EFFECT OF GRANULATED BLAST FURNACE SLAG AS SUBSTITUTE FOR FINE AGGREGATE IN CEMENT MORTAR AND CONCRETE

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Abstract

The objective of present investigation was to study the effect of granulated blast furnace slag as substitute for fine aggregate in cement mortar and concrete. Now a days, river sand becomes scarce and costly too, which is one of the very important ingredient of concrete and cement mortar mix especially in India and the world consumption of sand in concrete generation along is around 1000 to 1100 million tonnes per year, making its scarce and limited. Shortage of river sand resulted into the over dredging of river sand which causes environmental threat and loss of aquatic life also. In this paper granulated blast furnace slag is used as substitute for river sand in cement mortar and concrete, to overcome the environmental problems created due to over mining. In this investigation, in a cement mortar and concrete replacing natural sand by granulated blast furnace slag in a range of 20%, 40%, 60%,80% and 100%. The workability and strength of cement mortar and concrete with varying percentage of granulated blast furnace slag substitute which is then compare with workability and strength of conventional concrete. To determine the workability and strength of cement mortar and concrete, cubes of standard sizes 150mm x 150mm x 150mm (for concrete) and 70mm x 70mm x 70mm (for cement mortar) for 3rd day (cement mortar), 7th day and 28th days were casted and tested under compression testing machine . The work is extending to 100% replacement of natural sand with granulated blast furnace slag for M-20 grade of concrete and cement mortar. The compressive strength and flow characteristic of various mixes at various curing periods are studies. The study has shown that, the granulated blast furnace slag can be used as best alternative construction material over river sand. By these substitution and study one can achieve environmental protection as well as economy.

Keywords- *River Sand (RS), Granulated Blast Furnace Slag (GBS), Cement Mortar, Concrete, Workability, Compressive Strength.*

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1. INTRODUCTION

In the developing country like India, there is fast growth in infrastructure and residential field. In past few years construction of huge structures such as mega highways, dams, bridge etc has took place and still going on. It requires massive quantity of concrete for such a construction work and river sand being important constituent in concrete, the demand for river sand is increasing day by day, which is now become expensive and scarce. In the construction, river sand is used as an important building material, and the world consumption of sand in concrete generation along is around 1000 to 1100 million tonnes per year, making its scarce and limited.

Due to high increase in demand of river sand for construction of massive structures which has created the shortage of the same and caused treat to environment and society, created the situation to substitute the river sand. The growing environmental restrictions to the exploitation of river sand from river-bed in a search of alternative sand, particularly near the large developing areas. The deep dredging of river bed created ecological and environmental imbalance, which in turn affected the vegetation on the river banks and disturbed the aquatic life. It also caused the lowing of water table in the wells etc which affected the agriculture as well. By these substitution and study one can achieve environmental protection as well as economy. From previous study, the world steel industry produces about 780 Million tons of crude steel and simultaneously approximately 300 Million tons of solid wastes. Thus an average of about 200 to 400 Kg of solid by-product is generated per ton of crude steel. The total steel production in India is about 25Million Tonnes and the waste generated annually is around 10 Million Tonnes (considerably higher than the world average) but hardly25 % is being used mostly in cement production.

So, now a day the granulated blast furnace slag can be best substitution for fine aggregate in a cement mortar and concrete. Granulated Blast furnace Slag (GBS) is manufactured from molten blast furnace slag, a by-product produced simultaneously with iron. Therefore, it could be possible to prevent the environmental pollution especially in the region with excessive steel production.

In India, the steel manufacturing is one of the most successful industries. So application of these industrial waste like granulated blast furnace slag to reduce consumption of natural resources and pollution of the environment. The feasibility of the usage of granulated blast furnace slag (GBS) as percentage substitutes for fine aggregate in cement mortar and concrete is proposed to study.

This paper demonstrates the use of GBS as partially and fully replacement by river sand in a cement mortar and concrete.

