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EFFECT AND OPTIMIZATION OF FOUNDRY SAND, GGBS & STEEL FIBER ON STRENGTH OF CONCRETE

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ABSTRACT

As the technology keeps on growing day by da, it helps in the development of our nation, but at the same time it damages our surrounding environment too.

Concrete, which is the most important construction material, has some limited properties such as low tensile strength, low ductility and shrinkage and cracking problem related to hardening. These problems related to concrete can be tackled. To neutralize the problem related to low tensile strength, some material like steel fiber can be added to increase its tensile strength, along with its steel fibers also protect our structure from cracking and gives strength to concrete.

GGBS in concrete is used to reduce the rate of heat of hydration, improves its durability by giving high hindrance against sulphate and chloride attack. It goes on to improve resistance against corrosion of reinforcement bars. Another thing it provides to concrete is, it improves the compressive strength [1] and along with that the setting time of concrete, improvements in these properties increases the workability of concrete makes concrete. GGBS also holds a little edge in comparison to OPC as it provides longer service life and less maintenance of structures.

Foundry sand, when used in concrete [2], increases its strength and durability. Foundry Sand also adds to the workability of concrete and beside all these parameters, it may be used as an addition to improve different properties of concrete which may all lead to make concrete much stronger and durable.

This research paper concentrates on the study of tensile, compressive and flexural behavior of concrete by varying the percentage of GGBS & Foundry Sand.

Also, this research paper focuses on the characteristics of M25 concrete by adding 1% of steel fibers.

The varying percentages of GGBS & foundry sand are considered, on the basis of these varying percentages, eight samples of mix were prepared including a control sample. Each sample, excluding control sample consists a concrete mix with GGBS, foundry sand and steel fiber. The variation in the compressive strength, flexural strength and tensile strength is observed.

KEYWORDS: Compressive Strength, Flexural Strength, Foundry Sand, Ground Granulated Blast Furnace Slag, Steel Fiber, Tensile Strength

INTRODUCTION

Steel Fiber

Figure 1

After, the recent finds in concrete technology, we have started taking into account reinforcement in the form of fibers, most usually steel fibers, polymeric or glass fibers. Fiber-reinforcement is largely used for crack control. The concept of reinforcing materials with fibers is quite old, this interest of reinforcing cement with steel fiber or any other kind of fiber is based on research starting from way back in 1960's [5]. Since then, substantial researches and development activities related to this throughout the world are going on. Crack toughness, ductility and impact hindrance; all these defects of concrete are overcome when steel fiber is used and ultimately resulting in better performance of concrete. The infrastructure development of a nation is an important aspect in the overall development, and India is establishing itself as a major hub in the construction industry and along the way providing jobs and services.

Foundry Sand

Figure 2

Foundry sand is basically, sand which contains high quality silica sand that has uniform physical properties. It is basically obtained as a waste material from metal casting industries. The casting process and type of industry are the two factors which generally governs the physical and chemical characteristics of foundry sand.

Foundry industries use a good amount of silica sand for casting processes and due to which, a large amount of waste is produced on a daily basis which is around 700-1000tonn/day.

If we take a look at the present scenario of foundry industries, the amount of waste being generated and waste disposal methods being adopted by them, it is quite clear that in coming years, problems related to disposal of used foundry sand are going to become large. If only it can be used in other places such as in construction materials, ceramic industry, bricks (Hollow blocks), embankment construction & repair, mineral wool products, etc., it will give profit along with the production cost of the industry and the best thing is waste sand will get reduced. Also, by adopting such measures and using foundry sand as a waste product, we can contain a sustainable disposal of used foundry sand.

GGBS

Figure 3

GGBS i.e. Ground granulated Blast Furnace Slag, is extracted from the iron making industries, with the help of a process in which molten ash, which is obtained from the furnace is rapidly chilled or quenched. Water is used for chilling the molten ash. At the time of this process, the slag keeps on breaking down into smaller pieces and is then transformed into amorphous granules i.e. glass, which meets the requirement conforming to [6]. After that, granulated slag is processed in order to get the desired fineness for producing GGBS. Ground Granulated Blast Furnace Slag is basically, a by-product which is obtained during the manufacturing process of pig iron in the blast furnace and is formed when the constituents of the iron ore combines with limestone flux resulting in GGBS. When molten slag is rapidly quenched with the help of water in a pond, or when it is cool down using powerful water jets, it goes on to form small granules that are completely non-crystalline, are glassy in nature and finally forms a material known as granulated slag.

