# Experimental Evaluation of Waste Glass Powder as a Partial Replacement of Cement Concrete

**Er. Abrar Ahmad Malik[1] Er. Suhail Ashaq[2]**
[1]M Tech Student [2]Assistant Professor
[1,2]Department of Civil Engineering
[1,2]R.N CET Madlauda Panipat Haryana, India

*Abstract*— Cement manufacturing industry is one of the carbon-dioxide emitting sources besides deforestation and burning of fossil fuels. The global warming is caused by the emission of green-house gases, such as CO2, to the atmosphere. Among the greenhouse gases, CO2 contributes about 65% of global warming. The global cement industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. 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 ongoing 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 will be 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 will be partially replaced as 5%,10%, 20%, 30% and 40% and tested for its compressive, Tensile and flexural strength up to 28 days of age and will be compared with those of conventional concrete. Glass powder will be used as cement replacement material up to particle size less than 75µm to prevent alkali silica reaction. For study of size effect of glass powder the powder is divided into two grades one is glass powder having size less than 75 micron and another is glass powder having particle size ranges from 75 micron to 150 micron.

***Keywords:*** Waste Glass Powder, Cement Concrete

## I. Introduction

The interest of the construction community in using waste or recycled materials in concrete is increasing because of the emphasis placed on sustainable construction, the waste glass from in and around the small shops is packed as a waste and disposed as landfill. Glass is an inert material which could be recycled and used many times without changing its chemical property. Glass is amorphous material with high silica content, thus making it potentially pozzolanic when particle size is less than 75µm. Studies have shown that finely ground glass does not contribute to alkali – silica reaction. In the recent, various attempts and research have been made to use ground glass as a replacement in conventional ingredients in concrete production as a part of greenhouse management. A major concern regarding the use of glass in concrete is the chemical reaction that takes place between the silica – rich glass particle and the alkali in pore solution of concrete, which is called Alkali – Silicate reaction can be very detrimental to the stability of concrete, unless appropriate precautions are taken to minimize its effects. ASR can be prevented or reduced by adding mineral admixtures in the concrete mixture, common mineral admixtures used to minimize ASR are pulverized fuel ash (PFA), silica fume. A number of studies have proven the suppressing ability of these materials on ASR. The fact that glass has 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. Partial replacement of cement with milled waste glass benefits the microstructure and stability of cementitious materials. A denser 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. 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. These improvements result from the beneficial chemical reactions of milled waste glass with cement hydrates, which yield chemically stable products capable of refining the pore system in concrete.

Replacing cement by pozzolanic material like waste glass powder in concrete, not only increases the strength and introduces economy but also enhances the durability of concrete.

### A. General Pozzolana Information

The pozzolanic materials are essential a siliceous or aluminous material which itself possessing no cementitious properties, which will in finely divided form and in the presence of water, react with calcium hydroxide [$Ca(OH)_2$] liberated in the hydration process to form compounds possessing cementitious properties. The pozzolans can be used as partial replacement of cement. The pozzolanic materials when used as partial replacement of cement are generally substituted for 10 to 35 percent. This substitution produces concrete that is more permeable but much more resistant to the action of salt, sulphate, or acid water. Strength gain is usually slower than for the normal concrete. Pozzolans when added to concrete mixes, rather than substituted for a part of the cement, improve workability, impermeability and resistance to chemical attack. The overall effect depends on the aggregates used in concrete. The aggregate deficient in fine material give the best result. For a pozzolan to work to remediate ASR, it must be quite effective in powdered form (minus 325 mesh), and it must not bring unacceptable chemical constituents to the reaction. Deleterious chemical constituents include sulfides (turn concrete green), sulfates (can cause delayed expansion), and alkalis (which add more alkali to concrete which creates higher risk of ASR over the life of the concrete).

 

### *B. Recycled Glass as a Pozzolana*

The issue of recycled glass is quite complicated from a chemistry point of view. Years ago, the reinforcement fiberglass manufacturers saw a large market potential in using glass reinforcements as reinforcing fiber in concrete. Early tests soon indicated that normal chemistry reinforcement fiberglass almost totally dissolved in the concrete environment, as the extremely low alkali content of the fiber glass, about 1%, caused it to be highly susceptible to alkalis in concrete environments. The fiberglass manufacturers were able to address the problem by adding 16% zirconia to the glass chemistry to make it alkali resistant (so called AR glass). Borosilicate (Pyrex) type glasses are so expansive that they were selected to be the ASTM C441 (standard test method for effectiveness of pozzolans) test aggregate that severely tests the ASR mitigation capability of various pozzolans. Under no circumstances should borosilicate glass be added to concrete. Soda lime plate and bottle glass are reactive aggregates and must be mitigated with pozzolans and/or lithium compounds. Understanding the need for a pozzolan to be sacrificial, the phenomena of the quick reaction(in alkaline environments like concrete) of fiberglass led to the development of pozzolan powder derived from this same reinforcement fiberglass, called VCAS White Pozzolan.

