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Polypropylene Fiber Reinforced Concrete- A Review

Dr.T.Ch.Madhavi[1], L.Swamy Raju[2], Deepak Mathur
[1]Professor and Head, Department of Civil Engineering, SRM University, Ramapuram
[2]Additional Chief Engineer (Civil), BHAVINI, DAE, Kalpakkam
[3]Scientific Officer (Civil), BHAVINI, DAE, Kalpakkam

tchmadhavi@yahoo.com

***Abstract*—Polypropylene Fiber Reinforced Concrete is an embryonic construction material which can be described as a concrete having high mechanical strength, Stiffness and durability. By utilization of Polypropylene fibers in concrete not only optimum utilization of materials is achieved but also the cost reduction is achieved. This paper presents a comprehensive review on various aspects Polypropylene Fiber Reinforced Concrete concerning the behaviour, applications and performance of Polypropylene Fiber Reinforced Concrete. Various issues related to the manufacture and strength of Polypropylene Fiber Reinforced are also discussed.**

***Keywords*—Fiber Reinforced Concrete, Polypropylene Fibers, Concrete, Ductility, Mechanical Properties, Durability.**

I. INTRODUCTION

Concrete has better resistance in compression while steel has more resistance in tension. Conventional concrete has limited ductility, low impact and abrasion resistance and little resistance to cracking. A good concrete must possess high strength and low permeability. Hence, alternative Composite materials are gaining popularity because of ductility and strain hardening. To improve the post cracking behaviour, short discontinuous and discrete fibers are added to the plain concrete. Addition of fibers improves the post peak ductility performance, pre-crack tensile strength, fracture strength, toughness, impact resistance, flexural Strength resistance, fatigue performance etc. The ductility of fiber reinforced concrete depends on the ability of the fibers to bridge cracks at high levels of strain. Addition of polypropylene fibers decreases the unit weight of concrete and increases its strength.

II POLYPROPYLENE FIBERS

Polypropylene fibers are new generation chemical fibers. They are manufactured in large scale and have fourth largest volume in production after polyesters, polyamides and acrylics. About 4 million tonnes of polypropylene fibers are produced in the world in a year.

Polypropylene fibers were first suggested for use in 1965 as an admixture in concrete for construction of blast resistant buildings meant for the US Corps of Engineers.

Subsequently, the polypropylene fiber has been improved further and is now used as short discontinuous fibrillated material for production of fiber reinforced concrete or as a continuous mat for production of thin sheet components. Further, the application of these fibers in construction increased largely because addition of fibers in concrete improves the tensile strength, flexural strength, toughness, impact strength and also failure mode of concrete

These fibers are manufactured using conventional melt spinning. Polypropylene fibers are thermo plastics produced from Propylene gas. Propylene gas is obtained from the petroleum by products or cracking of natural gas feed stocks. Propylene polymerizes to form long polymer chain under high temperature and pressure. However, polypropylene fibers with controlled configurations of molecules can be made only using special catalysts.

Polypropylene fibers were formerly known as Stealthe,. These are micro reinforcement fibers and are 100% virgin homopolymer polypropylene graded monofilament fibers. They contain no reprocessed Olifin materials. The raw material of polypropylene is derived from monomeric C_3H_6 which is purely a hydrocarbon.

For effective performance, the recommended dosage rate of polypropylene fibers is 0.9 kg/m^3, approximately 0.1% by volume.

Monofilament polypropylene fibers can be used in much lower content than steel fibers. The tensile strength and other mechanical properties are enhanced by subsequent multi stage drawing. These fibers have low density of 0.9 g/cc. They are highly crystalline, with high stiffness and excellent resistance to chemical and bacterial attack. The crystallinity of these fibers is about 70% while the molecular weight is 80,000 to 300,000 gm/mole.

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Polypropylene fibers should not be used for structural reinforcement. These fibers should not be used to produce thinner sections and also to increase joint spacing than those suggested for unreinforced masonry.

Polyrpopylene when copolymerized with ethylene is generally tough and flexible, which allows polypropylene to be used as engineering plastic. Polypropylene is reasonably economical and when uncoloured appears translucent. It is generally not readily available transparent as acrylic, polystyrene or other plastics. It is often opaque or made coloured using colouring pigments. It has good resistance to fatigue. Perfectly isotactic Polypropylene has a melting point of 171 °C while Commercial isotactic Polypropylene has a melting point ranging from 160 to 166 °C. Polypropylene is used in hinges of flip flop bottles, piping, loud speaker units etc. Thin sheets of polypropylene are used as dielectric in capacitors

Fig.1. Polypropylene fibers

Advantages

Polypropylene fibers are Non-Magnetic, rust free, Alkali resistant, safe and easy to use. Polypropylene twine is cheap, abundantly available and is of consistent quality.
Polypropylene fibers are also compatible with all concrete chemical admixtures and can be handled with ease. The high molecular weight of polypropylene, gives it many useful properties.

