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Study on Influence of Crushed Waste Glass on Properties of Concrete

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Abstract: ***Glass is one of the oldest and the most widely used materials in the world. Glass has a very limited life in the form in which it is used. Disposal of waste glass which is derived from the post-consumer beverage bottles is one of the environmental challenge. One option for safe environmental and economic disposal of this waste is to reuse them in building materials. So glass has to be recycled or reused to avoid environmental problems. Also during the past few decades the availability and cost of river sand has become a major concern. The objective of this project work is to study the effects of using waste glass as a partial replacement for fine aggregate. Different concrete mixes were prepared by varying the amounts of crushed waste glass. The waste glass was used to replace fine aggregate in the proportions of 0%, 5%, 10%, 15%, 20%, 25%, 30%. Various properties like compressive strength, split tensile strength, flexural strength have been reviewed in this paper. Also silica fume is added as a partial replacement for cement in order to compensate the strength lost due to addition of waste glass. Another attempt has also been made to replace cement with waste glass powder, in the same percentages and compressive strengths have been studied.***

Keywords: crushedwaste glass, compressive strength, split tensile strength, flexural strength, silica fume

1. Introduction

Glass is one of the oldest and the most widely used materials in the world. It is prepared by melting a mixture of materials such as silica, soda ash and $CaCO_3$ at high temperatures followed by cooling where solidification occurs without crystallization. The various forms in which it is produced includes packaging or container glass (bottles, jars), flat glass (windows, windscreens), bulb glass, cathode ray tube glass (TV screens, monitors) etc., All these glasses has very little life. Hence glass has to be recycled in order to avoid environmental problems. The waste glass which cannot be recycled, like mixed colour glass is generally sent for landfills. Land-filling has become a problem and a waste in itself. A lot of material that is being land filled can be reused with minimal process reducing demand on natural resources and landfills. In the few decades concrete has become one of the largest quantities produced in the world. Reusing waste glass in the production of concrete will convert a waste or a burden to a source. If we recycle the glass and use it, it will again become a waste after serving its purpose for a relatively short period of time. Rather if we use waste glass in concrete, it provides a long term solution. Glass is a 100% recyclable material and can be fully used after recycling. The various examples where recycled glass is successfully used are cullet in glass production, as raw material for the production of abrasives, in sand-blasting, as an aggregate in concrete production, in road beds, pavement and parking lots, as raw materials to produce glass pellets or beads used in reflective paint for highways, to produce fibre glass and as fractionators for lighting matches and firing ammunations. But the problem arises when the waste contains mixed colour glass. Mixed colour glass cannot be recycled and generally sent for landfills which is causing severe environmental problems.

The main factor limiting the replacement of waste glass in concrete is Alkali-Silica Reaction (ASR). The silica in the glass reacts with the alkalis in the cement and form a gel-like structure (ASR gel). This gel can absorb water and swell inside the microstructure of the concrete. This swelling causes internal stresses. When these internal stresses exceed the strength limit of concrete, then severe cracking and damage can occur. Reduction of the size of glass aggregates, witnessed no alkali-silica reaction. The susceptibility of glass to alkali implies that coarse glass or glass fibres could undergo ASR in concrete, possibly with deleterious effects. However, the fine ground glass is an effective ASR-suppressant, preventing ASR damage to the concrete.

Concrete is the most widely and extensively used material in the world. The fine aggregate used in the production of concrete is becoming highly expensive and scarce day by day. Also the use of river sand as fine aggregate leads to the exploitation of natural resources, lowering of water table, sinking of bridge piers and erosion of river bed. The construction industry has shown great gains in the utilization of recycled industrial by-products and wastes, including waste glass. If fine aggregate is replaced by waste glass by specific percentage and in specific size range, it will decrease fine aggregate content and thereby reducing the ill effects of river dredging and thus making concrete manufacturing industry sustainable. Using of these recycled by-products and wastes not only saves the landfill space but also reduces the demand for fine aggregate.

