Effect of Hybrid Fiber on Mechanical Properties of Concrete

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ABSTRACT

Hybrid fibre can provide reinforcement at all the range of strains. Combination of low and high modulus fibres can arrest cracks at micro level as well as macro level. Overcome disadvantage of lower workability caused due to use of only higher percentage of steel fibres. Potential advantage in improving concrete properties as well as reducing the overall cost of concrete production.

Keywords –*Compressive Strength, Flexural Strength, HyFRC, PPFRC, Split Tensile Strength*

I. INTRODUCTION

Concrete is a tension-weak building material, which is often crack ridden connected to plastic and hardened states, drying shrinkage, and the like. The cracks generally develop with time and stress to penetrate the concrete, thereby impairing the water proofing properties and exposing the interior of the concrete to the destructive substances containing moisture, bromine, acid sulphate, etc. The exposure acts to deteriorate the concrete, with the reinforcing steel corrosion. To counteract the cracks, a fighting strategy has come into use, which mixes the concrete with the addition of discrete fibers. Experimental studies have shown that fibers improve the mechanical properties of concrete such as flexural strength, compressive strength, tensile strength, creep behaviour, impact resistance and toughness. Moreover, the addition of fibers makes the concrete more homogeneous and isotropic and therefore it is transformed from a brittle to a more ductile material.

Most types of Fibre reinforced concrete used in practice contain only one type of fibre. However, it is known that failure in concrete is a gradual, multi-scale process. The pre-existing cracks in concrete are of the order of microns. Under an applied load, these cracks grow and eventually join together to form macro cracks. A macro-crack propagates at a stable rate until it attains conditions of unstable propagation and a rapid fracture is precipitated. The gradual and multi-scale nature of fracture in concrete implies that a given fibre can provide reinforcement only at one level and within a limited range of strains. For optimal result therefore different types of fibres may be combined and the resulting composite is known as hybrid-fibre-reinforced concrete.

The separate experimental findings were done by Dr MazinAdeen and A. Sivakumar on combination of metallic and non-metallicfibers at different volume fraction of fibers by volume of concrete (low volume fraction). Dr.Mazin used M35 grade of concrete and 0.5%, 1%, 1.5% volume fractions of fibers with different combination of metallic and non-metallicfibers. on the other hand A.Sivakumar used M60 grade of concrete and 0.3%, 0.4%, 0.5% volume fractions of concrete. Both of them made use of different proportions of steel-polypropylene combinations. Combination of steel-polypropylene fibers done by Dr.Mazin and A.Sivakumar were 100-0%, 70-30%, 50-50%, 30-70%, 0-100% and 100-0%, 90-10%, 80-20%, 70-30%.respectively.

Both of them shows test results on compressive strength as well as tensile strength for same volume fraction by of fiber by volume of concrete. As per Dr.Mazin's findings maximum compressive strength is for 0.5% volume fractions of fibers by volume of concrete with metallic and non metallic fibers proportions 50-50% (steel-polypropylene), while that of maximum tensile strength is for 1% volume fraction with proportion 70 - 30% (steel – polypropylene). Whereas A.Sivakumar found that, there is no significant change in compressive strength at varying volume fraction of fibers as well as combination of metallic and non metallic fibers. The maximum tensile strength is for 0.5% volume fraction with proportion 70-30% (steel-polypropylene).This project work is onto find the gap of information between Dr.Mazin and A.Sivakumar.

II. OBJECTIVES

1. To study the effect of hybrid fibre with 0.5% volume fraction by volume of concrete on normal concrete.
2. To study the mechanical properties of hybrid fibre with different hybridization ratio at 0.5% volume fraction of concrete.
3. To evaluate the strain energy absorbed at its ultimate level for SFRC at 0.5% volume fraction.
4. To evaluate the strain energy absorbed at its ultimate level for PFRC at 0.5% volume fraction.
5. To evaluate the strain energy absorbed at its ultimate level for hybrid fibres at 0.5% volume fraction with normal concrete.

