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An Experimental Study on Partial Replacement of Coarse Aggregate and Fine Aggregate With Ceramic Waste and Bottom Ash

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ABSTRACT

In this study we introduce the bottom ash as fine aggregate replacement and ceramic waste as coarse aggregate replacement in order to reduce the environmental pollution due to this waste. It has assessed that approximately 30 percent of the daily production is discarded as of ceramic waste, Hence for the sustainable development of concrete technology as well as safe environment it has replaceable. The bottom ash is a byproduct of combustion coal in power plants. Generally power plants produce approximately 20 percent of total ashes .These ashes were dumped in landfills, nearby ponds and rivers which cause Environmental pollution. Therefore the ash is used as a fine aggregate to reduce environmental pollution.

In this project, ceramic waste is being used as a partial replacement for coarse aggregate. The maximum percentage of ceramic waste used is about 30% of the mass of coarse aggregate. The percentages in which the ceramic waste was replaced were 0%, 5%, 10%, 15%, 20%, 25%, and 30%. The increase in the percentage of ceramic waste as a partial replacement for coarse aggregate gives the moderate strength properties of concrete. In order to increase the strength, 10 % of bottom ash is added to the concrete as a partial replacement of fine aggregate to achieve better results. Experimental tests are carried out to determine the fresh and hardened properties of concrete such as compressive strength, split tensile strength, flexure strength test, workability at 7,14, 28 days of curing were calculated and compared with ceramic waste bottom ash aggregate.This study will result in bulk utilization of ceramic waste and bottom ash that indirectly control the environmental pollution and preserve the natural resources.

INTRODUCTION

Concrete is a composite material consist of mainly water, aggregate, and cement. The physical properties desired for the finished material can be attained by adding additives and reinforcements to the concrete mixture. A solid mass that can be easily moulded into desired shape can be formed by mixing these ingredients in certain proportions [1-3]. Over the time, a hard matrix formed by cement binds the rest of the ingredients together into a single hard durable material with many uses such as buildings, pavements etc.,when aggregate is mixed together with dry Portland cement and water, the mixture forms fluid slurry that is easily poured and moulded into shape. The cement reacts chemically with the water and other ingredients to form a hard matrix that binds the materials together into a durable stone-like material that has many uses. Often, additives such aspozzolanic or super plasticizers are included in the mixture to improve the physical properties of the wet mix or the finished material. Most concrete is poured with reinforcing materials embedded to provide tensile strength, yielding reinforced concrete [5].

Concrete is one of the most durable building materials. It provides superior fire resistance compared with

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construction made with other materials and gains strength over time. Structures made of concrete can have a long service life. Concrete is used to make architectural structures, foundations, pavements, motorways, bridges, multi-story parking, walls, footings etc [7]. Its biggest advantage is that it bonds together bricks and stones better than any other method known to mankind. Concrete is strong in compression but weak in tension. For some purposes it needs to be reinforced with steel rods. These rods can be galvanized to prevent rusting and corrosion.

ADVANTAGES OF CONCRETE

- The ingredients of concrete are available easily.
- Unlike natural stones, Concrete is free from defects and flaws.
- Concrete can be manufactured to durability within economy
- The durability of concrete is very high.
- It can be cast to any desired shape.
- The casting of concrete can be done in the working site which makes it economical.
- The deterioration of concrete is not appreciable with age.
- Concrete makes a building fire safe due to its non combustible nature.

DISADAVANTAGES OF CONCRETE

- Compared to other biding materials, the tensile strength of concrete is relatively low.
- Concrete is less ductile.
- The weight compared is high to its strength.

CONSTRUCTION WASTES IN INDIA

In the present construction world, the solid waste is increasing day by day from the demolitions of constructions [9]. There is a huge usage of ceramic tiles in the present constructions is going on and it is increasing in day by day construction field. Ceramic products are part of the essential construction materials used in most buildings. Some common manufactured ceramics include wall tiles, floor tiles, sanitary ware, household ceramics and technical ceramics. They are mostly produced using natural materials that contain high content of clay minerals. However, despite the ornamental benefits of ceramics, its wastes among others cause a lot of nuisance to the environment. And also in other side waste tile is also producing from demolished wastes from construction. Indian tiles production is 100 million ton per year in the ceramic industry, about 15%30% waste material generated from the total production [11]. This waste is not recycled in any form at present, however the ceramic waste is durable, hard and highly resistant to biological, chemical and physical degradation forces so, we selected these waste tiles as a replacement material to the basic natural aggregate to reuse them and to decrease the solid waste produced from demolitions of construction.