## II. Literature Review

### *A. Slump Test*

Jangid Jitendra B. and Saoji A.C. [2012] resulted that the workability decreases as the percentage glass powder in the mix increases.

Khatib J.M et. al [2012] in his study showed that there was a systematic increase in the slump as the glass powder content in the mix increases.

Chikhalikar S.M. and Tande S.N. [2012] studied the properties of SFRC (Steel Fibre Reinforced Concrete) containing waste glass as pozzolon and concluded that the 20% replacement of cement by waste glass powder gives better workability.

Vasudevan Gunalaan and Kanapathy pillay Seri Ganis [2013] studied slump property in his research and resulted that compared to control mix, by using waste glass powder will give another benefit which is the workability of concrete which is much higher.

R .Vandhiyan et. al [2013] investigated that 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.

Kumarappan N. [2013] presented that there is a systematic increases in the slump as the glass powder in the mix increases. The slump ranged from around 40mm for the reference mix (i.e. 0% glass powder) to 160mm at 40% glass powder.

### *B. Compressive Strength*

Oliveira L.A Pereira de et. al [2010] study focused on the assessment of the pozzolanic activity of green, amber and flint color waste glass of different particle sizes(75µm – 150µm,45µm – 75µm and < 4µm) as a component of cementitious materials used as filler or binder in mortar and concrete. He concluded that 30% of 45-75 µm ground waste glasses size range could be incorporated as cement replacement in mortar or concrete without any detrimental effects caused by the expansivity provoked by the alkali silica reaction.

Bajad M.N. et. al [2011] studied the strength properties containing glass when subjected to sulphate attack and showed that the peak compressive strength is achieved at 20% replacement of cement by waste glass powder both when concrete is not subjected to sulphate attack and when concrete subjected to sulphate attack and the increment continues upto 25% replacement beyond which it decreases.

## III. Objectives

The objective of the research is to study the effect of the use of Glass Powder as a partial 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. In this study, finely powdered waste glasses will be 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 will be partially replaced as 5%,10%,15%,20%,25% 30% and tested for its compressive, Tensile and flexural strength up to 28 days of age and will be compared with those of conventional concrete.

- The primary objective of this study is to investigate the practicality, versatility and feasibility of utilizing recycled glass as a partial replacement to cement.
- To evaluate the recyclability of powdered waste glass as a pozzolana as partial replacement of cement in the concrete.
- To Study the influence of waste glass on hardened properties of concrete mixes such as: compressive strength, flexural and splitting resistance.
- Determine the optimum waste glass powder to be added as a partial replacement of cement.

## IV. Scope

Cement manufacturing industry is one of the carbon dioxide emitting sources besides deforestation and burning of fossil fuels. The global warming is caused by the emission of green house gases, such as CO2, to the atmosphere. Among the greenhouse gases, CO2 contributes about 65% of global warming. The global cement industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. In order to address environmental effects associated with cement manufacturing, there is a need to develop alternative binders to make concrete.

- Due to cement replacement by glass powder the cement use in construction will be lesser, thereby effecting the production of cement which in turn will affect the generation of green house gases positively.
- Many researchers have revealed that by replacing cement with waste glass powder upto 40%, an increase

in compressive strength of about 34% occurs,hence it can be used where high strength concrete is required.

## V. EXPERIMENTAL WORK

### A. *Preparation of Materials*

All materials shall be brought to room temperature, preferably 270 + 30̊ C before start the results. The cement samples, on arrival at the laboratory, shall be carefully mixed dry either by hand or in a appropriate mixer in such a manner as to ensure the maximum possible blending and uniformity in the material, care is being taken. The cement shall then be stored in a dry place, preferably in air-tight metal containers. Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. In general, the aggregate shall be separated into fine and coarse portion and recombined for each concrete batch in such a way as to produce the desired grading. IS sieve 480 shall be normally used for separating the fine and coarse fractions, but where special grading are being investigated, both fine and coarse aggregate shall be separated into different sizes.

#### 1) *Proportioning*

The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work. Where the proportions of the ingredients of the concrete as used on the site are to be specified by volume, they shall be calculated from the proportions by weight used in the test cubes and the unit weights of the materials.

