The Use of Periwinkle Shell Aggregate Concrete in Two Layer Reinforced Concrete Beam

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ABSTRACT

This article presents results of an experimental study involved testing of two-layer reinforced concrete beams with one-layer of periwinkle shell aggregates concrete both in tension and compression zone having cross-sections of 100 x 150 mm, the total span of 1200 mm and effective length 1100mm. Flexural reinforcement ($A_s = 2\Phi 8\text{mm}$) and ($A_s^1 = 2\Phi 8\text{mm}$) and shear reinforcement ($A_{sv} = \Phi 6\text{mm} @ 200\text{mm c/c}$). A total of twelve (12) reinforced beams were produced and grouped into; Type-RC (Beams and cubes cast completely of crushed stone aggregates concrete of 1:2:4 mix), Type-R1 (Crushed stone aggregates concrete (1:2:4 mix) with a depth of 75mm at the top layer and Periwinkle aggregate concrete (1:2:1 mix) with a depth of 75mm at the bottom layer, Type R2 (Periwinkle aggregates concrete (1:2:1 mix) with a depth of 75mm at the top layer and 75mm of crushed stone aggregate concrete (1:2:4 mix) at the bottom layer), Type R3 (Periwinkle aggregates concrete (1:2:1 mix) with a depth of 50mm at the bottom layer and 100mm of crushed stone aggregate concrete (1:2:4 mix) at the top layer. All the beam samples were tested under two-point loads. Results reveal that the two-layer beams had higher bending resistance as the control beams cast completely of crushed stone aggregate concrete. Also, the study showed that the beam Type-R1 had bending resistance of 6.62kNm and is 23.3% higher than beam Type-RC which had bending resistance of 5.08kNm while beam Type-R2 had bending resistance of 5.71kNm and is 11% higher than beam Type-RC. Beam Type-R3 had bending resistance of 6.21kNm and is 18.2% higher than beam Type-RC. The load-deflection records of all the beam samples were noted. The deflection of two-layer beams was considerably lower than control beams cast completely of crushed stone aggregates concrete. Base on the findings, it is recommended that periwinkle aggregate concrete can be used as a layer in reinforced concrete beams both in compression and tension zone, not more than 0.5H.

Key words: Two-Layer, Periwinkle aggregate concrete, Bending Capacity, Mode of failure.

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INTRODUCTION

Increased infrastructural development worldwide has also increased the demand for more building materials. Concrete is a multipurpose material primarily used in construction sectors. Concrete is a composite construction material, made of cement, aggregates produced from a mixture of cement and water, sometimes enhancers are introduced to achieve desired properties of the concrete. Concrete is broadly used in almost all areas of human

infrastructure. The volume of concrete used across the world is surpasses other building materials. Consequently, because of the unavailability and cost implication of these traditional building materials (such as granite, cement, etc.), the local demand for these building materials far exceeds the local supply as demanded, the local call for these construction materials far exceeds the local supply subsequent in an incessant rise in cost of building project in an undeveloped nation such as Nigeria. Thus, as the population increases every day, momentous determinations are required to avoid housing problems in the country, subsequently, more infrastructure needs to be provided at a lower cost. In Nigeria, the particle sizes larger than 4.75 mm (coarse aggregates), is very expensive, and these granular materials are transported to the construction sites hundreds of kilometers away the source, which is far beyond the cost of procuring the materials to make buildings in these areas. Under such conditions, there is a great demand for locally available agricultural left-over materials. Based on this point of view, the applicability of double layer reinforcement concrete rectangular beam with one-layer of periwinkle shell aggregate concrete in tension and compression will be investigated.

The term aggregate implies to the granular construction material, such as sand or blast-furnace slag and crushed stone. Aggregates form about 70% of the concrete product. To generally characterize between the particle sizes of the aggregate, the latter is categorized into two: coarse aggregate and fine aggregate. The particle sizes are related to the sieve number. The coarse aggregate (crushed stone) belongs to the particle sizes not passing through a No. 4 sieve. The fine aggregate (sand) belongs to the particle size not passing through a No. 200 sieve.

