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Flexural strength and Deflection of Sawdust – Quarry Dust – Plywood Composite Slab

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ABSTRACT
This Paper studies the flexural strength and deflection of Sawdust–Quarry dust–Plywood Composite Slab. The materials used include Cement, Quarry dust, Sawdust, Plywood, Nails, and water. Laboratory test were carried out on this composite according to standard test procedures. They were tested for flexural strength and deflection. It was observed that for a 1200mm width of slab with thicknesses between 100mm to 175mm and Plywood Thickness 12.5mm to 20mm, the average flexural strength of this composite slab ranges from 1.32MPa to 3.30MPa. The deflection slab ranges from 106mm to 33mm while those of plain composite slab ranges from 20mm to 5mm.

Introduction

As human population increase across the world, the need to provide one of the barest necessities of life – shelter becomes paramount. And as modernization and industrialization widen the gap between the rich and the poor, the need to provide affordable housing for the lowly in our society becomes even more imperative. Many researches have been conducted on how to improve on the engineering properties of various construction materials and also on various construction methods all in an effort to maximize the utilization of materials available within our environment in providing shelter for all. A lot of researchers have looked at various means of providing affordable, environmentally friendly and durable housing for all. Such works have established the cost effectiveness of using materials such as compressed stabilized Earth Block in building low cost and environmentally friendly buildings [1]. Also, materials such as Ferrocement has been shown to have cost benefits as a form of lightweight composite building Materials [2]. While others have looked at construction methods such as in-situ construction, pre-fabrication, precast of buildings etc.

Conventional structures such as buildings are mostly made of reinforced concrete. Reinforced concretes are concrete that have other materials such as fibers, steel bars of steel plates implanted in them to enhance their strength [3]. Reinforced materials are placed in the concrete in such a way that the two materials complement each in resisting the applied load.

Slab is a flat two-dimensional planar structural element having thickness that is very small compared to its other two dimensions [4]. Unlike beams, slabs are relatively thin structural members. They are normally used as floors and occasionally as roof systems in multi-storey buildings.

Slabs are very important component of buildings because they provide the surface on which must functions of the structure are performed.

As the world go greener and the need to effectively recycle construction waste product gains increasing emphasis, attention has been drawn to the need to further utilize Sawdust either directly or as its bye product – Plywood. Also, of interest is the need to increase the utilization Quarry dust which is obtained in large quantities during Quarry processes. For the purpose of this work, we shall be looking at a form of composite slab, made from Sawdust, Quarry dust, Plywood and cement. These materials apart from cement are bye products of wood and granite from saw mills and granite quarries respectively. They are two major construction waste materials.

2. Materials

2.1 Cement

The cement used for this work is Portland – Limestone Cement designated as CEM II/A-L 42.5N. The test of its chemical composition is according to BS EN 196 – 2: 2013 [5]. The chemical composition conforms to the provisions of BS EN 197: 2000 [6] and NIS 444 – 1:2003 [7]. It falls within the grinding fineness of Cement grade 42.5N which is the Normal setting cement suitable for medium and heavy concrete works.

2.2 Sawdust

Sawdust used for this work has particles sizes classified according to their granulometry, in sieves of different sizes according to BS EN 1015-1: 1999 [8]. It has a bulk density of 368.20Kg/M^3, an average specific gravity of 0.35 and a percentage of water absorption of 45%. Also, this sample has a coefficient of uniformity Cu of 2.8 and a Coefficient of curvature Cc of 1.0. The maximum aggregate size of this Sawdust is 4mm.

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2.3 Quarry dust

Aggregate was tested according to BS EN 1015-1: 1999 [8]. The size ranges from 0 – 5mm, with a bulk density of 1282Kg/M^3 and an average specific gravity of 2.76. Its coefficient of Uniformity is 6.8, while its Coefficient of curvature Cc is 0.65. The sieve analysis shows that it falls in Zone II of the grading of fine aggregates as given in BS 882:1978[9] and NIS 013–1: 1974 [10] and is suitable for making concrete.

