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Compressive and split tensile strength of Basalt Fibre Concrete as Partial Replacement of Fine Aggregate with Copper Slag

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Abstract — ***Plain concrete (PC) is a brittle material with low tensile strength and susceptible to cracking under tensile stress. Randomly distributed basalt fibres are able to link these cracks and obstruct their development. By this mechanism, the addition of chopped basalt fibres can enhance the mechanical behavior of plain concrete. Basalt fiber reinforced concrete (BFRC), a new high performance cement-based composite material. Basalt fibre concrete decreases the workability of concrete. Copper slag is an industrial by-product obtained during the smelting of copper which is used in concrete. Copper slag increases the workability of concrete. This experimental work carried out on concrete specimen containing chopped basalt fibre as additive materials and copper slag as partial replacement with fine aggregate. Adding different dosage of basalt fibre (1%, 2% and 3%) by weight of cement in concrete and partially replacement of copper slag (10%, 20%, and 30%) with fine aggregate by volume. Prepare standard cube and cylinder to measure compressive strength after 7days, 14days, and 28 days and split tensile strength after 28days of curing and compare this strength with M25 conventional concrete.***

Keywords- concrete, basalt fibre, copper slag, compressive test, split tensile test

I. INTRODUCTION

Concrete is a material of construction industry which is widely using all over the world. It is versatile, has desirable engineering properties, produced with cost effective materials which can be moulded into any shape. It is also brittle in nature. More than ten billion tons of concrete are consumed annually. Based on global usage, it was placed in second position next to water. The word concrete comes from the Latin word "concretus" whose meaning is compact or condensed [1]. The basic ingredients like sand (fine aggregate) and gravel (coarse aggregate), cement – used as a binder and water are used for making concrete. Sometimes admixtures are used to change various properties of concrete like accelerators, retarders, water reducers, high range water reducers, etc. The modern developments in the concrete field are like Fibre Reinforced Concrete (FRC), High Strength Concrete (HSC) Self Compacting Concrete (SCC), Autoclaved Aerated Concrete (AAC), High Performance Concrete (HPC), Reactive Powder Concrete (RPC), Ultra High Performance Concrete (UHPC) and Light Weight Concrete, Pervious Concrete, Composite Concrete, etc. [2].

In this modern world, civil engineering constructions include their own structural and durability requirements. For meet this requirement of structural integrity for every structure, modification in the traditional cement concrete has become mandatory. Plain concrete (PC) is a brittle material with low tensile strength. Consequently, PC is susceptible to cracking under tensile stress. It has been found that addition of different type of fibres in concrete with specific percentage improves the chemical and mechanical properties, durability and serviceability criteria of the structure. The study concluded that basalt fibres can be easily mixed with concrete without any balling or segregation. In addition, there was also a noticeable increase in the post-cracking energy absorption capacity and increase of the impact resistance. When mixed into concrete, randomly distributed fibres are able to bridge these cracks and arrest their development. By this mechanism, it has been well established that the addition of fibres can enhance the mechanical behaviour of PC [3].

For any construction industry, Concrete is a composite material which composed of cement, sand and aggregate are essential needs. Sand is a major material used for preparation of mortar and concrete and highly affected for the preparation of mix design. Use of natural sand is high, due to the large use of concrete and mortar. So, the demand of natural sand is very high in developing countries to satisfy the rapid infrastructure growth. Some other materials have already been used as a replacement of natural sand such as quarry dust, fly-ash and siliceous stone powder, limestone and filtered sand are used in concrete and mortar mixtures as a partial or full replacement of natural sand. Even though, in many countries such as the UK, Sri Lanka, Continental Europe, India and Singapore offshore sand is actually used but most of the records for use of this material found mainly as a lesser extent of practice in the field of construction. Since waste materials can be produced at lesser or no cost, it can be helpful for making significant contribution of the conservation of natural resources and maintenance of ecological and environmental balance [4].

II. MATERIALS

2.1 Basalt fibre

They are generally in the form of continuous monofilament or in the form of chopped length. The other forms are like basalt mesh, basalt rod, etc. They have high toughness and modulus of elasticity and also high temperature resistance capacity. For this research work the basalt chopped fibre strands of having 18 mm length and 13 µm diameters were taken.

