Experimental Investigation Of Using Ceramic Waste As A Coarse Aggregate Making A Light Weight Concrete

1T.Subramani, B.Suresh

1Professor & Dean, Department of Civil Engineering, VMKV Engg. College, Vinayaka Missions University, Salem, India
2PG Student of Structural Engineering, Department of Civil Engineering, VMKV Engg. College, Vinayaka Missions University, Salem, India

ABSTRACT

Making lightweight concrete has been the dominant use of lightweight aggregates in the past. It has been shown that the extra energy expended to expand shale, clay or slate in a rotary kiln can easily be recovered in the savings associated with the decrease in density of the concrete made from them. The savings arise not only from reduced footings, columns and beam sizes, but also from the enhanced thermal properties of the concrete. The manufacture of lightweight aggregates results in the release of some CO2 but the savings in CO2 emissions associated with the need for less of the other materials more than compensates for this release. More recently lightweight aggregates have found new uses such as for horticultural applications such as a growing medium for creating a lusher skyline with green roofs. Not only do the low density aggregates provide up to a 30% lighter growing medium, but the vesicules within the aggregates become a reservoir for irrigating water and fertilizers thereby reducing the cost of maintaining a green roof. Various other uses for lightweight aggregates are discussed that contribute to an environmentally friendly world.

Keywords: Experimental, Investigation, Using Ceramic Waste, Coarse Aggregate, Light Weight Concrete

1 INTRODUCTION

Lightweight aggregates can fill many roles that will make human activity more environmentally responsible. The greenhouse gas emission associated with both the processing of the raw material and from the fuel burned to produce the expansion of the raw material pales in comparison to the environmental rewards derived from its use. The raw material generally being high in silica content releases low amounts of greenhouse gases upon heating unlike the ingredients used to make cement. The emissions from manufacturing cement are about one tonne of CO2 per tonne of cement and for expanding shale, clay and slate is never above about 0.3 tonnes of CO2 per tonne of aggregates produced. With the rotary kiln used to make both cement and lightweight aggregates, the fuel consumption is significant being about 5.5 gigajoules per tonne for cement and 3.0 gigajoules per tonne for expanding shale, clay or slate. It was shown some three decades ago that the expenditure of energy to make lightweight aggregates could easily be recovered from savings associated with the reduction in the amount of materials needed. Studies have shown that these savings that accrue at the time of construction result from reduced footing, column and beam sizes, as well as reduced amounts of steel reinforcing. Long term benefits in some instances, as in the case of exterior walls and roofs, can be even greater than the initial savings, because of reduced annual heating and cooling costs. The reduced heating and cooling loads arise from the lightweight concrete being made with a vesicular aggregate. The emissions of greenhouse gases that result from the burning of fuel to run a kiln making expanded shale, clay or slate have been a concern to the industry, and it has sought sources of combustible waste liquids such as motor oils which normally would be consumed in an incinerator. Alternative methods of producing lightweight aggregate exist. Sintering preformed fly ash particles to produce a lightweight aggregate reduces emissions somewhat but this is only an alternate and less environmentally desirable use than using fly ash as a pozzolan in concrete mixtures. The same applies for lightweight aggregates made from blast furnace slag. Also lightweight aggregates can be manufactured without resorting to high temperature; however this process requires binding agents, which present additional environmental problems in the manufacture of these agents. The structural and insulating properties of lightweight concrete are well known and are well appreciated in practice. Less is known about the potentially greater impact on the environment of the many other ways in which expanded aggregates can be used. These uses emanate from the intrinsic nature of the lightweight aggregates themselves.
2 MATERIALS COLLECTION

2.1 Cement
The cement used was ordinary Portland cement 53 (OPC 53). All properties of cement were determined by referring IS 12269 - 1987. The specific gravity of cement is 3.15. The initial and final setting times were found as 55 minutes and 258 minutes respectively. Standard consistency of cement was 30%. Cement is one of the binding materials in this project. Cement is the important building material in today’s construction world. 53 grade Ordinary Portland Cement (OPC) conforming to IS: 8112-1989. Table 2.1 gives the properties of cement used.