2.4 Plywood

The Plywood for this work falls within the grade C-C that is, grade C group 1 (Equivalent to F8 grade) The 12.5mm and 20mm Plywood used in this work have bending strengths in N/mm width of 513 and 1240 for the face grain parallel to the span respectively and 225 and 635 for the face grain perpendicular to the span respectively.

2.5 Water

The water is potable and conforming to the specifications of BS EN 1008: 2002 [11] The water is clear in color, has a pH value of 7.1 and it is free from any physical organic matter, making it good for the production and curing of concrete.

2.6 Nails

They are 50mm in length, made from Aluminum alloys and belong the class known as Gypsum wallboard nails. They conform to BS 1202-3: 1974 [12].

3. Methods

3.1 Production of plain Sawdust-Quarry dust – Composite Slabs.

For the purpose of this work, 4 sets of Molds measuring 1200mm x 900mm x 100mm, 1200mm x 900mm x 125mm, 1200mm x 900mm x 150mm, and 1200mm x 900mm x 175mm were formed. A mixture of Sawdust – Quarry dust composite was produced using a mix ratio of 0.65:1:3:3 as shown in Plate 1. This mixture was placed in the various molds and vibrated to ensure adequate compaction. A total of 16 samples were produced, 4 from each of the 4 sets of molds. The samples produced were demolded after 24 hours and cured in cold wet environment. The production of the test samples was according to BS EN 12390 – 5: 2009 [13].

3.2Production of Sawdust - Quarry dust – Plywood composite Slabs.

The Plywood for the laminates were sawn and nailed together into laminate molds of sizes 1200mm x 900mm x 100mm, 1200mm x 900mm x 125mm, 1200mm x 900mm x 150mm, and 1200mm x 900mm x 175mm. Two sets of these laminate molds were produced using 12.5mm and 20mm thick Plywood sizes.

The Sawdust-Quarry dust composite was placed in the various laminate molds and vibrated to ensure adequate compaction. To ensure proper bond between Sawdust - Quarry dust–composite and the Plywood, stirrups were introduced at intervals of 300mm to hold the top and bottom members of the laminates together. A total of 32 slabs were cast, 16 slabs each from the two sets of laminate molds produced using 12.5mm and 20mm Plywood thicknesses. The samples were cured in cold wet environment 28 days.The production of the test samples was according to BS EN 12390 – 5: 2009 [13]. A typical example of Sawdust-Quarry dust – Plywood composite slab system is as shown in Figure 1.

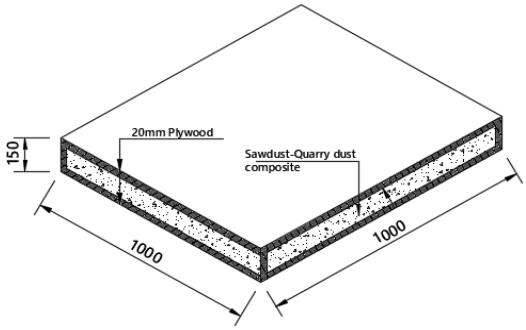

Figure 1. Typical example of Sawdust – Quarry dust – Plywood composite slab

3.3 Flexural Strength Test of Sawdust – Quarry dust – Plywood composite slab

Flexural strength tests were carried out in order to determine the Flexural strength of the Sawdust – Quarry dust – Plywood composite slab using the Magnus frame. In this test, the sample was cleaned, placed in the Machine and positioned such that the center of the slab is directly under the hydraulic press device. The hydraulic arm was operated manually to apply a continuous load on the middle of the test sample until failure occurs. The test set-ups are shown in Plates 1 and Plate 2. The load at failure is recorded against the test sample and used in to determine the flexural strength. This test conforms to BS EN 12390 – 5: 2009 [13].

