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Enhancing Concrete Performance Using GGBS and Waste Foundry Sand

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ABSTRACT :

To build anything, you need cement and good aggregates. Low- and middle-income households are finding it difficult to build their houses due to the drastically higher building prices caused by the growing demand for these materials. In order to reduce building costs, research institutes are constantly looking for alternative materials. One such solution that this study investigates is making use of waste products.

As a partial substitute for cement and fine aggregates, respectively, Ground Granulated Blast Furnace Slag (GGBS) and Waste Foundry Sand were used in this research. Since cement is the most costly part of concrete, there is a chance to save costs by using GGBS or another locally derived, environmentally friendly substance in its place. The cost burden connected with concrete and housing is reduced, and trash management is helped as a result. The enormous building-scale application potential of GGBS, which is created from industrial processes, has attracted attention from throughout the world. A common use for waste foundry sand is as a molding material; it is a high-quality silica sand that is generated by ferrous and nonferrous metal industries. This sand may be used again and again as a filler after its first usage. The experimental study's primary objective was to compare the strength characteristics of concrete made with different amounts of GGBS and Waste Foundry Sand. At 28, 56, and 90 days, tests involving compression, split tensile strength, flexural strength, and workability were carried out using an M30 mix design. The quantity of river sand replaced varied from 0% to 60%, with 20% GGBS also included. To further establish the ideal GGBS replacement %, cement mortar cubes were subjected to compressive strength testing.

Keywords: GGBS, Waste Foundry Sand, Compressive Strength, Split Tensile Strength, Flexural strength.

CHAPTER-1
INTRODUCTION

General:

The Latin word "concretus," meaning compact or condensed, is where the English word "concrete" comes from. Concrete has been a popular building material for a long time. Comprised of hydrated cement, fine aggregates like sand, and coarse aggregates like crushed stone or gravel, it is a composite material.

Concrete, in its widest definition, is any material that is formed by combining hydraulic cement with water or another cementing agent. Effective concrete performs admirably both when cured and while still wet, during mixing and transportation to the formwork. The new mixture has to be compaction-ready and cohesive enough to prevent segregation both in transit and on site.

The main need, in terms of its solidified form, is enough compressive strength. This strength is associated with several concrete characteristics, including density, impermeability, durability, resistance to abrasion and impact, tensile strength, and resistance to sulfate.

- **Aggregates**: Concrete is not what it is without aggregates. Coarse aggregates in lightweight concrete often consist of crushed stone and rocks, but it may also incorporate man-made components including slag, slate, fly ash, and clay. The hydrated cement paste needs fine aggregates, which are often found in river beds or quarries, to fill up the spaces between the coarse aggregates.
- **Cement**: Modern concrete cement is created by kiln-heating a combination of clay and limestone to temperatures ranging from 1400 to 1600 degrees Celsius. Cement types permitted by IS: 456-2000, the Plain and Reinforced Concrete Code of Practice, include the following:

1. Ordinary Portland Cement (IS: 269 - 1989)
2. Portland Slag Cement (IS: 455 - 1989)
3. Rapid-Hardening Portland Cement (IS: 8041 - 1990)

- **Water**: Section 5.4 of IS: 456 to 2000 specifies requirements for the water that must be utilized. To be more precise, "Curing and mixing water must not contain any organic compounds, oils, acids, alkalis, salts, sugar, or any other impurities that could damage concrete and steel."
- **Admixtures**: In accordance with IS: 1343 - 1980, admixtures that meet the requirements of IS: 9103 - 1999, which details the qualities of concrete admixtures, may be used. Chemical admixtures and mineral admixtures are the two primary groups into which these additives fall.

Waste Foundry Sand (WFS)

Sustainable waste management has emerged as a key environmental issue on a worldwide scale due to the continuous increase in waste materials and industrial byproducts. With landfill space becoming more limited and expenditures rising, the use of wastes and by-products has become an attractive disposal alternative. Waste Foundry Sand (WFS) is one example of an industrial by-product.