USE OF OTHER WASTE MATERIALS IN CONCRETE MAKING

It has been estimated that about 30 percent of daily production goes as waste in ceramic industry. Ceramic waste which is durable, hard and highly resistant to biological, chemical and physical degradation forces is not recycled so far. The rate of growth in waste has put pressure on the ceramic industries to find a solution for its disposal and to minimize the pollution. Other wastes like quarry dust, rice husk, fly ash, silica fume, glass, crushed bricks, oil palm shells, crushed red clay ceramics were also used in concrete making [13].

So in this study we are used the waste materials are:

- Ceramic waste
- Bottom ash

LIGHT WEIGHT CONCRETE

One of the disadvantages of concrete is its high self weight. Density of normal concrete will be in the range of order of 2200 to 2600 kg/m3. This heavy self weight will make the concrete to some extent as an uneconomical structural material. Attempts have been done in the past to reduce the self weight of concrete to increase its efficiency of concrete as a structural material. The light weight concrete density varies from 300 to 1850 kg/m3 by the use of various ingredients.

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Basically there is only one method for making lightweight concrete, by inclusion of air in concrete [15]. This is achieved in actual practice by three different ways.

(i) By replacing the usual mineral aggregate by cellular porous or lightweight aggregate.

(ii) Introducing the gas or air bubbles in mortar, known as aerated concrete.

(iii) Omitting the sand from the aggregates, called as No-fines concrete.

Lightweight concrete has become more popular in recent years and have more advantages over the conventional concrete.

SUSTINABLE CONCRETE TECHNOLOGY

Concrete is the most widely and extensively used material in the world. The fine aggregate used in the production of concrete is becoming highly expensive and scarce day by day. Also the use of river sand as fine aggregate, results in the exploitation of natural resources erosion of river bed, lowering of water table and sinking of bridge piers [2]. The construction industry has shown great gains in the utilization of recycled industrial by-products and wastes, including ceramic waste. If fine aggregate is replaced by bottom ash by specific percentage and in specific size range, it will decrease fine aggregate content and thereby reducing the ill effects of river dredging and thus making concrete manufacturing industry sustainable. Using of these recycled by-products and wastes not only saves the landfill space but also minimizes the demand for fine aggregate.

The advantages of developing alternative or supplementary cementing materials as partial replacements for ordinary Portland cement powder are sub-divided into ecological, economic, and engineering categories [4].

ECOLOGICAL OR ENVIRONMENTAL BENEFITS OFALTERNATIVE MATERIALS ARE AS FOLLOWS:

(1) The diversion of non-recycled waste from landfills for advantageous applications.

(2) The reduction in the adverse effects of producing cement powder, namely the utilization of nonrenewable natural resources.

(3) These materials reduces the energy required for cement production

(4) They reduce the emissions of greenhouse gasses.

The economic benefits of using alternative materials are best realized in the situations where the cost of the alternative material is cheaper than that of cement powder while providing comparable performance. This cost includes the source of the alternative material, its processing, transportation, and should consider savings through diversion, such as tipping fees and landfill management costs. The engineering or technical benefits of alternative materials are concluded when a specialized use for such material may be developed, such that the use of the alternative material is more favorable than use of concrete made with OPC [6].

MATERIALS AND ITS PROPERTIES

This project will execute in three stages, initially we are going to study the engineering properties of every material. Then we followed to the Mix Design for M30 with partial replacement of Ceramic aggregate and bottom ash. Later we go for methods of testing of each specimen and comparison with the replaced materials. Thus we conclude the values based on the above procedure executed and evaluated. The materials used in this project are ceramic waste is being used as a partial replacement for coarse aggregate. The maximum percentage of ceramic waste used is about 30% of the mass of coarse aggregate. The percentages in which the ceramic waste was replaced were 5%, 10%, 15%, 20%, 25%, and 30% [8]. The increase in the percentage of ceramic waste as a partial replacement for coarse aggregate gives the moderate strength properties of concrete. In order to increase the strength, 10 % of bottom ash is added to the concrete as a partial replacement of fine aggregate to achieve better results.

