SSRG International Journal of Civil Engineering Volume 6 Issue 7, 7-12, July 2019
ISSN: 2348 – 8352 /doi:10.14445/23488352/IJCE-V6I7P102

Structural Characteristics of Sawdust – Quarry Dust Composite

Owus. M. Ibearugbulem[1], Christopher. K. Amaechi[2], Ngozi L. Nwakwasi[2], Lewechi Anyaogu[3], Joan I. Arimanwa[4], Ignatius C. Onyechere[5].

[1,2,3,4,5:] *Department of Civil Engineering, Federal University of Technology Owerri, Imo State, Nigeria.*

Abstract.
This paper aims to study the Structural characteristics of Sawdust – Quarry dust Composite Slab. The composite slab is a mixture of Sawdust, Quarry dust, and cement. The was tested for compressive strength, split tensile strength test, density, Poison Ratio, static modulus, shear modulus, and flexural strength. Laboratory tests were conducted according to relevant British and United States standard test procedures. It was observed that for mix ratios 0.55:1:1:1, 0.65:1:2:2 and 0.75:1:3:3, the average compressive strengths for the three (3) mix ratios used were 5.50MPa, 4.45MPa, and 2.46MPa at 7day respectively, and 10.38MPa, 9.13MPa, and 4.36MPa at 28days respectively. The average flexural Strength of beam samples from the three (3) mix ratios are 2.32MPa, 2.04MPa, and 1.84MPa, respectively. The average splitting tensile strength for the three (3) mix ratios are 2.194MPa, 1.768MPa, and 1.521MPa, respectively. The average density of Sawdust – Quarry dust is $1575.64\ kg/m^3$. *The average static moduli for the mix ratios 0.55:1:1:1, 0.65:1:2:2 and 0.75:1:3:3 are 9.26Gpa, 8.69Gpa and 6.83Gpa respectively. The average Poisson's ratio ranges from 0.19 to 0.35, while the shear moduli range from 3.90MPa to 2.72MPa. The average flexural Strength of Sawdust – Quarry dust - Plywood composite slab ranges from 1.32MPa to 3.30MPa.*

Keywords ----- *Sawdust, Quarry dust, slab, compressive Strength, flexural Strength.*

I. INTRODUCTION

Slabs are very important components of buildings. The slab was defined in [20] as a flat two-dimensional planar structural element having a thickness that is very small compared to its other two dimensions. Unlike beams, slabs are relatively thin structural members. They are normally used as floors and occasionally as roof systems in multi-floor buildings.

The use of composite materials in buildings has been with us for ages. The most striking example of an early man-made composite is the straw-reinforced clay, which was used extensively by an ancient civilization and prehistoric times [25].

In modern times, steel bars have had the role of reinforcement. However, in recent times especially in the past decade, as described by [29], there has been an increased interest towards two alternative types of composite concrete construction; Fibre Reinforced Concrete (FRC) and Fibre Reinforced Plastic (FRP). FRC is a form of fiber within a concrete background, while FRP is an alternative to steel bars.

There have also been numerous efforts made towards finding alternatives to other aggregate components of concrete-like sharp sand and chippings. Such investigations include; The strength and durability properties of concrete containing Quarry rock dust as fine aggregates [21] and the use of sawdust for partial replacement of sand [27]. Reference [28] studied the "Mechanical Properties of Recycled Coarse Aggregate Concrete with Mineral Admixture."

The structural implication of replacing concrete floor slab with timber in composite construction was studied by [24]. In his work, [24] explored the feasibility of using cross-laminated timber (XLT) floor slab. This work shows that these timber slab forms are effective in buildings with supports up to 9m apart and with an imposed load of $4\ kN/m^2$ Or less.

Another serviceability consideration for wood-concrete composite like durability has also attracted the attention of some researchers. [18] studied the fire behavior of wood-concrete composite slab. They found that for a timber plank with a thickness of between 20 – 120 mm, a wood composite slab can withstand temperature in the range of 0 – 1000ºC for up to 0 – 90 minutes.

This work will investigate the structural characteristics of Sawdust – Quarry dust composite slabs made by combining Cement, Sawdust, and Quarry dust. It will specifically investigate its Strength in flexure, compressive Strength, shear strength, modulus of elasticity, Poisson Ratio, and shear modulus.

II. MATERIALS

This section contains a brief explanation of the various materials used in this work.

