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EXPERIMENTAL INVESTIGATION OF WASTE GLASS POWDER AS PARTIAL REPLACEMENT OF CEMENT IN CONCRETE

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Abstract:

Glass is used in many forms in day-to-day life. It has limited life span and after use it is either stock piled or sent to landfills. Since glass is non-biodegradable, landfills do not provide an environment friendly solution. Hence, there is strong need to utilize waste glasses. Many efforts have been made to use waste glass in concrete industry as a replacement of coarse aggregate, fine aggregate and cement. Its performance as a coarse aggregate replacement has been found to be non-satisfactory because of strength regression and expansion due to alkali-silica reaction. The research shows that there is strength loss due to fine aggregate substitution also.In this project we are going to replace the cement partially using glass powder which is rich in silica. Therefore, we have planned to prepare some numbers of cubes, using glass powder at various proportions like 0%, 10%, 20%, and 30%and going to test them for its compressive strength. The casted specimens will be tested for its strength. We have also planned to prepare some numbers of cubes using conventional concrete. From the test results, we are going to compare the behavior of glass powder concrete with conventional concrete. In this work we are going to use waste glasses, so the cost will be comparatively low when compared with normal concrete.

Keywords — **Waste Glass powder, Fine aggregate, Coarse aggregate, Compressive strength, Split tensile strength, Flexural strength.**

I. INTRODUCTION

Today many researches are ongoing into the use of Portland cement replacements, using many waste materials and industrial by products, for example, pulverized fly ash (PFA) and ground granulated blast furnace slag (GGBS). Like PFA and GGBS, a glass powder (GLP) is also used as a binder with partial replacement of cement which takes some part of reaction at the time of hydration; also it is act as a filler material. The term glass comprises several chemical varieties including binary alkali silicate glass, boro-silicate glass, and ternary soda lime silicate glass. Partial replacement of cement with milled waste glass benefits the microstructure and stability of cementitious materials. A denser (less porous) and more homogeneous structure is produced when milled waste glass is used as partial replacement for cement, which benefits the resistance to moisture sorption and thus the long-term durability of cementitious materials.

Partial replacement of cement with milled waste glass also benefits the stability of cementitious materials when potentially deleterious reactions between cement hydrates and the reactive aggregates is a concern. Mixed-color waste glass, when milled to about the particle size of cement and used in concrete as replacement for about 20% of cement, improves the moisture barrier qualities, durability, and mechanical performance of 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 application. 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, and 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 μor 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 75um. 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 s in the concrete. Glass powder is replaced for both 150microns and 300microns for every 10%, 20% and 30%. These results are compared with nominal cement concrete (Zero replacement of waste glass powder).

1.2 Advantages of glass powder

1) Waste glasses, if ground finer than 150u shows a pozzolanic behavior.
2) The lesser 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 has had slightly higher early strength as well as late strength.
4) Micro structural inspection shows that glass powder produces a denser matrix which improves the durability of concrete.
5) Glass waste is acknowledged to be increasing year by year in a large volume of construction areas and industries; hence it can be used very effectively.
6) This waste storage of in construction section advantageous in construction cost decreases.

1.3 Dis-advantages glass powder

1) Usage of glass powder is reasonable cost, when used in high quantity in concrete and for small construction it will be expensive.
2) Since glass is non bio-degradable material it is very harmful to the workmen's health.
3) If grinding is done by manually precautions measures to be taken unless otherwise it will be very hazard.
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) E.M. Negim, H.S. Sohl, (2012) Studied 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. The cement is partially replaced with 10%, 20%, 30% and 40% glass powder. The slump value for concretes with varying amounts of glass powder as partial replacement of cement. There is a systematic increase in slump as the glass powder in the mix increases. The slump ranged from around 40mm for the reference mix to 160mm at 40% glass powder. 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 the compressive strength of concrete is higher than that of the control. Concluded that, above 20% glass powder the strength substantially decreases.

2) K. Ramkumar and R. Ramya, (2013), Experimental Study on Replacement of Cement by Glass Powder and concluded that the Increment in strength was observed with rise in percentage if glass powder up to 10%. Ordinary Portland cement was used throughout the investigation. River sand form the river confirming to zone III was used as fine aggregate (F.A). Specific gravity of fine aggregate was 2.65. Broken stones form the local quarry was used as coarse aggregate (C.A). Specific gravity of coarse aggregate was 2.69. The glasses were grounded to powder to make glass powder(GP) of size that 100% passes through 90 micron sieve and 50 % retained in 75 micron sieve. The Specific gravity of glass powder is 2.39. Four different mix proportions were chosen for this study. A plane concrete with water cement ratio of 0.45 was used a control mix. In other three mixes 5%, 10%, 15% of cement is replaced by glass powder in weight. There is a small increase in the water demand when

the replacement percentage was increased to 10 % and above. This must be due to the increased surface area of finer glass particles; there was increase in the water demand. The initial setting time was reduced by very little up to 10 % replacement of glass powder but at 15 % replacement there was a 10 % reduction in the setting time. The workability was reduced due to the replacement and it reduced with increase in replacement, this is due to the increase in the surface area of the glass powder and also the angular shape of the glass particles. The compressive strength gain at various percentages of glass powder replacement at 7, 14 & 28th day. It can be reduction in the strength at the 15 % replacement. The flexural strength improves considerably at 10 % replacement and there is a reduction in the strength at the 15 % replacement here also. It can be concluded that 10% replacement of cement by glass powder is the best proportion.

