# Flexural Behavior of Concrete by Partial Replacement of Cement, Fine Aggregate by Glass Powder and Granite Powder

N.Elangovan
*M.E Structural Engineering*
*Gnanamani College of Engineering, Namakkal.*

D.Sri Ruban
*Assistant Professor*
*Department of Civil Engineering*
*Gnanamani College of Engineering, Namakkal*

***Abstract*** *— Most of the glass sheet cutting industries was not properly recycled and also disposing their waste materials as landfills. In Granite polishing industries also the waste granite powder was not disposed properly. These waste glass powder can be crushed finely and checked the possibility for incorporation into concrete as a pozzolanic material. It undergoes beneficial pozzolanic reactions in the concrete and could replace up to 20% of cement in some concrete mixes with satisfactory strength development. This thesis involves use glass powder 20% constantly as replacement of cement and to use granite powder 25% constantly as replacement of fine aggregate. The mechanical properties of glass and granite powder replaced concrete properties have been compared with the conventional concrete after the curing period of 7, 14 and 28 days. The grade of concrete used in this project is M20, M30 and M40. Waste glasses and granite wastes are to be used so the cost will be comparatively low when compared with normal concrete.*

***Keywords***—*Glass powder,Granite powder, Pozzolanic material Flexural strength test, compression strength test.*

## I. INTRODUCTION

The Concrete is obtained by mixing cement, aggregate and water in required proportion with or without a suitable admixture. Admixtures is a material, other than cement, water and aggregates, that is used an ingredient of concrete and is added to the batch immediately before or during mixing. Thorough mixing is essential for the production of uniform, high-quality concrete. The concrete which would be prepared to attaining the strength of the nominal mix and also the convention mix. The conventional mix of the concrete which means that the composite of the granite powder and glass powder which contain the related properties of cement and the fine aggregate , that's the way the replacement of cement and fine aggregate by glass powder and granite powder of 20% and 25% respectively. The introducing of waste glass powder in cement which increase the alkali properties to binding materials. The powder of granite and glass are been used as a construction material to reduce the environmental problems.

## II. SCOPE AND OBJECTIVE

### *A. Objective*

The objective of this project is to investigate the development of Concrete Strength using glass powder as a partial replacement for cement and granite powder for fine aggregate. In trial mixes fine aggregate is replaced 25% of its weight by Granite powder. And cement is replaced 20% of its weight by Glass powder in all mixes.

The investigation is also aimed at finding out the optimum grade of concrete for superior strength while using Glass powder and Granite powder.

### *B. Scope*

To evaluate the recyclability of powdered waste glass as a pozzolana as partial replacement of cement and waste granite powder as partial replacement of fine aggregate in the concrete.

- To achieve 28 days characteristic compressive strength
- To study the compressive strength of glass powder + granite powder concrete and conventional concrete.
- To carry out the comparative study of compressive strength of glass powder + granite powder concrete and conventional concrete.
- To study the effect on workability, and strength properties of concrete mix with varying grades of concrete by replacing of sand by Granite powder and cement by Glass powder.
- To find out optimum grade of concrete at which the concrete yields superior mechanical properties.
- To achieve better concrete composite and to encourage the use of glass powder and granite powder to overcome the environmental impacts caused due

to waste disposal and over depletion of river sand.

## III. MATERIALS

This chapter presents the details of materials for concrete and the mix design for performing the experimental study.

The materials to be used for the experimental study are detailed as follows:

- Cement (OPC)
- Fine Aggregate
- Coarse Aggregate
- Water
- Glass powder
- Granite powder
- Reinforcements

*Cement*

Ordinary Portland cement of grade 43 conforming to IS specifications is used to cast the test specimen. Cement is a material, generally in powder form, that can be made into a paste usually by the addition of water and, when moulded or poured, will set into a solid mass.