Polypropylene fibers are chemically inert and hence, any chemical that will not attack the concrete constituents will not have any effect on the fiber also. When more aggressive chemicals come in contact, the concrete will always deteriorate first before fibers.

The hydrophobic surface of fibers not being wet by cement paste, helps to prevent balling effect by chopped fibers and The water demand is nil for polypropylene fibers when used in concrete and there is no need for minimum amount of concrete cover. Presence of fibers reduces the settlement and bleeding in concrete. The resistance to abrasion, freeze and thaw, Impact is improved.

III NEED FOR POLYPROLYLENE FIBERS IN CONCRETE

Concrete develops micro cracks with curing and these cracks propagate rapidly under applied stress resulting in low tensile strength of concrete. Hence addition of fibers improves the strength of concrete and these problems can be overcome by use of Polypropylene fibers in concrete. Application of polypropylene fibers provides strength to the concrete while the matrix protects the fibers.

The primary role of fibres in a cementitious composite is to control cracks, increase the tensile strength, toughness and to improve the deformation characteristics of the composite. The performance of FRC depends on the type of the fibers used. Inclusion of polypropylene fibers reduces the water permeability, increases the flexural strength due to its high modulus of elasticity. In the post cracking stage, as the fibers are pulled out, energy is absorbed and cracking is reduced.

IV. LITERATURE REVIEW

The term fibre reinforced concrete (FRC) is defined by ACI Committee 544 as a concrete made of hydraulic cements containing fine and coarse aggregates and discontinuous discrete fibres [1].

Many researchers have investigated the effect of various types fibers on the mechanical properties of concrete. However, the research on polypropylene fiber reinforced concrete is limited and it is presented blew.

A. Workability

With addition of fibers, the entrapped air voids increase and hence the increased air content reduces the workability causing difficulty in compaction of mixes. The fibers may also interfere and cause finishing problems.

Workability of concrete decreased with increase in polypropylene fiber volume fraction [2].

Thirumurgan and Siva Kumar [3], reported that the workability of concrete decreased with the addition of polypropylene fibers but it can be overcome by addition of High Range Water Reducing Admixtures.

Gencel et al [4] used monofilament polypropylene fibers in self compacting concrete with fly ash and studied the workability and Mechanical properties. The materials used in this study showed no workability or segregation problems.

Preti A Patel et al [5] reported that the workability of concrete reduced with higher polypropylene fiber content. Vee Bee time indicated that at 0.5% of fiber content workability is high while at 1% it is medium.

B. Compression Strength

Compressive strength of concrete is one of the most important properties of concrete. It is a qualitative measure of concrete. Failure of concrete under compression is a mixture of crushing and shear failure. The compressive strength varies as a function of both cement paste and fibers. Higher binder ratio gives higher compressive strength.

Priti A. patel et al [5] found that the compressive, split tensile and flexural strength improved on addition of 1.5 % of polypropylene fibre in the concrete.

Vinod Kumar and Dr. M. Muthukannan [6] carried out experimental Investigations on Hybrid fibers using steel, glass and polypropylene fibres in different combinations to examine the mechanical properties of Hybrid Fiber Reinforced Concrete as compared to the conventional concrete.

Kumar et al carried out experimental investigations on M15, M20 and M25 grade fly ash concrete reinforced with 0%, 0.5% and 1% polypropylene fibers. The compressive strength also increased with increase in fiber content up to 1% for all the three grades of concrete.

Mehul and Kulkarni [2] used fibrillated polypropylene fiber of length 12mm and diameter 34 micron and low density of 0.9 kN/m^3, in percentages of 0.5%, 1% and 1.5% in high strength concrete. Super plasticizer Conplast-Sp430 was used. They observed that the compressive strength of concrete increased with addition of fibers.

Murahari, Rama Mohan Rao [7] studied the effect of polypropylene fibers in fly ash concrete. Fiber volume fraction of 0.15%, 0.2%, 0.25% and 0.3% was used in fly ash concrete with class C fly ash of specific gravity 1.96, obtained from NLC. Fly ash content was varied as 30%, 40% and 50%. 12 mm (40%) and 20 mm (60%) coarse aggregate with specific gravity of 2.7 were used. The cube specimens were tested for 28days and 56 days strength. The compressive strength gained maximum strength at early age as observed for all fly ash and polypropylene fiber concrete. It is also observed that the compressive strength increased gradually from 0.15% to 0.3% fiber content.

Rana et al, carried out tests for strength Prediction of Polypropylene Fiber Reinforced Concrete. Test results showed that the compressive strength increased by the addition of Polypropylene fiber.

The addition of polypropylene fibers to plain concrete increases its compressive strength from 4% to 17%. [8]

C.Split Tensile Strength

Split tensile strength can be determined by either direct methods, or indirect methods. The direct method has difficulties related to holding the specimen properly in the testing machine without introducing stress concentration, and in application of uniaxial tensile load which is free from eccentricity to the specimen. Since concrete is weak in tension even a small eccentricity of load will induce combined bending and axial force condition and the concrete fails at the apparent tensile stress rather than the tensile strength.