EXPERIMENTAL INVESTIGATION

Parameters like compressive strength, flexural strength and tensile strength are the three main properties of concrete, keeping in mind these properties, eight samples of concrete mix were prepared and casted based on the mix design for M25 grade concrete[7][10] and the samples consisted of: cube, cylinder and beams; and then were accordingly tested at 7 and 28 days. The variables considered are the different percentages of GGBS and Foundry Sand with an additional 1 % of steel fiber.

MATERIAL PROPERTIES

- **Cement:** OPC i.e. Ordinary Portland Cement of Grade 53, conforming to [8], was used throughout to prepare all the eight different mixes of samples. The initial and final setting time was observed as 90 minimum and 230 minimum. Specific Gravity of cement was 3.14 and its compressive strength after 28 days was found to be 53MPa. And, it has the fineness modulus of 225 sqm/Kg.

- **Fine Aggregate:** Fine aggregate, which was used for the project was crushed sand and it conforms to zone 4 i.e. the zone for Maharashtra of [9]. Specific gravity of sand is 2.65 and the bulk density is 1.652 gm/cc.
- **Coarse Aggregate:** Crushed hard granite stone of maximum size 20mm is used for concrete. Bulk density of aggregate used was 1.450 gm/cc while the specific gravity of the aggregate came out to be 2.67.
- **Water:** Water for casting and curing purpose was used as per [10].
- **GGBS:** Ground Granulated Blast Furnace Slag, which is generally known by its shot form, i.e. GGBS was used for the project which was having a color near to whitish. It has a fineness modulus of 425 sqm/kg and it has a specific gravity of 2.9 and bulk density of 1.250 gm/cc.
- **Foundry Sand:** Foundry sand used in our project is, sub-angular to rounded shape. Approximately, 90% material came out to be in between 0.6mm and 0.15mm, so based on this we can say that the grain size distribution of foundry sand used was very uniform. The specific gravity of foundry sand came out to be 2.40 and having a bulk density of 2.59 gm/cc.
- **Steel Fiber:** Steel fibers used in the project have an equivalent diameter of 0.15mm and length of 50mm. Steel fibers are crimped having a rough surface along their length.

CASTING

Molds were oiled for easy demolding and properly fixed using screws. Concrete is prepared with the use of the above mentioned materials and required variations of GGBS and Foundry Sand are done. Fresh properties of concrete are determined. The samples were cast and vibrations were given to it in order to remove any air voids present in it and then the space which got created after the vibration, was filled with extra concrete to make up for the escaped air and then the next day samples were denuded by loosening the screws and at the same time care was taken not to harm the samples, and were put in the water pond for curing.

Table 1

	CEMENT %	FINE AGGREGATE %	COARSE AGGREGATE %	FOUNDRY SAND %	GGBS %	STEEL FIBER %	CUBE	CUBE	CYLINDER	BEAM
							(7DAYS)	(28DAYS)	(28 DAYS)	(28 DAYS)
S1 (CONTROL SAMPLE)	100	100	100	-	-	-	3	3	3	3
S2 (15% FS)	100	85	100	15	-	-	3	-	-	-
S3 (20% FS)	100	80	100	20	-	-	3	-	-	-
S4 (25%FS)	100	75	100	25	-	-	3	-	-	-
S5 (20% FS 30% GGBS)	70	80	100	20	30	-	-	3	-	-
S6 (20% FS 40% GGBS)	60	80	100	20	40	-	-	3	-	-
S7 (20% FS 50% GGBS)	50	80	100	20	50	-	-	3	-	-
S7 (20% FS 30% GGBS 1% SF)	70	80	100	20	30	1	-	3	3	3

Note: FS: Foundry Sand, GGBS: Grand Granulated Blast Furnace Slag, SF: Steel Fiber

TESTING

After 28days of curing the samples are removed from the curing pond and are kept for surface dry. Cubes and cylinders are tested on the Compression Testing Machine and beams are tested using Universal Testing Machine.

