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# USE OF WASTE GLASS AS COARSE AGGREGATE OF CONCRETE

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***ABSTRACT***

***The study focuses on practical use of glass as coarse aggregate in concrete instead of stone chips or brick chips. Stone chips are costly and needed to collect straight from natural resource, brick chips are also expensive and its production causes environmental pollution. In this context, it can be said that waste glass may Open a new path of economic and pollution free concrete construction if desired strength can be achieved, rough textures in glass samples would have provided better bond and better strength. In this experimental investigation it was to required obtain the fresh concrete workability and the hardened concrete compressive strength as the essentials for the analyses following the methodology targeting to highlight the usefulness of considering waste glass materials as a main component within the concrete mix. Laboratory experiments were conducted on strength characteristics of concrete made with utilizing broken waste glass as coarse aggregate replacement. Coarse aggregates were replaced by broken waste glass as 10%, 20%, 30% and 40% by weight of coarse aggregate for M-20 mix. The nominal proportion for M20 i.e. 1:1.5:3 is used. These mixes were prepared following a specific W/C ratio of 0.5 and adding Alkali-Silica reaction inhibitor agents. A total of 75 cubes of 15cm are casted and tests were performed on them. The results concluded the permissibility of using waste glass as partial replacement of coarse aggregates up to 30% by weight for glass as coarse aggregate size up to 12mm. Thus the present study recommends that broken waste glass can be used as an alternate construction material to coarse aggregate in concrete without substantial change in strength. From the experimental observations it was observed that: Marginal decrease in strength is observed at 30 to 40% replacement level of waste glass with coarse aggregate, waste glass can effectively be used as coarse aggregate replacement, the optimum replacement level of waste glass as coarse aggregate is 30%, With increase in waste glass content, percentage water absorption decreases, with increase in waste glass content, average weight decreases by 5% for mixture with 40% waste glass content thus making waste glass concrete light weight, workability of concrete mix increases with increase in waste glass content, use of waste glass in concrete can prove to be economical as it is non-useful waste and free of cost and use of waste glass in concrete will eradicate the disposal problem of waste glass and prove to be environment friendly thus paving way for greener concrete.***

***KEYWORDS: Coarse aggregate, Compressive strength, Concrete, Durability, Environmental friendly, Waste glass.***

## INTRODUCTION

Glass is a transparent material produced by melting a mixture of materials such as silica, soda ash, and CaCO3 at high temperature followed by cooling where solidification occurs without crystallization. Glass is one of the oldest man-made materials. It is produced in many forms such as packaging or container glass, flat glass, and bulb glass, all of which have a limited life in their manufactured forms and therefore need to be recycled so as to be reusable in order to avoid environmental problems that would be created if they were to be stockpiled or sent to landfills. The construction industry has shown great gains in the recycling of industrial byproducts and waste, including waste glass materials. Quantities of waste glass have been rising rapidly during the recent decades due to the high increase in industrialization and the considerable improvement in the standards of living, but unfortunately, the majority of these waste quantities are not being recycled but rather abandoned causing certain serious problems such as the waste of natural resources and environmental pollution. Recycling of this waste by converting it to aggregate components could save landfill space and also reduce the demand for extraction of natural raw material for construction activities. Herein is a quick review for some of the previous research studies concerned with the waste glass as an aggregate material, but from different points of view and perspectives

## LITERATURE REVIEW

**Topçu and Canbaz (2003)** considered waste glass as coarse aggregates in the concrete mix. The effects of waste glass on workability and strength of the concrete with fresh and hardened concrete tests were analyzed. As a result of the study conducted, waste glass was determined not to have a significant effect upon the workability of the concrete and only slightly in the reduction of its strength.

Waste glass cannot be used as aggregate without taking into account its ASR properties. As for cost analysis, it was determined to lower the cost of concrete productions. This study considered the fact that waste glass could be used in the concrete as coarse aggregates without the need for a high cost or rigorous energy.

