Investigation of Strength and Durability Parameters of Glass Powder Based 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 as these wastes take up a very long period of time to decompose. Hence, there is strong need to utilize waste glasses. 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 [15]. Because of this problem, researches have been done to fully utilize these wastes as the final products for construction materials such as concrete and mortar. As the emphasis placed on sustainable construction the scope of using waste or recycled materials in concrete is the concern of the construction industry and also the potential materials related advantages offer by the some of the waste materials. Utilization of waste glass produced by the community is a partial solution to environmental and ecological problems [12]. The present study was conducted to investigate the effect of using waste glass powder in concrete by partially replacing cement. Laboratory work was conducted to determine the performance of control sample**

and concrete with waste glass powder. The % replacement of cement was 10%, 20% and 30% in the M20 grade of concrete. The performance of these types of concrete was determined by the workability test, strength test i.e. compressive strength test, flexure strength and split tensile test. The durability of concrete is determined using water absorption test and sorptivity test. The specimens were tested at the ages of 7 and 28 days to study the strength and durability parameters. The results indicate that the concrete with using waste glass powder were able to increase the workability of concrete and also the compressive strength.

Keywords: Cement Replacement, Waste Glass, Glass Powder, Workability, Strength, Durability.

1. INTRODUCTION

Much of the glass produced in the World is discarded, stockpiled or land filled. This pattern has influenced environmental organizations to pressure the professional community to lower the amount of glass being discarded as well as find use to the non-recycled glass in new applications. The waste glass is one of the issues of environmental problem. The usage of glass has increased considerably in every industry, which has in essence, contributed to the increase of waste disposal. In addition, glass waste is considered as non-decaying material that pollutes the surrounding environment. Due to global warming the need to cut down energy has increased. The effect of global gases has impacted everyone on the planet and is a well-recognised concept. High levels of energy are needed to produce cement, which releases large amounts of carbon dioxide (CO_2) and also contributes to the green house gases. Atmospheric levels of carbon dioxide have risen by about 30 percent over the past 200 years [9]. In recent years there has been significant increase in the use of waste material in construction projects, due to the fact that they are not detrimental to the short or the long term properties of concrete and providing the platform for their effective disposal. Waste glass powder is one such material.

A glass is defined as an inorganic product of fusion which has been cooled to a rigid condition without crystallization. According to this definition, a glass is a non-crystalline material obtained by melt quenching process [4]. Wastes are produced by the industries irrespective of the nature of their products.

Disposal of wastes is a challenging task for industries. Industrial wastes like fly ash, silica fume, blast furnace slag and other wastes like plastics, glass and agricultural wastes are causing environmental pollution. The concrete industry to some extent is making use of these industrial wastes in the production of concrete. Generally, wastes like fly ash, silica fume and blast furnace slag in concrete act as pozzolana and replace a part of cement. Pozzolanic reaction adds to the strength of concrete and also results in saving of cement. Waste glass when ground to a very fine powder shows pozzolanic properties as it contains high

SiO_2 and therefore to some extent can replace cement in concrete and contribute in strength development [10]. Glass is a widely used product throughout the world; it is versatile, durable and reliable. The uses of glass ranges drastically, it is used by the electronic industry in the making of computer and television screens; by the construction industry in the shape of windows and mirrors; by the medical industry in the making of medical equipment and most importantly by the food and beverage industry to make millions of packaging bottles. As a result, industry has made of glass a marketable good, as glass production keeps increasing throughout the United States and the world. Glass is an environmentally friendly material, as it can be recycled many times and used in many applications. It is not uncommon throughout the world to have glass products that are made up of nearly 50% recycled material due to the fact that it is one of the few materials that can be recycled many times without altering its chemical properties or composition. Glass containers are often reused in bottling and depending on its color (green, amber and clear) can also be crushed and reused in the making of new glass products.