<table>
<thead>
<tr>
<th>Description of test</th>
<th>Test results obtained</th>
<th>Requirements of IS: 8112 1989</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial setting time</td>
<td>65 minutes</td>
<td>Min. 30 minutes</td>
</tr>
<tr>
<td>Final setting time</td>
<td>270 minutes</td>
<td>Max. 600 minutes</td>
</tr>
<tr>
<td>Finess (specific surface by Blaine’s air permeability test)</td>
<td>412.92 m²/kg</td>
<td>Min. 225 m²/kg</td>
</tr>
</tbody>
</table>

2.2 Coarse Aggregate
20mm size aggregates-The coarse aggregates with size of 20mm were tested and the specific gravity value of 2.78 and fineness modulus of 7 was found out. Aggregates were available from local sources. Locally available crushed blue granite stones conforming to graded aggregate of nominal size 20 mm as per IS: 383 – 1970. Crushed granite aggregate with specific gravity of 2.77 and passing through 4.75 mm sieve and will be used for casting all specimens. Several investigations concluded that maximum size of coarse aggregate should be restricted in strength of the composite. In addition to cement paste – aggregate ratio, aggregate type has a great influence on concrete dimensional stability.

2.3 Fine Aggregate
The sand which was locally available and passing through 4.75mm IS sieve is used. The specific gravity of fine aggregate was 2.60. Locally available river sand conforming to Grading zone I of IS: 383 –1970. Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens. Fine aggregate is defined as material that will pass a No. 4 sieve and will, for the most part, be retained on a No. 200 sieve. For increased workability and for economy as reflected by use of less cement, the fine aggregate should have a rounded shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

2.4 Water
The water used for experiments was potable water. Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. It should be free from organic matter and the pH value should be between 6 to 7.

2.5 Tiles
A tile is a manufactured piece of hard-wearing material such as ceramic, stone, metal, or even glass, generally used for covering roofs, floors, walls, showers, or other objects such as tabletops. Alternatively, tile can sometimes refer to similar units made from lightweight materials such as perlite, wood, and mineral wool, typically used for wall and ceiling applications. In another sense, a tile is a construction tile or similar object, such as rectangular counters used in playing games (see tile-based game). The word is derived from the French word tuile, which is, in turn, from the Latin word tegula, meaning a roof tile composed of fired clay. Tiles are often used to form wall and floor coverings, and can range from simple square tiles to complex mosaics. Tiles are most often made of ceramic, typically glazed for internal uses and unglazed for roofing, but other materials are also commonly used, such as glass, cork, concrete and other composite materials, and stone. Tiling stone is typically marble, onyx, granite or slate. Thinner tiles can be used on walls than on floors, which require more durable surfaces that will resist impacts. The ceramic wastes such as flowerpot, tiles and brick ware were broken into small pieces about 5 – 40 mm sizes by a hammer. These small pieces are then fed into vibrator sieved to get the required 14 – 20 mm size. Figure 1 show the sample of ceramic waste coarse aggregate.
In general there are two types of waste named as quarry/cutting/sawing from in-situ marble stone site and polishing waste from construction sites. During the processing of marble stone, the raw stone block is cut as demanded either into tiles or slabs of various thickness (usually 2 or 4 cm), using diamond blades. Water is showered on blades while marble stone blocks are cut into sheets of varying thickness, to cool the blades and absorb the dust produced during the cutting operation. The amount of wastewater from this operation is very large. It is not recycled as the water is so highly alkaline that, if re-used, it can dim the slabs to be polished. In large factories, where the blocks are cut into slabs, the cooling water is stored in pits until the suspended particles settle (sedimentation tanks), then the slurry is collected in trucks and disposed off on the ground and left to dry. This water carries large amounts of stone powder. The polishing operation is fully automated with the use of powdered abrasives that keep on scrubbing the surface of the stone until it becomes smooth and shiny.