When all the byproducts from ferrous and "non-fer metal casting" industries are added together, they amount to millions of tons. In India alone, waste foundry sand production amounts to almost 2 million tons per year. Considering its extensive track record of efficient landfilling applications, WFS is mainly considered an afterthought by the steel castings sector. The chemical and physical characteristics of WFS may be influenced by a variety of furnace types and finishing procedures, including induction, electric arc, cupola, grinding, and coating

Ground Granulated Blast Furnace Slag (GGBS):

Granulated blast furnace slag, or GGBFS, is a material that is produced as a waste product during the iron manufacturing process. In this process, which includes adding limestone, iron ore, and coke to a furnace, melted slag develops and floats above the hot iron at temperatures ranging from 1500°C to 1600°C. The chemical composition of molten slag is quite similar to that of Portland cement, consisting of around 40% CaO and 30% to 40% SiO_2. When the molten iron is removed from the slag and it is rapidly quenched with water, glassy granulate is created.

This molten slag mostly consists of luminescent and siliceous byproducts. A very finely ground glassy granulate is the end product of drying and grinding. Production of GGBFS requires a stronger material than Portland cement. Using GGBFS instead of Portland cement may lower carbon dioxide emissions, making it an eco-friendly construction material.

Scope of the Present Work:

An improved understanding of the strength properties of grade M40 concrete mixes including waste foundry sand as a partial replacement for river sand, the fine aggregate, is the primary objective of the present investigation. Ten percent, twenty percent, thirty percent, forty percent, fifty percent, and sixty percent of the fine aggregate will be replaced with weight-based WFS. By determining the optimal proportion of GGBS to replace cement in binary mixed concrete, we may compare the two forms of concrete with respect to certain strength properties, including compressive strength, split tensile strength, and flexural strength.

CHAPTER -II

MATERIALS AND METHODOLOGY

Cement:

The 53-grade ultra tech cement, sometimes called regular Portland cement, was still in use in 1987, according to IS: 12269. Its physical characteristics were reviewed in line with IS 4031 (part II)-1988.

Physical Properties of Ordinary Portland Cement

S.No.	Property	Test Method	Test Result
1	Specific Gravity	Specific gravity bottle (IS 4031-Part 11)	3.16
2	Normal Consistency	Vicat apparatus (IS 4031-Part 4)	31.8 %
3	Initial Setting time	Vicat apparatus (IS 4031-Part 5)	40 min
4	Fineness	Sieve test on sieve no.9 (IS 4031-part 11)	7.2%

Chemical Properties of Ordinary Portland Cement

S.No.	Component	Specifications (%) as per IS: 12269	Result(%/wt)
1	SiO_2	17-25	22.96
2	Al_2O_3	4-8	5.75
3	Fe_2O_3	3-5	3.86
4	CaO	61-64	62.95
5	MgO	0.1-4	2.12
6	SO_3	1.3-3	1.53

7	K_2O	0.4-0.8	0.52
8	Na_2O	0.2-0.6	0.31

Fine Aggregate Properties:

Used as a fine aggregate was natural river sand sourced from a local market. Calculations were made for physical properties such as specific gravity, bulk density, gradation, and fineness modulus in accordance with IS: 2386, 1963.The fineness modulus was calculated from the results of the fine aggregate sieve test. In the sample, there were 1,000 grams.