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The materials which are using in this study are as follows:
1. Cement
2. Fine aggregate
3. Coarse aggregate
4. Water
5. Ceramic aggregate
6. Bottom ash

CEMENT

Ordinary Portland cement is the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, stucco, and most non specialty grout. It developed from other types of hydraulic lime in England in mid 19th century and usually originates from limestone. It is a fine powder produced by heating materials to form clinker. After grinding the clinker we will add small amounts of remaining ingredients. Many types of cements are available in market. When it comes to different grades of cement, the 53 Grade OPC Cement provides consistently higher strength compared to others. As per the Bureau of Indian Standards (BIS) [10], the grade number of a cement highlights the minimum compressive strength that the cement is expected to attain within 28 days. For 53 Grade OPC Cement, the minimum compressive strength achieved by the cement at the end of the 28th day shouldn't be less than 53MPa or 530 kg/cm2. The color of OPC is grey color and by eliminating ferrous oxide during manufacturing process of cement we will get white cement also.

Cement

COARSE AGGREGATE:

Crushed aggregates of not less than 20mm size produced from local crushing plants were used. The aggregate exclusively passing through 40mm sieve size and retained on 20mm sieve is selected. The aggregates were tested for their physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS: 2386-1963. The individual aggregates were mixed to induce the required combined grading [12]. The particular specific gravity and water absorption of the mixture are given in table.

Coarse aggregate

Waste materials used in concrete

The waste materials used in this experimental investigation are:

- Ceramic waste
- Bottom ash

In this Project, the properties and its effects of ceramic waste and bottom ash of concrete have been studied. The ceramic waste available is used for partially replacing coarse aggregate and bottom ash as fine aggregate replacement.

CERAMIC AGGREGATE

The waste generated by the ceramic industries is termed as ceramic waste. In this study ceramic waste was collected from various ceramic manufactures located in Vijayawada. Energy is the main criteria of modern civilization of the world over, and the electric power from thermal power stations is a dominant source of energy, in the order of electricity. In order to decrease

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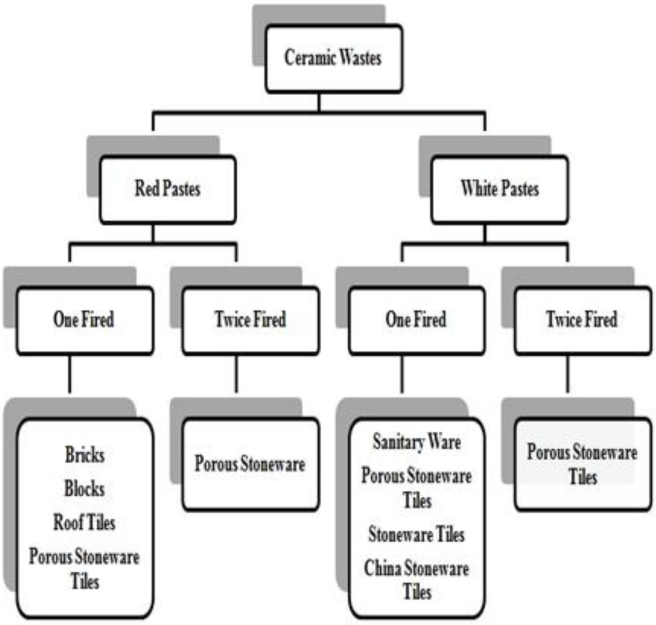
the wastes in the industry we are using ceramic waste as a replacement of coarse aggregate. A ceramic material may be defined as any inorganic crystalline material, compounded consists of metal and non-metal or metalloid atoms. Ceramic Materials [14 are strong and inert. Ceramic materials are brittle, hard, and solid in pressure, frail in strain and additionally in shearing. They can withstand compound disintegration that happens in an acidic or scathing environment. Ceramics generally can withstand very high temperatures that can go from 1,000 °C to 1,600 °C (1,800 °F to 3,000 °F).

