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Improving the Bending and Load Carrying Capacity of Reinforced Crushed Stone Concrete Beams Using Waste Ceramic Tiles Aggregate Concrete as a Layer

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Abstract: *The discussion on this paper is with regards to the result obtained from the research on improving the bending and load-carrying capacity of reinforced crushed stone concrete beams using waste ceramics tiles aggregate concrete as a layer. As specified by EN 1992-1-1:2004, study beam specimens were reinforced with two 8mm diameter bars both in tension and compression zone. 6mm diameter rebars were used as shear reinforcement spaced at 200mm centre to centre. A total number of twelve beams having a cross-section area of 100 x 150mm, with a length of 1200mm and effective span of 1100mm were formed. Three out of twelve reinforced concrete beam samples were set aside as reference beams which were produced completely of crushed stone aggregate concrete of 1:2:4 mix ratio. Then, the remaining beam were produced in two-layers with varying depth specified as follows; Type-BC (beams and cubes produced completely with crushed stone aggregate concrete of 1:2:4 mix ratio). Type-B1 (beams and cubes with 75mm depth of crushed stone aggregate concrete of 1:2:4 mix ratio at the top layer and 75mm depth waste tiles aggregate concrete of 1:2:3 at the bottom layer), Type-B2 (beams and cubes with 50mm depth of crushed stone aggregate concrete of 1:2:4 mix ratio at the bottom layer and 100mm depth waste tiles aggregate concrete of 1:2:3 at the top layer), Type-B3 (beams and cubes with 50mm depth of waste tiles aggregate concrete of 1:2:3 at the top layer and 100mm depth of crushed stone aggregate concrete of 1:2:4 mix ratio at the bottom layer). All beam types were subjected to a two-point load application to determine the bending and load-carrying capacity. Results shows that the load-carrying capacity of beams with 50mm depth of crushed stone aggregate concrete of 1:2:4 mix ratio at the bottom layer and 100mm depth waste tiles aggregate concrete of 1:2:3 at the top layer is 10.6% higher than beams produced completely with crushed stone aggregate concrete of 1:2:4 mix ratio. The beam Type-B1 load carrying capacity is 15.6% higher than beam Type BC. Deflection at failure was 30.6% higher than Type-BC. Beam Type-B1 and Type-B3 has a high tensile stress than beams Type-BC. Also, beam Type-B1 and Type-B2 has a high bending capacity than beams Type-BC. Base on the findings, it is recommended that waste ceramics tiles aggregate concrete could be used as a layer in a conventional reinforced concrete beam both in tension and compression zones.*

Key Words: *Crushed Stone Concrete, Crushed Waste Tiles Concrete, Two Layer Reinforced Concrete Beam, Load-Carrying and Bending Moment Capacity.*

1. INTRODUCTION:

Industrialization has generated fundamental problems worldwide, such as the reduction of natural resources and the large amount of waste generated by new development and demolition of old or failed civil engineering structures. A very effective way to cut down this problem is to use the waste generated from construction industry. The best alternative is to crushed and reuse waste tiles as crushed stone. Crushed tiles are discarded materials generated from construction site, instigates environmental pollution. Hence, the potential use of this waste tiles will possibly reduce environmental pollution. Ceramic construction materials account for 45% of waste in the construction site. Ceramic left-overs have considerably high resistant to chemical and physical deprivation

Many industrial waste materials in concrete were used to partially substitute the basic materials. (1) One of the visible problems currently is the continuous generation of construction waste and handling of construction waste. As a result of the large use of natural aggregate in construction, several nations around the world have tried to source for an alternative that could be used in construction, such as construction waste. The quantity of waste tiles produced is sufficient as coarse aggregate in concrete production. Tile is formed from alluvial sediment considerably at high temperatures. This material serves different purposes. Trash tiles are kept in industrial sites due to their usefulness. These leftover tiles can be reprocessed to save money. (2) The technology of recycling concrete is a distinguished practice in the United States. Recycling of Portland cement concrete is economical. Recycling of concrete for the production of structural concrete for the use of non-pavements is technologically possible, with certain preventive measures. For instance, it is largely acknowledged that when normal sand is utilized in concrete production, the naturally crushed stone aggregate can be substituted with a roughly recycled aggregate up to 30% without meaningfully influencing the mechanical properties of the concrete.

