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Glass Powder – A Partial Replacement for Cement?

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Abstract

The research work is (was done to) determination of the effect of the use of 'Glass Powder' as a replacement of cement to assess the pozzolanic nature of fine glass powder when mixed in concrete and compare the difference in performance with other pozzolanic materials are mixed in concrete like silica fume and fly ash.

The present study shows that waste glass, if ground finer than 600µm shows a pozzolanic behaviour. It reacts with lime at early stage of hydration forming extra CSH gel thereby forming denser cement matrix. Thus early consumption of alkalis by glass particles helps in the reduction of alkali-silica reaction hence enhancing the durability of concrete.

Numbers of test were conducted to study the effect of 5%, 10% and 15% replacement of cement by glass powder on compressive strength and durability. The particle size effect was evaluated by using glass powder of size 600µm-100µm.The results showed that the maximum increase in strength of concrete occurred when 10% replacement was done with glass powder.

Introduction

Concrete is the 2nd largest of the most widely used materials; but there are environmental issues associated with its use which are needed to be taken under consideration and cannot be ignored. Concrete production uses large quantities of natural resources as aggregates and contributes to the release of carbon dioxide during the production of cement.

One ton of carbon dioxide is released into the atmosphere for the production of one ton of cement , which is approximately 7% of the world's total yearly production of CO2 (Meyer, 2004). Concrete is a common construction material in India and its production causes the same environmental concerns as that of regular concrete.

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In recent years, there has been an increasing incentive to minimize the environmental effect of the construction industry through programs such as the Leadership in Energy and Environmental Design (LEED) Green Building Rating System, which rewards points for sustainable construction practices (CaGBC, 2009). Greater sustainability of the construction industry can be achieved if a portion of the virgin aggregate or cement is replaced with waste materials.

Significant experimental work were performed on the use of recycled concrete aggregate to replace virgin aggregate and on the use of pozzolanic materials to be used as partial replacement of cement in concrete, such as fly ash, silica fume and ground granulated blast furnace slag.

Due to the successful implementation of these waste materials into regular concrete there is increased desire to find new post-consumer materials which can be used as a partial replacement for cement. The experimental work presented in this research looks at the use of glass, as an eco-friendly material to replace cement in the production of concrete masonry blocks.

Objective

The objective of the research is to study the effect of the use of 'Glass Powder' as a replacement of cement to assess the pozzolanic nature of fine glass powder when mixed in concrete and to know the extent to which glass powder can replace cement.

Characteristics of Material used in Experimental Investigation

- ***Cement*** –
  - The cement used for this experiment is Ultratech Ordinary Portland Cement of Grade44.
  - It has confirmed to the requirements of Indian standard specification IS: 1489 (Part-I) 1991.

- ***Glass Powder***–
  - Glass is an amorphous (non-crystalline) that in essence, a super cooled liquid and not a solid.
  - Glass can be made with excellent homogeneity in a variety of forms and sizes from small fibres to meter-sizes pieces.
  - Primarily glass is made up of sand, soda ash, limestone and other additives (Iron, Chromium, Alumina, Lead and Cobalt).
  - Glass has been used as aggregates in construction of road, building and masonry materials

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- ***Source of Glass***–

  - Sand is filtered through three different size screens having three different sizes.
  - The finest sand makes the finest glass the largest sand makes the strongest glass.
  - Sand is melted in crucible to make glass.

- ***Source of Waste Glass***–

  - Glass food and beverages container.
  - Window repair shops
  - Glass decorative items
  - Old tube lights, electric bulbs
  - Glass polishing and glass window and door manufacturing shop

- ***Applications & Properties of Glass***–

  - Glass is a uniform amorphous solid material, which is generally produced when the viscous molten material cools very rapidly to below its glass transition temperature, without giving sufficient time for a regular crystal attice to form.
  - The most familiar form of glass is the silica-based material used for windows, containers and decorative objects.
  - Glass falls in the category of biologically inactive material that can be formed with very smooth and impervious surfaces.

Type	WGP	OPC	SF	FA
SiO_2	72.61	20.33	89.75	47.80
Al_2O_3	1.38	4.65	0.14	23.40
Na_2O	12.85	0.24	0.19	0.72
K_2O	0.43	0.59	0.34	1.70
Cao	11.42	61.78	0.38	3.36
MgO	0.79	3.29	0.05	0.81

(Comparison of Waste Glass Powder with Cement & other Pozzolans)

- ***Aggregate*** –

  - Natural river sand of maximum size 4.75 mm was used as fine aggregate.
  - Crushed stone of maximum size 20 mm was used as coarse aggregate.

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Experimental Investigations

1) *Preparation of Glass Powder*–

- The entire glass sample collected is broken into pieces and then it is sieved through300 micron sieve and glass powder passing through the 600 micron sieve is considered for this test.

2) *Casting of Specimen* –

- There were four type of mix considered; of which One control mixture S-1 (withoutglass powder) was designed according to Indian Standard Specification IS: 10262(1999) (1: 1: 2, W/C ratio = 0.42) to achieve 28 days strength 25 MPa.
- The other three concrete mixes were made by replacing the cement with 5%, 10% and 15% of glass powder weight.
- The details mixture proportions are given in Table.

Mix Identity	Mix Proportion
S1	100% Cement
S2	95% Cement + 5% WGP
S3	90% Cement + 10% WGP
S4	85% Cement + 15% WGP

3) *Procedure*–

- The control mix was M25 designed according to the design mix in the IS: 10262(1982).
- For all other mixes the proportions of sand, water and aggregates remained constant.
- With various proportions of cement was replaced by glass powder.
- All replacement was carried out by volume. Normal tap water was used for casting and curing.
- The test specimen was cast in steel moulds of steel of standard dimensions i.e. 150X150X150 mmand is vibrated.
- All specimens were removed from moulds after 24 hours.
- Tests carried out for compressive strength.