Ceramic waste



Classification of ceramic wastes by type and production process

BOTTOM ASH

Bottom ash is the coarser material, which drops into the bottom of the furnace in latest large thermal power plants and constitute about 20% of gross ash content of the coal fed in the boilers. It consists of non-combustible materials, and is the residual part from the incineration of household and similar waste. Raw bottom ash is a granular material that consists of a mix of inert materials such as sand, stone, glass, porcelain, metals and ash from burnt materials. Bottom ash is available from Thermal Power Station, Vijayawada.

The utilization of coal ash in normal strength concrete is a new scope in concrete mix design and if put to use on large scale would ameliorate the construction industry, by minimizing the construction cost and abating the ash content.

Bottom ash

DESIGN MIX OF CONCRETE

The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labor. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking [16].

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economic compromise, and depends on the size and type of job. The cost of labor depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labor to obtain a degree of compaction with available equipment.

TYPES OF MIXES:

Nominal Mixes:

In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes [7]. These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

Standard Mixes:

The nominal mixes of fixed cement-aggregate ratio vary widely in strength and may result in under or over rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes. IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20, M25, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28 day cube strength of mix in N/mm2.

Designed Mixes:

In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. The approach results in the production of concrete with the appropriate properties most economically. However, the designed mix does not serve as a guide since this does not guarantee the correct mix proportions for the prescribed performance. For the concrete with undemanding performance nominal or standard mixes (prescribed in the codes by quantities of dry ingredients per cubic meter and by slump) may be used only for very small jobs, when the 28-day strength of concrete approximately 30 N/mm^2.

TESTS ON FRESH CONCRETE

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. Workability is one of the physical parameters of concrete which affects the strength and durability as well as the cost of labour and appearance of the finished product. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e., without bleeding or Segregation. Unworkable concrete needs more work or effort to be compacted in place, also honeycombs &/or pockets may also be visible in finished concrete [9].Testing of concrete plays an important role in controlling and confirming the quality of concrete works. The main purpose of testing hardened concrete is to check and confirm that the concrete has attained the target strength. The tests conducted were compaction factor test for workability, density, compressive strength, split tensile strength and flexural strength.

DIFFERENT TEST METHODS FOR WORKABILITY MEASUREMENT:

Depending upon the water cement ratio in the concrete mix, the workability may be determined by the following three methods.

1. Slump Test
2. Compaction Factor Test
3. Vee-bee Consistometer Test

TESTS ON HARDENED CONCRETE:

COMPRESSIVE STRENGTH TEST:

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1. Prepare the concrete in the required proportions and make the specimen by filling the concrete in the desired mould shape of 15cm x 15cm x 15cm cube with proper compaction, after 24 hrs place the specimen in water for curing.
2. Take away the specimen from water when such as natural process time and wipe out excess water from the surface.
3. Clean the bearing surface of the testing machine.
4. Place the specimen within the machine in such a fashion that the load shall be applied to the other sides of the cube forged.
5. Align the specimen centrally on the bottom plate of the machine.
6. Apply the load step by step while not shock and incessantly at the speed of 140kg/cm^2/minute until the specimen fails
7. Record the utmost load and note any uncommon options within the form of failure.

Calculation:

COMPRESSIVE STRENGTH = (LOAD / AREA) in N/sq.mm

Cube mould

Cube placed in compressive testing machine

SPLIT TENSILE STRENGTH:

1. The concrete is prepared through machine mixing and for each proportion three cylinders are cast in the standard cylinder of length 300mm and diameter 150mm and cured for 28 days.
2. The cured cylinder is taken out from the curing tank and placed it outside until it gets dried.
3. Later, test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until the failure of the cylinder.

Mould of the cylinder

Cylinder placed in machine

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Calculation:

Split tensile strength = (2*P)/ (π*D*L)

Where, P= Failure load

D= Diameter of the cylinder

L= Length of the cylinder

The unit of Tensile strength is N/mm^2

RESULTS

The following are the test results of material properties and strength evaluated by (0-30%) replacement of coarse aggregate with ceramic aggregate and 10% replacement of fine aggregate with bottom ash. We are discussing here the comparison of material properties and strengths how they varied.

