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An Experimental Study on the Performance of Strength of Concrete By Partial Replacement of Cement By GGBS and Complete Replacement of Sand by M-Sand

Shrinath Rao K[1], Varun N M[2], Karthika T K[3], Mohamed Jahsan O[4]

[1]Associate Professor, Dept of Civil Engineering, Srinivas University Institute of Engineering and Technology, Mukka, Mangaluru, Bharat
[2]Student, B.Tech (Civil Engineering), Dept of Civil Engineering, Srinivas University Institute of Engineering and Technology, Mukka, Mangaluru, Bharat

ABSTRACT

Concrete is the most widely used material in the construction industry. Possessing high strength and stability, concrete is also an economical building material. Cement required in the concrete leaves enormous carbon foot print which shows an alarming impact on the global environmental conditions. Hence, there is a requirement of some material which can be effective in supporting cement when added along with it shows similar characteristics. Due to increased construction and infrastructure activities, we are consuming more quantity of concrete and hence we are consuming more energy in the extraction of mineral ores for the production of cement concrete. This in turn is contributing more production of carbon elements which is a challenge for the sustainable development. Hence, there is a need of utilization of waste materials which are produced as byproducts in the industries which can replace cement, fine and coarse aggregates to some extent. Ground Granulated Blast Furnace Slag (GGBS) is found to be one such material which has similar characteristics when mixed with cement. GGBS is a waste material (byproduct obtained from iron industry) which is required to be disposed. Similarly, in recent days, the demand for river sand is increasing due to its lesser availability and environmental considerations. Also, there are stringent norms for the extraction of river sand which is coming under the category of mining which is creating environmental issues during the rainy season. M-Sand is obtained as byproduct from quarry industry which has similar properties and characteristics to that of river sand. Hence the practice of replacing river sand with M-Sand is taking a tremendous growth. The main objective of this study is to investigate the performance of strength characteristics of concrete by replacing cement and fine aggregates, to provide an economical and environmentally friendly concrete, to make use of waste materials in useful manner, to reduce the demand of cement and hence to promote green concrete, sustainable construction and sustainable development. In this project work, the strength characteristics of M30 grade concrete is analysed. Concrete cubes, beams and cylinders are casted for the normal concrete as well as concrete with GGBS and M-Sand. The cubes, beams and cylinders casted with the different proportions of cement, GGBS and River Sand / M-Sand are tested for the compressive strength at the end of 7, 14 and 28 days of curing, and split tensile strength and flexural strength at the end of 28 days of curing at room temperature. Based on the test results, the optimum percentage of GGBS was found.

Keywords: Concrete, GGBS, M-Sand, River Sand, Sustainable Construction, Green Concrete

INTRODUCTION

Construction industry has become one of the most important parts of a country's economic and social development. Concrete has been utilized by the construction industry for the construction of most of the infrastructures which range from construction of foundations to retaining walls, dams to bridges, residential houses to tall skyscrapers. The most predominately used binder in concrete is blended cement. Today, public and private organizations have been giving considerable importance to different construction materials on account of their environmental behaviour. The growing use of cement made concrete in building projects and subsequent emission of harmful gases into the atmosphere causes a significant rise in earth's temperature. One thousand kilograms of cement produce nearly similar amount of carbon dioxide (CO_2). According to an estimate, around 6-8% of the total CO, globally emitted comes from ordinary cement production. The Construction Industry, vital for Societal Development, is concurrently a significant contributor to Environmental Degradation. Traditional Concrete, a staple in Construction, relies heavily on Natural Resources like Sand, which is being depleted at an alarming rate. Moreover, the Production of Conventional Concrete is associated with Substantial Carbon Emissions. In the pursuit of Sustainable Construction Practices, this research explores an innovative concrete Mix Design, aiming to Replace Conventional Sand with Manufactured Sand (M Sand) and GGBS as Partial Replacement for Cement.

M-Sand, a byproduct of the Crushing Process, is increasingly recognized as a viable alternative to Natural Sand. Its utilization not only addresses the depletion of Natural Resources but also tackles the Environmental repercussions of Sand extraction. By incorporating M Sand into concrete, we seek to evaluate its impact on the mechanical properties of the concrete mix. The integration of GGBS into the Concrete Mix serves a dual purpose. Firstly, it addresses the issue of solid waste management, a global concern with severe environmental implications. Secondly, GGBS act as a binding material, potentially enhancing the concrete's strength and durability. This research endeavours to assess the synergistic effects of M-Sand and GGBS, aiming for a sustainable and structurally robust alternative to traditional concrete. The motivation behind this study is rooted in the urgent need for sustainable practices in construction. As the demand for concrete continues to rise, so does the imperative to minimize its environmental footprint. This research aligns with the global shift towards greener construction methods, contributing to the ongoing discourse on eco-friendly building materials and techniques.

