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Application of Waste Ceramic Tile Aggregates in Concrete Production

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ABSTRACT: Aggregates and Cement, which are the most important constituents used in concrete production, are the most essential materials needed for the construction industry. This certainly led to a continuous and increasing demand of natural materials used for their production. A large quantity waste is produced annually in the world especially in the construction industry. Because, construction and demolition waste contribute the highest percentage of construction waste. Furthermore, ceramic materials contributes the highest percentage of waste within the construction industry and demolition waste of about 54%. In order to be environmentally friendly post-use, it was considered desirable to use this large amount of waste enumerating from construction industry as a useful raw material to replace coarse aggregate, while mixing the concrete, we used a m ix ratio of 1:2:4, and a water-cement ratio of 0.55 due to the compressive strength of the concrete. We replaced the coarse aggregate with ceramic tiles in three batches plus one batch of the concrete while served as control mix, so as to compare their properties with the aid of some tests. The replacement was in 10%, 15% and 25%. The concrete molds were cast and tested for compressive strength and split tensile strength after a curing period of 7, 14, 28 days. The result shows that increasing maximum compressive and split tensile strength are achieved as replacement percentage increased at 5% interval, the 25% replacement was the maximum in the study.
Keywords: Application, Waste Ceramic Tile Aggregates, Concrete Production

INTRODUCTION

Aggregate and Cement, which are the most important constituents used in concrete production, are the essential materials needed for the construction industry. This certainly led to a continuous and increasing demand of natural materials used for their production. Parallel to the need for the utilization of the natural resources emerges a growing concern for protecting the environment and a need to preserve natural resources, such as aggregate, by using alternative materials that are discarded as a waste. Therefore, one of the most serious problems of the world has been related to remove the wastage and reusing of it. A large quantity of wastage is produced annually in all countries. In particular, Construction and Demolition (C&D) wastes contributes the highest percentage of wastes worldwide about 75%. Furthermore, ceramic materials contribute the highest percentage of waste within the C&D wastes about 54%.

The global production of ceramic tiles during 2011-12 in the world is about 11,166 million square meters. China is the largest ceramic tiles producer (5,200 million square meters) which is 46.6% of world production as well as consumer (4,250 million square meters) which 38.9% of world consumption. Compared to China, India rank thirds; accounting for just 691 million square meters tiles production which is 6.2% of world production and also ranks third in terms of consumption (Shakeel Ahmad and Md Daniyal, 2015). This huge amount of productions has caused them to be among the most commonly-consumed materials in the world. Usually, the wastage related to tile. Ceramic and sanitary ware are created in different forms some of which are produced in companies during and after production

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process due to errors construction, human activities, and also inappropriate raw materials. Some others are produced in transportation and distribution procedures and finally, the most bulk of them are created as a result of destroying constructions. It is predicted that about 30% of daily production of ceramic materials in India change into wastage and this amount reaches to millions ton per year. This waste is not recycled in any form at present. Therefore, they are useless in practiced and cause environmental and disposal problems. However, the ceramic waste is durable, hard and highly resistant to biological, chemical and physical degradation forces. The properties of these materials make them a good suitable choice to be used in concrete. The use of waste ceramic tiles in concrete affects the properties of fresh and hardened concrete, and makes it economical and also solves some of the disposal problems (Khaloo, A.R., 1995). Some of previously studies have investigated the use of ceramic wastage in concrete as a partial replacement of cement or natural aggregates (fine/coarse). Khaloo (1995), observed that the concrete made with 100% crushed tile as the coarse aggregate has a lower density and higher compressive (+2%), tensile (+70%) and flexural (+29%) strengths. Lopez et al. (2007) concluded that this substitution process would increase slightly the compressive strength. Besides, Torgall and Jalali (2010) also concluded that using ceramic wastage as sand and coarse aggregate can slightly enhance compressive strength and also durability of concrete. Medina et al. (2012) also deal with the substation of ceramic as a coarse aggregate and finally reported a positive effect for the process. Tavakoli D. et al. (2013) estimated that the optimal case using tile wastage as sand are amounts of 25% and 50%. Besides, the best case of their use as coarse aggregate are amounts to 10% to 20%. Information regarding studies on concrete made with ceramic wastes is available in different forms in a scattered manner, and has also not adequately reached the large volume of stakeholders engaged in the construction activities across the length and breadth of our country. Due to this, the effective utilization of ceramic wastes in concrete has not attained the expected level in Nigeria even today. Hence, there is a compulsion on the part of civil engineering community, to take appropriate strategies so that the consumption of such potential waste by the construction industries will be on rise day-by-day leading to a green environment which is of course the need of the hour for our nation.

