Development of Self Compacting Concrete by Replacing Foundry Sand and Granular Blast Furnace Slag for Sand

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***Abstract*—The overuse of river sand for construction has various undesirable social and ecological consequences. As a solution for this, various alternatives such as foundry dust, wastes from demolished concrete, industrial wastes like copper slag,foundry sand, eco sand etc have been used. GBFS (Granulated Blast Furnace Slag) is a slag obtained from the manufacture of iron in steel industries. This research aims to investigate the possibility of replacing Granulated Blast Furnace Slag (GBFS) as a sand substitute in concrete.In this investigation, natural sand was replaced by GBFS and foundry sand in various percentages), with a constant water/cement ratio. Tests such as sieve analysis, specific gravity, fineness modulus, and water absorption were done for fine aggregate and GBFS sample. Different mix proportions for different percentage replacement of fine aggregate was obtained for M40 grade concrete as per IS 10262:2009. The compressive strength test, split tensile strength test, flexural strength test, were done for cube, cylinder and slab specimens of control mix and GBFS mix. It was found the strength of concrete was improved due to the addition of GBFS as fine aggregate. Different mix proportions for different percentage replacement of fine aggregate was obtained for M40 grade concrete as per IS 10262:2009. The compressive strength test, split tensile strength test, flexural strength test, were done for cube, cylinder and prism specimens of control mix and GBFS mix. It was found the strength of concrete was improved due to the addition of GBFS as fine aggregate.**

Keywords—industrial waste, river sand, granular blast furnace slag, foundry sand, self compacting concrete, workability, strength, environment.

I.INTRODUCTION

Due to the recent growth in the construction industry, demand for fine aggregate is escalating rapidly. River sand has been the most widely used fine aggregate in India and over exploitation of river sand to meet the demand has led to various harmful consequences such as increase in the depth of the river bed, lowering of the water table,and salinity intrusion into the rivers. Because of these environmental problems, there is a necessity to restrict river sand mining especially at vulnerable locations. As a remedial measure, the government imposes various restrictions on the extraction of river sand with consequent increases in prices.Excessive instream sand mining is a threat to bridges, river banks and nearby structures. Sand mining also affects the adjoining groundwater system and the uses that local people make of the river.Rising concerns to the alarming situation, of negative environmental impact, has seen strict measures making their way in the southern states of Tamilnadu, Kerala and Karnataka. After banning mining of river sand and other minor minerals without the mandatory environment clearance, the National Green Tribunal (NGT) has recently also banned beach sand mining from the sea coasts of Tamil Nadu and Kerala. Yet, news about illegal sand mining keeps making it's way to the national and regional dailies every now and then. The figures reported to have accounted for loss of minerals through such practices have run into multi-million tones.
Quarrying is thus seen in an unfavorable light because of the environmental impact it has. This is mainly due to de-fragmented operations.

The noticeable effects on environment and the eco system caused by sand mining, together with the growing demand of aggregates to fulfill the construction requirements of the urban world has made it imperative to look for alternate solutions to the concern.

Instream sand mining results in the destruction of aquatic and riparian habitat through large changes in the channel morphology. Impacts include bed degradation, bed coarsening, lowered water tables near the streambed, and channel instability. The development of specifying a concrete according to its performance and requirements, rather than the constituents and ingredients have opened innumerable opportunities for producers of concrete and users to design concrete to suit their specific requirements. One of the most outstanding advances in the concrete technology in the last decade is “self-compacting concrete” (SCC). SCC consolidates itself due to its self-weight and is de-aerated almost completely while filling the formwork. As defined earlier, no additional inner or outer vibration is necessary for the compaction. In structural members even with high percentage of reinforcement, it fills all voids and gaps completely. SCC flows like “honey” and has nearly a horizontal concrete level after placing. With regard to its composition, self-compacting concrete consists of the same components as conventionally vibrated normal concrete, which are cement, aggregates, water additives, water admixture and admixtures. While crushing the rock, extracting sand from private lands and mining for sand in submerged areas are being considered as alternative activities to using river sand, experts claim that 'Granulated Blast Furnace Slag' is the best option among all. "Granulated Blast Furnace Slag is produced from the slag that forms during the production of steel. An American Foundry Society (AFS) study in Illinois investigated foundry sand as a substitute for fine aggregate in concrete. When foundry sands without fines replaced a portion of the fine aggregate, the concrete produced had compressive strengths, tensile strengths and modulus of elasticity values comparable to mixtures composed of natural sand.

