Strength Studies on Slag Sand Concrete Blended with Glass Powder and Dolomite Powder

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Abstract

Cement is a crucial component in concrete production, but its manufacturing process contributes significantly to atmospheric CO2 emissions. It's estimated that the production of one ton of cement leads to the release of about 0.8 tons of CO2. To mitigate this environmental impact, incorporating mineral admixtures into concrete has become a promising solution. Dolomite powder, derived from the powdered sedimentary rock mineral dolostone, is being explored as a partial replacement for cement in concrete. Additionally, substituting conventional sand with slag sand, produced by crushing slag generated in the copper refining process into a sandy form using running water, can enhance the eco-friendliness of concrete. Another innovative approach involves integrating milled waste glass into concrete as a partial replacement for cement, further contributing to the development of environmentally friendly infrastructure. This study aims to investigate the effects of combining dolomite powder and glass powder on the strength and workability of concrete. Glass powder is introduced at variouslevels, such as 0, 10, and 20% of the cement's weight, while dolomite dust is used as a partial cement replacement at levels of 0, 10, 20, and 30% by weight. The research assesses the fresh properties of the concrete through tests like the slump cone, compaction factor, and vee bee tests. Strength properties are evaluated by measuring compressive strength at 28 and 90 days, as well as tensile and flexural strength.

Keywords: Slag sand, Glass powder, Dolomite powder, Compressive strength, Flexural strength and Tensile strength.

Introduction

The construction industry continually seeks innovative and sustainable approaches to enhance the performance and environmental footprint of concrete, a fundamental building material. Among these efforts, the incorporation of alternative materials like slag sand, glass powder, and dolomite powder into concrete mixtures has gained significant attention. These materials offer a unique opportunity to improve both the strength and workability characteristics of concrete while reducing its environmental impact.

Slag sand, a byproduct of the copper refining process, presents a potential replacement for conventional sand. It possesses properties that can enhance the structural integrity of concrete.

At the same time, the use of waste glass powder as a partial replacement for cement in concrete has emerged as a promising route towards more eco-friendly construction practices. Additionally, dolomite powder, derived from dolostone, presents an intriguing option as a partial substitute for cement. Not only can it influence the material's mechanical properties, but it also holds potential for reducing the carbon footprint associated with cement production, a process known for its high CO2 emissions.

This study delves into the synergistic effects of incorporating these three materials, namely slag sand, glass powder, and dolomite powder, into concrete mixtures. Specifically, the research aims to evaluate their combined impact on the strength and workability characteristics of concrete. Through a series of controlled experiments and tests, this investigation seeks to provide valuable insights into the feasibility and potential benefits of using these materials in concrete construction. The findings from this study have the potential to contribute to the development of more sustainable and robust concrete formulations, furthering the objectives of modern construction practices.

Literature Review

Suji and Chelladurai (2018) aimed to assess the mechanical and durability characteristics of slag sand concrete with varying glass powder replacement levels (10%, 20%, and 30%). The study found that the incorporation of glass powder reduced the compressive strength of the concrete. However, it improved the workability significantly, resulting in improved flow and ease of placement.

Tamilarasan and Anand (2021) examined the effect of incorporating slag sand concrete with dolomite powder and glass powder on split tensile strength. The results indicated that an optimum combination of 25% DP and 10% GP exhibited the highest tensile strength, suggesting the potential of these materials in enhancing the durability of slag sand concrete.

Natarajan and Murugesan (2017) investigated the strength characteristics of concrete incorporating glass powder as a supplementary material. This research, published in the International Journal of Innovative Research in Science, Engineering and Technology, aimed to assess the potential of glass powder as a sustainable and eco-friendly alternative to traditional cement in concrete mixtures. The authors' findings are anticipated to contribute to the growing body of knowledge on environmentally friendly construction materials and could have implications for reducing the environmental impact of the construction industry while enhancing the mechanical properties of concrete. The study represents an important step in exploring innovative approaches to sustainable construction practices.