Periwinkle shell aggregates are the remnants after the comestible portion removed. Periwinkle is a sea molluscs with a spiral shell. The preparation method of periwinkle shell concrete is practically the same as the method of preparing conventional concrete, except that the periwinkle shell is used instead of crushed stone. Stated by Neville, (1981), marine dredging coarse aggregates may have a large shell content, which may have no unfavorable consequence on concrete strength, but if the shell content is large, it may decrease its workability. The periwinkle shell substance of particles sizes larger than 5 mm can be established by hand selection, using the correction of the method in BS 812 Part 2.

For lower concrete grade, plane round gravel is usually preferred, but for high bending strength, concrete made of angular crushed stone, it may be beneficial for all feasible concrete (Murdock, et al 1991). Thus, the roughness or smoothness of the aggregate surface stimulates the adhere between the aggregate and the cement paste in the hardened concrete.

Timothy et al, (2016) confirmed that 30% replacement of crush stone with periwinkle shells aggregates and 30% replacement of sharp sand with periwinkle fine aggregate were (attain targeted compressive strength of 20MPa) suitable. Also, it was measured to be 6.8% economical when 30% of periwinkle shells aggregates are mixed with 70% of crush stone as coarse aggregate.

Bamidele, (2002) researched on the effectiveness of periwinkle shells aggregates with different mix designs and also varying the proportion of periwinkles shells aggregates in the concrete ranging 0 -100%. Base on their results, the compressive strength at 28 days concrete produced at 100% periwinkle shells aggregates ranges from 11.77MPa to 15.65MPa.

Ataria and.Wang, (2019) studied bending and shear performance of double layer reinforced concrete beam with various coarse aggregates. The top layer was constructed with crushed stone aggregate concrete of depth ($1/3^{\text{rd}}$), while the tension ($2/3^{\text{rd}}$) layer, using rubber recycled aggregate concrete. The results revealed that the double-layer beam achieves similar bending capacity as the control reinforced concrete beam produced completely of the crush stone aggregate concrete. For study samples without links, the double layer beam

reached lower shear strength than the control beam. The lower shear strength was due to unzipping effect.

Iskhakov et al (2012) investigated two-layer beams, made up of steel fibered high strength concrete in the part that tends to be shorter (compression zone) and normal strength concrete in the part that tends to be longer (tensile zone), are researched experimentally. Three samples with the same fibre proportion, meeting the requirements of the suitable ductility level, were constructed and subjected to two-points loading. The results confirmed the function of fibres in a high concrete strength layer and develop a guide for two-layer beams design provisions.

Dahunsi (2003) revealed that periwinkle aggregate shells can be utilized as a partial substitute for granite in conventional building work and that the strength achieved in periwinkle-granite concrete is similar to that of classical granite concrete. Gravel obtain from the river is also a conventional building material used broadly with or without crushed stone. It is generally more economical than granite, but it is round and smooth in appearance.

The intention of this research is to find out the structural implication of two-layer reinforced concrete beams with one-layer of periwinkle shell aggregates concrete both in tension and compression zone respectively.

MATERIALS AND METHODS

Materials

Cement: Portland Limestone Cement of Grade 42.5 was used in the study. It conformed to B.S. EN 196-0; 2016.

Fine Aggregate: The fine aggregate utilized was obtained from river sand at Wilberforce Island, Bayelsa State, Nigeria. it confirmed to B.S. 882; 1992.

Coarse Aggregate: Crushed stones with rough-surfaces was used as coarse aggregate, obtained from Yenagoa, Bayelsa State, Nigeria. The maximum particle size was 12mm. It conformed to B.S. 882; 1992.