Unlike other forms of wastes like paper or organic constitutes, glass waste will remain stable because glass is a non-degradable material. This is a main reason for environmental issues. The recycling of construction waste, including concrete, and the land-fill bound constituents of the municipal solid waste stream, including glass which occurs largely as mixed colour waste glass with limited market value, are considered as important steps towards sustainable construction practices. When waste glass is used in making concrete products, the cost of concrete will go down.

Cement manufacturing industry is one of the carbon dioxide emitting sources. The global warming is caused by the emission of green house gases, such as CO_2, to the atmosphere. Among the green house gases, CO_2 contributes about 65% of global warming. The global cement industry contributes about 7% of CO_2 gas emission to the earth's atmosphere. In order to address environmental effects associated with cement manufacturing, there is need to develop alternative binders to make concrete.
Waste glass, when grounded to very fine form, can be used for replacing cement. Waste glass, when it is grounded to very fine size, it exhibits pozzolonic properties and which results in increasing of compressive strength. This sized glass acts as an excellent filler, which improves the microstructure of the concrete, hence resulting in denser and less permeable concrete.

Objective of this project

In this study an extensive experimental work has carried out to find out the suitability of use of waste glass in concrete with the following objectives:

1) To study the compressive strength, split tensile strength and flexural strength of concrete using crushed waste glass as partial replacement for fine aggregate.
2) To study the workability of concrete using crushed waste glass as partial replacement for fine aggregate.
3) To study the density of concrete using crushed waste glass as partial replacement for fine aggregate.
4) To study the compressive strength of concrete using waste glass powder as partial replacement for cement.
5) To study the workability of concrete using waste glass powder as partial replacement for cement.

2. Literature Review

ZainabZ. Ismail and Enas A. AL-Hashmi did their work on Recycling of waste glass as a partial replacement for fine aggregate in concrete. They concluded from their research that 80% of pozzolanic strength activity is given by waste glass. The flexural strength and compressive strength of specimens with 20% waste glass content were 10.99% and 4.23%, respectively, higher than those of the control specimen at 28 days. The mortar bar tests demonstrated that the finely crushed waste glass helped reduce expansion by 66% as compared with the control mix.

Alaa M. Rashadconcluded from his research that the inclusion of 10% glass sand increased the residual compressive strength of concrete after exposure to fire up to 700 ^{0}C. The inclusion of glass sand in the matrix increased its sulphate and sulphuric acid resistance. On the same line, the inclusion of glass sand (5–20%) improved carbonation resistance at long terms (56 and 91 days), whilst it decreased carbonation resistance at ages of 7 and 28 days. Drying shrinkage decreased with increasing glass sand content. This reduction may be related to the low water absorption capacity and the impermeable properties of glass.

Dr.Haider K. Ammash, Muhammed S. Muhammed, Ali H. Nahhabreported that upto 20% replacement, the 28 days compressive strength of concrete and mortar is about 92% and 95% from the reference strengths, respectively.

S.P. Gautam, VikasSrivastava and V.C. Agarwaldid a project on use of glass wastes as fine aggregate in concrete and concluded that the optimum replacement level of waste glass as fine aggregate in concrete is 10%.

Ahmad Shayan did a research work on value added utilisation of waste glass in concrete. He reported that there is a great potential for the utilisation of waste glass in concrete in several forms, including fine aggregate,coarse aggregate and glass powder. It is considered that the latter form would provide much greater opportunities for value adding and cost recovery, as it could be used as a replacement for expensive materials such as silica fume, fly ash and cement. The use of glass powder would prevent expansive ASR in the presence of susceptible aggregate. He concluded that 30% glass powder could be incorporated as cement or aggregate replacement in concrete without any long-term detrimental effects. Upto 50% of both fine aggregate and coarse aggregate could be replaced in concrete of 32 MPa strength grade with acceptable strength development properties.

Roz-Ud-Din Nassar, Parviz Soroushian, in their report concluded that when glass is used partial replacement for cement in concrete, it is estimated to undergo pozzolanic reaction that results in improved microstructure of recycled aggregate concrete. Significant increase in the later age strength is achieved through the formation of denser and less permeable microstructure which is expected to be the result of the filling effect of the sub-micron sized glass particles.