SUSTAINABLE CONCRETE MIX DESIGN

Partial Replacement of Sand with M-Sand and Incorporation of GGBS, is underpinned by a compelling need to address critical challenges within the construction industry and contribute to sustainable development. The motivations behind choosing this specific topic are multifaceted and strategically aligned with current global concerns and advancements in construction practices, highlighted as below:

- Environmental Imperatives
- Plastic Waste Crisis
- Sustainability in Construction
- Innovation and Advancements
- Industry Relevance
- Holistic Evaluation

- Global Sand Scarcity
- Resilience to Climate Change
- Global Implications of Sand Scarcity
- Innovative Approach to Waste Management
- Potential for Scalability & Replicability
- Contribution to Sustainable Development Goals (SDGs)
- Resilience to Climate Change and Extreme Events
- Anticipation of Future Regulatory Changes

The research aims to be a catalyst for positive change, offering a tangible and scalable solution to a complex and urgent challenge. In summary, the selection of this topic is driven by a confluence of environmental urgency, a need for innovative solutions to waste-related challenges, a commitment to sustainable development, and the potential to catalyse positive changes in the construction industry. The research aspires to contribute not only to academic knowledge but also to the practical implementation of sustainable and resilient construction materials.

Sustainability in construction has become a global priority. The topic aligns with the broader trend of incorporating environmentally friendly practices in various industries, promoting a shift towards greener and more resilient construction methodologies. The research aims to contribute new knowledge to the field of sustainable construction by providing a detailed investigation into the mechanical, structural, and environmental aspects of M-Sand replacement and GGBS reinforcement in concrete.

By considering both M-Sand replacement and GGBS, the study takes a holistic approach to sustainable construction. It examines the combined effects of these innovations on various aspects of concrete performance. The topic has practical relevance as it delves into the applicability of M-Sand and GGBS in real-world construction projects. Understanding the challenges & opportunities associated with implementing these materials provides valuable insights for industry practitioners.

With the construction industry being a significant consumer of natural resources, there is a pressing need to adopt sustainable practices. The study aims to contribute to the discourse on sustainable construction methodologies by examining the potential benefits of M-Sand replacement. GGBS, being lightweight and durable, have gained attention as a reinforcement material in concrete. Exploring their partial replacement in conjunction with M-Sand offers a novel approach to enhancing the mechanical properties of concrete.

PROBLEM DEFINITION

The conventional production of concrete, a cornerstone of modern construction, poses significant environmental and resource challenges. The extraction of natural sand, a crucial component of traditional concrete, is reaching unsustainable levels, contributing to ecological degradation and habitat loss. Simultaneously, the global crisis presents an urgent need for innovative solutions to repurpose and minimize the environmental impact of non-biodegradable materials. The problem addressed by this project is the environmental impact and sustainability challenges associated with conventional concrete production. The depletion of natural sand resources and the increasing accumulation pose significant issues. The project aims to address these problems by exploring the feasibility and efficacy of replacing traditional sand with manufactured sand (M sand) and incorporating GGBS as a partial replacement for conventional reinforcements in concrete. Following are the key points to be considered:

- Performance and Durability Concerns
- Cost Implications

- Depletion of Natural Sand Resources
- Environmental Impact of Sand Extraction
- Limited Circular Economy Practices in Construction
- Need for Innovative Concrete Mix Designs
- Socio-economic Impact of Unsustainable Construction
- Infrastructure Resilience
- Global Impact
- Risk Mitigation for Future Challenges
- Community Engagement
- Energy Efficiency

OBJECTIVES

The project aims to address the pressing challenges facing the construction industry regarding sustainability and resource utilization. Traditional concrete production heavily relies on coarse aggregate and river sand, leading to environmental concerns such as depletion of natural resources and increased waste generation. By investigating the feasibility of replacing these conventional materials with GGBS and M-Sand respectively, the project seeks to evaluate their impact on the strength and durability of concrete structures. The primary problem to be addressed lies in determining whether these alternative materials can maintain or enhance the mechanical properties of concrete while offering environmental benefits. This research endeavour aims to contribute valuable insights into sustainable construction practices by offering practical solutions to reduce reliance on finite resources and minimize the environmental footprint of concrete production. Objectives are summarised as below:

- To determine the effect of replacement of sand by m-sand on properties of concrete.
- To study compressive strength and split tensile strength of hardened concrete.
- To assess the mechanical properties and durability of concrete mixes incorporating M sand and GGBS.
- To explore the possibilities of economic feasibility and community perceptions of the proposed sustainable concrete mix.
- To provide insights into industry adoption and standards compliance, laying the groundwork for the integration of the sustainable mix into mainstream construction practices.

LITERATURE REVIEW

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METHODOLOGY

First, a literature review was conducted to know about the strength analysis of concrete with M-Sand and GGBS. This helped to focus on the problem definition and possible solution for the same. Following methodology was adopted in this project work:

