Feasibility Studies on Waste Glass Powder

Sudharsan N, Saravanaganesh S

Abstract: The focus of this investigation to evaluate the possibility of using waste glass powders in concrete. Concrete is an artificial stone-like material used for various structural purposes made by mixing cement, water, sand and gravel that hardens into a super strong building material. Cement is the major component of the concrete than the others due to its pozzolanic and binding property. During the manufacturing of cement, it emits many greenhouse gases due to the burning of fossil fuels, and it causes environmental pollution. Cement production is growing by 2.5% annually, and it is expected to rise in the forthcoming years. The emission of greenhouse gases causes global warming. In order to overcome such effects, there is an alternative need to make concrete. Glass is one of the materials which are obtained as waste and it is disposed of at landfills. The exploitation of throw away glass materials in the concrete useful to lessen the environmental pollution and also strengthen the concrete. The waste glass components are usually made up of bottles, broken glassware, light bulbs, and it is disposed of as a waste due to its weight and density. It helps to provide a greener environment and concrete. The results and strength of this paper show that the glass powder has a pozzolanic property and used in the place of cement.

Keywords: Glass powder, Compressive strength, Sorptivity, Carbonation

I. INTRODUCTION

In today's scenario, concrete is indispensible material in construction. Creating a good concrete is an art, and if not give proper attention it will end up making a bad concrete. Hence as a civil engineer, one should be thorough with the entire factor of concrete from which he can produce good concrete. Sometimes improvements in concrete properties can be made by altering the ingredients in proportions. Most of today’s high-performance concrete mixtures one or more alternative cementsitious materials are used to enhance workability, strength, durability, service life, and other performance characteristics. Alternative cementsitious materials are finely divided materials that replace or supplement the use of Portland cement. These materials include the wastes such as fly ash, rice husk ash, silica fume, copper slag, steel slag, waste tires, glass, ground granulated blast furnace slag, etc. can be used as a replacement of cement in concrete. These materials are generally obtained as byproducts from other processes or natural materials. They can be used for improving the concrete performance in its fresh and hardened state. Utilization of cementitious products in cement offers greater advantages and name a few includes, reduction in cement plant volume capacity, reduction in fuel, lower CO₂ emission and reduced alkali-silica reactivity, and reduces permeability. Their use reduces the cost and improves one or more technical properties of concrete. Among the alternative cementsitious materials, the glass is one of the waste materials which have a great futuristic part could have a promising future in the construction industry as a partial substitute of cement.

Facts of waste glass

As the usage of the glass increases, the amount of waste gets also increases. In 2004 approximately 12.5 million tons or 77% of the waste glass generated in the United States. In America generated 11.6 million tons of glass in the municipal solid waste (MSW) stream in the year 2012. The sources of wastages of glass are from food, soft drink, beer, food, wine, and liquor which is disposed of in landfills and dumped as waste material and this causes environmental pollution. To prevent this, it can be recycled and reused for various purposes. The glass is one of the waste materials which could have a promising future in the construction industry as a partial substitute of cement. Glass has a significant potential of getting developed as a suitable alternative material to these resources. Many industrial by-products have been successfully used in the construction industry for the production of cement and concrete. Use of waste glass in concrete makes key contributions towards the development of a green concrete based infrastructure.

The strength of the recycled glass sand mixes was decreased by increasing the recycled glass content. Mixtures containing glass powder reduces the chloride ion permeability. The slower strength gain in early days and it exceeded about 15 Mpa at the later ages when compared to conventional. The glass powder having a particle size finer than 38 mm did exhibit a pozzolanic behavior and leads to a higher reactivity with lime, a higher compressive strength in concrete, and a lower expansion. The recycled glass powder can reduce the permeability of the concrete mix, and it enhances durability and restricts the migration of the water and ions inside the concrete mix. The use of glass powder in concrete reduces the expansion due to alkali-silica reaction and improving durability characteristics. Higher the glass powder content can improve the performance of workability and drying shrinkage. Glass powder shows that there is improve in the strength of mortars more than the conventional.

It is possible to re-softening and re-melting the glass numerous times, and hence it is ideal for glass recycling. Soda-lime glass is fairly cheap, quite hard material, and enormously workable. It has a lower melting point and a higher coefficient of expansion and contraction. Most of the colored and clear glass types the
Feasibility Studies on Waste Glass Powder

primary material is Soda-lime glass. Soda lime glass is prepared by melting the raw materials such as sodium carbonate, lime, dolomite, silicon dioxide, aluminium oxide and small quantities of sodium sulphate and sodium chloride. It is placed in a glass furnace and heating at a temperature of about 1675°C. The temperature is restricted to the quality of the furnace material and the glass composition. Instead of using pure chemicals in this process fairly low-priced materials such as sand, feldspar, trona be used.