Jain and Khan (2019) investigated the strength properties of concrete by introducing partial replacements of fine aggregate with dolomite powder and glass powder. This research, published in the Journal of Engineering Research and Reports, delves into an important aspect of concrete technology, as it explores the potential enhancement of concrete properties through sustainable alternatives. By examining the effects of these supplementary materials on concrete strength, the study contributes valuable insights that could have practical implications in the construction industry. This research paper serves as a pertinent source in the quest for more environmentally friendly and durable concrete formulations.

Venkatesan and Arivalagan in (2016) the authors investigated the strength characteristics of concrete incorporating glass powder as a partial replacement for conventional cement. Their experimental approach sheds light on the potential of glass powder as a supplementary cementitious material, exploring its influence on the compressive strength and durability of concrete. By examining the effects of glass powder on concrete properties, this study offers valuable insights into eco-friendly construction practices and paves the way for more sustainable infrastructure development.

Parvez and Ahmad (2014) the authors investigated the strength characteristics of concrete when cement was partially replaced by glass powder and fine aggregate was substituted with copper slag. The findings of this study are of significant importance, as they shed light on the potential of glass powder and copper slag as alternative materials in the construction industry, offering both environmental benefits and economic advantages. By exploring the impact of these substitutions on concrete strength, the research contributes valuable insights to the field of sustainable construction practices.

3. Objectives

To evaluate the hardened properties of slag sand concrete samples incorporating varying proportions of glass powder and dolomite powder.

To determine the optimal dosage and ratio of dolomite powder and glass powder that can enhance the compressive strength of the concrete. This objective helps in assessing the structural viability and load-bearing capacity of the material.

To understand how the inclusion of these admixtures affects the concrete's ability to withstand bending and tensile forces. This objective helps in assessing the material's suitability for construction applications where flexural strength is crucial, such as beams and slabs.

MATERIALS AND METHODOLOGY

MATERIALS

Cement

In this project, we utilized OPC 53 grade cement manufactured by Sri Chakra Super Tech. This type of cement is chiefly composed of clinker, gypsum, and minor additives. OPC 53 grade cement is renowned for its exceptional high compressive strength. The specific gravity of cement used is 3.15.

Slag Sand

Slag sand is a type of industrial byproduct used in construction. It is produced from the crushing and screening of granulated blast furnace slag, a waste material generated during the manufacturing of iron and steel. Slag sand is valued in construction for its properties, such as improved workability, durability, and environmental benefits. It is often used as a partial replacement for traditional sand in concrete mixes to enhance the performance and sustainability of construction materials. In this project I have used the slag sand which is manufactured by JSW. The specific gravity of slag sand is 2.61.

Coarse Aggregate

Coarse aggregates consist of irregular and granular materials like sand, gravel, or crushed stone and are a crucial component in concrete production. Typically, these coarse materials are naturally sourced and can be acquired by means of quarry blasting or mechanical crushing, including the use of crushers. In this specific instance, angular aggregates with a 20 mm size were chosen due to their advantageous properties, particularly their ability to blend well in concrete mixes and reduce the formation of voids or gaps within the material.

Glass Powder

Glass powder is commonly manufactured through the crushing and milling of glass waste, which can include items like unused glass bottles, containers, or glass sheets. Additionally, it can be produced from specifically processed glass materials. In the context of concrete applications, the inclusion of glass powder has been known to contribute to the enhancement ofboth compressive strength and the overall durability of the concrete. For this project, the glass powder utilized was sourced from SGS India Private Ltd.

Dolomite Powder

Dolomite is a naturally formed mineral that belongs to the carbonate rock category, primarily consisting of calcium magnesium carbonate (CaMg(CO3)2) It occurs typically in sedimentary rock formations and holds significant value in multiple sectors such as construction, agriculture, magnesium production, and chemical industries. In its powdered form, dolomite appears white, and laboratory tests confirm a specific gravity of 2.85.

