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Experimental investigation on Partial Replacement of sand with Waste glass powder and waste Plastic in Concrete

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ABSTRACT

The excessive extraction of natural sand for concrete has resulted in environmental degradation, while the disposal of waste glass and plastic has created serious pollution issues. The potential use of waste glass powder and shredded plastic in place of fine aggregates in the production of concrete has been evaluated in this study. Concrete mixtures were prepared with 0%, 5%, 10% or 15%replacement by these products, and compressive and flexural strengths will be evaluated at 7, 14 and 28 day intervals after casting. The results showed that strength increased with replacement up to ten percent and decreased beyond that level. The maximum compressive strength at 28 days was 28.94 N/mm2 compared to 25.71 N/mm2 for conventional concrete. The flexural strength also reached a maximum value of 3.36 N/mm2 at 10% replacement. Higher replacement levels resulted in reduced strength due to weaker bonding and increased voids. The study concludes that partial replacement up to ten percent is effective and supports sustainable construction.

1. INTRODUCTION

Concrete is widely used in construction due to its versatility and strength. The manufacture of concrete, however, used a significant amount of natural sand as a fine aggregate. Rapid urbanization and building development have contributed to this accelerated extraction of natural sand and subsequently created several environmental impacts such as the depletion of riverbeds and a destruction of ecosystems. Likewise, these issues have resulted from an ever-increasing accumulation of waste glass and plastic created by pollution and disposal. Waste glass powder, which has a high silica content and pozzolanic properties, can be used as a partial replacement of natural aggregates to improve the compressive strength and durability of concrete. Waste plastics, which do not react chemically, can enhance some of the physical properties of concrete while helping to minimize the amount of environmental waste created due to the dispositional problems associated with waste plastics. Several reports are available documenting the individual effects of waste glass powder and plastic on concrete; however, very few investigations exist that have evaluated the effects of combining both materials together to replace a portion of the natural sand fine aggregate used in the production of concrete. This study will evaluate the combined effect of replacing a portion of the sand used in concrete with waste glass powder and shredded plastic on the mechanical properties of the resulting concrete. Concrete mixes will be produced at a range of replacement ratios and tested for compressive strength and flexural strength after curing for determined amounts of time to help determine the optimum replacement ratio.

2. EXPERIMENTAL INVESTIGATIONS

Concrete specimens were prepared to evaluate the effect of partial replacement of fine aggregate using waste glass powder and shredded plastic. The experimental program included preparation of control mix and modified concrete mixes with different replacement levels.

A. *Material Used*

Cement: Water and Aggregates: Concrete was prepared using the conventional mix of cement, aggregates and water. For the whole study, Ordinary Portland Cement grade 53, following IS 12269:1987, was used as the binder. The fine aggregate was natural river sand with particles passing through the 4.75 mm sieve and falling under the Zone II grading according to IS 383:2016. As coarse aggregate, crushed angular stone was chosen, conforming to IS 383:2016 with a nominal maximum size of 20 mm (passing the 20 mm sieve and retained on the 4.75 mm sieve). The physical properties of fine and coarse aggregate were determined in line with IS 2386 (Part I_ IV):1963. Mixing and curing of concrete specimens was performed using potable water that meets the requirements stipulated in IS 456:2000.

Glass powder: Waste glass in this study was collected from local sources. The collected glass was pulverized to a fine powder after ensuring it was cleansed of impurities. To ensure uniformity in the particle size, the fine glass powder was sieved using a 75 micron sieve. This material has a high percentage of silica and has pozzolanic properties contributing to strength improvement in concrete.

Table 1: Physical Properties of Glass powder

S.No	Physical properties of Glass powder	
1	Specific Gravity	2.52
2	Particle size	75µm

Table 2: Chemical properties of Glass Powder

S.No	Chemical properties of Glass Powder	
1	pH	10.25
2	Color	Grayish White

Waste plastic: Waste plastic used in this study was collected from locally available packaging materials. The plastic was cleaned and shredded into small pieces of size approximately 2 to 4 mm. Low density polyethylene was used as partial replacement material. The plastic did not participate in chemical reactions but improved certain physical properties of concrete.

Figure 3: Plastic Waste fiber

Table 4: Physical properties Of Waste Plastic

S. No	Physical Property	Value
1	Specific gravity	0.91
2	Particle size	2–4 mm
3	Type	LDPE

B. *Mixed proportion and Testing of specimen*

Mixed design: The mix design for concrete was carried out as per IS 10262 guidelines for M25 grade concrete. The materials used include Ordinary Portland Cement, natural sand as fine aggregate, and crushed stone as coarse aggregate. In this study, fine aggregate was partially replaced with waste glass powder and shredded plastic at different percentages. The replacement levels were selected to evaluate the effect of waste materials on the strength properties of concrete. A control mix was prepared without any replacement, and modified mixes were prepared with varying percentages of glass powder and plastic. The mix design was kept constant for all mixes except for the replacement of fine aggregate. No chemical admixture was used in the present study.

