

STRESS ANALYSIS OF STICK REINFORCED GRANITE-PERIWINKLE CONCRETE SLAB UNDER UNIFORMLY DISTRIBUTED LOAD

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Abstract

This research work aims at providing alternative materials for coarse aggregate and steel reinforcement in concrete slab making in order to enhance affordable housing delivery. The materials were chosen based on their cheap cost and availability compared to the conventional materials. The long haulage distances and costly nature of granite has led to Periwinkle shells being used in the riverine (Niger-Delta) areas of Nigeria to wholly or partially replace granite in concrete, while Owa stick (*Jaundea Pinnata*) has been used for decades in reinforcing earthen houses. This paper reports the stress resistance of owa stick reinforced grano-periwinkle concrete slab compared with steel reinforced and plain grano-periwinkle concrete slab when subjected to uniformly distributed load. The mix ratio of 1:2:2 was used for the concrete; the ratio of 1:1 was used for granite and periwinkle shells with a water-cement ratio of 0.5. Concrete cubes were casted and used in testing for compressive strength. Slabs of 500x500x100mm were also used to test for the maximum flexural stress under uniformly distributed load with two sets of reinforcement spacing, 90mm and 150mm. The slabs were simply-supported (ssss) on all the sides. The 28-day compressive strength and density of the concrete was found to be 19.932N/mm² and 2617.48kg/m³. From this study it can be concluded that owa stick has elastic properties which helps in improving the tensile strength of concrete, though in comparison, steel is still preferred, but the stress resistance of owa stick reinforced concrete slab was more than that of plain concrete with the gain in stress of 25.30% at 90mm c/c and a loss of 16.87% at 150mm c/c. Also, owa stick reinforced slabs had more than 50% flexural stress resistance when compared to steel reinforced slabs. Also, while plain concrete slab failed in brittle, owa stick reinforced concrete did not.

Keywords: Periwinkle, granite, aggregate, concrete, owa stick (*Jaundea Pinnata*), flexural stress, uniformly distributed load (udl).

1. INTRODUCTION

The importance of concrete is widely seen in its used in construction work and for the foundation of most infrastructures. Its large use can be traced to being readily available and its suitable building properties such as the ability to support large compressive loads. However, the use of concrete is limited because it's low tensile strength. For this reason, reinforcement was introduced to take care of the tension that develops in concrete and one of the most popular of reinforcing bars (rebar) is steel. Steel has a relatively high tensile strength hence, complementing the low tensile strength of concrete. It is available and affordable in most developed countries but unfortunately the reverse is the case in developing and underdeveloped parts of the world like Nigeria. The high cost and low availability of Construction materials has lead researchers to sort for alternative materials for construction in order to provide affordable houses for dwelling. According to Job, Matawal and Achuenu (2009)[1], such alternative materials include sawdust, palm-kernel shell,

olive seed, and periwinkle shell which can be used to either partially or fully replace aggregate(s) in concrete.

However, as the demand for concrete structures increases geometrically, there has been a corresponding decrease in the availability of concrete construction materials and a corresponding increase in the cost of the materials.

It is against this background that researches have been carried out to identify other suitable materials, affordable and readily available to either serve as total or partial replacement for steel and coarse aggregate in concrete works.

In the quest to finding an alternative to steel reinforcement, there have been researches on the use of geogrid, Muda, Sharif, and Hong (2012)[2]; bamboo, Brink and Rush (1966)[3], cane, Anioke, Okoro, Maduh, and Madubueze (2007)[4] etc as reinforcement materials but the use of other locally available sticks has received little attention. Over the

years, “Owa” stick, (*Jaundea Pinnata*) has been used in the southern part of Nigeria (Akwa Ibom state) in reinforcing mud or earthen houses and it has proven to be a good construction material, hence, the need to study its performance as reinforcement in concrete slab. According to H.M. Burkill, in the book “Useful plants of west tropical Africa (2nd edition) [5], *Jaundea Pinnata* belongs to the family of Connaraceae, a shrub of 6-7m tall, or lianescent to the forest canopy. Widely dispersed from Guinea to South Nigeria, and unto Angola and North-East and East Africa

