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# EXPERIMENTAL STUDIES ON RC BEAM BY PARTIAL REPLACEMENT OF COARSE AGGREGATE BY CRUSHED WASTE GLASS AND RCA

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## ABSTRACT

This thesis report involves the study of concrete beam by the replacement of coarse aggregate partially by Recycled Concrete Aggregate (RCA) and crushed waste glasses. In order to conserve the virgin aggregate and thus to protect the natural resource the crushed waste glass and recycled concrete aggregates are used. The use of RCA in new concrete also helps in negotiating the scarcity of landfill. In this case, the waste glass can be used as a secondary aggregate. As the amount of waste glass is increasing day by day, it can be reused and make concrete products at a very low cost. In this study the replacement percentage is up to 50% with the conventional coarse aggregate. The composite replacement of recycled concrete aggregate is 0%, 25%, 30%, 40% and waste crushed glass is 0%, 25%, 20%, 10%. Concrete specimens are tested for various parameters such as compressive strength, split tensile strength, Flexural strength and modulus of elasticity.

***Keywords*** — Recycled Concrete Aggregate (RCA), Crushed Glass, Compressive strength, Split Tensile strength.

## I. INTRODUCTION

Concrete is the world's second most consumed material after water, and its widespread use is the basis for urban development. It is estimated that 25 billion tonnes of concrete are manufactured each year in our country. Twice as much concrete is used in construction around the world when compared to the total of all other building materials combined. In India 27% of the total waste generated is construction and demolition waste (C&DW). Many countries have recycling schemes for C&DW to avoid dumping to landfill, as suitable landfill sites are becoming scarce particularly in heavily populated countries. Charges on landfill dumping often make recycling concrete aggregate a preferred option.

Aggregate typically processed from demolition waste concrete is termed as Recycled Concrete Aggregate (RCA). The reuse of hardened concrete as aggregate is a proven technology. It can be crushed and reused as a partial replacement for natural aggregate in new concrete construction. The hardened concrete can be sourced either from the demolition of concrete structures at the end of their life – recycled concrete aggregate, or from leftover fresh concrete which is purposefully left to harden – leftover concrete aggregate. Additionally, waste materials from other industries such as crushed glass can be used as secondary aggregates in concrete. All these processes avoid dumping to landfill whilst conserving natural aggregate resources, and are a better environmental option.

Recycling or recovering concrete materials has two main advantages. It conserves the use of natural aggregate and the associated environmental costs of exploitation and transportation, and it preserves the use of landfill for materials which cannot be recycled. Waste glass is a major component of the solid waste stream in many countries. Glass is a transparent material produced by melting a mixture of materials such as silica, soda ash, and $CaCO_3$ (calcium carbonate) at high temperature followed by cooling during which solidification occurs without crystallization. It is widely used in our lives through manufactured products such as sheet glass, bottles, glassware, and vacuum tubing. The use of recycled glass helps save of energy.

The increasing awareness of glass recycling speeds up inspections on the use of waste glass with different forms in various fields. One of its significant contributions is to the construction field where the waste glass was reused for concrete production.

During the last decades it has been recognized that sheet glass waste is of large volume and is increasing year by year in the shops, construction areas and factories. Using waste glass in the concrete construction sector is advantageous, as the production cost of concrete becomes less. 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. There is huge potential for using waste glass in the concrete construction sector. When waste glasses are reused in making concrete products, the production cost of concrete will go down.

## II. LITERATURE REVIEW

The literature review presents the current state of knowledge and examples of successful uses of alternative materials in concrete and in particular, the use of Recycled Concrete Aggregates and recycled glasses as a coarse aggregate fraction in structural and non-structural concrete.

### 2.1 ALTERNATIVE MATERIAL OF COARSE AGGREGATE AS RECYCLED CONCRETE AGGREGATE

**Case study of Crushed Returned Concrete as Aggregates for New Concrete by Karthik Obla et al (2007**) The compressive strength and elastic modulus of concrete containing CCA is lower than that of the control concrete. However, the decrease in strength is not substantial and the strength drop RMC REF Report: Crushed Returned Concrete as Aggregates for New Concrete can be compensated for by normal mixture adjustments to achieve the desired strength. However, concrete containing 100% coarse Pile 1 CCA had significantly lower strengths.

**Experimental study on the replacement of natural aggregates by recycled aggregates by Valdir Schalch et al (2009)** The replacement of natural aggregates by recycled aggregates modified concrete's compressive strength and elastic modulus. In general, concrete produced with recycled aggregates had lower compressive strength, except concrete made of recycled fine aggregate from brick ceramic (RFB), where an increase in compressive strength was observed. For a same strength level, recycled aggregate concrete presented lower elastic modulus than concretes with natural aggregates.