I. MATERIALS

Cement

In this study, the Ordinary Portland cement (OPC) of grade 53 was used as per IS 4031-1988. It offers an advantage of greater speed in strength achievement. The physical and chemical properties of the cement as tabulated as follows.

Table 1 Physical Properties of Cement

<table>
<thead>
<tr>
<th>S.No</th>
<th>Properties</th>
<th>Relevant IS code</th>
<th>Observed values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Standard consistency</td>
<td>IS 4031(PART IV):1988</td>
<td>28 %</td>
</tr>
<tr>
<td>2</td>
<td>Initial setting time</td>
<td>IS 4031(PART IV):1988</td>
<td>44 minutes</td>
</tr>
<tr>
<td>3</td>
<td>Final setting time</td>
<td>IS 4031(PART IV):1988</td>
<td>693 minutes</td>
</tr>
<tr>
<td>4</td>
<td>Fineness</td>
<td>IS 4031(PART IV):1988</td>
<td>0 %</td>
</tr>
<tr>
<td>5</td>
<td>Specific gravity</td>
<td>IS 4031(PART II):1988</td>
<td>3.12</td>
</tr>
</tbody>
</table>

Table 2 Chemical Properties of Cement

<table>
<thead>
<tr>
<th>S.No</th>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CaO</td>
<td>63.41</td>
</tr>
<tr>
<td>2</td>
<td>SiO₂</td>
<td>21.22</td>
</tr>
<tr>
<td>3</td>
<td>Al₂O₃</td>
<td>6.27</td>
</tr>
<tr>
<td>4</td>
<td>FeO₃</td>
<td>3.08</td>
</tr>
<tr>
<td>5</td>
<td>MgO</td>
<td>1.85</td>
</tr>
<tr>
<td>7</td>
<td>Na₂O+K₂O</td>
<td>2.02</td>
</tr>
</tbody>
</table>

Glass

Two types of glass powders were used in this study were Soda lime glass powder and Boron glass powder. Both powders are obtained by crushing and grinding the glasses. The powders were sieved under the 75μ sieve. These powders have different in physical and chemical properties. The chemical composition of the two types of glass powders and the cement are tabulated in table 3.

Table 3 Properties of soda lime and boron glass powder

<table>
<thead>
<tr>
<th>S.no</th>
<th>Constituents</th>
<th>Glass powder</th>
<th>Soda lime</th>
<th>Boron</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Silica (SiO₂)</td>
<td></td>
<td>76.39</td>
<td>81.30</td>
</tr>
<tr>
<td>2</td>
<td>Alumina (Al₂O₃)</td>
<td></td>
<td>2.19</td>
<td>2.22</td>
</tr>
</tbody>
</table>

Fine aggregate

Locally available river sand is used for this study. The sand is washed thoroughly and sieved in the 600µ sieve. The properties of fine aggregate are monitored as per IS 2386-1963 (PART I, II, IV) / IS 383-1970 and the obtained results are represented in table 4.

Table 4 Properties of fine aggregate

<table>
<thead>
<tr>
<th>S.no</th>
<th>Properties</th>
<th>Relevant IS code</th>
<th>Observed values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fineness modulus</td>
<td>IS 383-1970</td>
<td>2.27</td>
</tr>
<tr>
<td>2</td>
<td>Specific gravity</td>
<td>IS 2386(PART II):1963</td>
<td>6.25</td>
</tr>
<tr>
<td>3</td>
<td>Water absorption</td>
<td>IS 2386(PART I):1963</td>
<td>0.7</td>
</tr>
<tr>
<td>4</td>
<td>Bulk density</td>
<td>IS 2386(PART II):1963</td>
<td>1736 kg/m³</td>
</tr>
</tbody>
</table>

Water

Water is to be used for mixing and curing should be free from impurities and harmful materials. Portable water is generally preferable for producing excellent concrete. The pH value of the water to be used should be greater than 6. In the present study, the water is collected from the campus, and it is used for both mixing and curing.

II. EXPERIMENTAL STUDY

Experiments were conducted on mortar cubes by replacing the waste glass powder of particle size 75μm in the place of cement.

Sample preparation

The fresh mortar mix samples were prepared by replacing the waste glass powder in the place of cement by 0%, 2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18%, and 20%.