In one of the communities in Akwa Ibom State, it was stated that over the years, owa stick otherwise known as Emong has been used for reinforcing mud or earthen houses because of its high durability. They went further to explain that once owa stick is dry, it doesn't absorb moisture again which gives it an advantage over bamboo. According to Ghavami (2005), bamboo is vulnerable to environmental degradation and attacks by insects and moulds [6]. There is a strong relation between insect attacks and the levels of starch plus humidity content of bamboo culm. In order to reduce the starch content, bamboo receives a variety of treatments including curing on the spot, immersion, heating or smoke, Ghavami (2005). According to the riverine dwellers, owa stick stays for years inside the walls of the house without being attacked by rodent or moulds because of its little or no starch and moisture content. Also, they concluded that it has high tensile strength when compared with bamboo.

Periwinkles (*Nodilittorina radiata*) are small greenish blue marine snails with spiral conical shell and round aperture, Adewuyi and Adegoke (2008) [7]. The average periwinkle lives three years and grows to a shell height of 20 mm, but the largest recorded winkle grew to 52 mm. They are common in the riverine areas and coastal regions of Nigeria where they are used for food. The hard shells, which are regarded as wastes ordinarily posed environmental nuisance in terms of its unpleasant odour and unsightly appearance in open-dump sites located at strategic places, are now being considered as coarse aggregates in full or partial replacement for expensive, unaffordable or unavailable crushed stones or local washed gravels. Periwinkle shells have been used by the people of the coastal states e.g. Rivers State of Nigeria for over 30 years as conglomerate in concrete reinforcement. These shells have been used for many purposes e.g. for homes, soak-away, slabs and road construction. The cost of these shells was more than 10 times cheaper than that of gravel as at the time of this study, Agbede and Mamasseh, (2009) [8].

Since Owa stick and periwinkle shell are naturally occurring materials common to the riverine areas of Nigeria, positive information obtained from this study on the flexural strength of Owa reinforced grano-periwinkle concrete slab will go a long way in minimizing the dependency on steel and granite as reinforcement material and aggregate for concrete slab respectively. Also, it will contribute immensely to housing

delivery, especially in the riverine areas of Nigeria where these materials are abundantly available. Hence, if members made from these materials should possess commensurable flexural strength with that of its counterpart, the study can guarantee its use as alternative materials for lightweight concrete constructions especially in areas where the weight of the structure is of great concern.

2. MATERIALS AND METHODS

2.1 Selection of Materials

The materials used in this research work were cement, water, sharp sand, granite, periwinkle shell, 6mm high yield steel, and 8 - 10mm owa stick. The type of binder or cement used for this research was ordinary Portland cement from Ibeto in conformity with the requirements of BS 12 (1978) [9]. For the mixing of the concrete into paste, the water used was borehole water gotten from a tap in Federal Polytechnic, Nekede, Owerri, Imo State. The fine aggregate used in this work was sharp sand gotten from Otamiri River in nekede, Owerri. The sand was free from deleterious materials.

The coarse aggregate used in this research work included 20mm granite. It was a normal weight aggregate gotten from the local market in Owerri, Imo State. It was free from debris. The Periwinkle shells were also used as coarse aggregate in this study. It was gotten from a stock pile in Abak, Akwa Ibom State, where it is wash dried and kept for buyers. It was free from deleterious matters. 6mm high yield steel was used as reinforcement for the concrete slabs as control for the Owa stick reinforced concrete slabs. It was gotten from the local market in Owerri. Owa stick, *Jaundea Pinnata*, was carefully cut from the bush in Umuchima, Imo State, with a diameter of 8 – 10mm in size. The stick was carefully peeled and dried before cutting into 450mm of length. This was done in order to take care of any decrease in size due to dehydration. The stick was then treated by soaking it in a solution of sodium chloride (NaCl) for 12 hours in order to kill any inherent rodent. It was later steamed for 24 hours to remove the inherent cellulose from the stick. Finally, the stick was sun dried and used for reinforcement of the slab. The reinforcement sticks were arranged with the aid of binding wire and in two sets. The spacing used was same for both the main and distribution reinforcement. The two sets of reinforcements were spaced at 150mm and 90mm centre to centre.

