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## Studies of Recycled Aggregate Concrete with Glass Powder

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**ABSTRACT:** The natural resources are being consumed in large quantity by concrete industry making them inadequate to meet challenges of increasing demand in now day's scenario. A huge number of old structures which have stopped serving life are being demolished creating huge amount of waste. The aim of this investigation is to access the feasibility of inclusion of Glass Powder for Recycled coarse aggregate based concrete to enhance its quality and secondly, to evaluate the effect of various percentages of glass powder and recycled coarse aggregate, on compressive strength, flexural strength and split tensile strength of concrete with the comparison of conventional strength of concrete. To determine the compressive strength, Flexural Strength and Split Tensile Strength of concrete specimen using the mix of M25 grade of concrete by varying percentages of recycled aggregate replacing natural aggregate by 0%, 20%, 50%, and 75% by weight. In addition of glass powder was used as 0%, 10% and 20% by weight replacing cement. Total 108 Concrete Specimen (Cube, Beam and Cylindrical) were made for the testing of the basic properties of hardened concrete. Regardless of the replacement ratio, recycled aggregate concrete (RAC) had a satisfactory performance, which did not differ significantly from the performance of control concrete in this experimental research. However, for this to be fulfilled, it is necessary to use quality recycled concrete coarse aggregate and to follow the specific rules for design and production of this new concrete type.

**KEYWORDS:** Controlled Concrete, modified concrete, Compressive Strength, Flexural Strength, Split Tensile Strength, Natural Aggregate, Recycled Aggregate, Glass Powder,

### I. INTRODUCTION

The natural resources are being consumed in large quantity by concrete industry making them inadequate to meet challenges of increasing demand in now days scenario. Approx, the total production of concrete is at an annual rate of 1m<sup>3</sup> per capita. The world wide total consumption of natural aggregate will increase to 49 billion metric tons after 2015. Every year, more than 1 billion tons of construction and demolition waste is generated worldwide similarly. A huge number of old structures which have stopped serving life are being demolished creating huge amount of waste. Research in many countries have shown grave concern and have implied a positive sign for the use of recycled aggregate and Glass powder in concrete. Which not only solve the waste disposal problem but is also beneficial for the usage of natural resource in more effective way to maintain the ecological balance? The researches of their arena of recycled aggregate concrete (RCA) and Glass powder are still progressing to find some implicit solution for the problem. Glass is a common product that can be found in different forms: bottles, jars, windows and windshields, bulbs, cathode ray tubes, etc., thus became integral part of our life. These products have a limited lifetime and generally disposed off after its usage. The current practice is still to landfill most of the non-recyclable glass. Since glass is a non biodegradable material, these landfills do not constitute an environmental solution and must be recycled in order to avoid environmental problems related to their stockpiling or land filling. Utilization of waste glass has attracted widespread construction site. Use of waste glass powder as aggregate in concrete has construction industry worldwide due to consumption of concrete in large quantity for been attempted by many more investigators.

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## II. RELATED WORK

In order to make clear the concept of using recycled aggregate and glass powder, it is prudent to review the related literature. As many researchers have been done previously, on the bases of literature available, relevant literature has been carried out.

**Priscilla M and Pushparaj A Naik** (2014) Experimental investigation of using waste glass powder, as partial replacement for cement, to overcome the drawbacks of recycled aggregate and the resulting concrete showed that waste glass, when milled to micro-scale particle size, is estimated to undergo pozzolanic reactions with cement hydrates, forming secondary calcium silicate hydrate (C-S-H). This paper has also attempted to provide concise information of strength of concrete containing waste glass powder and recycled aggregate when subjected to sulphate attack. [1]

**Raju Prajapati and Chaitanya Mishra** (2016) Research comprises of studies on offer of replacement of cement & aggregate by glass powder and recycled aggregate in concrete by some percentage for 28 days flexural strength of concrete. a result show that the flexural strength of modified concrete gives higher result (7.11N/mm<sup>2</sup>) with 5% glass powder & slightly lower result(6.50N/mm<sup>2</sup>) with 10% glass powder where as recycled aggregate percentage is fixed at 20. [2]

**Ismail Ansari and Sheetal Sahare** (2016) Experimental Investigations shows a positive result by enhancing the compressive and tensile strength of concrete. Workability decreases with increment in glass powder content. A review on utilization of a glass powder as a partial replacement of concrete and its effects on compressive and tensile strength of concrete is shown in this paper. [3]

