CHAPTER 3

EXPERIMENTAL INVESTIGATION

3.1 GENERAL

As discussed in Chapter 2, certain industrial wastes and non-conventional materials have been used as aggregate in concrete-making. In the present study the ceramic electrical insulator waste, after removal of its glassy outer skin, was used as coarse aggregate. Fine aggregate was prepared by mixing river sand (50 percent) and bottom ash (50 percent). Bottom ash was obtained from Neyveli Lignite Corporation-Thermal Power Plant II. 10 percent Silica fume by mass of cement was added in the concrete mix. The properties of ceramic waste and bottom ash aggregates were found out through separate investigations.

The experimental programme comprises the following stages:

i. Characterization of ceramic waste coarse aggregate, bottom ash fine aggregate (CWBA aggregate) and silica fume.

ii. Study on fresh and hardened concrete prepared using ceramic waste coarse aggregate and bottom ash fine aggregate (CWBA aggregate concrete) with silica fume.

iii. Proposing a guide line for mix proportioning.

iv. Study on permeation properties of CWBA aggregate concrete to ascertain the durability of the concrete.

v. Study on the flexural behaviour of reinforced ceramic waste coarse aggregate and bottom ash fine aggregate concrete (RCWBA) beam.

Properties of the crushed stone coarse aggregate and CWBA aggregate materials and the concrete prepared using the blend of the ceramic waste-bottom ash-sand-cement-silica fume mix were evaluated using standard test procedures as given in Figure 3.1.
Fig.3.1 Details of Experimental Investigation
3.2 TEST FOR CHARACTERIZATION OF CERAMIC WASTE COARSE AGGREGATE

In this study experiments were carried out on ceramic waste coarse aggregate to ascertain the suitability for concrete making.

3.2.1 Beneficiation of Ceramic Waste Coarse Aggregate

Ceramic waste (Figure 3.2) obtained from ceramic electrical insulator industry has a glassy outer skin. Initially the glazed surface was removed manually and it was broken into 100 mm to 150 mm size (Figure 3.3) by a hammer. Then it was fed into the jaw-crusher to get 20 mm graded aggregate. Figures 3.4 and 3.5 shows the ceramic waste coarse aggregate and crushed stone coarse aggregate respectively. Figure 3.6 shows the preparation process of ceramic waste coarse aggregate.

Fig. 3.2 Ceramic Waste

Fig. 3.3 Processed Ceramic Waste Coarse Aggregate

Fig. 3.4 20 mm Size Ceramic Waste Coarse Aggregate

Fig. 3.5 20 mm Size Crushed Stone Coarse Aggregate
3.2.2 Tests on Ceramic Waste Coarse Aggregate and Crushed Stone Coarse Aggregate

The following tests were conducted on ceramic waste coarse aggregate and crushed stone coarse aggregate:

i. Bulk density test
ii. Density (g/cm³) test
iii. Water absorption test
iv. Particle size distribution test
v. Crushing value test
vi. Impact value test
vii. Soundness test
3.2.2.1 Bulk Density Test

The bulk density is the weight of materials that would fill a unit volume. Bulk volume represents both the volume of aggregate and the volume of voids. This test was conducted as per IS 2386 (Part III) – 1963.

3.2.2.2 Density (g/cm³) Test

The density of aggregate including the pores is expressed as the density (g/cm³), which refers to the relative (as compared to water) density of a unit volume of aggregate. This test was conducted as per IS 2386 (Part III) - 1963.

3.2.2.3 Water absorption Test

All aggregates have pores in which water can be held for a long time. Water absorption and surface moisture determination is important in order to maintain the desired water-cement ratio in the concrete mix design. The water absorption of aggregate is determined by measuring the increase in weight of an oven dry aggregate when immersed in water for 24 hours. The ratio of the increase in weight to the weight of the dry aggregate is expressed as percentage of water absorption.

3.2.2.4 Particle Size Distribution Test

The water demand and workability are influenced by particle size distribution. To understand the grading, sieve analysis was conducted as per IS 2386 (Part I) – 1963.

Air dried aggregate was sieved through the test sieves and the residue in each sieve is weighed. The cumulative percentage of weight retained to the total weight is calculated, from which the percentages passing and fineness modulus of aggregates were calculated.