**An Investigatin on recycled materials of RAP and RCA by Gregory J et al (2009)** This laboratory investigation dealt with the determination of the resilient modulus of two recycled materials: recycled asphalt pavement (RAP) and recycled concrete aggregate (RCA). The investigation also dealt with the determination of the resilient modulus of one blended material consisting of approximately 50% RCA and 50% conventional base material. However, when properly scaled for the stress and strain levels, the low-strain modulus estimated from the different test methods are remarkably close to each other indicating the scalability of laboratory modulus to operating field modulus.

**Study on replacement of Coarse aggregate by CCA by Dr. Dimitrios Goulias (2009)** The CCA aggregates are viable materials for both the general concrete application and the special concrete application. The main obstacle of CCA aggregate is a lack of testing methodology to quantify the composition of the CCA aggregate which is composed of the aggregate and paste phases. Further research will be needed for the proper testing methodology to quantify the composition of the CCA aggregate.

**An experimental investigation on recycled-aggregate in concrete by Valeria Corinaldesi (2010)** Finally, on the basis of the results obtained it seems that, particularly if finer coarse recycled-concrete aggregate is used, lower shrinkage strains are detected especially for earlier curing times. This last aspect, when considered together with a lower elastic modulus, predicts a lower tendency to crack in the recycled-aggregate concrete.

**Study of demolished concrete as partial replacement in concrete by Vivian W. Y. Tam et al (2012)** In this paper, ten demolished concrete (DC) samples have been collected to investigate the correlation among the characteristics of DC, properties of recycled aggregate (RA) and 21 recycled aggregate concrete (RAC). This can save time and cost for the production of inferior quality

RA and ensure that high quality RA is produced for higher-grade concrete applications. RAC design requirements can also be developed at the initial concrete demolition stage. Recommendations are also given to improve the future concreting practice.

**Case study of Crushed Recycled Concrete as Aggregates in Concrete by Sunil .S (2013)** The use of recycled aggregate up to 30% does not affect the functional requirements of the structure as per the findings of the test results. Various tests conducted on recycled aggregates and results compared with natural aggregates are satisfactory as per IS 2386. Due to use of recycled aggregate in construction, energy & cost of transportation of natural resources & excavation is significantly saved. This in turn directly reduces the impact of waste material on environment.

**Experimental study on the replacement of natural aggregates by recycled concrete aggregates by David McLean et al (2014)** RCA does not have a significant effect on the compressive strength of hardened concrete for up to a 45% replacement for coarse natural aggregate. RCA does not have a significant effect on the modulus of rupture for concretes incorporating up to a 45% substitution of RCA for coarse natural aggregate. Concretes tested in this study met WSDOT modulus of rupture requirement of 650 psi for PCCP for up to a 45% replacement of coarse natural aggregate with coarse RCA.

### 2.2 ALTERNATIVE MATERIAL OF COARSE AGGREGATE AS WASTE GLASS

**Experimental study on the replacement of aggregates by recycled aggregates by Liang, Hong et al (2007)** This paper presents mainly the latter aspect, in which study, both fresh and hardened properties of architectural concrete were tested. Results demonstrate that the use of waste glass as aggregate facilitates the development of concrete towards a high architectural level besides its high performances, thereafter, the increasing market in industry.

**Experimental investigation on fine glass with the replacement of fine aggregate and coarse aggregate by Turgut, E. S (2009)** In this paper, a parametric experimental study for producing paving blocks using fine and coarse waste glass is presented. Some of the physical and mechanical properties of paving blocks having various levels of fine glass (FG) and coarse glass (CG) replacements with fine aggregate (FA) are investigated. The compressive strength, the flexural strength, the splitting tensile strength and abrasion resistance of the paving block samples in the FG replacement level of 20% are 69%, 90%, 47% and 15 % higher as compared with the control sample, respectively.

**Effect of glass on concrete by partial replacement by Abdullah A. Siam (2011)** The primary objective of this research was to study the effect of waste glass content on the properties of concrete mixes when added as a partial replacement of fine aggregate and coarse aggregate. Finally, for concrete mixes containing the optimal portion of coarse or fine waste glass, it was concluded that there was negligible effects on the poll-out strength, considerable enhancement of the flexural strength, and slight reduction of the splitting tensile strength of the mix.

**Study of optimized utilization of concrete aggregate wastes (CAW) in concrete by Patricija Kara et al (2012)** In present study is investigated the approach of optimized utilization of concrete aggregate wastes (CAW) in concrete. The produced concrete cube specimens with florescent waste glass powder/suspension and fly wood ash after determination of their mechanical properties are recycled and used as partial replacement of natural aggregates in recycled aggregate concrete (RAC). Recycled aggregates from demolished concrete are generally produced by crushing, screening and removing the contaminants by water cleaning, air-shifting and magnetic separation.

**A study on replacement of coarse aggregate as waste glass by Vikas Srivastava et al (2014)** The study indicated that Waste glass can effectively be used as coarse aggregate replacement (up to 50%) without substantial change in strength. While using waste glass as coarse aggregate replacement, 28 days strength is found to marginally increase up to 20% replacement level. Marginal decrease in strength is observed at 30 to 40% replacement level of waste glass with coarse aggregate.