**T.Subramani and S.B.Sankar Ram** (2015) This work examines the possibility of using Glass powder as a partial replacement of cement for new concrete. Glass powder was partially replaced as 10%, 20%, 30% and 40% and tested for its compressive, Tensile and flexural 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 75 $\mu$ m to prevent alkali silica reaction. [4]

**Ashutosh Sharma and Ashutosh Sangamnerkar** (2015) The present study shows that waste glass, if ground finer than 600 $\mu$ m shows a pozzolanic behavior. It reacts with lime at early stage of hydration forming extra CSH gel thereby forming denser cement matrix. Thus early consumption of alkalis by glass particles helps in the reduction of alkali-silica reaction hence enhancing the durability of concrete. Numbers of test were conducted to study the effect of 5%, 10% and 15% replacement of cement by glass powder on compressive strength and durability. The particle size effect was evaluated by using glass powder of size 600 $\mu$ m-100 $\mu$ m. The results showed that the maximum increase in strength of concrete occurred when 10% replacement was done with glass powder. [5]

## III. OBJECT AND SCOPE OF PRESENT RESEARCH

To determined the best combined of recycled aggregate and glass powder by replacing aggregate and cement content at which concrete shows its high flexural strength and durability of concrete with economical construction material.

As India is a fast growing and developing country all over networks of road ways is developing at a fast rate due towich old structures are being demolished in order to widening of roads & construction of sewage conveyance lines Due to this use of natural resources like natural aggregates has increased to a great extent. Now due to demolishing of old structures we are getting large amount of demolished concrete which can be recycled in form of aggregates and can be used in replacement of natural aggregate. The present investigation is carried out with the following objectives: 1. To determine the compressive strength of cube specimen using the mix of M25 grade of concrete by varying percentages of recycled aggregate replacing natural aggregate by 0%, 20%, 50%, and 75% by weight. In addition of glass powder was used as 0%, 10% and 20% by weight replacing cement. 2. To determine the flexural strength of Beam Specimen using M25 (By Indian Standard Mix Design Method) grade of concrete by varying percentages of recycled aggregate replacing natural aggregate by 0%, 20%, 50%, and 75% by weight. In addition of glass powder was used as 0%, 10% and 20% by weight replacing cement. 3. To determine the split tensile strength of cylindrical specimen for M25 grade of concrete at the age of 28 days and partially replacing cement and natural aggregate by glass powder and recycled

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aggregate concrete.7. To study the comparison between the properties of M25 Grade of Conventional concrete and M25 grade of Recycled aggregate concrete with glass powder.

## IV. MATERIALS

### Specification of Materials is;

- 1. Natural Aggregates (N.A)** Natural aggregates consists of rock fragments that are used in their natural state ,or are used after mechanical processing such as crushing ,washing and sizing. Coarse aggregates are used with size between 20mm-4.75mm. Crushed stone and sand and gravel are the two primary sources of natural aggregate, which are used directly in construction or as a raw material for construction products such as concrete and bituminous road materials.
- 2. Recycled Aggregates (R.A.)** Recycled aggregates maximum size up to 25mm is aggregates derived from the processing of materials previously used in a product and/or in construction. Examples include recycled concrete from construction and demolition waste material.
- 3. Glass powder** Glass powder is the waste product which can be obtained after cutting of glass product or also derived from grinding the waste glass material to fine powder. The glass powder from glass manufacturing industries can also be obtained in bulk amount which have same fineness modulus of cement. Cement Portland cement grade 43 is the most common type of cement in general usage .Cement is a most important constituent in concrete and well known binding material has occupied an indispensable place in the construction work. . For ordinary Portland cement, the residue by mass in 90 micron sieve should not exceed 10 percent.The standard cement should comply with the following conditions of fineness as given by IS: 460-1978 & IS: 269-1976.
- 4. Sand** A loose granular substance, typically pale yellowish brown, resulting from the erosion of siliceous and other rocks and forming a major constituent of beaches, river beds, the seabed, and deserts. Natural sand is provided with maximum size of 4.75 mm.
- 5. Water** is very actively participated in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully and secondly it acts as a lubricant of all other material and make concrete workable.