The flexural strength, f_{cf} (N/mm^2) is given by Equation 1.0

$$f_{cf} = \frac{F\,x\,L}{d_1 x {d_2}^2} \quad (1.0)$$

Where F is the breaking load (N);

d_1 and d_2 are the lateral dimensions of the cross-section (mm)

L is the distance between the supporting rollers (mm).

3.4 Deflection Test of Sawdust – Quarry dust – Plywood composite slab.

This test was carried out concurrently with the flexural test. The method used to measure deflection is according to [to BS EN 12390 – 5: 2009 [13].as illustrated in CS1: 2010 [14].

Plate 1. Positioning of composite slab.

Plate 2. Testing of composite slab.

4. Result Presentation

4.1 Flexural Strength Test Results on Sawdust – Quarry dust – Plywood composite slab.

The results of flexural strength test of Sawdust – Quarry dust – Plywood composite slab are as shown in Table 1.

Table 1. Results of 28th day Flexural Strength Test

Mix ratio	Thickness of plies (mm)	Sample Sizes (mm)	Average Flexural Strength
1:2:2	12.5	1200 X 900 X 100	1.319
1:2:2	12.5	1200 X 900 X 125	1.738
1:2:2	12.5	1200 X 900 X 150	2.187
1:2:2	12.5	1200 X 900 X 175	2.782
1:2:2	20	1200 X 900 X 100	1.520
1:2:2	20	1200 X 900 X 100	2.337
1:2:2	20	1200 X 900 X 150	2.64
1:2:2	20	1200 X 900 X 175	3.304
1:3:3	12.5	1200 X 900 X 100	1.145
1:3:3	12.5	1200 X 900 X 125	1.641
1:3:3	12.5	1200 X 900 X 150	1.937
1:3:3	12.5	1200 X 900 X 175	2.661
1:3:3	20	1200 X 900 X 100	1.345
1:3:3	20	1200 X 900 X 125	2.106
1:3:3	20	1200 X 900 X 150	2.585
1:3:3	20	1200 X 900 X 175	2.909

4.2 Flexural strength test results of plain Sawdust – Quarry dust composite slab.

The flexural strength of plain Sawdust – Quarry dust composite slab without reinforcement or Plywood laminate are as shown in Table 2,

Table 2. Results of 28th day flexural strength test for Plain Sawdust – Quarry dust composite slab.

Mix ratio	Sample Sizes (mm)	Crushing Load (KN)	Flexural Strength of Slab (MPa)	Average Flexural Strength (MPa)
1:3:3	1200 X 900 X 100	7.74	0.697	
1:3:3	1200 X 900 X 100	7.79	0.701	0.699
1:3:3	1200 X 900 X 125	14.29	0.823	
1:3:3	1200 X 900 X 125	14.10	0.812	0.818
1:3:3	1200 X 900 X 150	25.58	1.023	
1:3:3	1200 X 900 X 150	27.55	1.102	1.063
1:3:3	1200 X 900 X 175	44.98	1.322	
1:3:3	1200 X 900 X 175	42.60	1.252	1.287

4.3 Deflection at failure of Sawdust – Quarry dust – Plywood composite slab.

The results of deflection test for Sawdust – Quarry dust – Plywood composite slab are shown in Table 3.

Table 3. Results of 28th day Deflection Test for Sawdust – Quarry dust – Plywood composite slab.

Mix ratio	Thickness of plies (mm)	Sample Size (mm)	Average Deflection (mm)
1:2:2	12.5	1200 X 900 X 100	102.5
1:2:2	12.5	1200 X 900 X 125	82.5
1:2:2	12.5	1200 X 900 X 150	51
1:2:2	12.5	1200 X 900 X 175	22.5
1:2:2	20	1200 X 900 X 100	87.5
1:2:2	20	1200 X 900 X 125	75
1:2:2	20	1200 X 900 X 150	42
1:2:2	20	1200 X 900 X 175	21.5
1:3:3	12.5	1200 X 900 X 100	109
1:3:3	12.5	1200 X 900 X 125	92.5
1:3:3	12.5	1200 X 900 X 150	52.5
1:3:3	12.5	1200 X 900 X 175	34
1:3:3	20	1200 X 900 X 100	99
1:3:3	20	1200 X 900 X 125	82.5
1:3:3	20	1200 X 900 X 150	47
1:3:3	20	1200 X 900 X 175	33

4.4 Deflection test results for plain Sawdust – Quarry dust composite slab.

The results of deflection test for plain Sawdust – Quarry dust composite slab are shown in Table 4.