**Topçustated (2006)** in their study that the use of waste glass or glass cullet (GC) as concrete aggregate is becoming more widespread each day because of the increase in resource efficiency. Recycling of wastes is very important for sustainable development. When glass is used as aggregate in concrete or mortar, expansions and internal stresses occur due to an ASR. Furthermore, rapid loss in durability is generally observed due to extreme crack formation and an increase in permeability. It is necessary to use some kind of chemical or mineral admixture to reduce crack formation. In their study, mortar bars were produced by using three different colors of glass in four different quantities as fine aggregate by weight, and the effects of these glass aggregates on ASR were investigated, corresponding to ASTM C-1260. Additionally, in order to reduce the expansions of mortars, 10% and 20% fly ash (FA) as mineral admixture and 1% and 2% $Li_2CO_3$ as chemical admixture were incorporated by weight in the cement and their effects on expansion are examined. It was observed that among white (WG), green (GG) and brown glass (BG) aggregates, WG aggregate causes the greatest expansion.

In addition, it was recorded that concrete mix expansion increases with an increase in amount of glass. According to the test results, it was seen that over 20% FA and 2% $Li_2CO_3$ replacements are required to produce mortars which have expansion values below the 0.2% critical value when exposed to ASR. However, usages of these admixtures reduce expansions occurring because of ASR.

**Kou and Poon (2010)** investigated the effects of recycled glass cullet on fresh and hardened properties of self-compacting concrete. Recycled glass was used to replace river sand (in proportions of 10%, 20% and 30%), and 10 mm granite (5%, 10% and 15%) in making the self-compacting concrete mixes.

The experimental results showed that the slump flow, blocking ratio, air content of the recycled glass self-compacting concrete mixes increased with increasing recycled glass content. The results revealed that the compressive strength, tensile splitting strength and static modulus of elasticity of the recycled glass self-compacting concrete mixes were decreased with an increase in recycled glass aggregate content. Moreover, the drying shrinkage of the recycled glass self-compacting concrete mixes decreased when the recycled glass content increased.

**Federico and Chidiac (2012)** investigated the incorporation of waste bottle glass into concrete mixes as a supplementary cementing material and concluded that the pozzolanic properties of waste glass as an ASR are related to particle size and percent addition. In addition, lithium and barium additives control ASR expansion; however, the mechanism of this control has yet to be defined.

**Idir (2016)** stated that the demand for recycled glass has considerably decreased in recent years, particularly for mixed glass. Glass is cheaper to store than to recycle, as conditioners require expenses for the recycling process. In order to provide a sustainable solution to glass storage, a potential and incentive way would be to reuse this type of glass in concretes.

Depending on the size of the glass particles used in concrete, two antagonistic behaviors can be observed: alkali–silica reaction, which involves negative effects, and pozzolanic reaction, improving the properties of concrete. Their work dealt with the use of fine particles of glass and glass aggregates in mortars, either separately or combined.

Two parameters based on standardized tests were studied: pozzolanic assessment by mechanical tests on mortar samples and alkali-reactive aggregate characteristics and fines inhibitor evaluations by monitoring of dimensional changes. It is shown that there is no need to use glass in the form of fines since no swelling due to alkali–silica reaction is recorded when the diameter of the glass grains is less than 1 mm. Fine glass powders having specific surface areas within the range from (180 to 540) $m^2/kg$ reduced the expansions of mortars subjected to ASR, especially when glass aggregates of diameters larger than 1 mm are used. This study aimed to evaluate the preventive role of pozzolanic glass fines in counteracting the deleterious effect of alkali-reactive glass aggregates. It has been shown that in his study that the use of both types of glass particles is pertinent.

The main results were:

- Only glass classes of more than 1 mm gave expansions related to ASR.
- The use of glass fines led to the reduction of mortar expansion due to coarse particles; moreover, fines increased the compressive strength of mortars.
- No excessive crushing of glass fines was needed since the quantity of fines was the main parameter controlling the reduction of expansion due to coarse glass aggregates.

**Hong (2019)** investigated and stated that 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 value-added concrete production. Literature survey indicates that the use of waste glass as aggregates in concrete was first reported over 50 years ago. The concomitant ASR by using glass in concrete and its unique aesthetic properties have been investigated since then. However, no complete solution to ASR has been found and the application of glass in architectural concrete still needs improving.

Results demonstrated that the use of waste glass as aggregate facilitates the development of concrete towards a high architectural level besides its high performances, thereafter, the increasing market in industry.

