# USAGE OF CERAMIC WASTE MATERIAL AS A COARSE AGGREGATE IN CONCRETE

**Oluwasegunfunmi Victor and Olododo A.**
Department of Civil Engineering Technology; Rufus Giwa Polytechnic, Owo, Ondo State
Ogunsakinvictor5@gmail.com

**Abstract**
*There is a growing interest in using waste materials such as ceramics as alternative aggregate materials for construction. This paper centred on experimental investigation on the effect of replacement of coarse aggregate with ceramic waste materials. Ceramic wastes sourced from construction/demolition sites, were separated from other debris and crushed using a quarry metal hammer, it was sieved into coarse aggregates in line with standards. 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 were casted in the laboratory. The compressive strength of mix ratio of 1:2:4, 1:3:6, and 1:4:8 was carried out on the ceramic waste; and a control sample was prepared using gravel. Both samples were compared, this was done after 24hours of casting and the concrete samples were cured in a water tank at room temperature. The compressive strengths of the hardened concrete samples were determined after curing them for 7, 14, 21 and 28days. The results showed that the compressive strength increased appreciably with the curing age.*
**Keywords:** Ceramics waste, Compressive strength, Investigation, Concrete, Demolition, Crushed samples

## 1.0. Introduction

A large proportion of natural aggregates, which includes sand, gravel and water are being consumed in the production of concrete. In order to minimize these, researchers have concentrated on the use of waste materials as potential alternatives in the construction industry, especially in the construction of concrete. 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, et cetera. have been investigated as likely viable substitute materials to the conventional materials in concrete (Omole and Isiorho, 2011; Binici, 2007).

Ceramic waste utilization can solve problems of aggregate shortages in various construction sites. Moreover, it can reduce environmental problems related to aggregate mining and waste disposal. Using ceramic waste as aggregate in concrete will not only be cost effective, but will also be good from environmental point of view.

A ceramic is any of the various hard, brittle, heat-resistant and corrosion-resistant materials made by shaping and then firing an inorganic, nonmetallic material, such as clay, at a high temperature. Common examples are earthenware, porcelain, and brick. The word "*ceramic*" comes from the Greek word κεραμικός (*keramikos*), "of pottery" or" for pottery", from κέραμος (*keramos*)", potter's clay, tile, pottery. Ceramic material is an inorganic, non-metallic oxide, nitride, or carbide material. Some elements, such as carbon or silicon, may be considered ceramics. Ceramic materials are brittle, hard, strong in compression, and weak in shearing and tension. They withstand chemical erosion that occurs in other materials subjected to acidic or caustic environments. Ceramics generally can withstand very high temperatures, ranging from 1,000 °C to 1,600 °C (1,800 °F to 3,000 °F).

Ceramic products are hard, porous, and brittle. As a result, they are used to make pottery, bricks, tiles, cements, and glass. They are also used as white wares for application in spark plugs, electrical insulators, laboratory equipment, crucibles, dishes, and high-class potteries. Furthermore, they are used as stoneware for constructing sanitary fixtures, such as sinks and bath tubs. If we are summarizing their properties, we can say that ceramics have:

- High melting points (so, they are heat resistant).
- Great hardness and strength.
- Considerable durability (they are long-lasting and hard-wearing).

ISSN: 2714-3643
October, 2023

- Low electrical and thermal conductivity (they are good insulators).
- Chemical inertness (they are unreactive with other chemicals).

Ceramic wastes are generated as a waste during the process of dressing and polishing. It is estimated that 15 to 30% wastes are produced of total raw material used, and a portion of the wastes may be utilized on-site, such as for excavation pit refill. The disposals of these waste materials acquire large land areas and remain scattered all around, spoiling the aesthetic of the entire region. It is very difficult to find a use of ceramic waste produced. Ceramic waste can be used in concrete to improve its strength and other durability factors.

Ceramic waste can be used as a partial replacement of cement or as a partial replacement of fine aggregate sand as a supplementary addition to achieve different properties of concrete (Mujedu, Lamidi and Ayelabola, 2014).