### 2.3 SUMMARY OF LITERATURE REVIEW

As per the literature review studied, the recycled glass and crushed concrete aggregate has been utilized up to 30%. The aim of the study is to replace coarse aggregate with the composite materials such as glass and crushed concrete aggregate up to 50%. With that concrete mix, the strength tests are performed and evaluated.

## III. METHODOLOGY

The flow chart below clearly show the processes which have been carried out in this work. The step by step process of this thesis is explained in the flow chart.

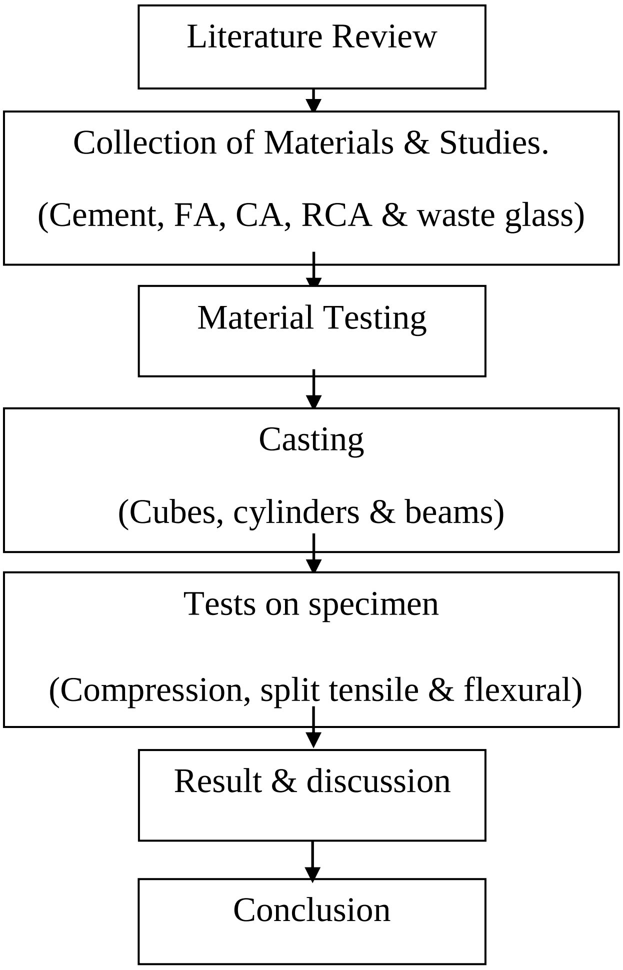



**Figure 3.1 Flow Chart of Methodology**

In the present work the composite material comprises of recycled concrete aggregate and crushed waste glass. The coarse aggregate used for the concrete works are partially replaced by the composite material comprising of recycled concrete aggregate and crushed waste glass. The concrete specimens are casted, cured and tested as per IS codes and standards for various strength aspects of cement concrete.

The main objective of this thesis is to study the following tests by using various specimens which are casted. As per IS: 516-1959 and IS: 5816-1999, the following harden concrete tests will be evaluated.

- Compressive strength test
- Split tensile test
- Flexural strength test

The composite materials are replaced for 50% of coarse aggregate by different proportions of 10% to 25% waste crushed glass and 25% to 40% of recycled concrete aggregate.

- **Conventional concrete cube : RCA 0% + CG 0%**
- **Sample 1 : RCA 25% + CG 25%**
- **Sample 2 : RCA 30% + CG 20%**
- **Sample 3 : RCA 40% + CG 10%**

## IV. CONCRETE MIX DESIGN

### 4.1 INTRODUCTION

Using the properties of materials the mix design has been adopted from IS 10262:2009 to design M20 grade of concrete. Based on the various design stipulations the mix ratio was obtained for all the specimens and the table shows the results obtained.

## 4.2 MIX DESIGN

**1. Stipulations of proportioning:**

Grade designation: M20
Grade of cement: OPC 43 grade
Maximum nominal size of aggregate: 20mm
Minimum cement content: 300 kg/m3
Maximum cement content: 450 kg/m3
Maximum W/C ratio : 0.55
Workability : 100mm (slump)
Exposure condition: Mild
Method of placing: Hand placed

**2. Test data for materials:**

Cement used : OPC 43 grade
Specific gravity of cement: 3.15
Specific gravity of water: 1
Specific gravity of fine aggregate: 2.65
Specific gravity of coarse aggregate: 2.7
Chemical admixture : None

**3. Target mean strength:**

fck' = fck+1.65S
where,
fck' = target average compressive strength at 28 days
fck = characteristic compressive strength at 28 days
From Table 1 of IS 10262:2009,
S = Standard deviation = 4
fck' = 20+1.5x4
= 26.6 N/mm$^2$

**4. Selection of W/C ratio:**

From table 5 of IS 456:2000,
Maximum W/C ratio = 0.55
Adopt W/C ratio= 0.45
0.45 < 0.55
Hence OK.

