Natural fibers are cheap and locally available in many countries. Thus, their use as reinforcement material for improving the properties of composite costs little. One of the disadvantages of using natural fibers is that they have a high variation in their properties (Lietal, 2006)

1.2 Polypropylene Material

Polypropylene (PP) is a versatile thermoplastic material, which is produced by polymerizing monomer unit's propylene molecules into long polymer atoms or chains within the sight of an impetus under painstakingly controlled warmth and weight (Brown et al 2002). Polypropylene is one of the fastest growing classes of commodity thermoplastics, with a market share growth of 6-7% per year. The volume of polypropylene produced is exceeded 13 only by polypropylene and polyvinyl chloride. The moderate cost and favorable properties of polypropylene contribute to its strong growth rate (Maier and calafut, 1998)

Polypropylene is extremely hard and stiff and is brittle at very low temperature. It gradually becomes softer and more flexible as the temperature increase until it softens beyond the range of usefulness. The crystalline structure of the polymer undergoes a major change at the melting point. The high melting point of polypropylene provides resistance to softening at elevated temperatures. Standard grades of polypropylene can withstand continuous service temperatures of over 107^{o}C and 121^{o}C for short periods of time (maier and Calafut, 1989).

Amorphous regions of the polypropylene resin undergo a glass transition at temperatures between -35 and 26^{o}C. This transition depends on the heating rate, thermal history and microstructure and measurement method. Molecules and segments of polymer chains above the glass transition temperature vibrate and move in non-crystalline polymer regions. The normal temperature range within which polypropylene is most commonly used is limited by the crystalline melting point on the high side and by the glass transition on the low side (Brown et al, 2001).

The mechanical properties of polypropylene are strongly dependent on the time, temperature and stress. Furthermore, it is a semi-crystalline material, so the degree of crystallinity and orientation also affects the mechanical properties. Also, the materials can exist as homopolymer, block copolymer and random copolymer and can be extensively modified by fillers, reinforcements and modifiers.

Polypropylene is a thermoplastic and hence softens when heated and hardens when cooled. It is hard at ambient temperatures and this inherent property permits economical processing techniques such as injection molding or extrusion. The softening point or resistance to deformation under heat limits its service temperature range. If the product has a wide working temperature range, then the coefficient of linear expansion becomes significant. The coefficient of linear expansion of polypropylene is higher than most commodity plastics but is less than that of polyethylene (Maier and Calafat, 1989).

1.3 Properties of polypropylene Fiber

Specific gravity of PP fiber is 0.90 – 0.91. Due to its low explicit gravity, polypropylene yields the best volume of fiber for a given weight. This high return implies that PP fiber gives great mass and spread, while being lighter in weight. Polypropylene is the lightest of all fibers and is also lighter than waterIt is 34% lighter than polyester and 20% lighter than nylon. Polypropylene fiber has the most reduced warm conductivity of any common or engineered fiber. Polypropylene filaments hold more warmth for a more drawn out timeframe. What's more, it stays adaptable at temperatures around - 55^{o}C. The liquefying purpose of polypropylene is about 165oC and keeping in mind that it doesn't have a genuine relaxing point temperature, the greatest preparing temperature of the fiber is roughly 140oC. Drawn out presentation to raised temperatures will cause corruption of the fiber, however enemies of oxidants are joined in polypropylene filaments to ensure them during handling and at ordinary assistance temperature. Nevertheless, this temperature is sufficiently high for the fiber to be processed satisfactorily in almost all normal manufacturing processes (Brown et al 2001).

Polypropylene has the best resistance of any common fiber to the action of most types of chemical and is affected only by the most aggressive acids and oxidizing agents. The fiber is unaffected by most acids, alkalis, and salts. Polypropylene fiber is not affected by bacteria or micro-organisms. It is also moth-proof and is inherently resistant to the growth of mildew and mold (Brown et al, 2001).

2. EXPERIMENTAL INVESTIGATION

The experimental investigations comprised of selection and testing of cement, aggregate, design of concrete mixtures, preparation and testing of fresh concrete, and preparation and testing of hardened concretes.

The following procedure were followed to carry out the research on polypropylene fiber included in concrete. The strength of the specimen including fibers was tested and was compared to standard specimens. And graphs were plotted to compare the two.

2.1 Test on Fresh Concrete

2.1.1 Slump Test - Concrete slump test is utilized to decide the usefulness or consistency of solid blend arranged in the research facility or at the building site during the advancement of work. Solid droop test is done from cluster to group to check the uniform nature of cement during development. It is the most straightforward functionality test for concrete, includes minimal effort and gives prompt outcome. It is carried out according to IS: 1199-1959.

Table -1: Slump Test Results

Percentage variation of fiber	Grade of Concrete	Slump Value (mm)	Slump value rating IS:456 (2000)
0%	M25	90	**0-25mm**, very dry mixes are used in road making **10-40mm**, low workability mixes are used for foundations with light reinforcement. **50-90mm**, medium workability mixes for normal reinforcement concrete placed with variation. >**100mm**; high workability concrete.
0.5%		75	
1%		70	
1.5%		60	
1.65%		65	
1.85%		50	
2%		55	

2.1.2 Compaction Factor Test

Compaction factor test is structured so that it very well may be utilized distinctly in research facility yet at times, it tends to be utilized for field solid tests. The compacting factor test has been created at the street Research Laboratory in United Kingdom. This test is one of the most precise tests acted so as to decide the functionality of cement.

This test takes a shot at the guideline of deciding the level of compaction accomplished by a standard measure of work done by permitting the solid to fall through a standard tallness. The level of compaction called the compacting factor is estimated by thickness proportion i.e, the proportion of the thickness really accomplished in the test to thickness of same cement completely compacted.