Pacheco-Torgal and Jalali (2010) studied the behavior of strength and durability of ceramic waste-based concrete. The researchers discovered that the water absorption of ceramic coarse aggregate was higher than the natural aggregate. It can be concluded that the extra water content leads to better internal curing than the controlled concrete.

Verra Reddy (2010) reported on impact value and crushing value of ceramic scrap as 18.2 and 24.7% respectively. These values were within the permissible limits according to IS 383-1970. Hence, it was safe to use as a coarse aggregate in concrete production. Kumar and Ramakrishna (2015) studied effective utilization of ceramic waste as a recycled coarse aggregate. It was produced by crushing of sanitary ware and its shape curve of recycled ceramic aggregate was similar to the natural coarse aggregate. Irregular shape of aggregate was presented in the ceramic waste. Superior surface area and better bonding were observed in experimentation. Consequently, this study focused on producing concrete of acceptable strength with using ceramic waste materials in different mix ratio.

## 2.0 Materials and Methods

Ceramic wastes which was broken into two pieces were collected from waste from tiles used in an industrial site (Fig. 1); further broken the ceramic into small chips manually using hammer.

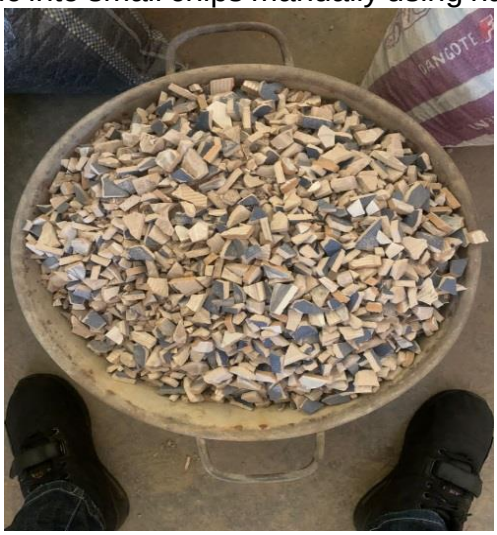

Fig. 1: ceramic waste

The method of making the concrete was mixing the materials, checking the consistencies, casting the cubes, curing the cubes and determining the comprehensive strength of the concrete (Figs 2-6).



Fig 2: Making of concrete mix

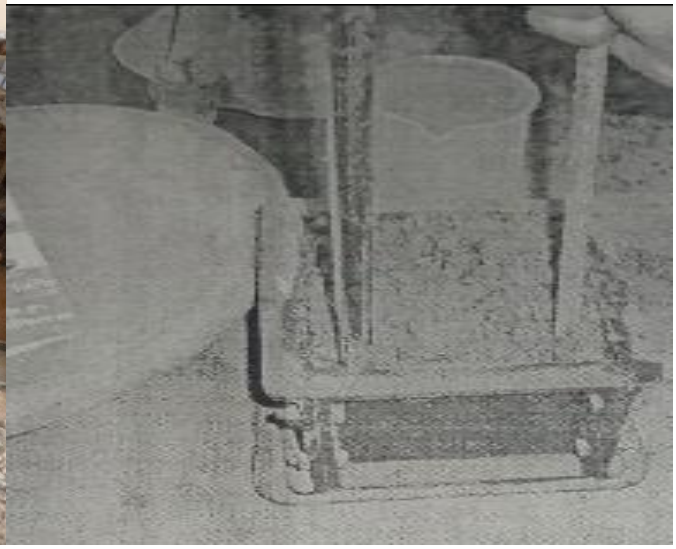

Fig. 3: Concrete Mould

ISSN: 2714-3643
October, 2023



Fig. 4: Compaction of concrete



Fig. 5: Curing of cubes



Fig. 6: Compressive test machine (Hatfield Farnel Testing Machine)

## 3.0 Results and Discussion

The results of the material testing are shown in Tables 1 – 6.

