International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

EXPERIMENTAL STUDY ON STRENGTH OF CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH GGBS AND COPPER SLAG WITH FINE AGGREGATE

B.SRAVAN KUMAR [1], D.MURALI MOHAN [2], C.BHARATH KUMAR[3], Y.UDAY KIRAN[4], D.SHAMEER BASHA[5], KAMSALA VAMSI KRISHNA[6]

[1]UG Scholar Department of civil Engineering, anatha Lakshmi institute of technology & sciences, itukulapalli, ananthapur, AP, India.
[2]UG Scholar Department of civil Engineering, anatha Lakshmi institute of technology & sciences, itukulapalli, ananthapur, AP, India.
[3]UG Scholar Department of civil Engineering, anatha Lakshmi institute of technology & sciences, itukulapalli, ananthapur, AP, India
[4]UG Scholar Department of civil Engineering, Chalapathi Institute of Technology, Mothadaka, Guntur, AP, India.
[5]UG Scholar Department of civil Engineering, anatha Lakshmi institute of technology & sciences, itukulapalli, ananthapur, AP, India
[6]Assistant Professor Department of Civil Engineering, anatha Lakshmi institute of technology sciences, itukulapalli, ananthapur, AP, India

ABSTRACT :

As a partial substitute for cement and fine aggregate, respectively, in M35 grade concrete, this research explores the possibilities of Ground Granulated Blast Furnace Slag (GGBS) and copper slag. We look at how two industrial by-products—GGBS from the steel industry and copper slag from copper production—affect the mechanical characteristics of concrete. A range of quantities of GGBS and copper slag were used to make concrete examples, including5%,7.5%,15%,17.5%, and 20%. At3,7, and 28 days, the material was tested for workability, compressive strength, split tensile strength, and flexural strength. The most effective mixture was determined to be 15% GGBS and 15% copper slag. More eco-friendly methods of making concrete are the focus of this research.

Keywords: GGBS, copper slag, compressive strength, split tensile strength, flexural strength, Etc.,

1. INTRODUCTION

The versatility and longevity of concrete have kept it among the most popular building materials. Yet, a substantial amount of carbon emissions are produced during the cement manufacturing process, which is an essential component. Environmental concerns and industrial waste are on the rise, prompting research into sustainable alternatives. The steel industry's GGBS and the copper industry's copper slag are both potential cement and fine aggregate substitutes.

1.1 History of Concrete

Even prehistoric societies made use of materials that resembled concrete. Its use was further enhanced by the Romans, who added volcanic ash and lime to it, after its early forms emerged around 6500 BC. To address a wide range of structural needs, reinforced and pre-stressed varieties of modern concrete were developed.

1.2 Objectives of the Research

- To determine whether GGBS may be used in lieu of certain cement.
- In order to determine the impact of using copper slag in place of fine aggregate.
- To determine the amended concrete's compressive, tensile, and flexural strengths.
- We want to see how the findings stack up against regular M35 concrete.
- In order to find the optimal combination in terms of cost and efficiency.

1.1 HISTORY OF CONCRETE

Concrete has a long and storied history, beginning with its usage by Nabataean merchants in 6500 BC. The Romans made great strides in the material's development, using lime and volcanic ash in their construction. Finally, the 19th century saw the advent of modern reinforced concrete. Nabataean merchants in the Syrian and Jordanian areas employed hydraulic lime to create the first concrete floors, houses, and subterranean terns.

1.2 OBJECTIVES OF RESEARCH

1. Investigate the possibility of using GGBS instead of cement in concrete production.
2. Secondly, we will replace 20%, 30%, and 40% of the cement with GGBS and then compare the resulting cubes' properties to those of the regular mix M35.
3. Investigate how concrete cubes' compressive strengths behave.
4. Check how it stacks up against regular, old concrete.
5. To determine the optimum proportion of replacement that minimises costs while maintaining strength.