Figure 4: Compressive Strength Test

Figure 5: Split Tensile Test

Figure 6: Flexural Test

ANALYSIS OF TEST RESULTS

Compressive Strength

Compressive strength of a concrete specimen of control volume was found to be 20.15 MPa at 7 days and 31.2MPa at 28days. Then, the mix was prepared by replacing fine aggregate by foundry sand with 15%, 20% &25% variation. The result was obtained as 20.51MPa, 22.54MPa & 17.7MPa respectively. From the above test results, it was clear that when foundry sand was added, the compressive strength increased, and observed to be maximum, when fine aggregate was replaced by foundry sand by 20%. Thereafter, the percentage of foundry sand was kept at 20% (constant) and the variations were done in the percentage of GGBS as 30%, 40%, 50%. The results, thereafter were obtained as 46.58MPa, 44.60MPa and 39.61MPa respectively at 28days of testing. It was found that the mix prepared with 20% of foundry sand (replacement with fine aggregate) and 30% of GGBS (replaced with cement) shows highest compressive strength. Further on foundry sand (20%) and GGBS (30%) are kept constant and along with it 1% steel fiber was added to it. Finally the results obtained was 51.56 MPa.

From the above test results, we came to the conclusion that when the cement was replaced by GGBS (30%), Fine Aggregate by Foundry Sand (20%) along with Steel Fiber (1%) the compressive strength was increased by 20.36 MPa (approx. 65%).

Comparison of Compressive Strength B/W Control & Replacement Sample

Table 2

SAMPLE	FOUNDARY SAND (IN %)	GGBS (IN%)	STEEL FIBER (IN%)	LOAD (KN)		CROSS SECTIONAL AREA (mm^2)	STRESS (N/mm^2)	
				7 DAYS	28DAYS		7 DAYS	28 DAYS
S1 (CONTROL SAMPLE)	-	-	-	453.6	701.6	150 x 150	20.15	31.2
S2 (15% FS)	15	-	-	462	-	150 x 150	20.51	-
S3 (20% FS)	20	-	-	507.6	-	150 x 150	22.54	-
S4 (25%FS)	25	-	-	398.43	-	150 x 150	17.7	-
S5 (20% FS 30% GGBS)	20	30	-	-	1048	150 x 150	-	48.49
S6 (20% FS 40% GGBS)	20	40	-	-	1003.67	150 x 150	-	44.6
S7 (20% FS 50% GGBS)	20	50	-	-	891.33	150 x 150	-	39.61
S8 (20% FS 30% GGBS 1% SF)	20	30	1	-	1160.33	150 x 150	-	51.56

Note: FS: Foundry Sand, GGBS: Grand Granulated Blast Furnace Slag, SF: Steel Fiber

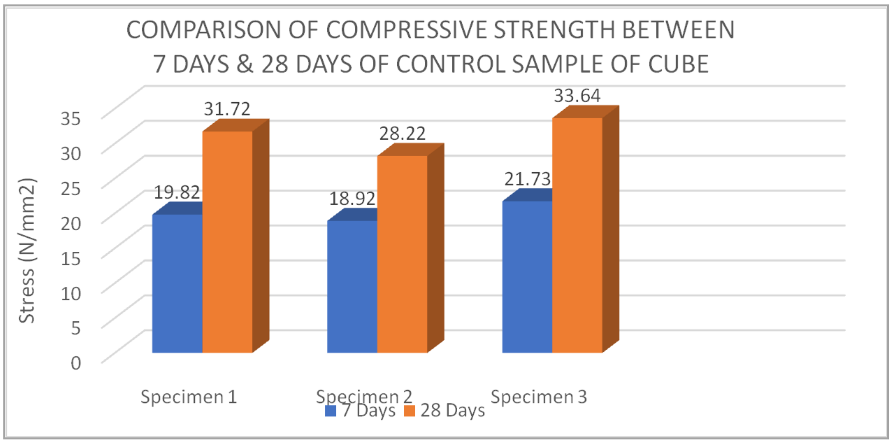


Figure 7

From the above figure we can conclude that the compressive strength of 7 days is approximately $2/3^{rd}$ of the compressive strength of 28 days.

Split Tensile Test

Tensile strength of control sample was found to be 3.04MPa after 28 days of testing Thereafter, a mix was prepared with 20% of foundry sand (replacement with fine aggregate) and 30% of GGBS (replaced with cement) along with its 1% steel fiber. Finally the result of the replacement sample was obtained as 3.99MPa which was increased by 0.95 MPa (approx. 31%).

