

LITERATURE

Suitability of Synthetic Fiber for the Construction of Concrete Pavements

Kumar, R., Goel, P., Mathur, R., & Bhattacharjee, B. (2014). Suitability of synthetic fiber for the construction of concrete pavements.

The study conducted by Rakesh Kumar et al. explores the suitability of synthetic fibers, particularly polypropylene (PP) multifilament and fibrillated fiber, for enhancing the properties of concrete used in pavement construction. The research aimed to address issues such as shrinkage cracks in plain cement concrete pavements, especially prevalent in tropical regions.

The findings indicate that the addition of synthetic fibers, specifically polypropylene multifilament and fibrillated fibers, to concrete mixes results in several improvements. These include:

Reduction in drying shrinkage: The incorporation of synthetic fibers led to a significant decrease in drying shrinkage, up to 40% compared to control concrete, thereby reducing the propensity for crack formation.

Enhanced abrasion resistance: Concrete mixes containing synthetic fibers exhibited increased resistance to abrasion, with a notable reduction in abrasion depth compared to control concrete, indicating improved durability.

Negligible impact on compressive and flexural strength: The addition of synthetic fibers did not significantly affect the compressive and flexural strength of the concrete mixes, maintaining strength properties comparable to control concrete.

Similar performance of multifilament and fibrillated fibers: Both types of synthetic fibers demonstrated similar effects on properties such as flexural strength and abrasion resistance, highlighting their comparable performance in enhancing concrete characteristics.

Overall, the study concludes that the addition of synthetic fibers, particularly fibrillated fiber, can effectively improve the properties of pavement concrete, making it suitable for withstanding dynamic loading and environmental conditions typically encountered in road construction. These findings suggest the potential for utilizing synthetic fibers to mitigate issues such as shrinkage cracking and enhance the durability of concrete pavements, thereby contributing to the overall quality and longevity of infrastructure projects.

Suitability of Synthetic Fiber for the Construction of Concrete Pavements

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Received 26 February 2013; revised 29 October 2013; accepted 27 January 2014

A pavement concrete undergoes dynamic loading and rigorous environmental conditions. Development of shrinkage cracks in plain cement concrete pavements is a major problem especially in tropical regions. To overcome this problem sometime the addition of synthetic fiber to the concrete mix is suggested. This paper briefly discusses the effects of the addition of polypropylene (PP) multifilament and fibrillated fibre on the properties of a paving grade concrete mix of compressive strength 48 MPa and flexural strength 5.4 MPa at 28-day. Concrete mixes containing different dosage of multifilament and fibrillated fiber besides one control mix were used. The important properties of the concrete relevant to its use in pavement such as flexural strength, drying shrinkage, and abrasion resistance etc. were evaluated. The study suggested a significant reduction in drying shrinkage, better resistance to abrasion, and strengths at least at par with controlled concrete for the concrete mixes reinforced with fibre. Further, the comparison of the affects of polypropylene multifilament and fibrillated fibres has indicated similar performance for concrete reinforced with fibrillated fibre.

Keywords: Concrete, Drying shrinkage, synthetic fiber, flexural strength, abrasion resistance

Introduction

The concrete used in the construction of road surfaces, bridge decks, airfield runways, and parking lots is generally known as pavement concrete or pavement quality concrete. This concrete has to undergo dynamic loading due to moving traffic and rigorous atmospheric environments. Therefore, this concrete has to possess good strength and durability properties relevant to its use in pavement such as resistance to abrasion, resistance to shrinkage cracking etc. Plain portland cement concrete possesses a low tensile strength as well as a low tensile strain capability consequently, it is prone to have numerous micro- and macro-cracks during its setting and hardening process. Use of synthetic fiber in concrete has been advocated by several researchers¹⁻⁴ for improving specific properties of the concrete. Thoroughly mixed and dispersed microfibers with a high specific fiber surface area are particularly effective in reducing plastic shrinkage cracking as they are closely spaced. This may delay the process by which the micro cracks coalesce to form large, macroscopic cracks known as macro cracks⁵. In this way the addition of synthetic fibers modifies the properties of concrete matrix.

