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Experimental Investigation on Strength of Concrete by Partial Replacement of Cement by Glass Powder

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ABSTRACT: The project aims to investigate the strength properties of concrete by partially replacing cement with glass powder. The study involves the use of various ratios of glass powder as a partial replacement for cement in concrete mixtures.

The experimental work involves preparing different concrete mixes containing various percentages of glass powder as a partial replacement for cement. The compressive strength, flexural strength, and split tensile strength of these concrete mixes will be tested and compared with the control mix (concrete mix without glass powder). The research will also explore the effects of using glass powder on the M20 grade. The study will evaluate the fresh properties of concrete, such as slump and compaction factor, and the hardened properties of concrete, such as water absorption and resistance to sulfate attack. The project aims to demonstrate that the partial replacement of cement with glass powder can improve the strength of concrete. Additionally, the use of glass powder as a partial replacement for cement can contribute to reducing the environmental impact of cement production, as well as reducing waste generated from glass products.

KEYWORDS: Cement Replacement, Waste Glass, Glass Powder, Compressive Strength, Split Tensile Strength, Flexure Strength

I. INTRODUCTION

Concrete is one of the most commonly used construction materials in the world. It is made by mixing cement, water, and aggregates such as sand and gravel. Cement is a primary component of concrete, but it is also one of the most environmentally damaging materials. Cement production is responsible for approximately 8% of global carbon dioxide emissions. Therefore, finding ways to reduce the amount of cement required in concrete without compromising its strength is an important step towards sustainable construction.

Glass powder is a waste material from glass manufacturing that has the potential to be used as a partial replacement for cement in concrete. Glass powder has pozzolanic properties, meaning it reacts with water and cement to form additional calcium silicate hydrates (C-S-H), which are responsible for the strength of concrete. Using glass powder in concrete not only reduces the amount of cement required but also provides a solution for the disposal of glass waste.

In this report, we will explore the strength of concrete by partial replacement of cement with glass powder. We will examine the effect of glass powder on the compressive strength, tensile strength, and flexural strength of concrete, as well as the optimal amount of glass powder to use.

II. LITERATURE REVIEW

[1] Khandaker, M. M., Hossain, M. M., Begum, R. A., & Ahsan, M. (2021). The objective of this work is to study the use of waste glass powder obtained from grinding crushed containers and building demolition to produce glass powder blended cement as concrete additives. The pozzolanic activity of the glass powder and the properties of glass powder blended cement were evaluated. Additionally, the effect of using glass powder as a cement replacement and as a cement addition was studied in terms of physical and mechanical properties. The glass powder contents considered were 0.0%, 5.0%, 10.0%, 15.0%, 20.0%, and 25.0% by weight of cement. The test results indicated that the glass powder exhibited pozzolanic characteristics and that its use had an

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insignificant effect on setting time and cement expansion. The use of 10% glass powder as a cement replacement enhanced the mortar's compressive strength by about 9.0%.

[2] Rashid, M. I., Jamaludin, S. B., & Farhana, M. N. (2021). This work focuses on comparing the effects of both green and clear glass on the properties of concrete when used as a partial replacement for cement. A significant amount of greenhouse gases are released into the atmosphere during cement manufacturing, which contributes to the greenhouse effect. Methods: Cubes, beams, and cylinders were cast to check the compressive, flexural, and split tensile strengths of concrete made by partially replacing cement with glass powder. Findings: Concrete with up to 30% green glass replacement proved that this was the optimum percentage to achieve excellent hardened properties, and at the same replacement level, green glass concrete exhibited greater strength than clear glass concrete. Improvements: This work has demonstrated that pollution caused by cement production can be reduced by partially substituting it with ground glass.