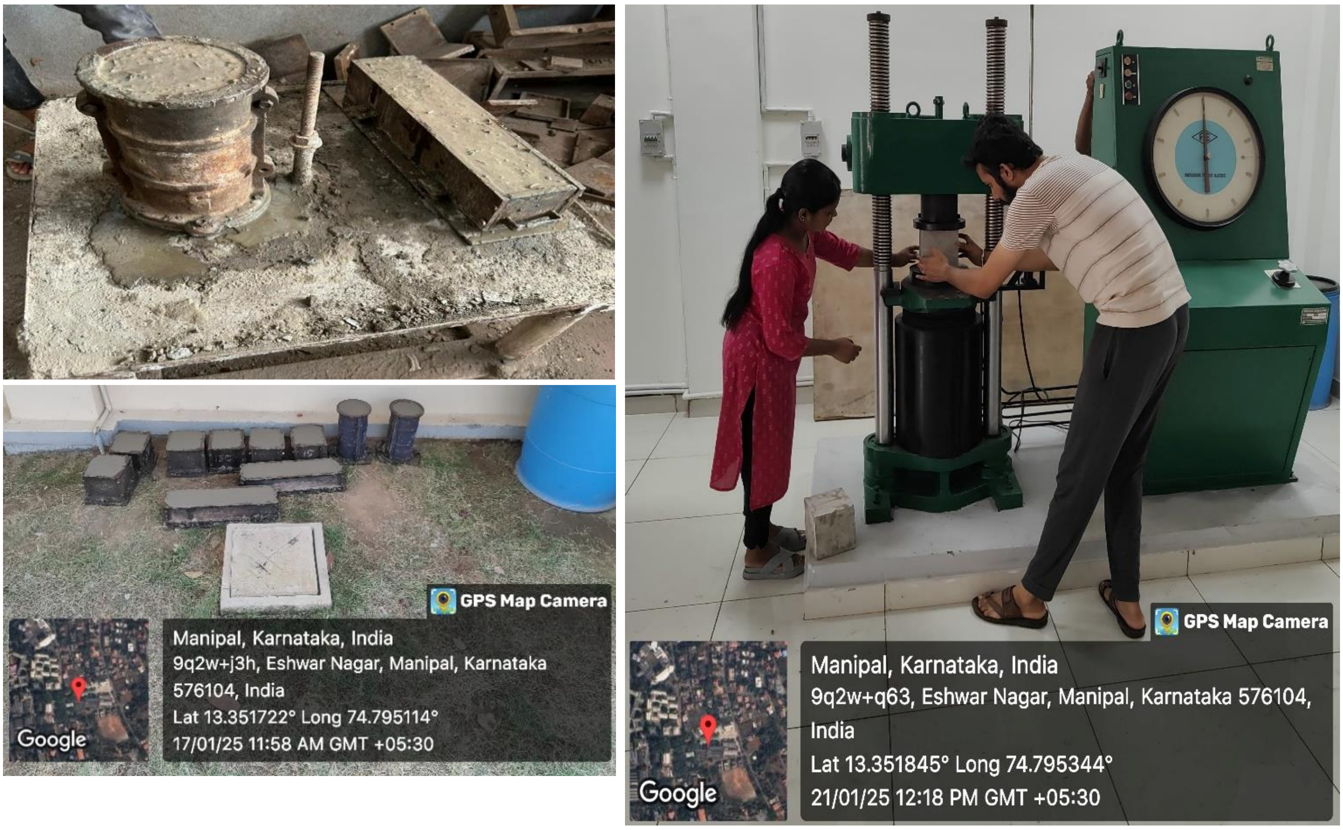
- Collection of Materials required OPC (Ordinary Portland Cement), Fine Aggregate, Coarse Aggregate, M-Sand and GGBS.
- Mix Design was done and the concrete was prepared for the proportion of 1 : 1.47 : 2.08
- M30 Grade Concrete was casted and a total of 10 stages of concreting was done.
- In each stage, 9 concrete cubes, 3 cylinders & 3 beams were casted.
- River Sand was used as Fine Aggregate in Stage 1, 7, 8, 9 and 10
- M-Sand was used as Fine Aggregate in Stage 2, 3, 4, 5 and 6
- GGBS was mixed in various proportions (10%, 20%, 30% and 40%) in Stage 3, 4, 5 and 6 along with M-Sand
- GGBS was mixed in various proportions (10%, 20%, 30% and 40%) in Stage 7, 8, 9 and 10 along with River Sand
- Compressive Strength Test was conducted for all the concrete mix at the end of 7, 14 and 28 days of curing, whereas Split Tensile Test and Flexural Strength Test were conducted at the end of 28 days of curing
- All the values of the results will be compared and a graph were plotted.

EXPERIMENTAL INVESTIGATION

Weighing of GGBS

Mixing of Aggregates, Cement & GGBS

Casting of Cubes, Beams and Cylinders



RESULTS AND DISCUSSIONS

Specific Gravity of cement: 3.12
Specific Gravity of coarse aggregate: 2.70
Specific Gravity of Fine aggregate: 2.65
Setting Time

- Initial Setting Time is 145 minutes
- Final Setting Time is 535 minutes

Normal Consistency: The normal consistency of cement is 30% of water the plunger had been to 6mm so the normal consistency is 30%

Table - Compression Strength Test Values

STAGES	DETAILS	Compression Strength (N/mm^2)		
		7 DAYS	**14 DAYS**	**28 DAYS**
1	Concrete with River Sand	23.90	31.83	35.63
2	Concrete with M-Sand	22.63	28.87	32.10
3	Concrete with M-Sand + 10% GGBS	20.36	28.05	33.57
4	Concrete with M-Sand + 20% GGBS	20.00	28.12	34.70
5	Concrete with M-Sand + 30% GGBS	18.10	26.30	32.44
6	Concrete with M-Sand + 40% GGBS	14.10	22.54	29.48
7	Concrete with River Sand + 10% GGBS	21.15	31.22	37.15
8	Concrete with River Sand + 20% GGBS	22.67	31.70	39.00
9	Concrete with River Sand + 30% GGBS	19.90	29.04	37.10
10	Concrete with River Sand + 40% GGBS	17.53	25.73	34.60