In order to provide financially viable building costs.

2. LITERATURE REVIEW

The use of GGBS and copper slag in concrete has been investigated by several researchers. The use of GGBS as a partial cement substitute might increase durability, according to research by Drs. Suresh and K. Nagaraju (2015). Mathematical models for forecasting thermal behaviour were provided by Yunus and Graham (2009) after studying the heat of hydration in concrete containing GGBS. The curing process and strength gain of GGBS-based concrete were examined by Shariq et al. (2008), who found that a 20-40% replacement increases strength. According to research by A. Oner and Akyuz (2007), the sweet spot for GGBS content in terms of strength improvement is approximately 40%, and longer curing times also improve performance.

3. MATERIALS AND METHODOLOGY

3.1 Materials

- UltraTech brand 53-grade ordinary Portland cement with a specific gravity of 3.15 and compliance IS 12269:2013 is the cement in question.
- Zone II sand with a specific gravity of 2.75 and a fineness modulus of 2.76 is considered fine aggregate.
- The coarse aggregate has a specific gravity of 2.71, a fineness modulus of 8.3, and a gradation range of 12.5–20 mm.
- The specific gravity of GGBS is 2.85 and its fineness is 4.25.
- Copper Slag: Fineness Modulus:3.4, Specific Gravity: 4.12.
- The water used for curing and mixing must be potable tap water.

3.1.1 CEMENT

The majority of non-specialty grouts, stucco, concrete, and mortar are made using ordinary Portland cement, the most widely used form of cement in the world. When making concrete, cement is the primary component. If you change the cement content in concrete, it will change its features drastically. This project's cement is 53-grade ordinary Portland cement, which conforms to IS 12269 - 2013. It typically comes from limestone and evolved in the mid-nineteenth century in England from other varieties of hydraulic lime. Clinker is made by heating materials until they become a fine powder. We will add little quantities of the other components once we ground the clinker. The market offers a wide variety of cements. Among the several cement grades, 53 Grade OPC Cement offers the most consistent and superior strength. In accordance with the Bureau of Indian Standards (BIS), a cement's grade number indicates the minimum compressive strength that it is anticipated to achieve after 21 days. The cement must reach a minimum compressive strength of 53MPa, or 530 kg/cm2, by the end of the 28th day for 53 Grade OPC Cement. We may acquire white cement by removing ferrous oxide from the cement production process; OPC is grey in colour.

In this study, we used ordinary Portland cement of Ultra Tech Company's 53 Grade brand, which is readily accessible in our local market. The purchase was meticulously prepared by mixing the ingredients separately and then storing them in airtight containers to ensure that they would remain unaffected by environmental factors. In compliance with IS: 169-1989 for physical standards and IS: 4032-1988 for chemical requirements, the cement that was so obtained was tested.

S No	Properties	Values observed
1	Specific Gravity	3.15
2	Normal consistency	32%

3	Initial setting time	33 min
4	Final setting time	480 min
5	Soundness	8.7 mm

Table 1 physical properties of Ordinary Portland cement -53 Grade

3.1.2 FINE AGGREGATE

Aggregate gradation is defined as the dispersion of particle sizes. Because it reduces voids via particle packing, grading is a crucial quality of aggregate for use in concrete. This has a domino effect on the amount of water and cement needed to make concrete. To illustrate grading, consider the total percentage of weights that pass through a certain IS sieve. According to IS 383-1970, there are four distinct zones for the grading of fine aggregate. For each zone, the table shows the range of passing percentages.

The sand in Zones I and IV are the roughest and smoothest, respectively, while the sand in Zones II and III are in the middle. For reinforced concrete, it is best to utilise fine particles that fall under either Zone II or Zone III grading.

