"The Potential of Recycled Waste Glass Sand as a Partial Replacement for Fine Aggregates in Concrete"

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Abstract – *This paper primarily aims to study the performance of recycled waste glass sand as a partial replacement for fine aggregate in concrete. Fine aggregates are replaced by recycled waste glass sand at varying fractions to check the compressive strength and workability. Replaced mixes are compared with the conventional mix in terms of workability and compressive strength to evaluate the effectiveness. The workability was determined by a slump test on fresh concrete with all the above waste glass sand fractions. Compressive strength at 7-days and 28-days curing was determined for all concrete mixtures. The obtained results were analyzed and compared with that of the conventional concrete mix of M25 grade. From the above analysis, mixing with 50% waste glass sand is considered optimal in terms of compressive strength. Hence this study verifies the potential of recycled waste glass sand as a construction material and thereby leading to a sustainable construction process.*

***Key Words:* Recycled waste glass sand, concrete, fine aggregate, compressive strength**

1.INTRODUCTION

Concrete is dominant in modern construction procedures due to its versatility, durability and strength. It serves as a foundational material for various structures including buildings, bridges, and infrastructure. Fine aggregates, being an important component of concrete, are mainly natural sand extracted from riverbeds. Since these natural resources are getting depleted day by day due to increased constructional activities, the industry is dealing with a dual challenge of balancing sustainability as well as infrastructural development.

The disposal of glass is a major environmental issue since it is a non-biodegradable material. Around the world, among 200 million tons of solid waste, 7% is contributed by glass. So, to promote a sustainable construction process, natural sand can be replaced by waste glass sand. Utilizing waste glass in concrete not only addresses environmental concerns by recycling glass but can also check its potential to enhance the performance of concrete. This approach reduces the demand for natural sand, mitigating the impact on riverbeds and ecosystems.

By appropriate addition of different fractions of glass sand, the variation in the properties of concrete can be studied in terms of its compressive strength and workability.

This study entails the performance analysis of concrete containing varying amounts of waste glass sand as a partial replacement for fine aggregates and thereby confirming its potential as an efficient construction material.

1.1. Aim

To study the performance of utilizing recycled waste glass sand as a partial replacement for fine aggregates in concrete.

1.2. Scope

- Study is limited to low grade concrete

2. METHODOLOGY

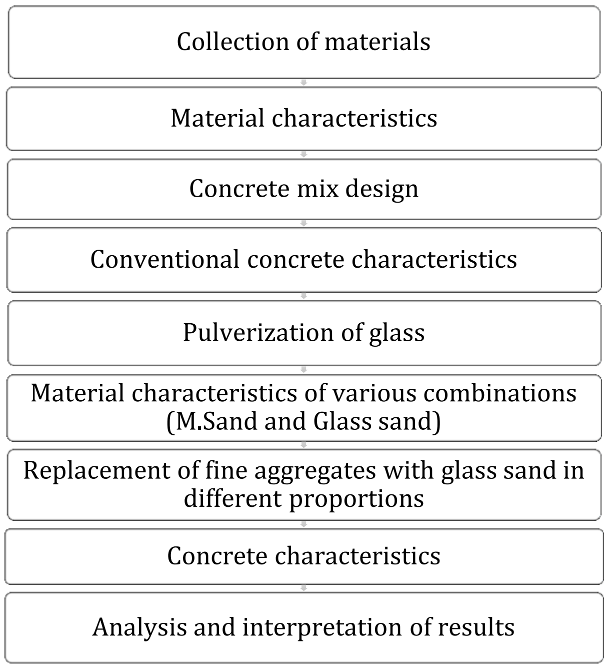

Figure 1-Steps involved in the project

3. MATERIALS AND PROPERTIES

3.1. Materials

3.1.1. Cement

Ultratech Portland Pozzolana Cement (PPC) is being used in the present investigation. The cement was tested for various physical properties according to relevant Indian Standards.