**5. Selection of water content:**

From table 2 of IS 10262:2009,
Maximum water content for 20mm aggregate = 186 litres
Increase by 3% for every additional 25mm slump
Estimated water content for 100 mm slump = 186+(6x186/100) = 197 litres

**6. Calculation of cement content:**

W/C ratio = 0.45
Cement content = 197/0.45 = 438 kg/m$^3$
From table 5 of IS 456:2000,
Minimum cement content for mild exposure condition = 300 kg/m$^3$
438 kg/m$^3$ > 300 kg/m$^3$
Hence OK.

**7. Proportion of volume of coarse aggregate and fine aggregate content:**

From table 3 of IS 10262:2009, volume of coarse aggregate corresponding to 20mm size aggregate, fine aggregate of zone 2 and for W/C ratio of 0.5 is 0.62.
In the present case W/C ratio = 0.45
Volume of coarse aggregate is required to be increased to decrease fine aggregate content. As W/C ratio is lower by 0.1, the proportion of volume of coarse aggregate is increased by 0.02(at the rate of ±0.01 for every ± 0.05 change in W/C ratio)

Therefore,
Volume of coarse aggregate for W/C ratio of 0.45 = 0.63
Volume of fine aggregate= 1-0.63 = 0.37

**8. Mix calculations:**

Mix calculations per unit volume of concrete are as follows:
a) Volume of concrete = 1m$^3$

b) Volume of cement = mass of cement / specific gravity of cement x 1 / 1000
= (438/3.15) x (1/1000)
= 0.139 m$^3$
c) Volume of water = mass of water / specific gravity of water x 1 / 1000
= (197/1) x (1/1000)
= 0.197 m$^3$
d) Volume of all in aggregate = [a-(b+c)]
= 1-(0.139+0.197)
= 0.664 m$^3$

e) Mass of coarse aggregate = d x volume of coarse aggregate x specific gravity of coarse aggregate x 1000
= 0.664x0.63x2.7x1000
= 1129.46 kg
f) Mass of fine aggregate = d x volume of fine aggregate x specific gravity of fine aggregate x 1000
= 0.664x0.37x2.65x1000

= 651 kg

**9. Mix proportion:**

Cement = 438 kg/$m^3$
Water = 197 kg/$m^3$
Fine aggregate = 651 kg/$m^3$
Coarse aggregate = 1129.46 kg/$m^3$
Water-cement ratio = 0.45

**10. Mix ratio of concrete:**

| CEMENT | FINE AGGREGATE | COARSE AGGREGATE | W/C |
|---|---|---|---|
| 1 | 1.49 | 3.0 | 0.45 |

## V. MATERIAL TESTING AND PROPERTIES

### 5.1 CEMENT

Cement is a binder, a substance that sets and hardens and can bind other materials together. It is usually fine, grey powder. It is mixed with water and materials such as sand, gravel, and crushed stone to make concrete. The cement and water form a paste that binds the other materials together as the concrete hardens. The ordinary cement contains two basic ingredients namely argillaceous and calcareous. In argillaceous materials clay predominates and in calcareous materials calcium carbonate predominates.There are several types of cement available in market; of which the Ordinary Portland Cement (OPC) is the most well-known & available one. OPC is the basic Portland cement and is best suited for use in general concrete construction. It is of three types namely, 33 grade, 43 grade and 53 grade. One of the important benefits is the faster rate of development of strength.

In the present work 43 grade Chettinad cement is used for casting cubes and cylinder for concrete mixes. A sample was tested to obtain the following characteristics:

- Specific gravity (determined by Le–Chatelier flask) (IS : 4031-1988 Part 11)
- Standard consistency (IS : 4031 – 1988 Part 4)
- Initial setting time (IS : 4031 – 1988 Part 5)
- Final setting time (IS : 4031 – 1988 Part 5)

**Figure No: 5.1 Cement**

The results of the tests on cement are given in the Table 5.1

**Table 5.1 Test on Cement**

| PROPERTIES OF CEMENT | VALUES |
|---|---|
| Specific Gravity | 2.95 |
| Standard Consistency | 28% |
| Initial Setting Time | 45 min |
| Final Setting Time | 10 hours |

### 5.2 FINE AGGREGATE

Fine aggregate or sand is an accumulation of grains of mineral matter derived from the disintegration of rocks. It is distinguished from gravel only by the size of grain or particle, but is distinct from clays which contain organic minerals. Sands that have been sorted out and separated from the organic material by the action of currents of water or by winds across arid lands are generally quite uniform in size of grains.