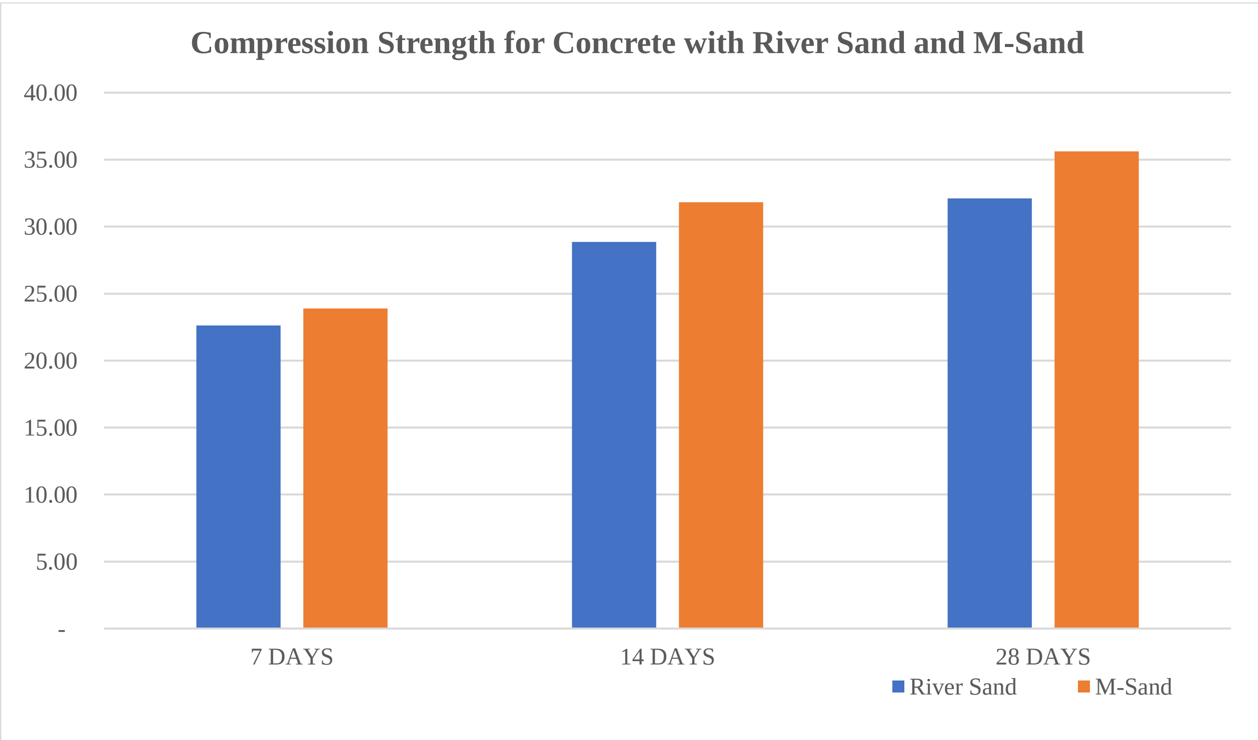
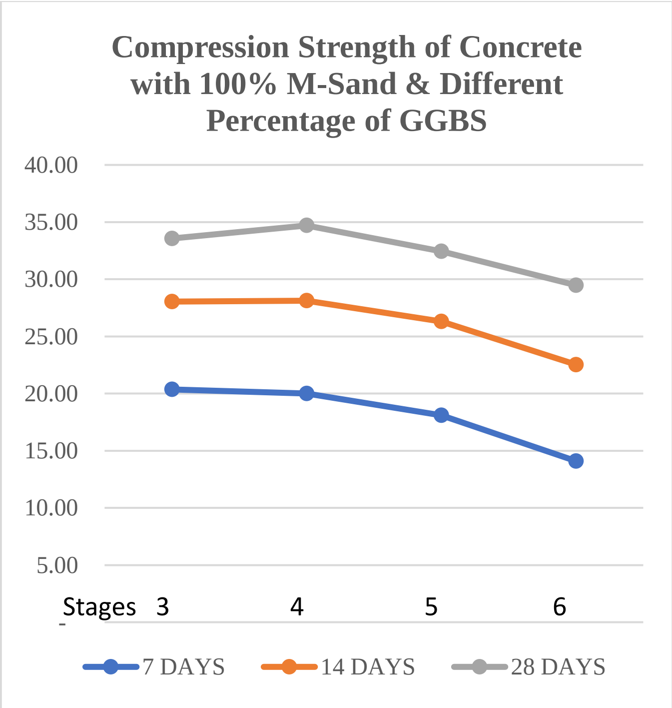
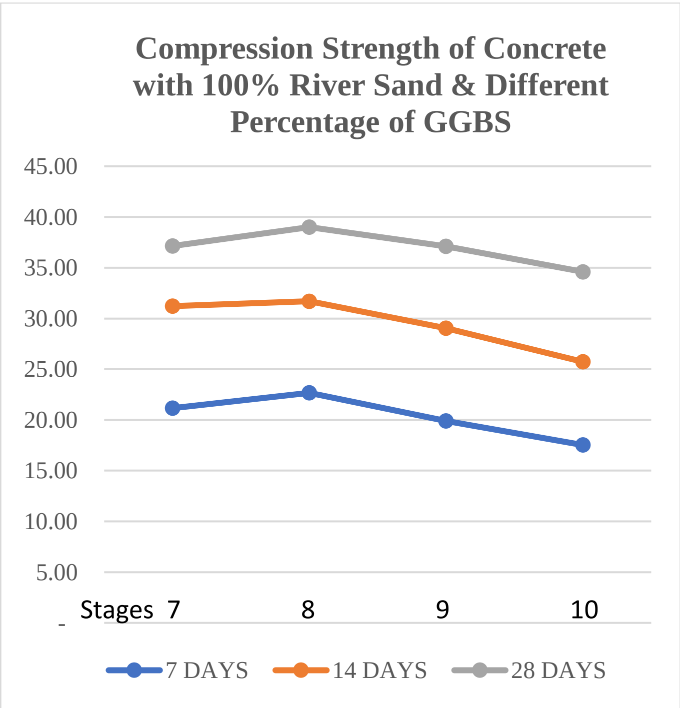