## V. PREPARATION AND TESTING OF MATERIALS

### Preparation of Specimens;

1. For preparation of cube samples, concrete mix was designed as per IS 10262:2009. The concrete mix proportions of Glass Powder, Recycled Coarse aggregate, natural coarse aggregate and fine aggregate was obtained as 1.870 kg (cement), 2.187 kg (sand) and 4.030 kg (natural coarse aggregate). Material were weighed on balances and mixed it manually. For casting of cube samples, steel moulds of cube were used and concrete was very well compacted. The side forms of moulds were stripped after 24 hours and left for water curing for 28 days.
2. The concrete mix proportions of Glass Powder, Recycled coarse aggregate, natural coarse aggregate and fine aggregate was obtained as 2.77 kg (cement), 3.24 kg (sand), 5.95 kg (natural coarse aggregate). Material was weighed on balanced and mixed it manually. For casting of beam samples, square steel moulds of beam on size 100mm X 100mm X 500mm were used concrete was very well compacted. The side forms of moulds were stripped after 24 hours and left for water curing for 28 days.
3. The concrete mix proportions of Glass Powder, Recycled coarse aggregate, natural coarse aggregate and fine aggregate was obtained as 2.77 kg (cement), 3.24 kg (sand), 5.95 kg (natural coarse aggregate). Materials were weighed on balances and mixed in electrically operated laboratory mixer. For casting of cylindrical specimens, cylindrical steel moulds were used and concrete was very well compacted. The side forms of moulds were stripped after 24 hours left for water curing for 28 days.

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## Arrangements and Instrumentation;

**1. Loading Arrangements of Cube Specimen:** In order to perform the compression testing of samples, a hydraulic testing machine was used in Strength of Material laboratory. The specimen is placed in the centre of loading area. Lower portion of the piston against the top of the concrete specimen by pushing the lever, Just place the piston on top of concrete cube specimen so that it's touching that. Monitor the concrete cube specimen, when it begins to break stop the applying load. Record the ultimate load on displaying on machine's display screen. Now we got the ultimate load. So we can now calculate the concrete compressive strength of concrete.

Compressive strength=Ultimate applying load (N) / area of the specimen (mm<sup>2</sup>). The unit of compressive strength will be N/mm<sup>2</sup>.

**2. Loading Arrangements of Beam Specimen** In order to perform the flexural strength of concrete, a hydraulic testing machine was used in Strength of Material laboratory. Bed of machine shall be provided with two steel rollers ballswitch a 38mm in diameter, on which a specimen is to be supported, and these rollers shall be so mounted that the distances from centre to centre is 40 cm for 10.0 cm specimens. In this process, load shall be applied through two same rollers mounted at the 3rd points of the supporting span (area) on the testing machine that is, spaced at 13.3cm centre to centre. The load is divided between two similar equally loading roller balls, and all rollers will be mounted in a manner that is the load is applied axially and without subjecting the specimen to any torsional stresses or restraints. The load is applied at a rate of loading of 180 kg/min for the 10.0cm specimens.

**3. In order to perform uniaxial compression test of concrete,** ratio of concrete material must be proper for cube filling, a hydraulic testing machine (H.T.M.) was used in Strength of Material laboratory work. In this method consists of applying diametrical force it's very important force, along the length of a cylindrical concrete specimen at a nominal rate, within the range 1.2N (mm<sup>2</sup>/min) to 2.4N (mm<sup>2</sup>/min) Maintain the rate, once adjusted, until failure. This loading induces tensile stress on the plane incorporate the applied load and relatively more compressive stresses in the area shortly around the applied load. Although we are applying a compressive load but due to Poisson's effect, tension is produced and specimen fails under tension. The maximum load applied shall then be recorded.

The rate of increase of load is calculated from the following formulas:

$$(1.2 \text{ to } 2.4) \times \pi/4 \times L \times d \text{ N/min.}$$

## VI. RESULTS

This part is describe the test results carried out to investigate the various properties of recycled aggregate concrete glass powder, mixes prepared in contrast with control mixes. The workability of concrete, compressive strength, flexural strength, and splitting tensile strength of M-25 grade of concrete and different replacement percentage of natural aggregate and cement by recycled coarse aggregate and glass powder respectively was studied. The cube samples were tested under compressive testing machine, and the beam samples were tested on flexural strength testing machine and the cylindrical samples were tested in compressive testing machine.

**1. Compressive strength Test:** For recycled concrete, the result shows that the addition of recycled aggregate with glass powder resulted in a significant reduction in compressive strength of recycled aggregate concrete with glass powder compared with the normal concrete strength. This strength reduction is slightly increased with increasing the percentage of recycled aggregate and glass powder.