Fine aggregate are material passing through an IS sieve that is less than 4.75 mm. Usually natural sand is used as a fine aggregate. At places where natural sand is not available crushed stone is used as a fine aggregate. The sand used for the experimental work was locally procured and conformed to grading zone II. The sand was first sieved through 4.75 mm sieve to remove any particle greater than 4.75 mm sieve and then washed to remove dust. According to IS 383: 1970 the fine aggregate is being classified in to four different Zone-I, Zone-II, Zone-III, Zone-IV.In the present investigation, the river sand, which was available at Cochin, was used as fine aggregate and the following tests were carried out on sand as per IS: 2386- 1963(iii) :

- Specific Gravity
- Sieve analysis and Fineness Modulus
- Bulk density

**Figure No: 5.2 Fine aggregate**

The results of the tests on fine aggregate are given in the Table 5.2

**Table 5.2 Test on Fine Aggregate**

| PROPERTIES OF FINE AGGREGATE | VALUES |
|---|---|
| Specific Gravity | 2.66 |
| Percentage of Voids | 24.5% |
| Fineness Modulus | 2.78 |
| Bulk Density | 1.78 |

## 5.3 COARSE AGGREGATE

Those particles that are predominantly retained on the 4.75mm sieve are called coarse aggregate. The broken stone is generally used as a coarse aggregate. The nature of work decides the maximum size of coarse aggregate. Locally available coarse aggregate having the maximum size of 20 mm was used in the present work.

According to IS 383:1970 coarse aggregate maximum 20mm coarse aggregate is suitable for concrete work. But where there is no restriction 40mm or large size may be permitted. In case of close reinforcement, 10mm size can also be used.

In the present investigation, the following tests were carried out:

- Specific Gravity
- Sieve analysis
- Crushing value
- Water absorption

**Figure No: 5.3 Coarse aggregate**

The results of the tests on Coarse aggregate are given in the Table 5.4

**Table 5.4 Test on Coarse Aggregate**

| PROPERTIES OF COARSE AGGREGATE | VALUES |
|---|---|
| Specific Gravity | 2.7 |
| Water Absorption | 0.4% |
| Fineness Modulus | 7.3 |

## 5.4 RECYCLED CONCRETE AGGREGATE (RCA)

The hardened concrete returned to concrete plant can be crushed and reused as a partial replacement for natural aggregate in new concrete construction. The hardened concrete can be sourced either from the demolition of concrete structures at the end of their life. It is termed as Recycled

Concrete Aggregate (RCA). Alternatively fresh concrete which is leftover or surplus to site requirements can be recovered by separating out the wet fines fraction and the coarse aggregate for reuse in concrete manufacture.

The aggregates were properly graded and then mixed with the respective natural aggregate in appropriate percentages. The use of recycled materials has become accepted throughout the ready mixed concrete industry in response to increasing environmental focus and the increasing cost of disposing of waste material.

**Figure No: 5.4 Demolition Concrete**

The figure 5.5 given below explains the processing of recycled concrete aggregate.


**Figure No: 5.5 Processing of recycled concrete aggregate**

**Table 5.5 Properties of RCA**

| PROPERTIES | VALUES |
|---|---|
| Specific Gravity | 2.77 |
| Water Absorption | 6.99% |
| Bulk density (kg/m3) | 1370 |
| Fineness modulus | 5.55 |
| Water absorption | 4.3% |
| Impact value test | 26.66% |
| Crushing Value Test | 25.60% |

## 5.5 CRUSHED WASTE GLASS

Glass is a transparent material produced by melting a mixture of materials such as silica, soda ash, and $CaCO_3$ at high temperature followed by cooling during which solidification occurs without crystallization. It is widely used in our day today life. It can be found in many forms, including container glass, flat glass such as windows, bulb glass and cathode ray tube glass. The use of glass as aggregates in concrete has a great potential for high quality concrete development. Its shape and size have potential benefit in obtaining a good particle size distribution in glass concrete.

The present investigation, the crushed waste glass and RCA was used for the following tests:

- Specific Gravity
- Sieve analysis
- Bulk density

**Figure No: 5.6 Crushed Bottles Glasses**

**Figure No: 5.7 Crushed Container glasses**

The results of the tests on crushed waste glass are given in the Table 5.6

**Table 5.6 Physical Properties of Crushed Waste Glass**

| PROPERTIES OF CRUSHED WASTE GLASS | VALUES |
|---|---|
| Specific Gravity | 2.50 |
| Water Absorption | 0.17% |

**Table 5.7 Chemical Properties of waste glass**

| PROPERTIES | GLASS |
|---|---|
| $SiO_2$ (%) | 70.22 |
| CaO (%) | 11.13 |
| $Al_2O_3$ (%) | 1.64 |
| $Fe_2O_3$ (%) | 0.52 |
| $Na_2O$ (%) | 15.26 |
| Loss on ignition (%) | 0.80 |
| Density | 2.42 |

## 5.6 WATER

Water is an important ingredient of concrete as it actively participates 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 in to very carefully.

