An Experimental Investigation on Partial Replacement of Cement by Glass Powder in Concrete

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Abstract - *Non-degradable wastes has been a major issue now in the 21st century as more and more of these wastes are piling up in our world today and being disposed of in landfill areas without being recycled. These wastes take up a very long period of time to decompose. Because of this problem, researches have been done to fully utilize these wastes as the final products for construction materials such as concrete. Increasing emphasis on the use of sustainable materials in construction has led to the use of variety of cement replacement materials in concrete. One such material, with an underutilized potential is glass powder, given the vast amounts of glass that is present in the solid waste stream of any major city. This paper summarizes information on the mechanical & durability properties of cementitious systems containing a fine glass powder. It is shown on this paper that concrete mixtures could be proportioned to achieve similar or higher compressive strengths. A better understanding of the performance of a non-standard cement replacement material such as glass powder could lead to increased usage of this material, consequently contributing to sustainability.*

Key Words: Glass powder, Fine aggregate, Coarse aggregate, Compressive strength, Split tensile strength, Flexural strength.

1. INTRODUCTION

The waste glass generated in the US in 2008 was about 12.2 million tons, 77% of which was disposed of in landfills. The bulk of waste glass can be collected in mixed colours, and has limited markets. It is realized that mixed-colour waste glass gives desired chemical composition and reactivity for use as a supplementary cementitious material (SCM) for enhancing the chemical stability, pore system characteristics (pore refinement, discontinuity, and pore filling), moisture resistance and durability of concrete. To achieve these benefits, waste glass needs to be milled to micro scale particle size for accelerating its beneficial chemical reactions in concrete. These beneficial effects of milled waste glass can enhance the residual cement (which forms the interface in new concrete) occurring on the surface of recycled aggregates and are thus expected to improve the performance characteristics of recycled aggregate concrete. Earlier researchers have investigated the use of glass in normal Concrete. They observed that the long term compressive strength of concrete containing glass was higher than that of control mix. A glass is defined as an inorganic product of fusion which has been cooled to a rigid condition without crystallization. The glass being mainly a silica-based material in amorphous form can be used in cement-based applications. The main concerns for the use of crushed glasses as aggregates for Portland cement concrete are the expansion and cracking caused by the glass aggregates due to alkali silica reaction. Due its silica content, ground glass is considered pozzolanic materials and as such can exhibit properties similar to other pozzolanic materials such as fly ash, metakaolin, slag and wheat husk ash. This paper reports the preliminary results of an experimental investigation on the use of glass powder to partially replace cement in concrete applications.

Although there is strength reaction in the presence of glass powder, however, glass powder can be used to replace 30% of the cement in a concrete mix with satisfactory strength development due to its pozzolanic reaction. Authors found that using glass in mortar applications caused more expansion compared with mortars without glass particles. This expansion can in some cases cause deterioration to the material.

Efforts have been made in the concrete industry to use waste glass as partial replacement of coarse or fine aggregates. However, due to the strong reaction between the alkali in cement and the reactive silica in glass, studies of the use of glass in concrete as part of the coarse aggregate were not always satisfactory due of the marked strength reduction and simultaneous excessive expansion

It was found that if the glass was ground to a particle size of 300 μ or smaller, the alkali-silica reaction (ASR) induced expansion could be reduced. In fact, data reported in the literature show that if the waste glass is finely ground, under 150 μ, this effect does not occur and mortar durability is guaranteed. It also well know that typical pozzolanic materials might features high silica content, an amorphous structure and have a large surface area.

One of the possible channels for the recycling of mixed glass is cement-based materials, but most of existing studies recommend its use only as fine powders. Fine particles of glass usually present pozzolanic activity beneficial to the concrete, while coarse particles are usually deleterious to concrete due to alkali-silica reaction (ASR). Although the use of fine particles is an effective solution for glass in concrete, the crushing of glass represents a significant cost since several hours of treatment are needed to obtain an efficient fineness of glass (almost equivalent to cement). The aim of this study is to recycle glass in cement-based materials by combining fine and coarse glass particles, leading to a decrease in the crushing energy used. It is assumed that it is possible to take advantage of the beneficial activity of fine particles to counteract the deleterious effect of coarse grains.

