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Comparative Study On The Behaviour Of Hybrid Fiber Reinforced Concrete Using Basalt Fiber And Polyolefin Fiber

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Abstract - *Hybrid fiber reinforced concrete has shown high performance in both fresh and hardened state. A composite can be termed as hybrid, if two or more types of fibers are rationally combined in a common mix to produce a composite that gives benefits from each of the individual's fibers and exhibits a synergetic response. Combination of basalt fiber and polyolefin fiber together in a concrete shows very good results. This paper focuses on the experimental investigation carried out on hybrid fiber reinforced concrete (combination of basalt fiber and polyolefin fiber) with different volume fraction of concrete. Addition of basalt fiber generally contributed towards the mechanical properties, namely compressive strength, flexural strength, split tensile strength whereas, polyolefin fibers resulted in controlling the propagation of cracks and effectively improved in flexural toughness. Basalt fiber reinforced concrete (BFRC) with 12 mm length fibers are comparable to steel fiber reinforced concrete (SFRC). Fiber length, fiber dosage and concrete strength are the major factors that depends polyolefin fiber reinforced concrete (PFRC). Studies are done on hybrid fiber reinforced concrete short columns axially loaded in compression to failure. A total of 10 columns specimens comprising of two normal RCC columns, four fiber reinforced short columns, and four hybrid fiber reinforced short columns were tested. Result shows that M30 design mix concrete amalgamated with 0.75% basalt fiber and 0.25% polyolefin fiber is a good hybrid fiber reinforced concrete (HFRC). Hybrid fiber reinforced concrete not only increases the strength but also have influences on the crack patterns of columns. Results show that a combination of Basalt and polyolefin fibers can be efficiently used to optimize the behavior of concrete in fresh and hardened state.*

Key Words*: fiber reinforced concrete (HFRC), short column, Basalt fiber reinforced concrete (BFRC), polyolefin fiber reinforced concrete (PFRC), steel fiber reinforced concrete (SFRC)

1.INTRODUCTION

Industries are always trying to find new, advanced and economical material to manufacture new products with more strength, workability etc. In the recent years, various fibers developed and used in the construction industries all over the world. Many problems that faces in construction industries can be overcome by reinforcing with short discontinuous fibers. The concept of using fibers as reinforcement is not new. Fibers have been used as reinforcement since ancient times. Historically, horsehair was used in mortar and straw in mud bricks. Different types of fibers are available today. Low cost high performance fibers offer potential to solve cracking and structural failure of concrete. Earlier results shows that the addition of non-metallic fibers such as glass, polyester, polypropylene etc. results in good fresh concrete properties and reduced early age cracking. some non-metallic fibers also helps to improve mechanical properties of concrete. Basalt fiber is a high performance non-metallic fiber made from basalt rock melted at high temperature. Properties of fiber is compatible with metallic fibers basalt fiber has good hardness and thermal properties and has been successfully used for foundation such as slabs on ground concrete.[4-6]. Polyolefin fibers are also non-metallic fibers. Fiber length, fiber dosage and concrete strength are the major factors that depends polyolefin fiber reinforced concrete (PFRC**).**

A composite can be termed as hybrid, if two or more types of fibers are rationally combined in a common mix to produce a composite that gives benefits from each of the individual's fibers and exhibits a synergetic response. In this study experimental investigation on cube, cylinder and beam are done initially with various percentage of fibers. By taking the optimum values of fibers hybrid fiber reinforced concrete has been tested. A total of 10 columns specimens comprising of two normal RCC columns, four fiber reinforced short columns, and four hybrid fiber reinforced short columns were tested. Result shows that M30 design mix concrete amalgamated with 0.75% basalt fiber and 0.25% polyolefin fiber is a good hybrid fiber reinforced concrete (HFRC).