TABLE I Typical Composition of OPC

| S.No | Name of the compound | Oxide composition | Abbreviation |
|---|---|---|---|
| 1. | Tricalcium silicate | $3CaO.SiO_2$ | $C_3S$ |
| 2. | Dicalcium silicate | $2CaO.SiO_2$ | $C_2S$ |
| 3. | Tricalcium Aluminate | $3CaO.Al_2O_3$ | $C_3A$ |
| 4. | Tetracalcium Alumino Ferrate | $4CaO.Al_2O_3.Fe_2O_3$ | $C_4AF$ |

### A. *Fine Aggregate*

The fine aggregate used in this experimental investigation was natural river sand confirming to zone II of IS: 383 – 1970.

TABLE II Properties of Fine Aggregate

| Properties | Fine aggregate |
|---|---|
| Shape | Angular particle |
| Gradation zone | Zone II |
| Specific gravity | 2.50 |
| Fineness modulus | 2.95 |

### B. *Coarse Aggregate*

Coarse aggregate is chemically stable material in concrete. It contributes to the heterogeneity of the cement concrete and there is weak interface between cement mix and aggregate surface in conventional concrete. Coarse aggregate is used natural crushed aggregate. To suit the needs of scale of the test specimen, coarse aggregates is passed through IS 20 mm sieve and retained on IS 12.5 mm sieve.

TABLE III Properties of Coarse Aggregate

| Properties | Coarse aggregate |
|---|---|
| Specific gravity | 2.65 |
| Fineness modulus | 6.22 |
| Water absorption | 0.6% |

### C. *Water*

Water is an important ingredient of concrete as it chemically participates in the reactions with cement to form the hydration product C-S-H gel. The strength of cement concrete depends mainly from the binding action of the hydrated cement paste gel. A higher water-binder ratio will degrease the strength, durability, water-tightness and other related properties of concrete.

### D. *Glass Powder*

The issue of recycled glass is quite complicated from a chemistry point of view. 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.

Therefore, it takes much more bottle glass powder as a cement replacement to mitigate ASR. Adding all the extra bottle glass pozzolan required creates another set of problems. First, the more pozzolan that is added retards strength development in the concrete to an unacceptably low rate. Secondly, as the bottle glass powders do react, they add more alkalis in the form of sodium silicate (aka water glass) to the concrete, which are highly soluble and can migrate to the surface in the form of sodium efflorescence.

TABLE IV Chemical Composition of Glass Powder

| Chemical Composition | Glass powder (%) |
|---|---|
| $SiO_2$ | 67.33 |
| CaO | 12.45 |
| $Al_2O_3$ | 2.64 |
| $Fe_2O_3$ | 1.42 |
| MgO | 2.73 |
| $Na_2O_3$ | 12.05 |

### E. *Granite Powder*

Granite is an igneous rock. It is mainly composed of quartz, feldspar and mica. Feldspar is a silicate of aluminum with varying amounts of potash, soda or lime. The density of the granite is between 2.65 to 2.75 g/cm$^3$ and compressive strength will be greater

than 200MPa. its viscosity near STP is 3–6 • $10^{19}$ Pa·s. Thus the specific gravity of granite powder is determined that 2.5 - 3.0.

TABLE V Chemical Composition of Granite Powder

| Chemical Composition | Granite powder (%) |
|---|---|
| $SiO_2$ | 72.04 |
| $Al_2O_3$ | 14.42 |
| $K_2O$ | 4.12 |
| $Na_2O$ | 3.69 |
| CaO | 1.82 |
| $Fe_2O_3$ | 1.22 |
| MgO | 0.71 |

Fig 1. Glass powder and Granite Powder

*F. Reinforcement.*

Steel bars with 12mm, 8mm diameter and link with 6mm diameter were cut according to the required length.

TABLE VI Reinforcement Details for RCC Beams

| Beams | Reinforcement Bars | | |
|---|---|---|---|
| | Top | Bottom | Stirrups |
| Under Reinforced | 2 # 8 mm Dia | 3 # 8 mm Dia | 6 mm @ 100 mm c/c |
| Balanced Section | 2 # 8 mm Dia | 2 # 12 mm Dia + 1 # 8 mm Dia | 6 mm @ 100 mm c/c |

## IV. MIX DESIGN

The mix shall be designed to produce the grade of concrete having the required workability and the characteristic strength. The proportions are either by volume or by mass. The water-cement ratio is usually expressed in mass.