Hence, indirect tests are generally adopted in which a compressive force is applied to a concrete specimen in such a way that the specimen fails due to tensile stresses developed in the specimen. This failure stress is termed the tensile strength of concrete. The splitting test is the well known indirect test, in which compressive line load is applied along the opposite generators with the cylinder axis being horizontal between the compression platens. Due to compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter.

$$\text{Split tensile strength} = 2P/\pi\, DL$$

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Using log fibers gives more split tensile strength that short fibers for the same volume fraction of fibers.

Murahari, Rama Mohan Rao [7] from their experimental investigations observed that there is not much significant interference of fibers on the split tensile strength. The split tensile strength gained more strength at early age of 28 days compared to 56 days.

Gencel et al [4] conducted the split tensile strength using fibers upto 9 kg/m^3. It is found that the split tensile strength increased with increasing fiber content Fibers tend to bridge the micro cracks and hamper the propagation of cracks. When tensile stress is transferred to fibers, the micro cracks are arrested and thus improve the split tensile strength of concrete.

D. Flexural Strength

Kumar et al studied the with M15, M20 and M25 grade concrete with 0%, 0.5 % and 1% fibers for flexure and shear behaviour of deep beams and it is reported that there is marginal increase in flexural strength at first crack as fiber content increased from 0% to 1.0%.

Murahari, Rama Mohan Rao [7] tested 500 x 100 x 100 mm specimens under three point loading in accordance with ASTM C78. It is observed that the flexural strength increased with content upto 0.3% and gained more strength at 28 days when compared to 56 days. Gencel et al [4] reported that the flexural strength increases with addition of fiber content.

Rama Devi and Venkatesh Babu [9], studied the Flexural behaviour of Hybrid Steel-Polypropylene Fiber Reinforced Concrete Beams and observed that use of steel-polypropylene Hybrid fiber reinforced concrete improves flexural performance of the beams during loading.

Mahendra Prasad et al [10] conducted investigations on Polypropylene fiber reinforced silica fume concrete of M30 grade. The cement replacement by silica fume was 0%, 5%, 10%,15% and fibers were added in the 0%, 0.2%, 0.4%, 0.6% by volume fraction of concrete. It is reported that the increase in flexural strength was around 40% with use of Polypropylene fibers and silica fume in concrete.

Tamil Selvi and Thandavamoorthy [11], from their experimental investigations on hybrid fibres with crimped steel and polypropylene in concrete matrix to study the improvements in strength and durability properties, reported that the addition of steel and polypropylene fibres to concrete exhibit better performance

E.Shear Strength

Kumar et al reported that the ultimate shear strength of the deep beams increased up to 5% for all the M15, M20 and M25 grades of concrete.

F.Failure

Presence of polypropylene fibers inhibits intrinsic cracking in concrete. Fibers in the matrix increase cohesion and hence the failure is observed to be ductile and gradual for the fiber reinforced deep beams.

Chunxiang Qian and Piet Stroeven [12] reported that addition of polypropylene fibers controls the micro cracks due to shrinkage and thus enhances the longevity of the structure.

Thirumurugan and Siva Kumar [3] reported that Fiber addition has significant control on the failure modes of concrete and random orientation of fibers improve the fracture properties of concrete.

Peng Zhang and Li [13] used 0.04%, 0.06%, 0.08%, 0.1% and 0.12% of polypropylene fibers in concrete containing 15% fly ash and 6% silica fume. They reported by testing beam specimens under three point loading, that addition of fibers greatly improved the fracture parameters of concrete composite such as fracture toughness, fracture energy, effective crack length, maximum mid-span deflection, critical crack opening displacement etc. With increase in fiber volume fraction from 0 to 0.12%, there is increase in fracture parameters.

The fibers embedded in concrete affect the stress and strain, enhancing the stress redistribution and reducing strain localisation.

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The addition of polypropylene fibers to plain concrete reduces the crack width to an extent of 21% to 74%. [8]

Machine Hsie, et. al., [14] reported that polypropylene fibres have good ductility and dispersion so they can restrain the plastic cracks.

Jianzhuang Xiao, et. al., [15] also reported that polypropylene fibres can be utilized to control fresh and hardened properties of concrete and that PP fibres can decrease the plastic shrinkage.

IV APPLICATIONS

Polypropylene fibers are versatile and widely used in many industrial applications such as ropes, furnishing products, packaging materials etc. They are also used in packaging, labeling, carpets, textile, apparel markets, stationery, plastic parts, reusable containers, laboratory equipment, automotive components, loud speakers, etc

Polypropylene Fiber reinforced Concrete is used in roads and pavements, drive ways, Overlays and toppings, ground supported slabs, Machine foundations, Off shore structures, tanks and pools etc.

V CONCLUSIONS

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

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