2. LITERATURE REVIEW

Several reports on the design and construction reinforced concrete have been published which provide information on the use of basalt fiber and polyolefine fiber materials. "A. Sivakumar, Manu Santhanam" (2007)carried out experimental investigation on high strength hybrid fiber reinforced concrete up to a volume fraction of 0.5%. Result shows Metallic fibers improves flexural strength and toughness, Non-metallic fiber delaying the formation of crack Chaohua Jiang, Ke Fan, Fei Wu, Da Chen (2014) done experimental investigation using basalt fiber. Adding Basalt fiber significantly improves the tensile strength, flexural strength and toughness index, whereas the compressive strength shows no obvious increase. "Iftekar Jongsung Sim, Cheolwoo Park, Do Young Moon"(2005) done flexural strengthening evaluation, the basalt fiber strengthening improved both the yielding and the ultimate strength of the beam specimen up to 27% depending on the number of layers applied. "M.G. Alberti, A. Enfedaque, J.C. Gálvez"(2014) done experimental study on the mechanical properties and fracture behavior of polyolefin fiber-reinforced self compacting concrete. Result shows that polyolefin fiber slightly diminishes compression strength of SCC. It also helps to increase tensile strength, fracture energy and ductility of SCC. "Bing Chena, Juanyu Liu" (2012) investigated Residual strength of hybrid-fiber-reinforced high-strength concrete after exposure to high temperatures. normal HSC is prone to spalling after exposure to high temperatures, and its first spalling occurs when the temperature approaches 400ºC. HSC with high melting point fibers – spalling occurs at 800ºC. "*Marek Urbanskia, Andrzej Lapkob, Andrzej Garbaczc"(2013)* Investigation on Concrete Beams Reinforced with Basalt Rebars as an Effective Alternative of Conventional R/C Structures. It was noted that critical load for tested beams reinforced with BFRP bars was much greater than the carrying capacity of beams with conventional steel reinforcement. The failure of beams with BFRP reinforcement did not occur suddenly due to flexural BFRP reinforcement. "*Zongcai Deng a, Feng Shi b , Shi Yin c, Rabin Tuladhard"(2016)done experiments on* Characterization of macro polyolefin fibre reinforcement in concrete through round determinate panel test. A new characterisation method using toughness index based on RDPT was presented. A combined synergetic effect of fibre length, dosage and concrete strength was found. Equivalent reinforcement was achieved by adjusting combinations of fiber dosage, length and concrete strength. CFRP."WU Gang1,WEI yang, JIANG Jianbiao ,GU Dongsheng, HU xianqi"(2010) conducted a Comparative Study on Seismic Performance of Rectangular Concrete Columns Strengthened with BFRP and CFRP Composites. Test results show that basalt fiber tow winding retrofit technology can significantly improve the shear strength of the concrete columns, change the failure modes. Contrasting to the columns wrapped with CFRP, it is confirmed that with similar lateral confinement stiffness, the strength and ductility, energy absorbing and other structural performance of the columns wounded with BFRP could be achieved, while the price of BFRP is lower. It is worthy to be widely applied to strengthen engineering structures. From the literature surveys it can be concluded that regarding to improve the mechanical properties, shearing loading etc of ordinary concrete columns, lots of researchers have been looking for different strengthening materials. Steel sleeves and fiber reinforced polymer (FRP) were already acknowledged successfully in different periods. Influence of two different type fibers gives a synergetic response of each fibers. Combination of Basalt and polyolefin fibers can be efficiently used to optimize the behavior of concrete in fresh and hardened state.

3. MATERIAL USED

3.1 Material Properties

3.1.1 Cement

Ordinary Portland cement of Dalmia brand of grade 53 conforming to IS 12269:1987 was used. The properties of cement are given in the table 1.

Table 1: Properties of Cement

Sl. No	Property	Result
1	Specific gravity	3.16
2	Standard consistency	34%
3	Initial setting time	98 minutes
4	Final setting time	308 minutes
5	Fineness of cement	1.82%
1	Specific gravity	3.15

3.1.2 Fine Aggregate and Coarse Aggregate

M-sand, clear from organic impurities conform to IS 4031: 1988 and crushed stones of 20mm, 12.5mm and 6mm sizes conform to IS 2386: 1963 part 3 were used.

Properties of fine and coarse aggregate are shown in Table 2 and gradation curve of fine aggregate are in Figure 2.

