iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** III **Month of publication:** March 2025

DOI: https://doi.org/10.22214/ijraset.2025.68115

A Study on Performance and Evaluation of Various Properties and Potential of Glass Powder as a Partial Replacement of Cement

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Abstract:** This study examines the effects of partial cement replacement with glass powder and marble powder on the mechanical properties of M30-grade concrete. Ordinary Portland Cement (OPC) 30 grade, fine and coarse aggregatesand with water were used following IS codes . Glass powder was obtained by grinding waste glass for 60–90 minutes, sieved to 80 µm, and had a specific gravity of 2.9 with a pH range of 12.25 to 15.24. Marble powder was similarly processed, with a specific gravity of 2.7 and a high calcium carbonate content. We prepareThe concrete mix design followed IS 10262:2019 and IS 456:2000, using a water-cement ratio of 0.45 and superplasticizer per IS 9103:1999. AlsoCement was partially replaced with 10–50% of glass or marble powder, and specimens were cast and cured at 27±2°C for 7 and 28 days. We perform Strength tests mainly including compressive, split tensile, and flexural strength tests etc were performed as per IS 516:2020 specifications. After conducting the test we find that while glass powder alone did not improve strength parameters, marble powder shown a considerable enhancement in compressive, split tensile, and flexural strengthsand other tests. The highest compressive strength of 45.0 N/mm² was achieved at 50% marble powder replacement as compared to 36.25 N/mm² with glass powder. Similarly, marble powder improved split tensile strength to 4.2 N/mm² and flexural strength to 6.2 N/mm², while glass powder remained constant. Writers concluded that The study also highlights the potential of marble powder as a superior supplementary material for strength enhancement and durability in concrete.

***Keywords:** Glass Powder, Marble Powder, Strength, Test, Opc, cementitious materials , sustainable etc.*

I. INTRODUCTION

Glass powder Is a fine milled material obtained from various types of glass that plays a critical role in multiple industrial and scientific applications. It is obtained by crushing, grinding, and processing glass into fine particles mainly ranging from coarse granules to micron-sized powder. The properties of glass powder are mostly influenced by its chemical composition, manufacturing process, and its application. The production process usually involves collecting and sorting raw or recycled glassfollowed by crushing and sieving to achieve the desired particle size. Depending on the application there are different types of glass, such as soda-lime, borosilicate, or specialty glasses, may be utilized to achieve specific functional properties.One of the important characteristics of glass powder is its chemical inertness that make it highly resistant to environmental degradation, acids, and alkalis. Etc. This property allows its incorporation into construction materials, coatings, and filtration systems. Additionallyglass powder exhibits excellent thermal stability, making it a preferrable in high-temperature applicationssuch as refractory materials and specialized industrial coatings. Due to its hardness and abrasion resistanceit is commonly used in polishing agents, abrasives, and composite materials. Moreover the ability of glass powder to enhance mechanical strength and durability has led to its widespread adoption in concreteand ceramic industries.In the construction industry, glass powder serves as a sustainable alternative to traditional raw materials, contributing to the development of eco-friendly concrete and cementitious composites. The incorporation of glass powder in cement reduces the reliance on natural aggregates that enhances the durability of concrete, and minimizes environmental impact. Similarly, in the polymer and plastic industriesIt purposes as a reinforcing filler by improving the mechanical properties and stability of polymer-based products. Beyond industrial applications It has gained importance in environmental and biomedical fields. In water purification systems It serves as an alternative to conventional filtration media by offering efficient removal of contaminants. Additionally, in biomedical research, the bioactive glass powder is used for tissue engineering and bone regeneration due to its biocompatibility and ability to promote cell adhesion. Its application in high-performance further demonstrates its versatility, as precision-ground glass powders are essential in the manufacture of optical lenses and laboratory equipment.

The increasing demand for sustainable and economical materials has create innovations in the processing and utilization of glass powder. With the use of advancements in recycling technologies, we can say that waste glass can be efficiently transformed into high-value glass powders that reduces landfill waste and promoting circular economy practices. The potential to include glass powder into diverse fields, including nanotechnology, green construction, and advanced material sciences, highlights its significance in modern research and industrial development. Future advancements in material engineering are needed and expected to expand the scope of glass powder applications by further enhancing its role in sustainable manufacturing and innovative product design.

A. Properties of Glass Powder

Glass powder displays a range of physical and chemical properties that make it a versatile material for various industrial applications. One of its key characteristics is its high chemical stability as it remains inactive when exposed to most acids, alkalis, and environmental factors. This makes it a better and preferred choice for applications requiring long-term durability and resistance to degradation.also, It has excellent thermal stability that allows it to withstand high temperatures without significant changes. Its hardness and abrasion resistance contribute to its extensive use in polishing, grinding, and composite materials.