2. EXPERIMENTAL INVESTIGATIONS

2.1 Investigation of Cement Mortar

In this work, cement mortar mix with 1:4 and 1:6 was selected for 0, 20, 40, 60, 80 and 100 % substitution of natural sand with GBS for constant w/c ratio of 0.4 and 0.5.

2.1.1 For 1:4 Cement-Sand Ratio

Table-1: Compressive strength at 3rd, 7th and 28th day for different percentage substitution of GBS with 0.4 w/c ratio

Combination	Compressive Strength, N/mm²		
	3days	7days	28 days
100%NS	34.63	40.89	51.30
20%GBS+ 80% NS	34.32	40.04	51.40
40%GBS+ 60% NS	34.94	40.13	50.80
60%GBS+ 40% NS	34.69	39.11	48.58
80%GBS+ 20% NS	34.00	38.10	46.84
100%GBS	35.56	36.80	46.15

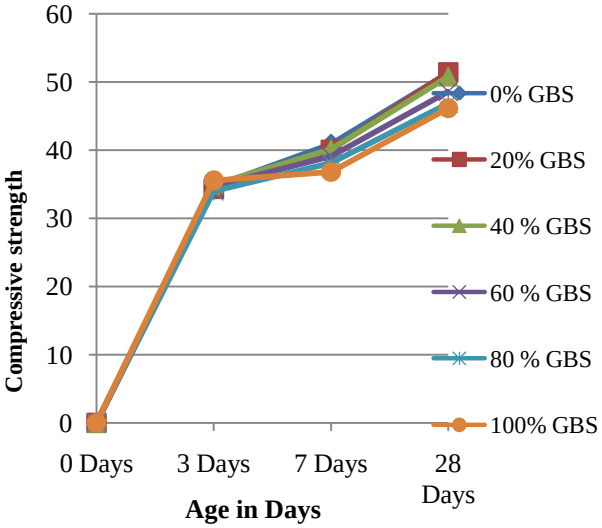

Fig-1: Variation of compressive strength at 3rd, 7th and 28th day for different percentage substitution of GBS with w/c ratio 0.4

Table-2: Variation of compressive strength at 3rd, 7th and 28th day for different percentage substitution of GBS with w/c ratio 0.5

Combination	Compressive Strength, N/mm²		
	3days	7days	28 days
100%NS	23.82	33.75	48.50
20%GBS+ 80% NS	26.13	33.20	48.01
40%GBS+ 60% NS	25.96	31.68	48.20
60%GBS+ 40% NS	25.09	30.55	46.29
80%GBS+ 20% NS	22.96	29.69	45.80
100%GBS	22.90	29.00	43.61

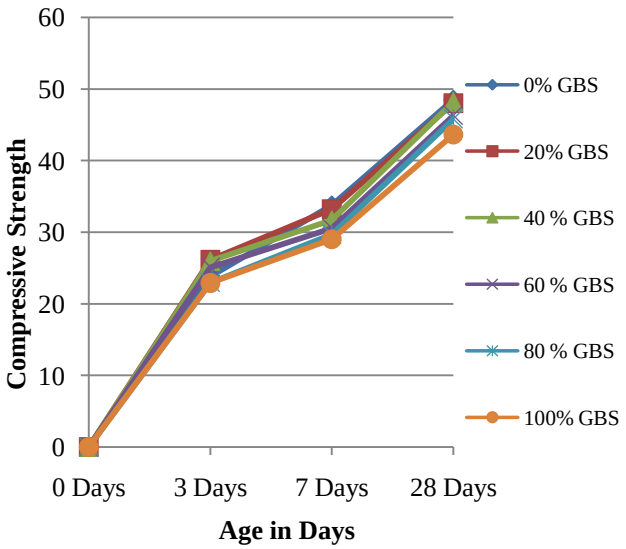

Fig-2: Variation of compressive strength at 3rd ,7th and 28th day for different percentage substitution of GBS with w/c ratio 0.5

2.1.2 For 1:6 Cement-Sand Ratio

Table-3: Variation of compressive strength at 3rd, 7th and 28th day for different percentage substitution of GBS with 0.4 w/c ratio