The recycling of glass starts by melting a mixture containing materials such as: soda ash, silica, calcium carbonate ($CaCO_3$), and recycled glass pieces. This blend is then heated to very high temperatures where they melt, followed by a rapid cooling process that effectively creates the crystallizations glass it is often associated with. After production, the glass is used and often returned to be set into production of new glass. A major concern for using waste glass in concrete is the alkali-silica reaction (ASR) that takes place between the alkalis in cement and the reactive silica in glass. This reaction can be detrimental to the stability of concrete. Recent studies have shown that there are several approaches that can effectively control the expansion of ASR due to glass aggregate.

II EXPERIMENTAL INVESTIGATION

Experiments were conducted on concrete prepared by partial replacement of cement by waste glass powder of particle size 90 micron sieve i.e. having fineness similar to that of cement. The cement was replaced by 10%, 20%, 30% and 40% of the waste glass powder and the mix design was prepared.

2.1 *Materials Used*

Concrete is prepared by mixing various constituents like cement, aggregates, water etc. which are economically available.

A. Cement
Ordinary Portland cement of 43 grade conforming to IS 8112 was used throughout the work.

B. Fine Aggregates
River sand confirming to zone II as per IS: 383-1970 was used as fine aggregate (F.A).

C. Coarse Aggregates
Broken stones were used in our experimental program confirming to table 2 of IS 383-1970, were used as coarse aggregate (C.A). Specific gravity of coarse aggregate was 2.74. Two size of coarse were used; 10 mm and 20mm.

D. Water
Water used in the study was ordinary potable water from the supply network installed in our lab.

E. Waste Glass Powder (WGP)

Waste glass locally available and it has been collected and made in to glass powder. Before adding glass powder in the concrete it has to be powdered to required size. In this experiments glass powder (GLP) having particle size less than 90 micron was used.

2.2 *Mixture Proportioning*

Mix design is carried out as per IS 10262: 2009. M20 grade of concrete was designed for this experimental work. The control mix (Mx-0) has proportion (by weight) of 1(cement): 1.5(sand): 3(coarse aggregate) and the water to cement ratio (w/c) is 0.43. In mixes Mx-1, Mx-2 and Mx-3, the cement is partially replaced with 10%, 20% and 30% glass powder.

Table 1:- Mix Design Proportion of Standard (M 20) Grade Concrete

Mix designation	Water	Cement	Fine aggregate	Coarse aggregate	Waste Glass Powder
Mx-0	186lt/m^3	432 kg/m^3	664.565 kg/m^3	1172.583 kg/m^3	0 kg/m^3
Mx-1	186lt/m^3	388.8kg/m^3	664.565 kg/m^3	1172.583 kg/m^3	43.2 kg/m^3
Mx-2	186lt/m^3	345.6kg/m^3	664.565 kg/m^3	1172.583 kg/m^3	86.4 kg/m^3
Mx-3	186lt/m^3	302.4kg/m^3	664.565 kg/m^3	1172.583 kg/m^3	129.6 kg/m^3

2.3 *Casting and Curing of specimens*

The moulds of cubes, cylinders and beams were cleaned thoroughly. A thin layer of oil was applied to inner surface of the moulds to avoid the adhesion of concrete with the inner side of the moulds; In this study, M20 grade standard concrete cubes of size 150 x 150 x150mm, beams of size 100mm x 100mm x 500mm and cylinders of size 150mm diameter and 300mm height were casted to determine harden concrete properties and cubes of size 100mm x

100mm x 100mm ,70.7mm x 70.7mm x 70.7mm were cast for determining the durability properties of concrete. The cast specimens were de-moulded at the end of 24±2 hours and cured for the required number of days with different curing methods. The objective of the curing in this study was to ensure controlled consistency in hydration for all of the samples. The samples were stored in a concrete tank full of water at room temperature. The water in the tank was replaced every two weeks with fresh water. Casted specimens were cured for 7 and 28 days in a curing tank filled with tap water

Fig. No.:-1:- Casting and Curing Of Specimens

2.4 Testing Of Concrete

The concrete was tested in fresh and hardened state for following tests shown in table 2