3) Prof.A.C.Saoji, (2013)"Experimental investigation of waste glass powder as the partial replacement of cement in concrete, he concluded that, higher strength was obtained when 20% cement was replaced by waste glass powder. M30 grade of concrete was used and ordinary Portland cement type (43 grades) was used throughout the work. The fine aggregates were used in with maximum size 4.75 mm diameter and the cement was replacement by glass powder (GLP) having particle size less than 90 µm was used. The replacement of cement by 5% to 40% at interval of 5% each. Chemical admixtures are not used in this experimental work and the mix proportion of 1:1:2 with water cement ratio of 0.48. Increment in strength was observed with rise in percentage if glass powder up to 20%. Highest percentage increases was about 30% in compressive strength. Peak percentage increases was about 22% at 20% replacement by GLP in flexure strength. Cement replaced beyond 20% by GLP shows decrement in compressive strength. Workability of concrete decreases that as percentage of glass powder increases. Slump value of experiment's concrete ranges from 80 to 100 mm. he concluded that strength point of view, replacement of glass powder shows positive results.

4) DHANARAJ MOHAN PATIL," (2013),he concluded that the glass 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. 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. M30 grade of concrete was used and ordinary Portland cement type (43 grades) was used throughout the work. For fine aggregates natural sand is provided with maximum size of 4.75 mm. Coarse aggregates are used with size between 20mm-4.75mm. In this paper, total of four groups of concrete mixes were prepared in laboratory. First group was cement replacement by fine glass powder (GLP) particle size less than 90 microns with replacement from 10% to 30%. Second group was cement replacement by fine glass powder (GLP) particle size from 90 micron to 150 micron with replacement from 10% to 30%. Third and fourth were normal concrete with cement and normal concrete with cement used only 90% to 70% that of design. At the level of 20% replacement of cement by glass powder meets maximum strength as compare to that of normal concrete and other percentage of replacement of cement.

5) Sunny .O, 2013**,**He explained 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.Waste glass as partial substitution for Portland cement in amounts of 5%, 20% and 30% were investigated. The waste glass material used was obtained solely from green glass cullet ground to a fineness of 300 µm. As aggregate for producing mortars, natural sand was used with maximum particle size 4.76 mm, a particle density of 2450 kg/m3 and Modulus of Fineness of 2.97. The water cement ratio was 1: 3:0.5 for all the mortar mixes. The control mixture contained the same material mix ratios, with no replacement. In the remaining three, mortar mixtures, glass powder was incorporated as 10%, 20%, 30%, cement replacement respectively, with the fine aggregate

content and the water-cement ratio remaining constant. Water absorption of concrete is an important factor in classifying its durability. Generally concrete of low water absorption will afford better protection to reinforcement within it had noticed that glass by nature is an impermeable material, so it could be assumed that the presence of glass particles in concrete can reduce the permeability of the concrete mix. However the values obtained from this study suggest similar water absorption for the 100% PC mortar and that containing 10% glass replacement, while the mixtures with higher glass contents were clearly more absorbent. Increasing the amount of glass in mortar causes a general decrease of compressive strength, but the decrease becomes less evident with prolonged curing time. The particle size distribution of waste glass used was the key factor influencing the strength development.

3. MATERIALS

CEMENT:In this investigation Penna Cement which is of the OPC (Ordinary Portland Cement)of 43 grade was used entire this works.

TABLE 1
PROPERTIES OF CEMENT

Sl. No	Test Conducted	Result Obtained	Requirement- As per 1s 8112
1.	Normal Consistency	34%	Not specified
2.	Initial setting time	81min	Shall not be less than 30 min
3.	Final setting time	240 min	Shall not be more than 600 min.
4.	Compressive Strength	55.2 MPa	Shall not be less than 53Mpa
5.	Specific gravity	2.67	3.16
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 amajor ingredient of concrete and mortar as it is actively participates in the chemical reaction with cement. Since it helps to form strength, giving cement paste, the quantity and quality of water is to be looked very carefully.

