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Effect of Recycled Glass Powder as Fine Aggregate on the Mechanical Properties of Concrete

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Abstract— **Concrete industry is one of the largest consumers of natural resources due to which sustainability of concrete industry is under threat. For the purpose of promoting increased sustainability and to add value to wastes, recycled waste glass was used to replace natural sand in concrete. This project examines the effect of replacement of fine aggregates with recycled glass on the mechanical properties of Portland cement concrete. Fine aggregates were replaced by waste glass powder as 0%, 20%, 40%, 60%, 80% and 100% by weight for M20 mix. Compressive strength, tensile strength and modulus of elasticity at 28 days of age were compared with those of concrete made with natural fine aggregates. Glass is used in many forms in day-to-day life. It has limited life span and after use it is either stock piled or sent to landfills. Since glass is non-biodegradable, landfills do not provide an environment friendly solution. In this paper, the issues of environmental and economic concern are addressed by the use of waste glass as partial replacement of fine aggregates in concrete. Using glass powder in concrete is an interesting possibility for economy on waste disposal sites and conservation of natural resources.**

Keywords— Concrete; recycled glass powder; mechanical properties; glass concrete

I. INTRODUCTION

Concrete is a mix of cement, sand, coarse aggregate and water. The fine aggregate for making concrete is the natural sand mined from the riverbeds. As the availability of river sand is becoming scarce due to the excessive nonscientific methods of mining from the riverbeds, lowering of water table, sinking of the bridge piers, etc., researches into innovative uses of waste materials are continuously advancing. These research efforts try to match society's need for safe and economic disposal of waste materials. The non-decaying waste materials cause a waste disposal crisis, thereby contributing to the environmental problems. The problem of waste accumulation exists worldwide, specifically in the densely populated areas. Most of these materials are left as stockpiles, landfill material or illegally dumped in selected areas. The use of recycled aggregates saves natural resources and dumping spaces and helps to maintain a clean environment. Among the various waste materials, glass is considered to be a good substitute for natural sand due to its similarities in physical properties and chemical compositions. This study outlines the use of such recycled glass powder as fine aggregate replacement and details workability and strength development of concrete containing glass as partial replacement of traditional materials. For that brown-colored, soda-lime glass beer bottles were collected from a local waste recycler. The bottles were soaked in tap water for one day to remove residua and manually cleaned and washed. After that, they were air dried and crushed using a road roller. Then required number of specimens was casted and test was conducted in fresh and hardened states for each replacement ratios as 0, 20, 40, 60, 80, and 100%.

A. Objective

- Identify the effects of adding waste glass on the properties of fresh concrete mixes such as workability by slump measures.
- To check the effectiveness of fine aggregate replacement by recycled glass powder in concrete.
- Study the influence of waste glass on properties of hardened concrete mixes such as: strength, modulus of elasticity and splitting resistance.
- To evaluate the recyclability of powdered waste glass as partial replacement of fine aggregate in the concrete.
- To develop a low-cost and environment suitable building materials from industrial wastes.

B. Scope

- It reduces the amount of waste glass to be disposed.
- It is a remedy to the increasing impact of sand dredging on the ecological environment.
- Reduces waste disposal crisis.

II. MATERIAL DESCRIPTION

Concrete mix is comprised of coarse aggregates, fine aggregates (usually sand), cement and water. 43 grade Ordinary Portland Cement [OPC] (according to IS8112:1989) is used in the present work. This is used as the main binder in the mixes. Aggregates are broken down into two main categories, which are coarse and fine aggregates. The economic part of concrete is to use as little cement as possible and still obtain the required strength. In this project the fine aggregates used are naturally available sand from Kalladayar river bed and recycled glass powder. Fine aggregate resulting from natural disintegration of rock and which passes through 4.75 mm IS sieve and contains 75 micron and conforms to IS 383-1970, zone-2 and coarse aggregate which passes through 20 mm IS sieve and retained on 4.75 mm according to IS: 383-1970, naturally occurring crushed stone are used in the work. Glass powder passing through 2.36mm IS sieve and retained on 300µm is used in this project work. The water used for mixing and curing is potable, fresh, colorless, odorless, and tasteless water that is free from organic matter of any type.