2.2 Mix Proportion, Casting of Cubes and Slabs

A constant mix ratio of 1:2:2 and a water-cement ratio of 0.5 were maintained throughout this work. Batching operation was done by volume because of the nature of periwinkle shells. The fine aggregate used was sharp sand. Cast iron mould of size 150x150x150mm was used in casting concrete cubes while wooden mould of 500x500x100mm was used in casting the concrete slabs.

Sieve analysis was carried out on sharp sand, periwinkle shells and crushed granite using sieves arranged in decreasing size of opening. The fraction retained on each sieve size was weighed and recorded. Slump and water absorption test were also carried out on samples.

The cube mould was assembled prior to mixing and properly lubricated for easy removal of hardened concrete cubes. The wooden mould was properly covered with polyethene to enhance easy removal and to avoid loss of mixing water to the surrounding. The percentage by volume of crushed granite to periwinkle shells as coarse aggregate was 50:50. The mixing surface was soaked with water two hours prior to concrete mixing to saturate the surface against absorbing mixing water. The mixture was properly turned with shovel until it reached a plastic state which was fed into the moulds. Water curing method was adopted in this project. The specimens were made in accordance with BS 1881[10].

The molded concrete slabs and cubes were kept for 24 hours to set before demoulding. They were then fully immersed into a large curing tank filled with pipe borne water in order to increase the strength of the concrete, promote hydration, eliminate shrinkage and absorb heat of hydration until the age of test. The specimens were cured for 28 days. Prior to testing, the specimens were brought out of the curing tank and air dried for about 2 hours before crushing. The cubes were weighed before testing and the densities of cubes at the time of testing were measured. The compressive strengths of the cubes were tested in accordance to BS 1881 using universal testing machine. The slab was simply supported (SSSS) on all the four sides by steel beams of 50x500mm surface area.



Fig-1: slab under uniformly distributed load.

The slab was loaded with uniformly distributed load over 380x380mm area at the center. The load was transferred from the 30mm diameter plunger to the slab through the help of a metal plate and a sand bed to aid in load distribution (fig. 1).

Loading was done gradually at about one minute interval between each thrust; this was to aid in giving time for proper distribution of load in the member. The load was increased until the specimen failed according serviceability limit state, and the maximum load applied to the specimen during the test was recorded. The slab was considered to have failed once there was a visible crack greater than 0.3mm at the bottom fiber according to Bs 8110-2:(1985) [11].

3. RESULTS AND ANALYSIS

From the grain size analysis data for sharp sand, granite and periwinkle shell, it was observed that aggregates were well graded (chart 1, 2, 3). At a water-cement ratio of 0.5, the slump was found to be 18mm. table 2 shows the density of cubes after 28days curing.

The density of the concrete resulting from a 1:1 grano-periwinkle aggregate was 2617.48kg/m³. According to BS, normal weight concrete is those with density of 2200 to 2600kg/m³. Therefore, grano-periwinkle concrete at 1:1 can be classified as structural normal weight concrete.

The 28-day compressive strength tested from the cubes gave strength of 19.932N/mm², which is close to what was gotten by Osarenmwinda and Awaro (2009) [12] in similar mix. According to ACI 213 (1987), structural lightweight aggregate concrete is a concrete whose 28-day compressive strength is equal to or greater than 17N/mm² [13] and also ASTM-C330 recommended minimum strength of 17N/mm² for structural lightweight concrete [14]. Hence, it can be seen that compressive strength is not enough factor to use in classifying concrete, being that its density qualifies it for another group. Also, the strength of each set of slab specimen was determined by the number of reinforcement hence, the reduction in maximum flexural strength between 90mm and 150mm spaced reinforced slabs.

