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Structural Characterisation of Sawdust-Palm Kernel Shellcrete Composite

Ezeh, J.C., Ibearugbulem, O.M., and Ihemegbulem, Ezekiel.O.
Department of Civil Engineering, Federal University of Technology, Owerri, Imo State, Nigeria.

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ABSTRACT

This study presents the structural characterization of sawdust-palm kernel shellcrete composite. It proffers solution to absence of structural characteristics of sawdust-palm kernel shellcrete composite, which is a concrete component mixture of cement, sawdust and palm kernel shell (PKS). The materials used in the experiments work included: Ordinary Portland Cement, saw dust, palm kernel shell and water. The physical characterization tests were performed on the aggregates used in this experimental work,of which sawdust gave values of 554.9kg/m^3, 0.503, 33.57%, 2.61, 1.0 and 2.83 for average bulk density, average specific gravity, average water absorption, finess modulus, coefficient of curvature (C_C) and uniformity (C_U) respectively. Palm kernel shell gave corresponding values of 729.09kg/m^3, 1.63, 11.8%, 6.03, 1.36 and 2.64. Batching was done by weight and the low bulk density of the aggregate materials (sawdust and palm kernel shell)were taken cognizance of. The mixing of the components were done manually. A total of six (6) cubes of size 150mm x 150mm x 150mm, six(6) cylinders of size 150mm x 300mm and six(6) beams of size 150mm x 150mm x 600mm were produced from mix ratios (water : cement : fine aggregate : coarse aggregate): 0.9:1:2 :2 and 0.9:1:2:3 for compressive strength test, split tensile strength test and flexural strength test respectively. The above water-cement ratio and mix ratio was adopted due to the high water absorption of the aggregate materials and to achieve the desired workability, strength and durability for light weight concrete. For the mix ratio of 0.9:1:2:2, the average compressive strength, flexural strength, split tensile strength and average static modulus of elasticity were 7.73MPa, 2.76MPa, 1.57MPa and 4.41GPa. The corresponding values for the mix ratio of 0.9:1:2:3 are 3.84MPa, 2.51MPa, 1.42MPa and 4.06GPa. The average Poisson's ratio ranges from 0.2 - 0.37. The shear modulus ranged from 1.48MPa – 1.84MPa. The average flexural strength of sawdust-palm kernel shellcrete beams ranged from 2.5MPa to 2.76MPa.

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Introduction

The continuous increase in the use of conventional concrete materials such as granite and sand has led to an increase in both noise and environmental hazards (air and land pollution) in the course of their minning processes [1]. Thus, the use of industrial and agricultural bye products (Sawdust and Palm kernel shell) becomes imperative as they are cheap, possess low self weight and poses no environmental hazards during minning of these materials.

In contrast to the former, convectional concrete materials such as sand, gravel and crushed stones possesses a high self weight which invariably increases the overall weight of the structure transmitted to the foundation thereby resulting to costly foundation structures [2]. In the same vein, as a result of the daily increase in demand of convectional concrete materials; cement, crushed stone, fine sand and steel have become very costly and unaffordable to low income earners [3]. Also it will aid to foster waste recycling of both sawdust and palm kernel shell; thereby becoming reuseable wastes and reducing their pollution to our environment and also a source of income to lumber millers.

Demand of convectional concrete materials; cement, crushed stone, fine sand and steel have become very costly and unaffordable to low income earners [3]. Also it will aid to foster waste recycling of both sawdust and palm kernel shell; thereby becoming reuseable wastes and reducing their pollution to our environment and also a source of income to lumber millers.

Saw dust – palm kernel shellcrete is a composite mixture of cement, water, sawdust (fine aggregate) and palm kernel shell (coarse aggregate). Usman et al. [4] investigated on the use of locally available materials (sawdust and palm kernel shells) as substitutes for fine and coarse aggregates in concrete with the overall aim of reducing the cost of construction. In their study, four sets of concrete (cement: sand: gravel, cement: sawdust: granite, cement: sand: palm kernel shells and cement: saw dust: palm kernel shells) were mixed at 1:2:4 and 1:3:6.

Various tests were carried out and from the result, it was observed that the reduction in strength of concrete with palm kernel shells as a coarse aggregate was due to factors such as porosity, the size and flaky shape of the palm kernel shell which prevent proper bonding between the constituents.

