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SHORT COMMUNICATION

Use of glass wastes as fine aggregate in Concrete

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Abstract

Glass is widely used in our lives through manufactured products such as sheet glass, bottles, glassware, and vacuum tubing. Glass is an ideal material for recycling. The use of recycled glass helps in energy saving. The increasing awareness of glass recycling speeds up inspections on the use of waste glass with different forms in various fields. One of its significant contributions is to the construction field where the waste glass was reused for concrete production. The application of glass in architectural concrete still needs improvement. Laboratory experiments were conducted to further explore the use of waste glass as coarse and fine aggregates for both ASR (Alkali-Silica-Reaction) alleviation as well as the decorative purpose in concrete. The study indicated that waste glass can effectively be used as fine aggregate replacement (up to 40%) without substantial change in strength.

Keywords: Glass, recycling, concrete, construction field, alkali-silica-reaction, fine aggregate.

Introduction

Glass is a transparent material produced by melting a mixture of materials such as silica, soda ash, and $CaCO_3$ at high temperature followed by cooling where solidification occurs without crystallization. Glass is widely used in our lives through manufactured products such as sheet glass, bottles, glassware, and vacuum tubing. Glass is an ideal material for recycling. The use of recycled glass saves lot of energy and the increasing awareness of glass recycling speeds up focus on the use of waste glass with different forms in various fields. One of its significant contributions is the construction field where the waste glass was reused for concrete production. The application of glass in architectural concrete still needs improvement. Several study have shown that waste glass that is crushed and screened is a strong, safe and economical alternative to sand used in concrete. During the last decade, it has been recognized that sheet glass waste is of large volume and is increasing year by year in the shops, construction areas and factories.

Using waste glass in the concrete construction sector is advantageous, as the production cost of concrete will go down. The amount of waste glass is gradually increased over the years due to an ever-growing use of glass products. Most of the waste glasses have been dumped into landfill sites. The land filling of waste glasses is undesirable because they are not biodegradable, which makes them environmentally less friendly. There is huge potential for using waste glass in the concrete construction sector. When waste glasses are reused in making concrete products, the production cost of concrete will go down (Topcu and Canbuz, 2004). Crushed glass or cullet, if properly sized and processed, can exhibit characteristics similar to that of gravel or sand.

When used in construction applications, waste glass must be crushed and screened to produce an appropriate design gradation. Glass crushing equipment normally used to produce a cullet is similar to rock crushing equipment. Because glass crushing equipment in glass sector has been primarily designed to reduce the size or density of the cullet for transportation purposes and for use as a glass production feedstock material, the crushing equipment used is typically smaller and uses less energy than conventional aggregate or rock crushing equipment (Egosi, 1992). Waste glasses are used as aggregates for concrete (Johnson, 1998, Masaki, 1995; Park, 2000). However, the applications are limited due to the damaging expansion in the concrete caused by ASR between high-alkali pore water in cement paste and reactive silica in the waste glasses. The chemical reaction between the alkali in Portland cement and the silica in aggregates forms silica gel that not only causes crack upon expansion, but also weakens the concrete and shortens its life (Swamy, 2003).

Ground waste glass was used as aggregate for mortars and no reaction was detected with fine particle size, thus indicating the feasibility of the waste glass reuse as fine aggregate in mortars and concrete. Estimated cost for housing is more and some construction materials like natural sand are also becoming rare. Waste glasses are used as aggregates for concrete. In this study, an extensive experimental work was carried out to find the suitability of use of waste glass in concrete with the following objectives:

1. To study the workability of concrete mode using glass waste as partial replacement of fine aggregate.
2. To study the compressive strength of concrete mode using glass waste as partial replacement of fine aggregate.

Materials and methods

In order to study the effect of waste glass as partial cement replacement on the strength of concrete, fine aggregate and coarse aggregate, 66 cubes of size 100 mm × 100 mm × 100 mm were cast for different percentage of demolished waste and for 0% waste glass for a mix have been cast in the laboratory. An effort has been made here to compare the strength of cubes made up with different percentage of demolished waste to the respective strength of conventional concrete at the end of 7 and 28 d of moist curing and to have an idea about the optimum percentage of demolished waste which does not affect the strength of recycled concrete considerably. Similarly fine aggregate and coarse aggregates was also partially replaced by demolished waste and only cubes were cast and tested after 7 and 28 d for mix of 1:1.67:3.33 at a w/c of 0.50.

Cement: In this work, Ordinary Portland cement (OPC) of Birla (43 grade) brand obtained from a single batches was used. The physical properties of OPC as determined are given in Table 1. The cement satisfies the requirement of IS: 8112-1989. The specific gravity was 2.96 and fineness was 2800 cm^2/g.

Table 1. Typical composition of ordinary portland cement.

Chemical	Weight
Tri-calcium silicate -C_3S	55%
Di-calcium silicate -C_2S	18%
Tri-calcium aluminate -C_3A	10%
Tetra-calcium alumino ferrite -C_4AF	8%
Calcium sulphate dihydrate -CSH_2	6%

Fine aggregate: Fine aggregate/sand is an accumulation of grains of mineral matter derived from the disintegration of rocks. It is distinguished from gravel only by the size of grain or particle, but is distinct from clays which contain organic minerals. Sands that have been sorted out and separated from the organic material by the action of currents of water or by winds across arid lands are generally quite uniform in size of grains. Usually commercial sand is obtained from river beds or from sand dunes originally formed by the action of winds. Much of the earth's surface is sandy, and the sand is usually quartz and other siliceous materials. Sand is used to make mortar and concrete and for making molds in foundries.