## MATERIAL AND METHODOLOGY

Concrete is a structural material that contains some simple elements but when mixed with water would form a rock like material. Concrete mix is comprised of coarse aggregates usually gravel, fine aggregates usually sand, cement, water, and any necessary additives. Concrete possesses many favorable properties as a structural material, among which are its high compressive strength and its property as a fire-resistant element to a considerable extent. The various concrete composite materials used are briefly described below:

### A. Cement

In this work, Ordinary Portland cement (OPC) of brand Khyber (43 grade) confining to IS 8112-1989 was usedthroughout the investigation. The specific gravity was 2.96 and fineness was 2800 cm2/gather typical chemical composition of ordinary Portland cement of 43 grades is given in the following table.

Table 1. Composition of OPC

| Composition | Percentage by mas |
|---|---|
| Silica ($SiO_2$) | 20.2-72.5 |
| Calcium oxide (CaO) | 9.7-61.9 |
| Alumina ($Al_2O_3$) | 0.4-4.7 |
| Iron oxide ($Fe_2O_3$) | 0.2-3.0 |
| Magnesium oxide (MgO) | 2.6-3.3 |
| Sodium oxide ($Na_2O$) | 0.19-13.7 |
| Potassium oxide ($K_2O$) | 0.1-0.8 |
| Sulphur trioxide ($SO_3$) | 0.43-0.9 |

### B. Water

Water is the element that is used to begin the hydration reaction where cement reacts with the water to produce a rock like substance. The reaction is also exothermic, where heat is released in the chemical reactions. This is an important fact because in very large structure like concrete dams, the heat released can pose a potential problem. The type of water that can be used to mix concrete must be potable which is essentially has neither noticeable taste nor odor. Basically, water containing less than 2000 ppm of total dissolved solids can be used. Thus the type of water that was used to mix concrete throughout the testing program was normal tap water with attention paid for not including impurities.

### C. Coarse aggregate

Crushed angular granite from local quarry of kulgam (J&K) is used as coarse aggregate. The cleaned coarse aggregate is chosen and tested for various properties such as specific gravity, fineness modulus, bulk modulus etc. The physical characteristics are tested in accordance with IS: 2386 – 1963.

Figure 1: Shows various aggregate used in investigation

**D. Fine aggregate**

The locally available river sand is used as fine aggregate in the present investigation. The cleaned fine aggregate is chosen and tested for various properties such as specific gravity, fineness modulus, bulk modulus etc. in accordance with IS : 2386-1963.

**E. Waste glass**

The waste glass materials used throughout this experimental study were gathered from local shops and disposals of reconstruction building of local school. These materials were primarily originated from pure and clear glass windows and empty bottles. The whole quantity was cleaned out of the dirt materials and impurities, and then crushed in crushing machines into different particles sizes. Then the same standard procedure was then applied to conduct another sieve analysis representative samples of waste glass and according to the IS specifications, the samples were grouped under coarse aggregates. The sieve analyses revealed that most of the coarse waste glass material was within the range between 4.75 mm to 12.5 mm in particle size diameter with a fairly good gradation pattern.

Figure 2 : Shows sieving of waste glass after crushing

**G. Alkali Silica Reaction Suppressant**

Barium hydroxide is used as alkali silica reaction suppressant by 1.5 percent of weight of glass.

## TEST METHODS

1. **Slump test**
2. **Compressive strength test**
3. **Water absorption test**

## RESULT

Laboratory experiments were conducted on strength characteristics of concrete made with utilizing broken waste glass as coarse aggregate replacement. Coarse aggregates were replaced by broken waste glass as 10%, 20%, 30% and 40% by weight of coarse aggregate for M-20 mix. The nominal proportion for M20 i.e. 1:1.5:3 is used. These mixes were prepared following a specific W/C ratio of 0.5 and adding Alkali-Silica reaction inhibitor agents. A total of 75 cubes of 15cm are casted and test is performed on them. There is a tendency of the reaction between the alkali in cement and silica in glass known as Alkali-silica reaction. These reaction results in the formation of silica gel which have a tendency of swelling which ultimately exert pressure on concrete results in cracking the concrete. To mitigate the alkali silica reaction we have used the barium hydroxide as alkali silica reaction suppressant. The concrete specimens were tested for compressive strength and durability at different ages of concrete and the results obtained were compared with those of normal concrete. The results concluded the permissibility of using waste glass as partial replacement of coarse aggregates up to 30% by weight for glass as coarse aggregate size up to 12mm.This paper recommends that broken waste glass can be used as an alternate construction material to coarse aggregate in concrete without substantial change in strength.