Polypropylene (PP) fiber is widely used for this purpose in the construction industry with a dosage of 0.1% by volume of concrete⁶. Polypropylene fibers are available in three different forms; monofilaments, multifilament and fibrillated⁷. Monofilament fibers are single strand of fibers having uniform circular cross-sectional area. Multifilament is a yarn consisting of a number of continuous filaments or strands. The diameters of the multifilament fibers depend on the number of monofilament fibers used, and how they are combined to form a yarn. Fibrillated fibers are manufactured in the form of films or tapes that are slit in such a way that they can be expanded into an open network to allow penetration of cementitious materials. In some cases, the fibrillated tape is twisted prior to cutting to enhance the opening of the bundle. Fibers thus, produced are termed fibrillated polypropylene and are cut to desired lengths. This fibre is also known as hi-tech fibre. In this condition, fibers are added to the concrete. During the mixing, due to friction with aggregates, the fibrils are broken that help to enhance the bond with the concrete matrix⁸.

Several researchers⁹⁻¹⁰ have reported that finer PP fiber is more effective in reducing the width of plastic shrinkage cracking than coarser fiber. The compressive and tensile strength of the concrete reinforced with low volume of PP fiber are not

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significantly different from those of the unreinforced matrix^{6, 11-12}. Several researchers^{6, 11, 13-14} have reported increase in flexural strength of concrete reinforced with PP fiber. A study by Ramakrishnan et al¹² on the use of fibrillated fiber in concrete has shown a slight increase (0.7- 2.6%) in flexural strength of concrete reinforced with fibrillated fiber at the dosage of 0.1% by volume and at 0.2- 0.3% by volume slight decrease in flexural strength have been reported⁶. In this paper, the effect of the addition of polypropylene multifilament fibers and fibrillated fiber on settlement, compressive strength, flexural strength, drying shrinkage and abrasion resistance of a paving grade concrete mix with respect to unreinforced concrete mix has been presented and discussed.

Experimental Study

Materials

The materials used included ordinary portland cement, well graded crushed quartzite coarse aggregate of nominal maximum size 20 mm, land quarried concrete sand, tap water, polycarboxylate ether-based high range water reducing agent (HRWRA) and polypropylene (PP) multifilament as well as fibrillated fiber of 18 mm average length. The average

length of both types of the fibres was 18 mm. Seven concrete mixes that contained different fiber contents (% by volume and in kg/m³) were as listed in Table 1.

All the concrete mixes were prepared in a tilted drum mixer. All ingredients except water and superplasticiser were mixed in dry state for few seconds in the concrete mixer. Then ¾ of the total required water was added to the mix and mixing was further continued for a couple of minutes. The HRWRA was added in remaining 1/4th of total mixing water and added to the mix in the final stage of mixing. The mix was further mixed for another couple of minutes. Upon completion of mixing, fresh state properties were evaluated.

Mix Proportions

The concrete mix proportions were designed to yield a characteristics compressive strength of

40 MPa and flexural strength of 4.5 MPa. Several trial mixes were used to establish the optimum dose of HRWRA and proportions of different ingredients. The final mix proportions of concrete satisfying required performance are as given below:

C: A: S: W/C:: 1: 2.48: 1.62: 0.38.

It contained 437 kg of cement, 1090 kg of coarse aggregate, 707 kg of fine aggregate and 168 kg of water besides 1.53 kg of HRWRA. The HRWRA dose was 0.35% by mass of cement. The control mix (S-1) was without synthetic fiber while other mixes contained synthetic fiber of different types and dosage as shown in Table 1. The amounts of fiber used were 0.45, 0.90, and 1.35 kg for one cubic meter of concrete. Each concrete mix was batched and mixed in the laboratory in accordance with ASTM C192- 2007¹⁵. The mixing procedure adopted was as described in earlier section.

Preparation and curing of test specimens

150 mm cube specimens for the evaluation of compressive strength, 100 × 100 × 500 mm beam specimens for flexural strength, 75 × 75 × 285 mm beam specimens for drying shrinkage and 500 × 500 × 100 mm slab specimens for abrasion resistance were cast from each of the concrete mix. The specimens were demoulded after 24 hrs of casting and curing in steel mould. Thereafter, the demoulded specimens were marked for identification and kept submerged in curing tanks at room temperature (27⁰ ± 2⁰C) till the age of testing.