Comparison B/W Tensile Strength of Conrol & Replacement Sample of Cylinder for 28 Days SS

Table 3

SAMPLE	SPECIMEN	LOAD (28DAYS)	STRESS (28DAYS)	AVERAGE STRESS (N/mm^2)	WEIGHT (KG)
S1 (CONTROL SAMPLE)	a	204.2	2.89	3.04 (28 days)	13.12
	b	225.1	3.19		13.25
	c	215.6	3.05		13.31
S8 (20%FS 30%GGBS 1% SF)	a	280.9	3.98	3.99 (28 days)	13.42
	b	268.8	3.8		13.432
	c	296.6	4.29		13.455

Note: FS: Foundry Sand, GGBS: Grand Granulated Blast Furnace Slag, SF: Steel Fiber

Flexural Strength Test

Flexural Strength of control sample was found to be 3.5 MPa after 28 days of testing. Thereafter, a mix was prepared with 20% of foundry sand (replacement with fine aggregate) and 30% of GGBS (replaced with cement) along with its 1% steel fiber. Finally the result of the replacement sample was obtained as 4.34 MPa.

From the above test result, we came to the conclusion that when the cement was replaced by GGBS (30%), Fine Aggregate by Foundry Sand (20%) along with Steel Fiber (1%) the flexure strength was increased by 0.84 MPa (approx. 24%).

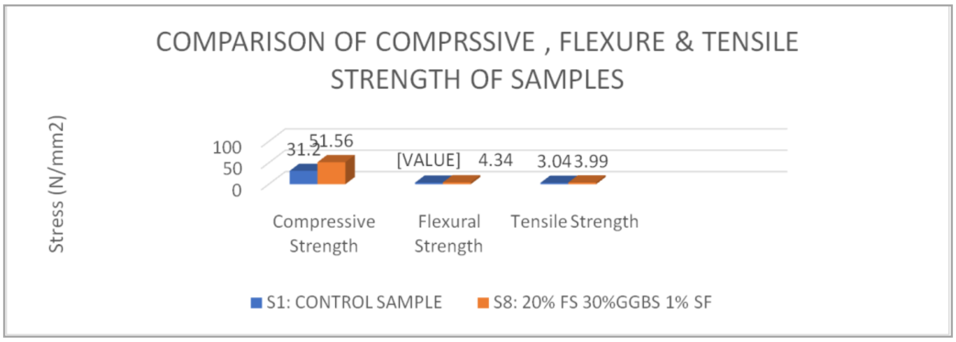
Comparison B/W Flexural Strength of Control& Replacement Sample of Beam for 28 Days

Table 4

SAMPLE	SPECIMEN	LOAD (KN) 28 DAYS	MOMENT (N.mm)	MI (mm^4)	Y (mm)	STRESS (N/mm^2)	AVERAGE STRESS (N/mm^2)	WEIGHT (KG)
S1 (CONTROL SAMPLE)	a	22.2	$22.2x10^6$	42187500	75	3.95	3.5	41.04
	b	17.6	$1.76x10^6$	42187500	75	3.12		40.63
	c	19.25	$1.925x10^6$	42187500	75	3.42		41.24
S8 (20% FS 30%GGBS 1% SF)	a	24.2	$2.42x10^6$	42187500	75	4.32	4.34	40.17
	b	23.5	$2.35x10^6$	42187500	75	4.18		40.15
	c	25.55	$2.55x10^6$	42187500	75	4.53		40.37

Note: FS: Foundry Sand, GGBS: Grand Granulated Blast Furnace Slag, SF: Steel Fiber

Comparison of Compressive, Flexural & Tensile Strength of Samples



Note: FS: Foundry Sand, GGBS: Grand Granulated Blast Furnace Slag, SF: Steel Fiber

Figure 8

Workability Test

Comparison of Workability Test Results (Slump Cone Test)

Table 5

Sample	Slump Value (in cm)
S1 (CONTROL SAMPLE)	7.5
S3 (20%FS)	15
S5 (20% FS 30% GGBS)	13
S8 (20% FS 30%GGBS 1% SF)	12

Note: FS: Foundry Sand, GGBS: Grand Granulated Blast Furnace Slag, SF: Steel Fiber

The workability test was conducted by using the slump cone test. It was observed that the foundry sand was used as a replacement; the workability was enhanced by twice. This was due to the fineness of foundry sand.

CONCLUSIONS

After performing the series of tests, we have come to the conclusion that our project was able to achieve the higher strength in compression, tension and flexure as compare to the control sample and at the same time making it more economical.

Due to replacement of cement with GGBS, we were able to achieve higher compressive strength. With the use of GGBS the heat of hydration was decreased which ultimately resulted in increased hindrance against chloride attack, sulphate attack and corrosion.

Also, we were able to achieve the higher workability by the replacement of fine aggregate by foundry sand. We also encountered there was an increase in compressive strength.

Further, the addition of steel fiber helped us to enhance the tensile strength of concrete.

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