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The Suitability And Performance Of Ceramic Waste As A Substitute For Coarse Aggregate In The Production Of Concrete Using Different Mix Ratio

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ABSTRACT
There is a growing interest in using waste materials such as ceramics as alternative e aggregate materials for construction. This paper centered on the experimental investigation of the effect of replacement of coarse aggregates with ceramic waste materials. Ceramic waste sourced from construction and demolition water were separated fro other debris and crushed using a quarry metal hammer. Ceramic wastes were sieved into coarse aggregate in line with standards. A mix ratio of 1:2:4, 1:3:6, 1:4:8 were used for the work. Other materials used were gravel, river sand, cement and portable water. Workability of the fresh concrete was checked through slump test and concrete cubes of 150mm dimensions and cylinders of 100mm, 200mm were cast in the laboratory. After 24hours of casting the concrete samples remolded and were cured by immersion in water tank at temperature 22^0C. The compressive strength and split tensile strengths of the hardened concrete samples were determined after curing them for 7, 14, 21 and 28days. The results shows that the compressive strength and split tensile strength increased appreciably with the curing age,
Keywords: ceramic, wastes, demolition, compressive strength, slump test, laboratory, mix ratio.

I. INTRODUCTION

Concrete is the world's second most utilized substance after water and it shapes the built environment. It is also recoverable as recycled aggregate. An estimated 33 billion tonnes of concrete are manufactured globally each year. This means that over 1.7 billion truckloads each year, or about 6.4 million truckloads a day, or over 3.8 tonnes per person in the world each year. Twice as much concrete is used in construction around the world than the total of all other building materials, including wood, steel, plastic and aluminum. According to Nigerian Environmental Society (NES), Nigeria generates over 60 million tonnes of waste annually with less than 10% waste management capacity. The need to manage these wastes has become one of the most pressing issues of our time, requiring specific actions aimed at preventing waste generation such as promotion of resource recovery systems (reuse, recycling and waste-to-energy systems) as a means of exploiting the resources contained within waste, which would otherwise be lost, thus reducing environmental impact. According to (Rawaid K, Abdul J etal 2012), million tonnes of these waste materials are abundantly available and discarded every year in the world.

Recycling of such wastes as a sustainable construction material appears to be a viable solution not only for pollution problems control, but also as an economical option in the design of green buildings.

In Nigeria today, the increasing concern for environmental protection, energy conservation with minimal impact on the economy has been motivating researchers to look for other alternatives for coarse aggregates in concrete industry (Echeta C, Ikpnmwosa E etal 2013) In view, different industrial waste materials such as fly ash, blast furnace slag, quarry dust, tile waste, brick, broken glass waste, waste aggregate from demolition of structures, ceramic insulator waste, etc. have been investigated as likely viable substitute material to the conventional materials in concrete.

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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, it wastes among others cause a lot of nuisance to the environment.

As a general note, (Omole and Isiorho, 2011) reported the devastating influence of solid wastes in the Nigerian community.

Ceramic wastes are separated into two categories in accordance with the source of raw materials, (F. Pacheco-Torgal et S. Jalali 2010). One category is formed through generated fired ceramic wastes by structural ceramic factories that use only red pastes for product (brick, blocks and roof tiles) manufacture. The second encompasses fired ceramic wastes which are produced in stoneware ceramic (wall, floor tiles and sanitary ware). Meanwhile during ceramic production, studies have shown that about 30% of the material goes to wastes, (Medina C, et al 2012), and currently they are not beneficially utilized. This attests to the need for exploring innovative ways of re-using ceramic wastes. Aggregates constitute about 70% of total constituents in concrete production. The cost is increasing as a result of high demand from rural and urban communities.

