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MECHANICAL STUDIES ON PARTIAL REPLACEMENT OF FINE AGGREGATE BY GLASS POWDER

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Abstract: Concrete is widely utilized in construction due to its exceptional compressive strength and its ability to be molded into various structural forms. Its primary constituents include coarse aggregate, fine aggregate, cement, and water. Despite its prominence, the concrete industry faces significant challenges, particularly in environmental and economic spheres. One solution to address these concerns involves the incorporation of waste glass as a partial substitute for fine aggregate in concrete. Various percentages of waste glass powder (5%, 10%, 15% and 20% by weight for M25 mix) will replace fine aggregates. The resulting concrete specimens will undergo testing for compressive strength and split tensile strength at 7, and 28 days, respectively. These results will then be compared with those obtained from traditional concrete mixes. Waste glass, sourced from discarded items such as shop waste, broken glass sheets, and flat solid cutting, stands to be repurposed effectively in this process, reducing environmental impact and promoting sustainability.

Index Terms **– Fine aggregate, waste Glass powder, Compressive strength, Split tensile strength.**

I. INTRODUCTION

Concrete stands as one of the most commonly utilized materials in building construction, crafted from a combination of four essential raw materials: cement, fine aggregate, coarse aggregate, and water. Upon closer examination of concrete compositions, it becomes apparent that portions of the raw materials can be substituted with recycled materials. In recent years, there has been a heightened awareness regarding environmental pollution stemming from household and industrial waste. Consequently, pollution control boards have been established to address environmental degradation caused by industrial waste. Globally, a significant quantity of waste glass is generated, with India alone accounting for 0.7% of total urban waste consisting of glass. The concrete industry ranks among the largest consumers of natural resources, posing a threat to its sustainability. To foster sustainability within the concrete industry, employing waste materials in lieu of natural resources emerges as one of the most effective strategies. The utilization of river sand as fine aggregate leads to the depletion of natural resources. By replacing fine aggregate with waste glass at specific rates and within specific size ranges, the content of fine aggregate can be reduced, thereby mitigating the adverse effects of river dredging. The volume of waste glass generated has steadily increased in recent years, with a significant portion of it being disposed of in landfill sites. Landfilling waste glass is undesirable due to its non-biodegradable nature, which adversely impacts the environment.

II. MATERIALS USED

In this experimental setup, we utilized ordinary Portland cement, potable water, glass powder, and aggregates. Glass powder and fine aggregate (river sand) conforming to Indian specifications were employed as the fine aggregate material. Concrete samples were prepared using river sand, characterized by a specific gravity of 2.65, and crushed coarse aggregates with a nominal size of 20 mm and a specific gravity of 2.82.

III. EXPERIMENTAL PROGRAM

Two different concrete compositions were evaluated.

1. Conventional concrete
2. Concrete with glass powder

In the initial phase of this investigation, preliminary testing was conducted on the materials. This involved determining the standard consistency, initial and final setting times, soundness, specific gravity, and fineness of the cement. Specific gravity, water absorption, and fineness modulus were calculated for river sand, while specific gravity, water absorption, and fineness modulus were determined for the coarse aggregate.

In the second part of the experiment, the characteristics of hardened concrete were examined using different proportions of Glass fine (0%, 5%, 10%, 15%, 20%, and 25%) for M25 grade concrete. The workability of concrete was assessed using the slump test. Concrete samples were cast in 150×150×150mm cube molds, and properties such as compressive strength were measured after 7 and 28 days of curing. The strength properties of concrete with varying percentages of sand replaced by glass powder were compared to those of normal concrete (NC).

Table 1: Mix proportions

Item	W/c ratio	Cement kg/m^3	Glass powder kg/m^3	Water kg/m^3	Sand kg/m^3	Gravel kg/m^3	Slump cms	Air %
Normal concrete	0.40	380.32	0	191.57	871.26	1099.91	8.5	2.5
Concrete with glass powder	0.40	348.32	130.68	191.57	740.57	1099.91	6.3	0.25

IV. Methodology

To assess the strength properties of each mixture, a compression test was conducted on a concrete cube measuring 150x150x150 mm. The test was carried out using a testing machine with a 1000 KN capacity, following Indian standards. Compressive strength of the concrete was measured at both 7 and 28 days.

For evaluating the strengths of each mixture, a concrete cylinder measuring 150x300 mm was subjected to a tensile test. The test was performed using testing equipment with a 1000 KN capacity, in accordance with Indian standards. The ability of the concrete to resist splitting was examined after both 7 and 28 days.

Selection and Procurement of Materials:

V. Results

5.1 Compressive Strength

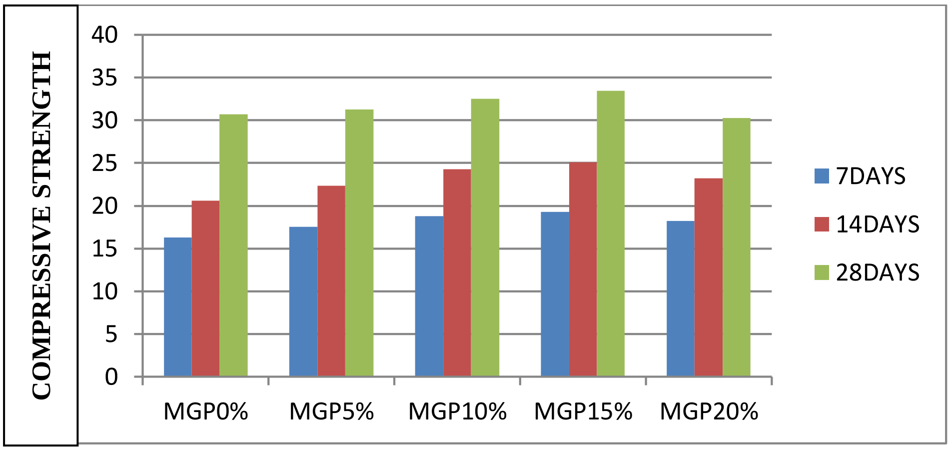
The observations from the compression strength test of cubes are presented in the following table (Table 2). Cubes were cast with varying percentages of demolished waste (0%, 5%, 10%,15% and 20%) as fine aggregate replacements for the M25 mix (1:1:2 ratios). These specimens were then tested after 7, 14, and 28 days of curing to facilitate a comparative analysis. Three concrete cubes, each measuring 150 mm in size and prepared with the specified M25 mix ratio, were prepared for testing. For each mix ratio, three cubes were cast with waste replacement, along with one cube containing normal aggregates, amounting to a total of four cubes for each mix ratio.