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**Table 1** Results of compressive strength tests.

| S. No. | Notation          | Glass Powder (%) | Recycled Aggregate (%) | W/C ratio   | Compressive Strength (Mpa) |
|--------|-------------------|------------------|------------------------|-------------|----------------------------|
| 1      | RCA0 GP0          | 0                | 0                      | 0.45        | 26.55                      |
| 2      | RCA20 GP0         | 0                | 20                     | 0.45        | 23.83                      |
| 3      | RCA50 GP0         | 0                | 50                     | 0.45        | 20.44                      |
| 4      | RCA75 GP0         | 0                | 75                     | 0.45        | 18.22                      |
| 5      | RCA0 GP10         | 10               | 0                      | 0.45        | 26.10                      |
| 6      | <b>RCA20 GP10</b> | <b>10</b>        | <b>20</b>              | <b>0.45</b> | <b>25.10</b>               |
| 7      | RCA50 GP10        | 10               | 50                     | 0.45        | 21.55                      |
| 8      | RCA 75 GP10       | 10               | 75                     | 0.45        | 20.10                      |
| 9      | RCA0 GP20         | 20               | 0                      | 0.45        | 25.45                      |
| 10     | <b>RCA20 GP20</b> | <b>20</b>        | <b>20</b>              | <b>0.45</b> | <b>25.05</b>               |
| 11     | RCA50 GP20        | 20               | 50                     | 0.45        | 17.75                      |
| 12     | RCA75 GP20        | 20               | 75                     | 0.45        | 15.45                      |

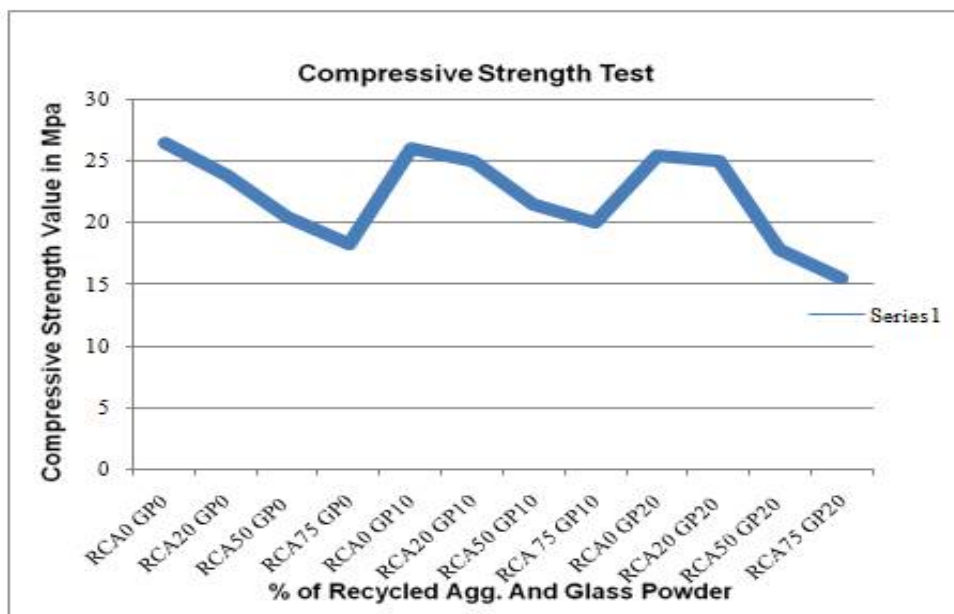


Figure 1 Graph of Compressive Strength test

The strength of concrete slightly decrease with increase in the percentage of Recycled aggregate and glass powder this may be due to lose mortar around the recycled aggregate, that do not allow the proper bonding between the cement paste and recycled coarse aggregate and glass powder.



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**2. Flexural strength Test:** Flexural strength is one measure of the tensile strength of concrete. It is a measure of a concrete beam or slab resist failure in bending the flexural strength is expressed as modules of rupture (M.R.) in measured Psi (mpa). Flexural strength is checked after 28 days curing of beam for both controlled concrete & modified concrete. The specimen are tested in universal testing machine with 2 ton load carrying capacity as per IS : 516-1959 (2004) By this comparison of flexural strength we have accessed the effect of glass powder and recycled aggregate on the flexural strength of concrete.