Comparison of material properties of fine aggregates are as follows:

S.NO	PROPERTY	BOTTOM ASH	RIVER SAND
1.	Density	2.52	2.67
2.	Specific Gravity	2.15	2.65
3.	Fineness modulus	2.80	2.72
4.	Bulk Density loose) (compact)	14160 16030	16200 18300
5.	Voids (loose) (compact)	43.2 38.42	36.52 30.71
6.	Water absorption	2.1	1.8

Comparison of material properties of coarse aggregates are listed below:

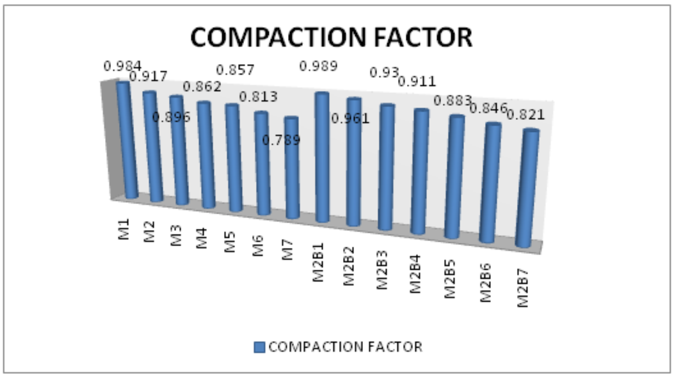
S.NO	PROPERTY	CERAMIC WASTE	CRUSHED STONE
1	Density (g/cm3)	2.78	2.73
2	Maximum size	20	20
3	Fineness Modulus	6.98	6.92
4	Surface texture	Rough	Smooth
5	Water absorption (24hr)	1.26	0.71
6	Crushing Value	23	25
7	Impact Value	16	17
8	Bulk Density Loose Compact	15430 16710	14100 15230
9	Voids Loose compacted	44 39.81	48 44.32

Tests conducted on fresh concrete:

Workability:

The workability of concrete containing ceramic waste aggregate as partial replacement for coarse aggregate of (0-30%) replacement and bottom ash of 10% replacement in an descending manner.

S.NO	MIX	COMPACTION FACTOR
1.	M1	0.984
2.	M2	0.917
3.	M3	0.893
4.	M4	0.862
5.	M5	0.857
6.	M6	0.813
7.	M7	0.789
8.	M2B1	0.989
9.	M2B2	0.961
10.	M2B3	0.930
11.	M2B4	0.911
12.	M2B5	0.883
13.	M2B6	0.846
14.	M2B7	0.821



Tests on Hardened properties of Concrete:

Compressive strength:

The compressive strength of cubes has increased its strength similarly with an increasing manner of ceramic aggregate replacement up to 20% .In order to Compensate this value adding of 10% bottom ash has taken. By increasing the Replacing Ratio of Mix Proportion the Strength also increased. The compressive strengths of Ceramic aggregate concrete and ceramic aggregate bottom ash Concrete are listed below:

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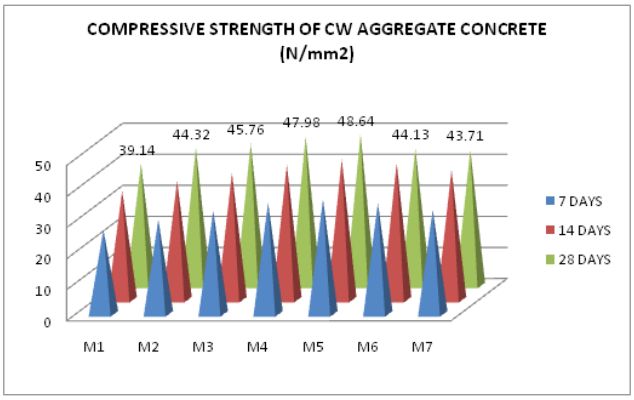
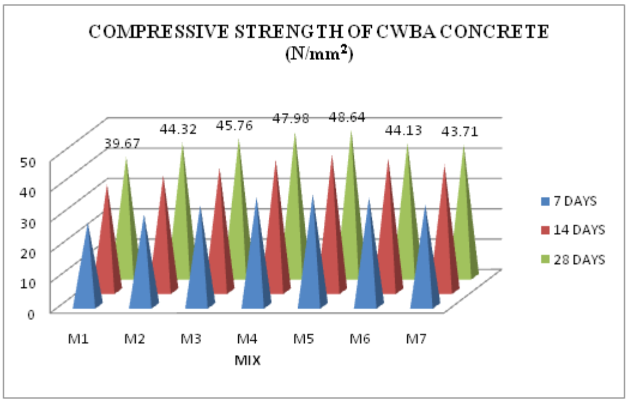
Ceramic Aggregate Concrete:

