AN EXPERIMENTAL AND INVESTIGATION OF CONCRETE WITH PARTIALLY REPLACEMENT OF CERAMIC WASTE INSTEAD OF COARSE AGGREGATE

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***Abstract*: In accordance with conservation efforts, this research focuses on ceramic tile waste as partial coarse aggregates replacement for concrete production, prevention of environmental considering the elements of sustainable and cost-saving construction projects, especially material usage. Moreover, many of the construction industry in Malaysia produce construction waste that contributes largely in solid waste. Utilizing ceramic tile waste, this research will focus on ceramic wastes obtain from the construction industry. Presently, much of ceramic industries production goes to waste, which is not undergoing the recycle process yet. A total forty cubes with the same dimensions (100 mm x 100 mm x 100 mm) were cast with five different proportion. Eight cube as one type of control proportion that is 0 % percentage of ceramic waste as partial replacement of coarse aggregates and the remaining 32 cubes are 5%, 10 %, 15% and 20% of ceramic as partial replacement of coarse aggregates. Besides that, all other parameters are constant. The concrete cube were tested as destructive test at last which is compression test that to find out compressive strength of specimens of hardened concrete at 7days,14 days and 28 days .Before undergoing the destructive test, the performance of the concrete was determined by undergoing slump test, compressive strength test, water absorption test. From the results of the study, samples of concrete with 15% ceramic coarse aggregate replacement (A4) has reached optimum strength. Findings showed that concrete containing Ceramic Tile 15% showed the highest amount of strength compared with other specimen. Addition of 25%ceramic material has led to compaction of concrete structures in ceramics and exhibit low water absorption rate.**

Index Terms: Compressive strength, Flexural strength, Marble waste, Mix design, Split tensile strength.

1. GENERAL:

Ceramic is non-metallic soli which is inorganic, produced by the action of heat and subsequent cooling. The structure of ceramic materials may be crystalline or partly crystalline, or amorphous (e.g., a glass). Since most common ceramics are available in crystalline form, the term ceramic is often referred to inorganic crystalline materials. The earliest ceramics made by humans were pottery objects, including 27,000 year old figurines, made from clay, either by itself or mixed with other materials, hardened in fire. Then glazing and heating of ceramics is done to create a coloured and smooth surface. Ceramics now include domestic, industrial and building products and a wide range of ceramic art. In the 20th century, new ceramic materials were developed for use in advanced ceramic engineering; for example, in semiconductors. Various products of ceramic wastes include sanitary ware, floor tiles, wall tiles, roof tiles, ceramics from refractory and vitrified clay tiles [4]. Ceramic waste may come from two sources The first source is the ceramics industry, and this waste is classified as non-hazardous industrial waste (NHIW). According To Integrated National Plan on Waste 20082015, NHIW is all waste generated by industrial. The second source of ceramic waste is associated with construction and demolition activity. For this project work, ceramic waste from Construction Demolition Waste is used.

1.1 Composition of ceramic:

The chemical bonds in ceramics can be covalent, ionic, or polar covalent, depending on the chemical composition of the ceramic. When the components of the ceramic are a metal and a nonmetal, the bonding is primarily ionic; examples are magnesium oxide (magnesia), MgO, and barium titanate, $BaTiO3$ .Industrial ceramics are commonly understood to be all industrially used materials that are inorganic, non-metallic solids. Usually they are metal oxides (that is, compounds of metallic elements and oxygen), but many ceramics (especially advanced ceramics) are compounds of metallic elements and carbon, nitrogen, or sulfur. In atomic structure they are most often crystalline, although they also may contain a combination of glassy andcrystalline phases. These structures and chemical ingredients, though various, result in universally recognized ceramic-like properties of enduring utility, including the following: mechanical strength in spite of brittleness; chemical durability against the deteriorating effects of oxygen, water, acids, bases, salts, and organic solvents; hardness, contributing to resistance against wear; thermal and electrical conductivity considerably lower than that of metals; and an ability to take a decorative finish.The ceramic composition first depends on the composition of the precursor, which supplies elements such as Si, B, C, N, etc. There is a significant modification of the composition during the pyrolysis. Depending on the pyrolysis conditions, several elements can be removed partially (C, N, B, Si, …) or completely (H, C, N). On the other hand, some elements (O, B, N, …) can be introduced during the curing step or pyrolysis using a reactive gas such as NH_3 or O_2. The pyrolysis in an inert atmosphere often results in ceramics containing an excess of carbon, leading to the formation of a “free-carbon” phase.To adjust the composition of the final ceramic, it is often necessary to tune the composition of the precursor by design of the monomer, copolymerization of different monomers, or chemical modification