A. Preparation of recycled glass powder

Brown-colored, soda-lime glass beer bottles were collected from a local waste recycler. The bottles were soaked in tap water for one day to remove residua. Then it was cleaned manually with scrubber. After that, they were air dried and crushed using a road roller. The glasses were reduced to a smaller size. The crushed glass was then sieved through 4.75mm IS sieve and the retained pieces of glass were discarded. The glass particles were again sieved through a set of IS sieves. The glass passing through 2.36mm IS sieve and retained on 300µm IS sieve was chosen.

III. EXPERIMENTAL WORKS ON CONSTITUENT MATERIALS

Various material tests were conducted on cement, natural sand, recycled glass powder and coarse aggregate to analyze the different material properties according to the respective IS codes. The test conducted for cement were fineness (IS-4031(part 1):1996), consistency (IS-4031(part 4):1988), setting time (IS 269-1989, IS 8112-1989, IS 12269-1987), compressive strength (IS 8112-1989) and specific gravity (IS-4031-1988) and for fine aggregates, specific gravity (IS 2386:1963 part III clause 2.4.2), sieve analysis (Table 4 IS 383:1970, IS 2386:1963 part I), water absorption and chemical composition tests were conducted. Specific gravity (IS 2386 - Part III) and water absorption (IS 2386 - Part III) were done on coarse aggregate.
X-ray Diffraction [XRD], Energy Dispersive Spectroscopy [EDS] and Scanning Electron Microscopy [SEM] imaging were used to study the microstructure and chemical composition of the natural sand and recycled glass powder. Chemical composition was used to categorize and compare different constituents of natural sand and recycled glass powder.

A. Test results on cement

Table I shows the test results on cement.

TABLE I.

Test	Results	Standard
Specific Gravity	3.16	3.14 – 3.25
Fineness test	6.33%	Should be < 10% for OPC
Consistency test	32%	30% - 35%
Initial and final setting time	90mins.(initial) 480mins.(final)	Not less than 30mins. Not more than 600mins.
Compressive strength	43N/mm^2	43N/mm^2

B. Test results on fine aggregates

Table II shows the test results on fine aggregates. Table III shows the test results on chemical composition of natural sand and glass powder.

TABLE II.

Test	Natural Sand	Glass powder	Standards
Specific gravity	2.605	2.515	2.6-2.8
Sieve Analysis • Zone. • Fineness modulus.	Zone ll 2.738	3.6165	Zone I,II,III,IV 2.6 – 2.9
Water absorption	14.4%	5%	

TABLE III.

Element	The Mass percentage	
	Natural sand	Glass powder
Carbon	3.58	_
Oxygen	42.9	36.27
Aluminum	6.28	_
Silicon	47.24	42.58
Sodium	_	10.13
Magnesium	_	1.6
Calcium	_	9.41
Total	100	100

C. Test results on coarse aggregates

Table IV shows the test results on coarse aggregates.

TABLE IV.

Test	Result	Standard
Specific Gravity	2.648	2.6-2.8
Water absorption	6.53%	Should not be >0.6

IV. MIX PROPORTION AND TESTING SPECIMENS

A. Mix Proportion

The concrete mix design was proposed by using Indian Standard for control specimen. The grade was M20. The mixture was prepared with the cement content of 372kg/m3 and water to cement ratio of 0.5. Here 4 cubes and 6 cylinders were made for each replacement ratio. The mix proportion of materials was obtained as 0.5:1:1.66:3.12 according to IS 10262 1982. Chemical admixture was not used here.

B. Preparation of test specimen

Take a measured quantity of cement, natural sand, glass powder, coarse aggregate and water with respect to the mix proportion. Cement, natural sand and glass powder are mixed thoroughly in a mixing tray, until a uniform color is obtained. Add coarse aggregate in to this uniform mixture and continue the mixing. A required amount of water is added to this to obtain the required concrete mix. The concrete mix is filled in to the mould in three different layers. Each layer is tamped 25 times to expel the entrapped air. Remould the specimen after a period of 24 hours. Cure the specimen for 28 days.

C. Test on fresh concrete

Slump test was conducted on fresh concrete to measure its workability according IS 1199. The slump values obtained is shown in table V.

TABLE V

Replacement ratio (sand by glass)	**Slump value (mm)**	**Replacement ratio (sand by glass)**	**Slump value (mm)**
0%	20	60%	32
20%	24	80%	35
40%	29	100%	37

D. Test on hardened concrete

Tests were conducted to determine the compressive strength (IS 516-1959), split tensile strength (IS 5816-1999) and modulus of elasticity (IS : 516 - 1959) of concrete. The values for each replacement ratio were determined by conducting the tests on the specimen. Three trials were done for each replacement ratio and the average of the three was taken. Table VI, VII and VIII shows the split tensile values, compressive strength values and modulus of elasticity values respectively. Fig. 1 shows the crack formed at the time of compression testing.