S.No	Property	Result
1	Fineness Modulus	2.76
2	Specific Gravity	2.75

Table 2 Physical properties of fine aggregates

3.1.3 COARSE AGGREGATE

Coarse aggregate is the material that passes through an IS Sieve with a size of 4.75 mm. Particles in Self Compacting Concrete may typically be no larger than 10–20 mm, however sizes of 40 mm and more have been used. In many cases, gap graded aggregates are preferable than continuously graded ones since the latter might cause grader internal friction, which in turn reduces flow and costs money. In terms of the properties of the various aggregates, crushed aggregates are known to increase strength by the interlocking of angular particles, while rounder aggregates are known to increase flow via reduced internal friction. For this project, we utilised locally sourced coarse aggregate with a size range of 20 mm to 12.5 mm. The aggregates were cleaned to eliminate any debris and then dried until they were completely dry. According to IS: 383-1970, the aggregates underwent testing.

S.No	Property	Result
1	Fineness Modulus	8.3
2	Specific Gravity	2.71

Table 3 Physical properties of coarse aggregates

3.1.4 GROUND GRANULATED BLAST FURNACE SLAG (GGBS)

A glassy, granular byproduct of iron and steel production, ground-granulated blast-furnace slag (GGBS) is created by cooling molten iron slag from a blast furnace in water or steam. The resulting product is then dried and ground into a fine powder. In the batching plant of a concrete maker, GGBS cement may be mixed with water, aggregates, Portland cement, and other ingredients. Everything stays the same in terms of the typical cementitious material to aggregates and water ratios. You may use GGBS in lieu of Portland cement weight for weight. By decreasing the heat of hydration and increasing sustainability, ground granulated blast-furnace slag (GGBS) improves the workability, durability, strength, and overall performance of concrete.

S.No	Property	Result
1	Specific Gravity	2.85

2	Fineness	4.25

Table 4 Physical properties of ggbs

3.1.5 COPPER SLAG

You may use copper slag in lieu of some of the sand while making concrete. Shaped into blocks, copper slag is used as a construction material. To prevent pavement cracks caused by ground frost in winter, you may use the insulating and drainage capabilities of the granulated slag (<3 mm size fraction). Using this slag lowers the building's energy demand since it decreases the utilisation of basic materials and the depth of construction. For the same reasons, granulated slag may be used as an insulating material and filler in cold climate home foundations. Slag insulation is used in the foundation of many homes in the area. The process of smelting copper ore produces the waste product known as copper slag. Slag forms during the smelting process and floats on top of the molten metal, representing impurities. The angular grains produced by quenching slag in water are either recycled or discarded.

S.No	Property	Result
1	Fineness Modulus	3.4
2	Specific Gravity	4.12
3	Bulk density	2.31 G/CC

Table no 5 physical properties of copper slag

3.1.6 WATER

In most cases, concrete may be mixed with water that is safe to drink. In most cases, you may also use water from marine-life-containing lakes and streams. There is no need to sample water when it is acquired from the sources indicated before. You shouldn't use water in concrete if you have any reason to believe it contains sewage, mining water, or industrial plant or cannery waste—until testing prove otherwise. You shouldn't use water from such sources for casting since the quality of the water might vary when the water pressure is low or when the water is utilised intermittently. The concrete may be mixed and cured using the drinkable water without any problems.

3.2 Methodology

The concrete mixes were made according to the specifications of IS 10262:2019, utilising M35 grade proportions. Copper slag (5-25% by weight of fine aggregate) and ground glass beads (5-20% by weight of cement) were used as substitutes. The specimens were subjected to curing, casting, and compacting for3,7, and 28 days prior to mechanical property testing.

3.2.2 PROCEDURE

One common approach to studying the impact of using GGBS (Ground Granulated Blast Furnace Slag) and copper slag as cement substitutes is to make concrete mixes with different percentages of these materials, then examine the characteristics of the mixture both while it's fresh and after it has hardened. The following steps can be taken to partially replace cement with GGBS and fine aggregate with copper slag in concrete: ascertain the amount of each material to be replaced, mix the materials according to a concrete mix design, test the concrete's properties, and make any necessary adjustments to the mix.

