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Partial Replacement of PPC with Glass powder

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Abstract–*Disposal problem of waste material is becoming critical day by day. Millions tone of waste glass powder generated every year in world. In this topic, attempt has been made to utilize glass powder, which is waste of glass industry. The research work is determination of the effect 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 flume and fly ash. The concrete in place of cement to some extent i.e., 10%, 20%, 30% and mechanical properties of M40 (Design Mix) are investigated. Cube specimen of 36 numbers were cast, cured and tested for 3, 7, and 28 days strength. Compression was conducted and the results were compared. The finding revealed an increase in compressive strength with the increase in the replacement of cement by Glass powder. To reduce the demand of cement, glass powder decreases the unit weight as well as the porosity as indicated by decrease in water absorption. It reduce the quantity of cement to be used in concrete. Also glass powder is proved to be economical and is considered as environmental friendly construction material.*

Key Words – *Glass Powder, Replacement to PPC, compressive and tensile strength, cost effective material, M40 (Design Mix).*

I. Introduction

1.1 General Information

Cement- based materials are the most abundant of all man-made materials and are among the most important constructional materials and it is most likely that they will continue to have the same importance in the future; however these construction and engineering materials must meet new and higher demands. When facing issues of productivity, economy, quality and environment, they have to compete with other construction materials such as plastic, steel, wood. 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.

In sustainable construction importance of waste materials usage in concrete is increasing in manner. The waste glass from small shops is disposing it as a landfill waste. Without changing its chemical property the glass can be used so many times. This waste glass is used for water filtration, grit plastering, sand cover for sport turf and sand replacement in concrete.

Each year about 62 million tons of waste glass is generated in the India, 77% of which is disposed of in landfills, accounting for 6 wt. % of the total municipal solid waste stream. Globally, about 5 wt. % of the 27.02 billion tons/year of municipal solid waste generated is glass. Postconsumer waste glass can be cost-effectively collected in mixed color; there are, however, limited markets for mixed color waste glass. Disposal of waste glass in landfills is costly, considering increasing tipping fees; the non - biodegradable nature of glass further complicates the environmental impact of its disposal in landfills. Stricter environmental regulations and the scarcity of landfill space are other factors encouraging diversion of waste glass from landfills for value-added use in new applications. The reuse of very finely ground waste glass in concrete has economical and technical advantages. If the glass could be ground to a very fine size, it could satisfy the active pozzolanic behavior. Glass waste is recognized to be increasing year by year in a large volume from shops, construction areas and factories. These waste storage disposals are becoming a serious environmental problem.

Due to global warming the need to cut down energy consumption has increased. The effect of global warming has impacted everyone on the planet and is a well-recognized concept. The interest of construction community in using waste or recycled materials in concrete is increasing because of the emphasis placed on sustainable construction. Presently the waste glass in and around the small shops is packed as a waste and disposed as landfill. Waste glass contain high silica (SiO2) i.e. 72%. Waste glass when ground to very fine powder (600

micron) reacts with alkalis in cement (pozzolanic reaction) and cementinious product that help contribute to the strength development.

Glass is a very useful member in the family of wastes found in most urban environments as well as some rural settlements. It is a result of several inorganic mineral raw materials, which after undergoing a process of controlled cooling becomes a hard homogenous, stable, inert, amorphous and isotropic material (Frederico and Chidiac, 2009). Presently, glass is being reused in several applications apart from its uses in the concrete and cement industry. This include majorly industrial (as filler in paints and other products, agricultural fertilizers, fiber glass insulation etc.) and craft applications (as in making of jewelries, vases, and other visually pleasing pieces by glass fusing). Waste glass, however, is majorly post-consumer glass and industrial waste glasses. Post- consumer glass can be found in various colours (especially green, brown and clear) and this affects the recycling process of waste glass as there is no economically friendly and automated equipment to sort the various colours. The difficulty of separating waste glass from other materials such as plastic bottles, ceramic plates and undifferentiated trash and more so into various colours has discouraged recycling glass into new containers.