2.6 Problems by dumped Marble stone waste
In general, all the mines affect their surrounding environment to a little or more extent, but open cast mining i.e. in case of marble, granite, lime stone, sandstone and other type of building stone quarries leads to complex nature of environmental problems such as:
(1) Choking of drains in rainy season
(2) Dust nuisance
(3) Fine particles of slurry (with size less than 363 micron) become air borne and cause air pollution
(4) Slurry affects productivity of land due to decreased porosity, water absorption and percolation
(5) Slurry dumped areas cannot support vegetation and remain degraded
(6) Due to long-term deposition of slurry on land, the finer particles block the flow regime of aquifers. Thus, seriously affecting underground water availability So these waste material needs to be utilized meaningfully in an economic way.

3. MATERIALS PROPERTIES
3.1 Cement
The type of cement used was Portland Pozzalona Cement.
3.1.1 Specific Gravity
The density bottle was used to determine the specific gravity of cement. The bottle was cleaned and dried. The weight of empty bottle with brass cap and washer \( W_1 \) was taken. Then bottle was filled by 200 to 400g of dry cement and weighed as \( W_2 \). The bottle was filled with kerosene and stirred thoroughly for removing the entrapped air which was weighed as \( W_3 \). If it was emptied, cleaned well, filled with kerosene and weighed as \( W_4 \).
3.1.2 Fineness (By Sieve Analysis)
The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence faster development of strength. 100 grams of cement was taken on a standard IS SieveNo.9(90 microns). The air-set lumps in the sample were broken with fingers. The sample was continuously sieved giving circular and vertical motion for 15 minutes. The residue left on the sieve was weighed.
3.1.3 Consistency
The objective of conducting this test is to find out the amount of water to be added to the cement to get a paste of normal consistency. 500 grams of cement was taken and made into a paste with a weighed quantity of water (% by weight of cement) for the first trial. The paste was prepared in a standard manner and filled into the vicat mould plunger, 10mm diameter, 50mm long and was attached and brought down to touch the surface of the paste in the test.
block and quickly released allowing it to sink into the paste by its own weight. The depth of penetration of the plunger was noted. Similarly trials were conducted with higher water cement ratios till such time the plunger penetrates for a depth of 33-35mm from the top.

3.1.4 Initial Setting Time
The needle of the Vicat apparatus was lowered gently and brought in contact with the surface of the test block and quickly released. It was allowed to penetrate into the test block. In the beginning, the needle completely pierced through the test block. But after sometime when the paste starts losing its plasticity, the needle penetrated only to a depth of 33-35mm from the top. The period elapsing between the time when water is added to the cement and the time at which the needle penetrates the test block to a depth equal to 33-35mm from the top was taken as the initial setting time.

3.2 Coarse Aggregate
20mm down size aggregate was used.

3.2.1 Specific Gravity
A pycnometer was used to find out the specific gravity of coarse aggregate. The empty dry pycnometer was weighed and taken as \( W_1 \). Then the pycnometer is filled with 2/3 of coarse aggregate and it was weighed as \( W_2 \). Then the pycnometer is filled with part of coarse aggregate and water and it weighed as \( W_3 \). The pycnometer was filled up to the top of the bottle with water and weighed it as \( W_4 \).

3.2.2 Bulk Density
Bulk density is the weight of a material in a given volume. It is expressed in Kg/m\(^3\). A cylindrical measure of nominal diameter 250mm and height 300mm was used. The cylinder has the capacity of 1.5 liters with the thickness of 4mm. The cylindrical measure was filled about 1/3 each time with thoroughly mixed aggregate and tampered with 25 strokes. The measure was carefully struck off level using tamping rod as straight edge. The net weight of aggregate in the measure was determined. Bulk density was calculated as follows.

\[
\text{Bulk density} = \frac{\text{Net weight of coarse aggregate in Kg}}{\text{Volume}}
\]

3.2.3 Surface Moisture
100g of coarse aggregate was taken and their weight was determined, say \( W_1 \). The sample was then kept in the oven for 24 hours. It was then taken out and the dry weight is determined, says \( W_2 \). The difference between \( W_1 \) and \( W_2 \) gives the surface moisture of the sample.

3.2.4 Water Absorption
100g of nominal coarse aggregate was taken and their weight was determined, say \( W_1 \). The sample was then immersed in water for 24 hours. It was then taken out, drained and its weight was determined, says \( W_2 \). The difference between \( W_1 \) and \( W_2 \) gives the water absorption of the sample.