By Bhupendra Singh Shekhawat, Dr. Vanita Aggarwal. The present study investigates the effect of using waste glass powder in concrete by partially replacing cement. Laboratory work assessed the performance of both the control sample and concrete with waste glass powder. The percentage of cement replacement was 10%, 20%, and 30% in the M20 grade of concrete. The performance of these types of concrete was evaluated through workability tests and strength tests, including compressive strength, flexural strength, and split tensile tests. Concrete durability was assessed using a water absorption test and sorptivity test. The specimens were tested at 7 and 28 days to study the strength and durability parameters. The results indicate that concrete incorporating waste glass powder improved both workability and compressive strength.

[4] Kamei, T., Matsui, K., Saito, M., & Nakamura, H. (2019). Utilization of waste glass powder in concrete: A review. Procedia Structural Integrity, 18, 432-439. This review article examines the use of waste glass powder as a partial replacement for cement in concrete, discussing factors that affect its performance and potential applications in construction.

[5] Ceramic Waste: Effective Replacement of Cement for Establishing Sustainable Concrete - By Amitkumar D. Raval, Dr. Indrajit N. Patel, Prof. Jayeshkumar Pitroda. Concrete mixtures were produced, tested, and compared in terms of compressive strength to conventional concrete. These tests were conducted to evaluate the mechanical properties over 7, 14, and 28 days. As a result, compressive strength is achieved by up to 30% when replacing cement with ceramic waste. This research focuses on the experimental investigation of concrete strength and the optimal percentage for partial replacement by substituting cement with 0%, 10%, 20%, 30%, 40%, and 50% ceramic waste. The investigation aims to study concrete behavior while varying proportions of ceramic waste.

III. MATERIALS USED

A. Glass powder

Glass powder is a fine material obtained by crushing and grinding waste glass. It has various potential applications, including its use as a partial replacement for cement in concrete. When incorporated into concrete, glass powder can improve strength, durability, and other properties, while also reducing the amount of cement needed for a specific application, thus lowering the environmental impact of concrete production. Additionally, using glass powder in concrete can help decrease waste generated by the glass industry, making this approach eco-friendly and sustainable. However, careful consideration of factors such as particle size, chemical composition, and fineness of the powder, as well as the appropriate proportions for the concrete mix, is necessary. One major finding is that adding glass powder to concrete can enhance its mechanical properties, including compressive strength, flexural strength, and modulus of elasticity.

Table -1: Physical Properties Of Glass Powder

S.NO	PROPERTIES	VALUES
1.	Specific gravity	2.58
2.	3.43	3.43

B. Coarse Aggregate

In the case of M20 grade concrete, which is a commonly used grade of concrete, the proportion of coarse aggregate to be used is typically 1:1.5:3 (cement:sand:coarse aggregate) by volume. This means that for every part of cement used, 1.5 parts of sand and 3 parts of coarse aggregate are added to the mix. The size of the coarse aggregate used in M20-grade concrete is typically between 20 mm to 10 mm.

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Table -2:Physical properties of coarse aggregate

S.NO	PROPERTIES	VALUES
1.	Specific gravity	2.76
2.	Bulk density	1642.67kg/m3
3.	Water absorption	0.67%
4.	Impact value	13.8%

Table -3:Physical properties of Fine Aggregate

S.NO	PROPERTIES	VALUES
1.	Specific gravity	2.53
2.	Bulk density	1550.22kg/m3
3.	Water absorption	2.4%
4.	Fineness modulus	3.54

C. Fine Aggregate

In M20 grade concrete, the proportion of fine aggregate to be used is typically 1:1.5:3 (cement:sand:coarse aggregate) by volume. This means that for every part of cement used, 1.5 parts of sand and 3 parts of coarse aggregate are added to the mix. The size of the fine aggregate used in M20-grade concrete is typically between 4.75 mm to 0.15 mm. According to the Indian Standard Code of Practice for Concrete Mix Proportioning (IS 10262:2009), the recommended maximum size of fine aggregate for M20 grade concrete is 10 mm. The code also specifies that the fineness modulus of the fine aggregate should be between 2.3 and 3.1. The fineness modulus is a measure of the fineness of the aggregate calculated by adding the cumulative percentages of aggregate retained on each of the standard sieves and dividing the sum by 100.