2. LITERATURE REVIEW:

John et al., (3) researched on the structural behaviour of two-layer reinforced concrete beams with one-layer of periwinkle shell aggregates concrete both in tension and compression. From the research, it was detected that the two-layer beams had higher bending and load-carrying capacity than the control beams formed completely of crushed stone aggregate concrete, it also revealed that the deflection of two-layer beams was noticeably lower than control beams cast fully of crushed stone aggregates concrete. The authors recommended that periwinkle aggregate concrete can be used as a layer in reinforced concrete beams both in compression and tension zone, not more than 0.5 times its depth. Also, John et al., **(4)** investigated two-layer reinforced rectangular concrete beam with one layer of clam-shell aggregate concrete. The results show that the deflections of all the two-layer beams at ultimate failure load were higher than that of the control beams cast completely of crushed stone aggregates concrete. The authors recommended that two-layer beams with one layer of clam-shell as coarse aggregate concrete at the compression zone can be of great use in the concrete industry. Saswat and Vikas (5) studied the partial replacement of particle sizes less than 4.75mm (fine aggregate) with tiles and waste generated from demolition activities in concrete road pavement. They established that by exploiting ceramic and demolition waste, 40% normal fine aggregate can be protected while constructing concrete pavement and that up to 20% ceramic waste, the compressive strength is greater compared to conventional concrete. Hardil and Arora, (6) experimentally found that up to 30% ceramic waste powder can substitute natural fine aggregates in the production of cement concrete without a meaningful reduction of compressive strength. The authors establish that, compared to regular concrete, approximately only 1% loss of tensile strength is attained. Hemanth et al., (7) the effect of waste tiles in partially replacing coarse aggregates and fine aggregate concrete was researched. In their study, waste crushed tiles were used to replace fine aggregates and coarse aggregates partially up to 10 - 20%. They found out that the best dosage of coarse aggregate that could be replaced by crushed waste tiles was 10%. Shruti et al., (1) have also researched to recycle waste tile in the form of aggregates in concrete. In their investigation, tile scraps were used in concrete to replace natural coarse aggregates with concrete substitution (0%, 10%, 920% and 30%). The study revealed that the maximum compressive strength was attained for 30% replacement of ceramic. Topcu and Canbaz, (2) investigated the effect of the replacement of waste tiles as particle sizes greater than 4.75mm in concrete production, partially replace natural aggregates (0, 50 and 100%). Physical and mechanical tests were conducted. The crushed waste tiles aggregate concrete strength and unit weight were reduced compared to control concrete. Fung, (8) found that the allowable dosage of reused coarse aggregate can be increased to 50% of the existing practice of 20% dosage for C25/30 concrete strength and 30% replacement for C35/40 to C45/50. Lower dosage levels are recommended for reprocessed aggregates of lesser quality. Dunster (9) illustrates the practice of natural stone waste and man-made waste as a coarse aggregate in cement concrete landscape products. A lot of these precise products characteristically include industrial products for reuse products and aggregates. This example primarily consists of reused concrete aggregates. More and more landscape product manufacturers are smashing this material into reused concrete aggregates at the production site and partially to replace aggregates. In this research, our intention is to find out the bending strength and the failure mode of a double-layer reinforced concrete beam with one layer of crushed waste tiles aggregate concrete.

3. MATERIALS:

In this phase, materials used in this research are expounded. Different kinds of reinforced concrete beams and cube samples compositions with and without crushed waste tiles are also classified and elaborated. Finally, the achieved tests to illustrate the routine of the crushed waste tiles and the concrete cube samples are described.
Cement: The binder (cement) used in the experimental research was Portland Lime Cement of Grade 42.5 as specified by (10)

Fine Aggregate: The fine aggregate used was sourced from river at Wilberforce Island, Bayelsa State, Nigeria. It conformed to (11).