Sieve Analysis Chart of Fine Aggregate

S.No.	IS Sieve Size	Weight Retained in (gms)	Cumulative Weight Retained	Cumulative % Weight Retained	% Passing
1	4.75 mm	4	4	0.4	99.6
2	2.36 mm	10	14	1.4	98.6
3	1.18 mm	78	92	9.2	90.8
4	600µ	305	398	39.8	60.2
5	300µ	435	833	83.3	16.7
6	150µ	135	969	96.9	3.1
7	Pan	20	990	_____	0.00

Physical Properties of Fine Aggregate

S.No.	Property	**Test Method**	**Test Results**
1	Fineness modulus	Sieve analysis (IS 2386-1963 Part 2)	2.41
2	Specific gravity	Pycnometer (IS 2386-1963 Part 3)	2.58
3	Bulk density (kg/m^3) - Loose Bulk density (kg/m^3) - Dense	(IS 2386-1963 Part 3)	1535 1675

Coarse Aggregate Properties:

For this study, we sourced our crushed coarse aggregate from a local Hyderabad crusher facility; the maximum angular size of the stones was 16 mm. The specific gravity, bulk density, gradation, and fineness modulus of the coarse aggregate were ascertained in accordance with IS 2386-1963.

Sieve Analysis Chart for Coarse Aggregate

IS Sieves Size	Weight Retained (gms)	Cumulative Weight Retained (gms)	Cumulative % Weight Retained	% Passing
20 mm	2245	2245	45.43	54.57
10 mm	2163	4409	89.04	10.96
4.75 mm	432	4842	97.87	2.13
pan	111	4953	-------	------

Physical Properties of Coarse Aggregate

S.No.	Property	**Test Method**	**Value**
1	Fineness modulus	Sieve analysis (IS 2386-1963 Part 2)	7.45
2	Specific gravity	Pycnometer (IS 2386-1963 Part 3)	2.75
3	Bulk density (kg/m^3) - Loose Bulk density (kg/m^3) - Dense	(IS 2386-1963 Part 3)	1372.4 1507.8

Waste Foundry Sand Properties:

Agarwal Rolling Mills of Hyderabad and Shamshabad were among the local providers of waste foundry sand. The specific gravity, bulk density, gradation, and module of fineness were computed in accordance with IS: 2386-1963.

Chemical Composition of Waste Foundry Sand

S.NO.	Constituent	Percentage
1	SiO_2	82.8
2	Al_2O_3	0.91
3	TiO_2	0.32
4	CaO	1.52
5	MgO	0.77
6	Fe_2O_3	5.29
7	Na_2O	0.78
8	K_2O	1.24
9	SO_3	0.25
10	Mn_3O_4	0.046

Sieve Analysis Chart for Waste Foundry Sand

IS sieve size	Weight retained (gms)	Cumulative weight retained (gms)	Cumulative percentage weight retained	Cumulative percentage passing
4.75mm	8	8	0.80	99.20
2.36mm	10	18	1.80	98.20
1.18mm	11	29	2.9	97.10
600µ	75	104	10.4	89.60
300µ	490	594	59.4	40.60
150µ	295	889	88.9	11.10
pan	104	993	-----	-----

Physical Properties of Waste Foundry Sand

S.No	Property	Test Method	Test Results
1	Fineness modulus	Sieve analysis (IS 2386-1963 Part 2)	1.72
2	Specific gravity	Pycnometer (IS 2386-1963 Part 3)	2.41
3	Bulk density (kg/m^3) - Loose Bulk density (kg/m^3) - Dense	(IS 2386-1963 Part 3)	1242 1348

Chemical Composition of GGBS:

The following table displays the chemical composition of the GGBS used in this experiment.

Chemical Composition of GGBS

S.No.	Constituent	Percentage (%)
1	SiO_2	31.32
2	Al_2O_3	17.76
3	Fe_2O_3	3.78
4	CaO	32.42
5	MgO	12.38
6	SO_3	1.59