Test methods

Fresh mix properties

The workability of fresh concrete mixes was determined by slump test as per IS- 1199:1959¹⁷. The settlement of concrete mixes was measured in 150 mm diameter and 300 mm height cylindrical moulds filled with fresh concrete and fitted with two dial gauges for this purpose. The settlement of concrete was determined for mixes S-1, S-3, and S-6 only. Mixes S-3 and S-6 contained a fibre dosage

Table 1—Details of the concrete mixes

Description	Mix designation and proportions						
	S-1	S-2	S-3	S-4	S-5	S-6	S-7
Fibre type	Nil	MF	MF	MF	FF	FF	FF
Fibre dosage, % by volume	0.0	0.05	0.10	0.15	0.05	0.10	0.15
Fibre dosage (kg/m ³)	0.0	0.45	0.90	1.35	0.45	0.90	1.35

Note: MF stands for multifilament fibre and FF stands for fibrillated fibre

of 0.90 kg/m^3 i.e. the prescribed dosage by the manufacturers. The fresh density of concrete was also determined at this fibre dosage. The bleeding of concrete mixes was judged visually.

Compressive and flexural strength

The compressive and flexural strength of each concrete mix was determined using the standard specimens as per IS-516:1959¹⁶. Three specimens from each concrete mix were tested to determine their 28-day average compressive and flexural strength.

Shrinkage of concrete

Prismatic concrete specimens were cast for conducting drying shrinkage test. The test was conducted at 28 days according as per IS-1199:1959¹⁷ (Fig. 1). The beams were demoulded after 24 hrs of casting and curing in steel mould. Thereafter, the demoulded specimens were marked for identification and kept submerged in a curing tank at room temperature ($27^0 \pm 2^0\text{C}$) for the period of 28 days and initial length was measured. After the initial reading, the specimens were dried in at a temperature of $50 \pm 1^0\text{C}$ and 17% relative humidity and then length changes were determined. The specimens were subjected to a cycle of drying, cooling and measurement of length until constant length was attained, that is, when the difference between the two consecutive readings



Fig. 1—A concrete specimen under drying shrinkage test

separated by a period of drying of at least 44 hours, followed by cooling for at least four hours, is less than 0.02 mm. The drying shrinkage was calculated as the difference between the original wet measurement and the dry measurement expressed as the percentage of wet length.

Abrasion resistance

Abrasion resistance of concrete slab was determined at 28 days following the procedures of ASTM C 779-1995¹⁸. The abrasion machine consists of three discs, which rotate about their vertical axis and at the same time also travels on circular paths at a speed of 12 revolutions per minute in a planetary motion. During the rotation of discs silicon powder falls from the cup (attached at top of the shaft) at the rate of 4 to 6 gm/min which helps in abrading the slab surface. After five minutes of initial charge the abrasion depth is measured with the help of a micrometer, at the each end 5 readings were taken. This represents the initial reading. Abrasion charge is again applied for the period of thirty minutes and abrasion depths are measured. This process is further continued for a period of thirty minutes and final abrasion depths were measured in mm. Difference between the average initial and average final depths give total abrasion of horizontal slab in mm. Average depths obtained on duplicate specimens are reported here.

Results and Discussion

Properties of fresh concrete

The test results of slump and settlement of concrete mixes are listed in Table 2. The results showed that the addition of both types of fiber i.e. multifilament as well as fibrillated has a detrimental effect on the workability (slump) of the mixes. Further, a greater slump reduction for concrete mixes containing multifilament fiber than fibrillated fiber was noted. Increase in slump reduction with an increase in fiber dosage was also seen. This is attributed to the fact that fibre acts as an aggregate. Similar trends were also observed by other researchers^{1-5,7}.

Table 2—Slump and settlement of concrete mixes

Description	Concrete Mix						
	S-1	S-2	S-3	S-4	S-5	S-6	S-7
Slump, mm	75	35	18	15	50	45	28
Settlement, mm	2.17	NA	1.25	NA	NA	0.5	NA

Note: NA stands for not available as it was not determined.

The settlement of concrete was determined only for the fibre content of 0.9 kg/m³ as this is the normal prescribed dose of fibre by its manufacturers. The results showed the maximum settlement for control concrete mix than the mixes with fiber. Fibrillated fiber reduces concrete settlement more effectively than the multifilament fiber. This reduction in settlement of concrete containing fiber may be attributed to the action of fibers in the mix similar to the formation of a three-dimensional sieve, stopping the air passing up through the sieve and preventing the aggregate from pass down¹⁹. No bleeding was noticed in the concrete mixes. The fresh density of concrete mixes containing fibre was slightly less than control concrete.