Dr.G.Vijayakumar, Ms. H. Vishaliny, Dr. D. Govindarajuluhave reported intheirworkthat glass powder concrete increases the compressive, split tensile and flexural strengths effectively, when compared with conventional concrete. Very finely ground glass has been shown to be excellent filler and may have sufficient pozzolonic properties to serve as partial cement replacement, the effect of ASR appear to be reduced with finer glass particles.

Shayan and Xucarried out a research to evaluate the incorporation of glass sand powder to replace natural sand and cement respectively. They detected a pozzolanic reaction of glass with cement that contributed to the development of compressive strength. The densification of the inner structure also increases the concrete mixes' resistance to chloride penetration. There was no expansive reaction related to the incorporation of glass sand.

3. Experimental Work

3.1Materials

The materials used in this project work are cement, fine aggregate, coarse aggregate, water, silica fume and crushed waste glass. The following are the details of the materials used in this project.

3.1.1 Cement

In this work, Ordinary Portland Cement (OPC) of Zuari brand and 53 Grade conforming to IS:12269-1987 is used. The properties of cement are tabulated in Table 1.

Table 1: Properties of Cement

S.No	Property	Values obtained
1.	Specific Gravity	3.13
2.	Fineness	4%
3.	Standard Consistency	31%
4.	Initial Setting Time	55 minutes
5.	Final Setting Time	260 minutes
6.	Compressive strength	54 MPa

3.1.2 Aggregates

Fine aggregate used in this project is natural river sand which is collected from the beds of river Tungabhadra. According to IS 383-1970 the fine aggregate used conforms to Zone II. The properties of fine aggregate are shown in Table 2. Coarse aggregate used in this project are well graded angular crushed stones. The properties of coarse aggregate are tabulated in Table 3.

Table 2: Properties of Fine Aggregate

S.No	Property	Results
1.	Specific Gravity	2.65
2.	Particle Size	4.75 mm
3.	Fineness Modulus	2.7

Table 3: Properties of Coarse Aggregate

S.No	Property	Results
1.	Specific Gravity	2.73
2.	Maximum Nominal Size	20 mm
3.	Fineness Modulus	4.6

3.1.3 Water

Potable, fresh, colourless and clean municipal tap water, which is free from organic matter, is used in this project work.

3.1.4 Crushed waste glass

The waste glass used in this project is crushed waste bottles which are collected from the scrap. After collecting, all the unwanted materials, like labels, corks are removed. Then it is washed and crushed into required sizes. The properties of glass are given in Table 4.

Table 4: Properties of Crushed Waste Glass

S.No	Property	Result
1.	Specific Gravity	2.20
2.	Colour	LightGrey
3.	Size for fine aggregate replacement	1.18mm-150µ
4.	Size for cement replacement	Passing 90µ sieve

3.1.5 Silica Fume

Silica fume used in this project work conforms to ASTM C 1240 and IS 15388:2003. Properties of silica fume are tabulated in Table 5.

Table 5: Properties of Silica Fume

S.No	Property	Value
1.	Specific Gravity	2.63
2.	Colour	White
3.	Physical state	Micronized powder
4.	Packing density	0.76 gm/cc
5.	Moisture	0.058%

3.2 Experimental Procedure

In this work, M35 grade concrete with water/cement ratio of 0.43 was designed by using IS code IS:10262-2009. Total of 16 concrete mixes were prepared, including the reference mix. The mix proportions for fine aggregate replacement and cement replacement have been tabulated in Table 6 and Table 7 respectively. For each mix, cubes for finding compressive strength, cylinders for split tensile strength and beams for flexural strength have been casted. The size of cube is 150mmX150mmX150mm, the size of cylinder is 150mm diameter and 300mm height and the size of beam is 100mmX100mmX500mm. Mixing of concrete was carried out in a mixer. The concrete was casted in all the moulds by compacting with tamping rods. After that, it was kept on a vibrating table to remove all the air voids. The specimens were demoulded after 24 hours and cured for 28 days in curing tanks. After 28 days of curing, the specimens were taken out of the curing tanks and then tested. Different tests like compressive strength, split tensile strength, flexural strength and density have been carried out and the results were tabulated.