2.2 Copper slag

Copper slag (CS) is an industrial waste generated in huge amount from copper industries and can be exploited as a potential substitute to river sand in concrete production. The CS is obtained as by-product from copper metal either as dense CS or granulated CS depending upon the method of cooling of molten slag discharge from the furnace. The molten slag solidified by pouring into the water results in granulated CS whereas gradually air cooled slag form the dense CS. It was estimated that to yield 1 ton of copper, about 2.2–3 tons of CS is generated as a by-product.

Table.1 Chemical composition of copper slag

Component (%)	Copper slag
SiO_2	30.21
Al_2O_3	2.14
Fe_2O_3	58.87
CaO	0.97

Table.2 Physical properties of copper slag

Sr. No.	IS Sieve Size	Wt. Retained (gm)	Cum. Weight Retained (gm)	Cumulative Weight Retained (%)	Cumulative Weight Passing (%)	Requirements as per IS: 383(1973)
1	10mm	0.0	0.0	0.0	100.0	100
2	4.75mm	6.0	6.0	6.0	99.40	90-100
3	2.36mm	71.0	77.0	7.70	92.30	75-100
4	1.18mm	527.0	604.0	60.40	39.60	55-90
5	600µm	279.0	883.0	88.30	11.70	35-59
6	300µm	72.0	955.0	95.50	4.50	08-30
7	150µm	17.0	972.0	97.20	2.80	0-10
8	Pan	22.0	1000.0	100.0	0.0	
	Total	1000.0		301.7	---	
Physical properties						
1	Zone of Copper slag				II	---
2	Fineness Modulus of copper slag				3.5	---
3	Water Absorption (%)				1.1	Max - 2 %
4	Sp. Gravity of Copper slag				3.59	2.6 - 2.7
5	Silt Content in % (finer than 75 µ)				6.0	max.- 3 %

2.3 Aggregate

Generally, locally available coarse aggregate with combination of 20mm (70%) and 10mm (30%) are used in the present work. Also, natural available river sand of Zone II is used as a fine aggregate.

III. MIX DESIGN AND MIX PROPORTION

Mix design for concrete grade of M-25 has been carried out as per IS-10262:2009 and mix proportion shown in table,

Table.3 Mix proportion for mixes

M 25 grade of concrete for 1 m^3								
No.	Cement (kg)	Basalt fibre (%)	Copper slag (%)	Fine aggregate (kg)	Copper slag (kg)	Kapachi (kg)	Grit (kg)	Water (kg)
Mix1	395	0	0	688	0	751	422	197.32
Mix2	395	1	10	619.2	92.5	751	422	197.32
Mix3	395	1	20	550.4	185	751	422	197.32
Mix4	395	1	30	481.6	277.52	751	422	197.32
Mix5	395	2	10	619.2	92.5	751	422	197.32
Mix6	395	2	20	550.4	185	751	422	197.32
Mix7	395	2	30	481.6	277.52	751	422	197.32
Mix8	395	3	10	619.2	92.5	751	422	197.32
Mix9	395	3	20	550.4	185	751	422	197.32
Mix10	395	3	30	481.6	277.52	751	422	197.32

IV. EXPERIMENTAL STUDY AND TEST RESULTS

For compressive strength test, cube specimens of dimensions 150mm x 150mm x150 mm were casted, then cubes are placed in water for curing after 24 hours of casting. The cubes are tested for compressive strength on compressive testing machine after 7day, 14day and 28day. For split tensile test, cylinder specimens of dimeter and height 150mm x 300 mm are casted, then cylinder are placed in water for curing after 24 hours of casting. The cylinder is tested for split tensile strength after 28day.

