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Strength and Workability Studies on Slag Sand Concrete Blended with Flyash and Glass Powder

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Abstract

The depletion of natural resources and the environmental impact caused by conventional building materials have led to the exploration of sustainable alternatives. The use of industrial wastes and its by-products in the construction industries has become widely popular in recent years because of their beneficial properties and potential for reducing the environmental impact. This study investigates the effects of fly ash, glass powder and slag sand in M30 grade concrete. In this process, cement is partially replaced by fly ash at a percentages of 0, 10, 20 and 30% and addition of glass powder at a percentage of 0, 10 and 20%. This eco-friendly concrete was made using slag sand instead of natural sand. The main objective of this research is to evaluate the mechanical properties of slag sand concrete with various combinations of cement, fly ash and glass powder. In order to evaluate the concrete specimens' performance, strength and workability tests were conducted on them. The hardened properties, including compressive strength were assessed after a curing period of 28 days and 90 days, while split tensile strength and flexural strength were assessed after curing period of 28 days. The results are encouraging in producing sustainable M30 grade concrete.

Keywords: Slag sand, Fly ash, Glass powder, Compressive strength, Flexural strength, Split tensile strength.

1. Introduction

Indeed waste disposal has become a significant issue for industries in recent times. Even if 0.1% of this lost to the atmosphere, it can cause havoc environmentally. To overcome this issue these wastes are either recycled or reused in construction. The Construction industry has become an integral part of the country's economic and social development. Concrete is often the largest single material component in the constructed environment. If it is possible to reduce its embodied energy without compromising its performance or increasing its cost, considerable environmental and economic advantages may be achieved. Concrete consists primarily of Portland cement, aggregates, and water. While Portland cement typically accounts for only twelve percent of the concrete's mass, it accounts for approximately ninety-three percent of the overall embodied energy and six to seven percent of the world's carbon dioxide emissions. Extraction of sand from riverbeds or coastal areas can have a negative impact on the environment including habitat destruction and erosion. In some areas availability of sand may be limited. Keeping in view of eco-friendly approaches, cost and availability, both cement and sand are to be replaced with industrial wastes or By-products such as fly ash, rice husk ash, silica fume, metakaolin, glass powder, slag sand etc.

These waste materials or byproducts possess pozzolanic qualities that matched with the properties of cement. Fly ash is used in this case as an additional cementitious ingredient because of its pozzolanic characteristics. It creates C-S-H gel when it reacts with portlandite, which has a structure similar to that gained by cement hydration. Improper disposal of glass can lead to hazardous health risks. However, incorporating glass powder in concrete with an appropriate amount can effectively improve the concrete internal micro structure and mechanical properties. This enhancement can be attributed to the dual influence of glass powder serving as both a micro filler and participating in pozzolanic reactions. By completely replacing the fine aggregate with slag sand, the concrete becomes more sustainable and environmentally friendly.

The combination of slag sand, flyash and glass powder in concrete mixtures offers several advantages. Firstly, it reduces the demand for cement which leads to a significant reduction in carbon dioxide emissions. Secondly it utilizes waste materials that would otherwise end up in landfills reducing environmental pollution. Thirdly it improves the performance of concrete making it more durable and long-lasting.

2. Literature review

[1] **Chen et al. (2015)** Examined the compressive strength of slag-sand concrete with various fly-ash and glass powder content levels. It was discovered that while adding glass powder somewhat decreased strength, adding fly ash slightly boosted compressive strength. The use of fly ash and glass powder together, however, demonstrated a synergistic impact that increased compressive strength compared to control concrete.

[2] **Li et al. (2017)** Research was done on the flexural strength and split tensile strength of concrete made using slag sand and a mixture of fly ash and glass powder. Their findings demonstrated that the inclusion of fly ash boosted the flexural and cracking tensile strengths, whereas the addition of glass powder had little impact. In contrast to the control concrete, the use of fly ash and glass powder together improved the flexural and splitting tensile strengths.

[3] **Srinivasan et al. (2017)** Evaluated the workability of concrete made with fly ash, glass powder, and slag sand. According to the findings, adding these ingredients made the concrete mixtures easier to work with. The lubricating properties of the small particles and the better particle packing, according to the researchers, were responsible for this improvement.

[4] **P. Kumar et al. (2018)** Studied how slag sand concrete's strength qualities were affected by fly ash and glass powder. The experimental findings demonstrated that the addition of fly ash and glass powder boosted the concrete's compressive strength. Compared to normal slag sand concrete, the mixture of slag sand, fly ash, and glass powder produced stronger characteristics. Additionally, the study noted that the inclusion of fly ash and glass powder enhanced the concrete mix's workability, making it simpler to handle and apply.