3.2.2.5 Crushing Value Test

This test measures the quality of the rock rather than the quality of the aggregate. The material to be tested should pass through a 12.5 mm sieve and get retained on a 10mm sieve.
Using compression testing machine, the aggregate was subjected to a load of $400 \times 10^5$N through a plunger. This test was conducted as per IS 2386 (Part IV) – 1963 and crushing value of aggregate was obtained.

3.2.2.6 Impact Value Test

The toughness of aggregate which is measured as the resistance of the aggregate to failure by impact and impact test (Figure 3.7) was conducted as per IS 2386 (Part IV) – 1963.

![Aggregate Impact Testing Apparatus](image)

**Fig. 3.7 Aggregate Impact Testing Apparatus**

3.2.2.7 Soundness Test

The soundness indicates that the ability of the aggregate to resist excessive volume change due to environmental conditions. The soundness test was conducted as per IS 2386 (Part V) - 1963 to determine the resistance to disintegration of aggregates by saturated Sodium Sulfate Solution and oven drying it under specified conditions.
The accumulation and growth of salt crystals in the pores of the particles is thought to produce disruption of particles to the action of crystallization of salt. Loss in weight was measured for the specified number of cycles.

3.3 TEST FOR CHARACTERIZATION OF BOTTOM ASH FINE AGGREGATE

In this study experiments were carried out on bottom ash fine aggregate to ascertain its suitability for concrete making.

3.3.1 Beneficiation of Bottom Ash

Bottom ash is the byproduct of coal fired furnace used in thermal power plants. It is sand like material with granular structure with the same upper and lower particle size limits as river sand. Large size bottom ash particles have a porous inner core, and it can be very easily crushed between fingers. But smaller size particles of bottom ash exhibit higher strength. Figures 3.8 and 3.9 show the bottom ash and river sand respectively.

![Fig. 3.8 Bottom Ash](image1)

![Fig. 3.9 River Sand](image2)

3.3.2 Tests on Bottom Ash Fine Aggregate

The following tests were conducted on bottom ash fine aggregate and sand.
Physical Properties

i. Density (g/cm³)
ii. Bulk density
iii. Sieve analysis
iv. Water absorption

Tests for evaluating the properties of bottom ash fine aggregate were carried out in accordance with the provisions of IS 2386 (I to VIII) – 1963. The values found out for bottom ash fine aggregate were compared with the respective values for river sand fine aggregate. The value obtained for properties of bottom ash fine aggregate fulfilled the limits specified in IS 383-1970, and were acceptable for usage in concrete.

3.3.3 Chemical Composition of Bottom Ash

The samples of bottom ash were tested at chemical testing analytical laboratory (CTAL, Chennai).

3.3.4 X-ray Diffraction (XRD) Analysis of Bottom Ash

The X-ray diffraction (XRD) analysis was carried out for the samples of bottom ash at the Regional Research Laboratory located at Thiruvananthapuram Kerala. The crystalline phase of bottom ash was investigated using XRD technique.

3.4 CHARACTERIZATION OF SILICA FUME

In this study the physical properties and chemical composition of silica fume are given by the supplier M/s Elkem India (Pvt) Limited, Mumbai. Silica fume (Figure 3.10) is a by-product in the manufacture of silicon. This is a very fine pozzolanic material composed of amorphous silica. The properties of silica fume to be used in cement concrete are specified in ASTM C1240. Silica fume undergoes pozzolanic reaction with calcium hydroxide in cement paste to improve the mechanical properties of concrete.
Another improvement achieved by the addition of silica fume in concrete is the reduction in permeability of concrete, which effectively stops the ingress of chloride ions and protects the reinforcing steel from corrosion. This reduction in permeability of concrete makes it suitable for marine environment with salt content in water.

Silica fume leads to reduction in bleeding of concrete by absorbing excess water by virtue of its large surface area. Presence of silica fume also reduces the formation of micro pores on the surface of concrete, thus reducing the bubbles and resulting gaps after curing of concrete. As per IS: 456-2000 Silica fume is added 10 percent by mass of cement in concrete composition.

3.5 DEVELOPMENT OF CERAMIC WASTE COARSE AGGREGATE AND BOTTOM ASH FINE AGGREGATE CONCRETE

Electrical insulator ceramic waste coarse aggregate as a replacement of crushed stone coarse aggregate, bottom ash (50 percent) as a replacement of fine aggregate and 10 percent silica fume by mass of cement were added in concrete and other ingredients were cement, sand and water. Mechanical and durability properties of concrete were investigated.
3.5.1 Mix Proportions

The conventional mix design methods cannot be applied to multiple mineral admixtures with artificial ceramic waste aggregate. Hence, in general, it is recommended that the trial mixes are to be made with suitable adjustments in grading and proportioning to achieve the desired properties of concrete. Considering the above factor and the properties of ceramic waste, bottom ash aggregates, silica fume and sand, mix proportion was carried out by absolute volume method.