Combination	Compressive Strength, N/mm²		
	3days	7days	28 days
100%NS	36.65	43.80	53.64
20%GBS+ 80% NS	36.72	43.54	53.15
40%GBS+ 60% NS	36.56	43.45	52.98
60%GBS+ 40% NS	35.91	43	51.98
80%GBS+ 20% NS	35.50	42.50	49.32
100%GBS	34.35	42.26	49.95

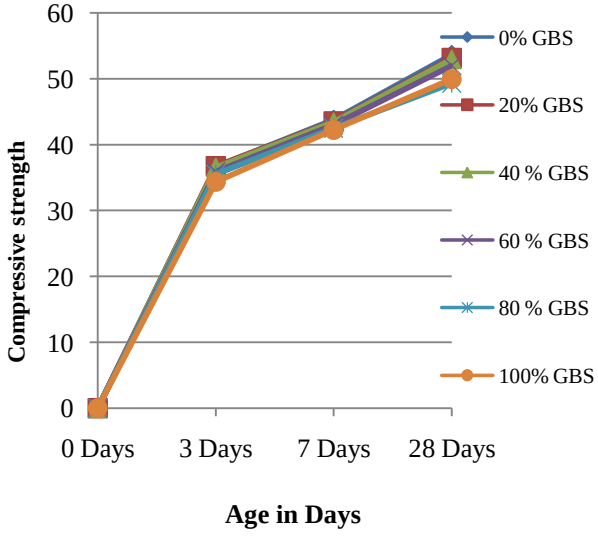

Fig-3: Variation of compressive strength at 3rd, 7th and 28th day for different percentage substitution of GBS with w/c ratio 0.4

Table-4: Compressive strength at 3rd, 7th and 28th day for different percentage substitution of GBS with w/c ratio 0.5

Combination	Compressive Strength, N/mm²		
	3days	7days	28 days
100%NS	25.80	36.51	52.04
20%GBS+ 80% NS	24.95	36.33	52.00
40%GBS+ 60% NS	24.69	36.27	51.70
60%GBS+ 40% NS	25.09	35.54	49.67
80%GBS+ 20% NS	24.18	35.51	48.64
100%GBS	24.31	34.66	48.32

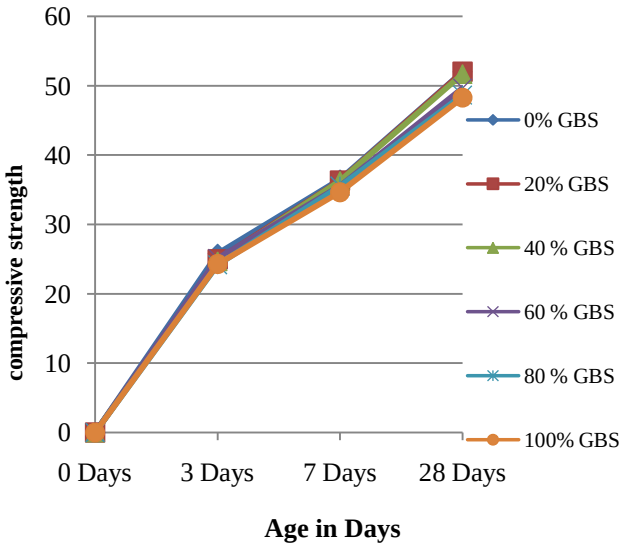

Fig.4: Variation of compressive strength at 3rd, 7th and 28th day for different percentage substitution of GBS with w/c ratio 0.5

Observation

- Strength gaining as per age is found less for the mortar (1:4) due to 100% substitution of GBS.
- For Rich mortar (1:4) sand content is less, substitution of GBS make the mortar harsh. So strength observed is less.
- Mortar in which sand content is more, substitution of GBS is preferable. The reduction in strength due to substitution of GBS is almost 5% to 7%.