The use of partial cement replacement material obtained from waste or by product streams of other industries is favoured in concrete production due to their advantages in improving some or all the properties of concrete. While the benefits of incorporating fly ash, ground granulated blast furnace slag, & silica fume in concrete are well known, the past few years have witnessed an increase in attention towards the use of finely divided glass powder as a partial cement replacement material. High contents of silica in glass make it a potentially pozzolanic material. This paper provides data on the mechanical & durability properties of cementatious systems containing a fine glass powder and compares them to systems containing same amounts of a class F fly ash as a cement replacement material. It covers several characteristics of cementatious systems with glass powder and compares them with fly ash system with an aim of providing information to the user that could help with wider application of glass powder in concrete.

Research studies on the use of waste glass in concrete have been reported. Crushed glass aggregates are being used in several decorative concrete applications, and there is reported literature on its use as coarse aggregate in conventional concretes and precast blocks. The fact that glass has a high silica content has led to laboratory studies on its feasibility as a raw material in cement manufacture. The use of finely divided glass powder as a cement replacement material has yielded positive results. Glass is amorphous with high silica content, thus making it potentially pozzolanic when the particle size is less than 75μm. Studies have also shown that finely ground glass does not contribute to alkali-silica reaction. Successful implementation of waste glass powder in concrete will provide a boost to the use of such non-conventional materials which are typically of local or regional origin.

1.1 Objectives of the study

This investigation looks at the partial replacement of cement by waste glass powder of size 150microns and 300microns separately in the concrete. Glass powder is replaced separately for both 150microns and 300microns for every 10%, 20%, 30% and 40%. These results are compared with nominal concrete (0% replacement of glass powder).

1.2 Advantages of glass powder

1) Waste glass, if ground finer than 150μ shows a pozzolanic behavior.
2) The smaller particle size of the glass powder has higher activity with lime resulting in higher compressive strength in the concrete mix.
3) Compared to fly ash concrete, finer glass powder concrete had slightly higher early strength as well as late strength.
4) Micro structural examination shows that glass powder produces a denser matrix which improves the durability property of concrete.
5) Glass waste is recognized to be increasing year by year in a large volume from shops, construction areas and factories hence it can be use effectively.
6) This waste storage of in construction section is advantageous in construction cost decreases.

1.3 Dis-advantages glass powder

1) Usage of glass powder is economical only when used in high quantity, for small scale construction it will costly.
2) Since glass is non bio degrable material it is very effective to the workers' health.
3) If grinding is done by manually precautions measures to be taken otherwise it will leads danger.
4) Finely grounded glass powder which is light in weight can easily mix up with the air leads cause respiratory problems for the workers.
5) It reduces flexural strength of the concrete.

2. REVIEW OF LITERATURE

1) "Value-added utilization of waste glass in concrete"

This paper shows that there is 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 in concrete would prevent expansive ASR in the presence of A large proportion of the post-consumer glass is recycled into the packaging stream again, and some smaller proportion is used for a variety of purposes including concrete aggregate. However, a significant proportion which does not meet the strict criteria for packaging glass is sent to landfill, taking the space that could be allocated to more urgent uses. Glass is unstable in the alkaline environment of concrete and could cause deleterious alkali-silica reaction problems. This property has been used to advantage by grinding it into a fine glass powder (GLP) for incorporation into concrete as a Pozzolonic material. In laboratory experiments it can suppress the alkali-reactivity of coarser glass particles, as well as that of natural reactive aggregates. It undergoes beneficial Pozzolonic reactions in the concrete and could replace up to 30% of cement in some concrete mixes with satisfactory strength development. The drying shrinkage of the concrete containing GLP was acceptable.

2) "Experimental investigation of waste glass powder as partial replacement of cement in concrete"

This paper entitled that waste glass powders have been used as replacements to the concrete ingredient i.e. cement and the mechanical properties like compressive strength are measured. Also we were studied the size effect of glass powder on strength of concrete. For checking strength effect of replacement of cement by glass powder, the cement is replaced at 10%, 20% and 30%. For study of size effect of glass powder the powder is divided in to two grades one is glass powder having size less than 90 micron and another is glass powder having particle size ranges from 90 micron to 150 micron. Concrete is a construction material composed of cement, aggregates (fine and coarse aggregates) water and admixtures. Today many researches are ongoing into the use of Portland cement replacements, using many waste materials like pulverized fly ash (PFA) and ground granulated blast furnace slag (GGBS). Like PFA and GGBS a waste glass powder (GLP) is also used as a binder with partial replacement of cement which take some part of reaction at the time of hydration, also it is act as a filler material. It is found from study, Initial strength gain is very less due to addition of GLP on 7th day but it increases on the 28th day. It is found that 20% addition of GLP gives higher strength. And also GLP size less than 90 micron is very effective in enhancement of strength.