Fig.1. Compression testing

TABLE VI

Replacement ratio(sand by glass)	Split tensile strength(N/mm^2)
0%	3.04
20%	2.532
40%	2.499
60%	2.38
80%	2.37
100%	234

TABLE VII

Replacement ratio (Sand by Glass)	**Area of specimen (mm^2)**	**Compressive strength (N/mm^2)**
0%	22500	26
20%	22500	22.814
40%	22500	28.89
60%	22500	23.03
80%	22500	27.407
100%	22500	26.96

TABLE VIII

Replacement Ratio (%)	Modulus Of Elasticity (kN/mm^2)
0	25.7715
20	21.199
40	26.7465
60	24.258
80	26.6445
100	25.7195

V. RESULTS AND DISCUSSION

All concrete mixtures showed a slump value greater than 20 mm. There was no clear change or trend in the slump values due to incorporation of glass sand. Compared with manufactured aggregates and recycled concrete aggregates, one apparent advantage of glass sand is its negligible water absorption capacity. As a result, the glass particles would not absorb water from cement paste, leading to no reduction in workability. The above graph shows the variation of slump value with increase in replacement ratio. The slump value increased with increase in percentage replacement of sand by glass.

From the observations given in table VII, a graph (Fig.2.) was plotted with compressive strength values on y-axis and replacement ratio on x-axis. The graph shows that there is no significant variation on compressive strength with respect to the control specimen (0% replacement of sand by glass). 12.25% variation from the compressive strength of control

specimen was observed in the 20% replacement of sand by glass powder and that for 40%, 60%, 80% and 100% were found out to be 11.11%, 11.42%, 5.4% and 3.6% respectively. Thus we can conclude that, none of the replacements of sand by glass did show much variation in its compressive strength compared to the control specimen.
From the split tensile values given in table VI, a graph (Fig.3.) was plotted with replacement ratio on x-axis and split tensile values on y-axis. Split tensile strength value decreases with increase in replacement ratios. The high split tensile strength was observed in control specimen (0% replacement).

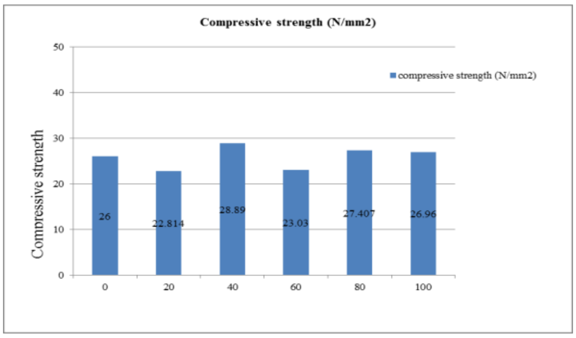

Fig.2 Compressive strength

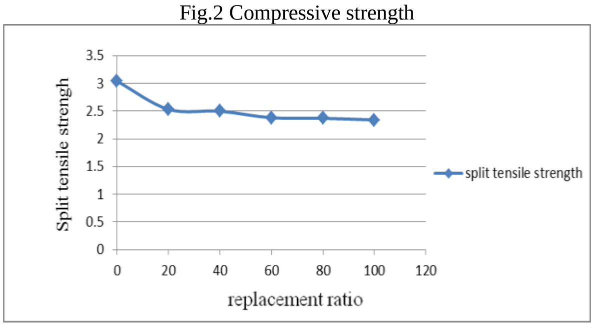

Fig.3. Split tensile strength

The elastic modulus values given in table VIII were found out by plotting a graph with strain on x-axis and stress values on y-axis for each replacement ratio and by determining the slope of the graph. The slope of each graph represented the modulusof elasticity values of each replacement ratio.

VI. CONCLUSION

- There is no significant variation in the mechanical properties of concrete while replacing natural sand by glass powder.
- Due to similarity in chemical composition and crystalline structure, recycled glass powder can be used as an alternative material for river sand.
- By using low-cost and environmental friendly building materials from industrial waste, we can produce a sustainable concrete.
- It is additional option for communities targeting glass for recycling, and to potentially reduce the costs of glass disposal and concrete production.
- Glass is a good recyclable waste material, as partial replacement of fine aggregate in the concrete.

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