Compressive and flexural strength

Table 3 shows 28-day average compressive and flexural strength of the concrete mixes. It is obvious from the results that the addition of synthetic fiber to the concrete mixes has not significantly affected the compressive strength of concrete in comparison to the control mix. This trend confirms the earlier reported work^{6,11,12}.

The flexural strength of concrete mixes containing fiber is slightly higher than control concrete mix as reported by other reserachers^{6,11,13,14}. Concrete mixes with multilament fiber developed flexural strength slightly higher than concrete containing fibrillated fiber for the same fiber content. This increase in flexural strength may be due to the crack bridging action of the multifilament fibre. Further, the fibrillated fiber has higher diameter and its fibrils are broken during the mixing resulting in a lower effective aspect ratio of fibrillated fiber than multifilament fibre. So in case of multifilament fiber, effective fiber reinforcing index (product of aspect ratio to volume fraction of fiber) is higher than effective fiber reinforcing index of fibrillated fiber. However, the increase in flexural strength is less than 10%. In general it may be concluded that concrete containing fibrillated fibre performs similar to concrete containing multifilament fiber in the development of flexural strength within the fibre dosages used in this study.

Drying shrinkage

Figure 2 shows the drying shrinkage test results. A reduction in drying shrinkage up to 40% of that of the control concrete may be observed for both the fibers. This reduction in shrinkage is attributed to the higher tensile strength of fibers that enable it to carry more tensile stresses in comparison of plain concrete. Further, early age volume changes in concrete cause weakened planes and cracks to form the growth of these micro shrinkage cracks is inhibited by mechanical blocking action of the fibers. A better performance for the fibrillated fiber in controlling drying shrinkage than multifilament fiber is obvious. This may be due to better stabilization of matrix by the net of fibrillated fiber.

Abrasion resistance

Abrasion resistance was measured in term depth of the abraded concrete surface. The results obtained on duplicate specimens are shown in Figure 3. The results show a significant reduction (up to 29%) in abrasion depth for concrete containing fiber in comparison to control concrete indicating an increased abrasion resistance for those mixes. This increased abrasion resistance for the concrete containing fiber is mainly due to discourage of the development of large capillaries pores due to bleed water migration to the surface leading to improvement in microstructure of surface zone concrete. Another reason for the enhancement in abrasion resistance could be the bonding between the fibers and the concrete matrix which might have not allowed the

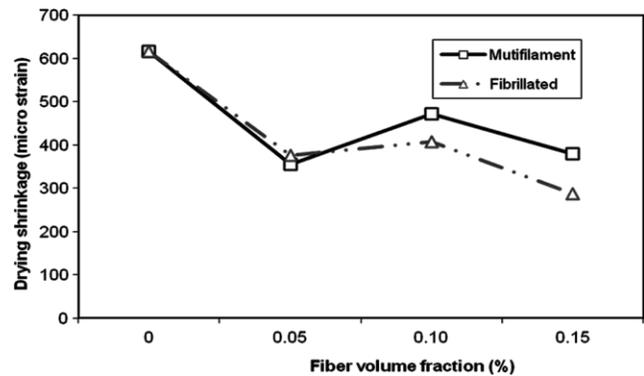


Fig. 2—Drying shrinkage vs. fiber volume fraction

Table 3—28-day compressive and flexural strength of concrete mixes

	Concrete mix						
	S-1	S-2	S-3	S-4	S-5	S-6	S-7
Compressive strength, MPa	48.2	48.8	50.0	48.0	50.5	46.5	50.5
Flexural strength, MPa	5.4	5.3	6.2	6.4	5.7	5.9	6.1

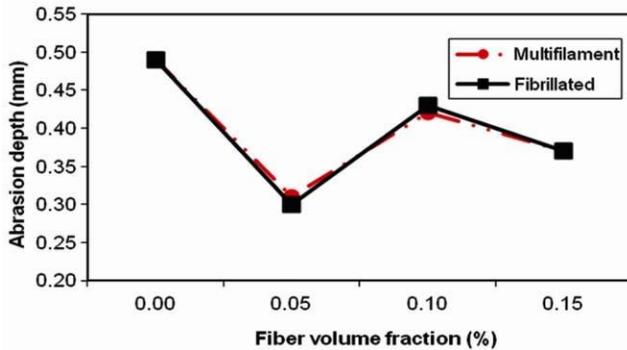


Fig. 3—Abrasion depth vs. fiber volume fraction

particles to move away during the testing. It may be concluded that for the same volume fraction of fiber, multifilament as well as fibrillated fiber have similar effect on the abrasion resistance of the concrete.