**Table 2** Results of Flexural strength tests.

| S. No. | Notation          | Glass Powder (%) | Recycled Aggregate (%) | W/C ratio   | Flexural Strength (Mpa) |
|--------|-------------------|------------------|------------------------|-------------|-------------------------|
| 1      | RCA0 GP0          | 0                | 0                      | 0.45        | 6.60                    |
| 2      | RCA20 GP0         | 0                | 20                     | 0.45        | 5.80                    |
| 3      | RCA50 GP0         | 0                | 50                     | 0.45        | 3.60                    |
| 4      | RCA75 GP0         | 0                | 75                     | 0.45        | 3.10                    |
| 5      | RCA0 GP10         | 10               | 0                      | 0.45        | 6.10                    |
| 6      | <b>RCA20 GP10</b> | <b>10</b>        | <b>20</b>              | <b>0.45</b> | <b>5.20</b>             |
| 7      | RCA50 GP10        | 10               | 50                     | 0.45        | 3.80                    |
| 8      | RCA 75 GP10       | 10               | 75                     | 0.45        | 2.90                    |
| 9      | RCA0 GP20         | 20               | 0                      | 0.45        | 5.90                    |
| 10     | <b>RCA20 GP20</b> | <b>20</b>        | <b>20</b>              | <b>0.45</b> | <b>5.00</b>             |
| 11     | RCA50 GP20        | 20               | 50                     | 0.45        | 4.60                    |
| 12     | RCA75 GP20        | 20               | 75                     | 0.45        | 3.10                    |

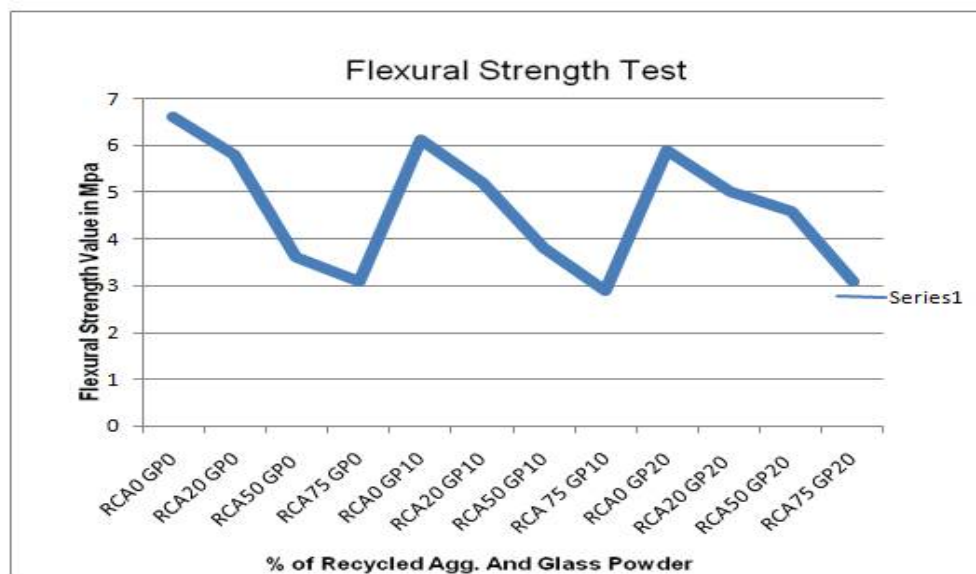


Figure 2 Graph of Flexural Strength test

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From the results obtained, it can be concluded that as the amount of recycled aggregate and glass powder content increases in more amount, the reduction in the flexural strength also increases with a concrete of medium and high strength compressive values.

**2. Split Tensile Strength Test:** Split tensile strength test was used to determine the tensile strength of concrete. The test was performed on cylindrical specimen with the dimension of 300 mm in length and 150 mm diameter after 28 days curing. The split tensile strength is generally greater than the direct tensile strength and lower than the flexural strength (modulus of rupture). This test method consists of applying a diametrical force or load along the length of a cylinder at a rate that is within a prescribed range until the failure.