3.2.3 MIX PROPORTIONS

One typical method for making M35 grade concrete mixes using GGBS instead of cement and copper slag for the fine aggregate is to use a percentage of each: 20–40% copper slag and 20–30% GGBS. Make sure to use either IS 10262:2019 for India or ACI 211.1 for the US when designing the control mix. Find out how much of each material you'll need. Vary the water-cement ratio according on the GGBS concentration. Verify that the copper slag meets the grading requirements defined in IS 383:2016.

3.2.4 CASTING OF SPECIMEN

Gather the necessary moulds, such as 150 mm x 150 mm x 150 mm cube moulds or 150 mm diameter x 300 mm high cylinder moulds. To make demolding easier, coat the inside of the moulds with a thin coating of grease or oil. Use a tamping rod to tamp down each of the three layers of filling 25 times in the moulds. To eliminate air pockets and guarantee adequate compaction, use a vibrating table.

3.2.5 CURING

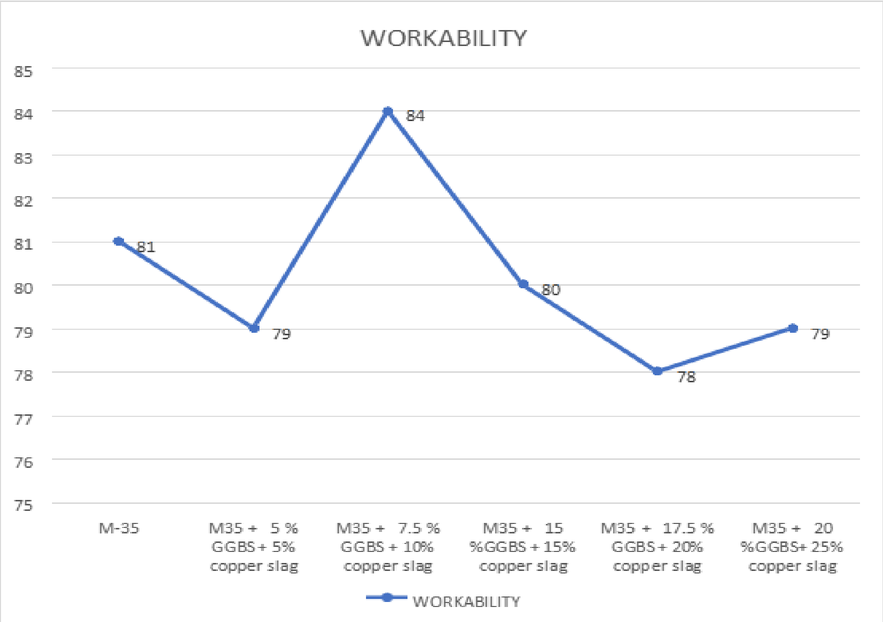
Deform the samples after a day. To cure (as per IS 516:1959), submerge them in clean water for 3,7, or 28 hours, depending on when you want to test them.

4. RESULTS AND DISCUSSION

MIX PROPORTIONS	Deform the samples after a day. To cure (as per IS 516:1959), submerge them in clean water for 3,7, or 28

	hours, depending on when you want to test them.
M-35	81
M35 + 5 %GGBS + 5% copper slag	79
M35 + 7.5 % GGBS + 10% copper slag	84
M35 + 15 % GGBS + 15% copper slag	80
M35 + 17.5 % GGBS + 20% copper slag	78
M35 + 20 % GGBS + 25% copper slag	79