**Figure No: 5.8 Water**

The water is relatively free from organic matter, silt, oil, sugar, chloride and acidic material as per the requirements of water for concreting and curing. Portable water is generally considered satisfactory. In present investigation, tap water was used for both mixing and curing purpose

# VI. EXPERIMENTAL WORK AND RESULT ANALYSIS

## 6.1 COMPRESSIVE STRENGTH TEST

The compressive strength of concrete is determined at the age of 7 days and 28 days using cubes. The test was carried out on 150mm x 150mm x 150mm size cube as per IS: 516-1959. A 3000kN capacity standard compression testing machine was used to conduct the test. This is done by putting cement paste and spreading smoothly on whole area of specimen. For the studies on compressive strength, cubes are tested with a replacement of 50% of coarse aggregate by RCA and crushed glass in various proportions as 3 samples.

Compressive strength=Crushing load/ Area of cross section=W/A (N/mm$^2$)
Size Of mould =150mmx150mmx150mm
Area of cube=150mmx150mm = 22500mm$^2$
Crushing load =600KN

**Figure 6.1Compressive strength test of concrete**

**Table No: 6.1 Compressive Strength Result**

<table>
<tr><th rowspan="2">Sl.No.</th><th rowspan="2">SAMPLES</th><th colspan="4">COMPRESSIVE STRENGTH N/mm<sup>2</sup></th></tr>
<tr><th colspan="2">7 Days</th><th colspan="2">28 Days</th></tr>
<tr><td rowspan="2">1.</td><td rowspan="2">CONVENTIONAL CONCRETE</td><td>11.65</td><td rowspan="2">12.08 (Avg.)</td><td>21.10</td><td rowspan="2">21.03 (Avg.)</td></tr>
<tr><td>11.89</td><td>20.45</td></tr>
</table>

| | | | | | |
|---|---|---|---|---|---|
| | CUBE (RCA 0% + CG 0%) | 12.71 | | 21.54 | |
| 2. | SAMPLE 1 (RCA 25% + CG 25%) | 12.11 | 12.40 (Avg.) | 24.44 | 22.06 (Avg.) |
| | | 13.42 | | 21.22 | |
| | | 11.67 | | 20.54 | |
| 3. | SAMPLE 2 (RCA 30% + CG 20%) | 18.70 | 19.63 (Avg.) | 27.12 | 27.29 (Avg.) |
| | | 19.33 | | 26.86 | |
| | | 20.85 | | 27.89 | |
| 4. | SAMPLE 3 (RCA 40% + CG 10%) | 13.27 | 14.04 (Avg.) | 26.67 | 24.01 (Avg.) |
| | | 14.20 | | 23.59 | |
| | | 13.98 | | 21.77 | |

**Figure 6.2 Comparison of Compressive Strength Test**

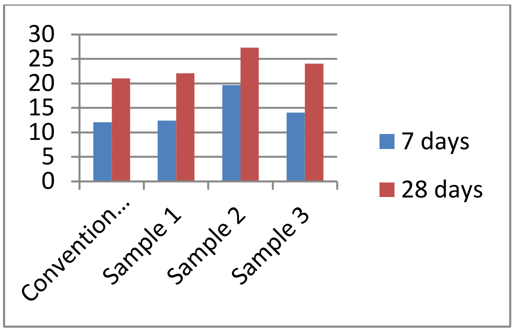



**Figure 6.3 Concrete cube under compressive strength test**

## 6.2 SPLIT TENSILE STRENGTH TEST

The splitting tests are well known indirect tests used for determining the tensile strength of concrete cylinders also referred as split tensile strength of concrete. The test consists of applying a compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontally. Due to the compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter as obtained from an elastic analysis. The magnitude of this tensile stress fsp is given by the formula (IS: 5816-1999):

$$Fsp = 2P/\pi dl \ N/mm^2$$

where, Fsp=Split tensile strength ($N/mm^2$)
P=Load at Failure (N) =180 kN
d =Diameter of the specimen (mm)
l =Length of the specimen (mm)
Diameter of the specimen=150mm
Length of the specimen =300mm

**Figure 6.4 Split tensile test**

**Table No: 6.2 Split Tensile Strength Results**

| Sl.No. | SAMPLES | COMPRESSIVE STRENGTH N/mm² | | | |
|---|---|---|---|---|---|
| | | 7 Days | | 28 Days | |
| 1. | CONVENTIONAL CONCRETE CUBE (RCA 0% + CG 0%) | 11.65 | 12.08 (Avg.) | 21.10 | 21.03 (Avg.) |
| | | 11.89 | | 20.45 | |
| | | 12.71 | | 21.54 | |
| 2. | SAMPLE 1 (RCA 25% + CG 25%) | 12.11 | 12.40 (Avg.) | 24.44 | 22.06 (Avg.) |
| | | 13.42 | | 21.22 | |
| | | 11.67 | | 20.54 | |
| 3. | SAMPLE 2 (RCA 30% + CG 20%) | 18.70 | 19.63 (Avg.) | 27.12 | 27.29 (Avg.) |
| | | 19.33 | | 26.86 | |
| | | 20.85 | | 27.89 | |
| 4. | SAMPLE 3 (RCA 40% + CG 10%) | 13.27 | 14.04 (Avg.) | 26.67 | 24.01 (Avg.) |
| | | 14.20 | | 23.59 | |
| | | 13.98 | | 21.77 | |