3.1.2 Coarse and fine aggregates

The aggregates used in this study were sourced from Indian suppliers. The coarse aggregate had a nominal maximum aggregate size of 20 mm and fine aggregate used was M. Sand.

3.1.3 Conplast SP430

Conplast SP430 is a chloride free, super-plasticizing admixture based on selected sulphonated naphthalene polymers. It is supplied as a brown solution which instantly disperses in water. Conplast SP430 significantly improves the workability of site and precast concrete without increasing water demand.

3.1.4 Glass sand

Figure 2-Glass sand

Glass sand was manufactured by manually crushing the collected waste glass bottles followed by pulverization by means of a pulverizing machine.

3.2. Properties

3.2.1. Specific gravity

Table 1-Specific gravity of materials

Material	Specific gravity
Cement	2.75
Coarse aggregate	2.77
Fine aggregate (M. Sand)	2.70
Glass sand	2.53

3.2.2. Sieve analysis

Table 2-Sieve analysis of coarse aggregate(20mm)

IS Sieve(mm)	Percentage passing
40	100
20	95.3
10	39.3
4.75	0.8

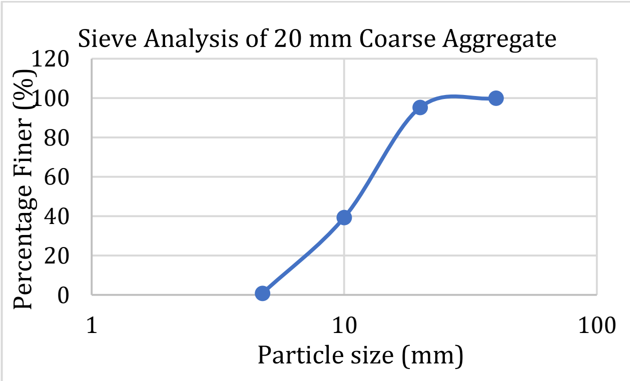

Figure 3-Particle size distribution of coarse aggregate (20mm)

Table 3-Sieve analysis of coarse aggregate(12mm)

IS Sieve(mm)	Percentage passing
16	100
12.5	90.7
10	42.7
4.75	0.5

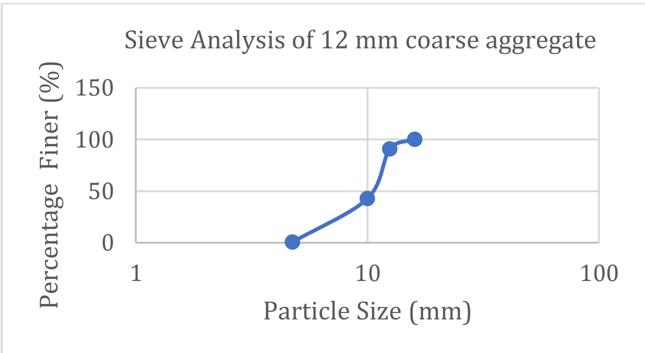

Figure 4-Particle size distribution of coarse aggregate (12mm)

Table 4- Sieve analysis of fine aggregate (M. Sand)

IS Sieve(mm)	Percentage passing
10	100
4.75	100
2.36	99.8
1.18	76.2
0.6	40.2
0.3	18.6
0.15	10

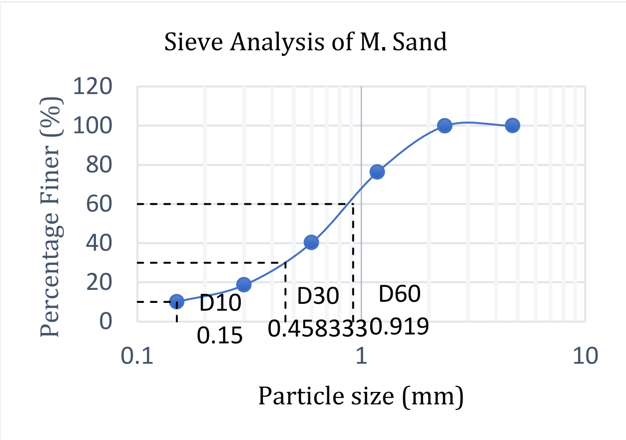

Figure 5-Particle size distribution of fine aggregate (M. Sand)

