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Performance of hybrid fiber reinforced fly ash concrete with polypropylene and glass fiber.

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Abstract—Concrete is a weak building material in tension. Inherently, micro cracks will be present in concrete. The formation of micro cracks is normally due to shrinkage of concrete. Fibers when introduced act as bridge towards crack propagation and increase the energy absorption capacity of the concrete. Moreover, concrete suffers from low tensile strength, limited ductility and little resistance to cracking. In order to improve these properties, an attempt has been made to study the effect of addition of polypropylene and glass fibers in ordinary Portland cement concrete partially replacing cement with flyash. In the investigation, it is mainly focused on the effect of mechanical properties on M 60 grade of concrete by providing hybrid fibers with different dosage levels by volume of concrete.

***Index Terms* - (Micro cracks, Crack propagation, Polypropylene Fibers, Glass Fibers, Flyash, Mechanical Properties, Hybrid Fibers)**

I. Introduction

Concrete, as a widely used structural material, the material properties are critical toward determination of structural ductility and reliability. Despite its popularity in large scale structures, it suffers material limitations; specifically, with respect to its inability to carry moderate tension forces as experienced in flexural or direct tension loading. In compression loading, the maximum capacity and subsequent ductility can only be reached upon the addition of confining stress, commonly applied through reinforcing steel stirrups/spirals. To improve the integral properties of concrete with respect to both tension loading and element ductility, fibers can be introduced which provides additional energy absorption mechanisms to delay crack growth and element failure. Fibers present in the fracture process zone ahead of the crack tip can subdue and delay crack propagation, while fibers incorporated in the crack wake provide a load transfer path to maintain load carrying capacity and restrict crack growth. The addition of multiscale fiber reinforcement optimizes fiber-crack interactions through the process of delaying macro crack formation and providing post cracking ductility. **P. Rossi (1997)** started the concept of multi scale fiber incorporation into concrete in which the studies focused on steel fiber and multi fiber additions respectively. The mix developed is described by **J. Blunt and Ostertag (2009)**, they advanced in the study by incorporating both steel and polyvinyl alcohol (PVA) fiber types and shall hereafter be referred to as Hybrid Fiber Reinforced Concrete (HFRC).

II. literature review

Antonio Caggiano (2012) discussed the results of experimental tests performed on concrete specimens reinforced with polypropylene and steel fibers. Specifically, samples of five mixtures (plus a reference plain concrete), characterized by the same total volume of fibers, but different fractions of polypropylene and steel fibers, and were tested under compression and in bending. This study was aimed to clarify the influence of different combinations of these fibers on the resulting fracture behavior of Hybrid Fiber-Reinforced Concrete (HFRC). Besides, FRC specimens made of only polypropylene fibers exhibited an excellent post-cracking toughness for the small crack opening ranges of relevance for the Serviceability Limit State, while an apparent decay was observed in terms of post-cracking response, especially at wide crack openings.
On the other hand, a marked re-hardening response was observed in the post-cracking behavior for specimens with higher percentage of steel fibers; however, at the same time, the corresponding results showed a relevant scatter.
Shaikh Faiz Uddin Ahmed (2006) investigated the Strain hardening and multiple cracking behavior of hybrid fiber reinforced cement composites containing different hybrid combinations of steel and polyethylene (PE) fibers under four-point bending are reported. The total volume fraction of fibers was kept constant at 2.5% to maintain a workable mix. Generally, the steel–PE hybrid composites exhibited lower flexural strength but higher deflection capacity than steel–PVA hybrid composites. The rate of strength loss after peak load in steel–PE hybrid composites was found low compared to steel–PVA hybrid system. The 50% replacement of cement by fly ash is found to be an optimum fly ash content in hybrid fiber composites.

Jing Jun Li (2017) investigated the effect of high-performance polypropylene (HPP) fiber on the mechanical properties of lightweight aggregate concrete (LWC). The mechanical properties include the compressive strength, splitting tensile strength, flexural strength, flexural toughness and the impact resistance. Two types of interfacial transition zone (ITZ) at aggregates/cement paste and fibers/cement paste were investigated by using Scanning Electron Microscope (SEM). The experimental results showed that the addition of HPP fibers in LWC could significantly improve its mechanical properties due to better bond property between aggregates and cement paste than that between fibers and cement paste, the aggregate-paste interface is not the weakest link in LWC.

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When the addition of HPP fibers is increased beyond 9 kg/m3 (0.95% Vol.), the dispersion of fibers becomes very difficult. Based on various mechanical strengths, to enhance the mechanical properties of concrete, the optimal fiber content of 9 kg/m3 (0.95% Vol.) is recommended.

Cengiz Duran Atis (2009) reported the comprehensive study on the properties of concrete containing fly ash and steel fibers. Properties studied include unit weight and workability of fresh concrete, and compressive strength, flexural tensile strength, splitting tensile strength, elasticity modulus, sorptivity coefficient, drying shrinkage and freeze–thaw resistance of hardened concrete. Fly ash content used was 0%, 15% and 30% in mass basis, and fiber volume fraction was 0%, 0.25%, 0.5%, 1.0% and 1.5% in volume basis. The laboratory results showed that steel fiber addition, either into Portland cement concrete or fly ash concrete, improve the tensile strength properties, drying shrinkage and freeze–thaw resistance. However, it reduced workability and increased sorptivity coefficient. Although fly ash replacement reduces strength properties, it improves workability, reduces drying shrinkage and increases freeze–thaw resistance of steel fiber reinforced concrete.

III. materials

Cement:
Ordinary Portland cement of 53 grade, conforming to IS: 12269-1999 with particle size of 90µ has been used in the present investigation. The specific gravity, standard consistency was 3.12 and 32% respectively.