The main reason of this study is to create a better environment that free from polluted space and also to find better solution for concrete mixture that can give higher strength to concrete from the waste glass product. Even it may give less cost of using this kind of admixture rather than buying expensive admixture to get great and higher strength in concrete now a days it's the admixture that in market are very expensive and often increased the cost of construction..

1.2 The advantages of using glass powder concrete:

a. In PPC, costly clinker is replaced by cheaper pozzolanic material, hence economical.
b. Soluble Calcium hydroxide is converted into insoluble cementations products resulting in improvement of permeability, ultimately durability of concrete.
c. It generates reduced heat of hydration and that at a low rate.
d. It improves fire resistance qualities of the concrete.
e. It helps to reduce alkali aggregate reaction, where it is encountered.

Fig no 1: Glass powder sample

1.3 Glass powder

In order to address environmental effects associated with cement manufacturing, there is a need to develop alternative binders to make concrete. Consequently extensive research is on going into the use of cement replacements, using many waste materials and industrial by products. Efforts have been made in the concrete industry to use waste glass as partial replacement of coarse or fine aggregates and cement. In this study, finely powdered waste glasses are used as a partial replacement of cement in concrete and compared it with conventional concrete. This work examines the possibility of using glass powder as a partial replacement of cement for new concrete. Glass powder was partially replaced as 5%, 10%, 15% and 20% and tested for its compressive, tensile strength up to 28 days of age and were compared with those of conventional concrete; from the results obtained, it is found that glass powder can be used as cement replacement material up to particle size less than 600µ to prevent alkali silica reaction.

Glass is a transparent material produced by melting a mixture of materials such as silica, soda ash, and CaCO3 at high temperature followed by cooling during which solidification occurs without crystallization. Glass is widely used in our lives through manufactured products such as sheet glass, bottles, glassware, and vacuum tubing. The amount of waste glass is gradually increased over the recent years due to an ever-growing use of glass products. Most waste glasses have been dumped into landfill sites. The Land filling of waste glasses is undesirable because they are not biodegradable, which makes them environmentally less friendly. So we use the waste glass in concrete

to become the construction economical as well as eco-friendly. Composition of cement and Glass Powder is as shown in Table I.

Table 1.1 : Chemical Composition of Glass Powder

Sr. No.	Chemical Constituents	Values	Units
1	Silicon Di Oxide	67	%
2	Aluminum Oxide	2.62	%
3	Ferric Oxide	1.42	%
4	Titanium Di Oxide	0.157	%
5	Calcium Oxide	13.45	%
6	Magnesium Oxide	2.664	%
7	Sodium Oxide	10.05	%
8	Potassium Oxide	0.927	%
9	Zirconium Oxide	0.020	%
10	Strontium Oxide	0.016	%
11	Phosphorous pent oxide	0.041	%
12	Nickel Oxide	0.014	**%**

1.4 Admixture

There are essentially four ingredients in concrete i.e. coarse aggregate, fine aggregate, cement and water. However, in order to improve certain properties of concrete both in plastic and hardened state it is necessary to add the fifth ingredient in concrete mix. The fifth ingredient is Admixture which can be a Mineral or Chemical admixtures.

1. Mineral admixtures:

- Silica fume
- Ground granulated blast furnace slag
- Rice husk ash
- Fly ash

2. Chemical admixture

- Accelerating admixture
- Retarding admixture
- Water-reducing admixture
- Air entering admixture
- Super- plasticizing admixture

1.5 Chemical Admixture

There are several types of admixtures available but the most popular and most often used is the plasticizer. Plasticizer is a chemical admixture and it is extensively used in concrete mixes for the past four decades the world over. However in India the usage has considerably increased in last ten years. Plasticizers are aids to modify good mixes and good construction practices to achieve certain specific requirements which can be conveniently achieved. There are two types of plasticizers. Ordinary plasticizer or plasticizer is one type and the other is superior plasticizer or super plasticizer. Plasticizers are also called as water reducing admixtures.

1.6Plasticizer

Ordinary water reducing plasticizers enables the reduction of water up to 15 %.Plasticizers are helpful in difficult condition for obtaining higher workability without using excess of water.
The basic product constituting plasticizers are as follows.