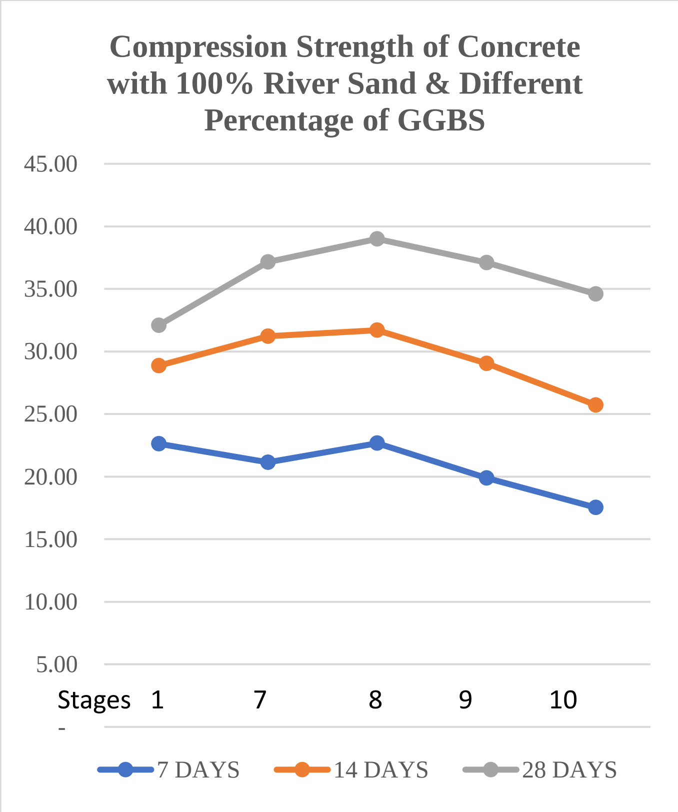
Chart - Compression Strength values of concrete for Stage 1 Vs Stage 2



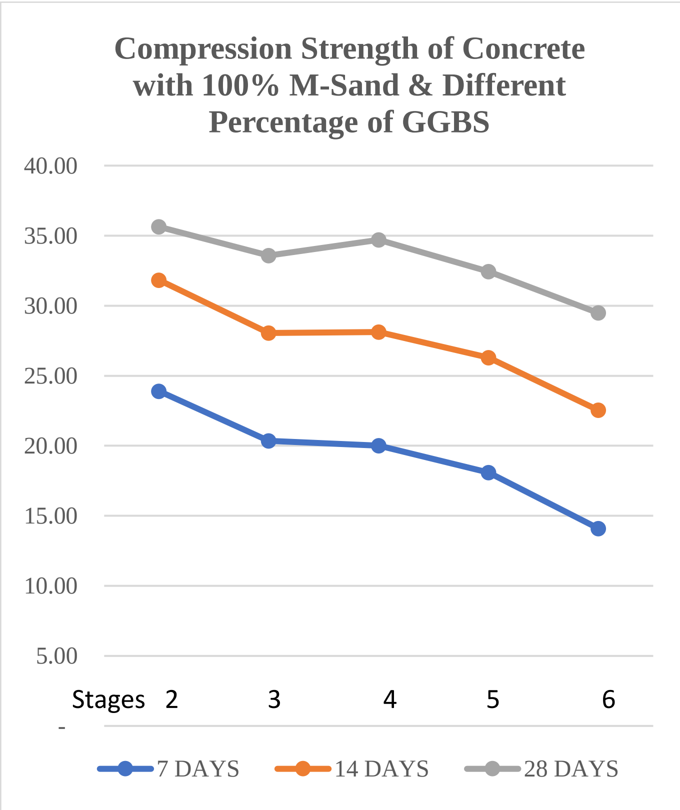
Compression Strength Test values of concrete for Stage 3, 4, 5 and 6



