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Shear Strength of Concrete Beams by Using Basalt Fibres

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***Abstract*— During the past 5 decades, the concrete construction field has seen a growing interest in the advantages that fiber reinforcement has to offer. Between the different types of fibers available basalt fiber is considered promising new material to use. It has extremely good strength characteristics and thermal resistances, high resistances to an alkaline environment, and is cheap product, making it an excellent material to reinforced concrete in view of the significant of basalt fiber for concrete and because different lengths and proportion of basalt fibers have an effect on the mechanical properties of concrete, it is proposed to review the effect of using different basalt fiber lengths and content on the mechanical properties of concrete. The mechanical properties of concrete reviewed are compressive strength, tensile strength, shear strength, workability and unit weight. The research work will be carried out on experimental investigation of basalt fiber reinforced concrete. Properties of concrete checked by testing cubes, cylinder and beams the specimens are casted using M30 grade concrete with locally available material. The object of present work is to study effect of different proportion of fibers in the mix design and find out optimum percentage of fibers with maximum strength criteria. The specimens like cubes, cylinder and beams tested for compressive strength, split tensile strength and shear strength**

***Index Terms*— Concrete, Basalt fibers, Fine Aggregate (FA), Coarse Aggregate (CA)**

I. INTRODUCTION

Concrete is known as the construction material most used around the world it is strong in compressive as the aggregates can effectively carry the compression load. However, concrete is weak in tension, as the cement holding the aggregate can crack, causing concrete to break an effective way to improve the tensile strength of concrete and reduce the number of defects is by adding different fraction of fibers.

Plain concrete is very weak in taking tension because it contains numerous micro-cracks. When an externally applied load will act on the matrix, the micro cracks begin to propagate. As a result, plain concrete members cannot withstand tensile stresses developed due to the applied forces without the addition of rebars in the tensile zone. Thus a rapid propagation of micro-cracks and macro-cracks will occur and it cannot be arrested or slowed by the use of continuous reinforcement. So a number of studies are concentrated over this area to modify the properties of concrete. Most of the studies found that by the addition of fibers, cracking was controlled and the mechanical properties of plain concrete such as durability and serviceability of the structure were improved.

Basalt fiber is produced from a volcanic rock called Basalt and it is an inorganic material. The basalt fibers are environmentally safe and it is non-toxic in use. Basalt fiber reinforced polymer is a material made from fine basalt particles. It was manufactured by melting the basalt rock. This basalt fiber reinforced polymer does not contain any other additives BFRP have a better tensile strength compared to other fiber reinforced polymer bars.

Basalt fiber is a “multi-performance” fiber. For example, it is resistant to alkalis and acids ;it is thermally, electrically and sound insulated; its tensile strength can be greater than large tow carbon fiber, its elongation is better than tow carbon fiber.

Basalt fiber is one of the natural fibers because it will be extracted from the basalt rock. The only crushed rock to be used in the manufacturing of a fiber is the basalt fiber. The fiber is obtained by melting the igneous basalt rock for about 2,700° F. Basalt fiber has high modulus of elasticity than glass fiber so it acts as better replacement of glass rebar in the concrete beam . It is good resistance to salt, alkali’s, impact load and fire. so, it enhances the mechanical and impact strength than the carbon fiber concrete. Basalt fibers with different percentages 0%, 1% and 2% are being used in this study in volume fraction

II. LITERATURE REVIEW

Use of Basalt Copped Fiber as Reinforced material in the concrete has enhanced the strength and stiffness of the concrete. Basalt Chopped Fiber has number of favorable mechanical properties; reinforcing material possesses high tensile strength, thermal resistance and high resistance to an alkaline environment and is economical making it an excellent material to reinforce concrete. The following section gives a brief about the literature carried out by the different authors on Basalt Chopped Fibers.

Arivalagan et al. [2012] concluded that the usage of Basalt fibers in low cost composites for civil infrastructure applications gives good mechanical properties like strength and lower cost predicted for basalt fiber. Basalt fiber has used as a cost effectively replace to fiberglass, steel fiber, polypropylene, polyethylene, polyester, aramid and carbon fiber products in many applications.