[5] **Yadav et al. (2018)** Investigated how well slag sand concrete mixed with fly ash and glass powder flowed and resisted segregation. According to their research, the flowability increased when fly ash was added, however the flowability marginally decreased when glass powder was added. Fly ash and glass powder, when used together, increased the flowability and segregation resistance of the concrete mixture, resulting in higher workability and homogeneity.

[6] **Pandey et al. (2019)** Cement was substituted in concrete compositions by using a combination of glass powder, fly ash, and slag sand. The results revealed that the concrete containing these additional cementitious components had greater compressive strength than the control concrete. This improvement, according to the researchers, is due to the blended concrete's enhanced micro structure and greater hydration product production.

[7] **S. Anand et al. (2019)** Focused on how different fly ash and glass powder ratios affected the workability and strength of slag sand concrete. The findings showed that the compressive strength and split tensile strength of the concrete mix increased along with the quantity of fly ash and glass powder. Additionally, the study discovered that adding fly ash and glass powder improved the workability of the concrete, producing a mixture that was simpler to work with throughout construction.

[8] **M. Pradhan et al. (2020)** studied how varied slag sand, fly ash, and glass powder mixtures affected the mechanical characteristics of concrete. According to the findings, the inclusion of fly ash and glass powder increased the concrete mix's compressive strength, flexural strength, and split tensile strength. The study also discovered that the addition of fly ash and glass powder improved the concrete mix's workability, indicating simpler handling and placing.

3.Objectives of Study

1. The main objective of this research entails a comprehensive examination of the strength and workability characteristics of M30 grade slag sand

Concrete incorporated with glass powder and fly ash.

2. This study aims to determine the optimal combinations and proportions of fly ash, slag sand and glass powder for achieving enhanced compressive strength, tensile strength, and flexural strength while assessing the influence of these supplementary materials on the concrete's workability and placement feasibility.

3. By evaluating the mechanical performance and sustainability aspects of these blended concrete mixtures, this research aims to contribute valuable insights to the construction industry, fostering the development of environmentally friendly and resilient concrete solutions.

4. Methodology

4.1. MATERIALS

4.1.1. Ordinary Portland cement

In this experiment, Sri Chakra Ordinary Portland cement (OPC) is used to prepare the Mix design. OPC 53 grade cement is a type of cement that has a higher strength compared to other types of cement with specific gravity 3.14.

4.1.2. Slag sand

Slag sand is a byproduct of the steel and iron manufacturing process. Slag sand is great choice for concrete when it’s used as a fine aggregate in construction. Due to its pozzolanic properties enhance concrete durability, reduce heat of hydration, leading to higher compressive strength and reduce shrinkage, ultimately resulting in cost savings in over time. In this research, we are using JSW Slag sand instead of natural sand. The specific gravity of slag sand was 2.64.

4.1.3. Coarse aggregate

Coarse aggregate serves as the backbone of concrete, contributing essential properties that determine its strength, durability, and performance. It consists of gravel, crushed stone, or recycled materials with particle sizes ranging from 4.75mm to 20mm. Coarse aggregates also play a pivotal role in controlling volume stability, mitigating the effects of temperature and moisture-related expansion and shrinkage, thus preventing cracking and preserving the structural integrity of the concrete. In this research we used 20mm size aggregate with specific gravity 2.83.

4.1.4. Water

Water plays a crucial role in the concrete mixing and curing process. It is one of the main ingredients in concrete along with cement, aggregates and admixtures. Proper water content is necessary for achieving the desired strength and workability of the concrete mixture. Therefore, it is crucial to carefully control and measure the water-to-cement ratio to ensure their optimal performance. Clean and potable water has been used in this study.

4.1.5 Glass powder

Glass powder refers to finely ground particles of glass that are typically obtained by grinding or milling glass materials. It plays a significant role as a supplementary material in concrete applications because of its fine particle size and pozzolanic properties, which improve the workability, mechanical characteristics, and durability of concrete mixtures. Furthermore, the use of glass powder in concrete offers an environmentally friendly solution to the growing issue of glass waste management. Glass powder manufactured by SGS India private limited, Mumbai has been used in this investigation.