II. MATERIALS AND THEIR PROPERTIES

A. Cement
In this experimental study, Ordinary Portland Cement 53 grade, conforming to IS: 8112-1989 to be used. The different laboratory tests are to be conducted on cement to determine the physical and mechanical properties of the cement used.

B. Fly Ash
Fly ash is defined as 'The finely divided residue that results from the combustion of powdered coal and that is transported by flue gases from the combustion zone to the practical removal system'. Fly ash particles are typically spherical, finer than Portland cement and line, ranging in diameter from less than 1 to 150μm

C.Foundry Sand
The raw materials used for making sand molds for metal castings are usually recycled. After a repeated use they lose their characteristics, thereby becoming unsuitable for further use in the manufacturing process. All these materials are then discarded as a waste. They are mainly molding sand and core sand.

D. Granular slag [GBS]
Granular slag from the local steel making plant; Blast Furnace Slag is a byproduct of the steel industry. It is defined as "the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace".

E. Coarse Aggregates
Coarse aggregate to be used is 12mm maximum nominal size. The coarse aggregates confirmed to BIS specifications.

F. Admixtures
A carboxylic-ether polymer based super plasticizer GLENIUM B233 to be used.

III. METHODOLOGY

The properties of Self Compacting Concrete is studied where in the river sand is completely replaced in percentages of Foundry sand and GBS. The sand replacement materials was introduced in step of 20 percent (0, 20, 40, 60, 80 and 100) proportionally with foundry sand and GBS.SCC mix design of M40 Grade was carried out by trial and error with reference to European Guidelines. The mix proportion for M40, Cement: Fine aggregate: Coarse aggregate: Fly ashwas 1: 2.18: 1.79: 0.25 with water cement ratio of 0.38. The effect of varying percentages of foundry sand and GBS is subjected to evaluation of fresh properties of SCC namely Slump flow value and V funnel time for filling ability, J ring readings and U box Readings for passing ability and L box readings for segregation resistance, The effects on Hardened Concrete for compressive, split tensile and flexure strength are also determined. Casting and testing of specimens are carried out as perIS codes. IS: 516-1959 for compressive strength for cube of size (150mmx150mmx150mm)& split tensile strength for cylinder of size (150mmx300mm), flexural strength for slab of size (500mmx500mmx75mm). Materials are weigh batched, mixed in a rotating drum mixer, casted.The specimens were stored in room temperature for 24 hours, then removed from the moulds, and cured in normal water until tested.

Figure 1- Compressive test of cube specimen

Figure 2- Split tensile test of cylinder specimen

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Figure 3- Flexural strength test of Slab specimen

IV. RESULTS AND DISCUSSION

The results of tests on fresh concrete and hardened concrete are obtained based on experimental study. Identification of specimens is as shown in table 2.

Table 1Identification of specimen

Specimen name	***River Sand in %***	***GBS in %***	***Foundry Sand in %***
CS	100	-	-
R1	-	100	0
R2	-	80	20
R3	-	60	40
R4	-	40	60
R5	-	20	80
R6	-	0	100

A. Observation on workability tests

The workability tests are conducted on fresh concrete and the results are shown in table 3 and represented through fig 4 to 8.

Table 2Workability test results

Specimen	***Slump***		***U Box H2-H1*** *mm*	***L Box H2/H1***	***V funnel*** *Sec*	***J ring*** *mm*
	mm	sec				
CS	700	3.00	17	0.90	10.00	5
R1	660	3.00	33	1.10	13.00	10
R2	645	3.50	28	0.85	12.00	11
R3	600	4.00	25	0.80	12.50	11.5
R4	590	4.00	24	0.80	12.50	12
R5	565	4.50	20	0.78	12.80	12
R6	540	5.00	15	0.73	13.00	13