*A. Factors to be considered*

- The grade designation giving the characteristic strength requirement of concrete.
- The type of cement influences the rate of development of compressive strength of concrete.
- Maximum nominal size of aggregates.
- The cement content is to be limited from shrinkage, cracking and creep.
- The workability of concrete and maximum temperature of concrete at the time of placing.

*B. Mix proportions*

TABLE VII Mix Proportions

| S.No | Grades of Concrete | Cement Kg/m$^3$ | Fine Aggregate Kg/m$^3$ | Coarse Aggregate Kg/m$^3$ | Water Kg/m$^3$ |
|---|---|---|---|---|---|
| 1 | $M_{20}$ | 369 | 646 | 1117 | 203 |
| | | 1 | 1.55 | 3.03 | 0.55 |
| 2 | $M_{30}$ | 440 | 629 | 1088 | 198 |
| | | 1 | 1.43 | 2.47 | 0.45 |
| 3 | $M_{40}$ | 480 | 623 | 1077 | 192 |
| | | 1 | 1.30 | 2.25 | 0.4 |

*C. Casting And Curing*

The main objective of the test program is to study the strength characteristics of concrete with replacement of Glass powder and Granite powder. The main parameters were studied the Compressive, Split tensile and Flexural strength.

*1) Casting of Cubes*

Initially the constituent materials were weighed and dry mixing was carried out for Cement, Fine aggregate, Coarse aggregate, Glass powder and Granite powder. This was thoroughly mixed manually to get uniform colour of mix. The mixing was carried out for 3-5 minutes duration. Then the mix poured in to the cube moulds of size 150 x 150x 150 mm and then compacted manually using tamping rods. Cubes are prepared by using the mixes of M20, M30 and M40 Grade namely conventional concrete and concrete made by replacing 20% of Glass powder and 25% of Granite powder.

*2) Casting of Cylinders*

Initially the constituent materials were weighed and dry mixing was carried out for Cement, Fine aggregate, Coarse aggregate, Glass powder and Granite powder. This was thoroughly mixed manually to get uniform colour of mix. The mixing was carried out for 3-5 minutes duration. Then the mix poured in to the cylinder mould by layer by layer and each layer effectively compacted by the cylinders of 150 mm dia and 300 mm height were casted for each design mixes.

*3) Casting of RCC Beams*

The concrete mixes were filled in the Beam moulds after laying the reinforcements with the required cover and compacted effectively by using damping rod. The beams of dimension 700 x100 x 100 mm were casted for each design mixes.

*4) Curing*

The Cubes, Cylinders and Beams are de-moulded after 1 day of casting and then kept in water for curing at normal temperature. The concrete specimens are taken out from curing tank after 7days, 14 days & 28 days for testing. Curing is a procedure that is adopted to promote the hardening of concrete under conditions of humidity and temperature which are conducive to the progressive and proper setting of the constituent cement. They should 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. Concrete that has been specified, batched, mixed, placed, and finished can still be a failure if improperly or inadequately cured.

*D. Testing Of Specimens*

The following tests are conducted to the casted concrete specimens.

*1) Compressive Strength Test:* The tests were carried out on 150x150x150mm size cube, as per IS: 516-1959. The compression test is the most common test conducted on the hardened concrete, partly because it is an easy test to perform, and partiy because most of the desirable characteristic properties of concrete are qualitatively related to its compression strength. The compression test is carried out on secimens cubical or cylindrical in shape. The specimen was placed between the steel plates of the compression-testing machine. The load is applied and the failure load in KN is observed from the dial gauge of the Compression Testing machine. The compression test on cubes was conducted according to Indian Standard specifications. The compressive strength of the cube specimen is calculated using the following formula:

Compressive Strength, $f_c = P/A$ N/mm$^2$.

Where,

P = Load at the point of failure in N

A = Area of compression in mm$^2$.