Table 2: Shows the compressive strength of the test specimens

| **Percentage of glass used (%)** | **Test Specimen** | **Strength after 3 days ($N/mm^2$)** | **Average strength ($N/mm^2$)** | **Strength after 28 days ($N/mm^2$)** | **Average strength ($n/mm^2$)** |
|---|---|---|---|---|---|
| **0** | **1** | **10.44** | **10.32** | **28.32** | **28.96** |
| | **2** | **10.44** | | **29.00** | |
| | **3** | **10.3** | | **29.65** | |
| | **4** | **10.10** | | **28.88** | |
| **10** | **1** | **8.67** | **9.45** | **30.50** | **30.48** |
| | **2** | **10.9** | | **31.08** | |
| | **3** | **8.89** | | **29.35** | |
| | **4** | **9.33** | | **30.98** | |
| **20** | **1** | **9.33** | | **27.90** | |

| | | | | | |
|---|---|---|---|---|---|
| | 2 | 8.89 | 9.17 | 26.35 | 28.99 |
| | 3 | 8.89 | | 27.28 | |
| | 4 | 9.55 | | 26.5 | |
| 30 | 1 | 8.89 | 9 | 27.10 | 27.33 |
| | 2 | 8.44 | | 27 | |
| | 3 | 8.67 | | 25.25 | |
| | 4 | 10 | | 25.98 | |
| 40 | 1 | 6.44 | 6.11 | 24.20 | 23.45 |
| | 2 | 6 | | 23.70 | |
| | 3 | 5.33 | | 23.85 | |
| | 4 | 6.67 | | 22.05 | |