Table 2: Properties of Fine and Coarse Aggregate

Sl. No	Property	Result
1	Specific gravity of fine aggregate	2.60
2	Specific gravity of coarse aggregate	2.77
3	Water absorption	0.52%

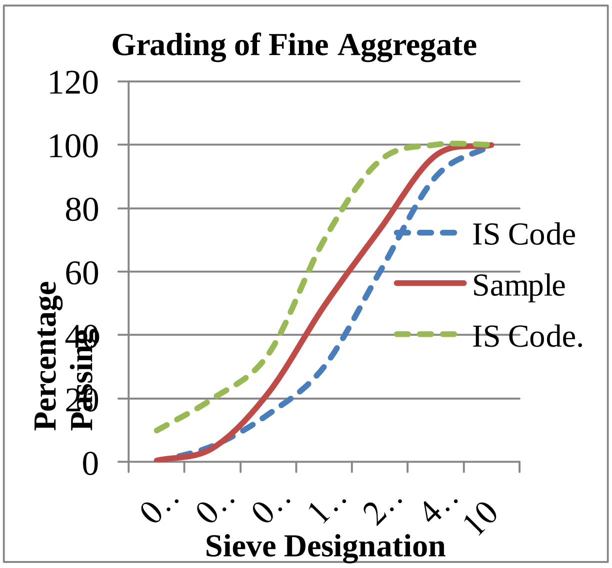

Figure 2: Gradation curve of fine aggregate

3.1.3 Super Plasticizer

Auromix 300 was used as Super plasticizer. Properties of Auromix 300 are shown in table 3.

Table 3: Physical and Chemical Properties of Super Plasticizer

Sl. No	Property	Result
1	Appearance	Yellow coloured liquid
2	Ph	Minimum 6
3	Volumetric massat 20°C	1.09kg/liter
4	Dosage	0.5-0.3 liter/100kg of cementatious material

3.1.4 Basalt Fiber

12 mm length size Basalt fiber was used. It helps to increases Compressive strength, tensile strength and toughness of concrete.

Properties of Basalt Fiber

a) Physical Properties

Color:- available in golden brown in color.
Diameter:- available in different diameter.
Length:- Available in 6mm,8mm,12mm etc.
Density:- 2.75 g/cm^3
Coefficient of friction:- 0.42 to 0.50

b)Chemical Properties

Basalts are more stable in strong alkalis. Weight loss occurs in boiling water, Alkali and acid is also significantly lower. Possess resistance to UV- Light & biologic and fungal contamination.

Figure 3: Micro Steel Fiber

- **3.1.5. Polyolefin fiber**

Polyolefin is any of a class of polymers produced from a simple olifen a synthetic fiber having low moisture absorption. Keeps its strength in wet or dry conditions and is very resilient. Finer is more effective. Have plastic stress strain characteristics. Density is about 0.986 g/mm^2. Polyolefin fiber are shown in figure 4.

Figure 4: E-Waste fiber

4. EXPERIMENTAL INVESTIGATION

4.1.Concrete Mix Design

Concrete mix design was done as per IS 456:2000 and IS 10262:2009. Mix proportion for M30 mix is given in table 5.

Table 5: Mix Proportion

Sl No.	Material	Quantity(Kg/m^3)
1	Cement	350
2	Fine Aggregate	760
3	Coarse Aggregate	1220
4	Water	160
5	Super Plasticizer (0.4%mass of cement)	1.45
6	Water Cement Ratio	0.45
Mix Proportion (C:FA:CA:W)		**1:2.17:3.48:0.45**

4.2.Design of Column

Design of column was done as per IS 456:2000. As per the design, 4 numbers of 12mm diameter bars were provided as main reinforcement and 8mm diameter bars are used as transverse reinforcement. Cover provided is 20mm. The reinforcement detail for column is shown in figure 5.