Trial mixes were performed to optimize the constituent materials to get good workability, cohesiveness and yield. It was observed that the minimum operating water required was 175 liters per cubic meter of concrete for 20 mm maximum size of aggregate to get the slump range 75mm to 100 mm.

Concrete containing OPC 43 grade as binder, mix of sand (50 percent), bottom ash (50 percent) as fine aggregate and 20 mm crushed ceramic waste as coarse aggregate were prepared. Silica fume was added to concrete at 10 percent by mass of cement.

Six different cement contents were adopted for preparation of experimental specimens, viz., 300, 350, 400, 450, 500, 550 kg/m³ since the weight of water added to the concrete remained at 175 liters per cubic meter of concrete. The water-cement ratios worked out to 0.58, 0.50, 0.44, 0.39, 0.35 and 0.32 respectively. In all the six mixes the water content and volume of ceramic waste coarse aggregate were kept constant to understand the ceramic waste coarse aggregate behavior in the mix. For all mixes 1 percent entrapped air was assumed.

Similarly, six more crushed stone coarse aggregate concrete mixes were designed. Ceramic waste coarse aggregate and crushed stone coarse aggregate were in a saturated and surface dry condition. The volume of individual ingredients was the same in both ceramic waste coarse aggregate concrete (CWBA aggregate concrete) and crushed stone coarse aggregate concrete for the respective water-cement ratio.
Totally twelve mixes were prepared: CW1, CW2, CW3, CW4, CW5 and CW6, were ceramic waste coarse aggregate concrete mixes and mixes CC1, CC2, CC3, CC4, CC5 and CC6 were the corresponding crushed stone coarse aggregate concrete mixes. The mix proportions are presented in Tables 3.1 and 3.2 respectively. The details of number of specimens prepared from different mixes are presented in Table 3.3.

Table 3.1. CWBA Aggregate Concrete Mix Proportions per Cubic meter

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Mix</th>
<th>W/C</th>
<th>Water Liters</th>
<th>Cement Kg</th>
<th>Cement m³</th>
<th>Fine Aggregate BA kg</th>
<th>Fine Aggregate BA m³</th>
<th>Fine Aggregate Sand kg</th>
<th>Fine Aggregate Sand m³</th>
<th>Coarse Aggregate kg</th>
<th>Coarse Aggregate m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CW1</td>
<td>0.58</td>
<td>175</td>
<td>300</td>
<td>0.095</td>
<td>370.50</td>
<td>0.1482</td>
<td>395.69</td>
<td>0.1482</td>
<td>1119.3</td>
<td>0.41</td>
</tr>
<tr>
<td>2</td>
<td>CW2</td>
<td>0.50</td>
<td>175</td>
<td>350</td>
<td>0.116</td>
<td>347.50</td>
<td>0.1390</td>
<td>371.26</td>
<td>0.1390</td>
<td>1119.3</td>
<td>0.41</td>
</tr>
<tr>
<td>3</td>
<td>CW3</td>
<td>0.44</td>
<td>175</td>
<td>400</td>
<td>0.127</td>
<td>324.75</td>
<td>0.1299</td>
<td>346.96</td>
<td>0.1299</td>
<td>1119.3</td>
<td>0.41</td>
</tr>
<tr>
<td>4</td>
<td>CW4</td>
<td>0.39</td>
<td>175</td>
<td>450</td>
<td>0.143</td>
<td>302.00</td>
<td>0.1208</td>
<td>322.00</td>
<td>0.1208</td>
<td>1119.3</td>
<td>0.41</td>
</tr>
<tr>
<td>5</td>
<td>CW5</td>
<td>0.35</td>
<td>175</td>
<td>500</td>
<td>0.158</td>
<td>280.37</td>
<td>0.1121</td>
<td>299.31</td>
<td>0.1121</td>
<td>1119.3</td>
<td>0.41</td>
</tr>
<tr>
<td>6</td>
<td>CW6</td>
<td>0.32</td>
<td>175</td>
<td>550</td>
<td>0.175</td>
<td>256.25</td>
<td>0.1025</td>
<td>273.67</td>
<td>0.1025</td>
<td>1119.3</td>
<td>0.41</td>
</tr>
</tbody>
</table>