Table 6: Mix proportions for Fine Aggregate replacement

% of Crushed Waste Glass	Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Crushed Waste Glass (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (lit)
0%	445.535	626.550	0	1118.110	191.580
5%	445.535	595.228	26.008	1118.110	191.580
10%	445.535	563.899	52.016	1118.110	191.580
15%	445.535	532.572	78.024	1118.110	191.580
20%	445.535	501.244	104.032	1118.110	191.580
25%	445.535	469.916	130.039	1118.110	191.580
30%	445.535	438.589	156.048	1118.110	191.580

Table 7: Mix proportions for Cement replacement

% of Waste Glass Powder	Cement (Kg/m^3)	Waste Glass Powder (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (lit)
0%	445.535	0	626.550	1118.110	191.580
5%	423.258	22.277	626.550	1118.110	191.580
10%	400.982	44.554	626.550	1118.110	191.580
15%	378.705	66.830	626.550	1118.110	191.580
20%	356.428	89.107	626.550	1118.110	191.580
25%	334.151	111.384	626.550	1118.110	191.580
30%	311.875	133.660	626.550	1118.110	191.580

4.1.2 Strength Properties of Hardened Concrete for Fine Aggregate replacement

The compressive strengths and split tensile strengths are obtained by testing the cube specimens and cylinder specimens in Compressive Testing Machine (CTM). The flexural strengths are obtained by testing beam specimens in Universal Testing Machine (UTM). The results are tabulated in Table 9. It was observed that there is an increase in compressive strength, split tensile strength and flexural strength upto 15% replacement of fine aggregate with crushed waste glass. After 15%, all the properties decreased gradually. In order to compensate the reduction in these properties, 10% silica fume is replaced for cement for 20%, 25% and 30% crushed waste glass replacement. These values are tabulated in Table 10.

Table 9: Strength Properties of Hardened Concrete (Average values)

S.No	% of Crushed Waste Glass	Compressive Strength (N/mm^2)	Split Tensile Strength (N/mm^2)	Flexural Strength (N/mm^2)
1.	0%	46.670	2.617	1.920
2.	5%	46.815	2.971	2.013
3.	10%	47.111	3.289	2.148
4.	15%	48.890	3.325	2.590
5.	20%	42.592	2.829	1.650
6.	25%	40.148	2.546	1.628
7.	30%	39.259	2.400	1.543