3.2.5 Fineness Modulus
The sample was brought to an air-dry condition by drying at room temperature. The required quantity of the sample was taken (3Kg). Sieving was done for 10 minutes. The material retained on each sieve after shaking, represents the fraction of the aggregate coarser then the sieve considered and finer than the sieve above. The weight of aggregate retained in each sieve was measured and converted to a total sample. Fineness modulus was determined as the ratio of summation of cumulative percentage weight retained (F) to 100.

3.3 Fine Aggregate
Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens.

3.4 Properties Of Ceramic Tiles Waste Coarse Aggregate
From observation, it was obvious that the particle shape analysis of ceramic waste coarse aggregate has different particles shape with the crushed stone normal concrete. The important parameters of coarse aggregate are its shape, texture and the maximum size. Since the aggregate is generally stronger than the paste, its strength is not a major factor for normal strength concrete. However, the aggregate strength becomes important in the case of higher-strength concrete. Surface texture and mineralogy affect the bond between the aggregates and the paste as well as the stress level at which micro cracking begins. The size for coarse aggregate ceramic waste is 14-20 mm. The ceramic waste coarse aggregate satisfied the aggregate requirement used for concrete. The surface texture of the ceramic waste aggregate was found to be smoother than that of crushed stone aggregate. In general, ceramic waste aggregate showed properties close to those of natural crushed stone aggregate.

3.4.1 Properties Of Ceramic Tiles Waste Coarse Aggregate Concrete
The properties of the ceramic waste coarse aggregate concrete are presented in Table 4. The results presented in the table are the average of thirty six tests. Fresh ceramic waste coarse aggregate concrete was more cohesive and workable than conventional concrete. This is due to the lower water absorption and smooth surface texture of the ceramic waste coarse aggregate. The compressive strength varied from 4 to 21 MPa. As far as strengths are concerned, the basic trend in the behavior of ceramic waste coarse aggregate concrete is not significantly different from that of the conventional crushed stone aggregate concrete. However, the slump test result is still in designed range that is between 30 – 60 mm.
3.5 Properties Of Marble Stone Waste

Table 5: Properties of Marble Stone Waste

<table>
<thead>
<tr>
<th>S.NO</th>
<th>PROPERTY</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specific gravity</td>
<td>2.12-2.67</td>
</tr>
<tr>
<td>2</td>
<td>Bulk density, (kg/m³)</td>
<td>1300-1500 (SL)</td>
</tr>
<tr>
<td>3</td>
<td>Water absorption (%)</td>
<td>22-24(SL)</td>
</tr>
<tr>
<td>4</td>
<td>Max. particle size (mm)</td>
<td>0.062 (Dry)</td>
</tr>
<tr>
<td>5</td>
<td>Fineness modulus(FM)/ Blaine fineness (cm²/g)*</td>
<td>5100-5250</td>
</tr>
<tr>
<td>6</td>
<td>Color</td>
<td>White/ Dirty white</td>
</tr>
</tbody>
</table>

Different stone waste like granite, marble, limestone, sandstone etc. have different properties. However, a particular stone waste may have different physical and chemical properties depending on the method of generation of waste. It has been found that in cutting waste, calcium oxide (CaO) and in polishing waste, silicon-di-oxide (SiO₂) is the main constituent. The properties of some types of stone waste used as an aggregate in concrete are presented in Table 5.

3.6 Properties Of Water

Water used for mixing and curing shall be clean and free from injurious amounts of Oils, Acids, Alkalis, Salts, Sugar, Organic materials. Potable water is generally considered satisfactory for mixing concrete. Mixing and curing with seawater shall not be permitted. The pH value shall not be less than 6.

3.7 Fresh Concrete Properties

3.7.1 Workability

The property of fresh concrete which is indicated by the amount of useful internal work required to fully compact the concrete without bleeding or segregation in the finished product.