**Table 3** Results of Split tensile strength tests.

| S. No. | Notation          | Glass Powder (%) | Recycled Aggregate (%) | Load in (N)   | Split tensile Strength (Mpa) |
|--------|-------------------|------------------|------------------------|---------------|------------------------------|
| 1      | RCA0 GP0          | 0                | 0                      | 183690        | 2.60                         |
| 2      | RCA20 GP0         | 0                | 20                     | 151897        | 1.95                         |
| 3      | RCA50 GP0         | 0                | 50                     | 127170        | 1.80                         |
| 4      | RCA75 GP0         | 0                | 75                     | 116573        | 1.65                         |
| 5      | RCA0 GP10         | 10               | 0                      | 190755        | 2.70                         |
| 6      | <b>RCA20 GP10</b> | <b>10</b>        | <b>20</b>              | <b>141300</b> | <b>2.00</b>                  |
| 7      | RCA50 GP10        | 10               | 50                     | 134235        | 1.90                         |
| 8      | RCA 75 GP10       | 10               | 75                     | 123637        | 1.75                         |
| 9      | RCA0 GP20         | 20               | 0                      | 194288        | 2.75                         |
| 10     | <b>RCA20 GP20</b> | <b>20</b>        | <b>20</b>              | <b>148365</b> | <b>2.10</b>                  |
| 11     | RCA50 GP20        | 20               | 50                     | 151897        | 1.95                         |
| 12     | RCA75 GP20        | 20               | 75                     | 130703        | 1.85                         |

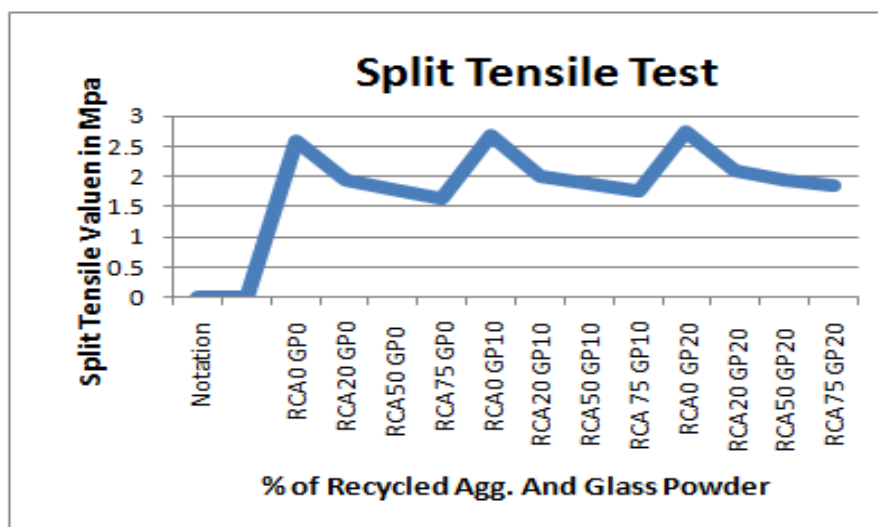


Figure 3 Graph of Split Tensile strength Test

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The maximum split tensile strength of recycled concrete is observed as 2.10 Mpa for M25 grade of concrete with 20 % replacement of natural aggregate with recycled aggregate and 20% replacement of cement with glass powder. The drop of strength is about 19.23% to the normal controlled concrete which are under limit and acceptable in to account.

## VII. CONCLUSION

The various conclusions drawn from the above studies are summarized as below:

1. The introductions of recycled coarse aggregate and glass powder into concrete significantly decrease the slump and decrease the workability of concrete.
2. The combination is RCA20GP20 of recycled aggregate concrete with glass powder is gives the better result in compressive strength test is about 25.10 N/mm<sup>2</sup>. In this combination the drop of strength is about 3.56% as compared to the normal controlled concrete, this strength is still above the acceptable limit i.e. 25 N/mm<sup>2</sup>
3. The compressive strength for fresh concrete increased with increase of incorporation of recycled aggregate. The most important benefit is reduced the permeability to aggressive chemicals and water. Properly cured concrete made with glass powder creates a denser concrete because the pores size is reduced. This increases strength and reduces permeability.
4. The flexural strength for fresh concrete increased with increase of incorporation of small amount of glass powder and the flexural strength for fresh concrete decreased with increase of incorporation of recycled aggregate in concrete.
5. The split tensile strength for fresh concrete increased with increase of incorporation of glass powder the maximum tensile strength is about 2.60 Mpa for M25 grade of concrete with replacement of 0% cement with glass powder and 0% replacement of natural aggregate with recycled aggregate.
6. Similarly the two combinations is give the better strength in the split tensile strength test i.e. RCA20GP10 in this combination the slight drop of strength is about 23.07% to the controlled concrete and RCA20FA20 shows the drop of strength is about 19.23% to the controlled concrete this two combinations shows the better result as compared to the normal controlled concrete and the results are still above the acceptable limit.
7. Use of glass powder in concrete can save the coal and thermal industry disposal costs and produce a 'greener' concrete for construction of civil structures.

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