Experimental Investigation on Mechanical and Durability Properties of Concrete Incorporating Glass Powder as a Partial Replacement for Fine Aggregate

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***Abstract*—The use of natural sand is decreasing because it is running out and because throwing away glass creates environmental problems. So, people are looking for other materials to use in making concrete. This study looks at using waste glass powder as a substitute for sand in concrete to help make construction more sustainable. The glass powder was passed through a 600 μm sieve and used to replace natural sand at 0%, 5%, 10%, 15%, 20%, and 30% of the total weight. The concrete mixes used regular cement, natural aggregates, and clean water, without any special additives. The flow of fresh concrete was tested using the slump test, and its strength was measured through tests for compression, bending, and splitting at 7, 14, and 28 days. The results showed that adding up to 10% glass powder improved the strength of the concrete. This is probably because the glass powder fills in the tiny gaps and reacts a little with the cement, making the concrete denser and stronger. But when more than 15% of the sand is replaced, the strength goes down because the connection between the cement and the sand becomes weaker. Also, the cost analysis showed that using 10% glass powder in concrete is a bit cheaper than regular concrete, saving about Rs 84 per cubic meter based on local prices. The study suggests that using waste glass powder as a partial substitute for sand can improve the strength and reduce costs, while helping to use up waste and make concrete production greener.**

***Index Terms*—Compressive strength, Cost analysis, Fine aggregate replacement, Glass powder, Sustainable concrete, Waste glass utilization.**

I. INTRODUCTION

Concrete is one of the most widely used construction materials in the world and plays a vital role in modern infrastructure development. It is commonly used in buildings, bridges, roads, dams, and other structural applications due to its high compressive strength, durability, and cost-effectiveness. Concrete is primarily composed of cement, water, fine aggregates, and coarse aggregates. Among these materials, fine aggregate, usually natural river sand, plays an important role in improving the workability and strength of concrete.

In recent years, the demand for natural sand has increased significantly due to rapid urbanization and infrastructure development. Excessive extraction of river sand has caused several environmental problems such as riverbank erosion, ecological imbalance, and depletion of natural resources.

Therefore, there is a need to identify alternative materials that can partially replace natural sand in concrete.

Waste glass is one of the major solid wastes generated from domestic and industrial activities. Since glass is non-biodegradable, its disposal creates serious environmental issues. One possible solution to this problem is the utilization of waste glass in construction materials. When waste glass is crushed and ground into fine powder, it can be used as a partial replacement for fine aggregate in concrete.

Glass powder contains a high amount of silica and may exhibit pozzolanic properties when finely ground. The fine particles can fill the voids within the concrete matrix, leading to improved density and strength. However, excessive replacement of sand with glass powder may reduce the bonding between aggregates and cement paste, which can affect the strength of concrete.

Therefore, this study investigates the mechanical performance of concrete containing waste glass powder as a partial replacement for fine aggregate at different replacement levels.

II. OBJECTIVES OF THE STUDY

The main objective of this research is to investigate the suitability of waste glass powder as a partial replacement for fine aggregate in concrete and to evaluate its effect on the mechanical performance of concrete.

The specific objectives of the study are as follows:

1. To evaluate the feasibility of using waste glass powder as a partial replacement for natural fine aggregate in concrete.
2. To determine the optimum percentage of glass powder replacement that can be incorporated without adversely affecting the mechanical properties of concrete.
3. To study the workability characteristics of fresh concrete mixes containing different proportions of glass powder using the slump test.
4. To investigate the compressive strength behavior of concrete containing varying percentages of glass powder at curing ages of 7, 14, and 28 days.
5. To examine the flexural strength and split tensile strength of concrete mixes incorporating glass powder and compare them with conventional concrete.

III. SCOPE OF THE STUDY

This study investigates the use of waste glass powder as a partial replacement for fine aggregate in concrete. Glass powder passing through a 600 μm sieve is used to replace natural sand at proportions of 0%, 5%, 10%, 15%, 20%, and 30% by weight. Concrete mixes are prepared using ordinary Portland cement, natural coarse aggregates, and potable water without chemical admixtures.

The workability of fresh concrete is evaluated using the slump test, while mechanical properties such as compressive strength, flexural strength, and split tensile strength are determined at curing ages of 7, 14, and 28 days. The study is limited to laboratory experiments and aims to determine the optimum percentage of glass powder for concrete production.

IV. LITERATURE REVIEW

4.1 G. Srikanth and Mohd Mahboob Hussain Aiyaz (2025) conducted an experimental study on the mechanical properties of concrete using glass powder as a partial replacement for fine aggregate along with basalt and PVA fibers. The study evaluated compressive, flexural, and split tensile strength of fiber reinforced concrete. Results showed that the addition of fibers up to 0.3% improved compressive and flexural strength, while the improvement in split tensile strength was comparatively small.