Mujendu et al investigated the suitability of broken tiles as coarse aggregates in concrete production and observed that the compressive strength and density are are maximum for concrete cubes with 100% crushed granite and minimum when broken tiles content is 100%. It was also reported that replacement of crushed granite with 39% to 57% broken tiles concrete showed satisfactory result. Kumar et al. They opined that the optimum percentage of coarse aggregate that can be replaced by crushed tiles is 10%.Takakoi. et al, studied the properties of concrete produced with waste ceramic tile aggregate and observed that the optimal replacement of ceramic tile aggregate for sand falls within 25% to 50% and 10% to 20% replacement levels was the best range for coarse aggregate. Binic used crushed ceramic waste and pumice stone as partial substitute for fine aggregate in the production of mortar and concrete, the results showed that the resultant product had good compressive strength and abrasion resistance as well as strong resistance to chloride attack Gomes S studied the viability of incorporating coarse aggregate from concrete waste and ceramic block waste in the production of new concrete and concluded that as regards durability, structural concrete can be made using recycled aggregates, but that the 4-32mm fraction of natural aggregates cannot be totally substituted. investigated the effect of waste ceramic tiles as partial replacement of coarse and fine aggregate in concrete and concluded that the compressive strength increased for all mixes and the maximum strength was obtained for the mix having 10% of crushed tiles and 20% of tiles powder. Numerous researchers have identified ceramics as having the potential to replace natural aggregates; Consequently, the current study explores the mechanical characterization of concrete made using ceramic floor and wall tiles wastes from construction and demolition sites in Owo, Ondo State as partial replacement of natural aggregates.

II. MATERIALS AND METHODS

2.1 Materials

In carrying out this investigation, the following materials were used:cement, fine aggregates, coarse aggregates, ceramic waste and water. Ordinary Portland Cement produced in accordance with the standards NIS 444 Standard of cement and BS 12 Specifications for Portland Cement. Portable water was used for the experiment, it is free from sulphate, ferric, vegetable, alkaline, oils and salt that could affect the properties of concrete in the fresh or hardened state. Sand obtained from a location within the Polytechnic area in Owo, Ondo State Nigeria was used as fine aggregate. The sand was dried with the aperture size of 3.35mm and retained on sieve 63um. The coarse aggregate used in this work was crushed granite from igneous rock and the size varied between 12.5mm and 19mm. the ceramic waste was obtained from demolition of some buildings along the Owo axis in Ondo State.

The ceramic waste was crushed manually and made into smaller pieces about 5-40mm sizes using hammer blow, it was now sieved using vibrator to get the required size of 12.5mm to 19mm. A mix ratio of 1;2;4, 1;3;6, and 1;4;8 by weight of cement, sand and coarse aggregates was used and water cement ratio of 0.60 was adopted. The granite in the mix ratio was partially replaced with ceramic waste at an interval of 25% up to 100% . Concrete with 0% Ceramic Waste replacement serve as control.

2.2 Methods

The laboratory procedures carried out in this report are stated below

PHYSICAL ANALYSIS OF MATERIALS

Laboratory test carried out on the aggregate include particle size distribution, specific gravity, dry and bulk densities, and moisture contents. Water absorption test was performed on both the ceramic waste and granite by keeping the samples immersed in water and removing the excess water on the surface of the sample after 24 hours and measuring the saturated weight. After that, the sample were kept in the oven, oven dried weight of the samples was recorded and water absorption capacity evaluated

Plate 2.1 Crushed Ceramic Waste

2.3 WORKABILITY TEST

The slump test was carried out in accordance with the provision of BS EN 12350: PART 2 A method for determination of slump. British standards institute, London, 2010. The replacement of coarse aggregate with ceramic waste was done at interval of 1:2:4, 1:3:6 and 1:4:8. The sample without ceramic waste serves as the control

Plate 2.2: Mixing of the materials

Plate 2.3: Curing of concrete cubes

3.8 COMPRESSIVE STRENGTH TEST

Compressive strength test was carried out in accordance with BS EN 12350-6 TESTING fresh concrete density of test specimens. British standard, 2009 and BE EN 12390-3 testing hardened concrete. For the test, 150*150*150 mm cube specimens were used. This test was performed to confirm whether the Targeted 28-days compressive strength for both the normal concrete and concrete having ceramic waste were achieved. The cubes were tested for their compressive strength at 7,14,21,28 days curing ages. The strength characteristic of each cube were determined on Hatfield Farnel Testing Machine. Four specimen for each mix were tested at each curing age and the values of the crushing load were taken.