*2) Split Tensile Strength Test:* A direct measurement of ensuring tensile strength of concrete is difficult. This is an indirect tension test . Thia is also refered to as Brazilian test. The split tensile strength test was carried out on the universal testing machine. The split tensile strength of the cylinder specimen is calculated using the following formula:

Split Tensile Strength, $f_{sp} = 2P / \pi LD$ N/mm$^2$

Where,

P = Load at failure in N

L = Length of the Specimen in mm

D = Diameter of the Specimen in mm

*3) Flexural Strength Test:* Flexural strength, also known as modulus of rupture, bending strength or fracture strength a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. The value of modulus of rupture depends on the dimension of the beam and type of loading .The loading is central or third – point loading. In the the third-point the critical crack may appear at any section, where the bending moment is maximum or the resistance is weak . The flexural strength represents the highest stress experienced within the material at terms of stress, here given the symbol calculated using the following formula:

The flexural strength when a >133 mm for 100 mm specimen, $f_{fb} = Pa / bD^2$

The flexural strength when a < 133 mm for 100 mm specimen, $f_{fb} = 3Pa / bD^2$

b = measured width of specimen in mm

D = measured depth in mm of the specimen at the point of failure.

a = distance of the crack from the nearer support in mm

P = maximum load in N applied to the specimen.

## V. RESULTS AND DISCUSSIONS

*A. General*

Castings of the specimens were done as per IS: 10086-1982. The mixing, compacting and curing of concrete are done according to IS 516: 1959. The plain samples of cubes, cylinders and beams were cured for 28 days in water at room temperature. The specimens were taken for testing such as compression test, split tensile strength test and flexural strength test. The concrete specimens

which we prepared were tested in the universal testing machine. Three numbers of specimens in each were tested and the average value is calculated. The results were compared and analyzed with that of conventional mix.

The following tables and graphs give the details of the experimental results of concrete mixed with Glass powder and Granite powder.

### B. *Compressive Strength*

Compressive strength of concrete is the one of most important property of the hardened concrete. The concrete cubes were casted, cured and tested accordance with the IS standard and 7, 14 and 28 days. Compressive strength results of concrete. The highest compressive strength value is 41.13 Mpa which is obtained at 28 days for M40 grade by replacement of 20% Glass powder and 25% Granite powder in concrete when compared to the conventional mix.

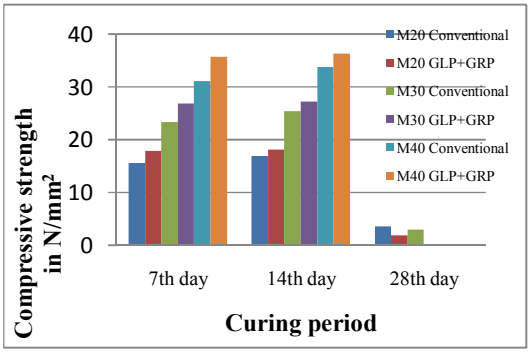


FIG.2. Compressive Strength of Concrete in N/mm$^2$

Figure.2. was drawn between compressive strength and curing periods for the various mixes. The compressive strength is gradually increased when the grade of concrete is increased. Maximum Compressive strength of cube is found to be 41.13 Mpa (for M40) at 20% Glass powder and 25% Granite powder replaced with cement and fine aggregate respectively in concrete and it increased the compressive strength by 12% than the conventional concrete.

### C. *Split Tensile Strength*

After curing of Cylinder specimens they are placed in testing machine. The load is applied on the cylinder specimens. The cylinder specimen is failed at ultimate load which is noted from dial gauge reading. From the result, split tensile strength is increased with respect to the grade of concrete by 12 % when compared to the conventional mix.

