An Exploratory Study on the Feasibility of Partial Utilization of Industrial Slag into Concrete Mix.

PROF.RODRIGUES J. S[1], RAJLAXMI. N[2], PREMDEEP. S[3], KUNAL. H[4]

[1]*Assistant Professor, Dept. of Civil Engg, DKTE Society's Textile and Engineering Institute, Ichalkaranji.*

[234]*UG Students, Dept. of Civil Engg, DKTE Society's Textile and Engineering Institute, Ichalkaranji.*

Abstract— Concrete is the most widely used construction material in civil engineering industry due to its high structural strength and stability. The concrete industry is actively seeking alternative materials, such as supplementary cementitious materials or industrial byproducts, in order to decrease carbon dioxide emissions, which pose a significant threat to the environment. And on other side River sand is indeed an essential component in concrete mixtures as it serves as a fine aggregate, helping to fill voids and enhance the overall structure. However, it's important to recognize that river sand is a natural resource with finite availability, and its usage should be carefully managed to avoid depletion. Therefore, we have to find some alternative for these two materials and Industrial slag is one of the best alternatives we can use in concrete mix. The solid waste produced by industries, known as ground granulated blast furnace slag (GGBS), is utilized as a substitute material for cement. And Granulated Blast Furnace slag (GBS) is used for replacement of Fine Aggregate. Therefore, in this study we are going to replace Cement and Fine aggregate simultaneously with GGBS and GBS respectively. Compressive strength test was carried out for 7 and 28 days

Index Terms— Industrial slag, Ground Granulated Blast Furnace slag (GGBS), Granulated Blast Furnace slag (GBS), Compressive strength.

I. INTRODUCTION

Sustainable development could be achieved through minimization of the use of natural resources and optimum utilization of different industrial waste in developing various types of construction materials (Patra and Mukharji , 2017). Concrete, is one of the most widely used construction materials globally, plays a important role in shaping the infrastructure and built environment of societies (Gagg,c. 2014). However, its production comes at a significant environmental cost due to the high energy consumption and carbon emissions associated with cement production, the primary binding agent in concrete.

The cement industry is the most important and major source of greenhouse gases worldwide. China produces largest amount of cement in world in 2012 the production was 2.15 billion metric tonnes. After China, India is second largest producer of cement. As the demand for cement increasing the consumption of non-renewable resources like Lime stone were increased. (Mohamad, N. al.,2021). Apart from this cement industry produces large amount of greenhouse gases like CO2. The cement industry has always been among the greatest CO2 discharge sources as 900 kg CO2 released to the environment for producing one ton of cement. (Bakhtyar, et.al.,2017). In 2018-2019, India had an annual cement consumption of 337 million tons and this is expected to increase up to 550 million tons by 2025.

Sand is second largest resource that is used in the world after water. The increasing demand for sand in construction industry causes harmful impact on nature. The large sand mining on either side of the river is one of the major causes of environmental degradation and it also causes a threat to the biodiversity (Bhoopathy, V., &Subramanian, S. S 2022). From 2010 to 2020 river sand usage in Indian Construction sector increased from 630 to 1400 million tonnes. Due to harmful impact of sand mining on environment several states banned river sand as fine aggregate in India (Santhosh, et.al.,2021).

Due to this negative impact of river sand in environment few states are exploring the option like M-sand. But the stones required for production of manufacture sand is heavily extracted from land. It has many negative environmental impacts like disruption of animal habitat, vegetation destruction, soil erosion, river siltation, noise pollution due to blasting of mountain, transport of rocks by truck, dumper etc., and dust pollution (Mahapatra,2022). Therefore, the M-sand also has negative impact on environment.

To meet the demand of Cement and Fine aggregate we have to find some alternatives and one of such promising alternatives are Industrial slags. There is large amount of slag is produced from the steel and Iron manufacturing companies. Slag is a waste material of the steelmaking process which is composed of a mixture of metal oxides, SiO2, metal sulphides and elemental metals that accumulate on the surface of impure molten metals. We can utilize this industrial by-product as replacement of materials in concrete (Oge, M, et.al.,2019).