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Plate 2,4: Compressive Test (Hatfield Farnel Testing Machine)

III. RESULTS AND DISCUSSIONS

3.1: Physical Properties

The results of the preliminary investigation on some physical properties of cement, ceramic waste and aggregates used presented in the table 3.1 below. The values of bulk density and the specific gravity (weight features of materials) for ceramic waste were lower than that of the granite. A higher water absorption value was observed for ceramic waste because of large surface area, pore structure and clay content. The aggregate crushing value (ACV) for ceramic was lower than that of normal aggregate and this suggests the possibility of reduction in the compressive strength because ceramic waste exhibited lower capacity to resist load.

TABLE 3.1: Physical Properties Of Aggregates, Cement And Ceramic Waste

Physical Property	Sand	Granite	Ceramic Waste	Cement
Fine Content ($^0/_0$ passing through sieve 600 µm)	-	-	-	99.5
Specific Gravity	2.50	2.76	2.16	3.15
Texture	-	Rough on all sides	Rough on all sides except top	-
Shape	-	angular	Flaky	-
Dry Density (kg/m^3)	1356.52	1352.06	826.51	-
Bulk Density (kg/m^3)	1524.63	1586.68	1356.58	-
Moisture Content ($^0/_{0)}$)	0.139	0.5475	0.203	-
Aggregate Crushing Value ($^0/_0$)	-	17.49	13.52	-
Water Absorption ($^0/_0$)	-	0.10	0.18	-

Source: Field Work, 2022

3.2: Effect of Ceramic Waste on Workability

The measure of concretes workability or fluidity is called Slump.

It was observed that the slump value decreased as ceramic waste content increased. This indicates that the inclusion of ceramic waste (cw) in the mix has effect on the cohesiveness of the mix to the extent of causing shear or collapse slump. This decrease in slump value with increased in ceramic waste content can be attributed to higher water absorption capacity and the angular shape of the ceramic waste.

3.3: Effect of Ceramic Waste on Concrete Density

The density of concrete is a measurement of concrete's solidity. It was observed that concrete density increased gradually as curing age increased. Also, as the content of ceramic waste increased, the density of concrete decreed. The fact that ceramic waste was lighter than the normal coarse aggregate could also have attributed to the lower density as a result of loose packed inner matrix. The numerical values of all the densities at all replacement levels were in the density range for normal concrete of between 2200-2550kg/m^3 in accordance with (ACI Committee, 2000). Thus, replacing normal coarse aggregate with ceramic waste will reduce the dead weight of concrete structures.

3.4: Effect of Ceramic Waste on Compressive Strength of Concrete

The compressive strength of concrete cube for different mix ratio of ceramic waste are shown in table 1-6. it was observing that the compressive strength decreased with the increase in mix ratio of ceramic waste content, the decreased in strength may be due to flaky nature and the smooth surface texture of ceramic waste aggregate, this probably resulted in poor bonding properties of the matrix, the strength value increased progressively as the curing age increased; an indication of effect of curing age on concrete strength development.

Table 3.2: The Compressive Strength For Concrete Produce From Sand, Cement And Ceramic Waste for 1:2:4 mix ratio

Cube No.	Date Casted	Age for Testing	Age Tested	Weight of Cube	Density of Cube	Crushing Load (N)	Crushing Strength N/mm^2
1	26/2/2022	2/3/2022	7	7570	2.24	180	8
2	26/2/2022	9/3/2022	14	7764	2.30	200	8.89
3	26/2/2022	16/3/2022	21	7893	2.34	240	10.67
4	26/2/2022	23/3/2022	28	7912	2.34	280	12.44