Table 5 Properties of-soda lime and boron glass powder

<table>
<thead>
<tr>
<th>S.No</th>
<th>Constituents</th>
<th>Glass powder</th>
<th>Soda lime</th>
<th>Boron</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Calcium oxide  (CaO)</td>
<td>6.05</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Iron oxide (Fe₂O₃)</td>
<td>1.08</td>
<td>0.94</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Magnesium oxide (MgO)</td>
<td>1.18</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Sodium oxide and potassium oxide (Na₂O+K₂O)</td>
<td>11.70</td>
<td>3.55</td>
<td></td>
</tr>
</tbody>
</table>
both soda lime and boron glass powders.

III. RESULT AND DISCUSSIONS

Compressive Strength

The following graph fig.1 represents the Compressive strength for soda lime powder for 7 days and 28 days respectively.

![Graph of Compressive Strength for Soda Lime Powder](image)

**Fig. 1 Compressive strength of soda glass powder added cubes**

The fig.2 represents the Compressive strength for Boron glass powder for 7 days and 28 days respectively.

![Graph of Compressive Strength for Boron Glass Powder](image)

**Fig. 2 Compressive strength of Boron glass powder added cubes**

From the above graphs, it clearly is shown that the strength is improved when compared to conventional mix and it showed the optimum percentage of 10% and 8% of replacing soda lime and boron glass powder respectively in the place of cement.

Sorptivity test

This test is conducted to quantify the rate of ingress of water through the mortar under capillary action. The specimen is cast by using the mould of size 100 mm dia and 50 mm high. After casting the specimen, which was oven dried at 110°C for 24 hours. Then it is placed under the water not more than 5 mm above the base of the specimen and the remaining portion of the specimen is sealed or coated. Then the specimen is weighed after 30 minutes to measure the quantity of water observed by the specimen. It is determined by using the relation,

\[
S = \frac{I}{t^{1/2}}
\]

\[
I = \Delta_w / A_d
\]

\[
\Delta_w = \text{Weight deviation} = W_2 - W_1
\]

\[
W_1 = \text{specimen dry weight (gm)}
\]

\[
W_2 = \text{Weight of specimen after capillary suction formed (gm)}.
\]

![Sorptivity Test Graph](image)

**Fig. 3 Sorptivity of soda glass powder added cubes for 28 days**

**Fig. 4 Sorptivity of boron glass powder added cubes for 28 days**

Carbonation

Carbonation is caused by atmosphere’s CO₂, has the effect of reducing the pH. This test is carried out to evaluate the portion of affected concrete because of the CO₂ from atmosphere and moisture and thereby depletion of concrete alkalinity level.

It was used 0.2% phenolphthalein as pH indication of concrete. The change of pink color indicates the concrete is not affected by carbonation and the no changes in color take place; it is suggestive of carbonation-affected concrete.

![Carbonation Test Graph](image)

**Fig. 4 Carbonation of Glass powder added cubes**

IV. CONCLUSION
The proposed approach explained the utilization of glass powder produced from the industrial wastes as a fractional substitute for cement in cement sand mortar paste. A 10% and 8% of cement substituted by soda lime and boron glass powder respectively were established to be best one. Sorptivity test also proves that water absorption is less up to 10% and it gradually increased in both Soda lime and Boron glass powders. Carbonation test also proves that the mortar prepared by using soda lime and boron glass partially in the place of cement free from carbonation effect. The result from this study, the utilization of waste glass powder as a fractional substitute in cement material shows good cementitious property and also gives high strength and durability.

REFERENCES


AUTHORS PROFILE

Dr. N. Sudharsan received his B.E in Civil Engineering, from K.S.R. College of Engineering, India in 2006 and M.E in Structural Engineering from Government College of Technology, Coimbatore, Tamilnadu in 2008. He worked as Assistant Engineering Manager in L & T ECC Division, Chennai from June 2008 to December 2010. He has received his Ph.D from Anna University, Chennai in 2017. He published a number of international journals in Scopus and U.G.C. approved list. He has attended Several International and national Conference. He Received “Best Faculty Award” on the occasion of GRABS Awards -2018 on 8th April 2018 by GRABS Educational Charitable Trust, Chennai and Gold medal Award for “Young Scientist in Structural Engineering” on the occasion of 3rd Annual Research Meet on 11th November 2017, Chennai by Venus International, Chennai. His area of research is waste utilization in building materials.

S. Saravanaganesh completed his B.E (Civil) and M.E., (Structural). from K. S. Rangasamy College of Tech in 2013 and K.S.R. College of Engg in 2015 respectively. He published a number of national and international conference papers and journals also he participated several conferences, workshop, seminar and Faculty development Programme.