3) "Studies on Glass Powder as Partial Replacement of Cement in Concrete Production".

Experiment were conducted on concrete prepared by partial replacement of cement by waste glass powder of particle size 75µm.The waste glass powder was replaced by 10%, 20%, 30% and 40% of the binder and the mix design was prepared. The physical and chemical characteristic was studied and the chemical components of the glass powder used in the concrete were also determined by XRF.

It was observed that with a 30% replacement of cement by amber waste glass content of particle size 75µm along with fly ash, the compressive strength of concrete increase 25% at 7 days and 35% when tested for 28 days strength (Pereira de Oliveira. L.A, J.P. castro – Gomes, P. Santos, 2008). This effect provide ample evidence that both fly ash and waste glass sand can be used together to produce concretes with relative high strength without any adverse reaction. Particle sizes under that threshold had no effect on length variations. Glass was ground to a particle size of 300 or smaller, the alkali reaction (ASR) induced expansion could be reduced.

4) "Glass powder utilization in concrete production"

This paper investigates the performance of concrete containing glass powders partial substitution of cement. Portland cement (PC) was partially replaced with 0-40% glass powder. Testing included ultrasonic pulse velocity, compressive strength and absorption. Specimens were cured in water at 20°C. The results indicate that the maximum strength of concrete occurs at around 10% glass powder. Beyond 10% glass powder the strength of concrete reduces and is lower than that of the control.

This paper concludes that using ground glass powder can reduce the use of cement and the associated energy demand and impact on air pollution and CO emission. The slump of concrete seems to increase with the increase in glass powder in the concrete mix. At 10% glass powder content compressive strength of concrete is higher than that of the control. Above 20% glass powder the strength substantially decreases.

5) "Strength characteristics of pre cast concrete blocks incorporating waste glass powder".

This paper deals with studies on the use of waste glass powder in concrete with moderate level of decrease in compressive strength at 28 days , is locally available, and its use as a cement replacement material presents an efficient waste management option, without compromising concrete performance.

Research studies on the use of waste glass in concrete has been reported. Glass concrete products can be categorized as commodity products and value –added products. On the other hand in case of the value added products the aesthetic potential of the glass is utilized because its attractiveness, the use of finely divided glass powder as a cement replacement material has yielded positive results. Glass is amorphous with high silica content, thus making it potentially pozzolonic when the particle size is less than 75 micron. Studies have also shown that finely ground glass does not contribute to alkali-silica reaction.

This paper concludes that the % decrease in 28 days strength of concrete by replacement of cement with 20% glass powder is only about 10%. It is clear that about 15% of cement replacement by fine glass powder provide the most optimal strength results because with this replacement the decrease in strength is less than 6%.

3. MATERIALS

CEMENT: In this investigation Dalmia cement which is of the Ordinary Portland cement of 43 grade was used throughout the work.

Table -1: Properties of cement

Sl. No	Test Conducted	Results Obtained	Requirement As Per Is 8112
1.	Normal Consistency	34%	Not specified
2.	Initial setting time	81min	Shall not be less than 30 min.

3.	Final setting time	463min	Shall not be more than 600 min.
4.	Compressive strength	55.2 MPa	Shall not be less than 53Mpa
5.	Specific gravity	3.15	3.15
6.	Soundness	5.1mm	Shall not be more than 100mm

Fig 1: Ordinary Portland cement

FINE AGGREGATE: The fine aggregate used in this investigation was clean river sand, whose max size is 4.75mm the sand was first air-dried in order to reduce considerably its moisture content.

Fig 2: Fine aggregate

COARSE AGGREGATE: Machine crushed blue granite stone angular in shape and rough surface was used as coarse aggregate of size 20mm passing through 16mm retained as per IS:2386-1963 recommendation.

Fig 3: Coarse aggregate

WATER: Water is an important ingredient of concrete and mortar as it is actively participates in the chemical reaction with cement. Since it helps to form strength, giving cement gel, the quantity and quality of water is to be looked very carefully.