Factors affecting workability

- Water content in the concrete mix
- Amount of cement & its Properties
- Aggregate Grading (Size Distribution)
- Nature of Aggregate Particles (Shape, Surface Texture, Porosity etc.)
- Temperature of the concrete mix
- Humidity of the environment
- Mode of compaction
- Method of placement of concrete
- Method of transmission of concrete

How To improve the workability of concrete

- Increase water/cement ratio
- Increase size of aggregate
- Use well-rounded and smooth aggregate instead of irregular shape
- Increase the mixing time
- Increase the mixing temperature
- Use non-porous and saturated aggregate

3.7.2 Segregation And Bleeding

Segregation in concrete is commonly thought as separation of some size groups of aggregates from cement mortar in isolated locations with corresponding deficiencies of these materials in other locations. Segregation results in proportions of the laid concrete being in variation to those as designed. Segregation could result from internal factors such as concrete that is not proportioned properly and not mixed adequately, or too workable a mix. It also could result from external factors such as too much vibration, improper transportation, placement, or adverse weather conditions. The corresponding increase in proportion of cement paste in upper areas would tend to make them susceptible to increased shrinkage and formation of cracks. These cracks could be 10 μm to 500 μm wide, formed perpendicular to the surface, and be in the form of map patterns. Bleeding is a form of segregation where some of the water in the concrete tends to rise to the surface of the freshly placed material. This arises due to the inability of the solid components of the concrete to hold all of the mixing water when they settle downwards (water being the lightest of all the mix constituents). Bleeding of the water continues until the cement paste has stiffened enough to end the sedimentation process.
3.7.3 Slump Test
Fresh concrete when unsupported will flow to the sides and sinking in height will take place. This vertical settlement is known as slump. The workability (ease of mixing, transporting, placing and compaction) of concrete depends on wetness of concrete (consistency) i.e., water content as well as proportions of fine aggregate to coarse aggregate and aggregate to cement ratio. The slump test which is a field test is only an approximate measure of consistency defining ranges of consistency for most practical works. This test is performed by filling fresh concrete in the mould and measure the settlement i.e., slump.

3.8 Hardened Concrete Properties

3.8.1 Compression Test On Concrete Cubes
The determination of the compressive strength of concrete is very important because the compressive strength is the criterion of its quality. Other strength is generally prescribed in terms of compressive strength. The strength is expressed in N/mm². This method is applicable to the making of preliminary compression tests to ascertain the suitability of the available materials or to determine suitable mix proportions. The concrete to be tested should not have the nominal maximum size of aggregate more than 20mm test specimens are either 15cm cubes or 15cm diameter used. At least three specimens should be made available for testing. Where every cylinder is used for compressive strength results the cube strength can be calculated as under. Minimum cylinder compressive strength = 0.8 x compressive strength cube (15cm x 15 cm x 15cm) The concrete specimens are generally tested at ages 7 days, 14days, 28days.

3.8.2 Split Tensile Test On Cylinder
Concrete is strong in compression but weak in tension. Tension stresses are likely to develop in concrete due to drying shrinkage, rusting of reinforcement, temperature gradient etc. In concrete road slab this tensile stresses are developed due to wheel loaded and volume changes in concrete are available to determine this. Split test is one of the indirect methods available to find out the tensile strength.

3.8.3 Flexural Test On Beams
It is the ability of a beam or slab to resist failure in bending. It is measured by loading un-reinforced 6x6 inch concrete beams with a span three times the depth (usually 18 in.). The flexural strength is expressed as “Modulus of Rupture” (MR) in psi. Flexural MR is about 12 to 20 percent of compressive strength.

4 MIX DESIGN

4.1 Definition
Mix design is the process of selecting suitable ingredient if concrete and determines their relative proportions with the object of certain minimum strength and durability as economically as possible.

4.2 Objective Of Mix Design
• The objective of concrete mix design as follows.
• The first objective is to achieve the stipulated minimum strength.
• The second objective is to make the concrete in the most economical Manner. Cost wise all concrete’s depends primarily on two factors, namely cost of material and cost of labor. Labor cost, by way of formwork, batching, mixing, transporting and curing is namely same for good concrete.

5. TESTING PROCEDURE

5.1 General Procedure
Within the experimental research program concerning the development of mechanical properties of a partially replacement of cement by flyash, partially replacement of sand by bottom ash and glass is used reference concrete of grade M25 (REF) was considered with the following composition, accordingly. The w/c-ratio is 0.43. Coarse aggregates were chosen, having a particle size mainly varying between 2 mm and 20 mm. An intensive experimental program is performed to study the effect of internal curing on different types of concrete properties: (i) fresh properties (slump and density); (ii) mechanical properties (compressive strength, flexural strength, splitting tensile strength).