MATERIALS

Water, Cement, Coarse Aggregate, Fine Aggregate, Ceramic Tiles

Water

The water used was gotten from Landmark University and the suitability was confirmed.

Cement

The cement used was ordinary Portland cement from Dangote cement industry.

Course Aggregate

The coarse aggregate used was gotten in Landmark University, Omu-Aran.

Fine Aggregate

The fine aggregate passed through a 20mm diameter sieve

Ceramic Tiles

This was broken ceramic tiles sourced for in landmark

METHOD

Mixing Method

In the mixing of the concrete, we used a mix ratio of 1:2:4, and a water-cement ratio of 0.55 due to the compressive strength of the concrete. We replaced the coarse aggregate with ceramic tiles in three batches plus one batch of the concrete which served as control mix, so as to compare their properties with the aid of some tests. The replacement would be in 10%, 15% and 25%.

Mix Design

Mix	Cement (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Tiles (Kg)	Water/Cement Ratio (%)
0% Title	8	18.36	37.43	0	0.55
10%	8	18.36	33.68	3.74	0.55
15%	8	18.36	31.82	5.62	0.55
25%	8	18.36	28.07	9.36	0.55

Cursing Method

The concrete cubes were curved for different time frames i.e. 7 days, 14 days, and 28 days. The four concrete batches have been cured at all this time frames so as to compare their compressive strength at different times.

Testing Method

The concrete was tested before and after hardening through a set of approved tests for concrete. The following tests was done;

Slump Test

The slumps test was used to determine the constituency of the concrete. The consistency, or stiffness, indicates how much water has been in the mix. This is performed on fresh concrete mix before hardening, this test would be performed on all the batches of concrete mix.

The Apparatus used in the test include:

- Slump Cone
- Tamping Rod
- Scale for Measurement

The slumped concrete takes various shapes, and according to the profile of slumped concrete, the slump is termed as:

- Collapse Slump
- Shear Slump
- True Slump

After the experiment the constituency of the concrete batches would be compared and the most suitable would be determined. The volume of concrete needed for each batch of this test is $5.8 \times 10^{-3} m^3$.

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Compressive Strength Test

This is done to check the political strength of the concrete under controlled conditions against the desires strength and to establish a strength- age relationship for the concrete under job conditions as a control for construction operations or the opening of the work. Before this test is done, the concrete would be cured. The apparatus needed for the compression testing machine. The volume of concrete needed for each batch is $3.375 \times 10^{-3} m^3$.

Splitting Tensile Strength Test

The tensile strength of concrete is one of the basic and important properties. Splitting tensile test on concrete cylinder is a method to determine the strength of concrete. Concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus it is necessary to determine the load at which the concrete members may crack.

Procedure of splitting tensile test:

1. Take the wet specimen from water after 7 days of curing
2. Wipe out water from the surface of specimen
3. Draw diametrical lines on the ends of the specimen to ensure that they are on the same axial place
4. Note the weight and dimension of the specimen
5. Set the compression testing machine for the required range
6. Keep a ply or metal strip on the lower plate and place the specimen
7. Align the specimen so that so that the lines marked on the ends are vertical and centered over the bottom plate
8. Place the other metal stripe above the specimen
9. Bring down the upper plate to touch the metal strip
10. Apply the load continuously without stock at a rate of approximately 14-21kg cm minutes
11. Note down the breaking load (p)

RESULTS AND ANALYSIS

This chapter shows the analysis of the various tests carried out. This study aim to investigate the engineering properties of ceramic tiles as coarse aggregate in concrete. The test on workability, compressive strength and split tensile strength are described below.