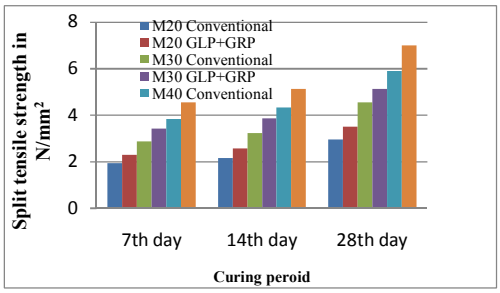


FIG.3.Split Tensile Strength of Concrete in N/mm$^2$

Split tensile strength is most important property of the hardened concrete. The concrete cylinders were cast, cured and tested accordance with the IS standard and 7, 14 and 28 days split tensile strength results of concrete. Based on the result, the highest split tensile strength value is 7.1 Mpa (for M40) which is obtained at 28 days by replacement of 20% Glass powder and 25% Granite powder in concrete. Figure.3 shows that the split tensile strength of concrete for various mixes. Strength is increased 18.2% than the conventional concrete.

### D. *Flexural Strength*

After curing of Beam specimens they are placed in testing machine having a maximum capacity of 40 tonne. The load is applied on the beam specimens. The specimen is failed at ultimate load which is noted from dial gauge reading. From the result flexural strength is increased with respect to the grade of concrete when adding 20 % of Glass powder and 25% of Granite powder when compared to the conventional concrete.

TABLE VIII Flexural strength

| Sl No | Grade of Concrete | Percentage of GLP + GRP Replacement | Flexural strength (N/mm$^2$) | |
|---|---|---|---|---|
| | | | *Under Reinforced section* | *Balanced Section* |
| 1 | $M_{20}$ | Conventional | 3.58 | 4.22 |
| | | 20% + 25% | 3.62 | 4.56 |
| 2 | $M_{30}$ | Conventional | 5.25 | 6.66 |
| | | 20% + 25% | 5.45 | 6.83 |
| 3 | $M_{40}$ | Conventional | 7.23 | 8.47 |
| | | 20% + 25% | 7.94 | 9.32 |

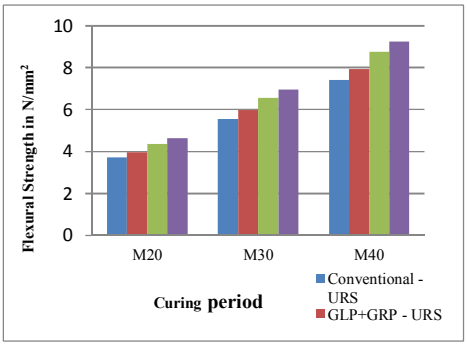


FIG.4. Flexural Strength of Concrete in N/mm$^2$

Flexural strength is property of the hardened concrete. The RCC Beams were casted, cured and tested accordance with the IS standard and 7,14 and 28 days flexural strength result of concrete are listed in table VIII

Based on the result, the highest flexural strength value is 9.32 Mpa (for M40) which is obtained at 28 days by replacement of 20% Glass powder and 25% Granite powder in concrete. Flexural strength is increased 7.2% than conventional concrete.

## VI. SUMMARY AND CONCLUSION

Experimental investigations were conducted to determine the Characteristics of Various grades of concrete such as M20, M30 and M40 by replacing of cement with Glass Powder (GLP) and fine aggregate with Granite powder (GRP). Concrete specimens were casted and tested for determine the Compressive strength, Split tensile strength and Flexural strength. Based on the test results it was inferred that at which percentage replaced with Glass powder and Granite powder given the better results than the conventional concrete with respect to 7,14 and 28 days Compressive strength, Split tensile strength and Flexural strength.

- Compressive strength increases with respect to the grade of concrete.
- Concrete acquires maximum compressive strength at 20% Glass powder and 25% Granite powder replaced for cement and fine aggregate respectively in all grades of concrete.
- Maximum Compressive strength of cube is found to be 41.13 Mpa for M40 and it is increased by 12% than the conventional concrete.
- Maximum split tensile strength of cylinder is found to be 7.1 Mpa for M40 and it is increased by 18.2% than the conventional concrete.
- Maximum flexural strength of specimen is found to be 9.32 Mpa for M40 Balanced section and it increased by 7.2 % than the conventional concrete.

From the above experimental results, it is proven that the Glass powder and Granite powder can be used as alternative ingredient in concrete, reducing cement consumption and reducing the cost of construction in the economical way.

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