Crushed Waste Tiles: The waste ceramic tiles were sourced from construction sites. They were crushed and subjected to Particle Size Distribution Test. It conformed to (11).

Coarse Aggregate: Coarse aggregate used was crushed natural stones having rough-surfaced sourced from Yenagoa, Capital of Bayelsa State, Nigeria. It conformed to (11)

Formwork: Marine Board was used for the construction of the formworks. It conformed to (12)

Steel Reinforcement: The reinforcing bar used was a deformed bar, which is considered by ribbed protrusions rolled onto their surfaces during the production process. It conformed to (13)

Water: Potable water utilized for missing of concrete was obtained from the Civil Engineering Laboratory of the Niger Delta University. It conformed to $^{(14)}$

4. METHOD:

Construction of Test Beams: As specified by EN 1992-1-1:2004, study beam specimens were reinforced with two 8mm diameter bars both in tension zone compression zone. 6mm diameter rebars were used as shear reinforcement spaced at 200mm centre to centre. A total number of twelve beams having cross-section area of 100 x 150mm, with a length of 1200mm and effective span of 1100mm were formed. Three out of twelve reinforced concrete beam samples were set aside as reference beams which were produced completely of crushed stone aggregate concrete of 1:2:4 mix ratio. Then, the remaining beam were produced in two-layer with varying depth as specified in Table 1. All the research beam types were tested under two-point loads application.

Table 1. Sample identification for R.C Beam-Type

Specimen Type	Description
Type-BC	Beams produced completely with crushed stone aggregate concrete of 1:2:4 mix ratio.
Type-B1	Beams and cubes with 75mm depth of crushed stone aggregate concrete of 1:2:4 mix ratio at the top layer and 75mm depth waste tiles aggregate concrete of 1:2:3 at the bottom layer.
Type-B2	Beams and cubes with 50mm depth of crushed stone aggregate concrete of 1:2:4 mix ratio at the bottom layer and 100mm depth waste tiles aggregate concrete of 1:2:3 at the top layer.
Type-B3	Beams and cubes with 50mm depth of waste tiles aggregate concrete of 1:2:3 at the top layer and 100mm depth of crushed stone aggregate concrete of 1:2:4 mix ratio at the bottom layer.
Type-BT	Concrete cube samples produced completely with Waste tiles aggregate of 1:2:3 mix ratio.

Cubes Samples: Fifteen concrete cubes of 150x150x150mm were produced for each set of beams to achieve the compressive strength, with a mix ratio of 1:2:4 for the crushed stone aggregate concrete cubes and a mix ratio of 1:2:3 for the waste tiles aggregate concrete cubes. Compressive strength test was carried out on the cube samples at 28 days curing.

5. ANALYSIS, DISCUSSION AND FINDINGS:

The experimental study results of the improving the bending and load-carrying capacity of reinforced crushed stone concrete beams using waste ceramics tiles aggregate concrete as a layer are reported, discussed, and analysis in this section. Table 2. presents laboratory test results of two-layer beams. Table 3, 4 and 5 presents computed results of bending capacity, cracking capacity and tensile stress respectively. Table 6 shows the 28 days compressive strengths of two-layer concrete cubes with varying depth.

5.1. Load Carrying Capacity:

The load-carrying capacity and the mode of failure of the research beam types are presented in Table 2. The R.C. beam type-BC was constructed with crushed stone aggregates only and was referred to as reference beams. The first crack was developed at 19.30kN load due to flexural stresses. The reinforced concrete beam Type-BC failed at 27.72kN load attributable to flexural, shear and crushing behaviour of the beam type.

Beam Type-B1 was formed 75mm depth of crushed stone aggregate concrete of 1:2:4 mix at the top layer and 75mm depth waste tiles aggregate concrete of 1:2:3 at the bottom layer. The initial crack occurs at 25.65kN load, and was detected to be flexural, as the load increases, shear cracks occur and propagates. The beam finally failed finally at 32.85kN load. The beam Type-B1 load carrying capacity is 15.6% higher than beam Type BC Deflection at failure was 30.6% higher than Type-BC.