Table 1: Material Test Properties of the mix

| S/N | Test | Values |
|---|---|---|
| 1 | Specific gravity of cement | 3.15 |
| 2 | Specific gravity of Coarse Aggregate | 2.76 |
| 3 | Specific gravity of Fine Aggregate | 2.50 |
| 4 | Specific gravity of Ceramic Waste | 2.16 |
| 5 | Water absorption ($^0/_0$) of ceramic waste | 0.18 |
| 6 | Crushing value of ceramic waste % | 13.52 |
| 7 | Moisture content of ceramic waste | 0.203 |

Table 2: Comparison of Properties of Ceramic waste and normal Aggregate

| S/N | Properties | Normal Aggregate | Ceramic Aggregate |
|---|---|---|---|
| 1 | Shape | Angular | Flaky |
| 2 | Texture | Rough | All sides rough except top |
| 3 | Water absorption | 0.1 | 0.18 |
| 4 | Crushing value | 17.49 | 13.52 |
| 5 | Specific gravity | 2.76 | 2.16 |

Table 3: The Compressive Strength for Concrete Produced from Sand, Cement and Ceramic wastes (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 $N/m^2$ |
|---|---|---|---|---|---|---|---|
| 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 |

Table 4: The Compressive Strength for Concrete Produce from Sand, Cement and Ceramic wastes (1:3:6 Mix Ratio)

| Cube No. | Date casted | Age for testing | Age tested | Weight of cube | Density of cube | Crushing load (kN) | Crushing strength |
|---|---|---|---|---|---|---|---|
| 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 |

Table 5: The Compressive Strength for Concrete Produced from Sand, Cement and Ceramic wastes (1:4:8 mix ratio)

| Cube No. | Date casted | Age for testing | Age tested | Weight of cube | Density of cube | Crushing load (N) | Crushing strength |
|---|---|---|---|---|---|---|---|
| 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 |

Table 6: The Compressive Strength for Concrete Produce without Ceramic Waste (control sample)

| Cube No. | Date casted | Age for testing | Age tested | Weight of cube | Density of cube | Crushing load (N) | Crushing strength |
|---|---|---|---|---|---|---|---|
| 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 |

### 3.1 Effect of Ceramic Waste on Workability

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 increase in ceramic waste content can be attributed to higher water absorption capacity and the angular shape of the ceramic waste.

### 3.2 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 decreased. The fact that ceramic waste was lighter than the normal coarse aggregate could also be 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 2200-2550 $kg/m^3$ in accordance with ACI Committee, 2000. Thus, replacing normal coarse aggregate with ceramic waste will reduce the dead weight of concrete structures.

### 3.3 Effect of Ceramic Waste on Compressive Strength of Concrete

The compressive strength of concrete cube for different mix ratio of ceramic waste is shown in Tables 3 - 5. It was observed that the compressive strength decreased with the increase in mix ratio of ceramic waste content. The decrease in strength (Fig. 7) 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.