5.2 Compressive Strength Test
Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. For cube test two types of specimens either cubes of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15 cm x 15cm x 15 cm are commonly used. This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. These specimens are tested by compression testing machine after 7 days curing or 28 days curing. (Figure.5.1)
5.3 Split Tensile Test

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure. Apart from the flexure test the other methods to determine the tensile strength of concrete can be broadly classified as (a) direct methods, and (b) indirect methods. The direct method suffers from a number of difficulties related to holding the specimen properly in the testing machine without introducing stress concentration, and to the application of uniaxial tensile load which is free from eccentricity to the specimen. (Figure.5.2)

Figure. 5.2 Split Tensile Test As the concrete is weak in tension even a small eccentricity of load will induce combined bending and axial force condition and the concrete fails at the apparent tensile stress other than the tensile strength. As there are many difficulties associated with the direct tension test, a number of indirect methods have been developed to determine the tensile strength. In these tests in general a compressive force is applied to a concrete specimen in such a way that the specimen fails due to tensile stresses developed in the specimen. The tensile stress at which the failure occurs is termed the tensile strength of concrete. The splitting tests are well known indirect tests used for determining the tensile strength of concrete sometimes referred to as split tensile strength of concrete. The test consists of applying a compressive line load along the apposite generators of a concrete cylinder placed with its axis horizontal between the compressive platens. 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.

5.4 Flexural Strength Test

Flexural testing is used to determine the flex or bending properties of a material. Sometimes referred to as a transverse beam test, it involves placing a sample between two points or supports and initiating a load using a third point or with two points which are respectively called 3 Point Bend and 4 Point Bend testing. Maximum stress and strain are calculated on the incremental load applied. Results are shown in a graphical format with tabular results including the flexural strength (for fractured samples) and the yield strength (samples that did not fracture). Typical materials tested are plastics, composites, metals, ceramics, and wood. (Figure.5.3)

Figure.5.3 Flexural Strength Test
6. TEST RESULT

6.1 RATIOS FOR SPECIAL CONCRETE (EXTRA INGREDIENTS)

VARIOUS PERCENTAGE OF MARBLE AND TILES

RATIO – I
Marble & Tile – 20% by replacement of Coarse Aggregate

RATIO – II
Marble & Tile – 25% by replacement of Coarse Aggregate

RATIO – III
Marble & Tile – 30% by replacement of Coarse Aggregate

- Compressive Strength Of Cube For 7 Days, 14 days and 28 days are given in Table 6.1, Table 6.2 and Table 6.3
- Split Tensile Test For Cylinder 7 Days, 14 days and 28 days are given in Table 6.4, Table 6.5 and Table 6.6
- Flexural Strength Of Beam For 7 Days, 14 days and 28 days are given in Table 6.7, Table 6.8 and Table 6.9

### Table 6.1: Compressive Strength Of Cube – 7 days

<table>
<thead>
<tr>
<th>Control Mix</th>
<th>Compressive Strength in N/mm² 7 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CC (0%)</td>
</tr>
<tr>
<td>M30</td>
<td>16.23</td>
</tr>
</tbody>
</table>

### Table 6.2: Compressive Strength Of Cube – 14 days

<table>
<thead>
<tr>
<th>Control Mix</th>
<th>Compressive Strength in N/mm² 14 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CC (0%)</td>
</tr>
<tr>
<td>M30</td>
<td>22.56</td>
</tr>
</tbody>
</table>

### Table 6.3: Compressive Strength Of Cube – 28 days

<table>
<thead>
<tr>
<th>Control Mix</th>
<th>Compressive Strength in N/mm² 28 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CC (0%)</td>
</tr>
<tr>
<td>M30</td>
<td>26.82</td>
</tr>
</tbody>
</table>

### Table 6.4: Split Tensile Test For Cylinder – 7 days

<table>
<thead>
<tr>
<th>Control Mix</th>
<th>Split tensile Strength in N/mm² 7 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CC (0%)</td>
</tr>
<tr>
<td>M30</td>
<td>1.78</td>
</tr>
</tbody>
</table>