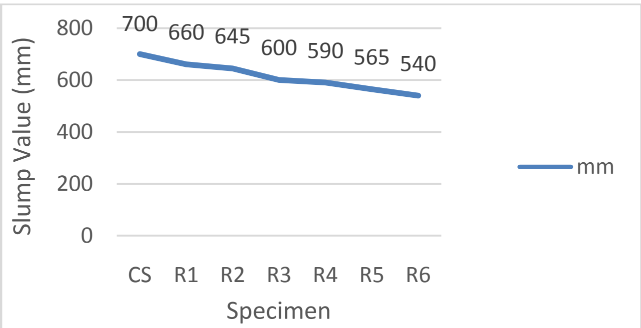

Figure 4- Slump flow

Figure 5- U Box test results

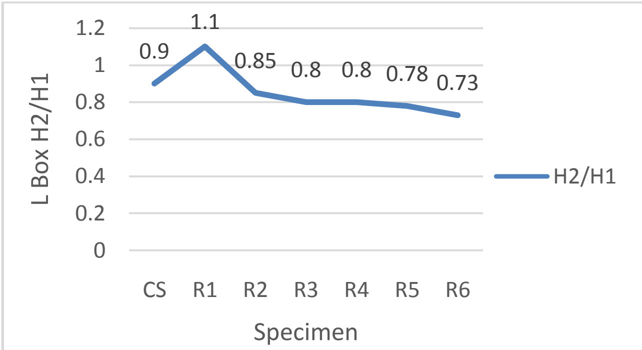

Figure 6- L box test results

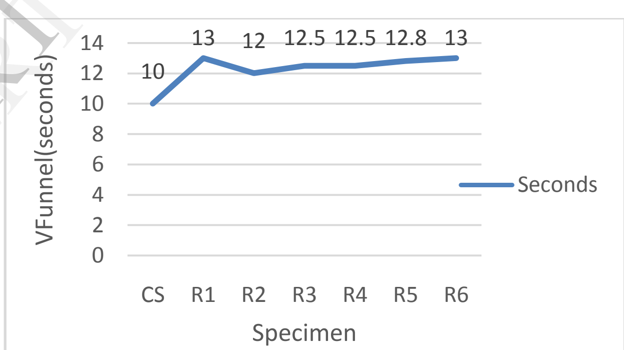

Figure 7- V funnel test results

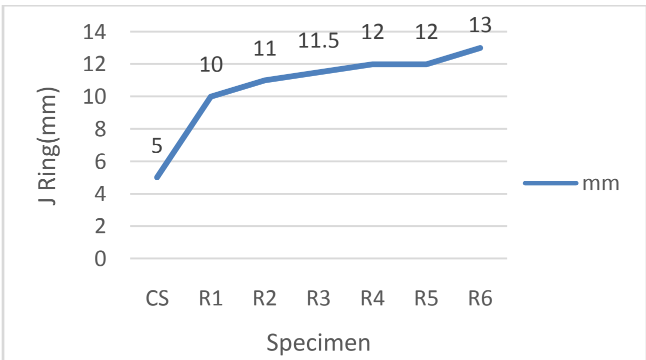

Figure 8- J ring test results

From fig 4 to fig 8, it is observed thatin the fresh state of SCC, the concrete is not as workable as in river sand. However, the workability requirement is mostly satisfied with full replacement of GBS and gets tougher to get workability with the addition of foundry sand.

B. Observation on compressive strengthtest

The cube specimens are subjected to compressive test as shown in fig 1. Table

4 shows the results of compressive test at 7 and 28 days. Fig 9 and 10 represents the bar and line graph of compressive strength for different specimens.

Table 3Compressive strength test results

Specimen name	*Compressive strength @ 7 Days in N/mm²*	*Compressive strength @ 28 Days in N/mm²*
CS	28.77	41.22
R1	28.64	40.89
R2	26.34	37.68
R3	23.79	34.03
R4	21.44	30.75
R5	20.14	29.74
R6	18.67	27.61