4.2 Pandit Randhir Kumar et al. (2024) investigated the use of glass powder as a partial replacement for cement in different grades of concrete. Cement was replaced by glass powder at 0%, 10%, 20%, 30%, and 40%. The results indicated that concrete with 20% glass powder showed improved compressive, flexural, and split tensile strength along with increased workability.

4.3 Khobragade Pallavi R. et al. (2023) studied the strength and durability characteristics of concrete by replacing cement with glass powder in M25 and M30 grade concrete. The experimental results showed that glass powder can enhance both strength and durability properties when used at appropriate replacement levels.

4.4 Ashbin Jini V and Belfin Raj S. (2023) examined the mechanical properties of concrete incorporating glass powder and GGBS as supplementary cementitious materials. The study found that the inclusion of glass powder improved compressive, split tensile, and flexural strength of concrete up to an optimum percentage.

4.5 Chandramouli et al. (2022) carried out an experimental investigation on M25 concrete by replacing fine aggregate with glass powder at various percentages. The results showed that replacement up to 15% improved compressive and split tensile strength, while higher replacement levels slightly reduced the strength.

4.6 Vivek Farendra et al. (2022) studied the effect of glass powder as a partial replacement for fine aggregate in M40 concrete. The experimental results

indicated that glass powder influences the workability and strength properties of concrete and can be used as an alternative material in concrete production.

4.7 Tanuja G. Lakshmi and Kumar A. Ravi (2021) investigated the use of waste glass powder as a partial replacement for sand in concrete. The study highlighted that waste glass can be effectively utilized in concrete mixtures, reducing landfill waste and promoting sustainable construction practices.

4.8 Mishra Suraj P. et al. (2020) conducted an experimental study on the partial replacement of fine aggregate with glass powder in M20 concrete. The results showed that glass powder can replace natural sand up to certain percentages without significant loss in compressive strength.

4.9 Katoch Deepak et al. (2020) investigated the strength properties of concrete by replacing fine aggregate with glass powder at different levels. The study concluded that the use of glass powder improves concrete strength up to an optimum replacement percentage.

4.10 Samuel and Raju (2018) studied the combined use of waste glass powder and CNC lathe waste in concrete. The experimental results showed that the replacement of fine aggregate with glass powder along with lathe waste fibers improved compressive, split tensile, and flexural strength of concrete.

4.11 Meena et al. (2018) conducted an experimental investigation on the use of glass powder as a partial replacement for cement in M35 concrete. The study reported that glass powder improved the mechanical properties of concrete up to an optimum replacement level while also reducing cement consumption.

4.12 Summary of Literature Review

From the review of previous studies, it is observed that waste glass powder has significant potential as a sustainable material in concrete. Many researchers have investigated its use as a partial replacement for cement or fine aggregate and reported improvements in mechanical properties such as compressive strength, split tensile strength, and flexural strength up to an optimum replacement level. The use of glass powder also helps in reducing environmental problems related to waste glass disposal and excessive use of natural resources such as river sand. However, the optimum percentage of glass powder varies depending on the concrete grade and mix proportions. Therefore, further investigation is required to determine the suitable replacement level of glass powder as fine aggregate in concrete. The present study focuses on evaluating the mechanical properties of concrete by replacing fine aggregate with different percentages of glass powder to determine the optimum proportion for sustainable concrete production.

V. METHODOLOGY

A. Materials used

1) Cement: Pozzolana Portland Cement (PPC) of 43 grade was used in this study. The physical properties of cement such as initial setting time, final setting time, specific gravity, fineness, and consistency were determined as per IS 12269:1989.

2) Fine Aggregate: Locally available river sand conforming to IS 383:2016 was used as fine aggregate. The sand passed through a 4.75 mm sieve and was classified as Zone III based on sieve analysis.

3) Coarse Aggregate: Crushed coarse aggregate with a nominal size of 20 mm retained on a 4.75 mm sieve was used. The aggregate properties such as specific gravity, water absorption, and moisture content were determined through laboratory tests.

4) Glass Powder: Waste glass bottles were collected, cleaned, and crushed manually to produce glass powder of size less than 2.7 mm. The glass powder had a specific gravity of 2.5 and satisfied the graduation requirements of Zone III as per IS 383:2016.

B. Mix design

The concrete mix design for M20 grade concrete was carried out as per the guidelines of IS 10262:2019. The proportions of cement, water, fine aggregate, and coarse aggregate were calculated based on the material properties obtained from laboratory tests. The water–cement ratio adopted for the mix was 0.54 to achieve the required workability and strength.