Table 4. Test results

Mix	Cube Compressive strength (N/mm^2)			Cylinder Compressive strength (N/mm^2)		
	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
Mix1 (OPC)	19.90	24.97	31.86	14.77	19.70	27.73
Mix2	20.28	26.78	32.29	15.86	20.67	28.67
Mix3	22.47	29.30	34.93	17.87	23.69	30.66
Mix4	24.54	31.69	35.01	19.11	24.97	31.41
Mix5	22.22	27.48	33.76	16.70	21.13	29.06
Mix6	24.82	31.73	35.32	18.96	24.63	31.15
Mix7	26.46	33.68	36.86	20.77	26.26	32.88
Mix8	22.02	26.98	33.18	16.74	21.09	28.01
Mix9	23.57	30.37	34.05	18.84	23.72	29.74
Mix10	23.59	31.13	35.48	20.24	24.79	30.17

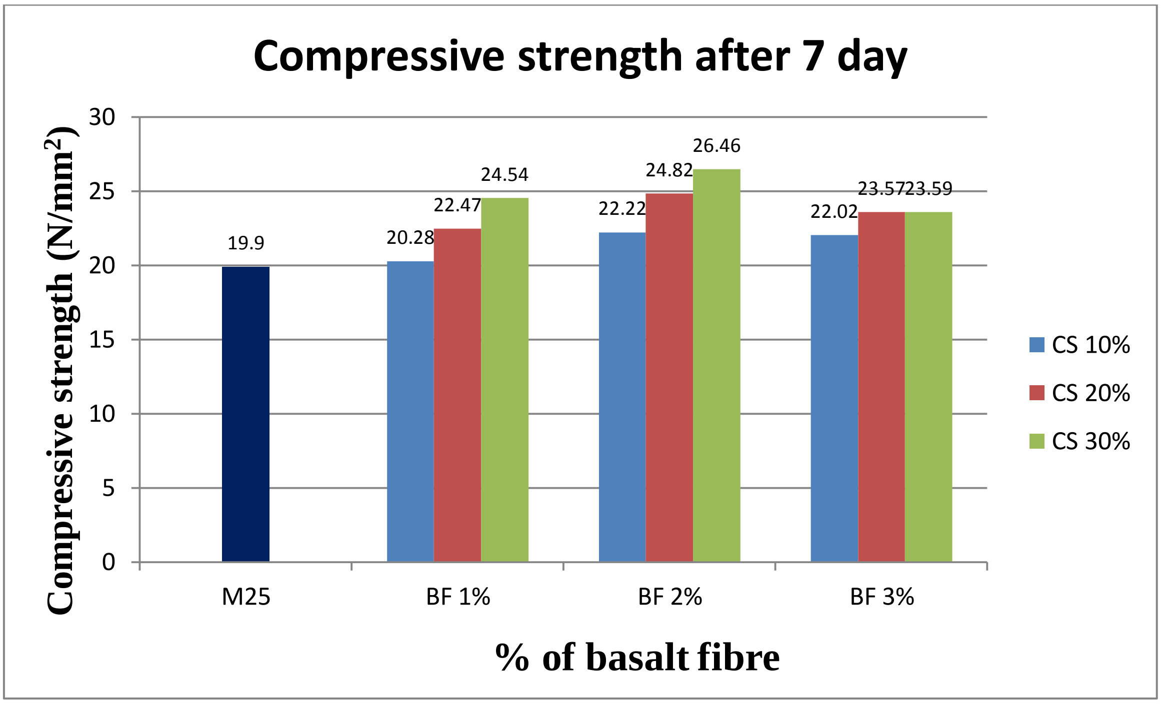

Chart-1 7day cube compressive strength

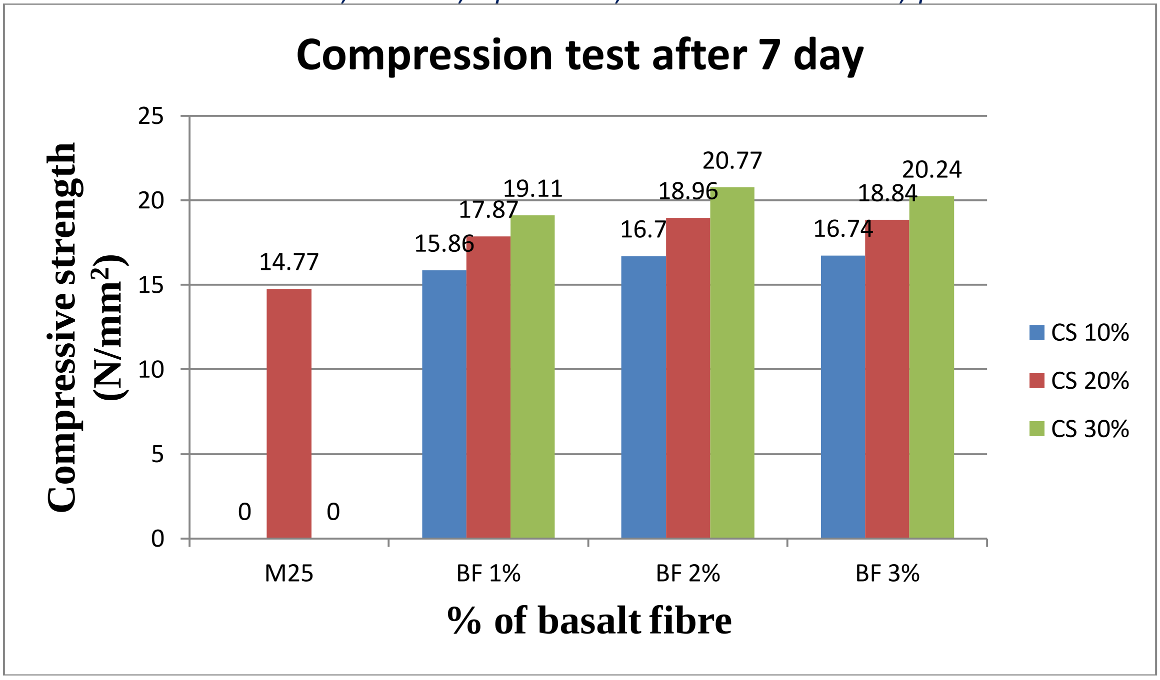

Chart-2 7day cylinder compressive strength

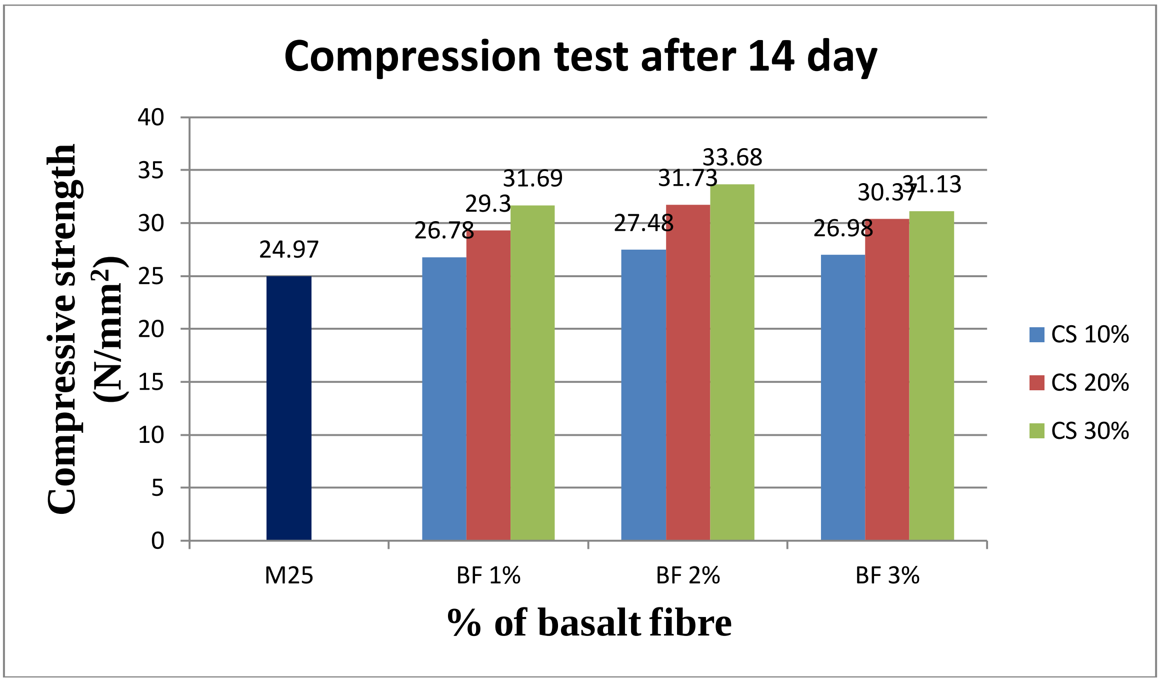