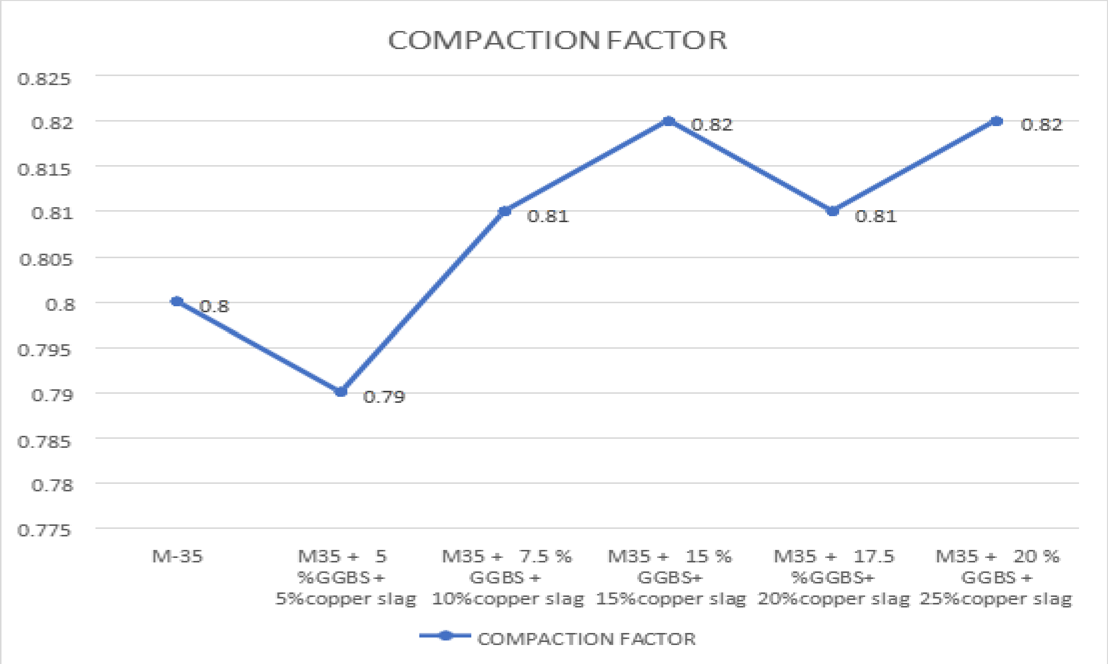
Table no 6 workability results



Graph no 1 workability results

MIX PROPORTIONS	**Workability values**
M-35	0.8
M35 + 5 %GGBS + 5% copper slag	0.79
M35 + 7.5 % GGBS + 10% copper slag	0.81
M35 + 15 % GGBS + 15% copper slag	0.82
M35 + 17.5 % GGBS + 20% copper slag	0.81
M35 + 20 % GGBS + 25% copper slag	0.82