Source: Field Work, 2022

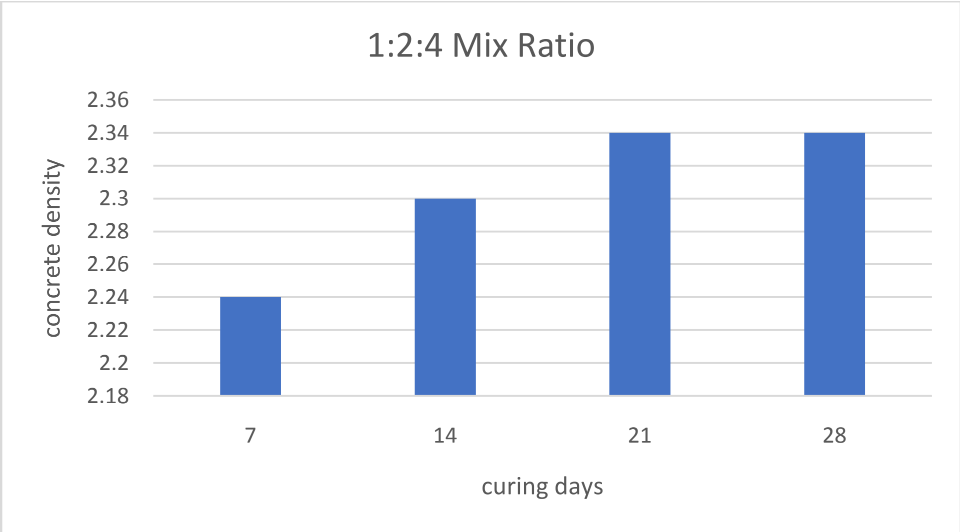

Fig. 3.11: Graph Showing Concrete Density of 1:2:4 Mix Ratio

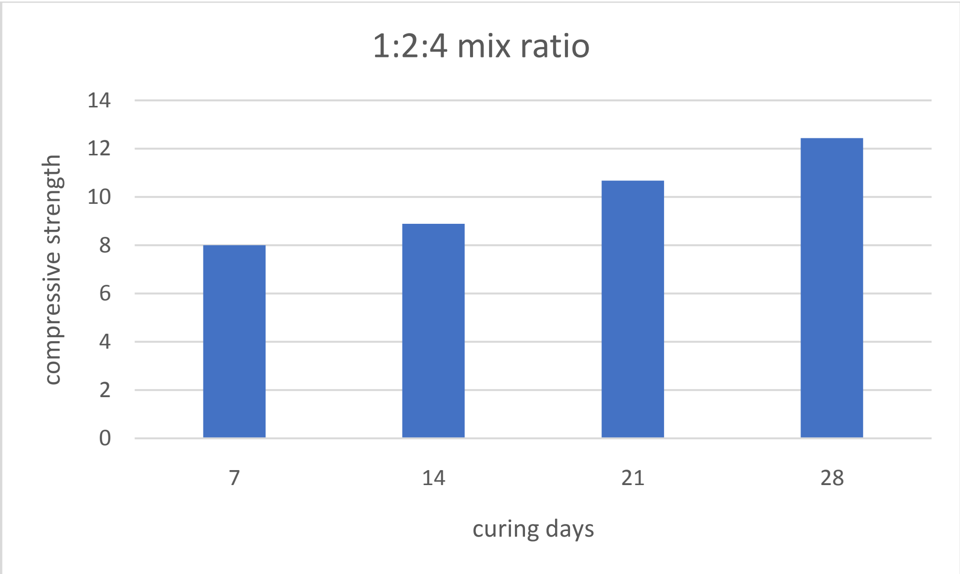

Fig. 3.2 Graph Showing Crushing Load of 1:2:4 Mix Ratio

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Table 3.3 The Compressive Strength For Concrete Produce From Sand, Cement And Ceramic Waste for 1:3:6 mix ratio

Cube No.	Date Casted	Age for Testing	Age Tested	Weight of Cube	Density of Cube	Crushing Load (N)	Crushing Strength N/mm^2
1	26/2/2022	2/3/2022	7	7436	2.20	100	4.4
2	26/2/2022	9/3/2022	14	7521	2.23	130	5.78
3	26/2/2022	16/3/2022	21	7660	2.27	150	6.67
4	26/2/2022	23/3/2022	28	7750	2.30	200	8.89