Ndoke [5] investigated the performance of Palm Kernel Shells as a Partial replacement for Coarse aggregate in asphalt Concrete.

Tele: +2348060244464
E-mail address: ihemeezekiel20@gmail.com

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He drew a conclusion that Palm kernel shells can be used as partial replacement for coarse aggregate up to 10% for heavily trafficked pavement and 50% for light trafficked pavement.

Olutoge [6], investigated on palm kernel shells and saw dust as aggregate replacement. They came to a conclusion that 25% replacement of both materials gave a good lightweight material, which resulted to reducing the overall weight by 14.5% to 17.9%.

Fakhrul et al. [7], investigated on properties of sawdust and wheat flour reinforced polypropylene composite. They came to a conclusion that the lesser the addition of saw dust and wheat flour, the lesser the average tensile strength of the composite. Up to this day, there has been no published research work on the Structural characterisation of sawdust-palm kernel shellcrete composite, thus, the need for this research work.

Materials and Methods

Sawdust:

Sawdust can be used as alternative substitute for fine aggregate in concrete production. Maharani et al. [8] defined sawdust as the tiny-sized wood waste produced by the sawing of wood. Sawdust should be washed and cleaned before use as concrete constituent because of large amount of resin which can affect setting and hydration of cement. Concrete obtained from sawdust is a mixture of sawdust, gravel with certain percentage of water to achieve the workability and full hydration of the cement which help in bonding of the concrete. Sawdust concrete is light in weight and has satisfactory heat insulation and fire resisting values. Nails can be driven and firmly hold in sawdust concrete compared to other lightweight concrete which nail can also easily drive in but fail to hold [9].

For the study, sawdust was obtained from the Wood Processing market (Ogbo-Osisi), Owerri North LGA, Imo State, Nigeria. First, the sawdust was washed and boiled to remove any resin from it. After boiling for about 3 hours the particles were dried completely. The sawdust was classified according to the results of its physical properties as performed in the laboratory. The physical and mechanical characterization tests were performed on the sawdust. Sawdust gave values of 554.9kg/m^3, 0.503, 33.57%, 2.61, 1.0 and 2.83 for average bulk density, average specific gravity, average water absorption, finess modulus, coefficient of curvature (Cc) and uniformity (Cu) respectively.

Palm Kernel shell

Palm kernel shells are the crushed outer part of palm kernel nut derived after the extraction of palm oil. Palm kernel shell (PKS) is the hard endocarp of palm kernel fruit that surround the palm seed. It is obtain as crushed pieces after threshing or crushing to remove the seed which is used in the production of palm kernel oil [10].

Palm kernel shell which is the shell housing the palm kernel seed is derived from the oil palm tree (elaeis guineensis), an economically valuable tree, and native to western Africa and widespread throughout the tropics [5].

Palm kernel shell (PKS) are available in large quantities in palm oil producing areas such as Umuagwo town, Ohaji Egbema, Akabo in Imo State. Also they can be found in Ode-aye farm settlement, Araromi obu rubber and oil plantations, Irele oil plantations in Ondo State, NIFOR and Okomu farms in Edo State, and in reasonable quantities in other towns and villages especially in the southern part of Nigeria. Palm kernel shell was obtained from the palm kernel processing palm tree plant in Umukene community, Umuagwo town, Ohaji / Egbema LGA, Imo State, Nigeria. First, the palm kernel shell was washed and boiled to remove any oil and fat from it. After boiling for about 3 hours the particles were dried completely. The palm kernel shell was classified according to the results of its physical properties as performed in the Palm kernel shell gave corresponding values of 729.09kg/m^3, 1.63, 11.8%, 6.03, 1.36 and 2.64 for average bulk density, average specific gravity, average water absorption, finess modulus, coefficient of curvature (Cc) and uniformity (Cu) respectively.