Beam Type-B2 was constructed with 50mm depth of crushed stone aggregate concrete of 1:2:4 mix ratio at the bottom layer and 100mm depth waste tiles aggregate concrete of 1:2:3 at the top layer. The first crack was developed at 18.25kN load. Beam Type-B2 also showed shear cracks as the load increases. The beam Type- B2 failed at 31.02kN load, which was as a result of internal reinforcements yielding in conjunction with concrete crushing at the compression zone. Assessment of beam Type-B2 with beam Type-BC shows that the load-carrying capacity is 10.6% higher than Type-BC. Deflection at ultimate failure load was 9.7% greater than Type-BC.

Table 2: Experimental results of tested two-layer beams

Specimen Type	Sample	First Crack Load (kN)	Failure Load (kN)	Deflection at Failure (mm)	Failure Mode
Type-BC	Sample 1	21.98	27.48	7.5	Flexural/Shear/Crushing
	Sample 2	17.59	27.84	3.99	Flexural/Shear/Crushing
	Sample 3	18.32	27.84	4.65	Flexural/Shear/Crushing
Type-B1	Sample 1	25.65	32.97	5.05	Flexural/Shear
	Sample 2	25.55	32.61	10.45	Flexural/Shear
	Sample 3	25.65	32.97	7.75	Flexural/Shear
Type-B2	Sample 1	18.32	31.14	6.47	Flexural/Shear/Crushing
	Sample 2	18.12	30.77	5.45	Flexural/Shear/Crushing
	Sample 3	18.32	31.14	5.96	Flexural/Shear/Crushing
Type-B3	Sample 1	18.32	28.21	5.65	Flexural/shear
	Sample 2	24.18	27.48	4.5	Flexural/shear
	Sample 3	21.25	27.85	5.08	Flexural/shear

Table 3: Bending Capacity of Beams

Specimen Type	Number Of Samples	Failure Load (kN)	Bending Capacity (kN)
Type-BC	Sample 1	27.48	5.04
	Sample 2	27.84	5.10
	Sample 3	27.84	5.10
Type-B1	Sample 1	32.97	6.04
	Sample 2	32.61	5.98
	Sample 3	32.97	6.04
Type-B2	Sample 1	31.14	5.71
	Sample 2	30.77	5.64
	Sample 3	31.14	5.71
Type-B3	Sample 1	28.21	5.17
	Sample 2	27.48	5.04
	Sample 3	27.85	5.10