Table 1: Densities of samples

SPECIMEN	SATURATED WET Kg/m ³	SATURATED Kg/m ³	DRY	SATURATED SURFACE DRY Kg/m ³
I	2580.74	2571.85		2562.96
II	2554.07	2539.26		2524.44
III	2675.56	2663.70		2651.85
IV	2500.74	2491.85		2477.04
V	2554.07	2542.22		2524.44
VI	2841.48	2823.70		2814.81
VII	2459.30	2441.48		2429.63
VIII	2764.44	2752.59		2737.78
IX	2758.52	2743.70		2728.89
X	2749.63	2731.85		2722.96



Fig 2: pattern of failure of slab subjected to uniformly distributed load

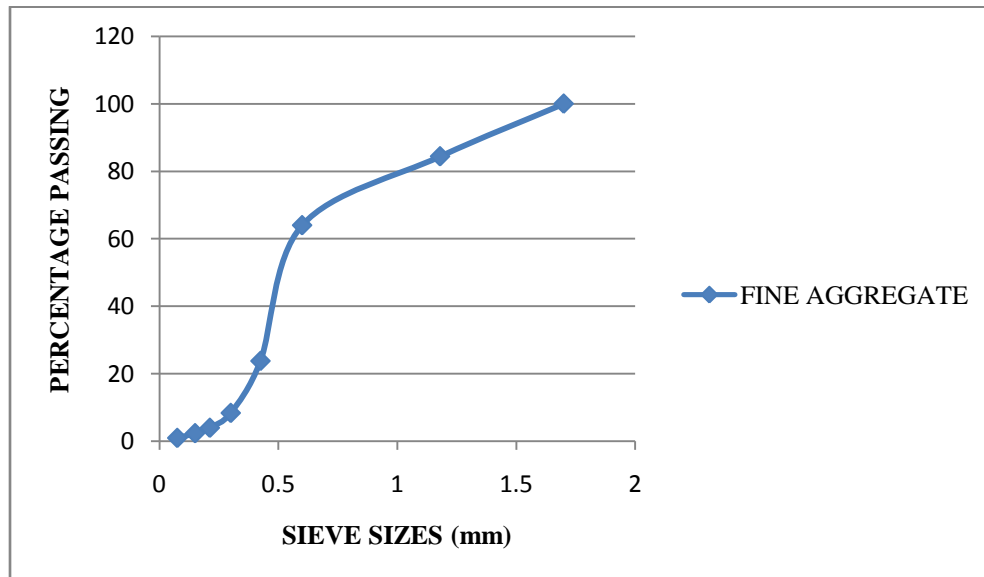


Chart-1: Grain size analysis graph for fine aggregate.

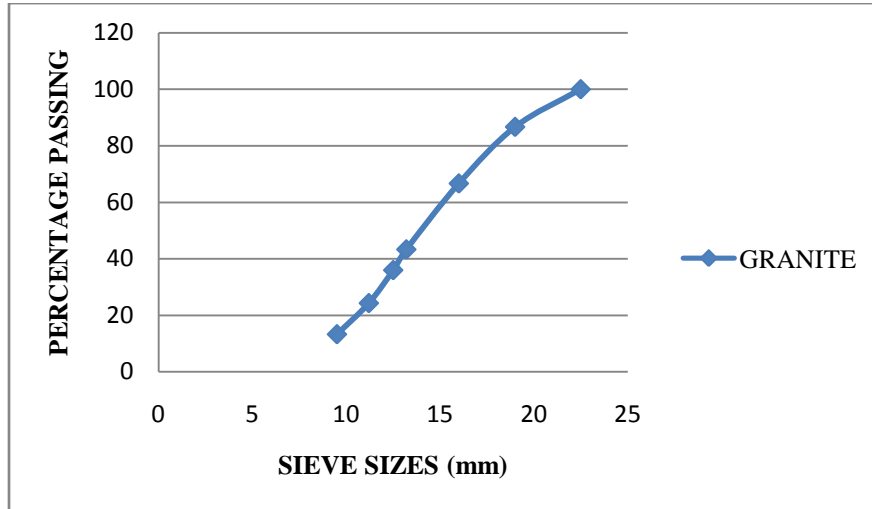


Chart-2: Grain size analysis graph for coarse aggregate (granite).