Ordinary Portland Cement

This is the most common type of cement in general use around the world and in Nigeria because it is a basic constituent of concrete and mortar. Portland cement is a finely ground material consisting primarily of compounds of lime, silica, alumina and iron, which when mixed with water forms a paste which hardens and binds aggregates such as sand, gravel or crushed rock to form a hard overall mass called concrete [11]. Portland cement can also be defined as an extremely finely ground product obtained by burning together at high temperature specifically proportioned amounts of calcareous and argillaceous raw materials, adding nothing also to the burnt product except gypsum in small percentage [12]. Ordinary Portland cement which conforms to the provisions of [13] was obtained from depot in Owerri

Water

Water was obtained from a borehole within the premises of Federal University of Technology, Owerri, Imo State. The water is potable and in accordance to the standard of [14]. The water met the standard for drinking, it is therefore good for making concrete and curing concrete.

Compressive Strength Test for Sawdust- Palm kernel shellcrete Composite

Compressive strength tests of the Sawdust-Palm Kernel Shellcrete were done in cube forms, by mixing manually in a mould measuring 150mm x 150mm x 150 mm in size. The moulds were first oiled for easy removal of the samples after setting. The sawdust-palm kernel shellcrete sample was introduced into the mould in three layers by proper vibration using a rammer. A total of six (6) cubes were cast using the mix ratios 0.9:1:2:2 and 0.9:1:2: 3 respectively. The Sawdust-Palm Kernel Shellcrete cubes were cured for 28days by spraying water on them. After 28days curing, compression test was carried out on them using Okhard Universal testing machine and in accordance to [15]. The compression loads at failure were recorded and compressive strengths were obtained using Equation (1).

$$\textbf{Compressive strength} = \frac{\textbf{Fc (N)}}{\textbf{A (mm}^2\textbf{)}} \quad (1)$$

where ; $\textbf{Fc} =$ **Compressive load cube at failure**(N),

A =**Cross sectional area**($\mathbf{mm^2}$)

From the results of the compressive strength, the dry density after the 28-day curing was obtained as it is a determinant factor for some other structural characteristics such as poisson ratio, static modulus of elasticity and shear modulus. The cubes for the compressive Strength Test were weighed in a digital weighing balance that has accuracy of 0.01g and recorded and the dry density of the samples were computed using Equation (2).

$$\textbf{Dry density}, \boldsymbol{\rho} = \frac{\mathbf{M}}{\mathbf{V}} \quad (2)$$

Where; M = Mass of dry sample, V= Volume of sample

Split tensile Strength Test for Sawdust- Palm Kernel Shellcrete composite

Splitting tensile strength tests of the sawdust-palm Kernel shellcrete were done using cylinders measuring 150mm x 300mm in size in accordance to the requirements of [15] and [16]. A total of six (6) cylinders measuring 150mm x 300mm were produced from the two mix ratios; 0.9 : 1 : 2 :

2 and 0.9 : 1 : 2 : 3 respectively. The Sawdust-palm kernel shellcrete cylinders were cured by spraying water on it for 28 days, and tested in Okhard Machine Tool's WA-1000B digital display Universal Testing Machine (UTM) compression machine thereafter. The cylinder specimens were placed with its longitudinal axis between the platens of the machine and the load gradually applied until failure occur by splitting along the centre line of the cylinder. The compression load at failure were recorded and equation (3) was used to determine the split tensile strength of the Sawdust-Palm Kernel Shellcrete.

$$\textbf{Split tensile Strength}, \delta_c = \frac{2F(N)}{\pi Ld\,(mm^2)} \quad (3)$$

F is the maximum load in Newton; L is the length of the specimen in milimetre; d is the cross-sectional diameter in milimetre of the specimen. The test will be in accordance to [15] and [16].

Flexural Strength Test of Sawdust-palm kernel shellcrete composite

Six (6) beams of size 150mm x 150mm x 600mm were cast from the mix ratios of 0.9 : 1 : 2 : 2 and 0.9 : 1 : 2 : 3 respectively. Manual mixing method was used during casting of the beams. The beams were cast in layers to make sure that proper vibration of the composite was obtained. The beam samples were tested in Okhard Machine Tool's WA-1000B digital display Universal Testing Machine (UTM); after been cured for 28 days in accordance to [17]. Equation (4) was used to obtain the Flexural strength.

$$\text{Flexural Strength}, f_{cf} = \frac{F \times L}{b \times {d_2}^2} \quad (4)$$

F is the breaking load (N);
b is the width and *d* is the depth of beam cross-section (mm);
For beam b = 150mm, d = 150mm;
L is the distance between the supporting rollers (in mm); for beam L = 300mm.