Slump Test

Result of the slump tests for each mixed concrete batch.

Concrete Mixture	Slump value (mm)
Control	67
10% Tiles Replacement	63
15% Tiles Replacement	58
25% Tiles Replacement	55

The results in table show the slump values of the freshly mixed concrete. It is observed that the increase in the percentage substitution of coarse aggregate decreases the workability of the concrete, which is understandable sue to the glassy nature o tile which may not bond well with tiles. The image below gives a graphical representation of the slump set results.

Slump height vs. Tile percentage

Compressive Strength Test

$$fck = \frac{P}{A}$$

Where,

Fck = compressive strength, in magapascal i.e. MPa

P= maximum load at failure, in new tons (N):

A= area of the specimen on which the compressive force acts of the specimens (EN 12390-1)

Average Compressive strength test results for 7days

Concrete Mixture	Avg. load@ 7days (₦)	Avg.load@7 days (₦)	Avg. Compressive Strength @7days (N/mm)
Control	283.766	283,766	12.61
10% Tiles Replacement	332.2	332,500	14.78
15% Tiles Replacement	404.100	404,100	17.96
25% Tiles Replacement	438.969	438,969	19.51

Table shows that the compressive strength of concrete at initial stage is relatively low, comparing to the strength gained at later stages. It's clearly demonstrating the affect of proper curing on concrete strength.

Average compressive strength vs. percentage replacement after 7 days

Average Compressive strength test results for 14 days

Concrete Mixture	Avg. load @ 14 days (₦)	Avg. load @ 14days (₦)	Avg.Compressive Strength @ 14days (Mpa)
Control	369.666	369.666	16.43
10%Tiles Replacement	428.618	428,618	19.05
15%Tiles Replacement	466.604	466,604	20.59
25%Tiles Replacement	515.899	515,899	23.0

Table shows 14 days of curing, and the various development of compressive strength, 25% tiles replacement yielding an average compressive strength of 23.0N/mm^{2,} which is close to the characteristics strength of the mix design (25N/mm^2).

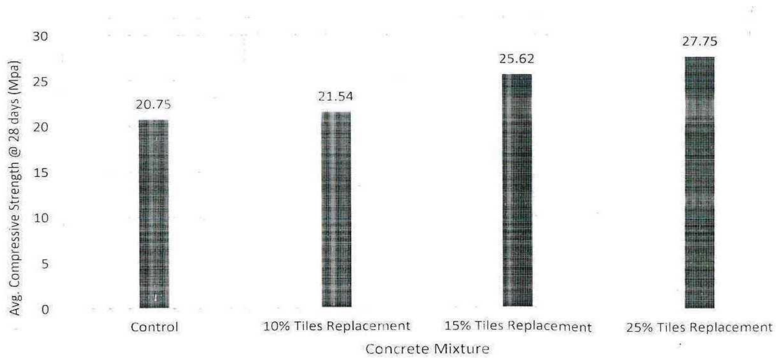
Average Compressive strength test results for 28 days

Concrete Mixture	Avg. load @28days (N)	Avg. load @ 28days	Avg. Compressive Strength @28days (Mpa)
Control	484.73	484.730	20.75
10% Tiles Replacement	466.827	499.827	21.54