**Figure 6.5 Comparison of Split tensile test**

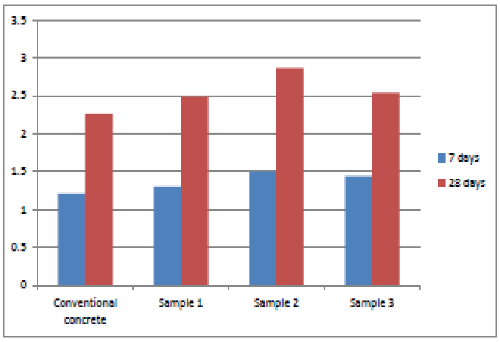



**Figure 6.6 Cracking of concrete cylinder**

## 6.3 FLEXURAL STRENGTH TEST

Direct measurement of tensile strength of concrete is difficult. Neither specimens nor testing apparatus have been designed which assure uniform distribution of 'pull' applied to the concrete. While a number of investigations involving the direct measurement of tensile strength have been made, beam tests are found to be dependable to measure the flexural strength property of concrete. The value of the modulus of rupture (extreme fiber stress in bending) depends on the dimension of the beam and manner of loading. The systems of loading used in finding out the flexural tension are central point loading and third point loading. In the central point loading, maximum fibre stress will come below the point of loading where the bending moment is maximum. In the symmetrical two point loading, the critical crack may appear at any section , not strong enough to resist the stress within the middle third , where the bending moment is maximum. It can be expected that the two point loading will yield a lower value of modulus of rupture than the centre point loading.

Flexural strength, F = $Pl/bd^2$

where,

P = maximum load in Newton
l = length of the specimen
b = width of the specimen
d = depth of the specimen

### 6.3.1 SPECIMEN DETAIL AND CASTING

The overall length 'L' of the test beam is taken as 1200mm, the effective length '$L_{eff}$' as 1000mm, total depth 'D' as 180mm, effective depth 'd' as 150mm, breadth 'b' as 150mm and clear cover 'c' as 20. High yield strength deformed (HYSD) bars having 415 $N/mm^2$ yield strength is used. The beam specimens were casted, based on the detailing shown in fig.6.7 and are cured for 28days.

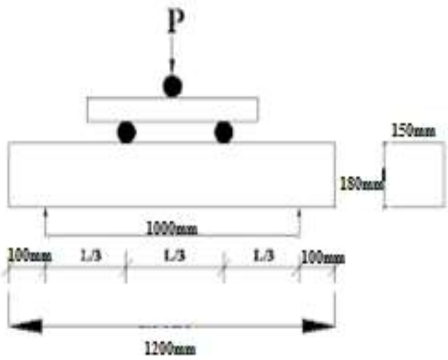
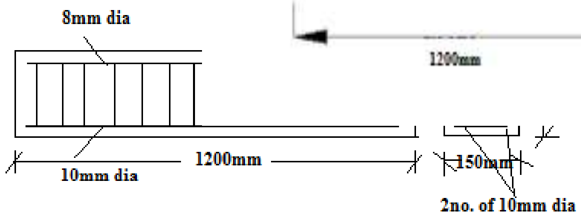



**Figure 6.7**




**Reinforcement details of test beams**

### 6.3.2 LOADING ARRANGEMENTS AND TESTING

The flexural strength tests were carried out as per IS: 516-1959. The structural properties are ascertained by conducting two-point load testing. This load case was chosen because it gives constant maximum moment and zero shear in the section between the loads, and constant maximum shear force between support and load. The moment was linearly varying between supports and load. Two point bending was applied on reinforced concrete beams of span 1.2m and the load was applied at points dividing the length into three equal parts as shown in Fig.6.8. Steel plates were used under the loads to distribute the load over the width of the beam. The testing equipment was a testing machine of 400KN capacity jack. A linearly variable differential transducer (LVDT), was used to measure the deflection at mid-span. Fig. 6.9 shows the test setup of a beam.