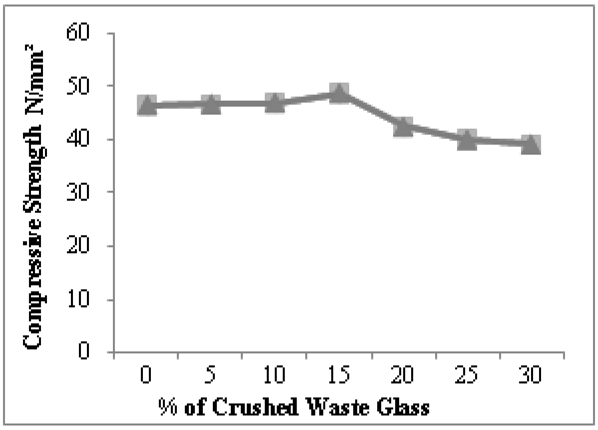

Figure 3: Graph between Compressive strength and % of crushed waste glass

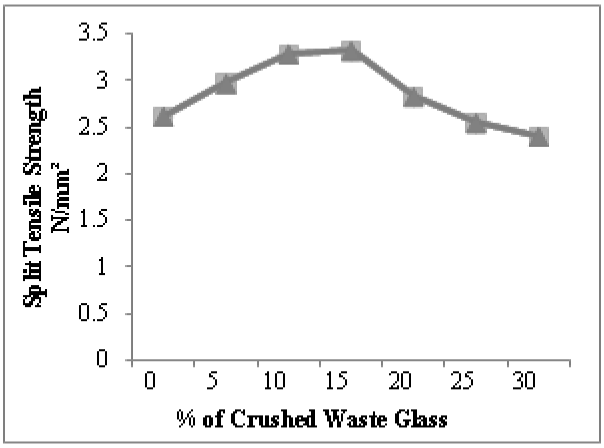

Figure 4: Graph between Split Tensile strength and % of crushed waste glass

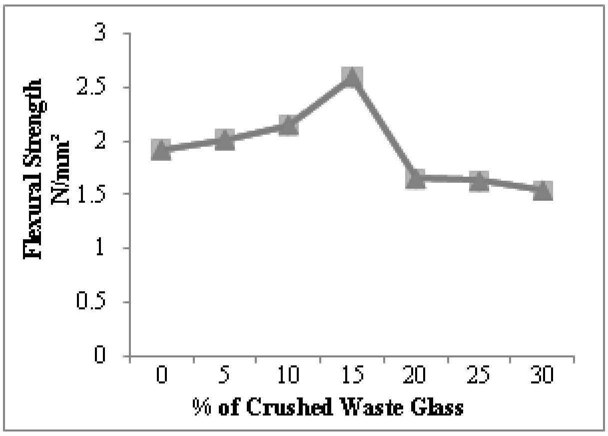

Figure 5: Graph between Flexural strength and % of crushed waste glass

Table 10: Strength Properties after adding Silica Fume (Average values)

S. No	% of Crushed Waste Glass	Compressive Strength (N/mm^2)	Split Tensile Strength (N/mm^2)	Flexural Strength (N/mm^2)
1.	20%	44.148	3.112	1.36
2.	25%	43.111	2.617	1.575
3.	30%	41.778	2.476	1.755

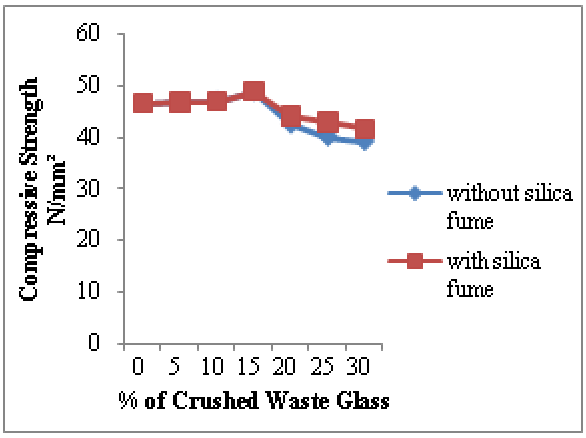

Figure 6: Variation of Compressive strength with and without Silica Fume

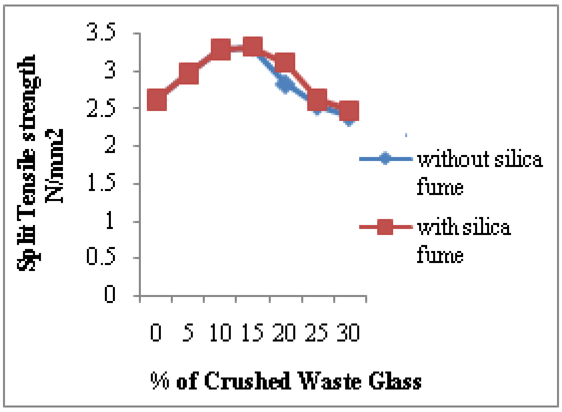

Figure 7: Variation of Split Tensile strength with and without Silica Fume

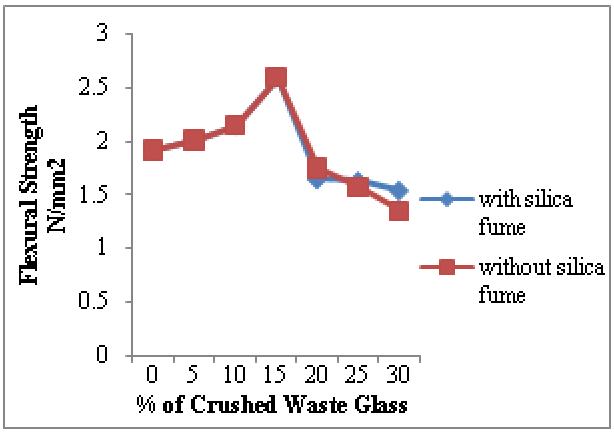

Figure 8: Variation of Flexural strength with and without Silica Fume

4.2.1 Workability for Cement replacement

For the same percentages, cement was replaced by glass powder. The compaction factor values are given in Table 11.