Static Modulus of Elasticity Sawdust-Palm Kernel Shellcrete composite

A function of the compressive strength and density was used to obtain the static modulus of elasticity of sawdust-palm kernel shellcrete composite in accordance to [18]. The elastic modulus of the composite can be obtained using Equation (5):

$$E_S = 1.7\rho^2 ⟦f_c⟧ \ {}^\wedge(0.33) \times 10^{-6}$$
(5)

Where *ES* =Static modulus of Elasticity
ρ = density
f_c = compressive strength

Poisson Ratio of Sawdust-Palm Kernel Shellcrete Composite

A function of the tensile stress at cracking in flexure and compressive stress at cracking for compression members was used to obtain the poisson ratio of sawdust- palm kernel shellcrete composite in accordance to [18] using equation (6). The value of Poisson μ is given as:

$$\textbf{Poisson ratio}, \ \mu = \frac{\delta_f}{\delta_c} \quad (6)$$

$$\delta_f = tensile\ stress\ at\ flexural\ crack$$
$$\delta_c = compressive\ stress\ at\ crack$$

Shear Modulus of Sawdust-palm kernel shellcrete composite

A function of the modulus of elasticity over the linear range of the deformation and Static Poisson's ratio was used to obtain the shear modulus of sawdust-palm kernel shellcrete composite in accordance to [18], using equation (7).

$$\text{Shear Modulus}, \ G = \frac{E_C}{2(\mu-1)} \quad (7)$$

μ = Static Poisson's ratio
E_c = modulus of elasticity of concrete over the linear range of the deformation.

Shear Strength of Sawdust-palm kernel shellcrete composite

The failure load in shear was derived from the flexural strength test and the shear strength calculated using equation (8):

$$\text{Shear Strength}, f_s = \frac{F}{A} \quad (8)$$

Where f_s = shear strength
F = shear load at failure
A= cross- sectional area of the test specimen

Results

28th day Compressive Strength values of Sawdust–palm kernel shellcrete composite:

The results of the 28th day compressive strength of Sawdust-Palm kernel Shellcrete composite are presented in Table 1:

Table 1. Results on 28th day Compressive Strength values of Sawdust–palm kernel shellcrete composite.

Mix ratio (cement:sawdust:PKS)	Sample No	Area of Sample(mm²)	Weight Of Sample (Kg)	Crushing load(KN)	Compressive Strength(N/mm²)	AverageCompressive strength(N/mm²)
1:2:2	A	22500	3.82	176.3	7.84	7.73
1:2:2	B	22500	3.88	173.5	7.71	
1:2:2	C	22500	3.95	171.7	7.63	
1:2:3	A	22500	4.18	89.3	3.97	3.84
1:2:3	B	22500	4.15	84.6	3.76	
1:2:3	C	22500	4.21	85.5	3.80	

28th day Density of Sawdust–palm kernel Shellcrete Composite

The results of the 28th day density of Sawdust-Palm kernel Shellcrete composite are presented in Table 2:

Table 2. Results on 28th day density of Sawdust–palm kernel shellcrete composite.

Mix ratio (cement:sawdust:PKS)	Sample No	Volume ofSample (m³)	Weight of Sample (Kg)	Density (Kg/m³)	Average Density in Kg/m³
1:2:2	A	0.003375	3.82	1131.85	1150.61
1:2:2	B	0.003375	3.88	1149.63	
1:2:2	C	0.003375	3.95	1170.37	
1:2:3	A	0.003375	4.18	1238.52	1238.51
1:2:3	B	0.003375	4.15	1229.63	
1:2:3	C	0.003375	4.21	1247.41	

28th day Split tensile strength of Sawdust–palm kernel shellcrete composite

The results of the 28th day Split tensile strength of Sawdust- Palm kernel Shellcrete composite are presented in Tables 3:

Table 3. Results on 28th day Split tensile strength of Sawdust–palm kernel shellcrete composite.