MIX DESIGN

The concrete mix was designed in accordance with the IS 10262-2019 standards, targeting M30 grade strength while maintaining a water-cement ratio of 0.5. A total of twelve distinct concrete blends were formulated, featuring variations in the percentages of Dolomite powder (0%, 10%, 20%, and 30%) and Glass powder (0%, 10%, and 20%). The primary focus of this research was an extensive evaluation of strength characteristics, encompassing compressive, flexural, and split tensile strength. To ensure the reliability of the testing process, six cubes, three cylinders, and three beams were meticulously cast and subjected to an examination of their matured properties. The specific mix proportions, as per the mix design, can be found 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

RESULTS AND DISCUSSIONS

The mechanical properties of concrete containing different percentages of Glass powder and Dolomite powder are discussed below.

MECHANICAL PROPERTIES

Compressive Strength

Compressive strength is a measure of a material's ability to withstand forces in compression. The evaluation of the cube's compressive strength was conducted in accordance with IS 10262:2019 guidelines. For this purpose, standard-sized cubes measuring 150x150x150mm were meticulously prepared. Following a curing period of 28 days, the cubes were positioned within a Compressive Testing Machine (CTM) with a maximum capacity of 2000kN.

Table No 2. Compressive strength test results for 28 days

Compressive strength for 28 days				
Glass powder (% addition)	**Dolomite Powder** (% replacement)			
	0%	**10%**	**20%**	**30%**
0%	37.9	42.8	40.9	38. 4
10%	41. 4	44.2	42.1	39.5
20%	39.1	41.7	39.8	36.9

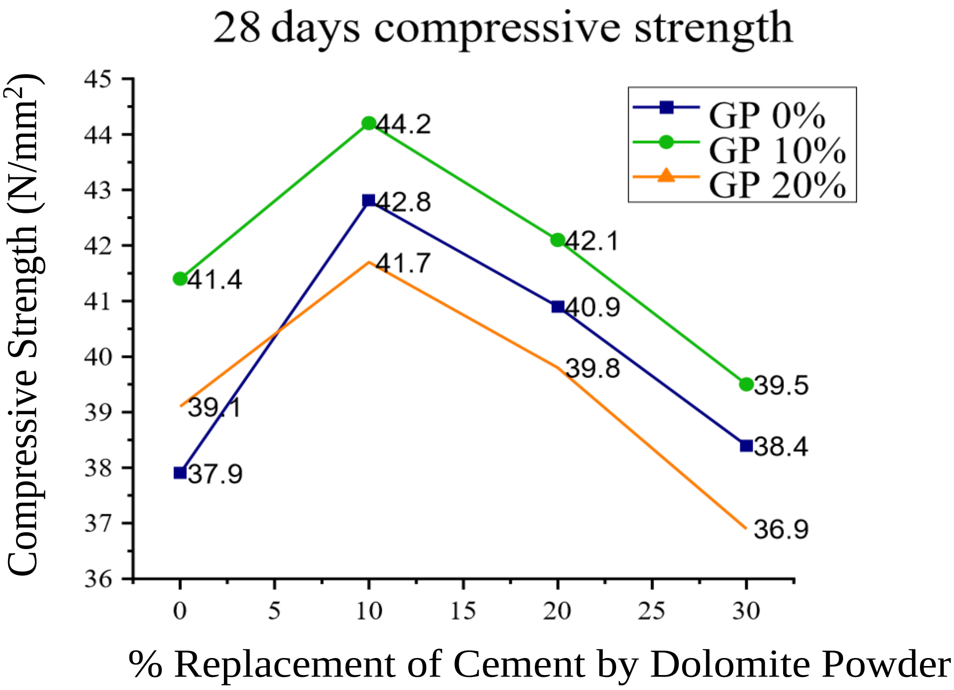

Figure No 1. Variation of Compressive strength at 28 days curing

Figure 1 illustrates the changes in compressive strength, particularly following the 28-day curing phase. A noticeable strength improvement was evident up to a 10% substitution for bothglass powder and dolomite powder, beyond which there was a decline. This enhancement in strength can be attributed to the pozzolanic reactions that transpired between the cement and the introduced admixtures. The highest recorded compressive strength reached 44.2 N/mm2, achieved with a 10% replacement of dolomite powder 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%	43.58	48. 48	46.58	44.08
10%	47.08	49.88	47.78	45.18
20%	44.78	47. 48	45. 48	42.58