Average Compressive strength test results for 28 days

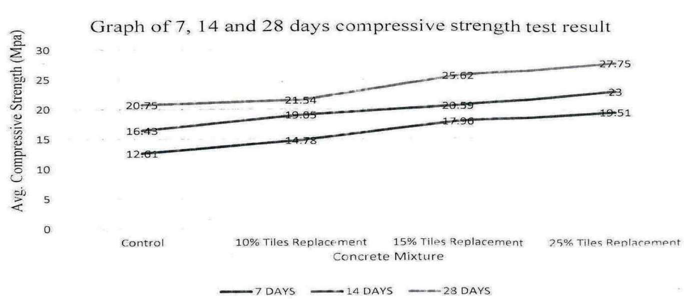
Concrete Mixture	Avg. load @ 28days	Avg. load @28days	Avg. Compressive Strength @28days (N/mm)
Control	484.73	484,730	20.75
10% Tiles Replacement	466.827	466,827	21.54
15% Tiles Replacement	576.449	576,449	25.62
25% Tiles Replacement	624.383	624,383	27.75

The result of the average compressive strength test given in the table above show clearly that the partially replacement of coarse aggregate with ceramic tile aggregate great increases the compressive strength of concrete.



Average compressive strength vs. percentage replacement after 28 days

Compressive Strength Curing Age Combo (Mpa)



Graph comparing the compressive strength of 7, 14, and 28 days

Split Tensile Strength Test

$$f_t = \frac{2p}{\pi H d}$$

f_t = tension splitting strength, in newtons per square millimeter i.e. (N/mm^2).
P= maximum load at failure, in newtons (N):
H= height of the cylinder, in mm (300mm);
d= diameter of the cylinder, in mm (150mm)
$\pi = 3.142$

Average Split Tensile strength test results for 7 days

Concrete Mixture	Avg. load@7days (KN)	Avg. load@ 7days (N)	Avg.Split Tensile Strength @7days (Mpa)
Control	133.93	133.930	1.89
10% Tiles Replacement	148.98	148980	2.11
15% Tiles Replacement	155.956	155,956	2.21
25% Tiles Replacement	171.99	171,990	2.43

Splitting tensile at the initial stage of 7 days curing which is lower than the later stages.

Average Split Tensile strength test results for 14 days

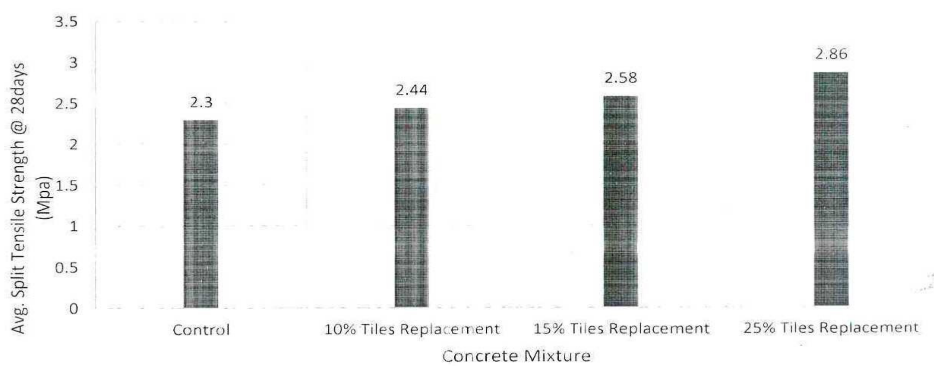
Concrete Mixture	Avg. load@ 14days (KN)	Avg. load @ 14days (N)	Avg. Split Tensile Strength @ 14days (Mpa)
Control	151.596	155,596	2.15
10% Tiles Replacement	164.396	164,396	2.32
15% Tiles Replacement	174.454	174,452	2.47
25% Tiles Replacement	184.442	184,442	2.61

Splitting tensile strength development after 14 days of curing

Average Split Tensile strength test results for 28 days

Concrete Mixture	Avg. load@ 28days (KN)	Avg. load @ 28days	Avg. Split Tensile Strength @ 28days (Mpa)
Control	161.915	161,915	2.30
10% Tiles Replacement	172.327	172,327	2.44
15% Tiles Replacement	182.469	182,469	2.58
25% Tiles Replacement	202.388	202,388	2.86

Splitting tensile strength development after 28 days. Splitting tensile strength increases with increase in percentage replacement of coarse aggregate with ceramic tile aggregate.