Mix ratio (cement:sawdust:PKS	**Sample No**	**πdL (mm²)**	**Weight of Sample (Kg)**	**Crushing load (KN)**	**split Tensile Strength (N/mm²)**	**Average split Tensile strength (N/mm²)**
1:2:2	A	141371.67	7.38	224.67	1.58	
1:2:2	B	141371.67	7.24	222.56	1.57	1.57
1:2:2	C	141371.67	7.21	219.75	1.55	
1:2:3	A	141371.67	7.47	204.55	1.45	
1:2:3	B	141371.67	7.55	200.81	1.42	1.42
1:2:3	C	141371.67	7.41	198.22	1.40	

28th day Flexural strength of Sawdust–palm kernel Shellcrete composite

The results of the 28th day flexural of Sawdust-Palm kernel Shellcrete composite are presented in Table 4:

Table 4. Results on 28th day flexural strength of Sawdust–palm kernel shellcrete composite.

Mix ratio (cement:sawdust:PKS)	**Sample No**	**Area of Sample (mm²)**	**Weight of Sample (Kg)**	**Crushing load (KN)**	**Flexural strength (N/mm²)**	**Average Flexural strength (N/mm²)**
1:2:2	A	90000	5.5	26.25	2.91	2.76
1:2:2	B	90000	5.5	24.55	2.72	
1:2:2	C	90000	5.5	23.89	2.65	
1:2:3	A	90000	5.5	22.67	2.53	2.51
1:2:3	B	90000	5.5	21.90	2.43	
1:2:3	C	90000	5.5	23.34	2.59	

Static Modulus of Sawdust–palm kernel shellcrete composite

The results of the Static Modulus of Sawdust-Palm kernel Shellcrete composite are presented in Tables 5:

Table 5. Results on the static modulus of Sawdust–palm kernel shellcrete composite.

Mix ratio	**Sample No**	**Density of Sample (mm²)**	**Weight of Sample (Kg)**	**Crushing load (KN)**	**Compressive Strength (N/mm²)**	**Static modulus of elasticity (GPa)**	**Average Static modulus of elasticity (GPa)**
1:2:2	A	1131.852	3.82	188.30	7.84	4.29	4.419447
1:2:2	B	1149.63	3.88	193.50	7.71	4.40	
1:2:2	C	1170.37	3.95	191.70	7.63	4.55	
1:2:3	A	1238.519	4.18	119.30	3.97	4.11	4.066206
1:2:3	B	1229.63	4.15	122.60	3.76	3.98	
1:2:3	C	1247.407	4.21	123.50	3.80	4.11	

Poisson ratio of Sawdust–palm kernel shellcrete composite

The results of the Poisson ratio of Sawdust-Palm kernel Shellcrete composite are presented in Table 6:

Table 6. Results on the poisson ratio of Sawdust–palm kernel shellcrete composite.

Mixratio (cement:sawdust:PK)	**Sample No**	**Density of Sample (mm²)**	**Crush load (KN)**	**Compressive Strength (N/mm²)**	**Tensile Strength (N/mm²)**	**Poisson ratio μ**	**Average poisson ratio, μ**
1:2:2	A	1131.85	176.3	7.84	1.58	0.20	0.20
1:2:2	B	1149.63	173.5	7.71	1.57	0.20	
1:2:2	C	1170.37	171.7	7.63	1.55	0.20	
1:2:3	A	1238.52	89.3	3.96	1.44	0.36	0.37
1:2:3	B	1229.63	84.6	3.76	1.42	0.37	
1:2:3	C	1247.41	85.5	3.82	1.41	0.36	

Shear modulus Value of Sawdust–palm kernel Shellcrete composite

The results of the Shear modulus of Sawdust-Palm kernel Shellcrete composite are presented in Table 7:

Table 7. Results on the shear modulus of Sawdust–palm kernel shellcrete composite.

Mix ratio	**Sample No**	**Density of Sample (mm²)**	**Tensile Strength (N/mm²)**	**Compressive Strength,Fc (N/mm²)**	**Static modulus of elasticity,Es(GPa)**	**Poisson ratio μ**	**Shear Modulus GPa**	**Average shear modulus GPa**
1:2:2	A	1131.85	1.58	7.83	4.29	0.20	1.78	
1:2:2	B	1131.85	1.57	7.71	4.41	0.20	1.83	1.84
1:2:2	C	1149.63	1.55	7.63	4.55	0.20	1.89	
1:2:3	A	1170.37	1.44	3.96	4.10	0.36	1.50	
1:2:3	B	1238.52	1.42	3.76	3.9	0.37	1.44	1.48
1:2:3	C	1229.63	1.40	3.8	4.11	0.37	1.50	

Shear strength Value of Sawdust–palm kernel shellcrete composite

The results of the Shear strength of Sawdust-Palm kernel Shellcrete composite are presented in Table 8:

Table 8. Results on the shear strength of Sawdust–palm kernel shellcrete composite.