Source: Field Work, 2022

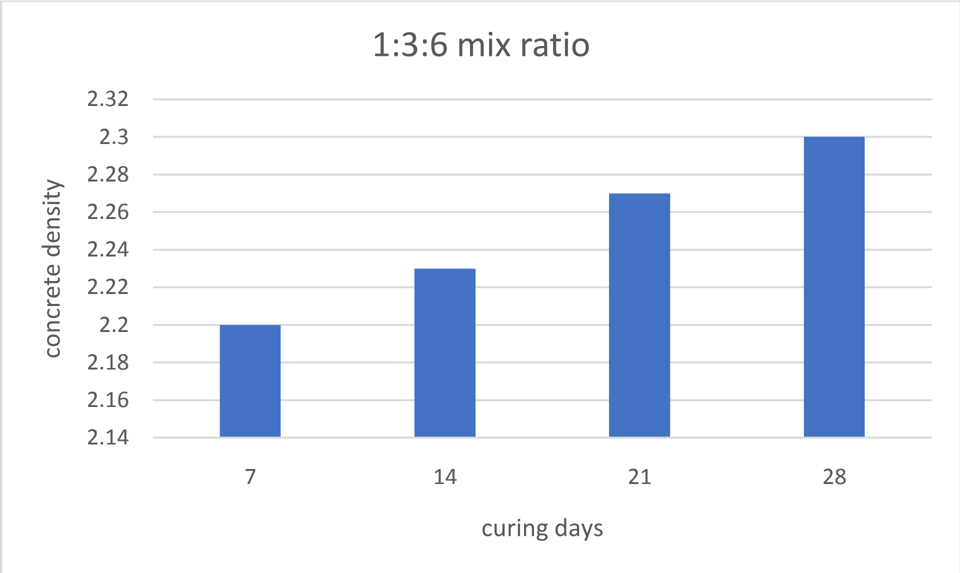

Fig. 3.3 : Graph Showing Concrete Density of 1:2:4 Mix Ratio

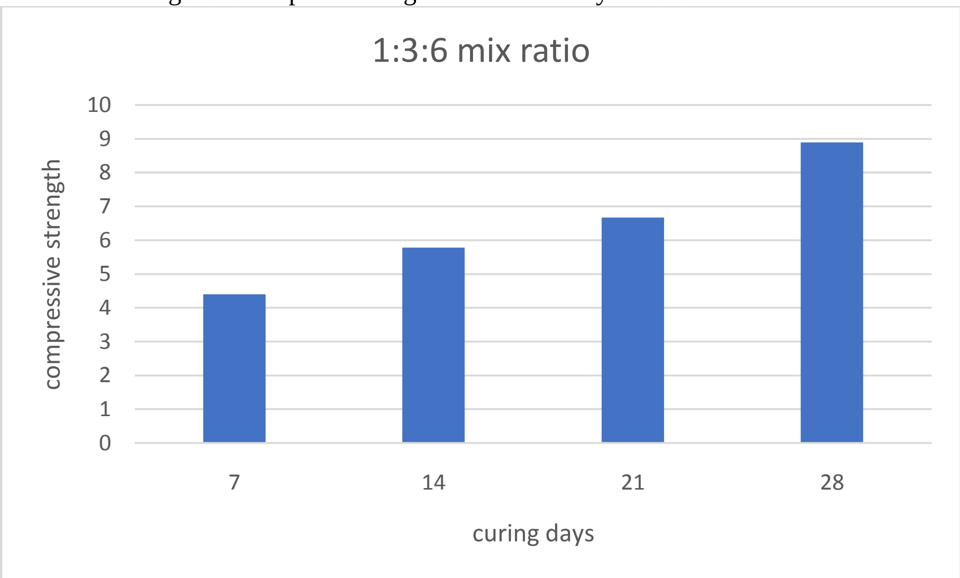

Fig. 3.4: Graph Showing Crushing Load of 1:2:4 Mix Ratio

Table 3.4: **The Compressive Strength For Concrete Produce From Sand, Cement And Ceramic Waste for 1:4:8mix ratio**