Table 2:-Tests Performed on Concrete

Green/Fresh Concrete	Slump Cone test
Hardened Concrete	**Strength Tests** Compressive Strength Test Flexure Strength Test Split Tensile Strength Test **Durability Tests** Water Absorption Test Sorptivity Test

III. RESULTS AND DISCUSSIONS

At the age of 7 and 28 days an increasing trend in strength was observed with increasing replacement of cement with glass powder up to 20%. Beyond 20%, the compressive strength started to fall steadily. The increase in the strength up to 20% replacement of cement with glass powder may be due to the pozzolanic reaction of glass powder. However, beyond 20 %, the dilution effect takes place over and the strength starts to drop. Thus it can be concluded that 20 %replacement of cement with glass powder is the optimum percentage with which cement can replaced for cost economy and better performance. Unit weight of concrete without waste glass is higher than with waste glass. Such a difference was attributive to the fact that the specific gravity of waste glass is 2.60 which is much lower than the specific gravity of cement which is 3.12

3.*1Slump Test*

Figure 2 shows 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 around 50mm for the reference mix (i.e. 0% glass powder) to 110mm at 30% glass powder.

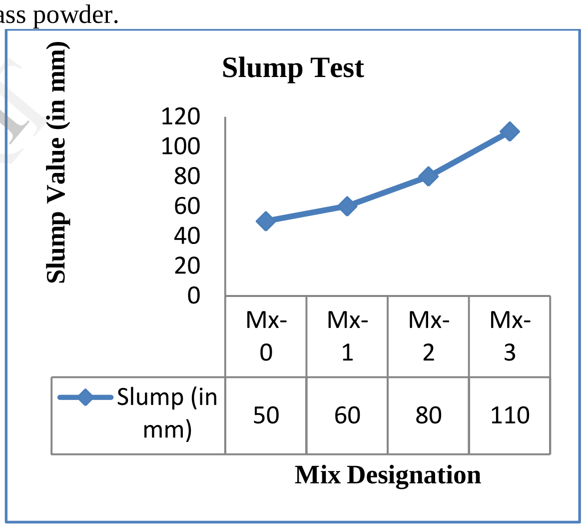

Fig No.:-2:- Slump Curve

3.2 Compressive Strength

The figure 3 shows the strength gain at various percentages of glass powder replacement at 7 and 28^{th} day. It can be seen clearly that there a reduction in the strength at the 30 % replacement. Waste glass when ground to a very fine powder, SiO2 react chemically with alkalis in cement and form cementitious product that help contribute to the strength development. When comparing the strength gain with the cement mortar strength gain it can be seen that there is increment of strength upto 20% glass powder replacement, beyond which it decreases. The presence of excess glass powder without necessary calcium to react, forms weak pockets in the concrete that reduces the concrete strength, this happens due to alkali silicate reaction.

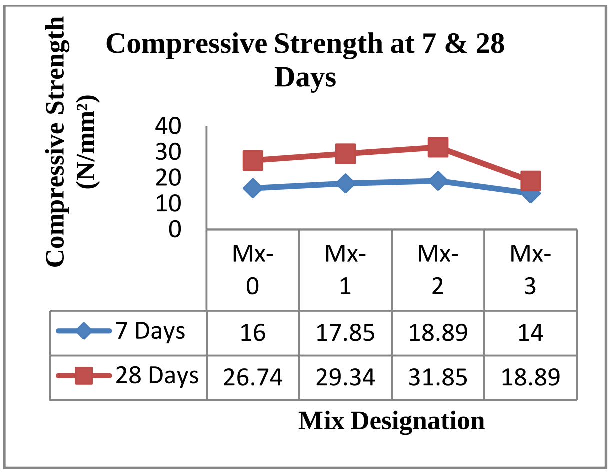

Fig No.:-3:- Compressive Strength at 7 and 28 Days

3.3 Flexure Strength

The figure 4 shows the flexural strength improvement at various percentages of glass powder replacement at7 and 28th day. It can be seen clearly that there is an increase in the strength upto the 20 % replacement here also. The flexural strength improves considerably at 10 % and 20% replacement which is about 8% and 10% at the age of 7 days and 12 % and 15% at the age of 28 days respectively as compared to the control specimen.