Fine Aggregates:
Locally available river sand conforming to Zone-II as per IS: 383-1999 has been used. The bulk density, specific gravity, and fineness modulus of the sand were 1.41g/cc, 2.68, and 2.9.

Coarse Aggregates:
Crushed granite aggregate of maximum 16 mm size conforming to IS: 383-1999 has been used. The bulk density, specific gravity and fineness modulus of the coarse aggregate were 1.46g/cc, 2.7 and 7.1.

Fly ash:
Fly ash of Class F conforming to IS: 3812: Part-II-2003 obtained from Ramagundam thermal power plant (India) with a specific gravity of 2.18 and fineness of 6422 cm^2/gm was used.

Glass Fibers:

Glass fiber of 6 mm length and tensile strength 1700 MPa were used. Aspect ratio of glass fibers was 428.57.

Polypropylene Fibers:

Tensile strength of polypropylene fibers was 350 N/mm^2, with an aspect ratio of 545.

Water:
Water plays a vital role in achieving the strength of concrete. For complete hydration it requires about $3/10^{th}$ of its weight of water. It is practically proved that minimum water-cement ratio 0.35 is required for conventional concrete. Water participates in chemical reaction with cement and cement paste is formed and binds with coarse aggregate and fine aggregates. If more water is used, segregation and bleeding take place, so that the concrete becomes weak, but most of the water will absorb by the fibers.

IV. experimental program

The investigation was aimed at studying the effect of glass fibers and polypropylene fibers on the standard specimens. Compressive strength and split tensile strength were evaluated on M60 concrete. Mix proportioning of concrete was based on guidelines of IS 10262: 2009. To study effect on strength of concrete the specimens was tested for 28 days of curing. Standard cubes (150x150x150 mm) were cast to investigate the behavior on mechanical properties. Slump and Compaction factor were done to test the effect on workability of concrete due to hybrid fibers. The inclusion of glass fibers varied from 0 to 0.09% with an increment of 0.03% i.e. 0, 0.06%, 0.09% by volume of concrete. The inclusion of polypropylene fibers varied from 0 to 0.2% with a variation of 0, 0.1%, and 0.2% by volume of concrete. The cement was replaced with flyash by 30% by weight of cement.

Table 1 - Mix Proportions of M60 grade in kg/m^3

Cement	Fly ash	Fine Aggregate	Coarse Aggregate	Water
435	130	812	765	175

V. results and discussion

Workability:

Workability test is performed on the fresh concrete by slump cone and compaction factor test. Slump cone test and compaction factor were conducted as per Indian standards as explained in previous chapter. The results of slump cone and compaction factor test for M60 grade of concrete with fibers are shown in table 2.

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Table 2 – Slump and compactor factor test values of concrete with glass and polypropylene fibers.

Dosage of Glass and polypropylene fibers (%)	**Slump (mm)**	**Compaction Factor Test**
0	98	0.95
GF(0.06)+PF(0.1)	89	0.94
GF(0.06)+PF(0.2)	82	0.91
GF(0.09)+PF(0.1)	78	0.89
GF(0.09)+PF(0.2)	69	0.87

Figure 1: Effect of glass and polypropylene fibers on workability of concrete

Mechanical Properties:

Compression testing machine of 2000 KN has been used for test the compressive strength. The results of compressive strength are given in the Table 3.

Table 3 – Compressive strength of M60 grade of concrete with glass and polypropylene fibers.

Percentages of fibers used	3 days N/mm^2	7 days N/mm^2	28 days N/mm^2
Controlled concrete	27.57	44.81	68.25
GF(0.06)+PF(0.1)	29.55	45.81	70.2
GF(0.06)+PF(0.2)	30.75	46.07	72.4
GF(0.09)+PF(0.1)	35.13	49.95	76.5
GF(0.09)+PF(0.2)	31.83	46.95	73.3

GF(0.06)+PF(0.1)	3.25	4.51	4.83
GF(0.06)+PF(0.2)	3.07	4.61	4.97
GF(0.09)+PF(0.1)	3.49	4.94	5.33
GF(0.09)+PF(0.2)	3.27	4.27	5.1

Figure 2: Effect of glass and polypropylene fibers on Compressive strength.

Table 4 – Split tensile strength of M60 grade of concrete with glass and polypropylene fibers.

Percentages of fibers used	3 days N/mm^2	7 days N/mm^2	28 days N/mm^2
Controlled concrete	2.76	4.03	4.56

GF(0.06)+PF(0.1)	3.81	4.72	7.21
GF(0.06)+PF(0.2)	3.89	4.74	7.42
GF(0.09)+PF(0.1)	4.14	4.97	7.82
GF(0.09)+PF(0.2)	3.94	4.69	7.26

Figure 3: Effect of glass and polypropylene fibers on Split tensile strength.

Table 5 – Flexural strength of M60 grade of concrete with glass and polypropylene fibers.

Percentages of fibers used	3 days N/mm^2	7 days N/mm^2	28 days N/mm^2
Controlled concrete	3.67	4.63	6.91

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Figure 3: Effect of glass and polypropylene fibers on Flexural strength.

VI. conclusions

A. Compressive strength of concrete increased with the increase in percentage of glass and polypropylene fibers.

B. Inclusion of fibers effected the workability of concrete, the max dosage of glass (0.09%) and polypropylene (0.2%) fibers adversely effected the slump value of concrete.

C. Compressive strength has marginally increased with inclusion both fibers in all dosages.

D. The effect of hybrid fibers is seen significantly in tensile properties (Split tensile and Flexural strength) of concrete.

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