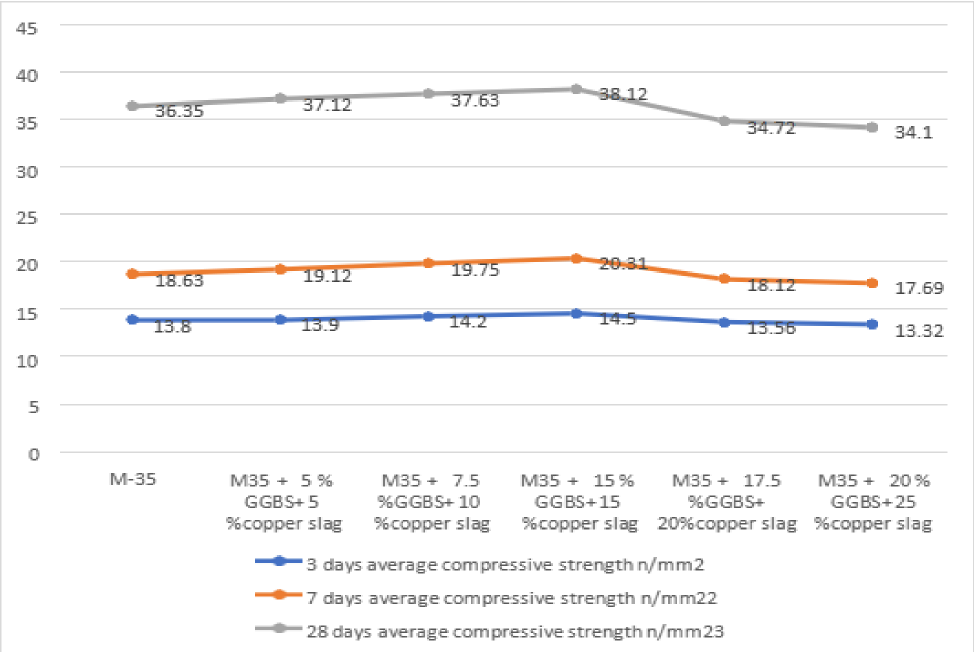
Table no 7 compaction factor results



Graph no 2 compaction factor results

MIX NO.	3 DAYS AVERAGE COMPRESSIVE STRENGTH	7 DAYS AVERAGE COMPRESSIVE STRENGTH	28 DAYS AVERAGE COMPRESSIVE STRENGTH
1.	13.8	18.63	36.35
2.	13.9	19.12	37.12
3.	14.2	19.75	37.63
4.	14.5	20.31	38.12
5	13.56	18.12	34.72
6	13.32	17.69	34.1

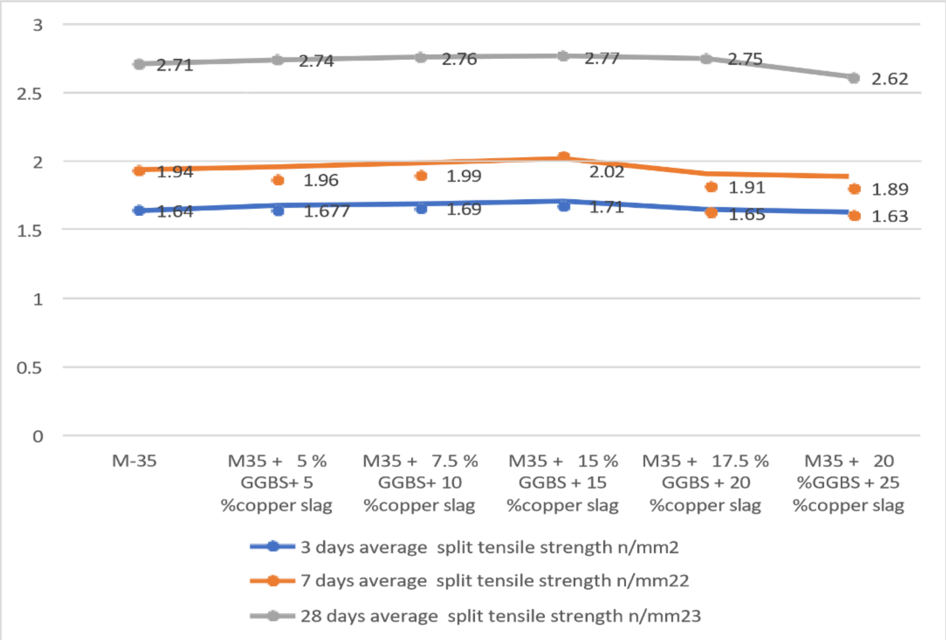
Table no 8 compressive strength results for 3, 7 and 28 days



Graph no 3 compressive strength results for 3, 7 and 28 days

MIX NO.	3 DAYS AVERAGE SPLIT TENSILE STRENGTH	7 DAYS AVERAGE SPLIT TENSILE STRENGTH	28 DAYS AVERAGE SPLIT TENSILE STRENGTH
1.	1.64	1.94	2.71
2.	1.677	1.96	2.74
3.	1.69	1.99	2.76
4.	1.71	2.02	2.77
5	1.65	1.91	2.75
6	1.63	1.89	2.62