1.2 TYPES OF CERAMIC:

The mention of the word ceramic takes you to the world of earthenware, clay pots etc. found in many households. Treasured by both the owner and the maker, these products are made from naturally occurring clay and sand. With the advancement of technology, ceramic materials are now being manufactured in a laboratory under the watchful eye of a scientist. Made with a variety of ingredients and a number of processing techniques, ceramics are made into a wide range of industrial products. Ceramics made through the above mentioned process are known as advanced ceramics or industrial ceramics. Their thermal stability, wear-resistance and resistance to corrosion of ceramic components make the application of ceramics the ideal choice for many industrial uses.

1.3 ALUMINA CERAMIC:

Alumina is one of the most widely used advanced ceramic, and is made from aluminium oxide. This ceramic can be made via different types of manufacturing processes including isotactic pressing, injection molding and extrusion. Finishing can be accomplished by precision grinding and lapping, laser machining and a variety of other processes. Alumina's high ionic inter-atomic bond makes it chemically very components, electrical insulations and automotive sensors.

1.4 STEATITE CERAMICS:

Choice of material for insulators for electrical components. Other properties of steatite include excellent dielectric strength, low dissipation factor, and high mechanical strength. Further, due to Steatite's excellent insulating properties it is used in thermostats and many other electrical household **stable,** thereby making it a good electrical insulator. Further it is extremely resistant to wear and corrosion and has a high mechanical strength. Due to all these qualities, alumina components are used in semiconductor components, pump product

1.5 ZIRCONIA CERAMIC:

Made from zirconium oxide, this ceramic has excellent strength and a high resistance to corrosion, wear and abrasion. Since it has a high tolerance to degradation, zirconia is the material of choice in the manufacturing of bearings and grinding. Further due to its high resistance to developing cracks, commonly referred to as 'fracture toughness', zirconia is used in structured ceramics, automotive oxygen sensors and dental ceramics

1.6 SILICON CARBIDE CERAMIC:

When the grains of silicon carbide are bonded together through a process called sintering, they form a very hard ceramic. Due to its hardness, it is used in applications requiring high endurance such as car brakes, car clutches, ceramic plates and bullet proof vests

1.7 CORDIERITE CERAMIC:

Cordierite typically occurs in contact of argillaceous rocks. Cordierite has a very high thermal shock resistance and thus widely used in high temperature industrial applications such as heat exchangers for gas turbine.

1.8 MULLITE CERAMIC:

Mullite is a very rare silicate material, formed at high temperatures and low-pressure conditions. Its properties include low thermal expansion, low thermal conductivity, excellent creep resistance, suitable high temperature strength and outstanding stability under harsh chemical environments. It is commonly used in thermocouple protection tubes, furnace muffles and kiln rollers.

2. CERAMIC WASTES AS AN AGGREGATE:

Ceramic is non-metallic solid which is inorganic, produced by the action of heat and subsequent cooling. The structure of ceramic materials may be crystalline or partly crystalline, or amorphous (e.g., a glass). Since most common ceramics are available in crystalline form, the term ceramic is often referred to inorganic crystalline materials. The earliest ceramics made by humans were pottery objects, including 27,000 year old figurines, made from clay, either by itself or mixed with other materials, hardened in fire. Then glazing and heating of ceramics is done to create a coloured and smooth surface. Ceramics now include domestic, industrial and building products and a wide range of ceramic art. In the 20th century, new ceramic materials were developed for use in advanced ceramic engineering; for example, in semiconductors.

2.1 SOURCES OF CERAMIC WASTE:

Various products of ceramic wastes include sanitary ware, floor tiles, wall tiles, roof tiles, ceramics from refractory and vitrified clay tiles [4]. Ceramic waste may come from two sources: • The first source is the ceramics industry, and this waste is classified as non-hazardous industrial waste (NHIW). According To Integrated National Plan on Waste 20082015, NHIW is all waste generated by industrial. • The second source of ceramic waste is associated with construction and demolition activity. For this project work, ceramic waste from Construction Demolition Waste is used. Ceramic waste was collected from Scrap yard in KC.