Sr. no.	Material	Quantity
1	Cement	426 kg/m3
2	Water	232.6 kg/m3

3	Fine Aggregate	747.9 kg/m3
4	Coarse Aggregate	1046.7 kg/m3

So, the mix design ratio is 1:1.75:2.45
The water–cement ratio adopted was 0.54.

C. Quantity of Materials

Material	GP Percentage					
	0%	5%	10%	15 %	20%	30%
Cement	9.54 kg	9.54 kg	9.54 kg	9.54 kg	9.54 kg	9.54 kg
Water	5.16 L	5.16 L	5.16 L	5.16 L	5.16 L	5.16 L
Fine Aggregate	16.62 kg	15.78 kg	14.94 kg	14.1 kg	13.32 kg	11.64 kg
Coarse Aggregate	23.4 kg	23.4 kg	23.4 kg	23.4 kg	23.4 kg	23.4 kg
Glass Powder	-	0.84 kg	1. kg	2.52 kg	3.30 kg	4.98 kg

D. Test Conducted

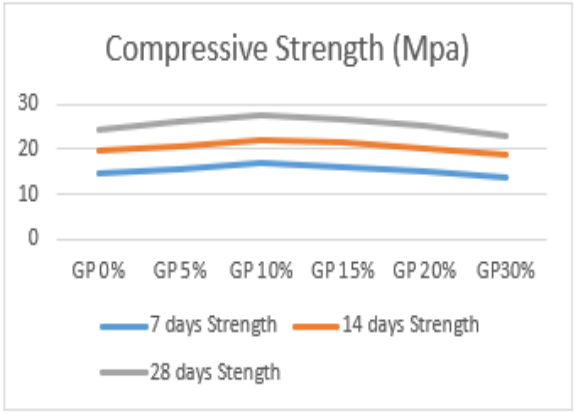
The mechanical properties of concrete were evaluated through compressive strength, flexural strength, and split tensile strength tests. The type and size of specimens used for each test are presented in Table.

Test	Specimen Type	Size
Compressive Strength Test	Cube	150 mm × 150 mm × 150 mm
Flexural Strength Test	Beam	100 mm × 100 mm × 500 mm
Split Tensile Strength Test	Cylinder	150 mm diameter × 300 mm height

VI. RESULTS AND DISCUSSIONS

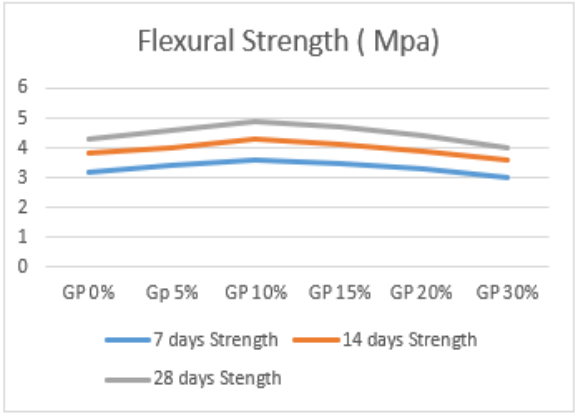
A. Compressive Strength Test

GP Replacement (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
0%	14.78	19.6	24.6
5%	15.62	20.7	26.1
10%	16.84	22.1	27.8
15%	16.21	21.4	26.9
20%	15.03	20.1	25.2
30%	13.86	18.7	23.1



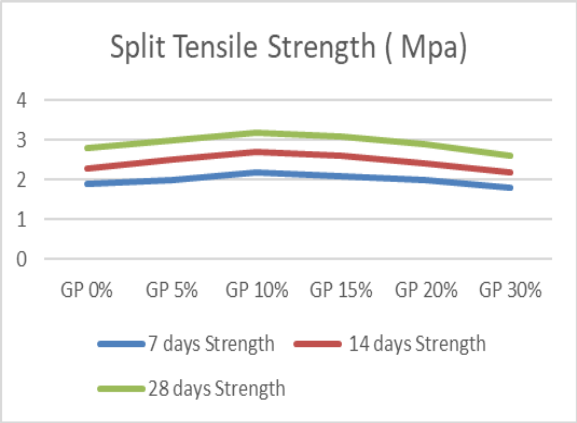
B. Flexural Strength Test

GP Replacement (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
0%	3.2	3.8	4.3
5%	3.4	4.0	4.6
10%	3.6	4.3	4.9
15%	3.5	4.1	4.7
20%	3.3	3.9	4.4
30%	3.0	3.6	4.0



C. Split Tensile Strength

GP Replacement (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
0%	1.9	2.3	2.8
5%	2.0	2.5	3.0
10%	2.2	2.7	3.2
15%	2.1	2.6	3.1
20%	2.0	2.4	2.9
30%	1.8	2.2	2.6



D. Cost Estimation

A cost comparison was carried out between conventional concrete and concrete containing 10% glass powder as partial replacement of fine aggregate. The estimation was based on the approximate material rates prevailing in Mumbai, Maharashtra, and the calculation was performed for 1 m³ of concrete to evaluate the economic feasibility of using glass powder in concrete production.