Table 3.2. Crushed Stone Coarse Aggregate Concrete Mix Proportions per Cubic meter

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Mix</th>
<th>W/C</th>
<th>Water Liters</th>
<th>Cement Kg</th>
<th>Cement m³</th>
<th>Fine Aggregate BA kg</th>
<th>Fine Aggregate BA m³</th>
<th>Fine Aggregate Sand kg</th>
<th>Fine Aggregate Sand m³</th>
<th>Coarse Aggregate kg</th>
<th>Coarse Aggregate m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CC1</td>
<td>0.58</td>
<td>175</td>
<td>300</td>
<td>0.095</td>
<td>827.7</td>
<td>0.31</td>
<td>784.98</td>
<td>0.294</td>
<td>1119.3</td>
<td>0.41</td>
</tr>
<tr>
<td>2</td>
<td>CC2</td>
<td>0.50</td>
<td>175</td>
<td>350</td>
<td>0.116</td>
<td>742.26</td>
<td>0.278</td>
<td>699.54</td>
<td>0.262</td>
<td>1119.3</td>
<td>0.41</td>
</tr>
<tr>
<td>3</td>
<td>CC3</td>
<td>0.44</td>
<td>175</td>
<td>400</td>
<td>0.127</td>
<td>659.49</td>
<td>0.247</td>
<td>614.00</td>
<td>0.230</td>
<td>1119.3</td>
<td>0.41</td>
</tr>
<tr>
<td>4</td>
<td>CC4</td>
<td>0.39</td>
<td>175</td>
<td>450</td>
<td>0.143</td>
<td>659.49</td>
<td>0.247</td>
<td>614.00</td>
<td>0.230</td>
<td>1119.3</td>
<td>0.41</td>
</tr>
<tr>
<td>5</td>
<td>CC5</td>
<td>0.35</td>
<td>175</td>
<td>500</td>
<td>0.158</td>
<td>659.49</td>
<td>0.247</td>
<td>614.00</td>
<td>0.230</td>
<td>1119.3</td>
<td>0.41</td>
</tr>
<tr>
<td>6</td>
<td>CC6</td>
<td>0.32</td>
<td>175</td>
<td>550</td>
<td>0.175</td>
<td>659.49</td>
<td>0.247</td>
<td>614.00</td>
<td>0.230</td>
<td>1119.3</td>
<td>0.41</td>
</tr>
<tr>
<td>Sl No</td>
<td>Size of the Specimen</td>
<td>Nature of Test</td>
<td>Curing Period</td>
<td>CWBA Aggregate Concrete</td>
<td>Crushed Stone Coarse Aggregate Concrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>100 mm ×100 mm×100 mm - Cube</td>
<td>Compression</td>
<td>28 d 56 d</td>
<td>12</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>100 mm diameter 200 mm height - Cylinder</td>
<td>Split tension</td>
<td>28 d 56 d</td>
<td>12</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>100 mm ×100 mm×500 mm - Prism</td>
<td>Modulus of Rupture</td>
<td>28 d 56 d</td>
<td>12</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>150 mm diameter 300 mm height – Cylinder</td>
<td>Modulus of Elasticity</td>
<td>28 d 56 d</td>
<td>12</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>100 mm ×100 mm×100 mm - Cube</td>
<td>Density, water Absorption and Voids</td>
<td>28 d 56 d</td>
<td>12</td>
<td>12</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>100 mm ×100 mm×100 mm - Cube</td>
<td>Sulfate attack</td>
<td>28 d 56 d</td>
<td>12</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>100 mm diameter 50 mm thick – Slices</td>
<td>Chloride penetration</td>
<td>28 d 56 d</td>
<td>12</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>100 mm ×100 mm×100 mm - Cube</td>
<td>Sorptivity</td>
<td>28 d 56 d</td>
<td>12</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total number of specimens for 12 mixes

100 mm ×100 mm×100 mm Cubes = 1152 Nos
100 mm diameter and 200 mm height cylinders = 288 Nos
150 mm diameter and 300 mm height cylinders = 288 Nos
100 mm ×100 mm×500 mm prisms = 288 Nos
100 mm diameter and 50 mm thick slices = 288 Nos
3.6 TESTS ON FRESH CWBA AGGREGATE CONCRETE AND CRUSHED STONE COARSE AGGREGATE CONCRETE

The ASTM: C125-93 has defined workability as the property determining the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity. Therefore, it is necessary to compact concrete to the maximum possible density. Slump tests and compaction tests were conducted to assess the workability of CWBA aggregate concrete.