1.1.Granulated Blast Furnace Slag (GBS):

Blast-furnaces are fed with a controlled mixture of iron-ore, coke and limestone and operated at a temperature of about 1,500°C. When iron-ore, coke and limestone melt in the blast furnace, two products are produced i.e. molten iron and molten slag. Granulated blast furnace is obtained by processing the molten slag by rapidly chilling or quenching with water or steam jet. This rapid cooling process causes the slag to solidify into small granules rather than forming a solid mass. This process produces a granular glassy aggregate. For that GBS is used as a partial replacement for natural sand in the mix design of concrete.

1.2.Ground Granulated Blast Furnace Slag (GGBS):
Ground Granulated Blast Furnace Slag is obtained After granulation of blast furnace slag, this granulated slag is typically dried to reduce its moisture content. This drying process can be carried out using various methods, such as rotary dryers or air drying. Once dried, the granulated slag is ground into a fine powder. To making it suitable for use with cement and concrete mix. Using the GGBS in concrete can reduce the demand for Portland cement, which is the major source of carbon emission during its production.

1.3.Objectives of present study:

• To evaluate the material properties of Ground Granulated Blast Furnace Slag (GGBS) & Granulated Blast furnace Slag (GBS).

• To determine the variation of Workability of concrete made with GGBS & GBS as partial replacement of cement and sand respectively.

• To analyze the compressive strength of conventional concrete and concrete with partial replacement of cement and sand using GGBS & GBS respectively.

II. MATERIAL USED

2.1. Cement:

In this experiment OPC (Ordinary Portland Cement) 53 Grade is a type of cement that conforms to the Indian Standard IS12269-1987 of Birala Shakti Brand cement is used for this experiment.

2.2. Admixture:

Superplasticizer used complied with IS:9103-1999 and it was of Sulphonated Naphthalene Formaldehyde base for concretes from grade M25 to M40.

2.3. GGBS:

The ground Granulated Blast Furnace Slag (GGBS) used in this project is of JSW. The Physical properties of cement and GGBS is given in Table no.I

Table No.I: Physical Properties of Cement and GGBS

Test	Cement	GGBS
Specific Gravity	3.15	2.9
Colour	Gray	Off white
Consistency	33%	31%
Initial Setting Time	150 min	180 min
Final Setting Time	255 min	305 min
Fineness (Sieving on 90µm)	96%	100%
Fineness (Blain's air permeability) (standard)	225 m^2/kg	360 m^2/kg

2.4. Fine Aggregate:

The aggregate passing through the sieve size 4.75mm is termed as fine aggregate.

2.4.1. M-Sand:

Manufactured sand (M-Sand) is a artificial sand through the crushing of hard stones into small sand-sized angular shaped particles. These particles undergo washing process and are finely graded to ensure optimal quality, suitable for utilization as fine aggregate in various construction applications.

2.5. GBS:

When molten slag is cooled and solidified by rapid water quenching to a glassy state, little or no crystallization occurs. This process results in the formation of sand size (or frit-like) fragments, usually with some friable clinker like material.

Table No.II: Properties of M-sand and GBS

Test	M-sand	GBS
Zone	II	II
Water Absorption	0.68%	1.54%
Fineness Modulus	2.61	2.34
Specific Gravity	2.90	2.49
Bulk Density	1.873 kg/Ltr	1.465kg/Ltr

2.. Coarse Aggregate:

The aggregate which retained on 4.75 mm sieve is termed as coarse aggregate. Minimum 10 mm & maximum 20 mm size of coarse aggregate are used for this experiment having specific gravity 2.78 and 2.79 respectively.

III. EXPERIMENTAL PROCEDURE

The experimental procedure has been described in following paragraphs.

3.1 Mix Design:

Proportion for concrete mix for M25 grade of concrete has been achieved by concrete mix design as per IS 456:2000 and IS 10262:2009. Composition of constituent material per cubic meter of concrete for different batches is given in Table III.