D. CEMENT

Cement is a binding material used in construction that sets, hardens, and adheres to other materials to bind them together. In this present study, Ordinary Portland Cement (OPC) of grade 43 is used for all concrete mixes. The specific gravity of cement is found as 3.15 and the standard consistency was 30%. The initial setting time was found to be 30 min and the final setting time was found to be 480 min. The cement used in this study is fresh and without any lumps

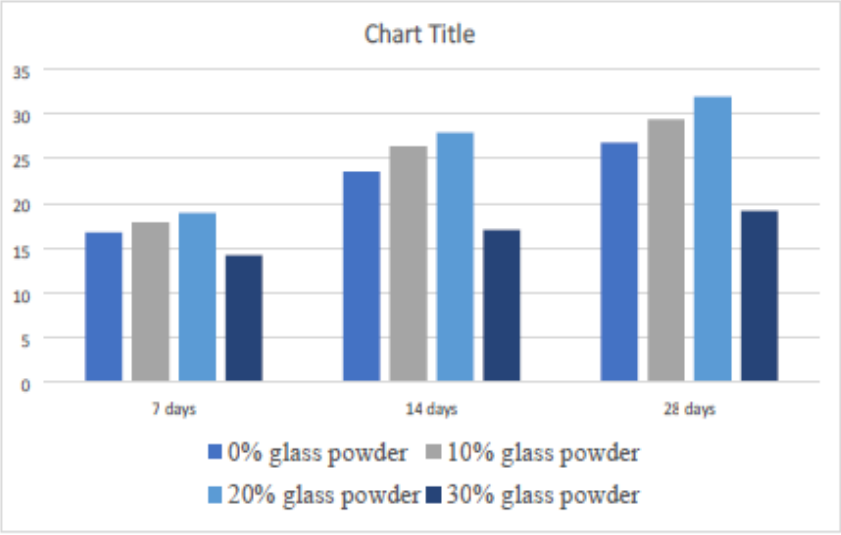
.

Table -4:Physical properties of cement

S.NO	PROPERTIES	VALUES
1.	Specific gravity	3.15
2.	Normal consistency	31%
3.	Initial setting time	45 mins
4.	Final setting time	300 minis

IV RESULT ANALYSIS AND DISCUSSION

Chart 1 -Compressive strength for concrete



A. Compressive Strength Test

To evaluate the compressive strength of each mix at a specific age, three 150x150x150 mm cube samples were tested. The strength gain at various percentages of glass powder replacement at 7,14 and 28th day. It can be seen clearly that there

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is a reduction in the strength at the 30 % replacement. Waste glass when ground to a very fine powder, SiO2 reacts chemically with alkalis in cement and formsa cementitious product that helps contribute to the strength development. When comparing the strength gain with the cement mortar strength gain it can be seen that there is an increment of strength up to 20% glass powder replacement, beyond which it decreases. The presence of excess glass powder without the necessary calcium to react forms weak pockets in the concrete that reduce the concrete strength, this happens due to an alkali-silica reaction.

Fig. 1 Testing of cube

Table -5 Compressive strength of concrete

S.No.	Sample Name	Percentages of glass powder %	Testing age in (days)		
			7 days	14days	28 days
1.	C1	0%	16.76	23.54	26.74
2.	C2	10%	17.85	26.34	29.34
3.	C3	20%	18.89	27.84	31.85
4.	C4	30%	14.23	17.02	19.14

B. SPLIT TENSILE STRENGTH TEST

Split tensile strength is another important property of concrete that measures its ability to resist tensile stresses that may be applied to it. When glass powder is added to the concrete mix, it can improve the split tensile strength of the concrete. This is because glass powder acts as a filler material, reducing the porosity of the concrete and increasing its strength and durability. To determine the split tensile strength of concrete with glass powder, cylindrical specimens are prepared with varying percentages of glass powder, cured under controlled conditions, and then tested using a compression testing machine. The load required to fracture the specimen is recorded, and the split tensile strength is calculated using a specific formula.