Table 11: Workability for Cement Replacement

S.No	% of Waste Glass Powder	Compaction Factor
1.	5%	0.957
2.	10%	0.875
3.	15%	0.852
4.	20%	0.825
5.	25%	0.819
6.	30%	0.799

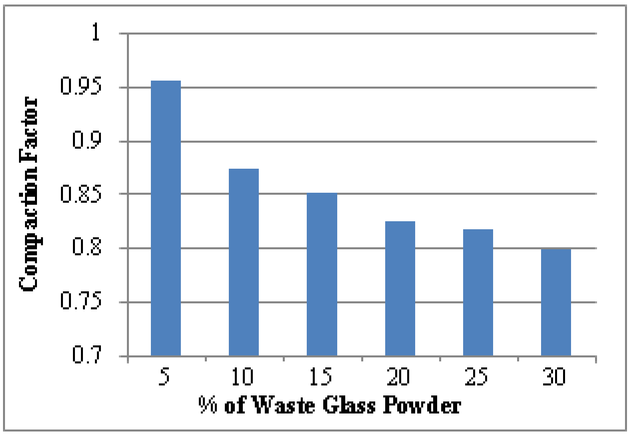

Figure 9: Graph between Compaction factor and % waste glass powder

4.2.2 Compressive Strength for Cement replacement

The compressive strength for cement replacement by glass powder is tabulated in Table 12. It is observed that compressive strength has increased upto 10% cement replacement by glass powder and thereafter decreased.

Table 12: Compressive Strength for Cement replacement

S. No	% of Waste Glass Powder	Compressive Strength (N/mm²)
1.	5%	43.259
2.	10%	43.555
3.	15%	40.000
4.	20%	38.222
5.	25%	35.556
6.	30%	32.296

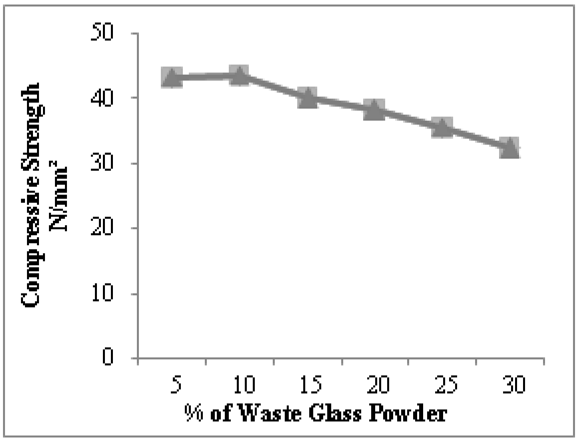

Figure 10: Graph between Compressive strength and % of waste glass powder

Conclusions

- When fine aggregate was replaced by crushed waste glass, then compressive strength, split tensile strength and flexural strength increased upto 15% replacement and thereafter decreased upto 30% replacement.
- For 15% replacement of fine aggregate by crushed waste glass, the increase in the percentages of compressive strength, split tensile strength and flexural strength with respect to reference mix is 4.76 %, 27 % and 34.89 % respectively.
- The workability of concrete decreased from 5% to 30% replacement of fine aggregate with crushed waste glass.
- When cement was replaced by glass powder, then compressive strength increased upto 10% and then decreased on further increase in percentage of glass powder.
- The increase in the percentage of compressive strength for 10 % replacement of cement with glass powder, with respect to reference mix is 6.67%.
- The workability of concrete for cement replacement also decreased from 5% to 30% replacement.
- The optimum percentage of glass waste for fine aggregate replacement is 15% and for cement replacement is 10%.

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