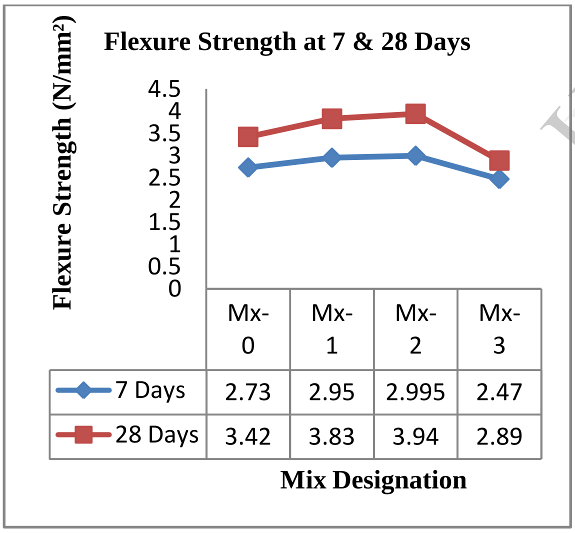

Fig No.:-4:- Flexure Strength at 7 and 28 Days

3.4 Split Tensile Strength

Figure 5 shows the split tensile strength gain at various percentages of glass powder replacement at 7 and 28th day. It can be seen clearly that there is a reduction in the strength after 10 % replacement. The split tensile strength improvement is marginal as compared to the compressive strength increase.

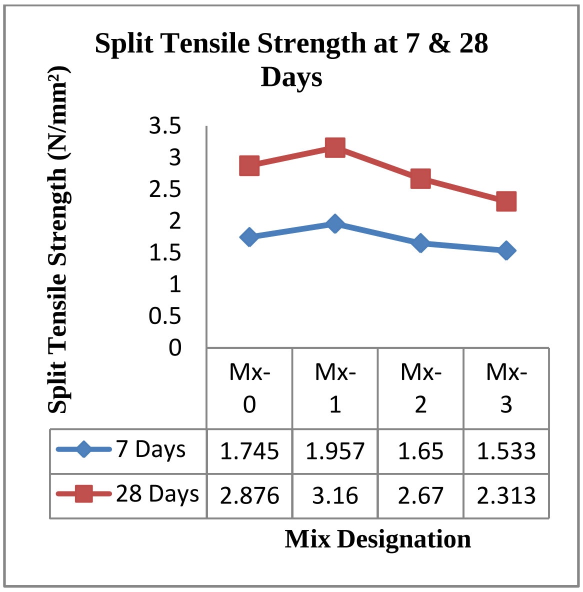

Fig No.:-5:- Split Tensile Strength at 7 and 28 Days

3.5 Water Absorption Test

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. It had been noticed by many researchers 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 that water absorption for the 100% cement concrete is more and that containing 10% glass replacement is having low absorption as compared to reference mix, while the mixtures with higher glass contents were clearly more absorbent than the mix with 10% replacement but less than the reference mix. Percent water absorption was calculated using the following formula

% Water Absorption = [(W2–W1) / W1] x 100 Where, W1 = Oven dry weight of cubes in grams, W2 = After 24 hours wet weight of cubes in grams.