3. OBJECTIVES:

- To replace fine aggregate in concrete by using ceramic waste in various proportions (0%, 25%, 50% and 75%)
- To cast and test the specimens for determining compressive strength, split tensile strength, flexural strength and modulus of elasticity of control mix and ceramic mix.
- To compare the test results and to find the optimum percentage of ceramic waste to be used in concrete.

4. MATERIALS USED:

The materials used are cement (OPC of grade 53), river sand, coarse aggregate, ceramic waste and potable water available in the campus. The collected waste ceramic tiles were crushed into aggregates using Jaw crusher available in the laboratory.

5. DETERMINATION OF CONCRETE MIX DESIGN

For M20 grade,

Concrete is made with the design mix ratio of 1: 1.5: 3 with the water cement ratio of 0.5

Step 1: Target mean strength of concrete

Fck = fck+1.65 S

= 20+(1.65x4)

Fck = 26.6 N/mm2

Step 2: Cement content

mass of water = 185 Kg/m3

Cement = 185 Kg/m3/0.45

= 411.11 Kg/m3

w/c = 0.45

air content = 2%

= 1- 0.02

= 0.98

Step 3: fine aggregate determination

0.98 = [w+ c/s.g +(1/Absolute volume x F.A/F.A specific gravity)] x 1/1000

0.98 = [185+411.11/3.15 +(1/0.315 x F.A /2.68)] x 1/1000

0.98 x 1000 = 185 + 130.51+ F.A / 0.819

980 -(185 + 130.51) = F.A /0.819

664.49 x 0.819 = F.A

F.A = 544.21 Kg/m3

Step 4: Coarse Aggregate determination

0.98 = (w+c /s.g + [1/Absolute volume x C.A/ C.A specific gravity]) x 1/1000

0.98x1000 = (185 + 411.11/3.15 + [1/068 x C.A/ 2.65])

980 - (185 + 130.51) = C.A / 1.81

684.49 x 1.81 = C.A

C.A = 1202.7 Kg/m3

6. TESTS ON PROPERTIES OF MATERIALS USED:

The physical properties of the materials were determined and the results are presented in the following topics.

6.1 Sieve Analysis Test:

Sieve Analysis is done to determine Fineness modulus of aggregates. In this test fineness modulus is determined which is an index number which generally indicates the mean size of coarse or fine the particles. If the fineness modulus value of the aggregate is more, it implies that it is coarser and lesser value implies that it is finer.

6.2. Specific Gravity Test :

Specific gravity is the ratio between the weight a given volume of a material at a standard temperature in air of to the weight of an equal volume of distilled water at the same stated temperature in air.[5] The specific gravity of fine-grained soil is determined by pycnometer method as per IS: 2720 (Part III/Sec 1) – 1980. IS:2386 (Part III)-1963[6]

6.3. Water Absorption Test:

It is the ratio of weight of water absorbed to the weight of dry sample expressed as a percentage [7]. It will not include the amount of water adhering to the surface of the particles. The results of the tests are presented in Table 1

S.no	Property	River sand	Ceramic waste aggregate	Reference
1	Specific gravity	2.7	2.3	IS 2386 - Part3
2	Water absorption	1.7	0.3	IS 2386 - Part3
3	Fineness modulus	2.66	3.29	IS2386 - Part1

7. EXPERIMENTAL INVESTIGATIONS:

Three numbers of cube specimens of size 150 mm for Compressive strength test, cylinder specimens of size 150 mm dia and 300 mm length for Spilt Tensile strength test and prism specimens of size 100 x 100 x 500 mm for Flexural Strength test were cast and tested at 7 days and 28 days respectively after curing.