### Table 6.5: Split Tensile Test For Cylinder – 14 days

<table>
<thead>
<tr>
<th>Control Mix</th>
<th>Split tensile Strength in N/mm² 14 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CC (0%)</td>
</tr>
<tr>
<td>M30</td>
<td>2.68</td>
</tr>
</tbody>
</table>

### Table 6.6: Split Tensile Test For Cylinder – 28 days

<table>
<thead>
<tr>
<th>Control Mix</th>
<th>Split tensile Strength in N/mm² 28 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CC (0%)</td>
</tr>
<tr>
<td>M30</td>
<td>4.98</td>
</tr>
</tbody>
</table>

### Table 6.7: Flexural Strength Of Beam – 7 days

<table>
<thead>
<tr>
<th>Control Mix</th>
<th>Flexural Strength In N/mm² 7 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CC (0%)</td>
</tr>
<tr>
<td>M30</td>
<td>4.1</td>
</tr>
</tbody>
</table>

### Table 6.8: Flexural Strength Of Beam – 14 days

<table>
<thead>
<tr>
<th>Control Mix</th>
<th>Flexural Strength In N/mm² 14 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CC (0%)</td>
</tr>
<tr>
<td>M30</td>
<td>4.98</td>
</tr>
</tbody>
</table>
Table. 6.9: Flexural Strength Of Beam – 28 days

<table>
<thead>
<tr>
<th>Control Mix</th>
<th>Flexural Strength In N/mm²</th>
<th>28 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC (0%)</td>
<td>5.2</td>
<td>6.03</td>
</tr>
<tr>
<td>M30</td>
<td>20%</td>
<td>5.64</td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td></td>
</tr>
</tbody>
</table>

7. CONCLUSION

The conclusions drawn from these experimental investigations are as follows.

- Use of ceramic waste results in the formation of lightweight concrete.
- Use of such ceramic waste cuts down the cost of construction.
- The strength of the concrete is found out to the M30 concrete.
- Compressive strength of concrete is high when containing ceramic waste 30% in concrete.
- The strength of concrete containing ceramic waste of 30% was high compared with that of the conventional mix and also compared with M30 mix design concrete.
- From the present experimental investigation it was found that the recycled aggregates will influence much in hardened properties of concrete.
- As the percentage of ceramic waste is increased, Coarse aggregate is replacement level of 30% ceramic waste in concrete mixes was found to be the level to obtain higher value of the strength and durability at the age of 28 days.
- 30% ceramic waste in concrete mixes was found higher value of the strength compared with ceramic waste used in concrete.
- Finally conclude the compressive strength, flexural & split tensile strength was high when containing ceramic waste 30% in concrete compared with M30 and ceramic waste used in concrete.

REFERENCES


AUTHOR

Prof. Dr. T. Subramani Working as a Professor and Dean of Civil Engineering in VMKV Engg. College, Vinayaka Missions University, Salem, Tamilnadu, India. Having more than 25 years of Teaching experience in Various Engineering Colleges. He is a Chartered Civil Engineer and Approved Valuer for many banks. Chairman and Member in Board of Studies of Civil Engineering branch. Question paper setter and Valuer for UG and PG Courses of Civil Engineering in number of Universities. Life Fellow in Institution of Engineers (India) and Institution of Valuers. Life member in number of Technical Societies and Educational bodies. Guided more than 400 students in UG projects and 150 students in PG projects. He is a reviewer for number of International Journals and published 102 International Journal Publications and presented more than 25 papers in International Conferences.

B. Suresh Completed his Diploma in Civil Engineering in M.P.N.M.J Polytechnic, Chennimalai, Erode. He done his BE Degree in the branch of Civil Engineering in VMKV Engineering College, Salem. He is having his own Civil Engineering Consultancy office in the name of TLR ASSOCIATEES in Dharmapuri as an Engineer and bank valuer. Now, he is The Secretary of Dharmapuri Civil Engineering Association, Dharmapuri. Currently he is doing ME Degree in the branch of Structural Engineering in the division of Civil Engineering in VMKV Engineering College, Salem.