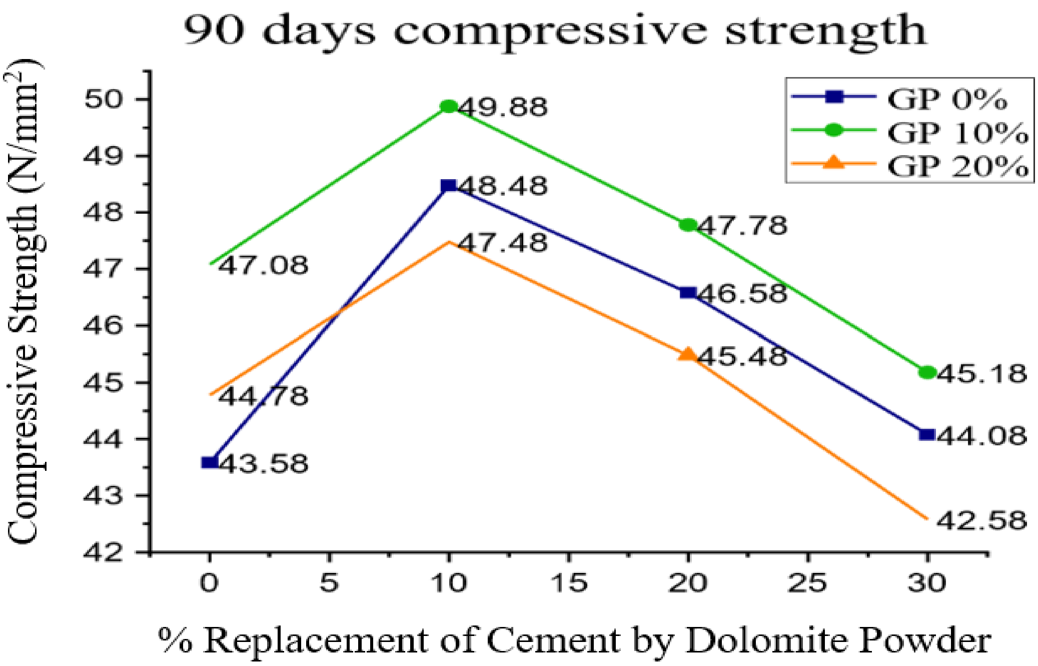

Figure No 2. Variation of Compressive strength at 90 days curing

In Figure 2, the alterations in compressive strength are depicted, specifically emphasizing the effects of a 90-day curing period. Significantly, it's worth noting that the compressive strength showed a substantial increase during the extended 90-day curing phase when compared to the 28-day duration. Similar to the findings at 28 days, there was a discernible strength improvement up to a 10% substitution of both glass powder and dolomite powder, followed by a decrease. This surge in strength can be attributed to the ongoing hydration processes involving the cement, water, and the introduced admixtures. The pinnacle of compressive strength, at 49.88 N/mm2, was attained with a 10% replacement of dolomite powder and a 10% addition of glass powder, mirroring the results obtained at the 90-day juncture.

Split Tensile Strength

Split tensile strength is a vital material property used to gauge a material's ability to withstand tensile or splitting forces. This property is particularly valuable when evaluating the tensile strength of brittle materials like concrete, rock, and ceramics. In a typical study, a cylindrical specimen with dimensions of 150 x 300 mm is subjected to diametrical compressive forces, leading to the specimen splitting along its length. Researchers measure the force required to cause this splitting and then divide it by the cross-sectional area of the specimen to determine the split tensile strength.

This testing method is of great importance in assessing a material's resistance to cracking and failure when subjected to tensile stress, making it especially relevant in fields such as construction and engineering, where the structural integrity and durability of materials are paramount.