COMPRESSIVE STRENGTH OF CW AGGREGATE CONCRETE (N/mm^2)			
MIX	7 DAYS	14 DAYS	28 DAYS
M_1	27.12	35.48	39.14
M_2	29.66	36.91	42.14
M_3	32.41	38.48	43.36
M_4	33.18	39.55	45.07
M_5	35.17	42.16	45.81
M_6	34.82	39.82	44.27
M7	32.80	39.82	42.48



Ceramic Aggregate Bottom Ash Concrete:

COMPRESSIVE STRENGTH OF CWBA AGGREGATE CONCRETE (N/mm^2)			
MIX	7 DAYS	14 DAYS	28 DAYS
M_1	27.54	35.68	39.67
M_2	30.24	38.25	44.32
M_3	33.17	40.78	45.76
M_4	35.89	43.55	47.98
M_5	36.92	45.24	48.64
M_6	35.74	43.93	44.13
M_7	33.48	41.80	43.71



CONCLUSION

- The basic objective of the study is to prepare a concrete much more stable and durable than the conventional by replacing both coarse and fine aggregates by minimizing the water cement ratio.
- Based on the work it has been concluded that the coarse aggregate was replaced by ceramic aggregate in the percentages of 0%, 5%, 10%, 15%, 20%, 25% and 30% and 10% fine aggregate replacement with bottom ash achieved increment of strengths up to 20% ceramic aggregate and 10%bottom ash replacement and later decreased in strengths.
- The Compressive Strength of Ceramic aggregate replacement was increased from 7 -14 days is 19.87% and 14-28 days is 15% and 14-28 days is 31.25%.
- The Compressive Strength of Ceramic aggregate and Bottom ash replacement was increased from 7 -14 days is 22.53% and 14-28 days is and 7-28 days is 36%.There is an increment in the strength levels from Ceramic aggregate concrete to ceramic aggregate bottom ash concrete.
- The Split tensile Strength of Ceramic aggregate replacement was increased from 7 -14 days is 31% and 14-28 days is 13% and 7-28 days is 55%.
- The Split tensile Strength of Ceramic aggregate and Bottom ash replacement was increased from 7 -14 days is 32% and 14-28 days is 23.71% and 7-28 days is 64%.There is an increment in the strength levels from Ceramic aggregate concrete to ceramic aggregate bottom ash concrete.
- The Flexure Strength of Ceramic aggregate replacement was increased from CW concrete To CWBA concrete 11% to 15%.
- Specific Gravity of ceramic waste is 2.15, which is 26% lower when compared to the specific gravity of coarse aggregate which is 2.73.So ceramic waste satisfied limit of specific gravity as per IS Code.

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- The Crushing and impact value of ceramic waste is 23 and16 and crushed stone aggregate is 25 and 17 was nearer to each other.
- The bulk Density of ceramic waste is 15430kg/m3 in loose and 15710kg/m3 in compacted and crushed stone is 14100kg/m3 and 15230 kg/m3.
- The Workability of concrete decreasing by increasing the Strength of the concrete.
- The specific gravity of Bottom ash is 2.52 and river sand is 2.67 and their respective densities are 2.52 and 2.67.
- The bulk Density of bottom ash is 14160kg/m3 in loose and 16030kg/m3 in compacted and river sand is 16200kg/m3 and 18300kg/m3.
- The void percentage of both fine aggregates are 12.44% and 18.91% and the void percentage of both coarse aggregates are 8.30% and 9.09%.
- The Overall Weight of the cubes decreased at a percentage of 18.14% . So the dead weight of the specimen became lighter.
- The Workability of the nix gradually decreases by increasing the strength of concrete.
- So, finally all the materials and their properties satisfied the IS CODE.
- The replacement of aggregates satisfied at increasing their strengths and proved that lighter in construction and economical too.
- The further investigation of work will proceed with varied W/c ratio by comparing strengths along with Durability Characteristics.

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