The results obtained from the testing can be used to determine the effectiveness of glass powder as an additive in improving the split tensile strength of the concrete. The addition of glass powder to the concrete mix can result in stronger and more durable concrete that can withstand tensile stresses and other environmental factors such as freeze-thaw cycles and chemical attacks. The split tensile strength gain at various percentages of glass powder replacement at 7,14 and 28th days. It can be seen clearly that there is a reduction in the strength after a 10 % replacement. The split tensile strength improvement is marginal as compared to the compressive strength increase.

Table -6 Split tensile strength for concrete

S.No.	Sample Name	Percentages of glass powder %	Testing age in (days)		
			7 days	14 days	28 days
1	T1	0%	1.68	2.35	2.87
2	T2	10%	1.87	2.98	3.29
3	T3	20%	1.62	2.25	2.78
4	T4	30%	1.52	2.1	2.36

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Table - 7 Flexure strength for concrete

S.No.	Sample Name	Percentages of glass powder %	Testing age in (days)		
			7 days	14 days	28 days
1	F1	0%	2.79	3.02	3.42
2	F2	10%	2.96	3.46	3.72
3	F3	20%	2.99	3.64	3.92
4	F4	30%	2.42	2.58	2.90

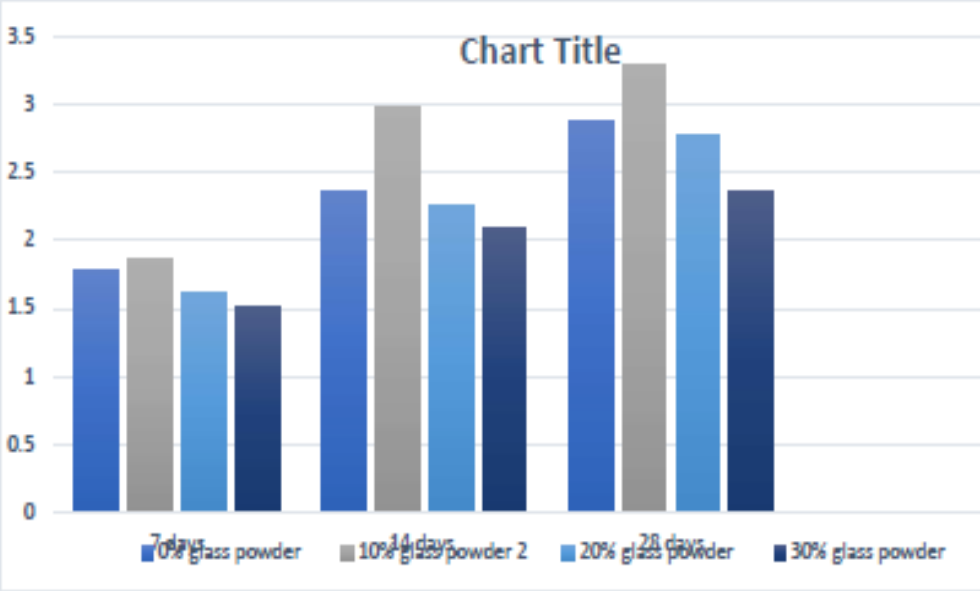

Chart 2 -Split tensile strength for concrete

C. FLEXURE STRENGTH TEST

Flexural strength, also known as bending strength, is a critical property of concrete used in structural applications such as beams and slabs. When glass powder is added to the concrete mix, it can improve the flexural strength of the concrete. This is because glass powder can act as a filler material, reducing the porosity of the concrete and increasing its strength and durability. To determine the flexural strength of concrete with glass powder, beam specimens are prepared with varying percentages of glass powder, cured under controlled conditions, and then tested using a three-point bending test. The load required to cause the beam to fail is recorded,and the flexural strength is calculated using a specific formula. The results obtained from the testing can be used to determine the effectiveness of glass powder as an additive in improving the flexural strength of the concrete. The addition of glass powder to the concrete mix can result in stronger and more durable concrete that can withstand bending stresses and other

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environmental factors such as freeze-thaw cycles and chemical attacks.