4.1.6. Flyash

Fly ash, a fine powder residue that is generated as a byproduct during the combustion of pulverized coal in power plants. In recent years it has gained significant attention in the construction sector as an additional cementitious material in concrete production. When added to concrete, fly ash enhances workability, lowers the heat of hydration, promotes the development of strength and improves durability. It also mitigates the environmental impact of concrete production by reducing the need for cement which is a major contributor to carbon emissions. Overall, fly ash utilization in concrete offers a sustainable and cost-effective solution for the construction industry while also addressing the challenges of waste disposal. Flyash manufactured by Esevaworld services private limited, Secunderabad has been used in this investigation.

4.1.7. Mix designing

The concrete mix design followed IS 10262-2019 standards to achieve M30 grade strength with a water-cement ratio of 0.5. A total of twelve different concrete mixes were developed, varying in concentrations of 0%, 10%, 20% and 30% Fly ash and 0%, 10% and 20% Glass powder addition. The main focus of the study was on the comprehensive assessment of strength properties, including compressive, flexural and split tensile strength. To ensure reliable testing, six cubes, three cylinders and three beams were carefully cast and studied for their hardened properties. The relative mix proportions as per mix design are presented in Table No.1.

Table No.1 Mix proportions

S.No	Materials	Quantities (kg/m^3)
1.	Cement	425
2.	Fine aggregate	560
3.	Coarse aggregate	1150
4.	W/C ratio	0.5

5. Results And Discussions

The mechanical characteristics of concrete containing various percentages of Fly ash and Glass powder at the age of 28 and 90 days are discussed below.

5.1. Mechanical Properties

5.1.1. Compressive Strength

This section presents and discusses the results of the compressive strength test performed on cube specimens of various mixes cured. The test was performed at 28 days and 90 days. Table No.2 and table No.3 illustrate the compressive strengths of the mixtures after 28 and 90 days of curing respectively.

Table No2. Compressive strength test results for 28 days

Compressive strength for 28 days				
Glass powder (% addition)	Fly ash (% replacement)			
	0%	10%	20%	30%
0%	38.7	43.5	41.3	38.2
10%	41.2	44.8	42.3	39.7
20%	39.6	42.6	40.1	37.4

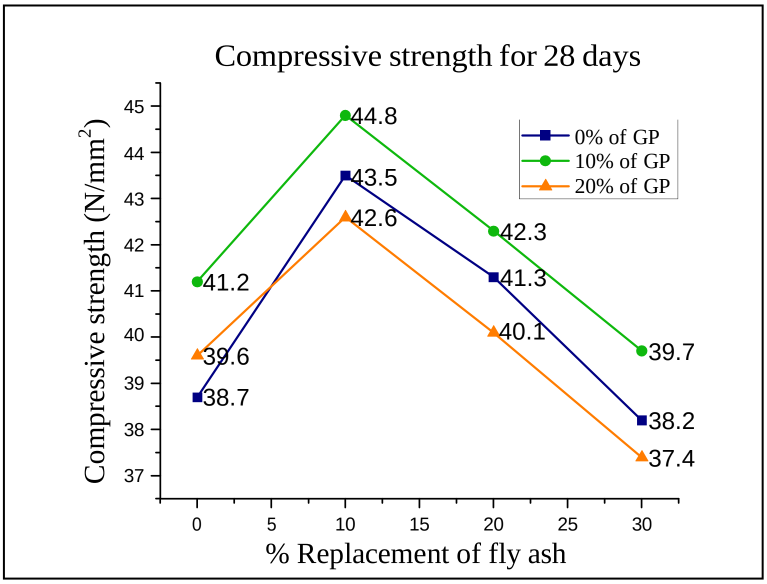

Fig No 1. Variation of Compressive strength at 28 days curing

The Fig No.1 represents the compressive strength variation after 28 days of curing, and the results indicate a considerable improvement in compressive strength up to 20%replacement with fly ash and a 20% addition of glass powder. This improvement can be ascribed to the pozzolanic reactions initiated by fly ash as well as the fine Particle characteristics of both the glass powder and the fly ash. Beyond this 20% threshold, the compressive strength starts to decrease. The highest observed compressive strength, peaking at 44.8N/mm^2, was achieved with a 10% replacement of fly ash and a 10% addition of glass powder.