Abdulhadi [2014] studied the effect of basalt and polypropylene fibers with different volumes and concluded that the compressive strength for C30 grade of concrete from to different type of fiber at different volume fraction shows different degree of reduction. The addition of 0.3%, 0.6%, 0.9% and 1.2% resulted in a decrease of compressive strength relative to plain concrete by 9%, 19%, 1% and 18% respectively. Similarly, addition of 0.3%, 0.6%, 0.9%and 1.2% volume of polypropylene resulted in a decrease of strength relative to plain concrete by 8%,7%,17%and 1% respectively. It was observed that the incorporation of fibers in the concrete matrix greatly increases splitting tensile strength. The addition of 0.3% and 0.6% volume of basalt fiber increase the splitting tensile strength of concrete of concrete by 2.6% and 22.9% respectively; while for 9% and 1.2% volume, the splitting tensile strength of concrete decreased by 11.3% and 19.8% respectively; therefore, the optimum dosage for the splitting tensile strength basalt fiber is in the vicinity of 0.6%.also , addition of 0.3%,0.6% and 0.9% volume of polypropylene fiber increased the splitting tensile strength of concrete by 15.11% , 7.8% and 5.6% respectively; therefore the optimum dosage for the splitting tensile strength of polypropylene fibe

Mumthas and Riyana [2020] this paper deals with the structural behavior of chopped basalt fiber reinforced concrete deep beam and compressive strength property of fiber reinforced concrete. The fiber reinforced concrete has been one of the top most innovations in concrete technology, highlighting improved structural integrity of the structure. This present work deals with experimental study of compressive strength of chopped basalt fiber reinforced concrete and the influence of fiber in deep beam behavior. In order to determine the optimum fiber percentage in concrete , cube specimens are prepared with varying percentage of basalt fiber adding like 0.1%, 0.15%, 0.2% . Performance analysis of normal concrete deep beam and fiber reinforced concrete deep beam are made on the basis of initial cracking load, number of cracks, diagonal cracking behavior, moment carrying capacity, ultimate load, pre cracking and post cracking behavior etc. In results we have found that basalt fibers can be used as an additive to enhance the concrete quality, and in deep beam it affect the width of diagonal cracks, shear and flexural cracking behavior, initial cracking load, Ultimate failure load, number of cracks etc. But it does not made significant change in moment carrying capacity.

Manibalan and R.Baskar [2020] the experiment investigation of basalt fiber concrete was done and concluded the behavior of compressive, tensile and flexural strength. The role of fiber was effective in the mechanical behavior of concrete. The specimen of all basalt fiber concrete as BF 0.3, BF 0.6, BF 0.9 and BF 1 showed the better strength than the conventional concrete. The addition of basalt fiber as 0.9% (BF 0.9) enhanced the compressive strength of 30% than the conventional concrete. The basalt fiber of 0.9% (BF 0.9) concrete increased the tensile strength as 64% than the conventional concrete. The basalt fiber of 0.9% (BF 0.9) concrete increased the flexural strength as 42% than the conventional concrete. From these results, the basalt fiber was an excellent alternate fiber for enhancing the mechanical properties of concrete. The concrete strength was depending upon the dosage of fiber. In this paper 0.9% of fiber shows the excellent result and 1% shows the significant reduction due to uneven dispersion of fiber. It leads a further research towards the ductile behavior of concrete beams due to its ductility and strain hardening.

III. MATERIALS AND METHODOLOGY

Cement: OPC grade 53, confirming to IS 456-2000 with a specific gravity of 3.15 will be used. Cement is a binder, a substance that sets and hardens and can bind other materials together. The word "cement" traces to Romans, who used the term opuscaementicium to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick supplements the were added to the burnt lime, to obtain a hydraulic binder, were later referred to as cementum, cimentum and cement. Ordinary Portland cement of 53 grades and specific gravity of 3.15 confirming to IS 269-1976 is used in the present investigation. It was tested for its physical properties in accordance with Indian Standard specifications

Fig-1: Cement

Fine Aggregates: Fine aggregate can be defined as the aggregate which passes through 4.75mm IS sieve and retained on 75micronsieve. Fine aggregate is available from river or can be obtained from crushing stone (Manufacture sand).Fine aggregate can be divided based on their particle size

1) Coarse sand. 2) Medium sand. 3) Fine sand

Fine aggregates was obtained from locally available river sand or the powder of crushed stone , clear from all organic impurities was used in this experimental program. The fine aggregates passing through 4.75 mm sieve and having specific gravity of 2.60 were used. The grading of fine aggregates was done and fall in zone II as per Indian Standard specifications.