Table 5- Sieve analysis of glass sand

IS Sieve(mm)	Percentage passing
10	100
4.75	100
2.36	80
1.18	60
0.6	46.4
0.3	26
0.15	8

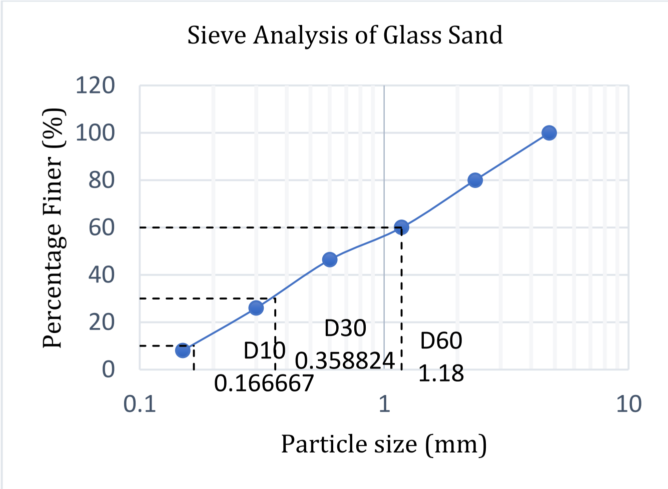

Figure 6-Particle size distribution of glass sand

4. MIX DESIGN

Concrete mix designs adopted throughout this study were undertaken in accordance with the procedure specified in Indian standards. All mixes were proportioned to achieve a design compressive strength of 31.6 MPa after 28 days. The type of cement used in this experiment is Ultratech Portland Pozzolana Cement (PPC). As per our mix design calculation the ratio of M25 grade of cement concrete for 0.4 w/c ratio is 1:1.98:3.05. A control mix was produced containing only natural aggregate, with five resulting mixes incorporating recycled waste glass sand as a partial replacement for fine aggregates in proportions of 20%,30%, 40%,50% and 60%.

Table 6-Concrete mix design for water cement ratio 0.4

Materials	Quantity
Water	152 L
Cement	380 kg
Fine aggregate (M. Sand)	753.92 kg/m³
Coarse aggregate	1160.19 kg/m³
20mm Coarse aggregate (60%)	696.114 kg/m³
12mm Coarse aggregate (40%)	464.076 kg/m³
Admixture Conplast SP430	1.93 L

The quantity of recycled waste glass sand and fine aggregate (M.Sand) used in each % of replacement are given by,

% of replacement	Recycled waste glass sand (kg/m^3)	Fine aggregate (M. Sand) (kg/m^3)
0%	-	753.92
20%	150.784	603.136
30%	226.176	527.744
40%	301.568	452.352
50%	376.96	376.96
60%	452.352	301.568

5. RESULTS AND DISCUSSION

The cement concrete cube of size 150mm×150mm×150mm were casted. These specimens are subjected to workability test on fresh concrete and compression test after 7 and 28 days of curing. Henceforth, the results are tabulated accordingly.

5.1. Workability test

Table 7-Slump obtained for various samples

Samples	Slump value(mm)
Conventional mix	105
M.Sand (80%) & Glass sand (20%)	99
M.Sand (70%) & Glass sand (30%)	91
M.Sand (60%) & Glass sand (40%)	88
M.Sand (50%) & Glass sand (50%)	85
M.Sand (40%) & Glass sand (60%)	80