4) *Experimental Setup*–

- The waste glass is collected from various places such as construction sites, industries, etc.

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- Then it is crushed to a size fine enough to achieve its pozzolanicbehaviour.
- Cement is now partially replaced by its weight by glass powder at varying amount such as 5%, 10% and 15%.
- Now, 2 cubes such as two specimens for each combination – is to be casted for the whole and cured at room temperature.
- At the end of curing period, each specimen is tested for compressive strength and theaverage is recorded.

Results

1) Compressive strength of Conventional Concrete in 3 days

Dimension (mm)	Load KN/mm^2	Strength (N/mm^2)
150 x 150 x 150	182	8.1
150 x 150 x 150	192	8.5

The compressive strength of Conventional Concrete Cubes = **8.3 N/mm^2**

2) Compressive strength of Concrete with 5% Glass Powder in 3 days

Dimension (mm)	Load KN/mm^2	Strength (N/mm^2)
150 x 150 x 150	250	11.097
150 x 150 x 150	262.17	11.653

The compressive strength of Concrete cubes with 5% Glass Powder= **11.38 N/mm^2**

3) Compressive strength of Concrete with 10% Glass Powder in 3 days

Dimension (mm)	Load KN/mm^2	Strength (N/mm^2)
150 x 150 x 150	277.18	12.95
150 x 150 x 150	262.17	12.95

The compressive strength of Concrete cubes with 10% Glass Powder = **12.643 N/mm^2**

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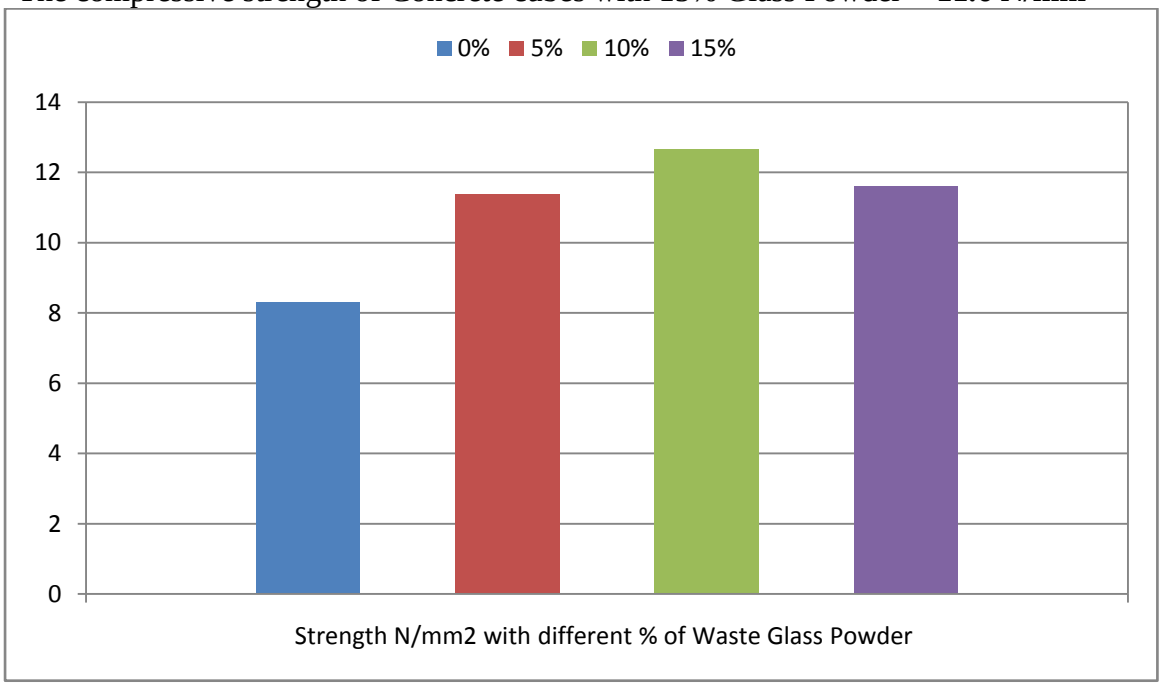
4) Compressive strength of Concrete with 15% Glass Powder in 3 days

Dimension (mm)	Load KN/mm^2	Strength (N/mm^2)
150 x 150 x 150	254.15	11.32
150 x 150 x 150	266.73	11.88

The compressive strength of Concrete cubes with 15% Glass Powder = **11.6 N/mm^2**



Conclusions

From the test results it was concluded that:

- Conventional concrete shows a 3days compressive strength as 9 N/mm2.
- 5% replacement of glass powder in cement will increases the compressive strength by 37% in 3 days.
- 10%replacement of glass powder incement will increases the compressive strength by 52.6% in 3 days.
- 15% replacement of glass powder in cement will increases the compressive strength by 39.8% in 3 days.

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We will get most positive result i.e. maximum strength at 10% replacement, further increase in glass powder concentration will decrease the strength of concrete.

Future Research

1) Determine the effect of glass powder on concrete with the replacement of combination of coarse and fine aggregate.
2) Replacement of cement with glass powder in different water cement ratio.
3) In the present study the ordinary Portland cement was used. Further its mechanical properties can be compared by using different cement.
4) Study on replacing coarse aggregate with glass pieces can be carried out.
5) Tests for chemical properties, tensile strength, slump loss, workability & many others can be done.
6) Glass fibre can be introduced in concrete.

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