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A Review on Study of Addition of Polypropylene Fibers in the Concrete

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Abstract:- *Polypropylene fiber reinforced concrete is a construction materials which has high mechanical strength, stiffness and durability. With the use of polypropylene fibers in concrete not only optimum utilization of material is achieved but also the cost considerably gets reduced. This paper presents a comprehensive review of various aspects of polypropylene fiber reinforced concrete concerning its behavior, applications and performance of polypropylene fiber reinforced concrete. Here 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 is good in compression where as steel is good in tension. Conventional concrete has limited ductility, low impact and abrasion resistance and small resistance to cracking. A good concrete must have high strength and low permeability. So alternative composite materials are gaining more 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 in concrete improves the pst peak durability performance, pre-cracking 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 fibers decrease the unit weight of concrete and increase the strength of concrete.

Polypropylene fibers

Polypropylene fibers are new generation chemical fibers. They're factory-made in giant scale and have fourth largest volume in production once polyesters, polyamides and acrylics. A total of 4 Million tonnes of Polypropylene fibers are produced in the world overall in a year.

Polypropylene fibers were first used in 1965 as a admixture in concrete for the construction of blast resistant building for US Corps of Engineers.

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

These fibers are manufactured using the conventional melt spinning. Polypropylene fibers are thermo plastics which are produced from propylene gas. Propylene gas is obtained from the petroleum by-products or cracking of natural gas. Propylene polymerizes to form longer polymer chain under high temperature and pressure. The polypropylene fibers with controlled configurations of molecule can be 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 C3H6 which is purely a hydrocarbon.
For effective performance, the recommended dosage rate of polypropylene fibers is 0.9 kg/m3, 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.

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

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.

II. Literature Review

ACI Committee 544, State of the Art Report on Fiber Reinforced Concrete, defined the fiber reinforced conbcrete as a concrete made by cement containing fine as well as coarse aggregates and discontinuous discrete fibers. Many researches have investigate the effect of various fiber on the mechanical properties of concrete. However, the research on polypropylene fiber is limited and it is presented below.

A) Workability

Mehul J. Patel, S.M.Kulkarni, found that with the addition of fiber, the entrapped air voids increases and hence reduce the workability causing difficulty in compacting of mixes. The fibers also gets interfere and affect the finishing problem. Hence workability of concrete decreased with increase in polypropylene fiber.

Thirumurgan and Siva Kumar reported that the workability of the conceret decreases with the addition of the polypropylene but it can overcome by the addition of the high range water reducing admixture agent.

Gencel et al, used monofilament polypropylene fiber in self compacting concrete with fly ash and it was studies that the workability and mechanical properties as there is no workability and segregation problem was found.

Preti A. Patel et al reported that the workability of concrete was reduced with higher polypropylene fiber content. Vee Bee time indicated that at 0.5% of fiber content workability was high while at 1% it was found to be medium.

B) Compressive 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 due to crushing and shear failure. The compressive strength varies as a function of both cement paste and fiber. Higher binder ratio gives higher compressive strength.

Priti A. Patel et al found that the compressive, split tensile and flexural strength improved when 1.5% of polypropylene fiber was added in concrete.

Vinod Kumar and Dr. M. Muthukannan carried out experimental investigation on hybrid fibers using steel, glass and polypropylene fibers in different proportion to examine the mechanical properties of hybrid fiber reinforced concrete as compared to the conventional concrete.

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

Mehul and Kulkarni used fibrillated polypropylene fiber of length 12mm and diameter 34 micron and low density of 0.9 kN/m^3 , in percentage 0.5% , 1%, and 1.5% in high strength concrete. Here super plasticizer Conplast-SP430 was used. They found that the compressive strength of concrete increased with addition of fibers.

Murahari, Rama Mohan Rao studied the effect of polypropylene fibers in fly ash concrete. Fiber in fraction content 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%. 12mm (40%) and 20mm(60%) coarse aggregate with specific gravity of 2.7 were used. The cube Specimens were tested for 28days and 56 days strength. All the fly ash and polypropylene fiber concrete gained the maximum compressive strength at the early age. It was observed that the compressive strength increased gradually frim 0.15% to 0.3% .

Rana et al, Carried out tests for strength prediction of polypropylene FRC. The test results showed that the compressive strength increased by the addition of polypropylene fibers.

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

Murahari, Rama Mohan Rao, 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, conducted the split tensile strength using fibers upto 9 kg/m3. 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, 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 reported that the flexural strength increases with addition of fiber content.

Rama Devi and Venkatesh Babu , 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, 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, 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, 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 , 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, 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.

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

Jianzhuang Xiao, et. al.,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.

III. Conclusions

Polypropylene fibers reduce the water permeability, shrinkage and settlement and carbonation depth. Workability of concrete decreases with the fiber volume fraction increases. However to achieve higher workability HRWR admixture should be added with w/c ratio of 0.3. Polypropylene fibers enhance the strength of concrete without causing the problems associated with steel fibers. The problem of low tensile strength of concrete can be overcome with the addition of polypropylene fiber in concrete. Notable increase in compressive strength is reported with addition of polypropylene fibers. In polypropylene fibers the failure is gradual and ductile. The durability of concrete when the addition of polypropylene fibers and a greater improvement in the fracture parameters of concrete. The compressive strength, split tensile strength, flexural strength and modulus of elasticity increases with the addition of fiber content as compared to the conventional concrete.

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