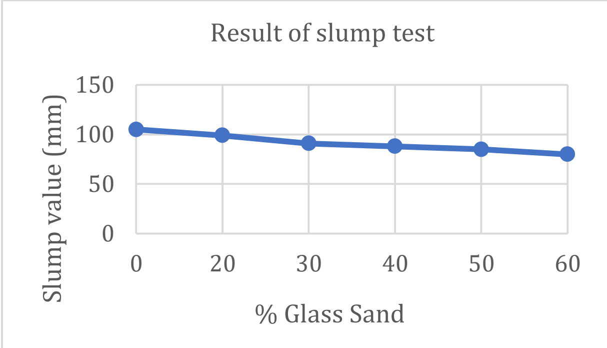

Figure 7-Slump value

5.2. Compressive strength test

Table 8-Average Compressive Strength

Samples	Average 7-day Compressive Strength (MPa)	Average 28-day Compressive Strength (MPa)
Conventional mix	20.92	33.14
M.Sand (80%) & Glass sand (20%)	21.44	34.44
M.Sand (70%) & Glass sand (30%)	22.02	38.37
M.Sand (60%) & Glass sand (40%)	22.67	39.89
M.Sand (50%) & Glass sand (50%)	23.11	40.33
M.Sand (40%) & Glass sand (60%)	21.80	37.78

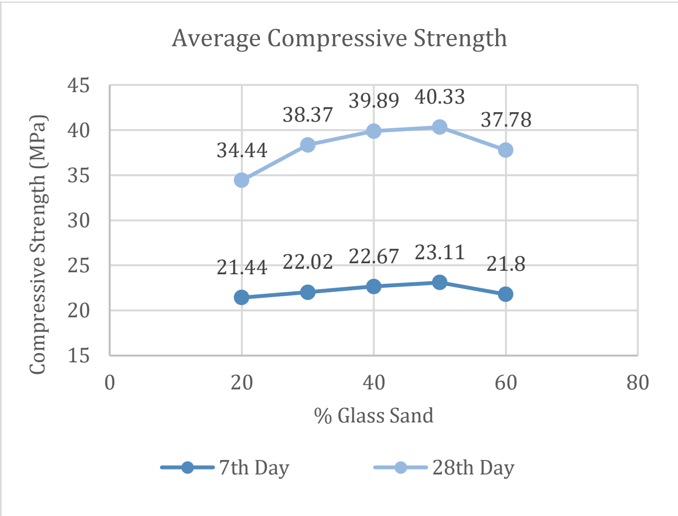

Figure 8-Average Compressive Strength

5.3. Cost Estimation

Table 9-Production cost of various samples

Samples	Production Cost (₹)
Conventional mix	6069
M.Sand (80%) & Glass sand (20%)	5905.60
M.Sand (70%) & Glass sand (30%)	5823.90
M.Sand (60%) & Glass sand (40%)	5742.20
M.Sand (50%) & Glass sand (50%)	5660.50
M.Sand (40%) & Glass sand (60%)	5562.46

6. CONCLUSIONS

Based on results obtained, following conclusions can be drawn:

- With increasing proportion of waste glass powder in the concrete mix the workability of the fresh concrete decreases, due to the angular nature of the glass particles.
- 50% replacement has obtained the maximum compressive strength in 28 days which is 21.70% greater than that of the conventional mix.
- The increase in compressive strength is due to the pozzolanic reaction.
- Beyond 50% the amount of calcium hydroxide available for pozzolanic reaction decreases resulting in a decrease in compressive strength.
- From the cost estimation it is evident that compared to conventional mix there is a decrease in the production cost of replacement mixes. Thus making it a cost effective approach.

From this study it is concluded that by incorporating waste glass sand in proportions of 30%, 40% and 50% in M25 concrete, a compressive strength greater than the target compressive strength required for M30 concrete is obtained. Thus, if required the cement content used for casting M25 concrete can be reduced without affecting its target compressive strength and can scale down the carbon footprint. The replacement mixes can be used for the construction of temporary shelters, thereby reducing the wastage of non-renewable resources. Hence the use of waste glass in concrete will preserve natural resources such as river sand, granite and limestone leading to sustainable construction.

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