7.1. Slump Test:

The consistency and degree of workability of fresh concrete is determined using slump test. The apparatus consists of a conical mould with a base plate. The mould is kept over the base plate and filled with the freshly mixed concrete of desired grade in three layers; each layer is tamped 25 times with a tamping rod of standard dimensions. After leveling the concrete, the mould is lifted upwards carefully and the concrete subsides. This depth of subsidence is termed as slump, and is measured in to the nearest 5 mm if the slump is <100 mm and measured to the nearest 10 mm if the slump is >10 mm[9]. The results of Slump test are

Test	Control Mix	5%	15%	20%
Slump value (mm)	45	40	50	60

7.2. Cube Compressive Strength Test:

Compressive test is the most common test used to test the hardened concrete specimen test. Concrete cube specimens of size 150 mm with various percentages of recycled aggregate were cast, cured and tested after 7th day and 28th day in the compression testing machine until failure. The compressive strength is calculated by the formula given below.
Compressive strength = A/ P Where, P= Compressive Load in N A= Area in mm2

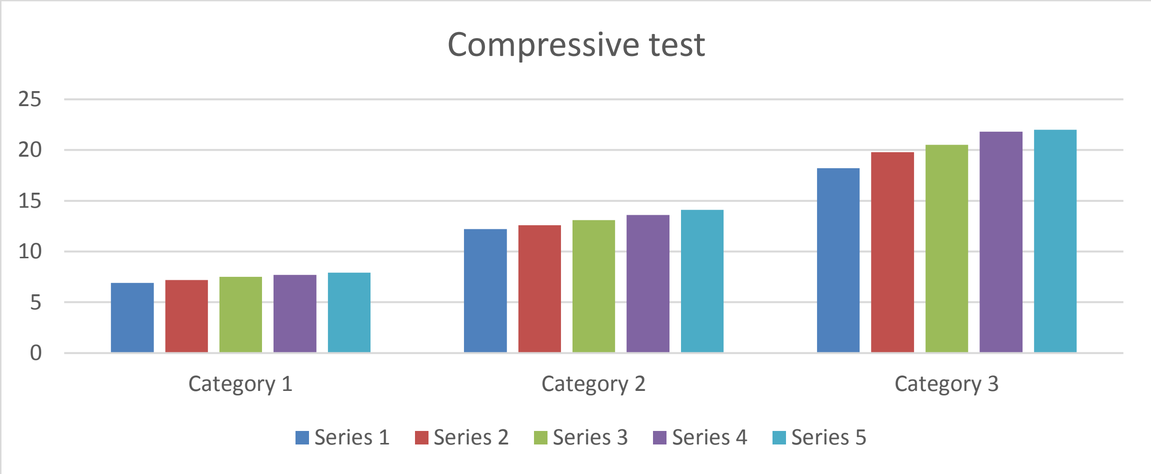

Fig: CUBE COMPRESSIVE STRENGTH TEST

7.3 Split Tensile Strength Test:

Cylinder specimen size 300 mm height 150 mm diameter are used for compressive test with various mix proportion such 5% ,10%,15%,20%.after 28 days curing. The cylinders specimens are placed vertically on the platform of compression testing machine. The load is applied continuously and uniformly without shock at the rate of 315 kN/min. The loading is continued until the specimen fails.

Where,
P = compressive load on cylinder
l= length of the cylinder = 300 mm
d= diameter of the cylinder = 150 mm