Cube No.	Date Casted	Age for Testing	Age Tested	Weight of Cube	Density of Cube	Crushing Load (N)	Crushing Strength N/mm^2
1	26/2/2022	2/3/2022	7	7250	2.15	80	3.56
2	26/2/2022	9/3/2022	14	7460	2.21	100	4.44
3	26//2022	16/3/2022	21	7585	2.25	145	6.44
4	26/2/2022	23/3/2022	28	7697	2.28	180	8

Source: Field Work, 2022

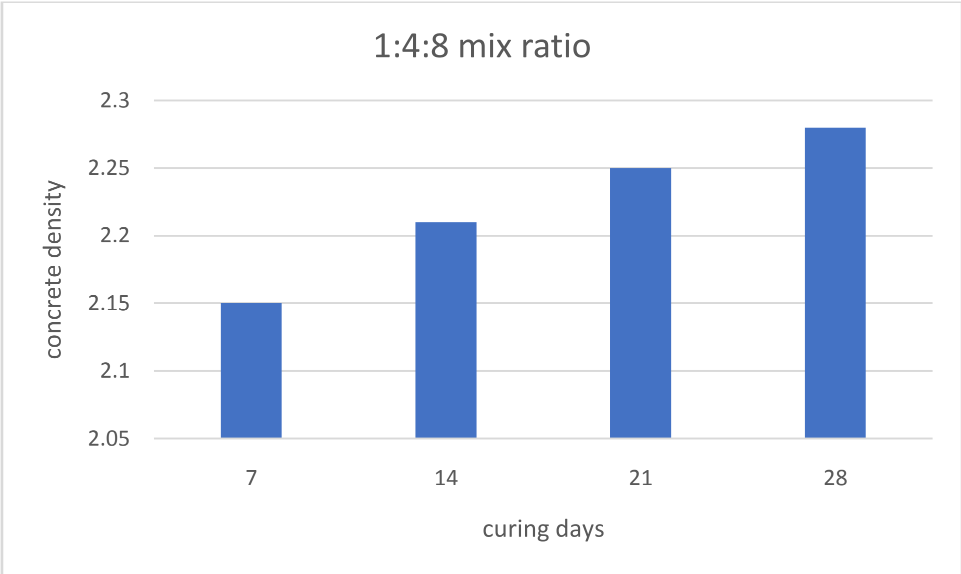

Fig. 3.5: Graph Showing Concrete Density of 1:2:4 Mix Ratio

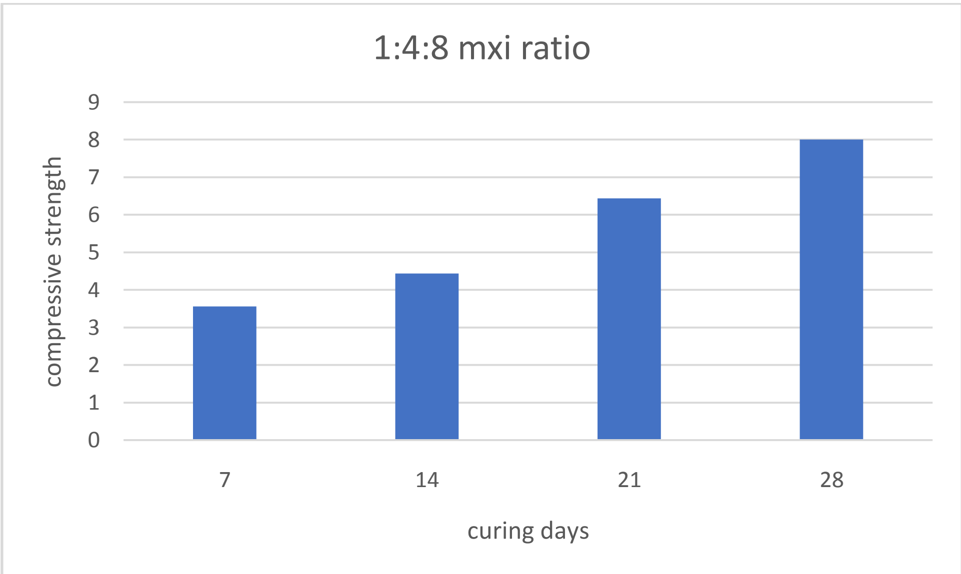

Fig. 3.6 Graph Showing Crushing Load of 1:2:4 Mix Ratio

Table 3.5: **The Compressive Strength For Concrete Produce From Sand, Cement And Ceramic Waste for 1:2:4 mix ratio**

Cube No.	Date Casted	Age for Testing	Age Tested	Weight of Cube	Density of Cube	Crushing Load (N)	Crushing Strength N/mm^2
1	26/2/2022	2/3/2022	7	8315	2.46	200	8.89
2	26/2/2022	9/3/2022	14	8195	2.43	250	11.11
3	26/2/2022	16/3/2022	21	8520	2.52	270	12
4	26/2/2022	23/3/2022	28	9091	2.69	300	13.33