#### 2) *Weighing*

Weigh batching is the correct method of measuring the materials. For important concrete, invariably weigh batching should be adopted. Use of weight system in batching, facilitates accuracy, flexibility and simplicity.

#### 3) *Mixing Concrete*

Thorough mixing of the materials is essential for the production of uniform concrete. The mixing should ensure that the mass become homogeneous, uniform in colour and consistency. There are two methods adopting for mixing concrete one is hand mixing and other is machine mixing.

#### 4) *Compaction of Test Specimens: (As Per is: 516-1959)*

Compaction of concrete is the process adopted for expelling the entrapped air from the concrete. In the process of mixing, transporting and placing of concrete air is likely to get entrapped in the concrete. The lower the workability, higher is the amount of air entrapped. In other words, stiff concrete mix has high percentage of entrapped air and, therefore, would need higher compacting efforts than high workable mixes. Therefore, it is imperative that 100% compacting of concrete is one of the most important aim to be kept in mind in good concrete making practices.

#### 5) *Compaction by Vibration*

When compacting by vibration, each layer shall be vibrated by means of an electric or vibrator or by means of a suitable vibrating table until the specified condition is attained.

#### 6) *Placing Moulds on the Vibrating Table*

This is the special case of formwork vibrator, where the vibrator is clamped to the table or table is mounted on springs which are vibrated transferring the vibration to the table. They are commonly used for vibrating concrete cubes. Any specimen kept on the table gets vibrated. This id adopted mostly in laboratory and in the making small but precise prefabricated R.C.C members.

Fig. 5.1: Vibrating table

#### 7) *Curing of Test Specimens: (As Per is: 516-1959)*

The test specimens shall be stored on the site at a place free from vibration, under damp matting, sacks or other similar material for 24 hours + ½ hour from the time of adding the water to the other ingredients. The temperature of the place of storage shall be within the range of 220 to 320̊ C. After the period of 24 hours, they shall be marked for later classification, removed from the moulds and, unless required for testing within 24 hours, stored in clean water at a temperature of 240 to 300̊ C until they are transported to the testing laboratory. They shall be sent to the testing laboratory well packed in damp sand, damp sacks, or other suitable material so as to arrive there in a damp condition not less than 24 hours before the time of test. On arrival at the testing laboratory, the specimens shall be stored in water at a temperature of 270 + 20̊ C until the time of test.

Fig. 5.2: Curing of test specimens.

The experimental work was carried out in our college concrete technology laboratory. In this study, total of seven groups of concrete mixes were prepared in laboratory. First group was normal cement concrete mix. Second, third, fourth, fifth, sixth, and seventh group was cement replacement by fine glass powder (GLP) particle size less than 75 micron with replacement from 5%, 10%, 15%,20%,25% and 30% respectively.

### B. *Compressive Strength Test*

Seven different mixes (Mix1, Mix2, Mix3, Mix4, Mix 5, Mix 6, & Mix 7) were prepared using cement replaced by glass powder at varying percentage of 0, 5, 10, 15, 20, 25 and 30. Fourty two number standard specimens of dimensions 150 × 150 × 150 mm were cast according to the mix proportion and cured in water at room temperature in the laboratory for 7 and 28 days. At the end of each curing period, three specimens for each mixes were tested for compressive strength and the average strength was recorded. The size of the specimen is as per the IS code 10086 – 1982. The compressive strength test on both conventional and glass added concrete was performed on standard compression testing machine of 3000kN capacity, as per IS: 516-1959.

The load shall be applied slowly without shock and increased continuously at a rate of approximately 140 kg/sq.cm/min until the resistance of the specimen to the increased load breaks down and no greater load can be sustained.

Fig. 7.3: compression test

### *C. Split Tensile Strength of Concrete*

Seven different mixes (Mix1, Mix2, Mix3, Mix4, Mix5, Mix6, Mix7) were prepared using cement replaced by glass powder at varying percentage of 0, 5, 10, 15, 20, 25 and 30. Forty two number standard specimens of dimensions 300 mm length and 150mm diameter were cast according to the mix proportion and cured in water at room temperature in the laboratory for 7 and 28 days. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of cylinder along the vertical diameter.