- Anionic surfactants such as lignosulphonates and their modification and derivates, salts of sulphonates hydrocarbons.
- Nonionic surfactants, such as polyglycol esters, acid of hydroxylated carboxylic acids and their modifications and derivates.
- Other products such as carbohydrates etc.

1.7 Action of Plasticizers

The action of plasticizers is mainly to fluidify the mix and improve the workability of concrete, mortar or grout. The mechanisms that are involved.

1.8 Dispersion

Plasticizer gets adsorbed on the cement particle and creates a particle to particle repulsive force which overcomes the attractive forces. Due to these repulsive forces the particles are deflocculated and dispersed. When cement particles are deflocculated, the water trapped inside the flocks gets released and now available to fluidity the mix.

1.9 Retarding Effect

As mentioned earlier that plasticizer gets adsorbed on the surface of cement particles and forms a thin sheath, which inhibits the surface hydration between water and cement as long as sufficient plasticizer molecules are available at the particle/solution interface. The quantity of plasticizers will progressively decrease as polymers become entrapped in hydration products.

1.10 Super Plasticizer

A substance which imparts very high workability with a large decrease in water content (at least 20%) for a given workability. A high range water reducing admixture (HRWRA) is also referred as Super plasticizer, which is capable of reducing water content by about 20 to 40 percent has been developed. These can be added to concrete mix having a low-to- normal slump and water cement ratio to produce high slump flowing concrete. The effect of Super plasticizer lasts only for 30 to 30 minutes, depending on compositions and dosages and is followed by rapid loss in workability.

One of the important factors that govern the issue water-cement ratio during the manufacture of concrete, lower the water-cement ratio lower will be the capillary pores and hence lower permeability and enhanced durability.

Although Super plasticizer are essential to produce a truly high performance concrete characterized by low water-cement ratio and workability level without high cement content. Concrete are being produced with w/c of as low as 0.25 or even 0.20 enabled the production of highly durable high performance concrete. The workability also increases with an increase in the maximum size of aggregate. But smaller size aggregate provides larger surface area for bonding with the mortar matrix, which increase the compressive strength. For concrete with higher w/c ratio use of larger size aggregate is beneficial.

The Super plasticizers are classified based on their chemical composition

- Sulphonated melamine – Formaldehyde condensates
- Sulphonated naphthalene - Formaldehyde condensates
- Modified lignosulphonates
- Carboxylated acrylic esters copolymers
- Others like sulphuric-acid esters, amide polysaccharide mixtures, carbohydrate esters etc.

Sulphonated naphthalene based plasticizers are more preferable for high ambient temperatures. Therefore they are more suitable for Indian conditions.

The Plasticizers are generally used to achieve the following

In Fresh Concrete

- Increase workability and / or pumpability without increasing the water/cement ratio.
- Improved cohesiveness and thereby reducing segregation or bleeding.
- Improve to some extent set retardation.

In Hardened Concrete

- Increase Strength by reducing the water/cement ratio, maintaining same workability.
- Reduce permeability and improve durability by reducing water/cement ratio.
- Reduce heat of hydration and drying shrinkage by reducing cement content.

II. Literature Reviews

The literature work carried out on the different Grade of concrete with different percentage of Glass powder. All research paper considering as recent research work only.

Dr. G. Vijayakumar, Ms H. Vishaliny, Dr. D. Govindarajulu [1] In this study the author was concluded that the strength of the concrete is increased when cement will replace to glass powder for M20 and as well as M40 grade of concrete. At 40% replacement of cement by glass powder the concrete attained maximum compressive strength for M20 grade of concrete. The split tensile strength of concrete is increased when cement is replaced with glass powder at 40% and it increased by 4.4%.the flexural strength of concrete is increased when cement is replaced