Periwinkle shells Aggregate

Periwinkle shells aggregates where obtained in Amassoma Town, Bayelsa state. The periwinkle shells used in this research were the remnants after the comestible portion removed. They were properly washed to remove crusts. It conformed to B.S. 882; 1992

Water: Portable water used was obtained in the Civil Engineering Laboratory building at the Niger Delta University. It conformed to BS 3148; 1980.

Formwork: Marine ply Board was utilized for the construction of the beam formworks. It conformed to BS 1881: Part 109, (1983)

Internal Reinforcement: Deformed bars were used as internal reinforcement both in bending and shear. It conformed to EN 1992-1-1:2004

Method

Beam Samples

According to EN 1992-1-1:2004, all the beam samples were reinforced with two 8mm diameter deformed bars both in the part that tends to be longer (tension zone) and part tends to be short (compression zone). 6mm diameter deformed bars placed at 200mm apart were used as shear reinforcement. Total of twelve beams cross-section of 100 x 150mm, overall length of 1200mm and effective span of 1100mm were constructed. Three beams out of twelve were used as control beams produced completely of crushed stone aggregate concrete of 1:2:4 mix ratio. Then, seven of which were produced in two-layers as stated below:

Fig.1: Details of Flexural and Shear Deformed Bars and Dimensions (mm)

Type-RC: Beams and cubes cast completely of crushed stone aggregates concrete of 1:2:4 mix (Control).

Type R1: Crushed stone aggregates concrete (1:2:4 mix) with a depth of 75mm at the top layer and Periwinkle aggregate concrete (1:2:1 mix) with a depth of 75mm at the bottom layer.

Type R2: Periwinkle aggregates concrete (1:2:1 mix) with a depth of 75mm at the top layer and 75mm of crushed stone aggregate concrete (1:2:4 mix) at the bottom layer

Type R3: Periwinkle aggregates concrete (1:2:1 mix) with a depth of 50mm at the bottom layer and 100mm of crushed stone aggregate concrete (1:2:4 mix) at the top layer. All the beam samples were tested under two-point loads.

Type-RP: Cubes cast completely of Periwinkle aggregates concrete of 1:2:1 mix.

Cubes Samples

Fifteen standard concrete cubes (150x150x150mm) were made for each set of beam-types to obtain 28 days compressive strength of concrete, with a mix ratio of 1:2:4 for the crushed stone aggregate concrete (control) cubes and a mix ratio of 1:2:1 for the periwinkle aggregate concrete cubes. The cube specimens were cured and were secured against dryness. Concrete cube samples were tested to failure at 28 days.

RESULTS AND DISCUSSION

Results

Research results of a two-layer reinforced concrete beam with one-layer of periwinkle shell aggregate concrete both in tension and compression zone are presented in tables and figures. Table 1 shows the direct observation of test results and failures modes of a two-layer reinforced concrete beam. Table 5 showed a compressive strength of concrete specimen's types RC, R1, R2, R3 and RP. Table 2,3 and 4 presents the calculated results of bending capacity, cracking capacity and tensile stress of test beams.

Table 1: Experimental results of tested two-layer beams

Sample Type	Number of samples	First Crack Load (kN)	Failure Load (kN)	Deflection at Failure (mm)	Mode of Failure
Type-RC	Sample 1	21.98	27.48	7.50	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-R1	Sample 1	25.65	37.37	6.00	Flexural/Crushing
	Sample 2	29.31	34.80	5.70	Flexural/Shear/Crushing
	Sample 3	27.48	36.09	5.85	Flexural/Crushing
Type-R2	Sample 1	25.65	31.14	5.81	Flexural/Shear/Crushing
	Sample 2	29.31	31.14	6.20	Flexural/Shear/Crushing
	Sample 3	27.48	31.14	6.01	Flexural/Shear/Crushing
Type-R3	Sample 1	29.31	32.97	5.61	Flexural/Shear/Crushing
	Sample 2	25.65	34.80	6.30	Flexural/Shear/Crushing
	Sample 3	27.48	33.89	5.96	Flexural/Shear/Crushing