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

Split Tensile Strength For 28 Days				
Glass Powder (% addition)	**Dolomite Powder** (% replacement)			
	0%	**10%**	**20%**	**30%**
0%	3.30	3.80	3.69	3.39
10%	3.80	4.01	3.76	3.58
20%	3.21	3.69	3.50	3.31

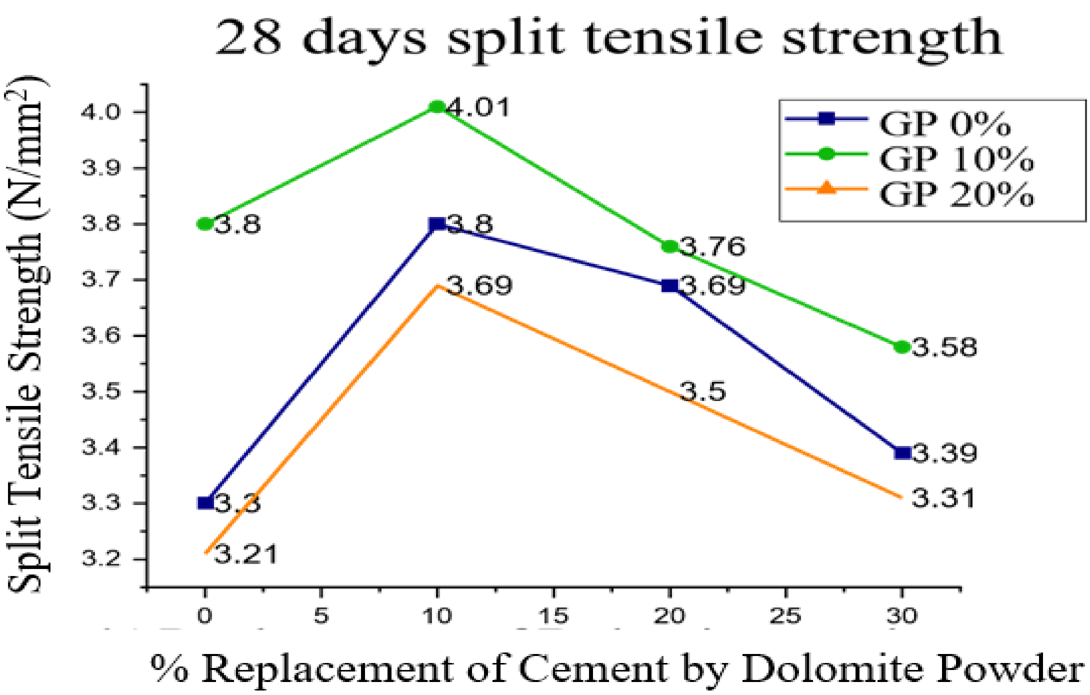

Figure No 3. Variation of Split tensile strength at 28 days curing

Figure 3 illustrates the changes in the 28-day split tensile strength of slag sand concrete. It's evident from the graph that as the slag content increased from 0% to 10%, the split tensile strength of the concrete increased. However, when the slag content exceeded 10%, there was a decline in split tensile strength. This behavior can be attributed to the pozzolanic reaction occurring between the glass powder and the properties of the cement. The optimum split tensile strength, which was reached at the point of 10% glass powder addition and 10% dolomite powder replacement, was measured at 4.01 N/mm².

Flexural Strength

Flexural strength, often referred to as the modulus of rupture, is a fundamental material characteristic that quantifies the maximum stress a material can endure before it undergoes failure or fractures when subjected to bending or flexural forces. In this specific study, a specimen with dimensions of 100 x 100 x 500 mm is employed. This specimen is subjected toa force applied perpendicular to its longitudinal axis, inducing bending. The flexural strength serves as a pivotal parameter in the evaluation of a material's capacity to withstand bending andflexural loads. This property is particularly significant in applications where materials are exposed to such stresses, such as in the construction and engineering fields. The beam specimens were tested for evaluating the flexural strength at the age of 28 days.