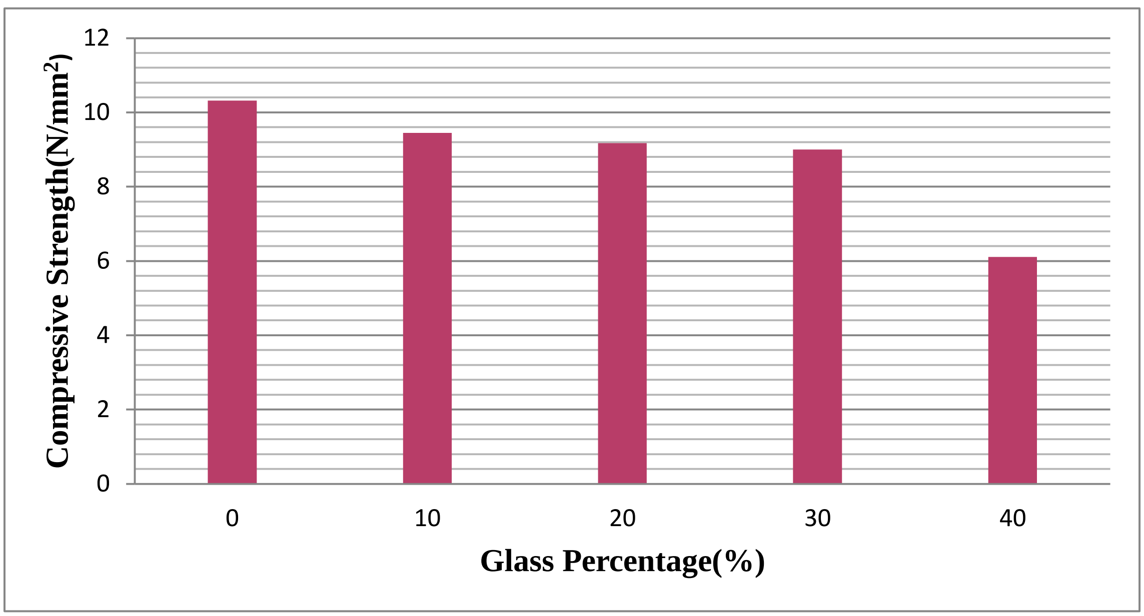


Figure 2 : 3 days compressive strength vs percentage of glass replacement

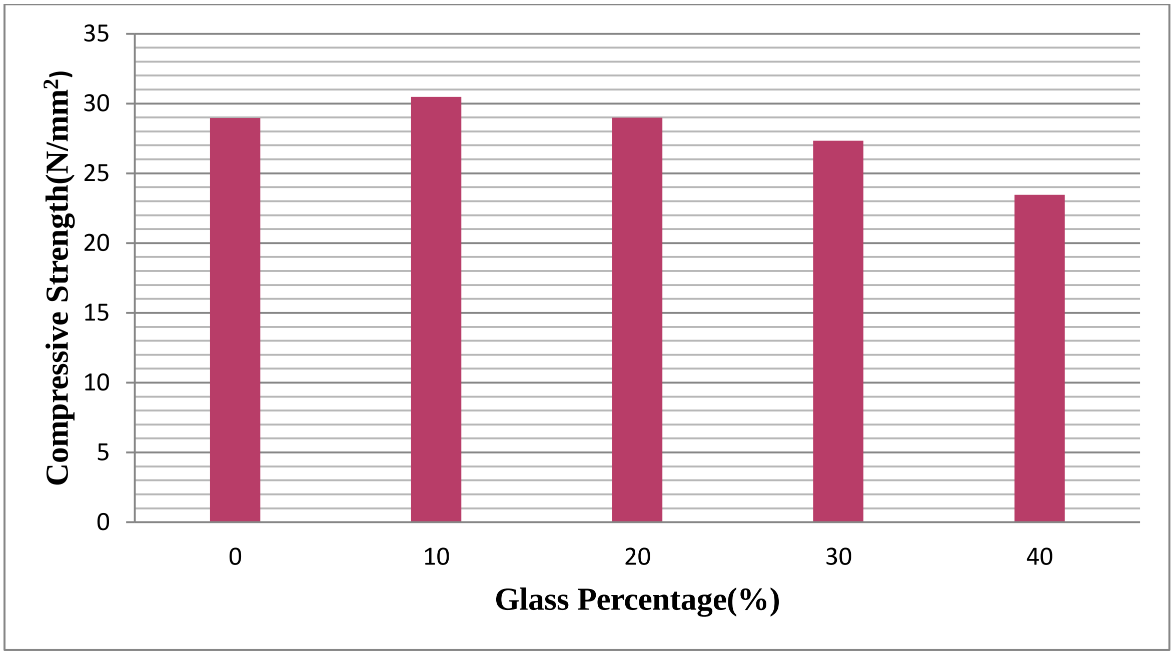


Figure 3: 28 days compressive strength vs percentage of glass replacement

Table 03: Light weight character test results

| Glass percentage (%) | Avg. dry wt. of cube (gm) | Avg dry density of cube ($KN/m^3$) | Percentage change in wt. as compared to reference (%) |
|---|---|---|---|
| 0 | 8390 | 24.86 | 0 |
| 10 | 8330 | 24.68 | -0.724 |
| 20 | 8220 | 24.36 | -2.011 |
| 30 | 8125 | 24.07 | -3.178 |
| 40 | 7946 | 23.54 | -5.309 |

Table 09: Water absorption test results

| Glass percentage (%) | Avg. dry wt. of cube(gm) | Avg. wet weight of cube(gm) | Water absorbed (gm) | Percentage water absorbed |
|---|---|---|---|---|
| 0 | 8390 | 8480 | 90 | 1.07 |
| 10 | 8330 | 8410 | 80 | .96 |
| 20 | 8220 | 8290 | 70 | .85 |
| 30 | 8125 | 8181 | 56 | .69 |
| 40 | 7946 | 7990 | 44 | .55 |

## CONCLUSION

1. Marginal decrease in strength is observed at 30 to 40% replacement level of waste glass with coarse aggregate.
2. Waste glass can effectively be used as coarse aggregate replacement.
3. The optimum replacement level of waste glass as coarse aggregate is 30%.
4. With increase in waste glass content, percentage water absorption decreases.
5. With increase in waste glass content, average weight decreases by 5% for mixture with 40% waste glass content thus making waste glass concrete light weight.
6. Workability of concrete mix increases with increase in waste glass content.
7. Use of waste glass in concrete can prove to be economical as it is non useful waste and free of cost.
8. Use of waste glass in concrete will eradicate the disposal problem of waste glass and prove to be environment friendly thus paving way for greener concrete.
9. Use of waste glass in concrete will preserve natural resources particularly river gravels and thus make concrete construction industry sustainable.

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