The composition of glass powder differs depending on the type of glass used in its production. The primary component of most glass powders is silica (SiO_2), which provides strength and thermal resistance. Other key parameters such as sodium oxide (Na_2O) and calcium oxide (CaO) are added to impact melting behavior and durability. The inclusion of aluminum oxide improves the strength and chemical resistance of the final invention. In specialized formulations and materials , boron oxide (B_2O_3) is introduced to improve thermal shock resistanceparticularly in borosilicate glass applications. Magnesium oxide (MgO) and potassium oxide (K_2O) may be present in lesser quantities to alter the physical properties of the glass powder. The manufacturers can improve the performance of glass powder for specific applications by ensuring its effectiveness across a wide range of industries and reserch areas.

B. Composition of Glass Powder

The composition of glass powder differssuggestively based on its intended use, with different oxides combined to optimize thermal, mechanical, and optical properties. While soda-lime glass powder is the most common due to its widespread availability and recyclability also specialized glass powders such as borosilicate, lead, and aluminosilicate glass providesmany advantages for high-performance applications. By Understanding the composition of glass powder enables industries to adapt its use for construction, coatings, biomedical applications, and advanced manufacturing processes. Glass powder is primarily composed of silica (SiO_2)which provides structural integrity, hardness, and thermal stability. Based on the type of glass used, additional oxides are merged to modify its physical and chemical properties.also Sodium oxide is commonly added to lower the melting temperature and improve workability, while calcium oxide (CaO) enhances durability and chemical resistance. Aluminum oxide (Al_2O_3) contributes to high mechanical strength and resistance to wear, making the glass powder more appropriate for industrial applications.

Boron oxide (B_2O_3) is introduced to improve thermal shock resistance mainly in borosilicate glasses used for high-temperatures. Magnesium oxide (MgO) and potassium oxide (K_2O) may also be used in smaller proportions to further adjust and modify the glass physical propertiessuch as improving resistance to crystallization or altering refractive indices. Trace elements like iron oxide (Fe_2O_3) can be found in recycled or colored glass, affecting optical characteristics and coloration. The specific composition of glass powder diverges based on its intended applicationwhether in construction, coatings, filtration, or advanced material science. We also findsBy carefully adjusting the ratios of these oxides, manufacturers can familiarize the performance of glass powder to meet the unique demands of different industries.

II. METHODOLOGY

This study applied Ordinary Portland Cement (OPC) M30 grade as per IS 12269:2013with fine and coarse aggregates conforming to IS 383:2016. River sand with a fineness modulus of 2.6 and specific gravity of 2.65 was used, along with 10 mm and 20 mm crushed aggregates. We use simple Potable water meeting IS 456:2000 standards was used for mixing and curing. Glass powder was obtained by grinding waste glass for 60–90 minutes, sieved to 80 µm, with a specific gravity of 2.9 and pH values ranging from 12.25 to 15.24 for alkanitytest . Marble powder was similarly processed, with a specific gravity of 2.7 and high calcium carbonate content. The test were conducted at the local private site near Srinagar.

On the other side Concrete mix design followed IS 10262:2019 and IS 456:2000 for M30 grade concrete, with a water-cement ratio of 0.45 and superplasticizer as per IS 9103:1999. Also we have done test with glass powder only but we donot find better results interms of strength and other properties of concrete then we use marble powder additionally with glass powder in cement .

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue III Mar 2025- Available at www.ijraset.com

Cement was partially replaced with 10–50% of glass or marble powder. Specimens were cast and cured at 27±2°C for 7 and 28 days. We try to perform test to find best performance and efficiencyCompressive, split tensile, and flexural strength tests were conducted per IS 516:2020. We assume suitable data accordingly as per standards. Data is analysis for compared strength and performance by findingideal replacement levels for enhanced mechanical properties and durability .

III. RESULTAND DISCUSSION

After test we find that marble powder improves compressive strength and it is higher as compare to glass powder shown in Table no 1, glass powder remains constant.In case of Split Tensile Strength Comparison there is a steady increase in tensile strength when we use marble powder.Where asFlexural Strength indicates that marble powder enhances flexural strength, while glass powder has no significant effect.Different strength comparison is shown in Table no 1

TABLE NO 1 DIFFERENT STRENGTH COMPARISON BETWEEN GLASS POWDER AND MARBLE POWDER

Replacement (%)	Compressive Strength (N/mm^2) - Glass	Compressive Strength (N/mm^2) - Marble	Split Tensile Strength (N/mm^2) - Glass	Split Tensile Strength (N/mm^2) - Marble	Flexural Strength (N/mm^2) - Glass	Flexural Strength (N/mm^2) - Marble
10	36.25	38.5	3.25	3.4	4.87	5.1
20	36.25	40.2	3.25	3.6	4.87	5.4
30	36.25	42.1	3.25	3.8	4.87	5.7
40	36.25	43.5	3.25	4.0	4.87	6.0
50	36.25	45.0	3.25	4.2	4.87	6.2