Conclusion

The major conclusions that emerged from the experimental study are as given below:

- 1) The addition of synthetic fibre reduces the slump of concrete mix. At the same fiber content the reduction in slump is more in case of concrete containing multifilament fibre than fibrillated fiber.
- 2) Fibrillated fibre is more effective in reducing the settlement of concrete than multifilament fiber.
- 3) The addition of synthetic fiber has insignificant effect on compressive and flexural strength of concrete.
- 4) Fibrillated fiber performs better than multifilament fiber in controlling drying shrinkage of concrete.
- 5) The addition of synthetic fibre to the concrete increases its abrasion resistance. However both the fibrillated and multifilament fiber has similar performance on abrasion resistance of concrete.
- 6) The addition of synthetic fibre can be used in a pavement concrete for specific purpose such as to minimize the growth of plastic shrinkage cracks and to improve the abrasion resistance.

Acknowledgement

The authors are grateful to the Director (Dr S. Gangopadhyay), Central Road Research Institute for his permission to publish the research paper.

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International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)

Impact Factor: 5.164



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2. In blast resistant structures, foundations for machinery where shock and vibrating loads are evident, for refractories where thermal gradient exists, in precast thin elements such as thin folded plates and shells, wall panels, precast roofing and flooring elements, manhole covers, car park deck slab etc.
3. As a biological shielding of atomic reactors and also to water front marine structures such as jetty armour, breakwater caissons etc. which have to resist deterioration at air water surface and impact loading.
4. In under water storage structures, water front wave house floors and wharf decking.
5. Used for repairs and new constructions on major dams and other hydraulic structures to provide resistance to cavitations impact and severe erosion.
6. Used in mining, tunneling and rock slope stabilization by gunite or shotcrete process.

2.6 Structural Use of FRC

As recommended by ACI Committee 544, 'When used in structural applications, steel fiber reinforced concrete should only be used in a supplementary role to inhibit cracking, to improve resistance to impact or dynamic loading, and to resist material disintegration in structural members where flexural or tensile loads will occur.....the reinforcing steel must be +capable of supporting the total tensile load'. Thus, while there is no. of techniques for predicting the strength of beams reinforced only with steel fibers, there are no predictive equations for large SFRC beams, since these would be expected to contain conventional reinforcing bars as well. An extensive guide to design considerations for SFRC has recently been published by the American concrete institute. In this section, the use of SFRC will be discussed primarily in structural members which also contains conventional reinforcements

2.7 Objectives

The main objective is to study the following properties of fiber reinforced concrete for the aspect ratio of 100 with different volume fraction of fibers as 0.5% and 1%. **1.**Develop suitable mix design **2.**To study the compressive strength **3.**To study the split tensile strength **4.**To study the flexural strength

3. FIBER REINFORCED CONCRETE (Polypropylene Fibers)

3.1 General

FIBRE REINFORCED CONCRETE (FRC), obtained by dispersing in concrete, very small sized reinforcement called fibres. The small closely spaced fibres so used act like crack arresters, substantially improve the static and dynamic strengths. That is the properties like toughness, impact resistance and stiffness under different loading conditions are improved. Naturally the properties of fibres influence the properties of FRC composites. When the fibre reinforcement is in the form of short discrete fibres, they act effectively as rigid inclusions in the concrete matrix. Physically, they have thus the same order of magnitude as aggregate inclusions; steel fibre reinforcement cannot therefore be regarded as a direct replacement of longitudinal reinforcement in reinforced and prestressed structural members. However, because of the inherent material properties of fibre concrete, the presence of fibres in the body of the concrete or the provision of a tensile skin of fibre concrete can be expected to improve the resistance of conventionally reinforced structural members to cracking, deflection and other serviceability conditions.