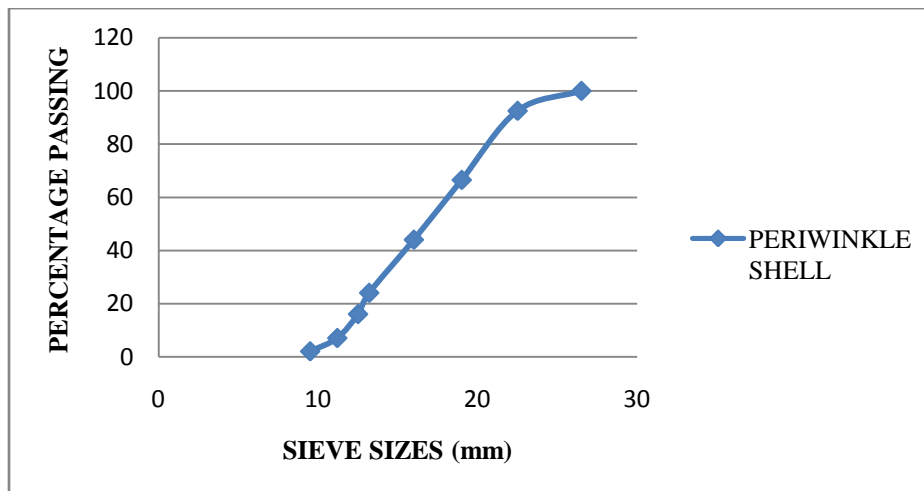


Chart-3: Grain size analysis graph for coarse aggregate (periwinkle).

Figure 2 shows the pattern of failure of grano-periwinkle slab when subjected to uniformly distributed load. The crack in both direction shows that the stress from the load was evenly distributed to all parts of the member. On testing the samples under uniformly distributed load, the steel reinforced slab showed high flexural strength and on failure, minimal cracks and crack width were obtained compared to stick reinforced and plain concrete slabs. Similarly, stick reinforced slabs failed with smaller crack width compared to plain concrete. The stick could be classified as ductile material based on its elastic performance in concrete. When loaded, just before failure point, once the load was removed or reduced, the slab completely recover and returns to its original shape and size; showing the elastic behavior of owa stick as reinforcement. For plain concrete, at the point of failure, the slab fails without any sign showing that is a brittle material with little or no

tensile strength. From the results, it was seen that owa stick reinforced concrete was able to carry more amount of tension and did not have brittle failure when compared to plain concrete. From the results, at 90mm c/c spacing of owa stick reinforcement, the gain in stress of owa stick reinforced slab over plain slab was 25.30% while at 150mm c/c spacing, there was a reduction in stress for about -16.87%. This showed that at 150mm spacing, the slab was under-reinforced, hence, the owa stick tend to become a weakness to the slab by causing a discontinuity in the concrete matrix such that the slab failed under a smaller load than the plain concrete slab. The reduction can be attributed to the inadequacy of the reinforcement bars and large bar spacing. Moreover, when compared with steel reinforced slab, it showed that owa stick reinforced slabs had 57.14% and 43.67% strength of steel reinforced at 90mm and 150mm respectively.

Table 2: failure load of concrete slabs reinforced with owa stick, steel, and plain subjected to uniformly distributed load.

SLAB REINFORCEMENT @ 90mm c/c	MARK	LOAD (Bar)	LOAD (KN/m ²)	LOAD (KN)	LOAD (KN/m)	AVGERAGE LOAD
STICK	A1	74	7400	5.232	36.23	
	A1	68	6800	4.808	33.30	33.947
	A1	66	6600	4.666	32.31	
STEEL	B1	126	12600	8.908	61.69	
	B1	118	11800	8.343	57.78	59.407
	B1	120	12000	8.484	58.75	
PLAIN	C	55	5500	3.889	26.93	
	C	57	5700	4.030	27.91	27.093
	C	54	5400	3.818	26.44	

Table 3 failure load of concrete slab reinforced with owa stick, steel, and plain subjected to uniformly distributed load

SLAB REINFORCEMENT @ 150mm c/c	MARK	LOAD (Bar)	LOAD (KN/m ²)	LOAD (KN)	LOAD (KN/m)	AVG. LOAD
STICK	A2	43	4300	3.040	21.05	
	A2	45	4500	3.182	22.04	22.523
	A2	50	5000	3.535	24.48	
STEEL	B2	108	10800	7.636	52.88	
	B2	102	10200	7.211	49.94	51.573
	B2	106	10600	7.494	51.90	
PLAIN	C	55	5500	3.889	26.93	
	C	57	5700	4.030	27.91	27.093
	C	54	5400	3.818	26.44	