Discussion

- Strength gaining in early age (3th day) is observed good at w/c ratio 0.4 for both the proportion of mortar 1:4 and 1:6. The strength gaining at early age (3th day) is low at w/c ratio 0.5 for both the proportions but there is marginal difference at 28th day strength between 0.4 and 0.5 w/c ratio.

3. M20 GRADE OF CONCRETE (M20)

A total of six series of concrete mixes were prepared in order to examine the effect of substituting of Granulated Blast Furnace Slag. An experiment investigation is carried out on a concrete containing granulated blast furnace slag in a range of 20%, 40%, 60%, 80% and 100% for M-20 grade. The workability and strength of cement mortar and concrete with varying percentage of granulated blast furnace slag substitute which is then compare with workability and strength of conventional concrete. To determine the workability and strength of concrete, cubes of standard sizes 150mm x 150mm x 150mm, for 7th day and 28th days were casted and tested under compression testing machine.

Proportions

W/C ratio (lit.)	C (kg)	FA (kg)	CA (kg)
0.51	1	2.1	3.55

3.1.1 Properties of Concrete in Fresh State

Fresh state of concrete in which workability & density of concrete can be tested.

Table-5: Following are the table and figures showing workability & density results.

Sr. no.	Designation of Substituted Mix	Combination of NS & GBS	Workability		Fresh Density (kg/m³)
			Slump (mm)	C.F.	
1	M1	100% NS	70	0.91	2814.815
2	M2	20% GBS+80% NS	60	0.90	2616.296
3	M3	40% GBS+60% NS	15	0.82	2770.37
4	M4	60% GBS+40% NS	15	0.77	2681
5	M5	80% GBS+20% NS	10	0.86	2607
6	M6	100% GBS	5	0.84	2548

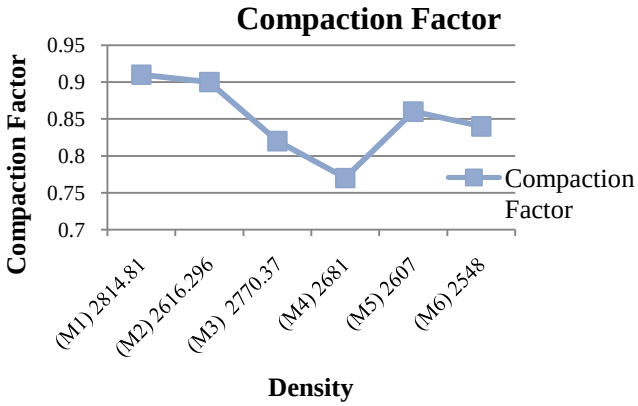

Fig-5: Relation between Compaction factor & Density for M20 grade of Concrete

Observations & Discussions

1. As the % of GBS increases the workability reduces.
2. As the % of GBS increases the slump reduces. However compaction factor is also reducing as % of GBS increases but up to60% GBS substitution i.e. M4. The compaction factor (C.F) is increasing for M5 and M6 in which GBS % is high.
3. Mix with natural sand (NS) has given highest density. As % of GBS increases, the density of concrete decreases by 9.5%.

3.1.2 Properties of Hardened Concrete

1. Compressive Strength

Table-6: Compressive strength at 7th day for M20 Grade of GBS with different % of GBS substitution

Sr. no.	Designation of Substituted Mix	Combination of NS & GBS	Compressive Strength 7th Day
1	M1	100% NS	17.87
2	M2	20% GBS+80% NS	17.85
3	M3	40% GBS+60% NS	19.08
4	M4	60% GBS+40% NS	17.61
5	M5	80% GBS+20% NS	16.14
6	M6	100% GBS	18.89