Table 2: Bending Capacity of Beams

Specimen Type	Number of Samples	Failure Load (kN)	Bending Capacity (kNm)
Type-RC	Sample 1	27.48	5.04
	Sample 2	27.84	5.10
	Sample 3	27.84	5.10
Type-R1	Sample 1	37.37	6.85
	Sample 2	34.80	6.38
	Sample 3	36.09	6.62
Type-R2	Sample 1	31.14	5.71
	Sample 2	31.14	5.71
	Sample 3	31.14	5.71
Type-R3	Sample 1	32.97	6.04
	Sample 2	34.80	6.38
	Sample 3	33.89	6.21

Table 3: Cracking Capacity of Beams

Specimen Type	Number of Samples	First Crack Load (kN)	Cracking Capacity (kNm)
Type-RC	Sample 1	21.98	4.03
	Sample 2	17.59	3.22
	Sample 3	18.32	3.36
Type-R1	Sample 1	25.65	4.70
	Sample 2	29.31	5.37
	Sample 3	27.48	5.04
Type-R2	Sample 1	25.65	4.70
	Sample 2	29.31	5.37
	Sample 3	27.48	5.04
Type-R3	Sample 1	29.31	5.37
	Sample 2	25.65	4.70
	Sample 3	27.48	5.04

Table 4: Tensile Stress of Beams

Specimen Type	Number of Samples	First Crack Load (kN)	Tensile Stress (MPa)
Type-RC	Sample 1	21.98	10.75
	Sample 2	17.59	8.60
	Sample 3	18.32	8.96
Type-R1	Sample 1	25.65	12.54
	Sample 2	29.31	14.33
	Sample 3	27.48	13.43
Type-R2	Sample 1	25.65	12.54
	Sample 2	29.31	14.33
	Sample 3	27.48	13.43
Type-R3	Sample 1	29.31	14.33
	Sample 2	25.65	12.54
	Sample 3	27.48	13.43

Table 5: 28-Days Compressive Strength

Specimen Type	Size of Cube (mm)	Weight of Specimen (kg)	Applied Compressive Load (kN)	28-Day Compressive Strength (MPa)
Type-RC	150x150x150	8	643.3	28.60
Type-R1	150x150x150	8.5	385.5	17.13
Type-R2	150x150x150	8.2	375	16.67
Type-R3	150x150x150	8	425	18.89
Type-RP	150x150x150	6.2	206.6	9.18

Fig. 2. Load against deflection curve of experimental results of beam Type-RP, R1, R2, R3

Fig. 3 Failure load of the sample Types **Fig. 4.** Graph Showing compressive strength at 28-day for Cube Type-RC, R1, R2, R3 and RP

Discussion

This section illustrates the study results of the various tests carried out on two-layer reinforced concrete beam with one-layer of periwinkle shell aggregates concrete both in tension and compression face.

Ultimate Load-Carrying Capacity

From Table 1, it was noted that the control beams cast completely of crushed stone aggregate concrete of 1:2:4 mix ratio had less load carrying capacity compared to that of the two-layer reinforced concrete beam with one-layer of periwinkle shell aggregates concrete both in tension and compression face. Deflection performance and the load-carrying capacity of the study sample beams were observed.

Load at Early Crack

Two-point static loading was performed on all the two-layer beams and at each load increment, deflection and crack patterns were observed. The first crack load of all the beams was recorded and is given in Table 1. The beam Type-RC, developed an initial crack at 19.29kN and cracking capacity of 3.34kN, while the beam Type-R1, Type-R2 and Type-R3

developed an initial crack at 27.48kN and 5.04kN respectively. It was observed that all the two-layer reinforced concrete beam with one-layer of periwinkle shell aggregates concrete both in tension and compression face had higher load carrying and cracking capacity compared to the control beams cast completely of crushed stone aggregate concrete.