Table – 2: Compaction Factor Results

Percentage Variation of fiber	Compaction factor	Compaction value rating IS:456 (2000)
0%	0.954	**0.80**; very dry mixes are used in road
0.5%	0.935	

1%	0.928	making.
1.5%	0.919	**0.87**; low workability mixes are used for foundation light reinforcement.
1.65%	0.903	
1.85%	0.88	
2%	0.85	**0.935**; medium workability mixes for normal Reinforced concrete placed with vibration. **0.96**; high workability concrete.

2.2 Test on Hardened Concrete

2.2.1 Compressive strength test result. - Compressive strength test of concrete cube provides an idea about the characteristics of concrete. With this test one can judge whether or not concreting has been done properly. Concrete compressive quality for general development shifts from 15MPa to 30 MPa and higher in business and modern structures. Test for compression is carried on either on cube or cylinder. For cube test two types of specimens either 15cm x 15cm x 15cm mould is generally used. The concrete is poured in the mould and tempered properly so as to not have any voids. After 24 hrs these moulds are removed and test specimens are put in water for curing. These samples are tested by compressive testing machine after 3days, 7days and 28 days of curing. Loading is applied gradually till the specimen fails. Load at failure divided by area of specimen gives compressive strength.

In this investigational programme, in order to calculate the compressive strength of concrete, cube specimens of dimensions 150 x 150 x 150 mm were cast using M25 grade of concrete individually with 0.5%, 1%, 1.5%, 1.65%, 1.85% and 2% of polypropylene fiber by weight of cement, respectively. Moulds were vibrated by table vibrator. The upper surface of the example was leveled and wrapped up.

Table – 3: Compressive Test Results

S. No	Types of concrete	Compressive Strength (N/mm²)		
		3 days	**7 days**	**28 days**
1	C_0	9.72	15.79	24.3
2	$C_{0.5}$	10.42	16.82	25.83
3	C_1	10.56	17.06	26.25
4	$C_{1.5}$	10.8	17.48	26.98
5	$C_{1.65}$	10.97	17.89	27.25
6	$C_{1.85}$	10.73	17.3	27.02
7	C_2	10.65	17.28	26.75

2.2.2 Split tensile Strength Test Result - Splitting tensile strength test on concrete cylinder is strategy to decide the rigidity of cement. The solid is extremely frail in strain because of its weak nature and isn't acknowledged to oppose the immediate pressure. The solid creates breaks when exposed to tractable powers. In this way, it is important to decide the elasticity of cement to decide the heap at which the solid individuals may split.

Direct tension test of concrete is not usually conducted because of difficulties in mounting the specimens and uncertainties to the secondry stress induced by holding devices. An indirect test for tensile strength of concrete is used. Accordingly, 3 specimens of cylindrical shape of diameter 150mm and length 300mm were tested under a compression testing Machine of 2000 KN capacity under a compressive load over the breadth along its length till the chamber parts. The pressure creates toward a path at right points to the line of activity of the applied load.

Table – 4: Split Tensile Test Results

S. No	Types of Concrete	Split tensile Strength (N/mm²)	
		7 days	**28days**
1	C_0	1.97	2.7
2	$C_{0.5}$	2.1	3.22
3	C_1	2.13	3.28
4	$C_{1.5}$	2.18	3.37
5	$C_{1.65}$	2.23	3.4
6	$C_{1.85}$	2.16	3.35
7	C_2	2.14	3.33

2.2.3 Flexural Strength - Flexural test evaluates the tensile strength of concrete indirectly. It tests the capacity of unreinforced solid pillar or section to withstand disappointment in bowing. The aftereffect of flexural test on concrete communicated as a module of burst which means as (MR) in MPa or psi.

Besides, modulus of burst is around 10 to 15% of compressive quality of cement. It is impacted by blend extents, size and coarse accumulated volume utilized by example development. Flexural strength is one measures of the tensile strength of concrete. Flexural tests are extremely sensitive to specimen preparation, handling, and curing procedure.

Table – 5: Flexural Strength Test Results

S. No	Types of Concrete	Flexural Strength (N/mm^2)	
		7 days	28days
1	C_0	2.6	3.98
2	$C_{0.5}$	2.8	4.25
3	C_1	3.02	4.87
4	$C_{1.5}$	3.52	5.24
5	$C_{1.65}$	4.02	5.89
6	$C_{1.85}$	3.41	5.6
7	C_2	3.28	5.3

3. CONCLUSIONS

In this experimental study the mechanical properties of fiber reinforced concrete have been investigated and the following outcomes have been drawn:

- Concrete with 1.65% of fiber is the optimum percentage of fiber, as we go on increasing the percentage of fiber the strength was shown to be decreasing.
- There was not much effect on compressive strength. It tends to increase with small percentage op to 1.65% of fiber after which it decreases. There was an increase of 12.86%, 13.29%, 12.13%, compressive strength at 3, 7 and 28 days respectively.
- There was moderate effect on split tensile strength. It tends to increase with small percentage up to 1.65% of fiber after which when the percentage of fibers is increased the Split tensile strength tend to decrease. There was an increase of 13.19%, 25.92%, in 7, 28 days strength respectively.
- There was good effect on Flexural strength. It tends to increase with small percentage up to 1.65% of fiber after which when the percentage of fiber of fibers is increased the Flexural strength decrease. There was an increase of 54.61%, 47.98% in 7, 28 days respectively.
- Workability of concrete tends to decrease with increasing percentage of fibers if admixtures are not added.
- 1.25kg of fiber costs 75 Rs/-, thus it becomes economical in use, as cement Is costly some portion of cement is removed with addition of the fiber
- It can be used for slabs, beams and parts of structure where tensile strength is required.

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