Compression Strength Test values of concrete for Stage 7, 8, 9 and 10



Compression Strength Test values of concrete for Stage 1, 7, 8, 9 and 10



Compression Strength Test values of concrete for Stage 2, 3, 4, 5 and 6

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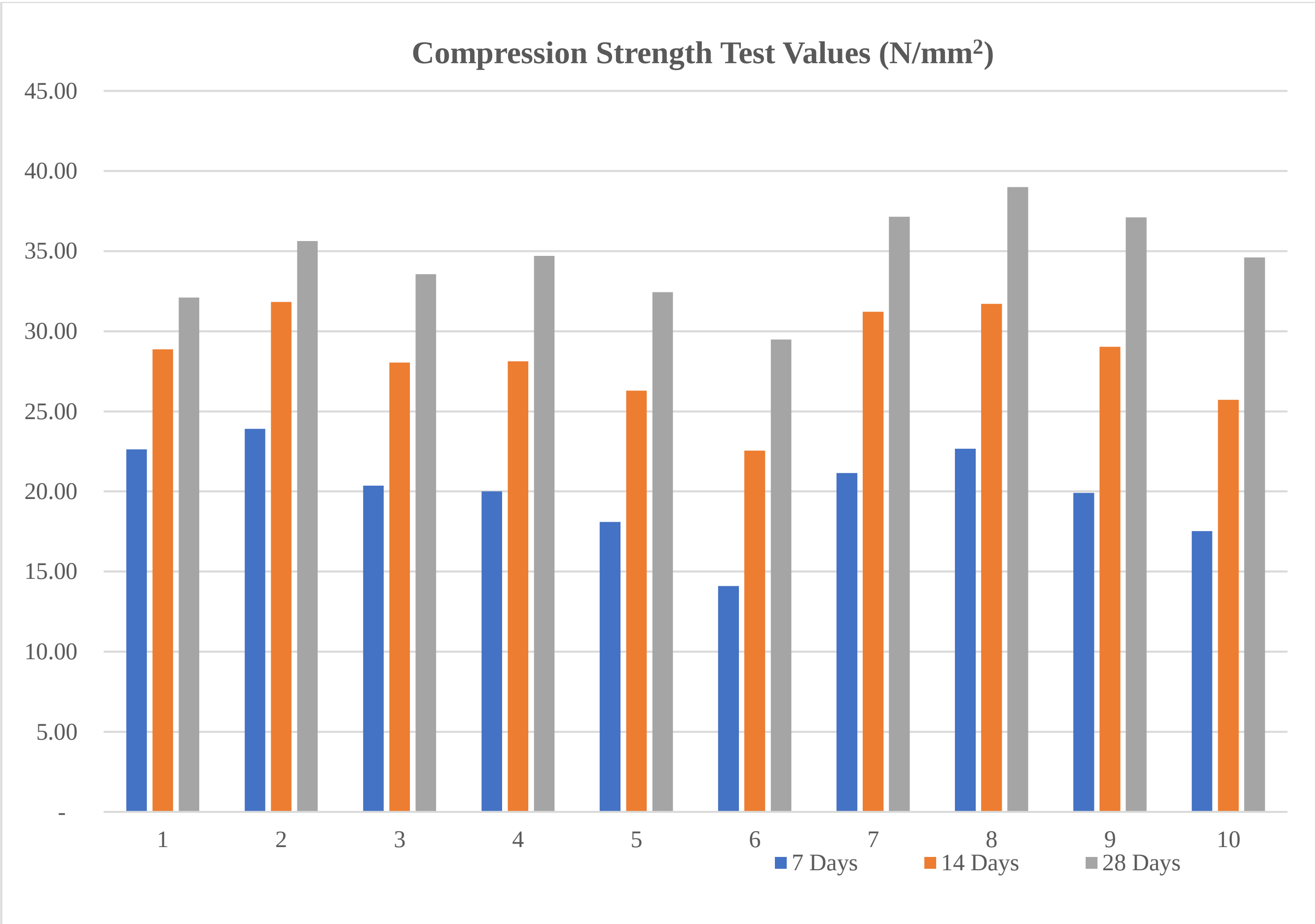
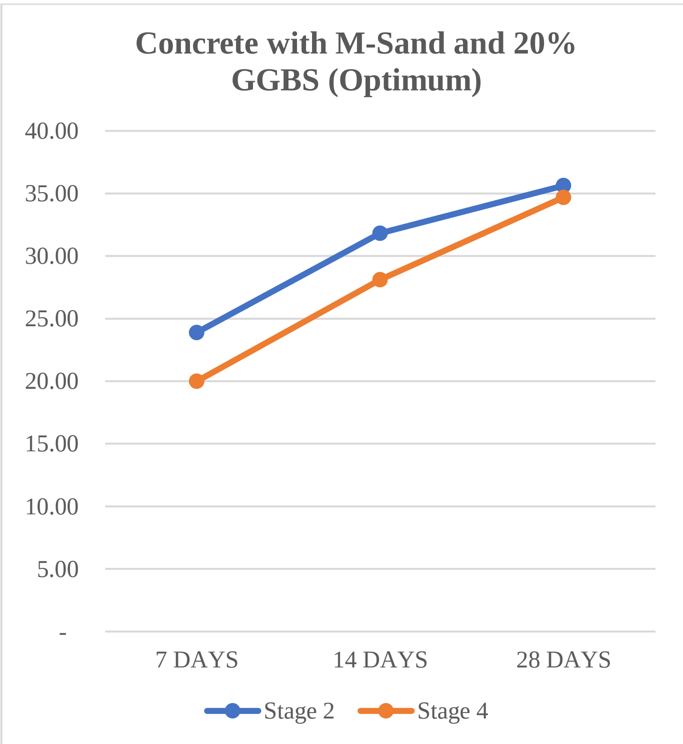
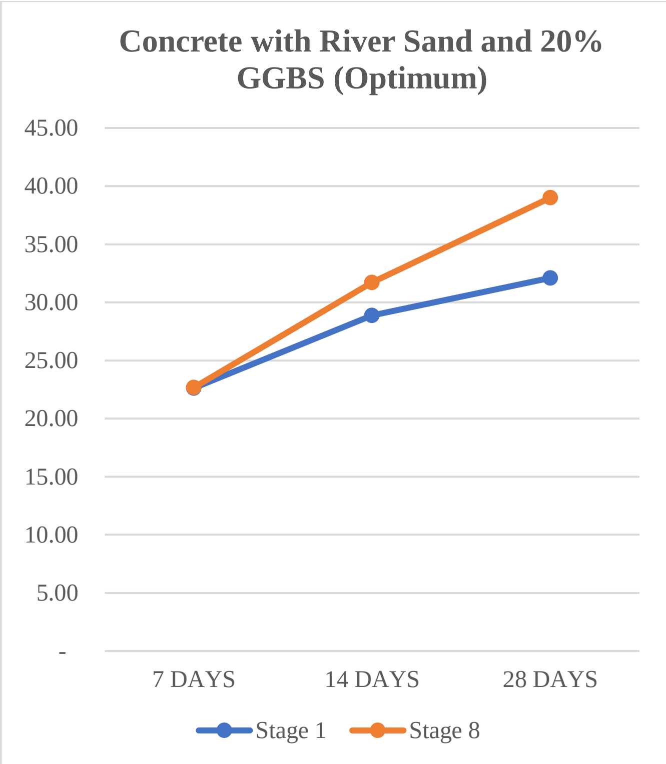