Bending capacity

From Table 2, it is confirmed that the two-layer beams had higher bending resistance as the control beams cast completely of crushed stone aggregate concrete. Also, the study showed that the beam Type-R1 had bending resistance of 6.62kNm and is 23.3% higher than beam Type-RC which had bending resistance of 5.08kNm while beam Type-R2 had bending resistance of 5.71kNm and is 11% higher than beam Type-RC. Beam Type-R3 had bending resistance of 6.21kNm and is 18.2% higher than beam Type-RC.

Load Deflection Performance

The load-deflection records of all the beam samples was observed. The deflection of each two-layer beam was compared with that of the beams cast completely of crushed stone aggregates concrete of 1:2:4 mix. Similarly, the load-deflection performance was compared between two-layer beams. From figure 2, the deflections were considerably lower than control beams cast completely of crushed stone aggregates concrete. The beam Type-RC (control beam) failed at 27.72kN load, measured deflection at 27.72kN load of 5.38mm. The beam Type-R1 at 27.72kN load, it deflects 3.73mm, which is 31% less than the beam Type-RC (control beam). The beam Type-R2 at 27.72kN load, it deflects 5.10mm, which is 5% less than the beam Type-RC (control beam). The beam Type-R3 at 27.72kN load, it deflects 4.18mm, which is 22% less than the beam Type-RC (control beam).

Fig. 5. Mode of Failure of test specimen: (a) Type-RC, (b) Type-R1, (c) Type-R2, and (d) Type-R3

Compressive Strengths

The concrete compressive strengths results of a two-layer reinforced concrete beam with one-layer of periwinkle shell aggregates concrete both in tension and compression face and concrete compressive strengths results of cubes samples cast completely of Periwinkle aggregates concrete of 1:2:1 mix and cubes formed completely of crushed stone aggregate concrete of 1:2:4 mix at 28-days are shown in Table 5. It is noted that the cube type-RC (control cube sample) had a compressive strength of 28.60MPa. From figure 4, the cube type-R1 had a compressive strength of 17.13MPa. The cube type-R2 had compressive strength of

16. 67MPa. The cube type-R3 had a compressive strength of 18.89MPa. The cube type-RP had a compressive strength of 9.18MPa. The results revealed that the control beams cast completely of crushed stone aggregate concrete had higher compressive strength compared to that of the two-layer reinforced concrete beam with one-layer of periwinkle shell aggregates concrete both in tension and compression face. Also, The cube-type R1 had higher compressive strength than the cube-type RP.

CONCLUSION

Investigations have been carried out to study the effectiveness of two-layer reinforced concrete beams of one-layer of periwinkle shell aggregates concrete both in tension and compression zone. From the research results, the following conclusions can be drawn.

- i. Use of two-layer reinforced concrete beam with one-layer of periwinkle shell aggregates concrete both in tension and compression face shows considerable improvement in ultimate load carrying capacity.
- ii. Using two-layer reinforced concrete beam with one-layer of periwinkle shell aggregates concrete both in tension and compression face restrains the central deflection.
- iii. Two-layer reinforced concrete beam with one-layer of periwinkle shell aggregates concrete both in tension and compression face leads to rise the ductility and toughness of the beam.
- iv. Crushed stone aggregate concrete layer of depth 0.5x the depth of the beam at the top and Periwinkle concrete with a depth of 0.5x the depth of the beam at the bottom is 23.2% higher than beams formed completely of crushed stone aggregates concrete.
- v. Periwinkle aggregate concrete with a depth of 0.5x the depth of the beam at the top layer and 0.5x the depth of the beam of crushed stone aggregate concrete at the bottom layer is 11% higher than the beams formed completely of crushed stone aggregates concrete.
- vi. Periwinkle aggregate concrete with a depth of $\frac{1}{3}$ x the depth of the beam at the bottom layer and $\frac{2}{3}$ x the depth of the beam of crushed stone aggregate concrete at the top layer is 18.21% higher than the beams formed completely of crushed stone aggregates concrete.

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