Graph comparing the compressive strength of 14 days

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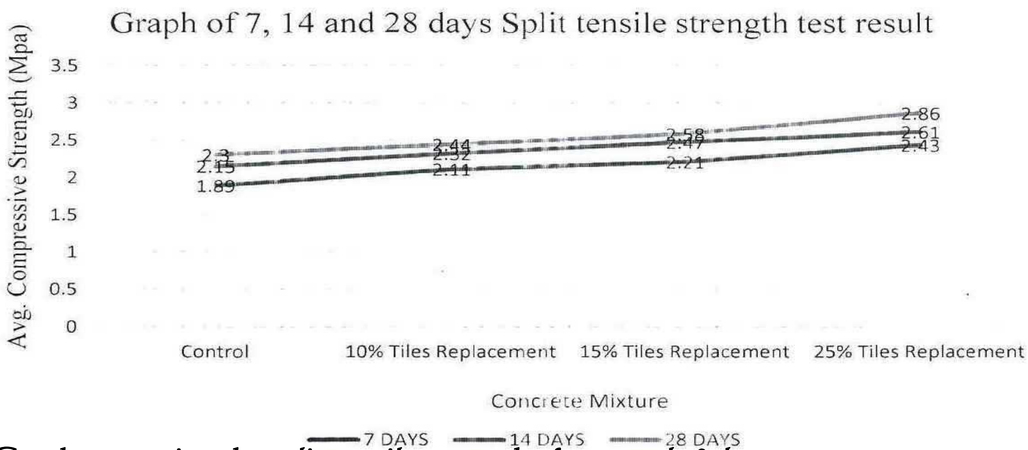
Split Tensile Strength Curing Age Combo (Mpa)



Graph comparing the split tensile strength of 7, 14 and 28 days

CONCLUSION

The effect of various percentage of ceramic waste as partial replacement for coarse aggregate in concrete production was analyzed in this paper. This study aimed to determine if the use of ceramic tile waste should be encourage more in heavy weight concrete. The comprehensive and tensile characteristics of broken tiles concrete were discussed and compared with conventional concrete. Based on result and analysis, the following deductions were made: The workability of the freshly mixed concrete decreases as the percentage substitution for ceramic tile increases. This is understandable and it is due to the glossy surface of ceramic tiles.

- The increasing maximum compression strength was achieved when 25% of ceramic tile was replaced with coarse aggregate after 28 days.
- The maximum compressive strength is obtained for 25% replacement of ceramic tile with coarse aggregate which yielded a strength gain of 25.23% compared to the control mix.
- From the test result, the use of ceramic waste in partial replacement of coarse aggregate is very effective and can be encouraged in heavy weight concrete production.
- Compressive strength increases with increase in percentage replacement of ceramic tile aggregate with coarse aggregates.
- By use of ceramic waste as partial replacement of coarse aggregate, effective utilization of ceramic waste can be achieved leading to a more ecofriendly environment devoid of unnecessary waste product.
- The maximum split tensile strength is achieved when 25% of ceramic tile aggregate was replaced with coarse aggregate, and split tensile strength increases as the percentage replacement for aggregate increases.

It can be concluded that, within the limited scope of the experiment in this investigation, concrete made with ceramic waste aggregate as a partial replacement of coarse aggregates can be considered as a suitable alternative for conventional concrete.

RECOMMENDATION

- More trials with different particle sizes of tile aggregate and percentage replacement of natural aggregate are recommended to get different outcomes and higher strength characteristics of concrete.
- In this study only compressive strength and split tensile strength were investigated, effect on flexural and ultrasonic pulse velocity strength of concrete with inclusion of the aggregates can be investigated.

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