Table 4. Results of 28th day deflection tests for Plain Sawdust – Quarry dust composite slab.

Mix ratio	Thickness of plies (mm)	Sample Size (mm)	Average Deflection
1:3:3	None	1200 X 900 X 100	20
1:3:3	None	1200 X 900 X 125	13
1:3:3	None	1200 X 900 X 150	9
1:3:3	None	1200 X 900 X 175	5

The Data from Tables 1 and Table 2 are graphically illustrated Figure 2, Figures 3 and Figure 4. From these Tables and figures, it can be seen that the flexural strength of Sawdust – Quarry dust composite slab increases significantly with the introduction of a Plywood laminate. Over a range of slab thicknesses 100mm – 175mm and mix ratio 1:3:3, the addition of the Plywood laminate led to increase in range of Flexural strength from 0.699MPa – 1.287MPa to 1.145Mpa – 1.287Mpa.

Figure 1 shows that increase in Plywood thickness over the same mix ratio leads to an increase in flexural strength. As illustrated in Figures 2 and Figures 3, there is also a net increase in this property with changes in mix ratio. This can be seen in the overall increase in flexural strength from 1.145MPa – 1.937MPa in Mix ration 1:3:3 compared to the 1.319MPa – 2.187MPa obtained with mix ratio 1:2:2. As expected, the flexural strength increases with increase in slab thickness. The results in Tables 1 show flexural strength in the range of 1.145MPa – 3.304MPa. This is however lower than the 6.2MPa and 7.6MPa obtained by [15] using Timber concrete composite floors with prefabricated Fiber Reinforced Concrete measuring 19 x 150 x 508 mm and 33 x 900 x 960.

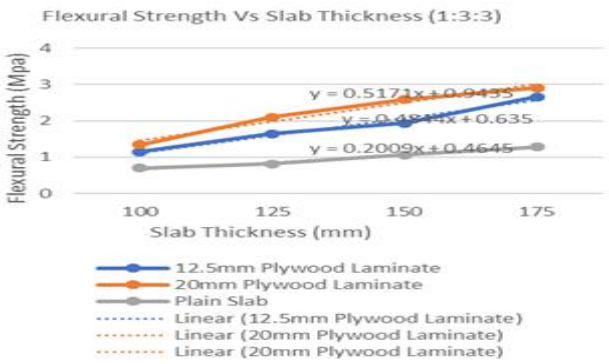

Figure 2. The relationship between Flexural Strength and Slab Thickness with mix ratio 1:3:3.

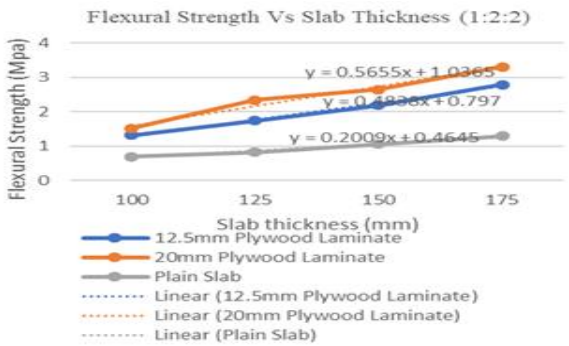

Figure 3. The relationship between Flexural Strength and Slab Thickness with mix ratio 1:2:2.