Mix ratio	Sample No	Cross sectional Area (mm²)	Weight of sample (kg)	Crushing load (kN)	Flexural strength (N/mm²)	Shear Strength (N/mm²)	Average Shear Strength (N/mm²)
1:2:2	A	90000	10.2	26.25	2.92	2.92	2.77
1:2:2	B	90000	10.34	24.55	2.73	2.73	
1:2:2	C	90000	9.56	23.89	2.65	2.65	
1:2:3	A	90000	10.9	22.67	2.52	2.52	2.52
1:2:3	B	90000	10.81	21.90	2.43	2.43	
1:2:3	C	90000	11.11	23.34	2.59	2.59	

Discussion

The average compressive strength of 1:2:2 and 1:2:3 are 7.73MPa and 3.84MPa respectively. The values obtained are less than the minimum compressive value of light weight concrete for 28-day strength which should not be less than 17.5 MPa for structural purposes.The average density of sawdust-palm kernel shellcrete for 1:2:2 and 1:2:3 are 1150.6Kg/m3 and 1238.5Kg/m3 respectively; from literature, the density of light-weight concrete should not exceed 1840kg/m3.

The split tensile strength of sawdust-palm kernel shellcrete composite ranges from 1.43MPa to 1.57MPa. The tensile strength of light weight concrete according to literature ranges from 1.87 to 2.75MPa. This shows that the split tensile strength of the Sawdust-palm kernel shellcrete did not conform to that specified for light weight concrete according to literature.

The average flexural strength of sawdust-palm kernel

Shellcrete beams ranged from 2.5Mpa to 2.76Mpa. The static modulus of elasticity of sawdust-palm kernel shellcrete composite ranges from 4.06MPa to 4.42MPa; but the static modulus of elasticity of normal concrete ranges from 21.4GPa to 46.4GPa that means the values obtained from sawdust-palm kernel shellcrete is less than those of normal weight concrete.

The Poisson Ratio of sawdust-palm kernel shellcrete composite ranges from 0.2 to 0.37 while that of normal concrete ranges from 0.13 to 0.3.The shear modulus of sawdust-palm kernel shellcrete ranges from 1.48 Gpa to 1.83Gpa while the shear modulus of sawdust-palm kernel shellcrete ranges from 2.72 to 4.15 according to literature.

Conclusion

From the results, the average compressive strength for the two mix ratios obtained are less than the minimum compressive value of light weight concrete for 28-day strength which should not be less than 17.5 Mpa for structural purposes. This pitfall can be augumented by the use of an additive. The average density of sawdust-palm kernel shellcrete for 1:2:2 and 1:2:3 are 1150.6Kg/m3 and 1238.5Kg/m3 respectively; from literature, the density of light-weight concrete should not exceed 1840kg/m3. Therefore, sawdust-palm kernel shellcrete composite is a light- weight concrete in terms of density.

Also, from the results, the split tensile strength of sawdust-palm kernel shellcrete composite falls within the standard tensile strength of light weight concrete, according to literature ranged from 1.87 to 2.75Mpa. Therefore, the tensile strength is virtually okay for a light - weight concrete. The Poisson Ratio of sawdust-palm kernel shellcrete composite ranged from 0.2 to 0.37 while that of normal concrete ranges from 0.13 to 0.3. These values conforms adequately and suitable for a light weight concrete.

Recommendation

From the results obtained, the following recommendations are made:

i. Further researches should be done on saw dust- palm kernel shellcrete using other possible mix ratios for light weight concrete, so as to see if there could be an improved strength .

ii.Further studies should be done on the structural properties of a light reinforced sawdust- palm kernel shellcrete with reinforcements such as bamboo stick or guinea corn straw. This will ascertain if the strength can be closely comparable to those of convectional slab for heavy structural purposes.

iii.Sawdust- palmkernel shellcrete composite should be exclusively for a light weight less critical structural elements such as slabs with a light imposed load than those of convectional concrete.

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