Chart - Compression Strength Test values for 7, 14 and 28 days for all the ten stages



Compression Strength values for concrete with M-Sand and 20% GGBS



Compression Strength values for normal concrete and concrete with 20% GGBS

Table – Split Tensile Strength Test and Flexural Strength Test

Split Tensile Strength Test			**Flexural Strength Test**		
Stages	Strength at 28 Days (kN)	Split Tensile Strength (N/mm^2) for 28 Days	Stages	Strength at 28 Days (kN)	Flexural Strength (N/mm^2) for 28 Days
1	220.65	3.12	1	9.81	4.91
2	240.26	3.40	2	12.36	6.18
3	250.07	3.54	3	13.00	6.50
4	256.94	3.63	4	13.68	6.84
5	228.50	3.23	5	11.33	5.67
6	181.43	2.57	6	10.54	5.27
7	152.01	2.15	7	10.54	5.27
8	185.84	2.63	8	14.08	7.04
9	162.79	2.30	9	12.31	6.16
10	166.22	2.35	10	13.54	6.77

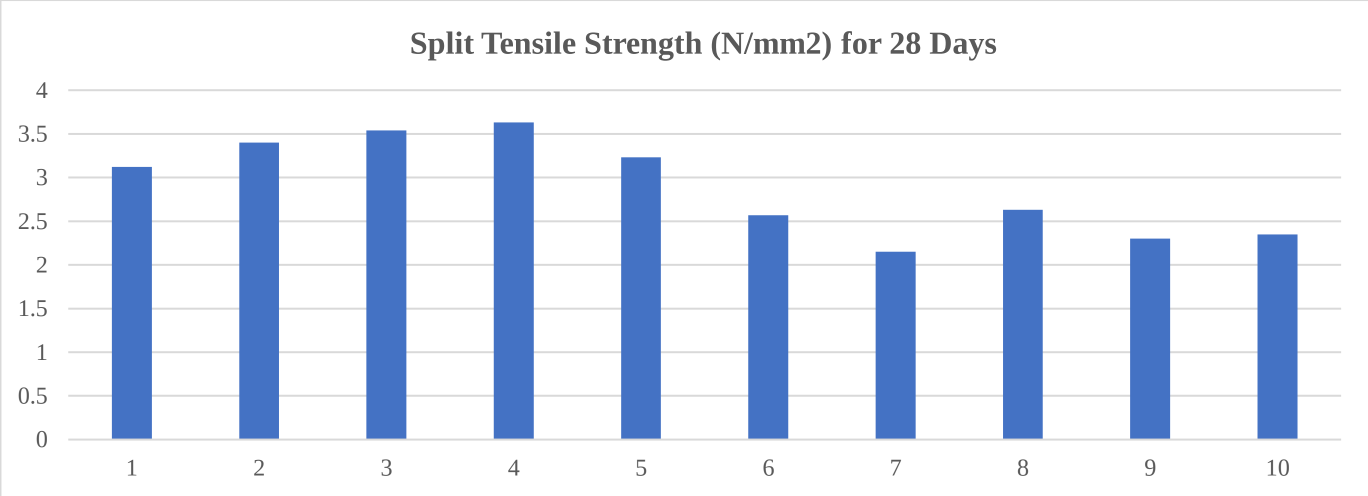


Chart - Split Tensile Strength Test Values

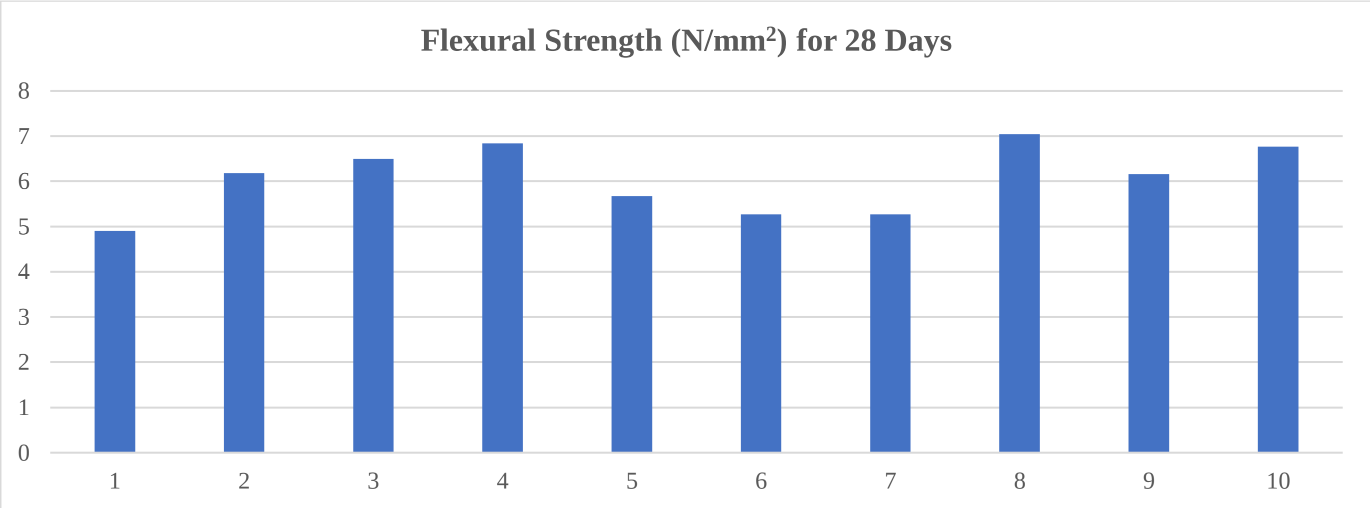


Chart - Flexural Strength Test Values

CONCLUSION

There are ten stages in this project. In the first stage we produced conventional concrete by mixing normal cement (OPC), sand & coarse aggregates. In the second stage we have fully replaced river sand with M-Sand and then we added coarse aggregates. In the third, fourth, fifth and sixth stages, we have done partial replacement of cement by GGBS in 10%, 20%, 30% and 40% respectively for concrete with 100% M-Sand. In the seventh, eighth, ninth and tenth stage, we have partially replaced cement by GGBS in 10%, 20%, 30% and 40% respectively for concrete with River Sand.

We have conducted Compression Test after 7 days, 14 days and 28 days. Also, we have conducted Split Tensile strength Test and Flexural Strength Test for the above 8 stages after 28 days of curing. We have observed positive results (optimum value) for 20% replacement of Cement by GGBS.

On comparing the test results after 7, 14 and 28 days of curing for stages 1 and 2 (Ref Table 5.7), we have observed that the compression strength of concrete with the 100% M-Sand is higher than normal concrete.

On comparing the test results after 7, 14 and 28 days of curing for stages 7, 8, 9 and 10, we have observed that the compression strength of concrete with 20% replacement of Cement by GGBS is higher than concrete with 100% River Sand and 100% Cement (stage 1). Similarly, on comparing the test results after

7, 14 and 28 days of curing for stages 3, 4, 5 and 6, we have observed that the compression strength of concrete with 20% replacement of Cement by GGBS is higher than concrete with 100% M-Sand and 100% Cement (stage 2).