**Figure 6.8 Two2-Point loading in Flexural Strength test**

**Figure 6.9 Test setup of beam under frame loading**

**Table No: 6.3 Load vs Deflection for conventional RC beam**

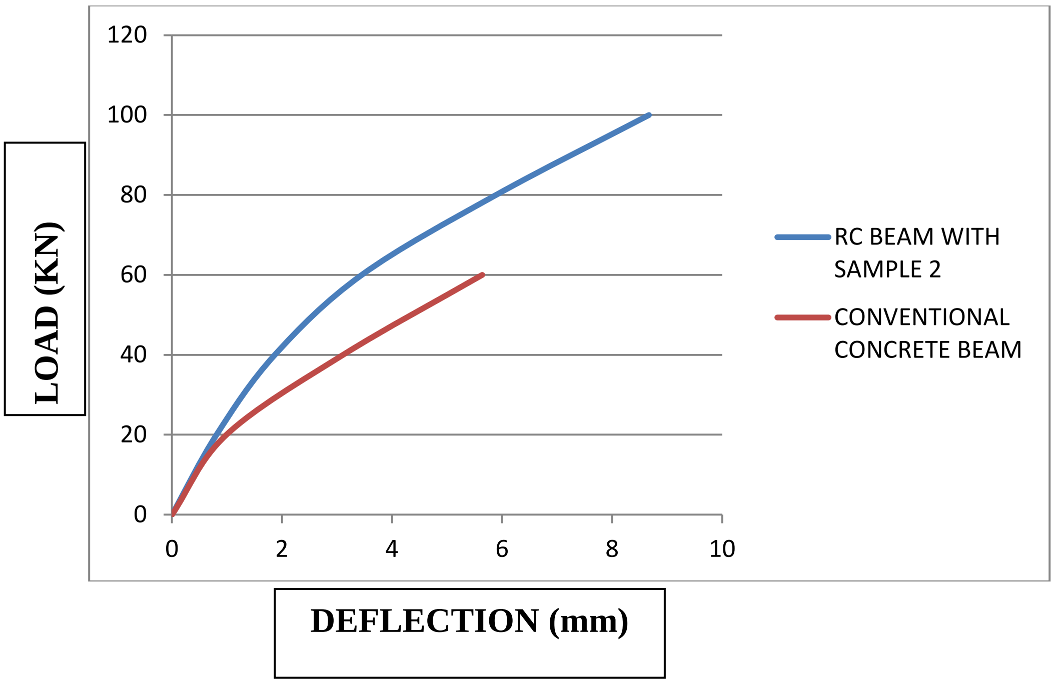
| Sl.No. | LOAD (KN) | DEFLECTION (mm) |
|---|---|---|
| 1. | 0 | 0 |
| 2. | 5 | 0.30 |
| 3. | 10 | 0.51 |
| 4. | 15 | 0.76 |
| 5. | 20 | 0.99 |
| 6. | 25 | 1.39 |
| 7. | 30 | 1.92 |
| 8. | 35 | 2.43 |
| 9. | 40 | 3.11 |
| 10. | 45 | 3.67 |
| 11. | 50 | 4.0 |
| 12. | 55 | 4.81 |
| 13. | 60 | 5.64 |
| 14. | 65 | 6.77 |
| 15. | 70 | 9.03 |
| 16. | 75 | 18.58 |

**Table No: 6.4 Load vs Deflection for RC beam consisting of Sample 2 (RCA 30% + CG 20%)**

| Sl.No. | LOAD (KN) | DEFLECTION (mm) |
|---|---|---|
| 1. | 0 | 0 |
| 2. | 5 | 0 |
| 3. | 10 | 0.20 |
| 4. | 15 | 0.43 |
| 5. | 20 | 0.81 |
| 6. | 25 | 1.05 |
| 7. | 30 | 1.30 |

| | | |
|---|---|---|
| 8. | 35 | 1.56 |
| 9. | 40 | 1.87 |
| 10. | 45 | 2.13 |
| 11. | 50 | 2.55 |
| 12. | 55 | 2.98 |
| 13. | 60 | 3.45 |
| 14. | 65 | 3.91 |
| 15. | 70 | 4.34 |
| 16. | 75 | 4.82 |
| 17. | 80 | 5.89 |
| 18. | 85 | 6.53 |
| 19. | 90 | 7.01 |
| 20. | 95 | 7.84 |
| 21. | 100 | 8.67 |
| 22. | 105 | 9.42 |
| 23. | 110 | 11.01 |

**Figure 6.10 Load-Deflection Curve**




## VII. CONCLUSION

In this study various tests were conducted with the composite replacement materials which include recycled concrete aggregate and waste crushed glass as alternate for the natural coarse aggregate in cement concrete. Concrete specimens are tested for various strength parameters such as compressive strength, split tensile strength and flexural strength test and the results are evaluated. In this research the replacement percentage is up to 50% with the conventional coarse aggregate. The composite replacement of recycled concrete aggregate is 25%, 30%, 40% and waste crushed glass is 25%, 20%, 10% for alternate virgin coarse aggregate in cement concrete. The test results proved that the sample 2, ie. RCA 30% + CG 20% can be used as a partial replacement for coarse aggregate. This sample mixing provides high compressive and tensile strength, which gives a proof that it can be used for structural members for beam, column, slab, roof, and retaining wall etc.When compared to the conventional concrete, the RC beam containing sample 2 gives maximum load with minimum deflection. ie., it shows high flexural strength.

This study helps to prove that the use of recycled material in construction helps to save the environment and reduces the waste material. Hence, the Recycled Concrete Aggregate (RCA) and Crushed Waste glass can effectively be used as coarse aggregate replacement.

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