CHATER -III

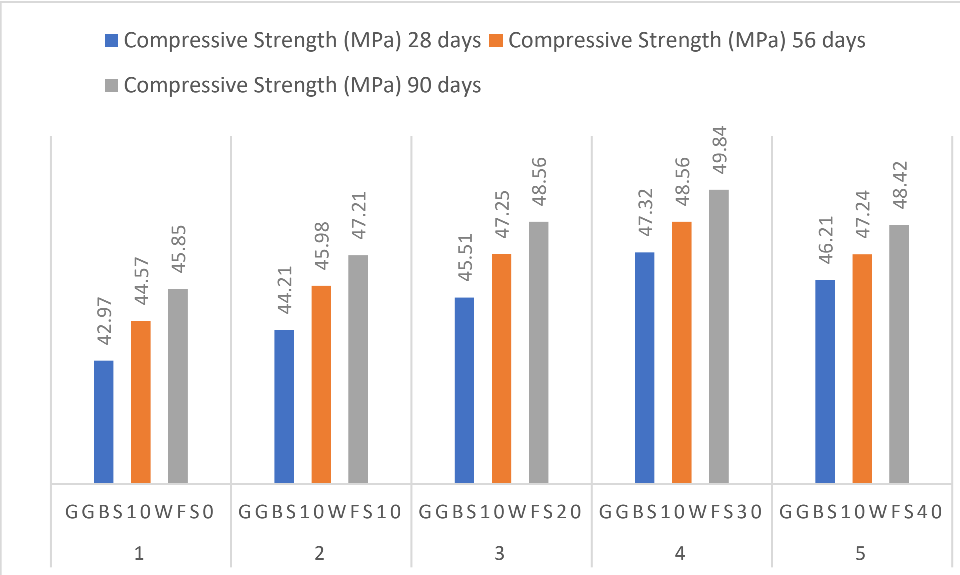
RESULTS AND DISCUSSION

Compressive Strength Test:

Cube specimens were subjected to compression testing in a compression testing machine. The failure load was used to determine the maximum compressive strength that could be achieved. For each age group, below Table displays the average compressive strength values at 28, 56, and 90 days for three specimens.

Compressive Strength of Concrete Mixes with GGBS and Various Percentage of Waste Foundry Sand at Different Ages

S.No.	Mix ID	Compressive Strength (MPa)		
		28 days	56 days	90 days
1	GGBS10WFS0	42.97	44.57	45.85
2	GGBS10WFS10	44.21	45.98	47.21
3	GGBS10WFS20	45.51	47.25	48.56
4	GGBS10WFS30	47.32	48.56	49.84
5	GGBS10WFS40	46.21	47.24	48.42



Compressive Strength of Concrete Mixes with GGBS and Various Percentage of Waste Foundry Sand at Different Ages

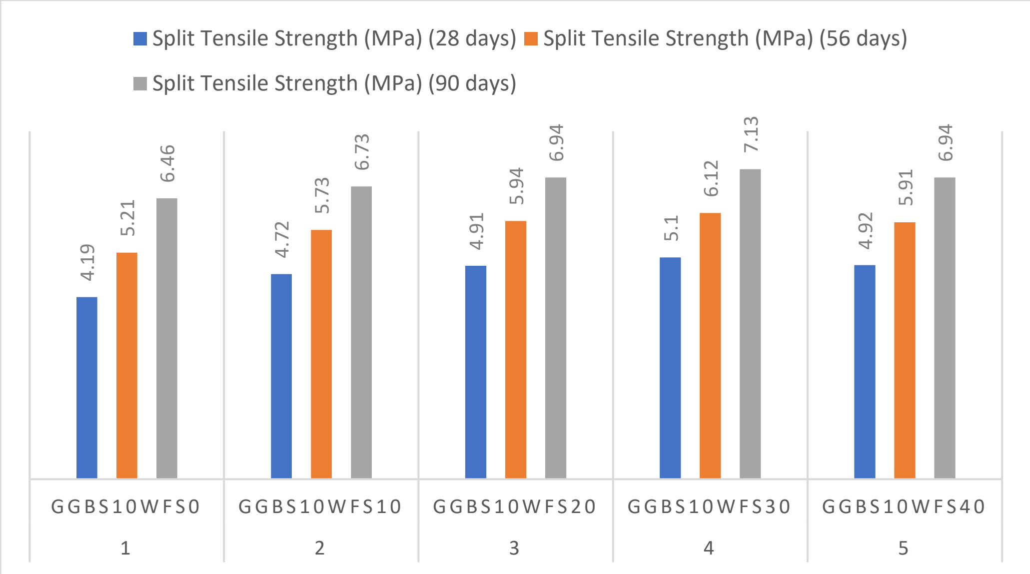
About 62% of the strength throughout 90 days was produced in the 28-day period. A little improvement in compressive strength was seen when the percentage of wasted foundry sand in concrete mixtures was raised. Using recycled foundry sand in place of traditional fine aggregate in concrete An increase of up to 40% in compressive strength is possible. Compressive strength began to decline as the quantity of residual foundry sand increased. Substituting foundry sand waste for 40% of the fine aggregate resulted in a maximum compressive strength of 49.84 MPa after 90 days.