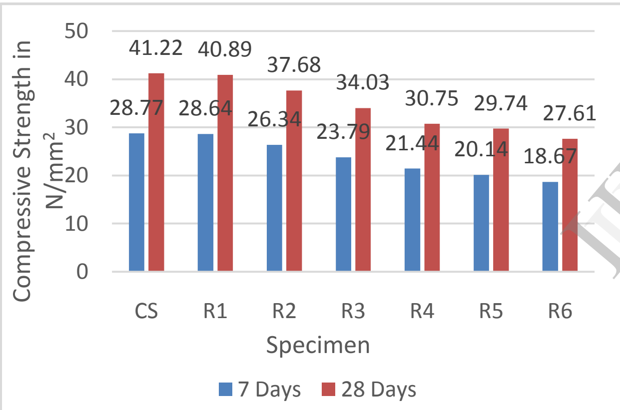

Figure 9- Bar chart representing compressive strength

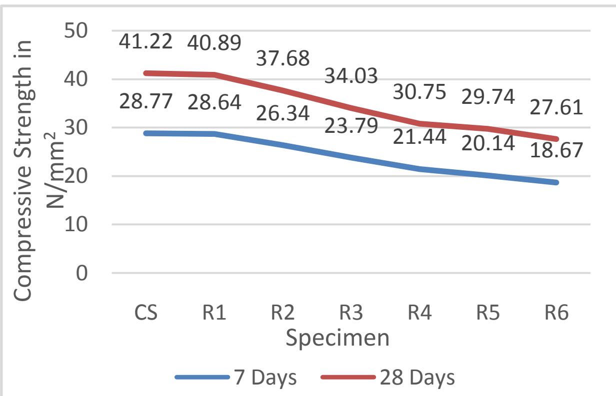

Figure 10- Line chart representing compressive strength

From Table 3, Fig 9 and 10. It can be noticed that concrete acquires almost same compressive strength at 100% GBS as sand replacement. The percentage of variation in strength with respect to control specimen is -0.80 percent which is negligible.

C. Observation on split tensilestrength test

The cylinder specimens are subjected to split tensile test as shown in fig 2. Table 5 shows the results of split tensile strength test at 7 and 28 days. Fig 11 and 12 represents the bar and line graph of split tensile strength for different specimens.

It can be noticed that concrete acquires almost sametensile strength of SCC with Sand replacement.Compared to SCC having River sand, the variation of strength is -3%.

Table 4Tensile strength test results

Specimen name	*Tensile strength @ 7 Days in N/mm²*	*Tensile strength @ 28 Days in N/mm²*
CS	1.48	2.43
R1	1.41	2.34
R2	1.29	2.15
R3	1.22	2.05
R4	1.24	2.09
R5	1.15	1.92
R6	1.13	1.84

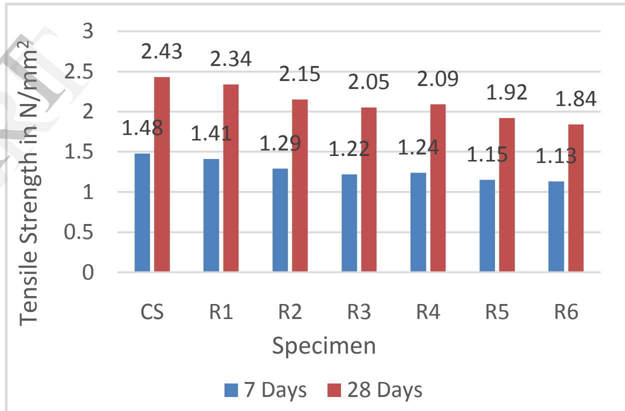

Figure 11- Bar chart representing tensile strength

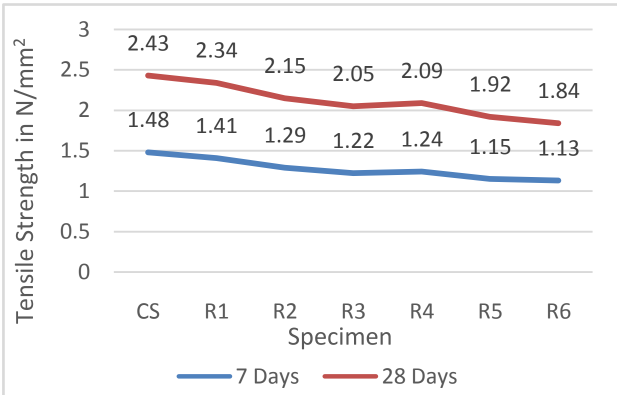

Figure 12- Line chart representing tensile strength

D. Observation on Flexural Test

The flexure test is performed in the universal testing machine by applying single point load at the central distance of effective length of slab specimen as shown in fig 3.Minimum reinforcement is provided. 6mm bars with yield strength of 250N/mm2 are provided at a spacing of 150m c/c.The load is applied at equal increments of 2.5KN till the ultimate load carrying capacity.