III. EXPERIMENTAL INVESTIGATION

3.1 Test materials and mix proportions

Portland pozzolona cement with ISI mark was used for test on fresh and hardened concrete. The compressive strength was 23.77 MPa and 33.21 MPa at 7 days and at 28 days respectively. Local river sand with fineness modulus 3.17 was used. The coarse aggregate with basalt origin, maximum size 20mm used from local stone crusher. Portable water, with pH of 7.1, was used. The design mixed M30with proportion 1:1.54:3.31(Cement: Fine aggregate: Coarse Aggregate) for concrete on weight basis. The mix design was done as per IS 10262:2009. Water cement ratio of 0.5kept constant for concrete.

3.2 Specimen details

Cube moulds of 150x150 x150 mm and cylindrical moulds of 150 mm diameter and 300 mm long are used for casting the specimen for compressive strength and split tensile strength test respectively. For flexure test, specimen size of 150x150x700 mm is cast. Specimens were cured for 28 days. But out of 4 specimens 3 specimens of compressive strength test are cured for 7 days and 3 specimens were cured for 3 days to obtain the compressive strength after 7 days and 3 days respectively.

3.2Testing

Flexural test were carried out on 18 beams, out of that each of 3 beams are tested for hybridization ratio 0-100%, 30-70%, 50-50%, 70-30%, 100-0% (Steel-Polypropylene). For all hybridization ratio fiber volume 0.5% by volume of concrete is kept constant.

Fig.1: Flexural test setup

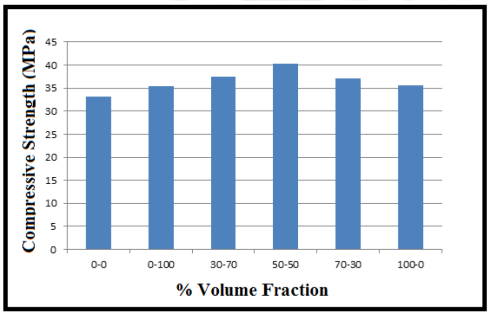
The beams were kept on UTM as shown in fig.1 the beams were tested under gradually applied two point loading on UTM machine for flexural strength. Ultimate loads and modes of failure of beams were noted. Compressive strength and split tensile strength are carried out on cubes and cylinders respectively, tested under compression testing machine.

IV. DISSCUSSIONS AND RESULTS

In present study cube compression test, split tensile test, flexural test on beams, and on plain and varying hybridization ratio of steel and polypropylene fibers reinforced concrete at 0.5% fiber volume fraction by volume of concrete are carried out. The experimental results and discussion for various tests are described below.

4.1 Compressive Strength

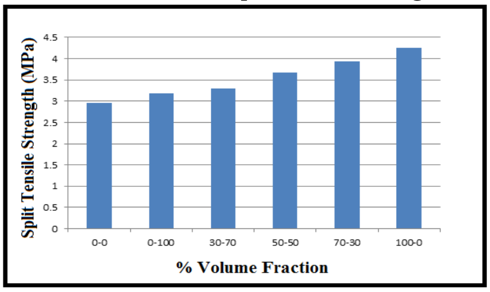
The results of compressive strength test at 28 days are given in table No.1. It is seen that at 0.5% volume fraction of fibers by volume of concrete the compressive strength of Hybrid fiber reinforced concrete (HyFRC) with 50-50% (Steel-polypropylene) hybridization ratio is maximum. Fiber addition with equal percentage assures maximum availability of fiber in the fibrous matrix of concrete as regard to volume. Maximum availability of fibers are advantageous as under the axial load cracks occurs in microstructure of concrete, fiber reduces the crack formation and development. Because of high strength and stiffness, Metallic fibers (steel) are responsible to arrest the macro cracks also modulus of elasticity of steel fibers is more hence provide ductility to the concrete. Concrete is very alkaline and as such it will corrode steel fiber very quickly so that non-metallic fibers (polypropylene) are used for effective reinforcement. Use of non-metallic fiber is to arrest only a micro cracks developed due to shrinkage. Modulus of elasticity of PP fiber is less than steel fiber hence PPFRC undergoes brittle failure after loading. Due to hybridization of steel and polypropylene (50-50%) mix provide better response to arrest micro and macro cracks hence improve the compressive strength of concrete as compare to plain concrete and all other combination of hybridization ratio.