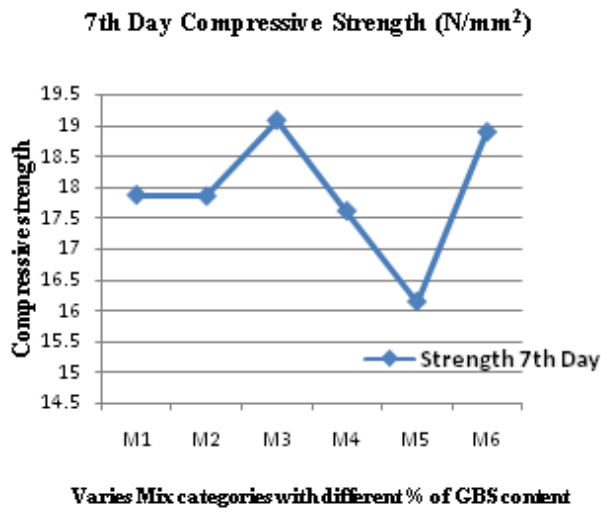

Fig-6: Graph representing Compressive strength at 7th day for M20 Grade of GBS with different % of GBS substitution

Observations and Discussions

1. For 7th day compressive strength, the values of M1 and M2 mix are almost same.
2. Higher 7th day strength is observed for mix M3 (40%).
3. Graph shows reduction in 7th day compressive strength for M4 and M5 mix. Again the strength is increasing for M6 as compared to M4 and M5 mixes.

Table-7: Compressive strength at 28th day for M20 Grade of GBS with different % of GBS substitution

Sr. no.	Designation of Substituted Mix	Combination of NS & GBS	Compressive Strength 28th Day
1	M1	100% NS	24.25
2	M2	20% GBS+80% NS	24.13
3	M3	40% GBS+60% NS	29.025
4	M4	60% GBS+40% NS	20.195
5	M5	80% GBS+20% NS	22
6	M6	100% GBS	26.48

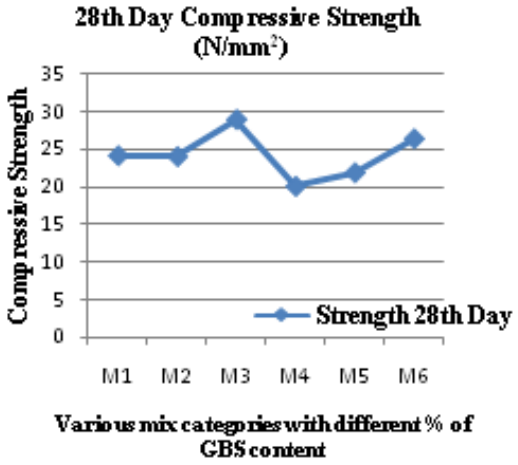

Fig-7: Graph representing Compressive strength at 28th day for M20 Grade of GBS with different % of GBS content

Observations and Discussions

1. The 28th day compressive strength is almost same for M1 & M2 mixes.
2. Higher 28th day strength is observed for mix M3 (40%).
3. Graph shows reduction in 28th day compressive strength for M4 mix. Again the strength is increasing for M5 and M6 as compared to M4.

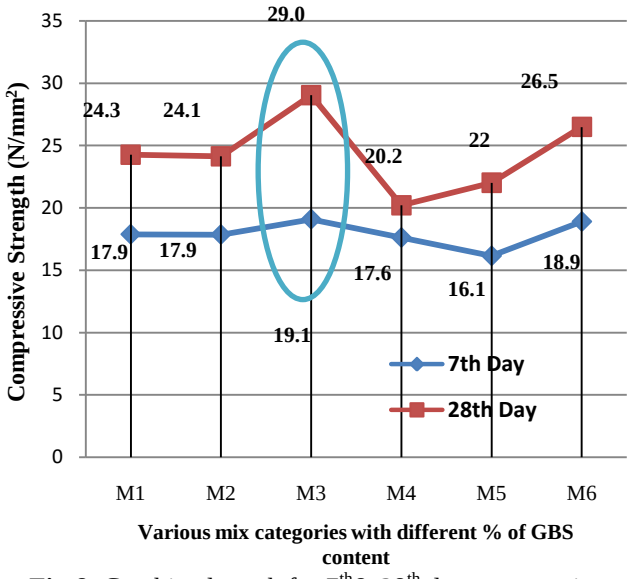

Fig-8: Combined graph for 7th& 28th day compressive strength for M20 grade of GBS concrete

Observation

1. The 7th and 28th day compressive strength are almost same for M1 and M2 mix. The gain in 7th day and 28th day compressive strength is observed for M3 mix.
2. Again the strength at 7th day and 28th day is reducing for M4 & M5 mixes.
3. The strength improvement is observed for M6 mix (100% GBS) as compared to M4 and M5.