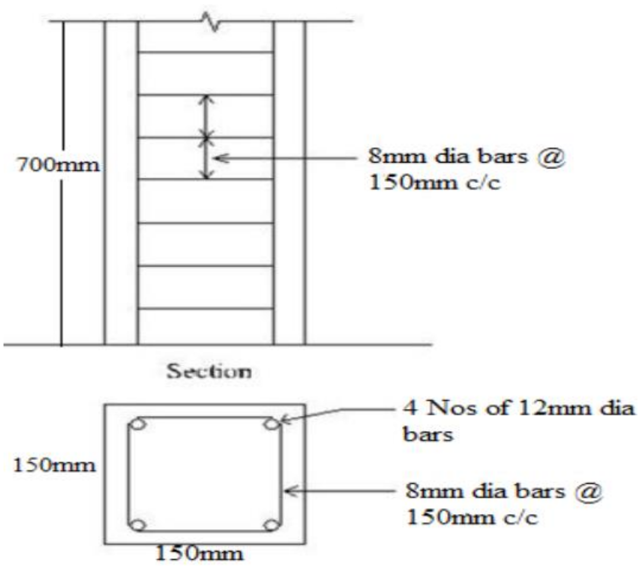

Figure 5: Reinforcement details of column

4.2. Test Specimen Details

An experimental research has been planned to study the behavior of short columns having 150 mm×150 mm×700 mm size in-filled with different types of concrete such as normal M30 mix, Basalt fiber reinforced concrete, polyolefin fiber reinforced concrete and hybrid fiber reinforced concrete (HFRC). To obtain suitable fiber reinforced concrete mix for columns several trials were done by standard compression test, flexural test and slit tensile test on cube, beam and cylinder respectively. From those test results the optimum dosages of different fibers was determined. Details of column specimens were given in table 6.

Table 6: Details of Test Specimen

Specimen	Specimen Designation	Percent of Basalt Steel Fiber	Percent of Polyolefin Fiber
RCC Column	C1	0	0
BFRC Column	C2	0.5	0
BFRC Column	C3	0 .75	0
PFRC Column	C4	0	0.25
HFRC Column	C5	0.75	0.25

4.3.Test setup

All short column specimens were tested on UTM (1000kN) as shown in figure 6. The test procedure of all the columns was same. The columns were cured for a period of 28 days and then the surface of columns cleaned and white wash were applied for the clear visibility of cracks. Load was applied on the column specimen until the failure took place. Axial strain of column noted at equal interval with help of strain gauge. Then ultimate load and corresponding strain was noted. The average of the few trials was taken and the stress-strain graph was plotted.

Figure 6: Test set up

V. RESULTS AND DISCUSSIONS

5.1. Standard Test Results

Compressive strength of concrete cubes for different HFRC mix, BFRC mix, PFRC and normal M30 are shown in table 7.

Table 7: Compressive strength of cubes

Concrete mix	% of Basalt fibers	% of Polyolefin fiber	Average compressive stress in 28 days(N/mm2)
Normal Mix	0	0	37.96
BFRC	0.25	0	38.34
	0.5	0	39.34
	0.75	0	40.67
PFRC	0	.15	33.37
	0	.25	38.12
	0	.35	36.48
HFRC	0.25	0.25	38.36
	0.5	0.25	41.11
	0.75	0.25	45.16

From the compression test results of HFRC cubes 0.75% basalt fiber and 0.25% polyolefin fiber were fixed as the optimum dosage. From the results of compressive strength, split tensile strength and flexural strength of cube, beam and cylinder for normal M30 mix concrete and finalized HFRC mix.

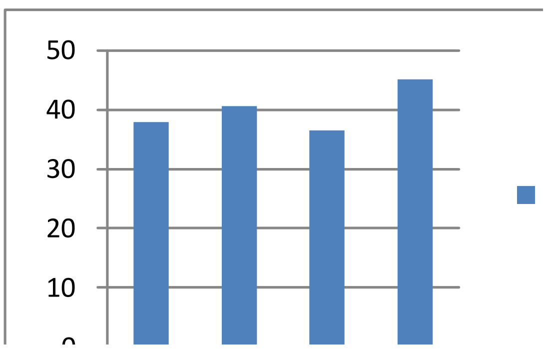

Fig 8: Comparison of 28 Days Compressive Strength of Different Mixes

5.2. Short Column Test Result

Comparison of failure pattern and strain relationships is presented. The ultimate load carrying capacities are calculated and are plotted. Hybrid fiber reinforced column specimen shows increase in ultimate load carrying capacity compared to normal specimen. In hybrid fiber reinforced column 87 % increase in ultimate load carrying capacity. Increase in load carrying capacity is due to the effect of fibers, they provide structural integrity to concrete and prevent the formation of micro cracks. The ultimate load carrying capacities of each column specimens are graphically plotted and compared with the control specimens.