The compressive strength test results, depicted in Figure 1, indicate that the presence of glass waste powder influences the compressive strength of concrete. As the percentage of glass waste powder replacement in concrete increases, there is a nominal increase in compressive strength values. The highest compressive strengths, as recorded in Table 2, were observed when concrete contained a 15% replacement of glass waste powder. However, beyond this optimal point of replacement, a steady decline in strength was observed.

Table 2: Compression test results

Designation of mix	Compressive strength [N/mm^2]		
	7 Days	14 Days	28 Days
MGP0	16.28	20.61	30.72
MGP5	17.56	22.36	31.24
MGP10	18.82	24.28	32.52
MGP15	19.32	25.12	33.45
MGP20	18.23	23.25	30.28

Figure 1 Compressive strength values of glass waste powder fine aggregate concrete for 7,14 and 28 days



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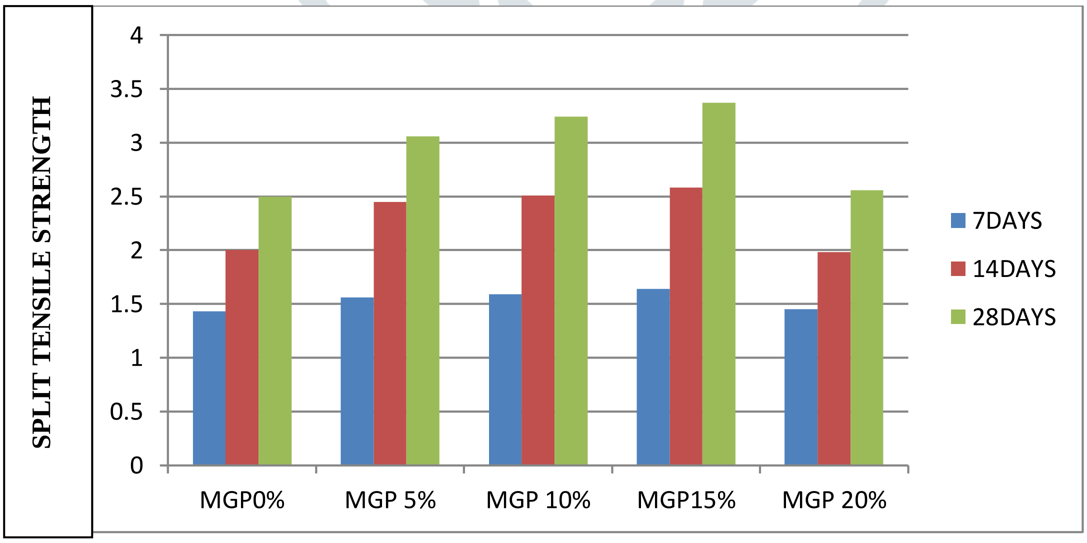
5.2 Split tensile strength

The experiment utilized the identical CTM setup to assess the tensile strength of concrete samples. Cylindrical specimens, measuring 150 mm in diameter and 300 mm in length, were employed for the split tensile test. These samples underwent testing immediately after being removed from water on the 7th, 14th, and 28th days. It was noted that once the glass waste powder replacement exceeded 15%, there was a decline in strength. Table 3 illustrates the split tensile strength comparison between glass waste powder and standard concrete samples, while Fig. 2 provides a visual representation. The split tensile strength consistently decreases with higher percentages of glass waste powder replacement, reaching its peak at the 15% replacement level.

Table 3: Split tensile strength test results

Designation of mix	Split tensile strength		
	7 days(mpa)	**14 days(mpa)**	**28 days(mpa)**
MGP0%	1.43	2	2.5
MGP 5%	1.56	2.45	3.06
MGP 10%	1.59	2.51	3.24
MGP15%	1.64	2.58	3.37
MGP 20%	1.45	1.98	2.56

Figure 2 Split tensile strength values of glass waste powder fine aggregate concrete for 7,14 and 28 days



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VI. Conclusions

Based on the experimental investigation into the incorporation of glass waste powder in concrete as a substitute for fine aggregate yielded the following conclusions:

1. The compressive strength, & splitting tensile strength of concrete increased by up to 15% when glass waste powder replaced fine aggregate in nominal mix concrete.

2. The use of glass waste powder in concrete offers additional environmental and technical advantages across related industries.
3. Substituting glass waste powder for fine aggregate partially reduces the cost of concrete production.
4. A marginal decrease in strength was observed at all levels of glass waste powder replacement with fine aggregate.
5. Optimal results are achieved when glass waste powder replaces fine aggregate by 15%.
6. Up to 15% of natural fine aggregates can be saved through this substitution with glass waste powder as a fine aggregate.

VII. References

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