Coarse aggregate: Coarse aggregate are the crushed stone used for making concrete. The commercial stone is quarried, crushed and graded. Much of the crushed stone used is granite, limestone and trap rock. Crushed angular granite metal of 10 mm size from a local source was used as coarse aggregate. The specific gravity of 2.6 and fineness modulus 6.05 was used.

The coarse aggregate are granular materials obtained from rocks and crushed stones. They can be also obtained from synthetic material like slag, shale, fly ash and clay for use in light-weight concrete.

Table 2. Physical properties of cement.

Standard consistency	Days	31%
Initial setting time	-	92 min
Final setting time	-	195 min
Compressive strength	3	27.1 MPA
	7	38.0 MPA
	28	80.0 MPA

Fig. 1. Test set up for compressive strength test of concrete.

Water: Potable water is used for mixing and curing. On addition of higher percentage of demolished waste the requirement of water increases for the same workability. Thus, a constant slump has been the criteria for water requirement but the specimens having 0% demolished waste, w/c of 0.50 has been used.

Concrete: The concrete mix design is done in accordance with IS: 10262 (1982). The cement content in the mix design is taken as 380 kg/m^3 which satisfies minimum requirement of 300 kg/m^3 in order to avoid the balling effect. Good stone aggregate and natural river sand of zone-‖ was used as coarse aggregate and fine aggregate respectively. Maximum size of coarse aggregate was 12.5 mm. A sieve analysis conforming to IS: 383-1970 was carried out for both the fine and coarse aggregate .Concrete may be produced as a dense mass which is practically artificial rock and chemicals may be added to make it waterproof or it can be made porous and highly permeable for such use as filter beds.

Table 3. Sieve analysis of aggregates.

Material sieve size	Percentage passing									
	40	20	10.5	10	4.75	2.36	1.18	0.6	0.3	0.15
20 mm	100	90.8	11.2	0.0	0.0	-	-	-	-	-
12.5 mm	-	-	98.8	83.8	-	1.4	0.0	-	-	-
Sand	-	-	-	100	100	93.2	65.2	38.9	12.5	0.8

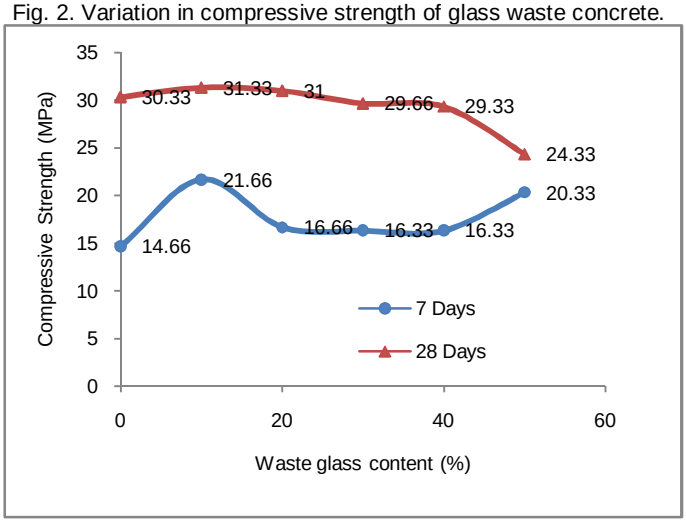
Table 4. Properties of aggregates.

Property	Sand	Coarse aggregate	
		20 mm	12.5 mm
Specific gravity	2.62	2.71	2.70
Bulk density (kg/m^3)	1573	1477	1489

Table 5. Compressive strength.

Cube designation	Compressive strength (N/mm^2)		Glass (%)
	7 days	28 days	
I	14.66	30.33	0
II	21.66	31.33	10
III	16.66	31.00	20
IV	16.33	29.66	30
V	16.33	29.33	40
VI	20.33	24.33	50

Fig. 2. Variation in compressive strength of glass waste concrete.



An air-entraining chemical may be added to produce minute bubbles for porosity. Normally, the full hardening period of concrete is at least 7 d. The gradual increase in strength is due to the hydration of the tri-calcium aluminates and silicates. Sand used in concrete was originally specified as roughly angular, but rounded grains are now preferred. The stone is usually sharply broken. The weight of concrete varies with the type and the amount of rock and sand.

Material properties: The materials were tested for their physical properties as per the relevant Indian Standards. The properties of cement, coarse sand, and single seized coarse aggregates of 20 mm and 12.5 mm (Table 2, 3 and 4).

Results and discussion

It is observed that when fine aggregate is replaced by 10% glass waste, the compressive strength at 7 d is found to increase by about 47.75% on average (Table 5 and Fig. 2). However, it is evident that increase in compressive strength at 28 d is only 3.30% at same replacement level.

It is observed that on replacing fine aggregate by 20% glass waste on average there is an increase in compressive strength at 7 d by 13.64% however, at 28 d; increase in compressive strength is 2.18%. It is seen that there is an increase in compressive strength at 7 d by about 11.32% whereas at 28 d compressive strength is decreased marginally at 30 and 40% replacement level.

Conclusion

From the above findings, the following conclusions may be made out of the study:

1. While using waste glass as fine aggregate replacement, 28 d strength is found to marginally increase up to 20% replacement level.
2. Marginal decrease in strength is observed at 30 to 40% replacement level of waste glass with fine aggregate.
3. Waste glass can effectively be used as fine aggregate replacement.
4. The optimum replacement level of waste glass as fine aggregate is 10%.

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