Chart-3 14day cube compressive strength

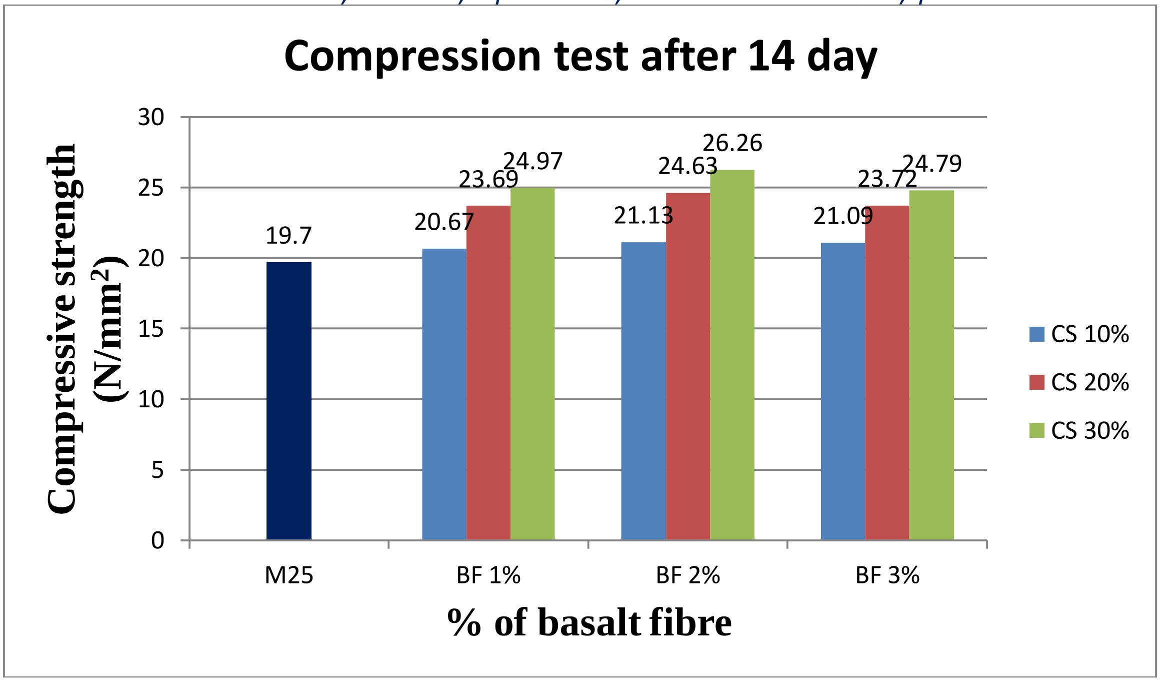

Chart-4 14day cylinder compressive strength

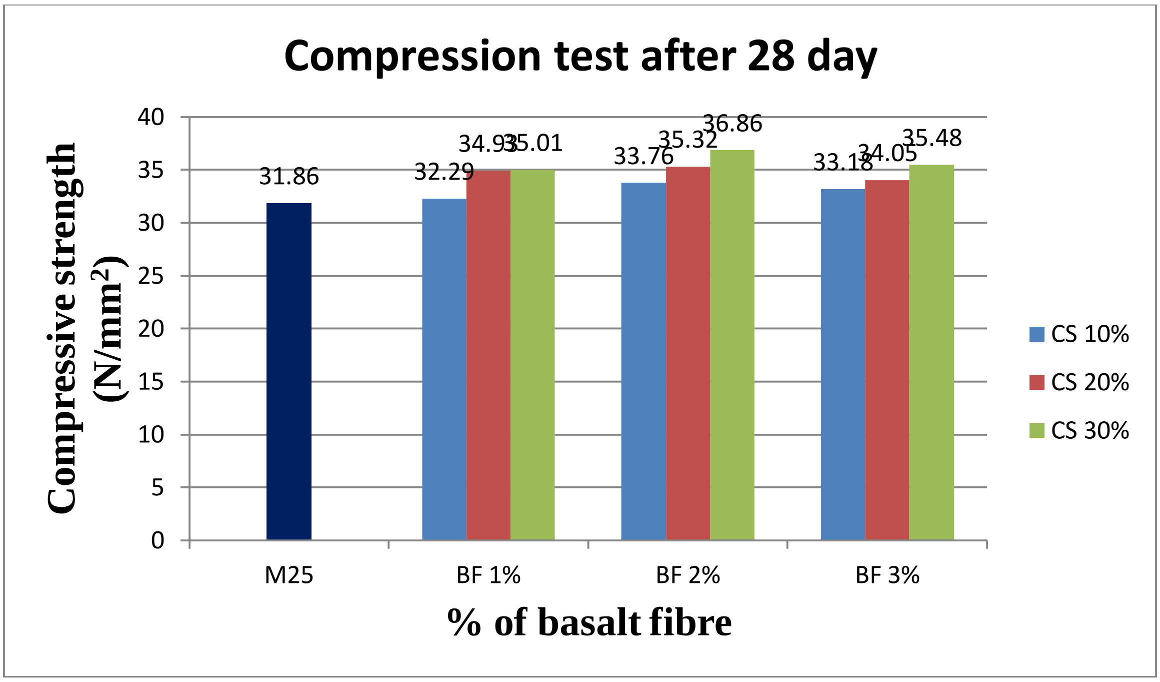

Chart-5 28day cube compressive strength

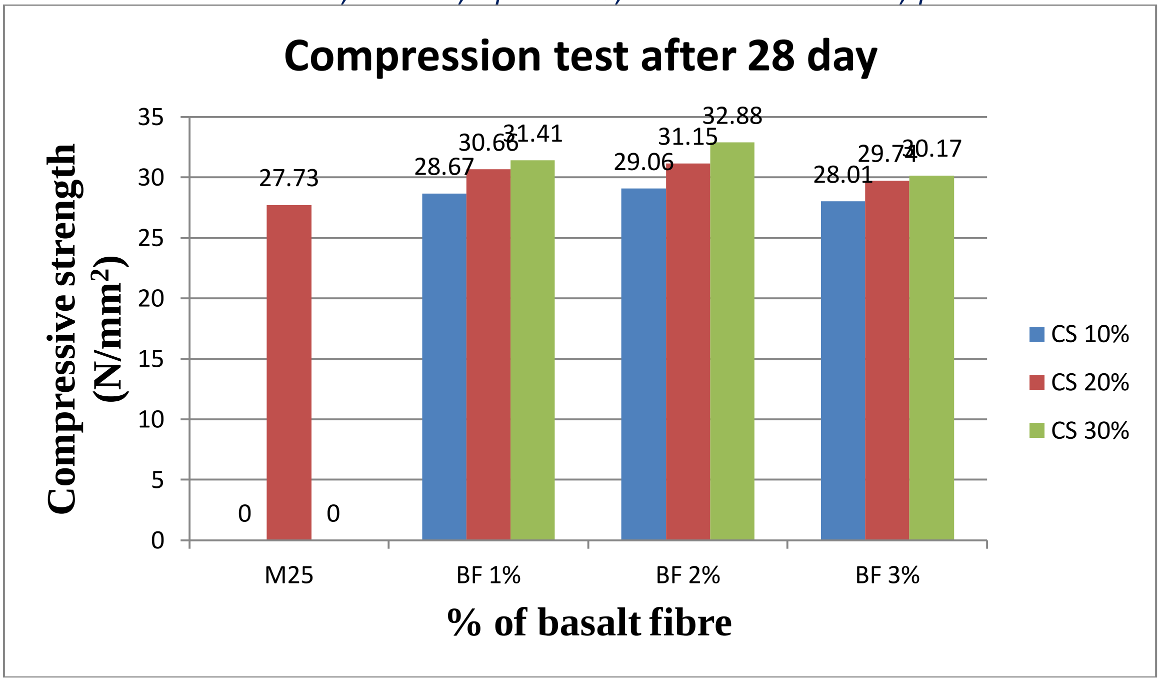

Chart-6 28day cylinder compressive strength

Table.5 Comparison of cube and cylinder compressive strength

Mix	Cube compressive strength (N/mm2)	Cylinder compressive strength (N/mm2)	Ratio	Split tensile strength (N/mm2)
	28days	28days		28 Days
Mix1(OPC)	31.86	27.73	0.87	3.20
Mix2	32.29	28.67	0.89	3.54
Mix3	34.93	30.66	0.88	3.50
Mix4	35.01	31.41	0.90	3.49
Mix5	33.76	29.06	0.86	4.11
Mix6	35.32	31.15	0.88	4.09
Mix7	36.86	32.88	0.89	3.99
Mix8	33.18	28.01	0.84	4.18
Mix9	34.05	29.74	0.87	4.10
Mix10	35.48	30.17	0.85	4.05