Table 5Flexural strength test results

Specimen	Percentage of fine aggregate	Maximum deformation in mm	Ultimate load in KN
CS	River sand 100	6.4	56.40
R1	GBS100 Foundry Sand 0	6.9	58.86
R2	GBS 75 Foundry dust 25	5.5	49.05
R3	GBS 50 Foundry dust 50	6.56	51.50
R4	GBS 25 Foundry dust 75	8.3	46.60
R5	GBS 0 Foundry dust 100	9.1	36.78

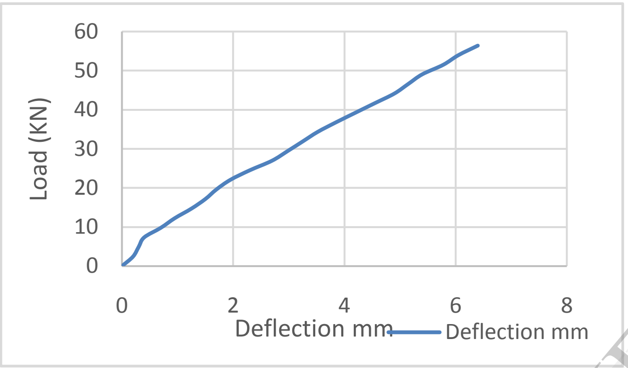

Figure 13- Load Deflection curve of Control Slab

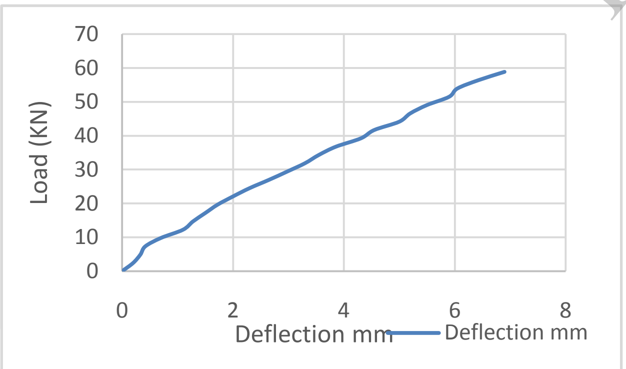

Figure 14- Load deflection curve of Specimen R1

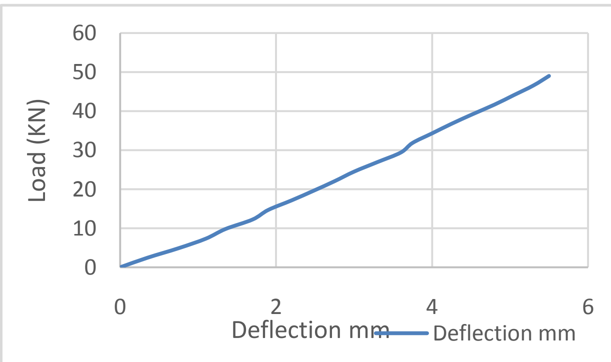

Figure 15- Load deflection curve of Specimen R2

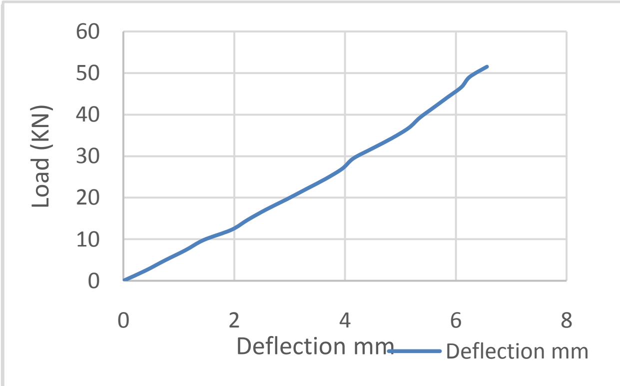

Figure 16- Load deflection curve of Specimen R3

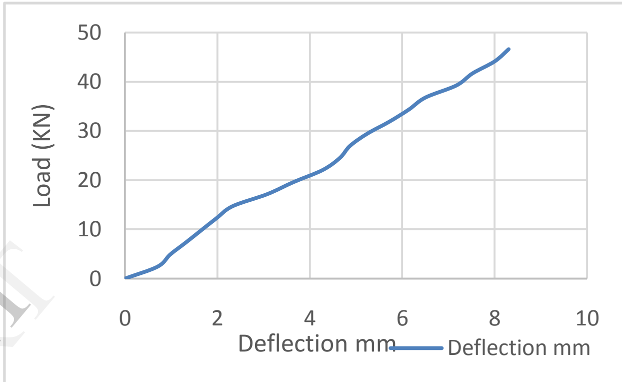

Figure 17- Load deflection curve of specimen R4

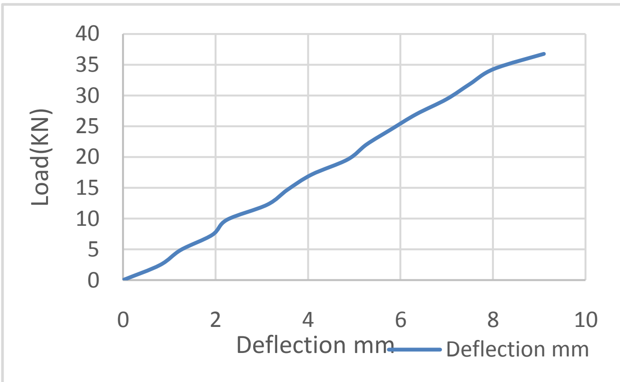

Figure 18- Load deflection curve of specimen R5

The slab specimens with replacement of river sand showed higher deflections compared to control specimen. The Slab specimen with 100 percent of GBS showed similar deflection and highest ultimate load carrying capacity as of river sand.The ultimate load carrying capacity of Slab is increased by 4.36 percent in comparison with control Slab.

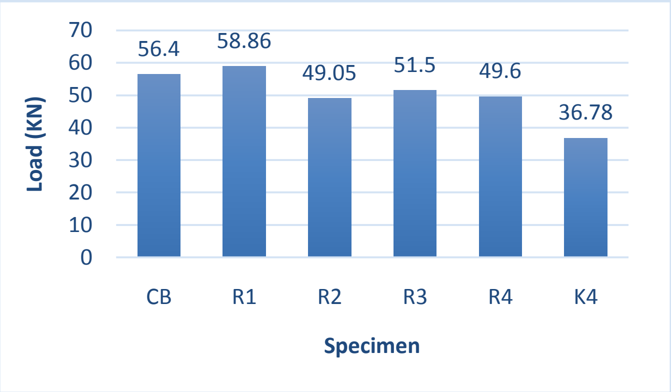

Figure 19- Comparison of ultimate loads

V. CONCLUSIONS

In the present study following conclusions are derived

1) Granular Slag &Foundry dust can be a very good replacement for river sand with respect to economy, strength and the considerations of availability of resources. The combination of Foundry dust and Granular Slag in place of River sand & along with fly ash shall be very economical and can also help in the utility of Industrial wastes and in maintaining the ecological balance thus reducing the consumption of cement and river sand.