After 90 days, the compressive strength reached 49.84 MPa, surpassing the goal value of 38.25 MPa. Incorporating GGBS into the concrete, which is much smaller than the cement particles, fills the empty areas, resulting in increased strength. The compressive strength of concrete may be increased by as much as 40% when used with leftover foundry sand. Using 40% of the foundry's rejected sand, the highest compressive force was achieved at 49.84 MPa. A strength of 52.15 MPa was achieved after 90 days, surpassing the desired strength, with 60% of the fine aggregate replenished.

Split Tensile Strength Test:

Split Tensile Strength of Various Concrete Mixes with GGBS and Different Percentages of Waste Foundry Sand

S.No.	Mix ID	Split Tensile Strength (MPa)		
		(28 days)	(56 days)	(90 days)
1	GGBS10WFS0	4.19	5.21	6.46
2	GGBS10WFS10	4.72	5.73	6.73
3	GGBS10WFS20	4.91	5.94	6.94
4	GGBS10WFS30	5.10	6.12	7.13
5	GGBS10WFS40	4.92	5.91	6.94



Split Tensile Strength of Various Concrete Mixes with GGBS and Different Percentages of Waste Foundry Sand at 28,56 and 90 days of curing

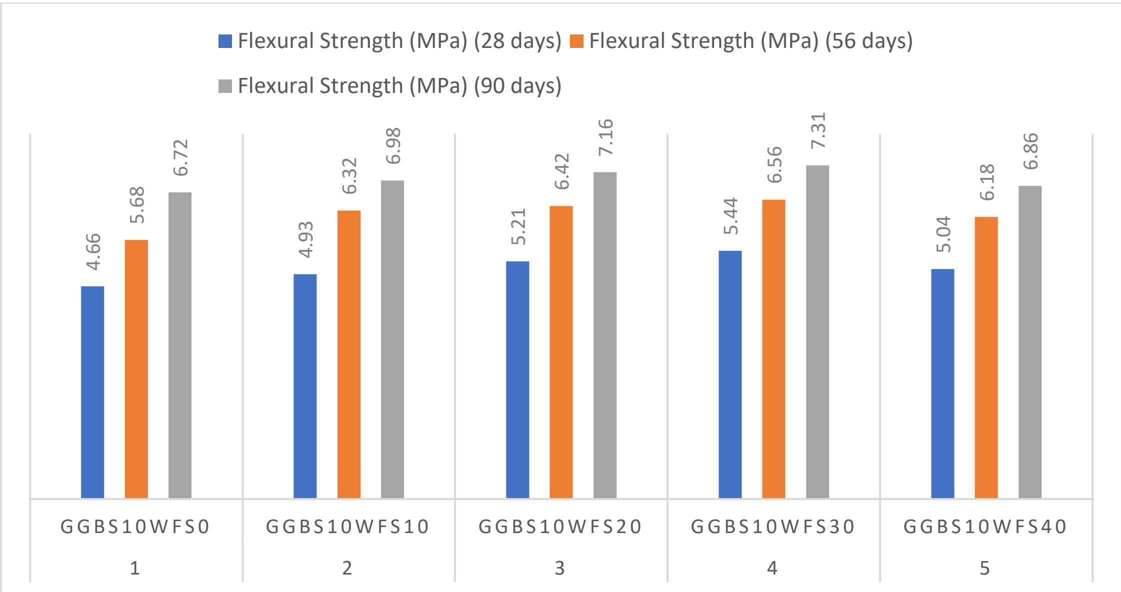
The desired split tensile strength of 7.13 MPa was achieved after 90 days. Split tensile strength increased by 40% in concrete mixtures that included waste foundry sand as a fine aggregate replacement. The highest strength of 7.13 MPa was achieved at 40% replacement. As the percentage of discarded foundry sand in the concrete mixture increased, its split tensile strength started to decrease.