4.5 Deflection of Sawdust – Quarry dust – Plywood composite slab

From Table 3, the average deflection of Sawdust – Quarry dust – Plywood composite slab with Plywood thickness of 12.5mm using mix ratio of 1:2:2 and slab Thicknesses between 100mm and 175mm ranges from 102.5mm to 22.5mm. That of 20mm thick Plywood laminate with same mix ratio and slab thickness ranges from 87.5mm to 21.5mm. On the other hand, for a mix ratio of 1:3:3, the slab with 12.5mm thick Plywood laminate and slab depth between 100mm and 175mm gave average deflection values in the range of 109mm to 34mm. while the slab with 20mm thick Plywood laminate, mix ratio of 1:3:3 and slab thicknesses between 100mm and 175m have average deflection ranging from 99mm to 33mm. For slab of same thickness, deflection also reduces with increase in Plywood thickness. From the above results, the deflection of Sawdust – Quarry dust – Plywood composite slab reduces with increase in Plywood thickness. From Table 4, The deflection of plain Sawdust-Quarry dust composite slab for thicknesses between 100mm to 175mm ranges from 10mm to 5mm.

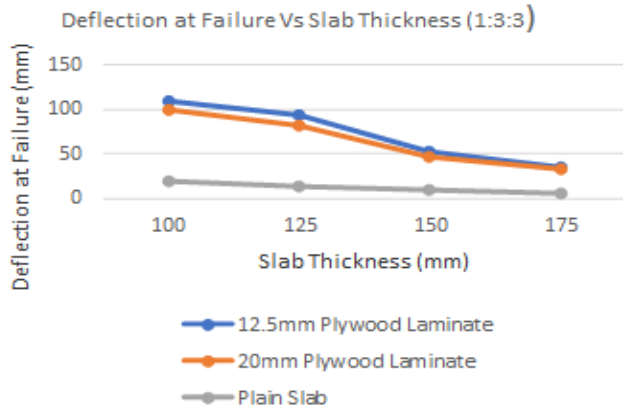

Figure 4. The relationship between Deflection and Slab Thickness with mix ratio 1:3:3.

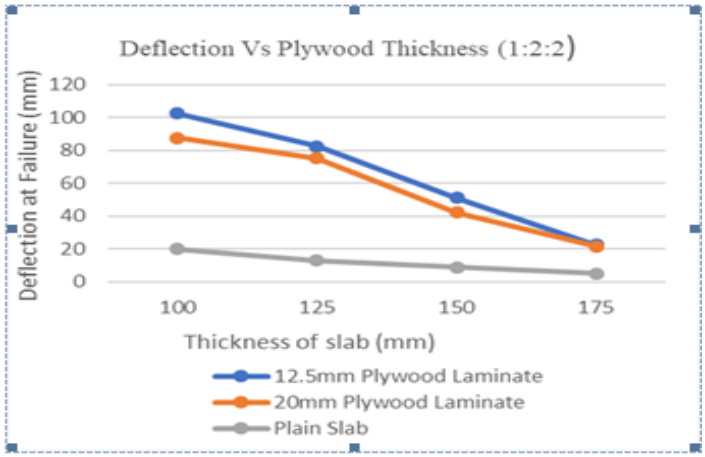

Figure 5. The graph of Deflection Vs Slab Thickness with mix ratio 1:2:2.

5. Conclusions

• The average flexural strength of plain Sawdust – Quarry dust composite slab ranges from 0.699 – 1.287Mpa for slab thickness in the range of 100 – 175mm.

• The Average flexural strength of Sawdust – Quarry dust – Plywood composite slab of thickness 100 – 175mm ranges from 1.32MPa to 3.30MPa. This is also affected by the thickness of the laminate Plywood.

• The deflection at failure of Sawdust – Quarry dust – Plywood composite slab ranges from 106mm to 33mm while those of plain Sawdust – Quarry dust composite slab ranges from 20mm to 5mm. for slab thicknesses of 100 – 175mm

• Comparing the deflection of plain Sawdust – Quarry dust composite slab and Sawdust – Quarry dust – Plywood composite slab shows that introducing the Plywood laminate increases the Flexural strength between 33.63% and 53.65%.

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