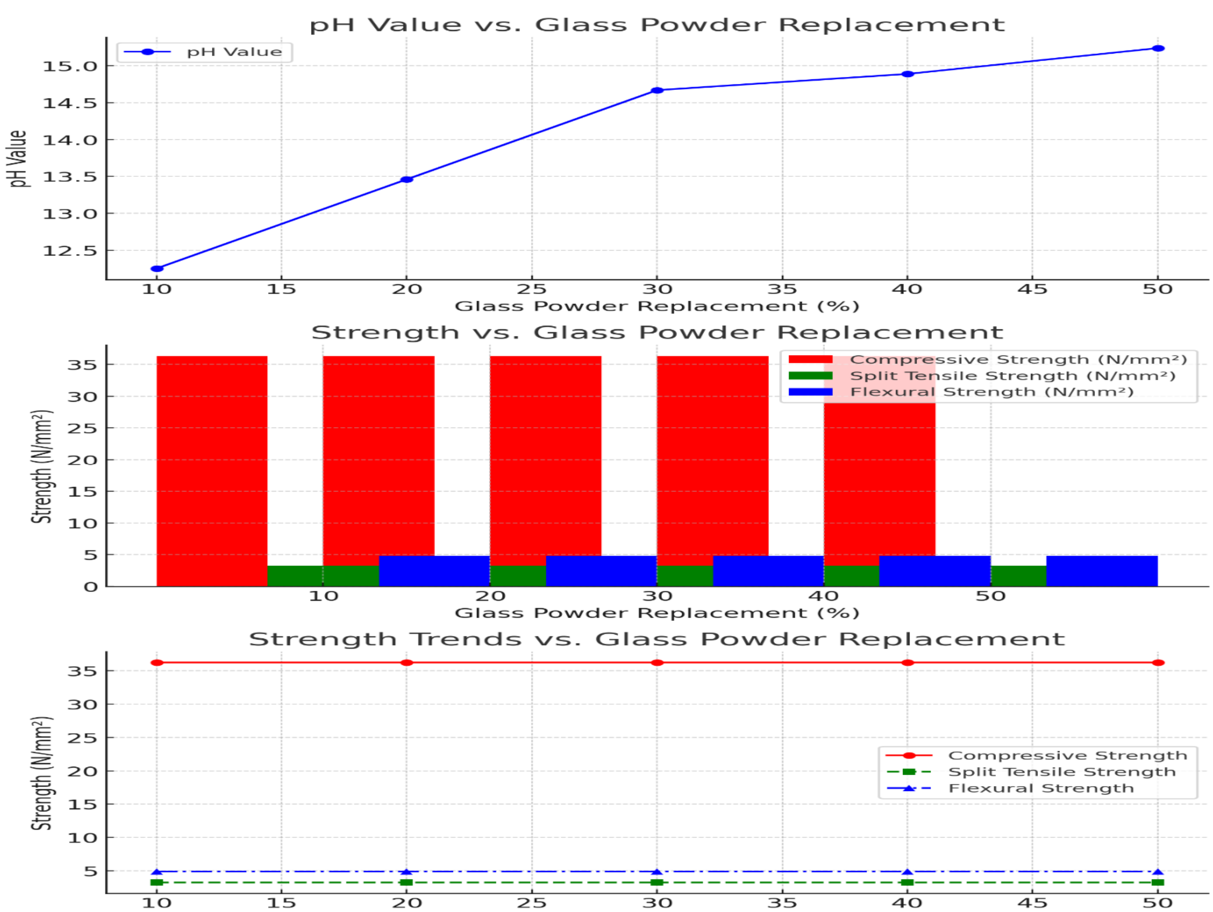

FIGURE NO 2 DIFFERENT TEST COMPARISION OF GLASS POWDER v/s STRENGTH

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue III Mar 2025- Available at www.ijraset.com

Ph valuefor 10% is 12.25. for 20% replacement is13.46. for 30% is 14.67 and for 40% is14.89 and for 50% 15.24 compressive test is 36.25 N/MM split tensile strength 3.25 Flexural Strengthis 4.87 N/mm