Flexural Strength Test

We examined the beam specimens' flexural strength. The specimens were subjected to two point loading tests that were carried out in compliance with IS 516-1959. At 90 days of age, Table displays the median value of two specimens per category.

Flexural Strength of Various Concrete Mixes with GGBS and Different Percentage of Waste Foundry Sand

S.No.	Mix ID	Flexural Strength (MPa)		
		(28 days)	(56 days)	(90 days)
1	GGBS10WFS0	4.66	5.68	6.72
2	GGBS10WFS10	4.93	6.32	6.98
3	GGBS10WFS20	5.21	6.42	7.16
4	GGBS10WFS30	5.44	6.56	7.31
5	GGBS10WFS40	5.04	6.18	6.86



Flexural Strength of Various Concrete Mixes with GGBS and Different Percentage of Waste Foundry Sand at days of curing

Curing after 90 days resulted in a flexural strength of 7.31 MPa. The flexural strength of the concrete is reduced when used more foundry sand, which is a waste product

CHATER -IV

RESULTS AND DISCUSSION

Conclusions :

- The combination became less workable when the amount of spent foundry sand was more than 40%.
- When mortar cubes were made using GGBS instead of cement, the strength went up to 10% replacement before it started to go down. Hence, a 10% replacement would be perfect for this situation.
- Substituting waste foundry sand for fine aggregate boosted the compressive strength of ordinary concrete of grade M30 by up to 40%; however, beyond this point, the strength began to noticeably fall. We reached our maximum strength at 40%.
- A combination of 10% GGBS and 30% WFS yields the maximum compressive strength of 49.84 MPa after 90 days, making it the ideal blend.
- To get the maximum split tensile strength (7.13 MPa at 90 days), the best blend is GGBS10WFS30 (10% GGBS + 30% WFS).
- The flexural strength reaches its peak at 90 days (7.31 MPa) when GGBS10 + WFS30 is used.
- Reduced flexural strength was the outcome of increasing the proportion of waste foundry sand to regular concrete.
- The optimal ratio of discarded foundry sand to cement for M30 grade concrete was found to be 10%.
- In some cases, such as when using bricks as a building material, ground granules blast furnace clay (GGBS) may be used in place of cement, however this substitution should not exceed 10%.

Scope for Further Investigations:

- The GGBS employed in this study may have their numerous physical properties examined in further depth.
- Researching the behavior of waste foundry sand in a kiln at different temperatures and burning periods may help evaluate the influence on strength attributes.
- The refinement of GGBS also separates the characteristics, thus it's important to study the impacts of different grinding hours on strength and durability.
- Additional study might be conducted to investigate the durability properties of concrete that substitutes part of the fine aggregate with leftover foundry sand.
- Play around with different fiber types and aspect ratios in concrete using leftover foundry sand. Try steel, recron, synthetic, natural, and glass fibers.
- Altering the proportions of fibers, cement, and mineral admixtures such fly ash and Metakaolin, as well as using scrap foundry sand in place of some of the fine aggregate, allows for more investigation into the concrete's characteristics.
- More research might be spurred by making self-compacting concrete from waste resources like foundry sand and other such materials.
- Research on alternative materials to aggregate and cement in concrete, and how they stack up in terms of quality, may continue.

CHAPTER -V

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