Fig-2: Fine Aggregate

Coarse Aggregates: The broken stone is generally used as a coarse aggregate locally available coarse aggregate of 20 mm down size will be used in the present work. Aggregate that is retained on 4.75mm sieve after passing through 80mm sieve are known as coarse aggregates. It may be crushed gravels or hard stones uncrushed gravels or stone. These aggregates commonly obtained from stream deposits, glacial deposits and alluvial fans.

The coarse aggregates used were non-reactive available from local quarry. The coarse aggregates passing through 20 mm and retained on 10 mm sieve were used in the present experimental program. The specific gravity of coarse aggregate is 2.60.

Fig-3: Coarse Aggregate

Water: Water to be used in the concrete work should have following properties

- It should be free from injurious amount of soils.
- It should be free from injurious amount of acids, alkalis or other organic or inorganic impurities.

- It should be free from iron, vegetable matter or any other type of substances, which are likely to have adverse effect on concrete or reinforcement.
- It should be fit for drinking purposes. The function of water in concrete.
- It acts as lubricant.
- It reacts chemically with cement to form the binding paste for coarse aggregate and reinforcement.
- It enables the concrete mix to flow into frame.

Ordinary tap water is used for casting and curing operation for the work. The water supplied in the campus is of the portable standard of Ph value= 7.50 are used.

Basalt fiber: Basalt fiber is a material made from extremely fine fibers of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine. The fibers used in the study are of 14 mm in diameter and 16 mm in length. Fibers used for this work are 1.5% and 2% by the weight of cement.

Fig-4: Basalt Fiber

METHODOLOGY

To accomplish the above set objectives in the present study mix design of M3s0 shall be developed. Shear strength of the beam is evaluated under monotonic four points loading using 500 KN servo controlled actuator. Crack pattern is noted. The set-up for the test is shown in Fig.3.1. The test beam of 1000 mm long, simple supported over a span of 1200 mm and tested under two concentrated loads placed symmetrically 370 mm apart. At the two ends of the beam, one hinge support was set available for the beam to rotate freely, and the other one a roller support allowing the beam to rotate and move in horizontal direction. A calibrated load cell will be placed A calibrated load cell will be placed beam while two linear displacement transducers (LVDT) are properly placed at mid-span section to measure the deflection during the test. The load will be applied by 500KN servo controlled actuator. A data acquisition system of the model will be employed while the load test shall be conducted. Both the loads and displacements shall be simultaneously monitored and recorded by way of load cell and LVDT during the loading process.

IV. MIX DESIGN & BATCHING PROPORTIONS

MIX DESIGN OF M30 GRADECONCRETE

Grade designation	M30
Type of cement	OPC 53grade
Maximum size of aggregates	20mm
Degree of workability	0.90 compaction factor
Degree of quality control	Good
Type of Exposure	Mild
Type of aggregates	Angular

Test data for materials

Specific gravity of cement 3.15

Compressive strength of cement aggregate satisfies the requirement of IS:269 -1989

Specific gravity of coarse aggregates 2.60

Specific gravity of fine aggregates 2.60

Water absorption

Coarse aggregate 0.50%

Fine aggregate 1.0%

Free (surface) moisture

Coarse aggregate nil

Fine aggregate nil

Target Strength for Mix Proportioning

1. Target mean strength: 36.6N/mm^2

F'ck	=	fck+1.65*s (IS 10262:2009)
	=	30+1.65*5
	=	38.25N/mm^2
f'ck	=	fck+x (IS 10262:2019)
	=	30+6.5