GLASS POWDER: Waste glass available in local shops has been collected and made into glass powder. Glass waste is very hard material. Before adding glass powder in the concrete it has to be powdered to desired size less than 150microns and 300microns. Glass powder is added to the cement separately before dry mixing with other material.
The specific gravity of glass powder was found to be 2.69. This value is far less than 3.15 for Portland cement.

Fig 4: 150µm size glass powder

Fig 5: 300µm size glass powder

SUPER PLASTICIZER: 0.5% of super plasticizer by weight of cement is added to the mix concrete to increase the workability. The name of plasticizer used Conplast sp-430.

4. METHEDOLOGY

Experiments were conducted on concrete prepared by partial replacement of cement by waste glass powder of particle size 150µm and 300µm separately in the concrete. The waste glass powder was replaced by 10%, 20%, 30% and 40% of the binder and the mix design was prepared. These results are compared with nominal concrete (0% replacement of glass powder).

In this project various test are conducting on cement, fine aggregate and course aggregate as well as workability measurement are conducting by using different methods. The observation is tabulated and the results are calculated. Graphs are plotted if it necessary by using suitable readings.

The various parameters of the strength characteristic studied are

1. Compressive strength
2. Tensile strength
3. Flexural strength

4.1 COMPRESSIVE STRENGTH TEST

Specimens of dimensions 150x150x150mm were prepared. They are tested on 2000KN capacity compression testing machine as per IS 516-1959.

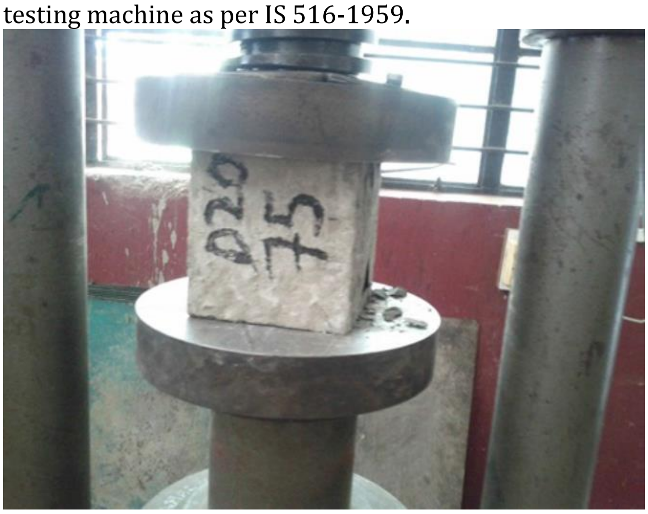

Fig 6: Compressive strength test

The compressive strength is calculated by using the equation,

$$F= P/A \text{---------} 1$$

Where,

F= Compressive strength of the specimen (in MPa).
P= Maximum load applied to the specimen (in N).
A= Cross sectional area of the specimen (in mm2) = 22500 mm2

TENSILE STRENGTH TEST

Cylindrical specimens of diameter 150mm and length 3000mm were prepared. Tension test was carried out on 2000 KN capacity compression testing machine as per IS 5816-1999.

Fig 7: Tensile strength test

The tensile strength is calculated using the equation,

$$F = 2P/ (\pi D L) \text{---------} 2$$

Where,

F = Tensile strength of concrete (in MPa).
P = Load at failure (in N).
L = Length of the cylindrical specimen (in mm).
D = Diameter of the cylindrical specimen (in mm).

FLEXURAL STRENGTH TEST

Beam specimens of dimensions 100x100x500mm were prepared. During testing two point loading was adopted on an effective span of 400mm as per IS 516-1959.

Fig 8: Flexural strength test

Flexural strength is calculated using the equation:

$$F= PL/ (bd^2) \text{----------} 3$$

Where,

F= Flexural strength of concrete (in MPa).
P= Failure load (in N).
L= Effective span of the beam (400mm).
b= Breadth of the beam (100mm).