3.2 Basic Concepts of FRC

All cement based materials are essentially anisotropic and heterogeneous in nature. These contain micro cracks and interfacial discontinuities which are root causes for the propagation of cracks and result in low tensile strength. Such problems caused the evolution of the FRC. The incorporation of short fibres in a relatively brittle cement matrix transforms uncontrolled tensile crack propagation into a slow controlled process. These fibres when provided in adequate proportion, the tensile strains in the concrete can be raised to several folds before failure.

3.3 Effect of Fibers in Concrete

Fibers are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete. Generally fibers do not increase the flexural strength of concrete, so it can not replace moment resisting or structural steel reinforcement. Some fibers reduce the strength of concrete. Some recent research indicated that using fibers in concrete has limited effect on the impact resistance of concrete materials. This finding is very important since traditionally people think the ductility increases when concrete reinforced with fibers. The results also pointed out that the micro fibers is better in impact resistance compared with the longer fibers

3.4 Classification of Fibers

The natural fibres like jute, coir, horse hair etc. have got low tensile strength and low elastic modulus. By addition of such fibres static strengths are not improved, while the dynamic properties are improved.

The Artificial fibres can be of both low or high tensile strength. For ex. Nylon, Polypropylene, polyethylene have got low tensile strength. Steel, Glass, Carbon have got high strength. The earlier three fibres are suitable for the main structures as they are less affected by the corrosion

3.5 Types of Fibers

3.5.1 Polypropylene fibres: The polypropylene fiber-reinforced concrete (PFRC) has provided a technical basis for improving these deficiencies. This paper presents an overview of the effect of polypropylene (PP) fibers on various properties of concrete in fresh and hardened state such as compressive strength, tensile strength, flexural strength, workability, bond strength, fracture properties, creep strain, impact and chloride penetration

3.5.2 Steel fibres: The use of steel fibers has led to the improvement of the concrete's mechanical properties such as material toughness in tension and also durability. Many types of steel fibers are used for concrete reinforcement. Round fibers are the most common type and their diameter ranges from 0.25 to 0.75 mm. Rectangular steel fibers are usually 0.25 mm thick, although 0.3 to 0.5 mm wires have been used in India. Deformed fibers in the form of a bundle are also used. The main advantage of deformed fibers is their ability to distribute uniformly within the matrix.

3.5.3 Glass fibres: The Glass fiber-reinforced concrete uses fiber glass, much like you would find in fiber glass insulation, to reinforce the concrete. The glass fiber helps insulate the concrete in addition to making it stronger. Glass fiber also helps prevent the concrete from cracking over time due to mechanical or thermal stress. In addition, the glass fiber does not interfere with radio signals like the steel fiber reinforcement does.

3.5.4 Nylon fibres:

Synthetic fiber-reinforced concrete uses plastic and nylon fibers to improve the concrete's strength. In addition, the synthetic fibers have a number of benefits over the other fibers. While they are not as strong as steel, they do help improve the cement pumpability by keeping it from sticking in the pipes. The synthetic fibers do not expand in heat or contract in the cold which helps prevent cracking. Finally, synthetic fibers help keep the concrete from spalling during impacts or fires.

3.6 Polypropylene Fibers

The capability of durable structure to resist weathering action, chemical attack, abrasion 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 and economic aspects of the construction polypropylene fiber-reinforced concrete (PFRC) has provided a technical basis for improving these deficiencies. This paper presents an overview of the effect of polypropylene (PP) fibers on various properties of concrete in fresh and hardened state such as compressive strength, tensile strength, flexural strength, workability, bond strength, fracture properties, creep strain, impact and chloride penetration



Figure No-3.8.1 Polypropylene fibers

Polypropylene fiber is added to concrete during batching. Thousands of individual fibers are then evenly dispersed throughout the concrete during the mixing process creating a matrix-like structure. The performance of fibers depends on both the dosage (kg/m³) and the fibers parameters (tensile strengths, length, diameter and anchorage). A key factor for quality fiber is the relationship between the length and diameter of the fibers. The higher l/d ratio, the better the performance.