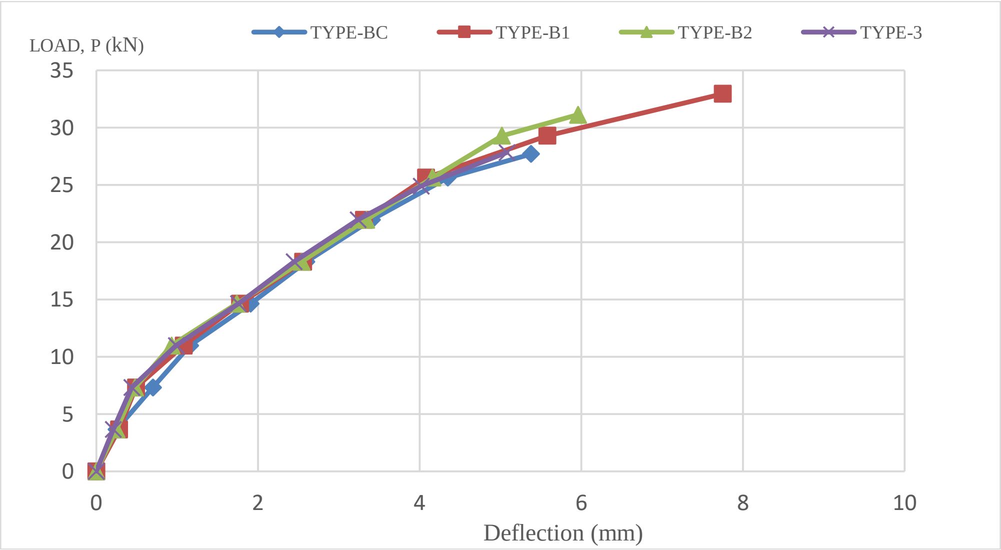

Figure 1. Load against deflection graph of beam Type-BC, B1, B2, B3

Beam Type-B3 was produced with a 50mm depth of waste tiles aggregate concrete of 1:2:3 at the top layer and 100mm depth of crushed stone aggregate concrete of 1:2:4 mix ratio at the bottom layer. The initial crack occurred attributable to flexural stresses at a load of 28.21kN. The beam failed at a load of 27.85kN. The results confirm that the load-carrying capacity of beam Type-B3 is 3.6% higher than Type-BC.

Load–deflection behaviour: The study results in Table 2 and the load against the deflection curve in Figure 1 reveal that the Type-BC, is stiffer than Type-B1, Type-B2 and Type-B3. Beams cast completely with crushed stone aggregates concrete had a smaller value of deflection than the two-layer beams at ultimate failure load.

Table 4: Cracking Capacity of Beams

Specimen Type	Number of Samples	First Crack Load (kN)	Cracking Capacity (kNm)
Type-BC	Sample 1	21.98	4.03
	Sample 2	17.59	3.22
	Sample 3	18.32	3.36
Type-B1	Sample 1	25.65	4.70
	Sample 2	25.55	4.68
	Sample 3	25.65	4.70
Type-B2	Sample 1	18.32	3.36
	Sample 2	18.12	3.32
	Sample 3	18.32	3.36
Type-B3	Sample 1	18.32	3.36
	Sample 2	24.18	4.43
	Sample 3	21.25	3.90

Table 5: Tensile Stress of Beams

Specimen Type	Number of Samples	First Crack Load (kN)	Tensile Stress (MPa)
Type-BC	Sample 1	21.98	10.75
	Sample 2	17.59	8.60
	Sample 3	18.32	8.96
Type-B1	Sample 1	25.65	12.54
	Sample 2	25.55	12.49
	Sample 3	25.65	12.54
Type-B2	Sample 1	18.32	8.96
	Sample 2	18.12	8.86
	Sample 3	18.32	8.96
Type-B3	Sample 1	18.32	8.96
	Sample 2	24.18	11.82
	Sample 3	21.25	10.39

Table 6: 28-Days Compressive Strength

Specimen Type	Size of Cube (mm)	Weight of Specimen (kg)	Applied Compressive Load (kN)	28-Day Compressive Strength (MPa)
Type-BC	150x150x150	8	643.33	28.60
Type-B1	150x150x150	7.5	430	19.11
Type-B2	150x150x150	8	490	17.13
Type-B3	150x150x150	8	579	21.78
Type-BT	150x150x150	8.5	316.67	14.07

5.2. Bending capacity: The results presented in Table 3 showed that Beam Type-B1 and Type-B2 have higher bending capacity than beams Type-BC. While Type-B3 is observed to have a similar bending capacity as the beam Type-BC. Beam Type-B1 and Type-B2 is 15.6% and 10.87% greater the Type-BC in terms of bending capacities.

5.3. Tensile Stress: The results in Table 5 revealed that Beam Type-B1(12.52MPa) and Type-B3 (10.39MPa) have higher tensile stress than beams Type-BC (9.44MPa). While Type-B2 (8.93MPa) is observed to have smaller tensile stress as the beam Type-BC. Beam Type-B1 and Type-B3 is 24.6% and 9% greater than Type-BC in terms of tensile stresses.