GLASS POWDER: Water glass available in local market 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 than150microns and 300microns. Glass powder is added to the cement before dry mixing with other material. The specific

gravity of glass powder was found to be 2.6. This value is might be less than 3.15 for Ordinary 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 in the concrete. The waste glass powder was replaced by 10%, 20% and 30% of the binder and the mix design was prepared. These results are compared with nominal concrete (Zero Percentage replacement of glass powder).

In this project various tests 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 as follows

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 ..... 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) = 22500mm2

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: Tensile 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

S. No	Volume of glass powder(%)	Curing age	Compressive strength (N/mm^2)
1	0	7 days	14.42
		28 days	29.23
2	10	7 days	18.78
		28 days	31.85
3	20	7 days	15.78
		28 days	27.01
4	30	7 days	12.23
		28 days	22.52

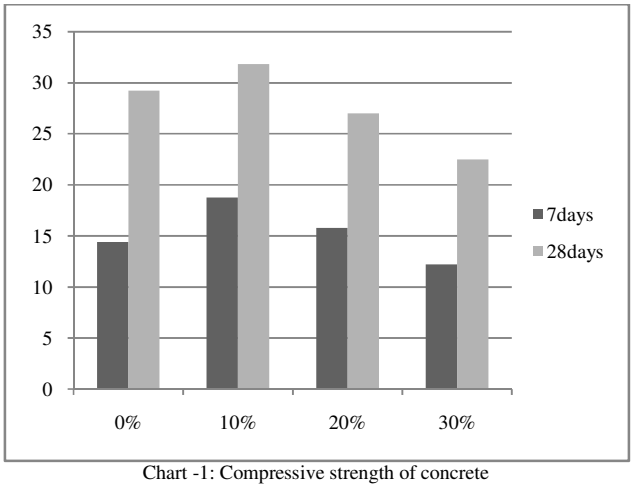

Chart -1: Compressive strength of concrete

Table – 3: Split Tensile Strength Test Results

Sl. No	Volume Of Glass Powder (%)	Curing Age	Split Tensile Strength (N/mm^2)
1	0	7 days	1.91
		28 days	2.61
2	10	7 days	2.55
		28 days	3.11
3	20	7 days	1.59
		28 days	2.33
4	30	7 days	1.16
		28 days	1.65

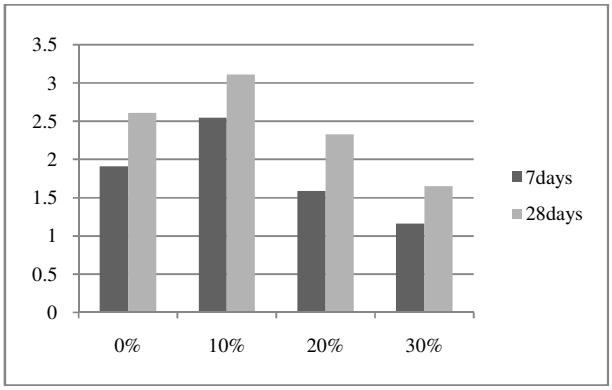

Chart -2: Split tensile strength of concrete

Table-4 Flexural Strength Test Results

Sl. No	Volume Of Glass Powder (%)	Curing Age	Flexural Strength (N/Mm2)
1	0	7 days	4.5
		28 days	7.25
2	10	7 days	5.2
		28 days	8.4
3	20	7 days	3.11
		28 days	6.25
4	30	7 days	2.65
		28 days	5.24

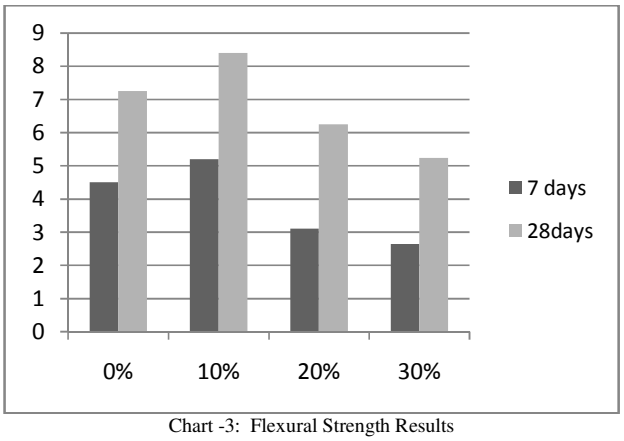

Chart -3: Flexural Strength Results

6. CONCLUSIONS

1) Glass Powder Concrete increases the compressive, tensile and flexural strength effectively, when compared with conventional concrete.
2) Average Compressive strength of the concrete containing will increases up to 10% replacement of cement in the concrete. Average Compressive strength of concrete containing Glass powder less than 300µ size will gradually decrease.
3) Workability of concrete decreases as percentage of glass powder increases.
4) 10% replacement of cement by glass powder is the best proportion for the concrete.
5) Cost of glass powder concrete per cubic meter is equivalent to that of conventional concrete with higher strength.

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BIOGRAPHIES

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