Table No 3. Compressive strength Test Results for 90 days

Compressive strength for 90 days				
Glass powder (% addition)	Fly ash (% replacement)			
	0%	10%	20%	30%
0%	44.50	50.02	47.5	43.93
10%	47.38	51.64	48.72	45.73
20%	45.58	49.1	46.17	43.04

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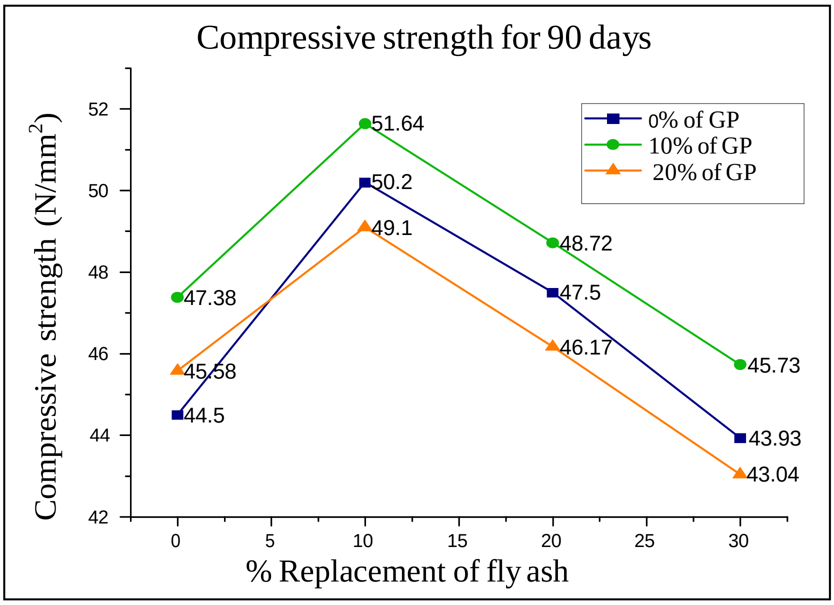

Fig No 2. Variation of Compressive strength for 90 days curing

The Fig No. 2 represents the compressive strength of concrete after a curing period of 90 days. It shows that the 90-days strength of slag sand concrete blended with fly ash and the addition of glass powder typically increases by around 15% more than the 28-days strength due to the prolonged curing period and continued development of the concrete's micro structure. The maximum compressive strength of concrete was 51.64 N/mm^2 at a curing of 90 days, which was 33.4% higher than conventional concrete. The results at 90 days have shown trends very much similar to that at 28 days.

5.1.2. Split tensile strength

This section presents and analyzes the results of a split tensile strength test performed on concrete specimens of various mixes. Table No.4 shows the split tensile strengths of all the mixtures after 28 days of curing.

Table No 4. Split tensile strength Test Results for 28 days

Split tensile strength for 28 days				
Glass powder (% addition)	Fly ash (% replacement)			
	0%	10%	20%	30%
0%	3.22	3.90	3.72	3.41
10%	3.88	4.13	3.86	3.63
20%	3.31	3.81	3.52	3.28

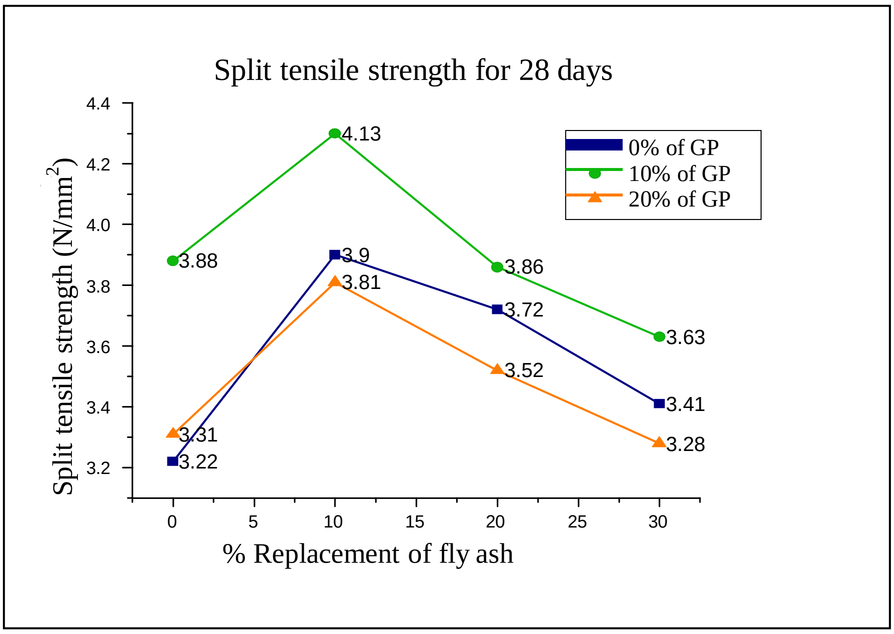

Fig No 3. Variation of Split tensile strength

The Fig No. 3 depicts the variation of 28 days split tensile strength of Slag sand concrete. It shows that 20% glass powder addition and 30% of cement replaced with fly ash gives the reasonable split tensile strength as compared to ordinary concrete. This is because these materials contribute to the production of additional C-S-H (calcium silicate hydrate) gel, which is essential for the structural integrity of concrete. The combination of 90% cement, 10% fly ash and 10% additon of glass powder yields the highest strength Of M30 grade slag sand concrete. The optimum split tensile strength achieved from this mixture is 4.13 N/mm^2, which is 28.2% higher than that of conventional concrete.