= 36.5N/mm^2

Characteristic strength at 28day : 30N/mm^2
Maximum water cement ratio : 0.55

Adopted water cement ratio : 0.50

Maximum water content : 186 kg/m^3

Estimated water content : 191.3 kg/m^3

Calculation of cement content

Water cement ratio : 0.5

Cement content : 383 kg/m^3

Mix calculations
Mix calculations present volume of concrete shall as

Volume of concrete in m^3 : 1 m^3

Volume of cement in m^3 : 0.121 m^3

Volume of water in m^3 : 0.191 m^3

Volume of all in aggregatem^3 : 0.688 m^3

Mass of coarse aggregate in kg/m^3 : 1188 kg/m^3

Mass of fine aggregate in kg/m^3 : 546 kg/m^3

Water (Lts)	Cement (Kgs)	FA (Kgs)	CA (Kgs)
369.2	738.5	553.9	1107
0.50	1	0.75	1.5

Table-1: Batching proportions for M30 grade concrete

SI.no	Mix	Proportion	w/c
1.	M30	1:1.38:2.58	0.5

Table-2: Concrete mix proportions with w/c

S.No	% of Basalt fiber	Cement (Kgs)	FA (Kgs)	CA (Kgs)	Water (Lts)	Basalt fibers (Kgs)
1	0%	1.5	1.3	2.36	0.44	-
2	1%	1.5	1.3	2.36	0.44	0.029
3	2%	1.5	1.3	2.36	0.44	0.058

Table-3: Batching proportions for M30 grade concrete for cubes

S.No	% of Basalt fiber	Cement (Kgs)	FA (Kgs)	CA (Kgs)	Water (Lts)	Basalt fibers (Kgs)
1	0%	2.35	2.02	3.73	1.175	-
2	1%	2.35	2.02	3.73	1.175	0.047
3	2%	2.35	2.02	3.73	1.175	0.094

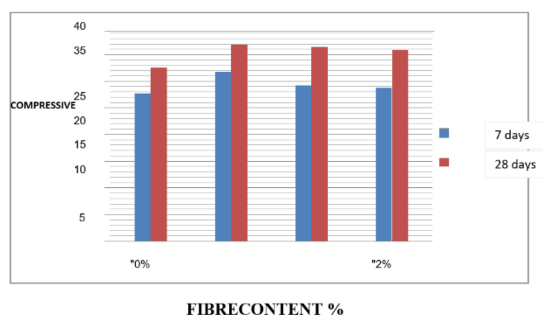
Table-4: Batching proportions for M30 grade concrete for cylinders

V. RESULTS AND DISCUSSIONS

Compressive strength: The cubes of size 150 mm x 150 mm x 150 mm are tested in a servo controlled compression testing machine of 2000 KN capacity as shown in Fig:4.4 (from previous chapter). The values of compressive strengths obtained are shown in Table 5.1, 5.2, 5.3. The compressive strength of basalt fibers reinforced concrete cube increased by 11.1% for 1.5% of fiber and 27.3% for 2% of fiber in comparison to control concrete cube.

SI. no.	Specimen ID	Fiber Content (%)	Compressive strength (MPa)	
			7 Days	28 Days
1.	M0	0.0	27.70	32.59
2.	M1	1.0	31.70	36.89
3.	M2	1.5	29.19	36.44
4.	M3	2.0	28.74	35.85

Table-6: Compression strength values



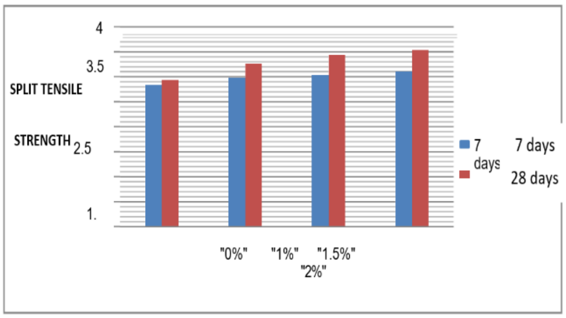
Graph-1: Compression strength values

For M30 grade concrete for 28 days, there is an increase in compressive strength of 11.1% and 27.3% for 1.5% and 2% of basalt fibers compared to conventional concrete. Hence, addition of basalt fibers, resist micro cracking as compressive strength of concrete increases.