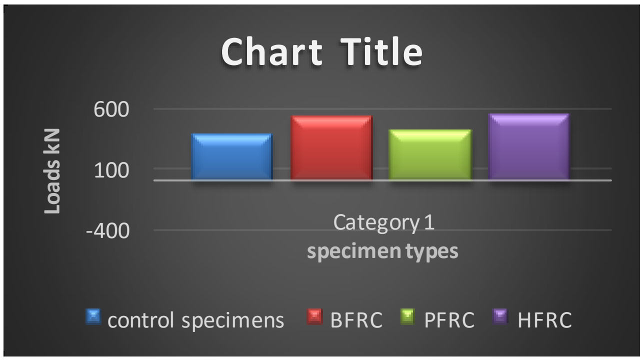

Figure 9: ultimate load values

5.3.Failure Pattern

Test was continued until the failure of the specimen occurs. Total a number of 5 specimens were tested. When the short columns are axially loaded, the reinforcement steel and concrete experience stress. It was found that HFRC short column showed higher resistance compared with normal RC column. Failure mode of specimen divided into three types based on their material properties and geometric configuration. From the failure patterns of the normal RC specimens it is clear that the failure occurs mainly due to crushing. As long as it is a short column there is no chance of buckling. Due to crushing failure the cracks are mainly seen at the top and bottom of the column specimen as shown in figure 10. The ultimate load carrying capacities of each column specimens are graphically plotted and compared with the control specimens.

Fig. 10: failure pattern of column

5.4.Stress-strain curves

In order to study the behavior of concrete columns, to plot appropriate analytic stress-strain graph. The better stress-strain graph results in reliable estimation of strength and deformation behavior of the structural members. The stress strain curve for normal specimen, BFRC, PFRC and hybrid fiber reinforced concrete short column were obtained. Figure 11 shows the stress strain curve for hybrid fiber reinforced concrete short column. Here the load values are taken upto 400kN. Figure 12 shows the stress strain curve of normal specimen.

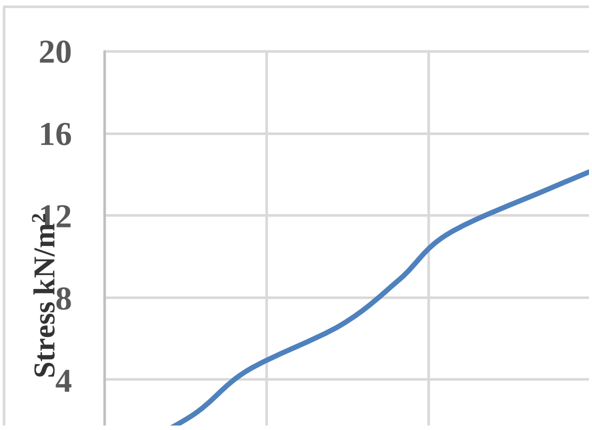

Figure 11: Stress train behavior of normal short column

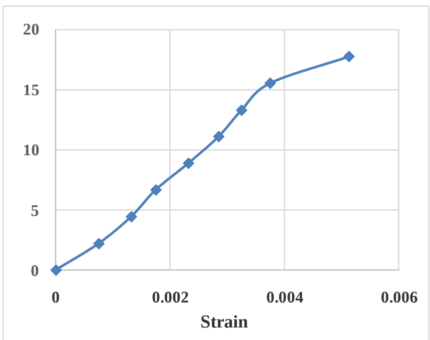

Figure 12: Stress train behavior of HFRC short column

3. CONCLUSIONS

Concrete short columns with or without fiber content were tested under axial loading condition. The behavior of short columns was analyzed with respect to ultimate load carrying capacity, and failure modes. From the experimental study the following conclusions were drawn.

- Hybrid fiber reinforced columns have 87 % increases in maximum load carrying capacity than that of the normal RC column due to the addition of fibers.
- In Basalt fiber reinforced column 80% increase in ultimate load carrying capacity. Increase in load carrying capacity is due to the effect of fibers, they provide structural integrity to concrete.
- Hybrid fiber reinforced concrete short columns were capable of carrying large amounts of strain than normal RC column.
- Polyolefin fiber enhances the crack initiation and its propagation.
- PFRC column have least buckling. Strain at ultimate load is about 0.00058, because of the increased ductility and crack resistance.

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