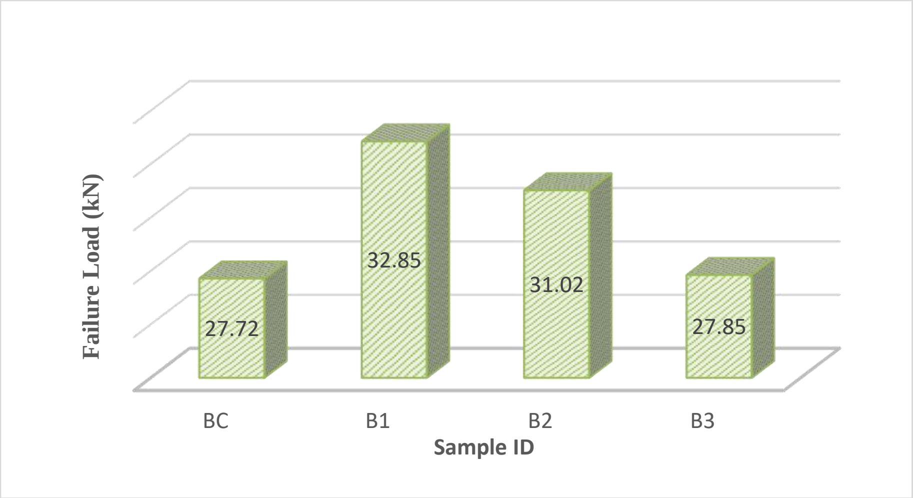

Figure 2. Ultimate Failure Load of Beam Specimen Types

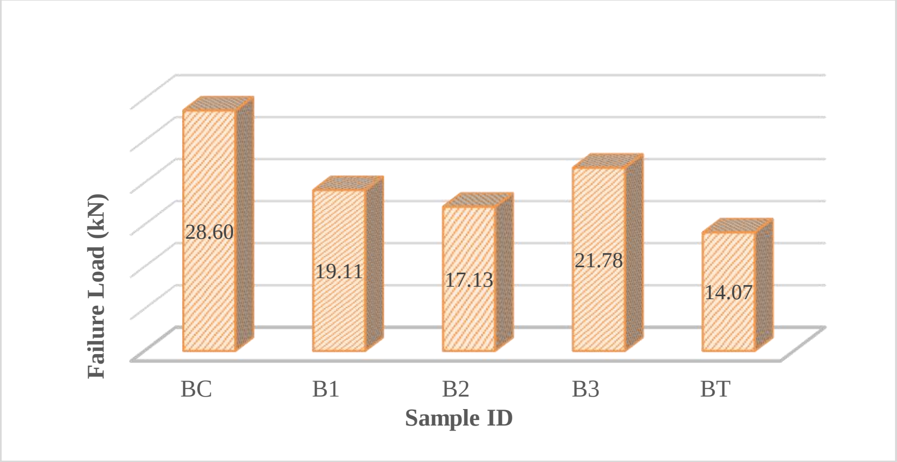

Figure 3 Compressive strength at 28-day for Cube Type-BC, B1, B2, B3 and BT

Figure 4. Crack Pattern of study samples: (a) Type-BC, (b) Type-B1, (C) Type-B3, and (D) Type-B2

6. RECOMMENDATIONS:

Based on the result of the investigation, the following recommendations are drawn:

- Waste ceramics tiles aggregate concrete could be used as a layer in a conventional reinforced concrete beam both in tension and compression zones.
- Waste tiles should be crushed and sieve according to (11), only the one caught in sieve #4 should be utilize as waste tiles aggregate concrete

7. CONCLUSION:

The conclusions drawn were established on the outcome of the present experimental investigation on improving the bending and load-carrying capacity of reinforced crushed stone concrete beams using waste ceramic tiles aggregate concrete as a layer both in tension and compression zone:

- The load-carrying capacity of beams with 50mm depth of crushed stone aggregate concrete of 1:2:4 mix ratio at the bottom layer and 100mm depth waste tiles aggregate concrete of 1:2:3 at the top layer is 10.6% higher than beams produced completely with crushed stone aggregate concrete of 1:2:4 mix ratio.
- The beam Type-B1 load-carrying capacity is 15.6% higher than beam Type BC. Deflection at failure was 30.6% higher than Type-BC.
- Using waste tiles as coarse aggregate in concrete cuts down the environmental effect caused by industrial waste.
- Beam Type-B1 and Type-B3 has higher tensile stress than beams Type-BC
- Beam Type-B1 and Type-B2 have higher bending capacity than beams Type-BC

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