The use of glass powder as a partial replacement for cement in concrete is an eco-friendly and sustainable approach that can improve the overall performance and durability of the concrete. The flexural strength improvement at various percentages of glass powder replacement at7, the 14, and 28th day. It can be seen clearly that there is an increase in the strength up to the 20 % replacement here also. The flexural strength improves considerably at 10 % and 20% replacement which is about 8% and 10% at the age of 7 days and 12 % and 15% at the age of 28 days respectively as compared to the control specimen.

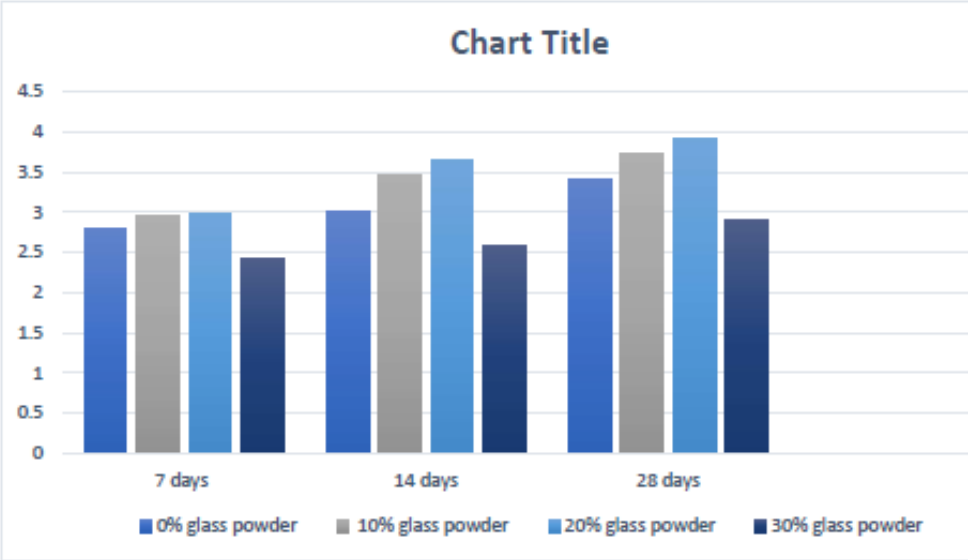

Chart-3 Flexure strength for concrete

V. CONCLUSION

The amount of incorporated waste glass significantly influenced the properties of the cement mortar. These results clearly indicate that ground glass can enhance the characteristics of the final concrete product if used at the appropriate level of replacement. The workability of the concrete mix increases with higher waste glass content. Cement can be replaced with waste glass powder up to 20% by weight, which results in increased compressive strength at 28 days; beyond this percentage, the strength begins to decrease. A 20% replacement of cement with waste glass powder demonstrated an 18% increase in compressive strength at 7 days and a 19% increase at 28 days. Flexural strength increases with waste glass powder content up to 20%, compared to the conventional mix, after which it starts to decline with further increases in WGP. The splitting tensile strength improves at a 10% replacement of cement with waste glass powder relative to the conventional mix, then diminishes as the waste glass content increases. As the waste glass content rises, the percentage of water absorption decreases, with 10% replacement being optimal. In addition, the sorptivity value decreases with increasing waste glass powder, with reductions of about 6%, 9.8%, and 19% for 10%, 20%, and 30% replacements of cement with waste glass powder, respectively, compared to the conventional mix.

The use of waste glass in concrete can be economical as it is non-useful waste and free of cost. Incorporating waste glass in concrete will address the disposal problem associated with waste glass and prove to be environmentally friendly, thus paving the way for greener concrete.

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