Table No.III: Mix Proportion of M25 grade concrete

Mix ID	Replacement (%) (GGBS – GBS)	Cement (kg/m3)	GGBS (kg/m3)	M-sand (kg/m3)	GBS (kg/m3)	C.A (kg/m3)	W/C ratio	Admixture (kg/m3)
A0	0-0	350.51	-	759.88	-	1244.76	0.45	2.103
A10	10-10	315.46	35.05	682.36	65.10	1242.09	0.45	2.103
A20	20-20	280.41	70.10	605.28	129.93	1239.38	0.45	2.103
A30	30-30	245.35	105.15	528.47	194.46	1236.78	0.45	2.103
A40	40-40	210.31	140.20	452.08	285.77	1234.25	0.45	2.103
A50	50-50	175.25	175.25	376.09	322.91	1232.14	0.45	2.103
A60	60-60	140.20	210.30	300.14	386.56	1229.16	0.45	2.103

3.2 Mixing Technique:

Machine mixing technique has been adopted in the whole experiment work. In each batch 6 specimen of cube of dimension 150mm x 150mm x 150mm has been made.

3.3 Properties of Fresh Concrete:

The Property of Fresh concrete is determined by workability in terms of slump value. The test has been performed according to IS 1199:1959. The results of which are given in Table IV.

Table No.IV: Slump Test Of concrete

Mix ID	A0	A10	A20	A30	A40	A50	A60
Slump (mm)	105	100	90	85	70	55	50

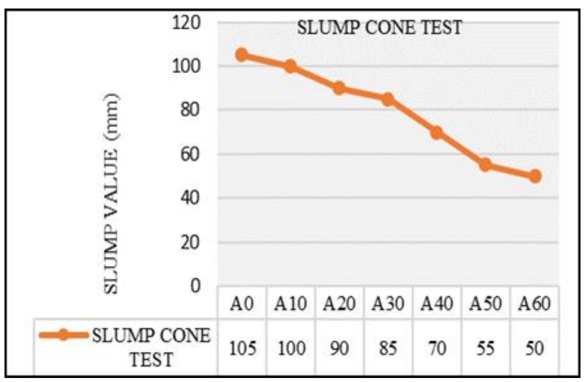


Fig.1. Slump Cone Test Results

From the slump cone test, it has been observed that the workability of concrete decreases as the percentage of GGBS and GBS increases up to 60% replacement.

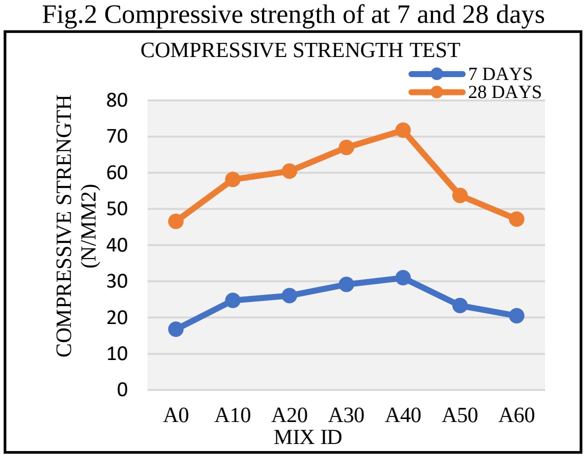
3.4 Properties of Hardened Concrete:

The compressive strength test is the most common test performed on the hardened concrete to check its strength. The test was performed in accordance with IS 516:1959 on the cube specimen after 7 days and 28 days curing. The results of which is given below in table. V.

Table No.V: Compressive Strength of concrete

Mix ID	Compressive strength N/mm^2		% Increase in strength at 28 Days
	7 Days	28 Days	
A0	16.76	29.84	-
A10	24.73	33.45	12.09
A20	26.03	34.45	15.33
A30	29.18	37.82	26.74
A40	30.96	40.76	36.61
A50	23.35	30.36	1.74
A60	20.5	26.67	-10.62

Fig.2 Compressive strength of at 7 and 28 days



The Graph showing the variation of compressive strength of concrete with different percentage of GGBS and GBS is presented below in fig.2.