2) The fresh state of SCC, with the presence of 100% GBS, it caused lower flow ability, passing ability and resistance to segregation of SCC mix. These workability properties gradually decreased with additional percentages of foundry sand. The concrete mixes can still meet the requirement of flow ability, resistance to segregation and passing ability of SCC .

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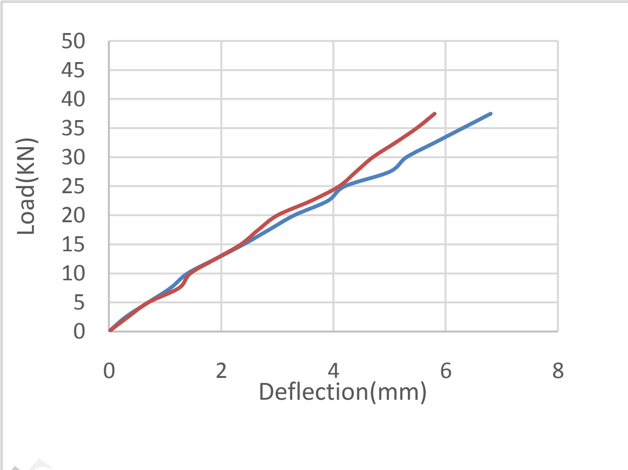
3) By experimental investigations it is indicated that the strength parameters such as compressive strength, split tensile strength and flexure strength is similar when compared to the normal SCC.

4) Concrete acquires similar strength in compressive strength at 100% GBS as sand replacement. There is a percentage decrease in strength with additon of foundry sand but economical to use.

5) Split tensile strength have similar strength with Sand replacement compared to SCC having River sand. There was 3 percent decrease in strength compared to river sand

6) The Slab specimens with replacement of river sand showed higher deflections compared to control specimen.The specimen with 100 percent of GBS higher deflection and highest ultimate load carrying capacity.The ultimate load carrying capacity of Slab is increased by 4.36 percent in comparison with control Slab.

7) With GBS alone, it is difficult to obtain proper compaction due to voids. Thus foundry sand upto strength requirement can be utilised. GBS upto 80 percent can also be used along with river sand to get optimum results thus saving ecology and also being economical.



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