3.6.1 Benefits of Polypropylene Fibers

- Improves ductility, compressive, flexural and tensile strength
- Reduces water permeability
- Improves homogeneity of concrete by reducing segregation of aggregates
- Improves durability of concrete
- Replaces or reduces “non-structural steel” in floors, roads and Pavement

3.6.2 Uses of Polypropylene Fibers

- Increases strength of mortar
- Used in concretes for tunnels, bridge decks
- Used for precast concrete blocks
- Used in pavements and in runways
- Makes wall surfaces cohesive and less porous

4. MATERIALS

4.1 General

In the present investigation, locally available materials have been used as ingredients for the preparation of concrete specimens. The concrete mixes are designed for strengths 50 N/mm² as per IS:10262-1982

4.2 Material Selection

The results of various physical tests are reported in methodology for ordinary Portland cement of grade 53 is used in the preparation of all the specimens. The fact that this cement conforms to specifications of IS:12269-1987 standards has been checked as per the results of physical tests recommended by IS:4031-1988. The locally available river sand belonging to zone II of IS:383-1963 has been used as the fine aggregate. For coarse aggregate, 10 mm and downsized granite metal of angular shape is utilized. Keeping in the view the restrictions on the size of the coarse aggregate as recommended in the literature. Ordinary portable tap water is used in the preparation of the concrete. The round type Human Hair fibers wire cut to required size is used as fibers.

4.3 Ingredients of Concrete

Concrete is used extensively as a construction material because of its versatility. It is good in compression, but weak in tension. This drawback can be overcome by providing steel in tension zone. This technique called “REINFORCED CEMENT CONCRETE”, improves the load carrying capacity of concrete members. At the same time durability of concrete is also important. Durability is mainly affected due to cracks developed by creep and shrinkage. This can be avoided by using certain chemical admixtures. But once a crack develops in the member there are no barriers to stop the propagation of such cracks. In RCC it leads to the corrosion of the reinforcement slowly and finally it results in the failure of the structure

4.3.1 Cement

Cements may be defined as adhesive substances capable of uniting fragments or masses of solid matter to a compact whole. Portland cement was invented in 1824 by an English mason, Joseph Aspin, who named his product Portland cement because it produced a concrete that was of the same colour as natural stone on the Isle of Portland in the English Channel. Raw materials for manufacturing cement consist of basically calcareous and siliceous (generally argillaceous) material. The mixture is heated to a high temperature within a rotating kiln to produce a complex group of chemicals, collectively called cement clinker. Cement is distinct from the ancient cement.

4.3.2 Fine and Coarse Aggregates

The problem is more complicated when the fibres are introduced into a concrete rather than a mortar matrix because they are separated not by a fine grained material which can move easily between them, which may lead to bunching of fibres. The uniform fibre distribution is more difficult to achieve as the aggregate size increases from 5mm to 10 mm to 20mm. In a normal concrete mix the particles finer than 5 mm occupy about 54% of the volume

4.3.2.1 Fine Aggregates

River sand passing through 4.75 mm sieve and conforming to grading zone II of IS: 383-1970 was used as the fine aggregate. Normal river sands are suitable for high strength concrete. Both crushed and rounded sands can be used. Siliceous and calcareous sands can be used for production of HSC

4.3.2.2 Coarse Aggregates

Crushed granite stone with a maximum size of 20 mm was used as the coarse aggregate. The properties of aggregates used

4.3.3 Polypropylene Fibers

Polypropylene Fibers with 0.025 mean diameter (Neglazable) and Length of 25 mm was used at a volume fraction of 0%, 0.5% and 1% of its weight

4.3.4 Water

The requirements of water used for mixing and curing shall conform to the requirements given in IS: 456-2000. However use of sea water is prohibited. **Water Cement Ratio:** Experience has shown that for a satisfactory fibre concrete it should contain a mortar volume of above 20% consisting of particles between 5mm to 10mm. (6). The strength of FRC achieved will be maximum when it is cast without any segregation at the maximum water cement ratio. It is found that FRC cast under good control will achieve its maximum strength at water cement ratio around 0.3 to 0.35. But due to the problem of balling at low water cement ratio it is advised to use either increased water cement ratio.

5. METHODOLOGY

5.1 General

This chapter describes the materials used, the preparation of the test specimens and the test procedures. They are listed down in this section.

5.2 Materials

The materials used in this study were cement, sand, aggregates (both fine and coarse) and water. The description of each of the material is described in the following sections.