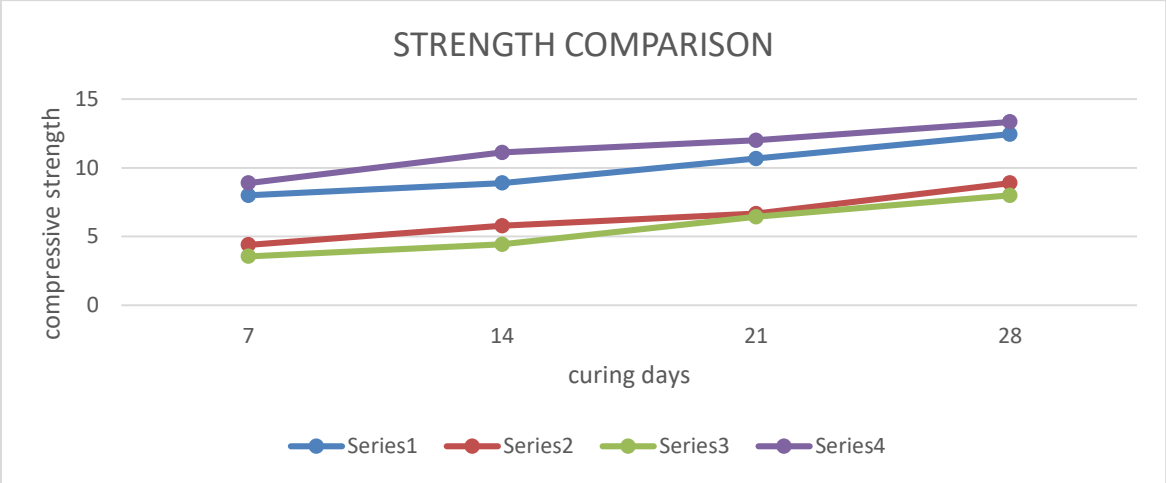


Fig. 7: Strength comparison of the samples

Series 1 = Compressive Strength of 1:2:4 mix ratio
Series 2 = Compressive Strength of 1:3:6 mix ratio
Series 3 = Compressive Strength of 1:4:8 mix ratio
Series 4 = Compressive Strength for control

## 4.0 Conclusion and Recommendation

The research on the usage of ceramic waste as a construction material is very important due to its gradual increase with the increase in population and increase in urban development. Many researchers did more investigation and analysis on the ceramic wastes because the wastes are easy to obtain and their cost is cheaper than normal aggregates. Hence, this study concludes that:

i. Ceramic wastes aggregate can be used as an appropriate material for substitution into concrete composition, based on its properties.
ii. Mechanical properties of ceramic aggregate are similar to the natural aggregate, though the behavior is similar but not the same. Water absorption value is higher than the natural coarse aggregate while the crushing value and specific gravity is lower.
iii. For all the concrete mix ratio (1:2:4, 1:3:6 and 1:4:8) the compressive strength of concrete decreases with the replacement by the ceramic waste aggregate which is due to the low specific gravity as compared to natural aggregate.
iv. By addition of ceramic waste into concrete, proper effective utilization of the ceramic waste can be achieved.
v. The use of ceramic waste in concrete mix resulted in considerable reduction in the workability. Therefore, it is recommended that adding some admixtures into the mixing can increase the workability of the concrete.

## References

Binici, H. (2007). Effects of crushed ceramic and basaltic pumice as fine aggregates on concrete mortars properties. *Construction and Building Materials*, Vol.21, issue 6, 1191-1197.

Mujedu, K. A., Lamidi, I. O. & Ayelabola, D. O. (2014). An investigation on the suitability of the broken Tiles as coarse aggregates in concrete production. *The International journal of Engineering and Science*, Vol.3, Issue 4, 35-41.

Tavakoli, D., Heidari, A., Karimian, M. (2013). Properties of concrete produced with waste ceramic tiles aggregate. Asian Journal of Civil Engineering Vol.14, 369-382.

Kumar H. & Ramakrishna A. (2015): Effect of waste ceramic tiles in partial replacement of coarse and fine aggregate of concrete. *International Advanced Research Journal of Science, Engineering and Technology*, Vol. 2, Issue 6, 13-16. IS 383 (1970): *Specifications for Coarse and Fine Aggregates from natural sources for concrete* (Second Revision) New Deihi: Bureau of Indian standards.

BS EN 12390-3 (2009). Testing Hardened Concrete compressive strength of Test specimens. British Standard.

Omole, D. O. & Isiorho, S. A. (2011). Waste Management and Water Quality Issues in Coastal States of Nigeria: The Ogun State Experience. *Journal of Sustainable Development in Africa*, 13(6), 207-217.

Osunade, J. A. & Babalola, J. J. (2005). Effect of Grain Size Ranges of Laterite and Fine Aggregates on the Tensile Strength of Lateritic Concrete. *International Journal of Housing Science and Its Application.* Pp. 10-14.

Pacheco-Torgal, F. & Jalali, S. (2010). Reusing Ceramic Wastes in Concrete. *Construction and Building Materials*, 24(5), 832-838.