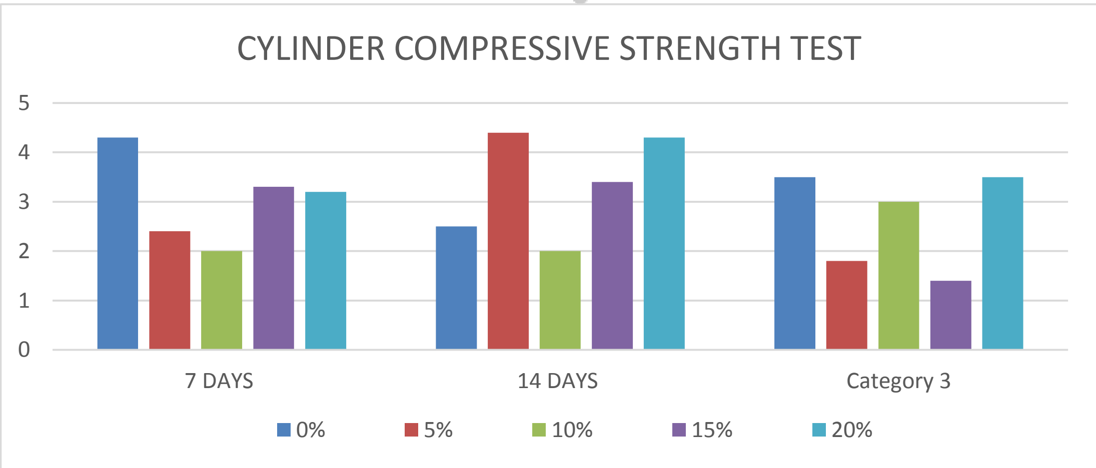

Fig: SPLIT TENSILE STRENGTH TEST

7.4 Flexural Strength Test :

Prism specimen size 100 mm height 100 mm depth and 500 mm length are to be used for flexural strength test by various mix proportion such as 5% ,10%,15%,20%.

Where, fb= flexural strength value (MPa) b= breath of beam (mm), d= height of beam (mm)
a= shorter length of beam (mm)

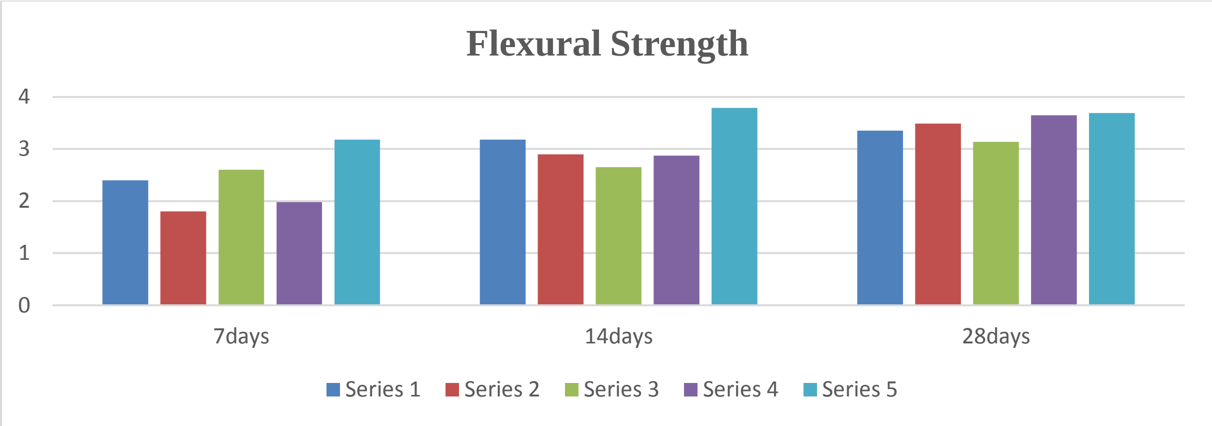

Fig: FLEXURAL STRENGTH TEST

8. CONCLUSION

•The cube Compressive strength, Split tensile strength, Flexural strength value of control mix are 25.27 N/mm2 , 2.64 N/mm2 , 3.82 N/mm2 respectively.

• For 5% replacement of fine aggregate by ceramic waste, the cube Compressive strength, Split tensile strength, Flexural strength values are 44.33N/mm2 , 3.25 N/mm2 , 5.77 N/mm2 respectively.

• For 10% replacement of fine aggregate by ceramic waste, the cube Compressive strength, Split tensile strength, Flexural strength values are 52.71 N/mm2 , 3.5N/mm2 , 6.2 N/mm2 respectively.

• For 15% replacement of fine aggregate by ceramic waste, the cube Compressive strength, Split tensile strength, Flexural strength values are 52.71 N/mm2, 3.5 N/mm2, 8.55 N/mm2 respectively.

• From this result it is inferred that strength gradually increases with the increase in replacement percentage of ceramic waste aggregate [10].

• It was noted these 20% replacement of ceramic waste gain strength and give better results than other percentage and control mix.

• It is concluded that ceramic waste may be used in concrete up to 20% there by it improves the strength as well as saves the natural resources.

• From this results it is inferred that 50% replacement by ceramic waste gain more strength and gives better result. Beyond 20% replacement the strength decreased. The strength loss may be due to increase in consumption of water to improve workability.

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