by glass powder at 40% and it increased by 100%. **Krati Gahoi, Rajeev Kansal [2]** The effect of glass powder on the properties of cement has been studied in this research. The various properties of concrete such as compressive strength, tensile strength, flexural strength and the percentage water absorption are studied. Tests are performed for different grades like M20, M40. The Author concluded that with the percentage of waste glass powder is increased in the concrete with increase in percentage of glass powder the unit weight of concrete may be decreases. There was an appreciable increment in the compressive strength, Tensile strength and flexural strength with increase in percentage of glass powder. **Veena V. Bhat, N. Bhavanishankar Rao [3]** The influence of replacement of cement by glass powder has been studied. Based on the experimental work conducted, the following conclusions are drawn.The replacement of cement by glass powder in concrete increases the compressive strength of concrete. Increase of 27% strength can be achieved when 20% cement was replaced by glass powder in concrete when water/ cement ratio was maintained. **G. M. Sadiqul Islam, M. H. Rahman, Nayem Kazi [4]** The optimum glass content is 20% in concrete compressive strength at 90 days. In this age the compressive strength was found slightly higher (2%) than the control concrete specimen. In general, considering the similar performance with replaced material, glass addition can reduce cost of cement production up to 14%. In addition, production of every six ton glass powder concrete results in the reduction of each ton CO_2 emission from cement production and save the environment significantly by reducing green-house gas and particulate production. **Gunalaan Vasudevan, Seri Ganis Kanapathy pillay [5]** Basically waste glass powders are made from the waste glass material that cannot be reused due to the high cost of manufacturing. Therefore the manufacture will disposed in the waste landfill. Due to environmental problem, researcher tries to use the waste glass in to concrete, to create a new material to use in construction field. Researcher found that, the main material composition of glass is silica that also contain in cement production and other compound that also similarly contain in cement production. From this research, using waste glass powder is giving positive value even though the value compare to standard mix it just less about 1N/mm^2 Concrete become lighter when mix with waste glass powder. The average cube density of concrete with using more percentages of waste glass powder averagely gives lowest value compared to control sample. Therefore, concrete mix that using glass powder is giving lightweight concrete. **Ashutosh Sharma, Ashutosh Sangamnerkar [6]** The researcher was concluded 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 in cement 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.

Gautam Singh, Gautam Singh, Akhil Bhaskar [7] In this study the researcher concluded increase the value of compressive strength as compare to conventional concrete with replacement of glass powder with sand by 5%,10%,15% and 20% and its increase in compressive strength by 20.22%, 30.12%, 43.39%, 49.22% respectively. **Dhanraj Mohan Patil, Dr. Keshav K. Sangle [8]** In this study the researcher studied addition of GLP increase the strength of concrete .At the level of 20% replacement of cement by glass powder meets maximum strength as compare to the normal concrete.

III. Strength

1. **Compression Strength test**
2. **Split Tensile Strength test**

1. Compressive Strength Test

a) Preparation of specimen

The specimen consists of a cube of size 150 mm. The fresh concrete is poured into the moulds, which are greased or oiled. Concrete is placed into the mould, the concrete is compacted on vibrator. Care should be taken that the concrete should not segregate while placing and compacting.

b) Test Procedure

The testing is carried out on a compression testing machine as per IS:516-1959 code. The cubes should not be loaded on the face other than the face from where it is casted. The load is applied and the load at which the specimen fails is noted down.

c) Calculation of Strength

$$\text{Compressive strength} = \frac{\text{Load}}{\text{Cross-sectional area}} = \frac{P}{150 \times 150} \text{ N/mm}^2$$

Where,

P = load at failure

Fig 2. : Compression test on concrete

Table No 3.1 Compression Strength Test

%Glass powder	3Day's	7Day's	28 Day's
0%	28.719	41.483	63.82
10%	21.726	31.382	48.28
20%	20.304	29.328	45.12
30%	18.963	27.391	42.14