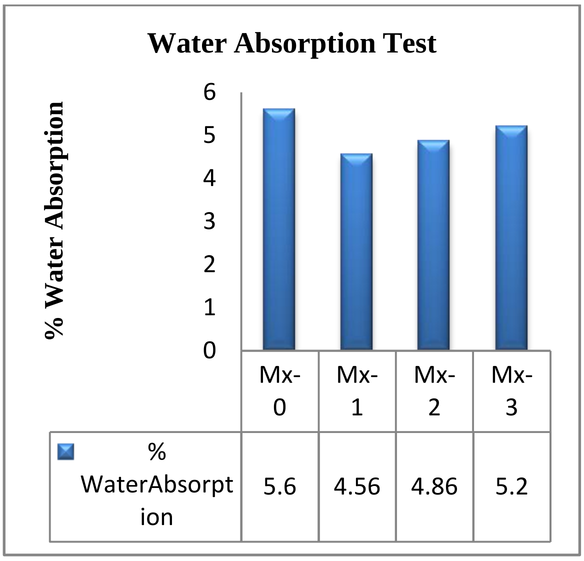

Fig No.:-6:- Water Absorption Curve

3.6 Sorptivity Test

After 28 days curing, the % replacement vs Sorptivity results are graphically shown in figure 7. From the results it is clear that the capillary rise of water or sorptivity reduces as the value of glass powder content increases in the mix i.e. with cement as only binder material, or for the conventional mix, sorptivity value is maximum and then it decrease at every % of replacement.

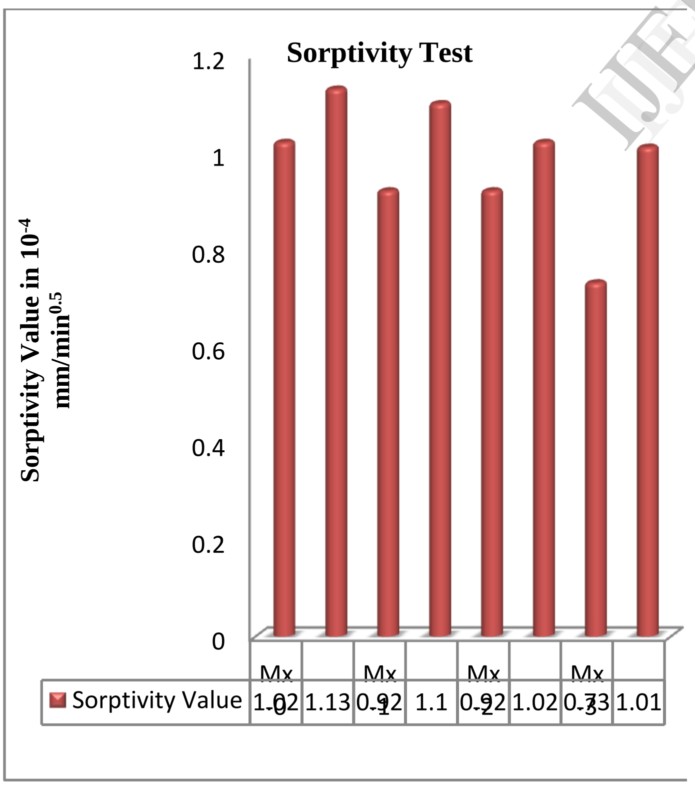

Fig. No.:-7:-% Replacement vs Sorptivity Curve

IV. CONCLUSION

On the basis of experiments performed, following conclusions can be drawn:
1. The amount of incorporated waste glass largely influenced properties of the cement mortar. It is evident from these results that ground glass could enhance the properties of the final concrete product if used at the right level of replacement. **2.** Workability of concrete mix increases with increase in waste glass content. **3**. Cement can be replaced by waste glass powder up to 20% by weight showing increase in compressive strength at 28 days beyond which strength decreases **4.** 20% replacement of cement by waste glass powder showed 18% increase in compressive strength at 7 days and 19% increase in compressive strength at 28 days.**5.** Flexural strength increases with increase in waste glass powder up to 20% as compared to conventional mix and then starts decreasing with further increase in WGP. **6.** Splitting tensile strength increases at 10% of replacement of cement by waste glass powder as compared to conventional mix and then decreases with increase in waste glass content **7.** With increase in waste glass content, percentage water absorption decreases, at 10% replacement it is optimum. **8.** With the increase in the waste glass powder the sorptivity value decreases and the % decrease is about 6%, 9.8%, and 19% for 10%, 20% and 30% replacement of cement by waste glass powder respectively as compared to the conventional mix.**9.** Use of waste glass in concrete can prove to be economical as it is non useful waste and free of cost. **10.** 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. **11.** Use of waste glass in concrete will preserve natural resources particularly river sand and thus make concrete construction industry sustainable

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