3.1.3 Improvement of Workability of Concrete

As the workability (slump) for mixes M3 (40% GBS), M4 (60% GBS), M5 (80% GBS), M6 (100% GBS) is not satisfactory, the strength is reasonable. So an attempt is made to improve the slump of M3, M4, M5 and M6 mixes. However the admixtures dosages with different % were tried to get desired workability. Following admixture dosages are finalized and again the properties of concrete have studied.

Table-8: Content of admixture in each mix

Sr. No.	Designation of Substituted Mix with Admixture	Combination of NS & GBS with admixture
1	MA1	40% GBS+60% NS+1% Adm.
2	MA2	60% GBS+40% NS+1% Adm.
3	MA3	80% GBS+20% NS+1% Adm.
4	MA4	100% GBS+1.3% Adm.

Table-9: Workability results of mixes with admixture

Sr. no.	Designation of Substituted Mix	Combination of NS & GBS	Workability
			Slump
1	MA1	40% GBS+60% NS	150
2	MA2	60% GBS+40% NS	135
3	MA3	80% GBS+20% NS	75
4	MA4	100% GBS	75

Table-10: Compressive strength at 7th day & 28th day for M20 Grade of GBS with different % of GBS substitution with Admixture

Sr. no.	Designation of Substituted Mix	Combination of NS & GBS	Strength	
			7th Day	28th Day
1	MA1	40% GBS+60% NS	20.51	25.81
2	MA2	60% GBS+40% NS	18.49	23.94
3	MA3	80% GBS+20% NS	17.85	24.68
4	MA4	100% GBS	21.32	26.40

Observations & Discussions

1. After several trials the % of dosage of admixture is finalised as 1%. The slump obtained for above dosage of admixture is reducing as % of GBS increasing.
2. While MA4 mix (100% GBS) requires 1.3% of dosage of admixture.
3. The 7th day strength is marginally increased for the mixes with admixture when compared to mixes without admixture i.e. M3, M4, M5, and M6.

4. CONCLUSION

4.1 Cement Mortar

1. For Rich mortar (1:4), especially for plaster work if sand is coarser; the substitution of GBS is limited to 20%.
2. For mortar proportion having 1:6 and more than that, the substitution of GBS is limited to 60%.
3. In practical sense (purpose) for brick mortar if natural sand is coarser the substitution of GBS is 40% and if natural sand is finer the substitution of GBS is 30%.

4.2 M 20 Grade of Concrete

1. The compaction factor and Density is reducing as percentage of Granulated blast furnace slag increasing, the compacting factor is reduced from M1 to M4 and again increased for M5, M6.
2. The workability of concrete is inversely proportional to the % substitution of granulated blast furnace slag.
3. The mix M3 (40% GBS) has given highest 7th and 28th day compressive strength but workability especially slump is affected. 20% substitution of Granulated blast furnace slag in natural sand has given medium workability (Slump=60mm and C.F=0.9) and reasonable strength. So 20% substitution in natural sand is preferable when chemical admixture is not used.
4. The major impact on concrete due to substitution of Granulated blast furnace slag is low slump and the reduction in slump is observed when 40% and more than 40% granulated blast furnace slag is substituted in natural sand. Super plasticizer with 1% dosage is required for concrete in which 40% to 80% Granulated blast furnace slag is substituted in Natural sand. 1.3% is the dosage required for 100% GBS to achieve desired workability.
5. If chemical admixture is used in concrete, 40% GBS substitution is suggested which gives high workability and required strength.

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