5.2.1 Cement

Cement used in this study was KCP brand Ordinary Portland Cement of grade 53. The cement was kept in an airtight container and stored in the humidity controlled room to prevent cement from being exposed to moisture. and various tests were conducted as per codal provisions

5.2.1.1 Initial and Final Setting Time

We need to calculate the initial and final setting time as per IS: 4031 (Part 5) – 1988. To do so we need Vicar apparatus conforming to IS: 5513 – 1976, Balance, Gauging trowel conforming to IS: 10086 – 1982

Procedure to determine initial and final setting time of cement

- ❖ Take 500gms of Cement sample and gauging it with 0.85 times the water required to produce a Cement paste of standard consistency.
- ❖ Start a stop-watch, the moment water is added to the cement.
- ❖ Fill the Vicar mould completely with the cement paste gauged as above, the mould resting on a non-porous plate and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared in the mould is the test block.
- ❖ The temperature of water and that of the test room, at the time of gauging shall be within $27^{\circ}\text{C} \pm 2^{\circ}\text{C}$

➤ Initial setting time

Place the test block under the rod bearing the needle. Lower the needle gently in order to make contact with the surface of the cement paste and release quickly, allowing it to penetrate the test block. Repeat the procedure till the needle fails to pierce the test block to a point $5.0 \pm 0.5\text{mm}$ measured from the bottom of the mould. The time period elapsing between the time, water is added to the cement and the time, the needle fails to pierce the test block by $5.0 \pm 0.5\text{mm}$ measured from the bottom of the mould, is the initial setting time.

➤ Final setting time

Replace the above needle by the one with by a circular attachment. The cement should be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression therein, while the attachment fails to do so. The period elapsing between the time, water is added to the cement and the time, the needle makes an impression on the surface of the test block, while the attachment fails to do so, is the final setting time. In other words the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5 mm

5.2.1.2 Consistency Test

The basic aim is to find out the water content required to produce a cement paste of standard consistency as specified by the IS: 4031 (Part 4) – 1988. The principle is that standard consistency of cement is that consistency at which the Vicar plunger penetrates to a point 5-7mm from the bottom of Vicar mould.

8. CONCLUSION & FUTURE SCOPE

Fiber reinforced concrete and high strength concrete are being widely used as important constructional materials due to their excellent properties. An extensive knowledge of the properties is necessary in order to make best and economic use of the material. In this context, present experimental investigation aims to find the different strength characteristics of high strength HFRC. (M50)

8.1 Conclusion

Crack formation and propagation are very much reduced showing that hair fibre reinforced concrete can have various applications in seismic resistant and crack resistant constructions, road pavement constructions etc.

- During our research work we also faced the problem of uniform distribution of Polypropylene Fibers in the concrete. So an efficient method of mixing of Polypropylene Fibers to the concrete mix is to be found out.
- Applications fiber on other properties of composites such physical, thermal properties and appearances.
- In Compressive strength test results the Concrete mix containing 1.0% Steel fibers (C - 3) as maximum improvement of 26.3% is observed.
- In Split Tensile strength test results the Concrete mix containing 1.0 Steel fibers (C - 3) as maximum improvement of 39.9% is observed
- Flexural strength Test results the concrete mix containing 1.0 Steel fibers (C - 3) as maximum improvement of 84.4% is observed.
- For heavy structures in order to decrease secondary reinforcement steel fibers is very much useful.
- In certain critical places the crack penetration can be arrested by using fibers.
- By using polypropylene in concrete, micro crack can be arrested.
- HFRC have more strength in compression, tension and Flexural Strength test

8.2 Future Scope

The present work leaves a wide scope for future investigators to explore many other aspects of Polypropylene Fibers reinforced concrete composites. Some recommendations for future areas of research include:

- To increase mechanical strength of these composites for their use in different sectors can be studied.
- Possible use of other fibers/flakes obtained from bio-wastes in the development of new composites.
- The use of animal and human hairs in concrete.
- The use of other Natural and Artificial fibers in concrete. To improve the Strength parameters

9. ACKNOWLEDGEMENTS

The Author would like to thank all the persons who helped in the completion of his experimental work. Also thanks are extended to **ASR College of Engineering**, Tanuku, West Godavari Dist, Andhra Pradesh, INDIA for support throughout the execution of the experimental work.

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CITE AN ARTICLE

Srinivasu, V., & Padmavathi, B. (2018). AN EXPERIMENTAL INVESTIGATION ON STRENGTH PROPERTIES OF POLYPROPYLENE FIBERS. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, 7(12), 419-436.