Table No 5. Flexural strength Test Results for 28 days

Flexural Strength For 28 Days				
Glass Powder (% Addition)	**Dolomite Powder** (% replacement)			
	0%	**10%**	**20%**	**30%**
0%	6.29	6.98	6.58	6.10
10%	7.79	8.16	7.61	6.83
20%	7.16	7.78	6.79	6.34

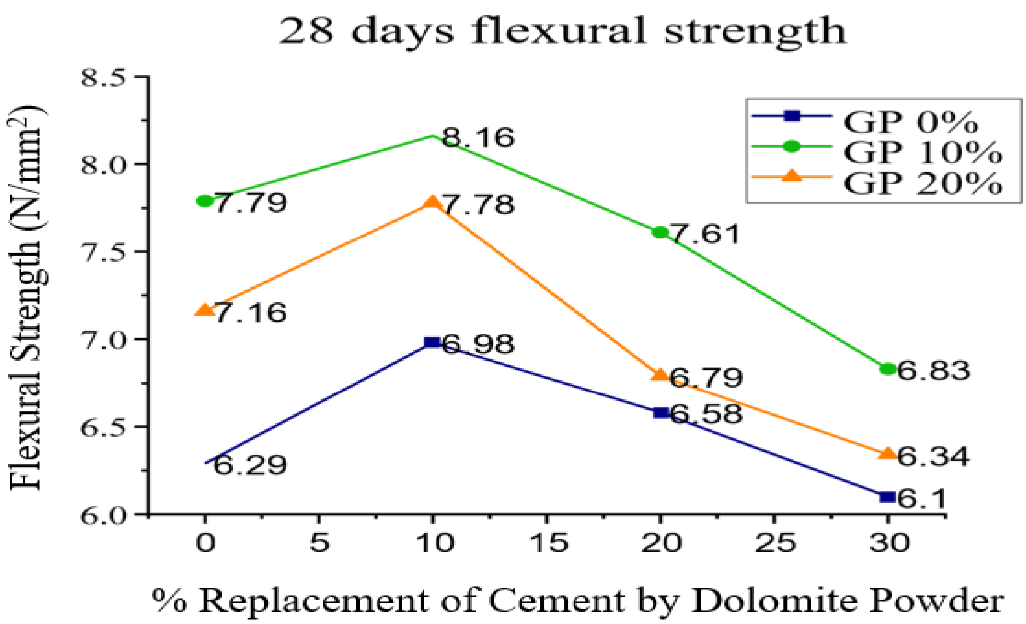

Figure No 4. Variation of Flexural strength at 28 days curing

Figure 4 displays the changes in the 28-day flexural strength of slag sand concrete. This increase in flexural strength can be attributed to the synergistic effect of these supplementary cementitious materials, which enhances the interconnectivity of hydration products. This, in turn, leads to improved bonding and increased resistance to cracking. Notably, the optimal combination for achieving the highest flexural strength in M30-grade slag sand concrete is the simultaneous use of 10% dolomite powder replacement and a 10% addition of glass powder. This blend results in an impressive flexural strength of 8.16 N/mm^2.As seen in the graph, the flexural strength of slag- sand concrete experiences a continuous increase up to a 10% addition of glass powder. Beyond this point, however, there is a diminishing trend in flexural strength. This study underlines the significance of this mixture in achieving optimal flexural strength in slag sand concrete.

CONCLUSION

The incorporation of glass powder and dolomite powder in slag sand concrete significantly improves its strength properties. Specifically, the combination of 10% dolomite powder replacement and 10% glass powder addition yielded the highest flexural and split tensile strengths, showcasing the potential for these additives to enhance concrete performance.

While the addition of supplementary cementitious materials can often lead to reduced workability, this study demonstrates that with careful proportioning, the workability of slag sand concrete can be maintained at acceptable levels. This is crucial for practical applications in construction, ensuring ease of placement and compaction.

Identifying the optimum mix proportion is essential for achieving the desired concrete properties. In this study, the optimal mix included 10% dolomite powder replacement and 10% glass powder addition, resulting in the highest flexural and split tensile strengths. This information is valuable for concrete mix design in practical applications.

The use of supplementary cementitious materials like glass powder not only enhances concrete properties but also promotes sustainability by recycling waste materials. This can contribute to reducing the environmental impact of construction projects.

In summary, this study underscores the potential of incorporating glass powder and dolomite powder in slag sand concrete to enhance its strength, workability and sustainability.

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