Table4. Maximum flexural strength of slab samples

REINFORC. SPACING (mm) c/c	TYPE OF REINFR.	FAILURE LOAD, KN	MAX. MOMENT KNm	MAX. FLEXURAL STRESS KN/m ²	% GAIN IN STRESS OVER PLAIN CONCRETE	OWA REINFR. AS A % OF STEEL REINFR. CONCRETE
90	STICK	33.947	1.2133	485.32	25.30	57.14
	STEEL	59.407	2.1232	849.31		
	PLAIN	27.093	0.9683	387.34		
150	STICK	22.523	0.8050	322.00	-16.87	43.67
	STEEL	51.573	1.8432	737.31		
	PLAIN	27.093	0.9683	387.34		

The following formulae were used in calculating for various parameters;

Where, R and Q are dimensionless quantities; $R = x/a$ and $Q = y/b$; $a = b = 0.5m$

From plate theory, using polynomial shape function, the displacement function for ssss plate is;

$$W = A(R - 2R^3 + R^4). (Q - 2Q^3 + Q^4) \dots \dots \dots 1$$

From Ritz energy equation

$$\Pi = \frac{abD}{2b^4} \int_0^1 \int_0^1 \left[\frac{1}{P^4} \left(\frac{\partial^2 W}{\partial R^2} \right)^2 + \left(\frac{\partial^2 W}{\partial Q^2} \right)^2 + \frac{2}{P^2} \left(\frac{\partial^2 W}{\partial R \partial Q} \right)^2 \right] \partial R \partial Q - abq \int_0^1 \int_0^1 w \partial R \partial Q$$

substituting the appropriate differential and integral form of equation 1 into Ritz energy method,

the parameter A, gives;

$$A = \frac{0.04236b^4q}{D}$$

From plate theory, moment, M, is given by;

$$M_x = -D \left[\frac{\partial^2 W}{\partial x^2} + \vartheta \frac{\partial^2 W}{\partial y^2} \right] \dots \dots \dots 40$$

$$M_y = -D \left[\vartheta \frac{\partial^2 W}{\partial x^2} + \frac{\partial^2 W}{\partial y^2} \right] \dots \dots \dots 41$$

For a square plate, $M_x = M_y$; and $\vartheta = 0.2$ (clause 2.4.2.4, BS 8110)

For ssss plate, maximum moment at the centre is;

$$M_R = M_Q = 0.047655b^2q \dots \dots \dots 48$$

$$\text{Maximum flexural stress, } \vartheta = \frac{6M}{bh^2} = 14.2965q$$

where $h = 0.1m, a = b = 0.5m$

The percentage water absorption of periwinkle shells and granite was 4 and 0.4 respectively. This is in-line with Ibearugbulem (2006) [15]. However, the water absorption value of periwinkle shell is different from that reported by Job, Matawal and Achuenu (2009) [1], but according to Oguara (1984), the varied absorption values could be due to the varied species available in West Africa [16].

4. CONCLUSIONS

From the test carried out on the stress resistance of owa stick reinforced grano-periwinkle concrete slab, the following conclusions can be drawn:

Granite-periwinkle concrete at a ratio of 1:1 in a mix of 1:2:2 can be classified as normal weight concrete because its density is greater than 2000kg/m3.

The strength of owa stick reinforced granite-periwinkle concrete slab is determined based on the properties of the shells; the percentage replacement and the quantity of owa stick reinforcements.

Owa stick has proven to be a good reinforcement material for concrete by providing 25.30% gain in stress resistance over plain concrete when spaced at 90mm c/c, and its elastic nature and durability has helped concrete not to have brittle failure.

Owa stick reinforced granite-periwinkle slab had strength of 57.14% and 43.67% when compared to steel reinforced at 90mm and 150mm reinforcement spacing respectively; which could be greater with increased number of reinforcement.

The percentage gain in stress of owa stick reinforced concrete can be enhanced by increasing the quantity of reinforcements.

The strength development in granite-periwinkle concrete is similar to those of the conventional granite concrete.

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