Sr. no.	Material	Conventional Concrete (₹)	Concrete with 10% GP (₹)
1	Cement	3360	3360
2	Fine Aggregate	1050	945
3	Glass Powder	-	21
4	Coarse Aggregate	2352	2352
5	Water and Miscellaneous	100	100
6	Total Cost	₹6862	₹6778

The results indicate that concrete with 10% glass powder replacement reduces the overall cost by approximately ₹84 per m³ compared to conventional concrete.

VII. CONCLUSION

The study shows that waste glass powder can be effectively used as a partial replacement for fine aggregate in concrete. The results indicate that the compressive, flexural, and split tensile strengths improved up to an optimum replacement level of about 10% glass powder, after which the strength gradually decreased. The improvement is mainly due to the filler effect and pozzolanic behavior of glass powder, which enhances the concrete matrix. In addition, the cost analysis shows that concrete with 10% glass powder is slightly more economical than conventional concrete. Therefore, the use of waste glass powder in concrete can provide both economic and environmental benefits, making it a sustainable alternative material in construction.

REFERENCES

[1] Suraj P Mishra, Kalpana D Thakur, Vicky N Gupta. Partial Replacement of Fine Aggregate by Glass Powder in Concrete: International Journal of Engineering Research & Technology (IJERT) Vol. 9 Issue 02, February-2020

[2] Dr. K. Chandramouli 1, J. Sree Naga Chaitanya 2, Dr. Sk. Bifathima 3, K. Gopi Krishna 4. An Experiment Investigation on Concrete by Partial Replacement of Fine Aggregate with Glass Powder for M25: International Journal for Multidisciplinary Research (IJFMR) E-ISSN: 2582–2160, Volume: 4, Issue: 4, July-August 2022

[3] G. Lakshmi Tanuja, A. Ravi Kumar, Experimental Study on Partial Replacement of Sand with Glass Powder as Fine aggregate in Concrete. A peer reviewed International Journal Volume 11, Issue 02, Feb 2021 ISSN: 2457-0362:

[4] Vivek Farendra, Yash Kumar Sinha, Anish Mandilwar, Divyarth Manas. Experimental Study on Partial Replacement of Fine Aggregate by Glass Powder- A peer reviewed referred journal 2022 IJCRT | Volume 10, Issue 1 January 2022 | ISSN: 2320-2882

[5] Jeba Samuel1 K. Lova Raju2. Experimental Study on Partial Replacement of Fine Aggregate by Waste Glass Powder and CNC Lathe Waste- IJSRD - International Journal for Scientific Research & Development| Vol. 6, Issue 10, 2018 | ISSN (online): 2321-0613

[6] Deepak Katoch, Sourabh Lalotra, Shivani Bhardwaj. Experimental Study on The Strength of Concrete by Partial Replacement of Fine Aggregates with Glass Powder- International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 07 Issue: 08 | Aug 2020

[7] Ashbin Jini V, Belfin Raj S. An Experimental Study of Mechanical and Durability Properties of Concrete Incorporating Glass Powder and GGBS as Supplementary Cementitious Materials- International Journal of Advanced Trends in Engineering and Management (IJATEM) pp. 36-42 ISSN (Online): 2583-7052

[8] Er. Manoj Kumar Meena1, Er. Jagriti Gupta2, Dr. Bharat Nagar3. Performance of Concrete by Using Glass Powder" An Experimental Study- International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 05 Issue: 09 | Sep 2018

[9] Randhir kumar pandit, Dr. Manish patkar Professor, Dr. Ravindra Gautm Prof Suraj Mishra Professor. A Review "Partial Replacement of Glass Powder as A Cementitious Material on Strength Properties of Different Grades of Concrete: An Experimental Investigation- Industrial Engineering Journal ISSN: 0970-2555 Volume: 53, Issue 12, No.1, December: 2024

[10] G.Srikanth, Mohd Mahboob Hussain Aiyaz. Experimental Study on Mechanical Properties of Concrete with Fibers Using Glass Powder as Replacement of Fine Aggregate with Conventional Concrete- IJCRT Volume 13, Issue 6 June 2025 | ISSN: 2320-2882

[11] Pallavi R. Khobragade, S. Kedar. S. N. Rokade Experimental Investigation on Strength and Durability Parameters of Concrete Replacing Cement by Glass Powder in Concrete with Different Dosages for M25 and M30 Concrete- March 2023| IJIRT | Volume 9 Issue 10 | ISSN: 2349-6002