5. EXPERIMENTAL RESULTS

Table-2: Compressive Strength Test Results

Sl No	% of Glass Powder	Size of Glass Powder	No, of Moulds	Mean Strength In N/mm²
1	0%		3	24.70
2	10%	<150µ	3	25.72
		<300µ	3	23.544
3	20%	<150µ	3	26.14
		<300µ	3	22.962
4	30%	<150µ	3	28.194
		<300µ	3	20.78
5	40%	<150µ	3	26.012
		<300µ	3	18.166

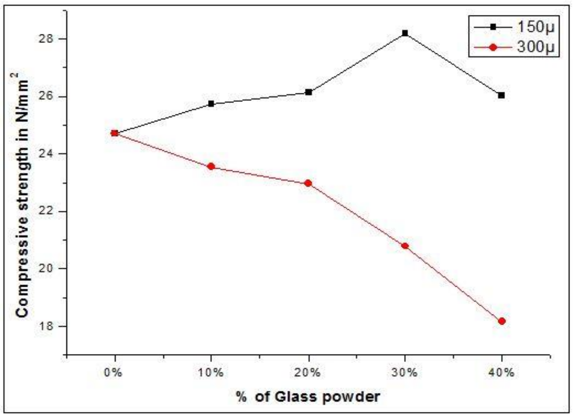

Chart-1: Compressive strength of concrete

Table-3: Split Tensile Strength Test Results

Sl No	% of Glass Powder	Size of Glass Powder	No, of Moulds	Mean Strength In N/mm²
1	0%		3	1.98
2	10%	<150µ	3	2.03
		<300µ	3	2.21
3	20%	<150µ	3	2.12
		<300µ	3	2.03
4	30%	<150µ	3	2.26
		<300µ	3	1.90
5	40%	<150µ	3	1.56
		<300µ	3	1.48

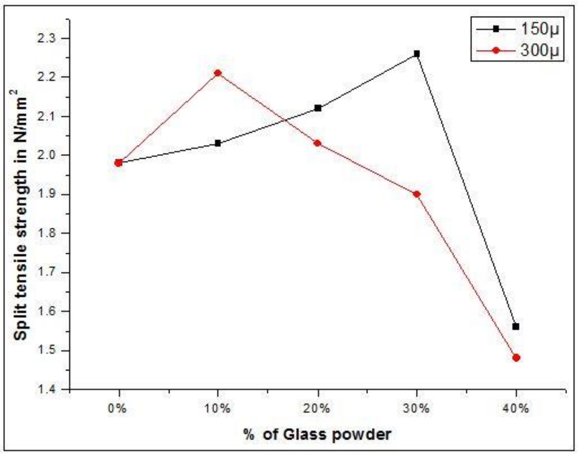

Chart-2: Split tensile strength of concrete

Table-3: Flexural Strength Test Results

Sl No	% of Glass Powder	Size of Glass Powder	No, of Moulds	Mean Strength In N/mm²
1	0%		3	6.94
2	10%	<150µ	3	6.98
		<300µ	3	6.95
3	20%	<150µ	3	7.02
		<300µ	3	5.40
4	30%	<150µ	3	6.24
		<300µ	3	6.20
5	40%	<150µ	3	5.34
		<300µ	3	4.85

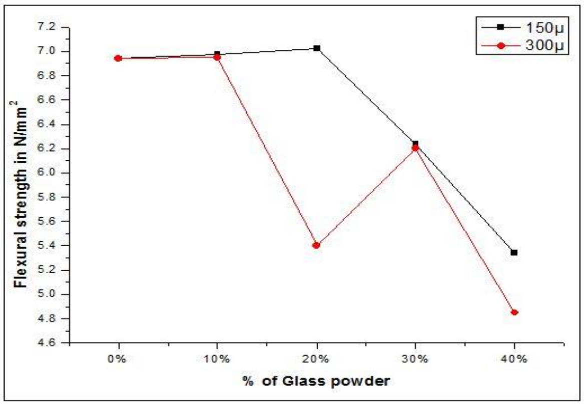

Chart-3: Flexural strength of concrete

6. CONCLUSIONS

1) Increasing the amount of glass above 30% in mortar causes a general decrease of compressive strength,
2) Average Compressive strength of the concrete containing Glass powder less than 150µ size will increases up to 30% replacement of cement.
3) Average Compressive strength of concrete containing Glass powder less than 300µ size will gradually decrease.
4) Average Tensile strength of the concrete containing Glass powder less than 150µ size will increases up to 30% replacement of cement.
5) Average Tensile strength of the concrete containing Glass powder less than 300µ size will decreases gradually up to 30% replacement of cement.
6) Average Flexure strength of the concrete containing Glass powder of size <150µ and <300µ will be decreased for any % replacement of cement

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BIOGRAPHIES

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