Split tensile strength, (T) =2P/πDL

Where, P= compressive load on cylinder

L= length of cylinder

Fig. 7.4: split tensile test

## VI. RESULTS AND DISCUSSION

### *A. Compressive Strength of M30 Concrete on 7th Day*

| S.no | Percentage of glass powder | Compressive strength N/mm$^2$ | | | Average compressive strength N/mm$^2$ |
|---|---|---|---|---|---|
| | | Sample 1 | Sample 2 | Sample 3 | |
| 1 | 0% | 21.90 | 21.98 | 22.06 | 21.98 |
| 2 | 5% | 19.03 | 19.21 | 18.99 | 19.07 |
| 3 | 10% | 18.33 | 18.61 | 18.47 | 18.47 |
| 4 | 15% | 17.77 | 17.90 | 18.15 | 17.94 |
| 5 | 20% | 19.20 | 19.28 | 19.36 | 19.28 |
| 6 | 25% | 19.01 | 19.03 | 18.66 | 18.91 |
| 7 | 30% | 16.57 | 16.61 | 16.74 | 16.64 |

Table 8.1: 7- Day Compressive Strength

### *B. Compressive Strength of M30 Concrete on 28th Day*

| s.no | Percentage of glass powder | Compressive strength N/mm$^2$ | | | Average compressive strength N/mm$^2$ |
|---|---|---|---|---|---|
| | | Sample 1 | Sample 2 | Sample 3 | |
| 1 | 0% | 31.11 | 31.05 | 31.09 | 31.08 |
| 2 | 5% | 32.19 | 32.78 | 31.73 | 32.23 |
| 3 | 10% | 33.00 | 33.11 | 33.08 | 33.06 |
| 4 | 15% | 34.01 | 34.66 | 34.91 | 34.52 |
| 5 | 20% | 35.76 | 36.02 | 36.41 | 36.06 |
| 6 | 25% | 33.01 | 33.11 | 33.08 | 33.06 |
| 7 | 30% | 31.53 | 31.21 | 30.07 | 30.96 |

Table 6.2 28 Day compressive strength

## VII. COST ANALYSIS BASED ON PER CUBIC METRE CONCRETE:

Volume of concrete = 1 $m^3$
Density of concrete = 2400 kg / m
Mix ratio = 1: 1.3 : 2.8
Quantity of cement in 1 $m^3$ concrete = 2400/5.1
= 470.59 kg
At optimum dosage of glass powder i.e 20%
Cement saved per metre cube of concrete = 20% of 470.59 kg
= 94.19 kg
Amount saved per metre cube of concrete = 94.19 x 8
= Rs 754.

## VIII. CONCLUSION

- On addition of GLP initial rate of gain of strength is low but at 28th day strength is more than the design strength.
- Addition of GLP increases the strength of concrete.
- At the level of 20% replacement of cement by glass powder, strength is higher as compare to that of normal concrete and other percentage of replacement of cement on 28$^{th}$ day.
- The compressive strength of glass powder concrete shows an increment of about 18% at the age of 28$^{th}$ days at optimum point.
- The flexural strength of glass powder concrete shows an increment of about 27% at the age of 28$^{th}$ days at optimum point.
- The split tensile strength of glass powder concrete shows an increment of about 29% at the age of 28$^{th}$ days at optimum point.
- Workability of concrete decreases with increase in percentage replacement of cement with glass powder.

## IX. FUTURE WORK

The project work was emphasized on use of glass materials as partially replacement of cement. Further one can extend this work as follows.

- The effect of glass materials on compressive strength of concrete as partially replacement of coarse aggregates and fine aggregates can be analysed and studied.
- The effect of pulverised glass materials on ductility at beam column joint, durability ,fire resistant properties etc. can be analysed and studied
- The glass powder and silica fume are the pozzolanic materials. Therefore compressive strength can be studied by using this materials same as partially replacement of cement in concrete. And also can be determined its optimum dosage range when concrete riches maximum strength.

## REFERENCES

[1] M.S.SHETY "Concrete technology theory and practice" S.chand publishing a division of S.chand & company .(ISO 9001 :2000 company)
[2] Dhanaraj Mohan Patil, Dr. Keshav K. Sangle: "Experimental Investigation Of Waste Glass Powder As Partial Replacement Of Cement In Concrete" International Journal of Advanced Technology in Civil Engineering, ISSN: 2231 –5721, Volume-2, Issue-1, 2013
[3] Dr. G.Vijayakumar, Ms H. Vishaliny, Dr. D. Govindarajulu : "Experimental Investigation Of Waste Glass Powder As Partial Replacement Of Cement In Concrete" International Journal of Emerging Technology and Advance 5d Engineering,2014
[4] Bhupendra Singh Shekhawat, Dr. Vanita Aggarwal : "Utilisation of Waste Glass Powder in Concrete" International Journal of Innovative Research in Science,Engineering and Technology (An ISO 3297: 2007 Certified Organization) Vol. 3, Issue 7, July 2014
[5] Ashutosh Sharma : Glass Powder – A Partial Replacement for Cement" International Journal Of Core Engineering & Management (IJCEM) Volume 1, Issue 11, February 2015