Workability Test: The workability of the fresh concrete was checked using the slump test with a slump cone as specified in IS 1199:1959. The result of the test is used to show the ease with which the concrete will be handled and its consistency. Each of the mixtures with different proportions of waste glass powder/waste plastic was tested. From the results of the test, it was seen that there was a decrease in the slump test values with an increase in the percentage of glass powder/waste plastic used in the mix as shown in fig 1 and 2. The decrease in workability is because of the increase in water content due to the finer powder of glass, as well as the decrease in cohesion between the other particles in the mixture owing to the presence of plastic. But all the mixtures were found to have a true slump, indicating that they have good workability.

Figure 5: Slump of Conventional Concrete

Figure 6: Slump of Replacement Concrete

Table 7: Slump Test Results of Concrete with Different Replacement Levels

Mix (%)	Slump Value (mm)	Type of Slump
0%	75	True slump
5%	70	True slump
10%	65	True slump
15%	60	True slump

Compressive Strength: Compressive strength tests were conducted on cube specimens as per IS 516:1959 as shown in fig 4 and 5. The specimens were tested at 7, 14, and 28 days using a compression testing machine. The average compressive strength values were calculated for each mix. The compressive strength of concrete increased with increase in replacement level up to 10 percent and decreased beyond that, as shown in Table 4. The maximum strength was obtained at 10 percent replacement for all curing periods. This is due to the pozzolanic action of glass powder, which improves bonding and densifies the concrete matrix. At higher replacement levels, the strength decreases due to poor bonding between plastic and cement paste and increased voids in the concrete. The results indicate that 10 percent replacement is the optimum level for achieving maximum compressive.

Figure 7: Concrete Cube under Load

Figure 8: Compression testing machine With Control panel

Table 9: Compressive Strength Results Of Concrete

Mix (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
0%	17.37	21.50	25.71
5%	18.20	22.80	27.20
10%	19.63	24.50	28.94
15%	18.10	23.10	27.00

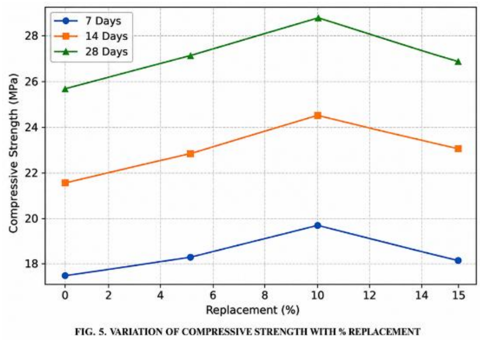

Figure 10: Variation of Compressive Strength with % Replacement

Flexural Strength: The flexural strength was determined from test beams subjected to two point loading as per the code IS 516:1959. The specimens were tested on 7th, 14th, and 28th days, and the average value was determined for all three days. From the table 5, it is observed that the flexural strength increases as the percentage of replacement increases up to 10 percent; however, above 10 percent replacement, it starts decreasing. The highest flexural strength was achieved when the percentage of replacement is 10 percent. The

Reason for the increase in flexural strength with the replacement is the increased particle packing and bond strength due to glass powder.

Table 11: Flexural Strength Results of Concrete

Mix (%)	7Days (MPa)	14 days (MPa)	28 days (MPa)
0%	2.03	2.66	3.13
5%	2.09	2.73	3.21
10%	2.18	2.86	3.36
15%	2.11	2.76	3.25

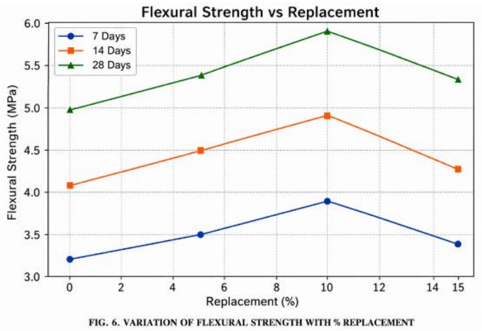

Figure 12: Variation Of Flexural Strength With % replacement

CONCLUSION

From the experimental analysis done concerning the partial replacement of fine aggregates using glass powder and plastic, the following conclusions can be drawn:

1. The workability reduced as the percentage of replacement increased, but all the mixes were true slump meaning acceptable workability.
2. Compressive strength improved as the percentage of replacement increased up to 10% after which it started decreasing. The highest compressive strength recorded was 28.94MPa at 10% replacement.
3. Flexural strength was observed to follow a similar trend and also attained its peak at 10 percent of replacement recording the highest flexural strength of 3.36 MPa.
4. Increased strength in concrete is associated with the presence of glass particles whose pozzolanic effect enhances the strength. The reduced strength at high percentages is because of weak bonding among plastic particles hence creating a porous structure.
5. Consequently, partial replacement of sand using plastic and glass powder is possible and will greatly contribute towards sustainability in construction.
6. The optimal percentage of replacement was determined to be 10 percent.

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