From the compressive strength test after 7 days and 28 days curing it is clear that the compressive strength increases with increase in the percentage of replacement of cement and M-sand with GGBS and GBS respectively. The optimum compressive strength is observed for concrete incorporating 40% GGBS and GBS, and reduction in compressive strength has been detected with further increment in GGBS and GBS percentage. Therefore, we can replace the Cement and M-sand with GGBS and GBS up to 40% which gives the highest strength i.e. 40.76 N/mm2.

CONCLUSION

- From the slump cone test it is clear that the workability of concrete mix decreases with increase in the percentage of replacement of cement and M-sand with GGBS and GBS respectively. This is due to some physical properties of GGBS and GBS like Fineness of GGBS is more than the OPC 53 cement, fineness modulus of GBS is less than M-sand and also the water absorption of GBS is more than M-sand etc.
- The Workability of the Conventional concrete mix obtained by performing slump cone test is 105mm and the workability of the concrete mix A40 is 70 mm. However, the workability of concrete significantly reduced beyond this replacement level hence increase in dosage of admixture is recommended for achieving a workable mix. The workability of A40 mix is in medium range so that we can use it for the concreting of heavily reinforcement sections in slabs, beams, column etc.(IS.456:2000, clause.7)
- From the compressive strength test, it is found that after 7 days and 28 days curing of concrete mix the compressive strength increased with increasing percentage of replacement of cement and M-sand with GGBS and GBS respectively. The optimum compressive strength is observed for concrete incorporating 40% GGBS and GBS, and reduction in compressive strength has been detected with further increment in GGBS and GBS percentage.

REFERENCES

[1] Bakhtyar, B., Kacemi, T., & Nawaz, M. A. (2017). A review on carbon emissions in Malaysian cement industry. *International Journal of Energy Economics and Policy*, 7(3), 282-286.

[2] Bhoopathy, V., & Subramanian, S. S. (2022). The way forward to sustain environmental quality through sustainable sand mining and the use of manufactured sand as an alternative to natural sand. *Environmental Science and Pollution Research*, 29(21), 30793-30801.

[3] Chaithra, H. L., Pramod, K., & Chandrashekera, A. (2015). An experimental study on partial replacement of cement by GGBS and natural sand by quarry sand in concrete. *Int J Res Appl Sci Eng Technol*, 3(4), 1539-1544.

[4] Chinnu, S. N., Minnu, S. N., Bahurudeen, A., & Senthilkumar, R. (2021). Recycling of industrial and agricultural wastes as alternative coarse aggregates: A step towards cleaner production of concrete. *Construction and Building Materials*, 287, 123056.

[5] Ganesh, P., & Murthy, A. R. (2019). Tensile behaviour and durability aspects of sustainable ultra-high performance concrete incorporated with GGBS as cementitious material. *Construction and Building Materials*, 197, 667-680.

[6] Mohamad, N., Muthusamy, K., Embong, R., Kusbiantoro, A., & Hashim, M. H. (2021). Environmental impact of cement production and Solutions: *A review. Materials Today: Proceedings*. doi: 10.1016/j.matpr.2021.02.212

[7] Oge, M., Ozkan, D., Celik, M. B., Gok, M. S., & Karaoglanli, A. C. (2019). An overview of utilization of blast furnace and steelmaking slag in various applications. *Materials Today: Proceedings*, 11, 516-525.

[8] Patra, R. K., & Mukharjee, B. B. (2017). Influence of incorporation of granulated blast furnace slag as replacement of fine aggregate on properties of concrete. *Journal of cleaner production*, 165, 468-476.

[9] Santhosh, K. G., Subhani, S. M., & Bahurudeen, A. (2021). Cleaner production of concrete by using industrial by-products as fine aggregate: A sustainable solution to excessive river sand mining. *Journal of Building Engineering*, 42, 102415.

[10] JSW GGBS Broachure.