3.6.1 Slump Test

The slump tests reflect the yielding of concrete under its own weight. The slump test was conducted as per IS 7320-1974.

3.6.2 Compaction Factor Test

The compaction factor measures the degree of compaction achieved by a standard amount of exerted work. The compaction factor test was conducted as per IS 1199-1959.

3.7 TESTS ON HARDENED CWBA AGGREGATE CONCRETE AND CRUSHED STONE COARSE AGGREGATE CONCRETE

The mechanical and durability properties of hardened CWBA aggregate concrete and crushed stone coarse aggregate concrete are assessed by the following tests. The methodology adopted to conduct the experiments is explained in the following section.

Tests for mechanical properties:

i. Compressive strength test
ii. Split tension test
iii. Modulus of rupture test
iv. Modulus of elasticity test
3.7.1 Compressive Strength Test

At 28 d and 56 d, the compression test was conducted on 100 mm x 100mm x 100 mm cubes as per IS 516 – 1959. The compression testing machine of capacity 2000 x 10³N was used. The maximum load applied to the specimen was taken as ultimate compressive load. Figure 3.11(a) shows the compression test set up.

3.7.2 Split Tension Test

The split tension test was conducted at 28 d and 56 d on 100 mm diameter and 200 mm height cylinders as per IS 5816-1970. The test was carried out along the longest splitting section (i.e. the length) of the block specimen. Prior to test, the block specimen was concentrically packed with two steel packing pieces on the top and bottom faces in contact with the platens of the loading machine. Then the load was applied gradually at the rate of 1.4 MPa per minute until the resistance of the specimen to the increasing load was broken down. The failure load was recorded and the tensile splitting strength was calculated based on the failure load. Figure 3.11 (b) shows the split tension set up.

3.7.3 Modulus of Rupture Test

The modulus of rupture test was carried out by testing standard test specimen of 100 mm x 100 mm x 500 mm prisms at 28 d and 56 d in the UTM of maximum capacity 1000 x 10³N as per IS 516 – 1959 by applying two points loading at a rate of 1.8 x 10³N /minute up to failure. The fracture appeared at a distance more than 133 mm from the nearest support Figure 3.11(c) shows the modulus of rupture test arrangement.

3.7.4 Modulus of Elasticity Test

The modulus of elasticity test was carried out on 150 mm diameter and 300 mm height cylinders as per 516-1959 at 28 d and 56 d in a compression testing machine of maximum
capacity 2000 x10³ N. The extensometer was attached to the ends of the specimen in the
direction parallel to axis of the gauge length 203.2 mm (8 inches) symmetrical about the
centre of the specimen. The load was applied gradually at a rate of 14 MPa per minute
until it reached one third of the average compressive strength. The load was maintained
for one minute and released slowly and second time the same procedure was repeated and
the extensometer reading was noted. It was carefully verified that the strain readings of
the second and third time should not differ by 5 percent. Figure 3.11 (d) shows the
experimental setup.

![Test on Hardened Concrete Setup](image)

(a) Compression Test Setup  (b) Split Tension Test Setup  
(c) Modulus of Rupture Test Setup  (d) Modulus of Elasticity Test Setup

*Fig. 3.11 Test on Hardened Concrete Setup*
3.8 TESTS FOR DURABILITY PROPERTIES

The following tests were conducted on hardened CWBA aggregate concrete and crushed stone coarse aggregate concrete to assess the durability:

i. Density, absorption, and voids tests.

ii. Sorptivity test

iii. Rapid chloride penetration test (RCPT)

iv. Sulphate resistance test.

The methodology adopted to conduct the above experiments is explained in the following sections.

3.8.1 Density, Absorption and Voids Tests

The determination of density, percentage of water absorption, and percentage of voids was carried out on 100mm x 100 mm x 100 mm cube specimen as per ASTM C 642-97 at 28 d and 56 d.