Graph no.1: Compressive strength after 28 days

4.2 Split Tensile Strength

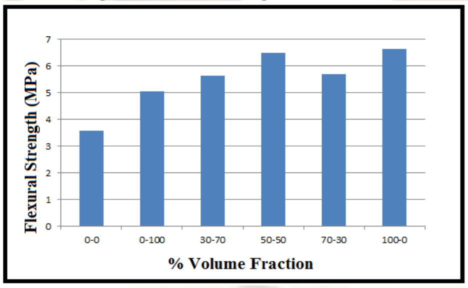
The results of split tensile strength test at 28 days are given in table No.1. The increase in split tensile strength due to incorporation of steel fiber is greater than polypropylene fiber. High modulus of elasticity of steel fiber makes the concrete more ductile. Tensile strength of ductile material is higher than brittle materials. Therefore gradual increase in % of steel fibers for different hybridization ratio split tensile strength of concrete also increases. Once the split occurs and continues the steel fibers provide bridging effect across the split portion. The split portion of the matrix transfer the stresses from matrix to the fibers and thus steel fibers are gradually supports the entire load. Stress transfer also improves the tensile strain capacity of the fiber reinforced concrete and increase the split tensile strength.



Graph no.2: Split Tensile Strength after 28 days

4.2 Flexural Strength

The results of flexural strength test at 28 days are given in table No.1. Flexural strength of concrete increases with increase in steel fiber percentage in specimen. It is also seen that the addition of polypropylene fibers increase the flexural strength. Flexural strength primary increase due to fiber intersecting the cracks in the tension half portion of the specimen. This fibers accommodate the crack face separation by process of stretching the fibers, thus providing additional energy absorbing capacity. It also provides stress relaxing mechanism at the tip of the cracks during micro cracks formation. The modulus of rupture of steel fibers is more as compare to polypropylene fibers. Therefore steel fibers are effective to arrest the macro cracks and undergoes ductile failure while Polypropylene fibers are only effective to arrest the micro cracks and undergoes brittle failure. Therefore steel-polypropylene combination also shows better performance during flexural strength test.



Graph no.3: Flexural Strength after 28 days

V. CONCLUSIONS

1) Compressive strength of HyFRC after 28days for 50-50 % (steel-polypropylene) hybridization ratio is maximum. It is increased by 21.41% with respect to normal concrete (i.e. Hybridization ratio 0-0 %). At 28 days Compressive strength of SFRC (i.e. Hybridization ratio 100-0 %) is increased by 7.37% with respect to normal concrete & compressive strength of PPFRC (i.e Hybridization ratio 0-100%) increased by 6.68% with respect to normal concrete.
2) Split tensile strength of HyFRC concrete for 28 days increases with increasing contribution of steel fiber in hybridization ratio. Split tensile strength of SFRC (i.e. Hybridization ratio 100-0%) is maximum. Split tensile strength of SFRC (i.e. Hybridization ratio 100-0%) increases 44.41% & Split tensile strength of PPFRC (i.e. Hybridization ratio 0-100%) increases 8.16% with respect to normal concrete respectively.
3) Flexural strength of HyFRC for 50-50 % & SFRC i.e. 100-0 % after 28days is nearly same. Flexural strength of HyFRC with 50-50% hybridization ratio and SFRC i.e. hybridization ratio 100-0% is increases 81.51% & 86.27% respectively than normal cement concrete. Flexural strength of PPFRC (i.e Hybridization ratio 0-100%) increased by 41.73% with respect to normal concrete.

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Table No1. Results for Compressive Strength test on cubes at 28 Days

Sr No.	Hybridization Ratio (steel-poly%)	Average Compressive strength (MPa)	Average Split Tensile strength (MPa)	Average Flexural strength (MPa)
1.	0-0	33.21	2.95	3.57
2.	0-100	35.43	3.19	5.06
3.	30-70	37.53	3.30	5.65
4.	50-50	40.32	3.67	6.48
5.	70-30	37.01	3.94	5.71
6.	100-0	35.66	4.26	6.65