Split Tensile strength: The cylinders of size 150 mm diameter and 300 mm height are tested in hydraulic compression testing machine of 2000 KN capacity as shown in Fig.4.6 (from previous chapter). The values of split tensile strengths obtained are shown in Table 5.4, 5.5, 5.6. The split tensile strength of basalt fibers reinforced concrete cylinders increased by 7.7% for 1.5% of fiber and 19.0% for 2% of fiber in comparison to control concrete cylinder.

SI. no.	Specimen ID	Fiber Content (%)	Split Tensile strength (MPa)	
			7 Days	28 Days
1.	M0	0.0	2.83	2.93
2.	M1	1.0	2.97	3.26
3.	M2	1.5	3.04	3.44
4.	M3	2.0	3.11	3.54

Table-7: Split tensile strength values



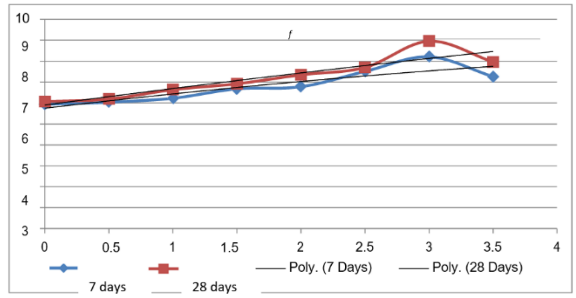
Graph-2: Split Tensile values

For 30 grade concrete for 28 days, there is an increase in split tensile strength of 7.7% and 19% for 1.5% and 2% of basalt fibers compared to conventional concrete. Hence, it can be concluded that by increasing the percentage of basalt fibers increases the split tensile strength

Shear Test: The shear strength of the concrete beam with basalt fiber was obtained. The shear strength of the plain concrete mix (M_0) and other with 0%, 1.5% and 2% of basalt fiber content to the volume of concrete was evaluated. The shear strength of 2.0% basalt fiber content mix (M_3) was found to be highest as compared to plain concrete mix (M_0) and other mixes of different proportion of basalt fibers. The percentage variation from M_0 to M_3 was found to be 38.22 % for 7 days and 47.61% for 28 days which is a significant increase from plain concrete. The overall result for shear is shown in table below.

SI. no.	Specimen ID	Fiber Content (%)	Shear strength (MPa)	
			7 Days	28 Days
1.	M0	0.0	5.94	6.07
2.	M1	1.0	6.23	6.64
3.	M2	1.5	6.68	6.92
4.	M3	2.0	6.78	7.35

Table-8: Shear strength values



Graph-3: Variation of shear Strength With Respect to Fiber Content

Increasing the volume fraction of the basalt macro fiber resulted in an improvement in the Shear strength capacity of the tested beams.

VI. CONCLUSION

- From the literature survey, it has been found that Basalt chopped fiber reinforced concrete serves the function of reinforcing material, containing 1.5% and 2% of basalt fiber by weight of cement.
- The mechanical properties of the basalt fiber reinforced concrete will be evaluated and compared with conventional concrete.
- The workability test, split tensile strength and compressive strength test, shear strength test with basalt fiber reinforced concrete results will be compared with conventional concrete.
- FRC cores had a gradual or slow failure mechanism compared to plain concrete cores.
- The gain of strength for the FRC is higher than that for plain concrete.
- Gradual type of failure is obtained for the FRC beams (unlike plain concrete).
- For M30 grade concrete for 28 days, there is an increase in compressive strength of 11.1% and 27.3% for 1.5% and 2% of basalt fibers compared to conventional concrete. Hence, addition of basalt fibers resist micro cracking as compressive strength of concrete increases
- For 30 grade concrete for 28 days, there is an increase in split tensile strength of 7.7% and 19.0% for 1% and 2% of basalt fibers compared to conventional concrete. Hence, it can be concluded that by increasing the percentage of basalt fibers increases the split tensile strength.
- Workability of the concrete increases as the fiber content increases.

VII. SCOPE OF FUTURE INVESTIGATION

Owing to the shortage of time and resources limited experimental work has been carried out in present study. Based on work carried out the scope for future study has been mentioned here with

1. To study the flexural behaviour of concrete beams using basalt fibers.
2. To study the shear strength of HSC for other higher grades of concrete.
3. To study the mechanical properties of concrete with Para basalt fibers.

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