5.1.3. Flexural strength

The beam specimens were tested for evaluating the flexural strength at the age of 28 days. Table No.5 shows the flexural strengths for all the mixtures.

Table No 5. Flexural strength Test Results for 28 days

Flexural strength for 28 days				
Glass powder (% Addition)	Fly ash (% replacement)			
	0%	10%	20%	30%
0%	6.32	6.92	6.52	6.24
10%	7.89	8.26	7.71	6.93
20%	7.26	7.88	6.89	6.44

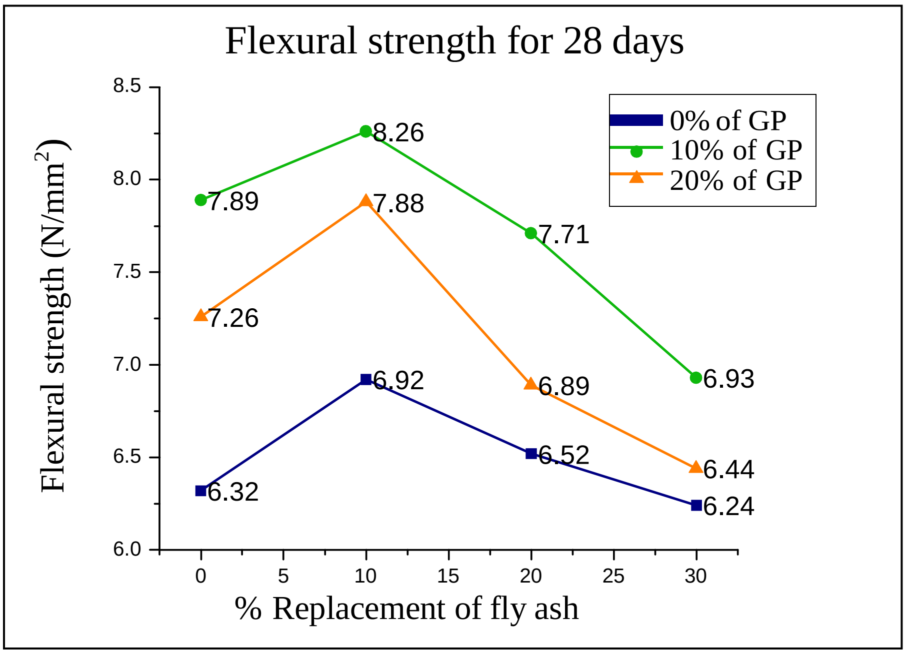

Fig No 4. Variation of Flexural strength

The Fig No. 4 presents variation of 28 days flexural strength of slag sand concrete. It shows that 20% glass powder addition and 30% of cement replaced with fly ash gives the reasonable flexural strength as compared to ordinary concrete. This is because the combination of these supplementary cementitious materials improves the inter connectivity of the hydration products, leading to improved bonding and resistance to cracking. The combination of 90% cement, 10% fly ash and 10% additon of glass powder yields the highest flexural strength of M30 grade slag sand concrete. The optimum flexural strength achieved from this mixture is 8.26 N/mm^2, which is 30.6% higher than the conventional concrete.

6. Conclusions

The current study explores the influence of fly ash and glass powder in slag sand concrete. The following findings were made based on the current research:

1. The combination of pozzolanic reactions, improved particle packing, enhanced bonding, reduced cracking tendencies, workability, and durability collectively leads to the observed increase in strengths in slag sand concrete blended with fly ash and glass powder.
2. Concrete prepared by replacing 10% and 20% cement by fly ash and 10% and 20% glass powder addition gave satisfied results compared to ordinary concrete.
3. Maximum values of compressive strength, tensile strength, and flexural strength is obtained at 10% replacement of cement by fly ash and 10% addition of glass powder.
4. The use of flyash and glass powder in concrete can improve strength, cost efficiency, and environmetal sustainability. But excessive use of these additives may dilute the cementitious content in mix, diminishing the positive effects and causing a decrease in strength. Therefore, it is crucial to carefully consider the dosage and proportions of these materials to maximize their benefits and avoid any negative effects on the strength of concrete.

7. References

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