On comparing test results after 28 days of curing, Split Tensile test (Ref Table 5.10) also has shown good results for 20% replacement of Cement by GGBS when compared to the normal concrete, as well as concrete with M-Sand. For concrete with 100% of M-Sand and 20% of GGBS, we have observed split tensile strength of 3.63 N/mm^2 which is higher than the reference value of 3.4 N/mm^2 of concrete without GGBS. Similarly, for concrete with 100% of River Sand and 20% of GGBS, we have observed maximum split tensile strength of 2.63 N/mm^2.

Even in the case of the Flexural Strength Test (Ref Table 5.11), the result was found satisfactory when Cement was replaced by 20% of GGBS with 100% M-Sand and 100% River Sand in concrete. For concrete with 100% River Sand and 20% of GGBS, we have observed flexural strength of 7.04N/mm^2 which is higher than the reference value of 4.91 N/mm^2 of normal concrete. Similarly, for concrete with 100% M-Sand and 20% of GGBS, we have observed maximum value of flexural strength of 6.84 N/mm^2 which is higher than the reference value of 6.18N/mm^2 of concrete with M-Sand. Hence, based on the compression strength test, split tensile strength and flexural strength, we can conclude that 20% of the Cement can be replaced by GGBS along with 100% of M-Sand or with 100% of River Sand. Hence, Optimum Value of GGBS is 20%.

The Mix Design was done for M30 Grade Concrete. One of the interesting points we have noted here is that other than stage six (29.48 N/mm^2, where 40% of cement was replaced by GGBS), all the values of Compression Strength in 9 stages have shown a value more than 30 N/mm^2. Hence, we can conclude that, when River Sand is used in concrete, we can achieve 20% economy in Cement, and when M-Sand is used in concrete, we can achieve 20% economy in Cement, and we can also achieve an additional economy of 60% in fine aggregates. M-Sand is available as byproduct in the quarries. Hence, it is creating solid waste management problem. In Karnataka, M-Sand is generally more cost-effective than River Sand, with prices ranging from ₹700 to ₹1200 per ton, while River Sand can cost between ₹2200 and ₹3000 per ton.

In this project, we have tried our level best to produce green concrete where we can replace river sand with M-Sand, also we have used GGBS in place of Cement. Hence, overall economy can be achieved and we can come up with green concrete which is environmentally sustainable and economical. Our project is an example for green concrete and sustainable development material.

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