3.8.2 Sorptivity Test

Sorptivity test was conducted on 100 mm x 100 mm x 100 mm cube specimen at 28 d. The cube’s side surfaces were coated with an impermeable epoxy to prevent the absorption through side surface during the test. After taking the initial weight, the specimen was placed on small supports in a water-tray, and water level was maintained in such a way that only the bottom 3 mm of the specimen was submerged in water. The weight of the specimen was taken for a selected time intervals continuously up to 180 minutes. The time interval was decided to get the value $t^{0.5}$ as a whole number to plot the graph between $t^{0.5}$ and i. The slope of straight line is considered as a measure of rate of movement of water through the capillary pores and it is called sorptivity.
The line diagram and sorptivity test setup are shown in Figures 3.12 and 3.13.

\[ i = S t^{0.5} \]

where

\[ i \] = W/A, absorbed water per unit area
\[ W \] = Increase in weight, in grams
\[ A \] = Area of the specimen through which sorption is taking place in mm\(^2\)
\[ t \] = The elapsed time in minutes
\[ S \] = Coefficient of Sorptivity in mm/min\(^{0.5}\)

**Fig. 3.12 Sorptivity Test Line Diagram**

**Fig. 3.13 Sorptivity Test Setup**
3.8.3 Rapid Chloride Penetration Test (RCPT)

RCPT is a quick test method that gives an electrical indication of concrete’s ability to resist chloride ions penetration. RCPT was conducted as per as ASTM 1202 – 97 on 100 mm diameter and 50 mm thick slices, cut from a 100 mm diameter x 200 mm height cylinder at 28 d and 56 d. In this test one surface of water saturated concrete specimen is exposed to a sodium chloride solution, and the other surface to a sodium hydroxide solution. A 60 volt DC electrical potential is placed across the specimen for six-hour period. The electrical charge (in coulombs) passed through the concrete specimen in that time represents its rapid chloride permeability.

Figures 3.14 and 3.15 show line diagram of the experimental arrangement and RCPT set up respectively.

![Fig. 3.14 Rapid Chloride Penetration Test (RCPT) Line Diagram](image)

3.8.4 Sulphate Resistance Test

Sulphate resistance test was conducted on 100 mm × 100 mm × 100mm cube specimen at 28 and 56 d. The sulphate solution was prepared by mixing 5 percent sodium sulphate
and 5 percent magnesium sulphate in distilled water. The specimen was immersed in the sulphate solution for 24 hours and it was allowed to dry for 24 hours at room temperature. This alternate wetting and drying is one cycle. Like this, the specimen was subjected to 30 cycles. Then the specimen was tested for compressive strength. Figure 3.16 shows the sulphate resistance test.
3.9. FLEXURAL BEHAVIOR OF RCWBA AGGREGATE CONCRETE BEAM

The flexural behavior of reinforced ceramic waste coarse aggregate, bottom ash fine aggregate concrete beam should be examined to study the strength and deformation characteristics for ultimate states.

3.9.1 Specimen Details

For flexural behavioral study, 150 mm x 250 mm x 3000 mm size beam was used. The beams with an average compressive strength of 53 MPa were cast. The beams were reinforced with 2 bars of Fe 415 grade, having 12 mm diameter at the bottom and 2 bars of Fe 415 grade, having 8 mm diameter at the top as hangers. Two legged shear stirrups of 8 mm diameter were placed at 150 mm spacing to strengthen the beam against shear failure. The beam specimens were cast in steel mould and the compaction was given by needle vibrator. After 24 hours the specimens were demoulded and were cured for 28 d in water. The beams were white washed to facilitate observation of cracks during testing. Figure 3.17 shows the experimental test setup.

3.9.2 Testing Procedure

The beam was tested statically with simply supported boundary conditions. The span of the beam is divided into three separate zones; each having a length of 933.33 mm. Two-point load system was adopted. Three dial gauges (DG) having a least count of 0.01mm was used to record the deflections at loading points and at mid span. Proving ring and jack arrangement was used to load the beam. The strains along the extreme compression fiber and along tension reinforcement line at the constant bending moment zone were also recorded using a mechanical strain gauge. The load was applied gradually with a constant increment of 0.25 x 10³ N. Deflections and strains were measured for an each load
increment. The moment curvature, load deflection relationships and ultimate load capacity of the test beam was found using the test results.

![Experimental Test Setup](image)

**Fig. 3.17 Experimental Test Setup**

### 3.10 SUMMARY

An emphasis has been given to the strength and deformation properties of RCWBA aggregate concrete beam, and suitable conclusions are drawn based on the results obtained from laboratory experiments and regression analysis.