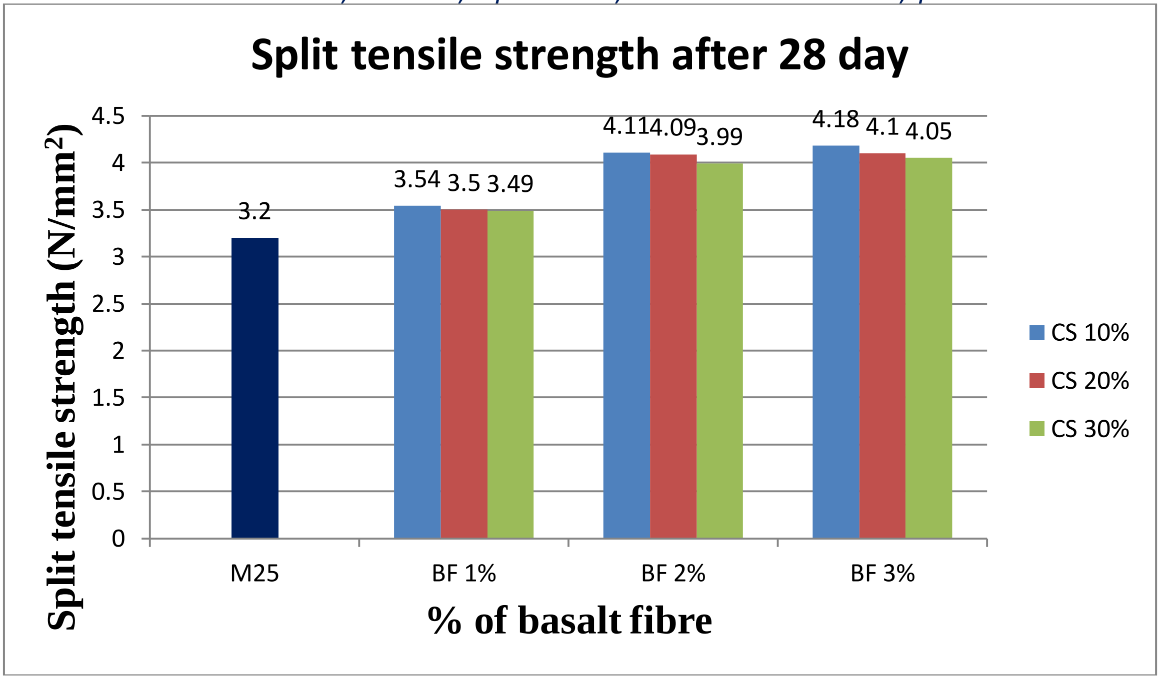

Chart-4 28day split tensile strength

V. CONCLUSION

By using basalt fibre and copper slag in concrete, gives some incremental results in compressive and split tensile strength. Because of higher density, silica content in copper slag and bonding characteristics of basalt fibre concrete gives some appropriate results. Split tensile strength of basalt fibre concrete increase because of elastic capacity of basalt fibre.

1) With the usages of 2% basalt fibre and 30% replacement of copper slag with sand gives 15.69% more cube compressive strength results as 36.86N/mm^2 with respect to M25 OPC mix.
2) Concrete mix with 2% basalt fibre and 30% replacement of copper slag gives 18.57% more cylinder compressive strength as 32.88N/mm^2 with M25 OPC mix.
3) With the use of 3% basalt fibre and 10% replacement of copper slag with sand gives 30.62% more split tensile strength as 4.18N/mm^2 among the mixes with M25 OPC mix.

VI. REFERENCES

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