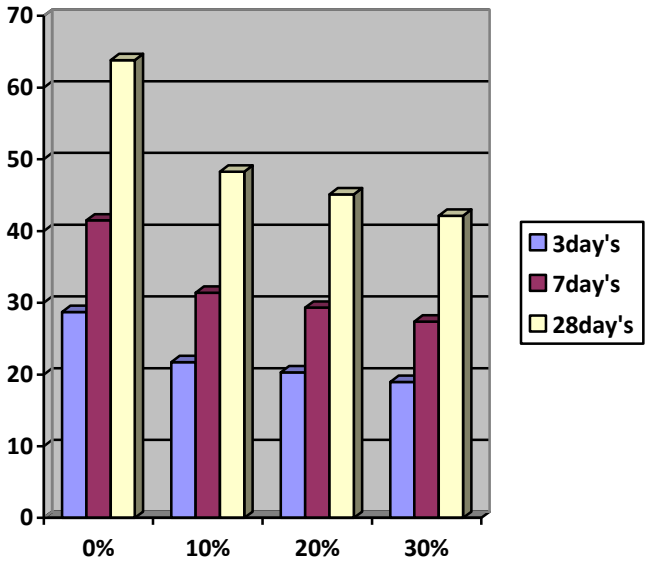

Fig No. 1 Compression Test STRENGTH

2. Split test or split tensile strength test

a) Preparation of specimen

The specimen consists of a cylindrical of dimension 150 mm & 300 mm length. The fresh concrete is poured into the mould, which are greased or oiled before concrete is compacted with the help of vibrator. Care should be taken that the concrete should not segregate while placing and compacting.

b) Test procedure

The testing carried out on a compression-testing machine. Placing the cylindrical specimen horizontally between the loading plates of the comp testing machine and the load is applied in that position i.e. along the specimen fails. The load at failure is noted down.

In order to reduce the magnitude of the high compression stress near the points of application of the load, packing strips/ plates of suitable material are placed between the specimen and loading plates of the testing machine.

c) Calculation of tensile strength

Tensile strength $= \frac{2P}{\pi LD}$

Where,

P = load at failure
L = length of cylinder
D = diameter of cylinder

Fig 3 : Split tensile test on concrete

Table No 3.3 Compression Strength Test

%Glass powder	28 Day's 'A'	28 Day's 'B'
0%	5.3	5.4
10%	5.4	5.2
20%	3.9	4.1
30%	2.9	3.2

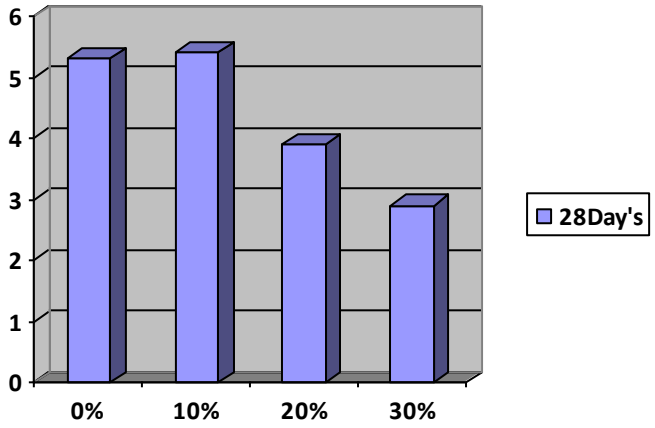

Fig No. 2 Split Tensile Test STRENGTH

IV. Conclusion

From the above graphs, we concluded that,

1) As per research paper for M20 grade concrete, when we have used glass powder after 30% strength will decrease but for M40 grade concrete we can use up to 10% replace.
2) If we are using glass powder for any M40 design strength will be same but cost as compare to conventional concrete decrease.
3) Compressive strength of concrete at 28 days without super plasticizer reduced gradually up to 10% of replacement and increased at 15% replacement. But target strength can be achieved up to 5%.
4) With super plasticizer, compressive strength with zero (0%) glass powder was less than that of without super plasticizer. It also gradually reduced up to 10% replacement then at 15% it is slightly increased and further at 20% it is reduced but more 40 N/mm². But target strength can be achieved up to 5%.
5) Split Tensile strength reduced gradually with increase in percentage of glass powder
6) Finally, it can be concluded that to achieve target strength PPC can be replaced up to 10% in M40 and up to 30% in M20 with glass powder.
7) If we are using up to 10% and 30% Glass powder when cost of concrete will decrees as compare to Normal concrete.
8) The main Aim of our Experimental study is to reduced they cost as compare to conventional concrete.

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