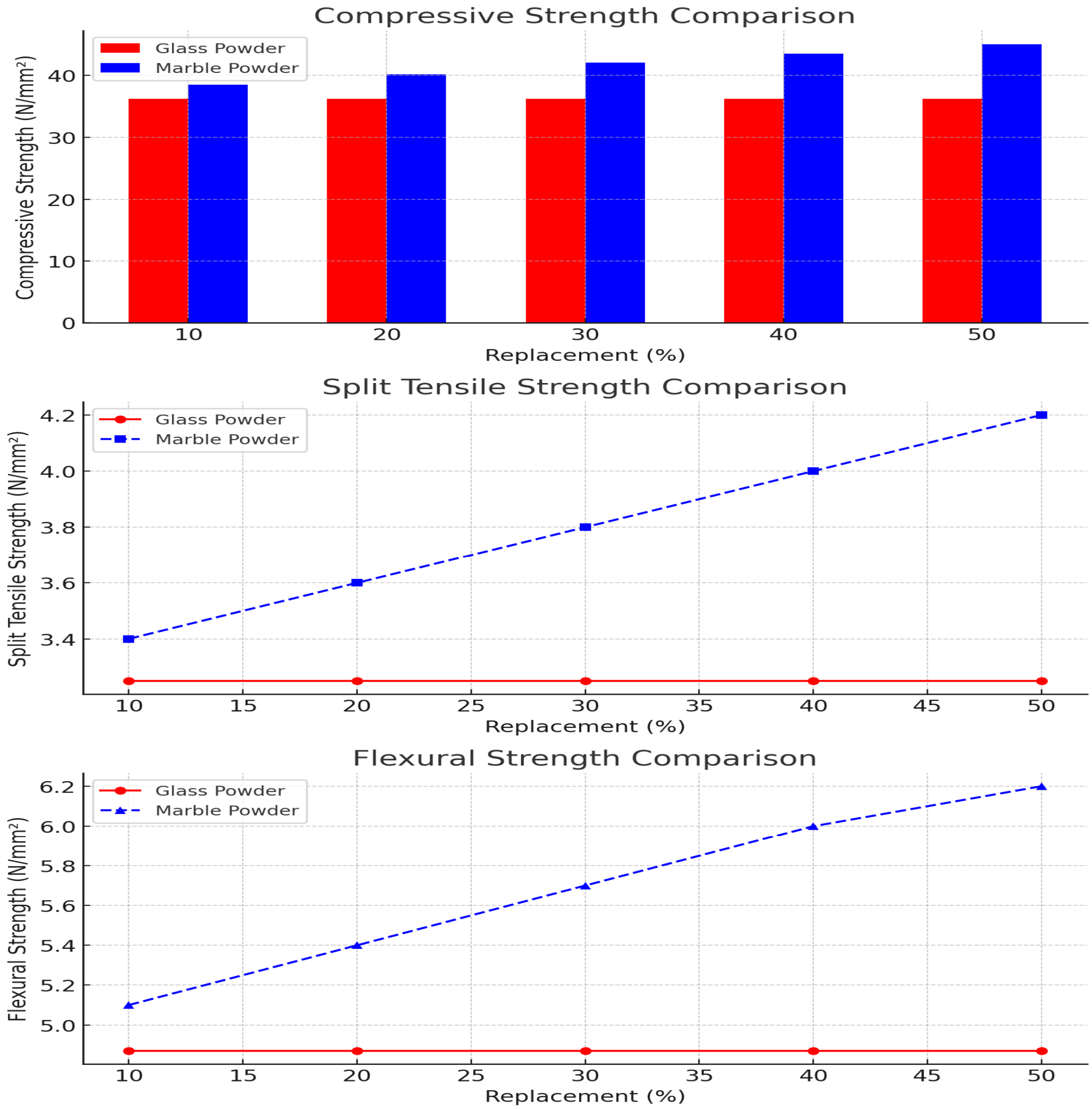

FIGURE NO 2 DIFFERENT TEST COMPARISION OF GLASS POWDER AND MARBLE POWDER

IV. CONCLUSON

After performing test we came on conclusion thatThe experimental results establish that using marble powder as a partial cement replacement significantly enhances the mechanical properties of concrete, whereas glass powder alone does not yield prominent improvements. Compressive strength tests revealed that marble powder replacement led to a steady increase in strength byreaching strength of 45.0 N/mm² at 50% replacement, whereas glass powder results remained constant at 36.25 N/mm².

Similarly, we observe split tensile and flexural strength testshas superior performance of marble powder having maximum values of 4.2 N/mm² and 6.2 N/mm²respectively. Also we observe that The pH analysis showed an increasing trend with replacement percentage by ensuring alkaline stability for concrete durability. The study concludes that marble powder serves as a practical alternative to traditional cementitious materials by promoting sustainability by reducing cement consumption and enhancing concrete performance.

Author suggests that Future research should be done it could explore the long-term durability and the combined effects of glass and marble powder in flexible proportions. This study highlights the importance of utilizing industrial waste materials to develop eco-friendly and high-performance concrete.

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