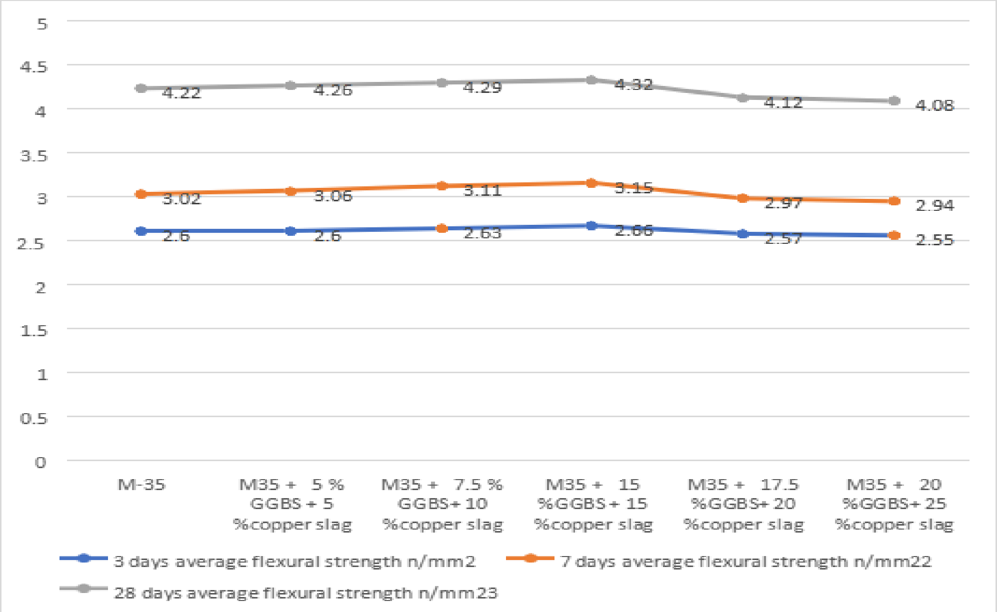
Table no 9 split tensile strength results for 3, 7 and 28 days



Graph no 4 split tensile strength results for 3, 7 and 28 days

MIX NO.	3 DAYS AVERAGE FLEXURAL STRENGTH	7 DAYS AVERAGE FLEXURAL STRENGTH	28 DAYS AVERAGE FLEXURAL STRENGTH
1.	2.60	3.02	4.22
2.	2.60	3.06	4.26
3.	2.63	3.11	4.29
4.	2.66	3.15	4.32
5	2.57	2.97	4.12
6	2.55	2.94	4.08

Table no 10 flexural strength results for 3, 7 and 28 days



Graph no 5 flexural strength results for 3, 7 and 28 days

4.1 Workability

Blends with 15% GGBS and 15% copper slag showed the best workability, according to slump test and compaction factor values.

4.2 Compressive Strength

The maximum compressive strength (38.12 N/mm²) was observed for the mix containing 15% GGBS and 15% copper slag after 28 days.

4.3 Split Tensile Strength

The highest split tensile strength (2.77 N/mm²) was noted in the same mix (M35 + 15% GGBS + 15% copper slag).

4.4 Flexural Strength

This mix also achieved the maximum flexural strength (4.32 N/mm²), confirming its overall superiority.

5. CONCLUSION AND FUTURE SCOPE

CONCLUSION

- A combination of 15% GGBS and 15% copper slag produced the best mechanical characteristics.
- When contrasted with the standard mix, the changed concrete demonstrated greater workability and strength.
- A Sustainability in building is enhanced by the use of industrial by-products.

FUTURE SCOPE

- Explore the impact on the ecosystem and how it will hold up over time.
- Investigate the use of nano-additives and other byproducts of industry as potential strategies.
- Suggest that these materials be standardised and that policies be in favour of their use.

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