Source: Field Work, 2022

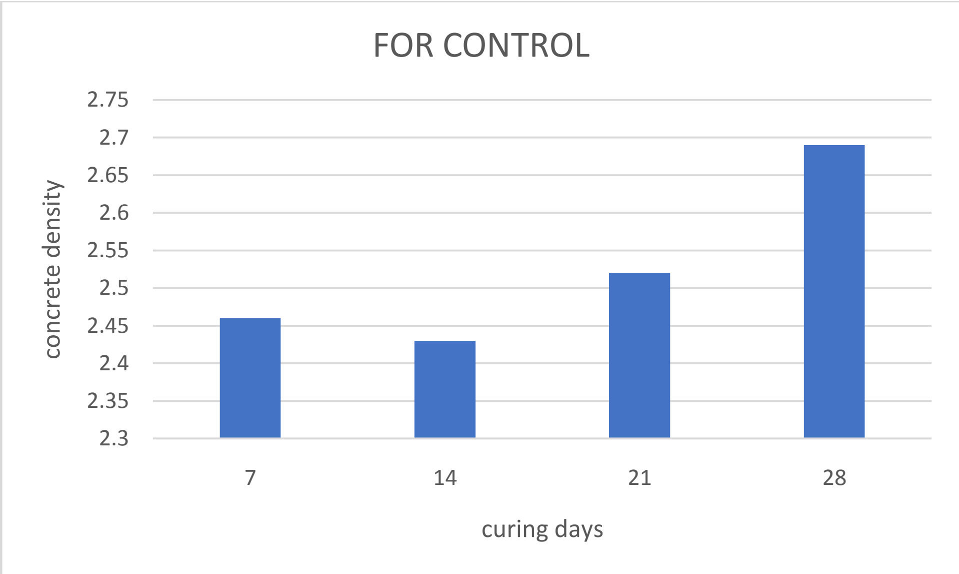

Fig. 3.7: Graph Showing Concrete Density of 1:2:4 Mix Ratio

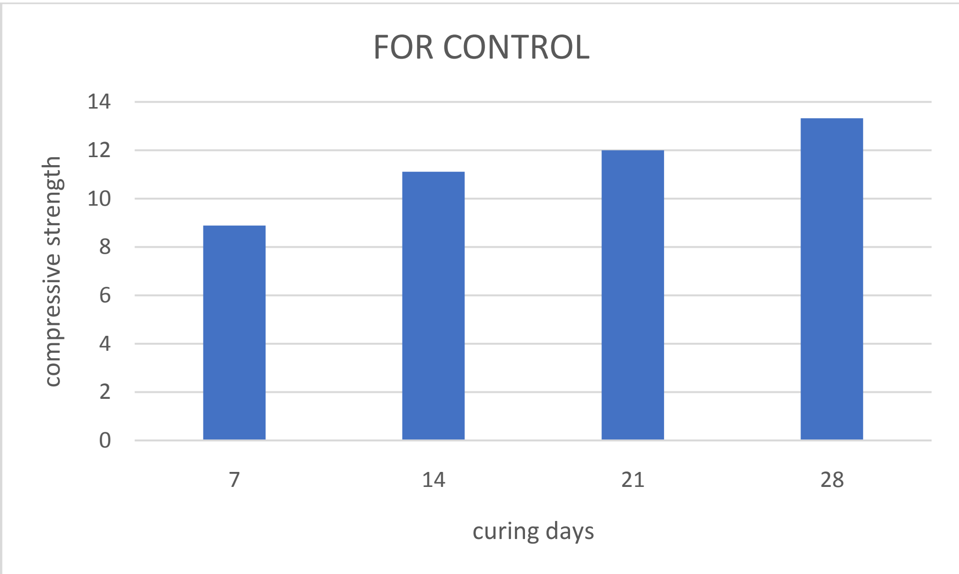

Fig. 3.8: Graph Showing Crushing Load of 1:2:4 Mix Ratio

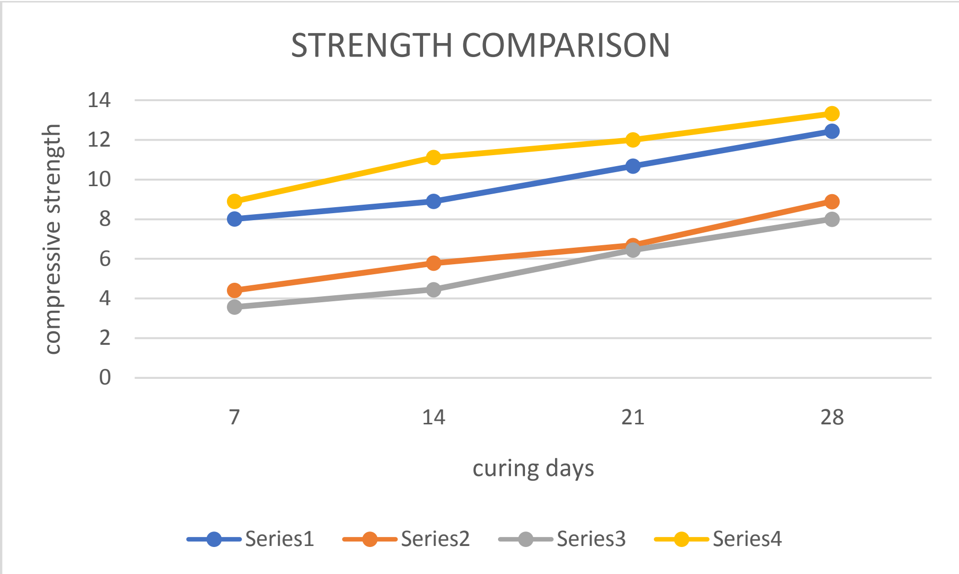

Fig 3.9: Strength Comparison of the Compressive Strength of the Mix. Ratio and the control

IV. CONCLUSION

From the result of the investigation after batching, casting, curing and crushing of the concrete cube and the crushing strength determined, it can be seen clearly that the strength of fresh aggregate is higher than that of ceramic waste irrespective of the mix ratio.

During the process of batching, the concrete must be mixed properly and compacted very well to give high compressive strength because the void space in the concrete is increase via the compressive strength.

The water cement ratio should be of very adequate proportion, care to make sure too much water is not added to the cement during mixing because the more the water a concrete contains, the more it will take for evaporation to take place and thus the compressive strength will be reduced.

The use of ceramic waste in production of fresh concrete resulted in the decrease of its density but was still within the normal range value, if used, this also could result in reduced dead weight of concrete structures.

The use of ceramic waste in concrete mix resulted in considerable reduction in the workability replacement level increased.

The use of ceramic waste in concrete is an effective way to reducing the costs of concrete and keeping the environment clean through efficient management of waste and decrease in the use of normal coarse aggregate in concrete production.

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