A. Cement

The cement used for this work is Portland Limestone Cement designated as CEM II/A-L 42.5N. Its physical properties conform to [9]. The chemical composition also conforms to BS EN 196 – 2: 2014. It falls within the grinding fineness of Cement grade 42.5N which is the Normal setting cement suitable for medium and heavy concrete works

B. Sawdust

Sawdust used for this work has particle sizes classified according to their granulometry, in sieves of different sizes according to [12]. It has a bulk density of $368.2\, kg/m^3$, 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 Sawdust used was 4mm.

C. Quarry dust

Aggregate size ranges from 0 – 5mm, with a bulk density of $128\, kg/m^3$ 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 [13] and is suitable for making concrete.

D. Water

The water is potable and conforming to the standard of [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.

III. METHODS

This section is contained a brief description of the procedures for the various laboratory tests carried out on the test specimens.

A. Compressive Strength Test of Sawdust – Quarry dust – composite

All tests carried out on the Sawdust – Quarry dust composite and the testing methods adopted are shown in Table 1. Manual methods were used in mixing the various components of the composite, and all batching of materials was done by volume.

Table 1: Testing methods adopted for the various tests.

Physical Properties Tested	Number of Samples Tested	Tested Method
Compressive Strength (F_c)	9	BS EN 12390-3:2009
Density	9	BS EN 12390-3:2009
		ASTM C 330 -2009
Split Tensile Strength	9	BS EN 12390-1 (2000) and BS EN 12390 – 6 (2009).
Static Modulus of Elasticity	9	BS EN 12390-13: 2013
Poisson Ratio	9	BS EN 12390-13: 2013
Flexural Strength	9	BS EN 12390-4 (2000).
Shear Strength	9	BS EN 12390-13: 2013
Shear Modulus	9	BS EN 12390-13: 2013
Flexural Strength	32	BS EN 12390-5:2000.
Deflection	41	BS EN 12390-5:2009

B. Production of plain Sawdust - Quarry dust – composite Slabs.

For the purpose of this work, 4 sets of Moulds measuring 1200mm x 900mm x 100mm, 1200mm x 900mm x 125mm, 1200mm x 900mm x 150mm, and 1200mm x 900mm x 175mm were formed. They were cleaned and well oiled. A mixture of Sawdust – Quarry dust composite was produced using a mix ratio of 0.65:1:2:2. 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 demoulded after 24 hours and cured in a cold, wet environment by sprinkling water on them 3 times daily for 7days and 28days as the test age requires. The production of the test samples was according to [14].

C. 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 composite slab using the Magnus frame. In this test, the Sample to be tested was cleaned of dust and any other foreign materials. The slab was placed in the Machine and positioned such that the center of the slab is directly under the hydraulic press device. Metal plates were used to ensure that adequate contact was made between the Hydraulic press device and the Sample being tested. The hydraulic arm was operated manually to apply a continuous load on the middle of the test sample until failure occurs. The load at failure is recorded against the test sample and used in Equation 3.12 to determine the flexural strength. This test conforms to[14]

IV. RESULT PRESENTATION

The results of the various laboratory tests carried out on the test specimen are presented in the following tables.

Table 2: Compressive strength Results

.Mix ratio	Area of Sample (mm^2)	Weight of Sample (Kg)		Crushing load (KN)		Compressive Strength (Mpa)		Average Compressive Strength (Mpa)	
		7days	28days	7days	28days	7days	28days	7days	28days
1:1:1	22500	5.12	5.4	118.4	230.56	5.26	10.25	5.50	10.38
1:2:2	22500	5.2	5.3	99.56	208.9	4.42	9.28	4.45	9.13
1:3:3	22500	5.13	5.34	55.34	97.89	2.46	4.35	2.46	4.36

Table 3: Dry Density Test Results

Mix ratio	Sample No	The volume of Sample in (m^3)	Weight of Sample in (Kg)	Density of the Sawdust-Quarry dust in kg/m^3
1:1:1	A	0.003375	5.4	1600.00
1:1:1	B	0.003375	5.36	1588.15
1:1:1	C	0.003375	5.3	1570.37
1:2:2	A	0.003375	5.3	1570.37
1:2:2	B	0.003375	5.34	1582.22
1:2:2	C	0.003375	5.25	1555.56
1:3:3	A	0.003375	5.34	1582.22
1:3:3	B	0.003375	5.23	1549.63
1:3:3	C	0.003375	5.34	1582.22

Average density of Sawdust – Quarry dust composite is 1575.64Kg/m^3

Table 4: 28th day Splitting tensile Strength Test Results

Mix ratio	Sample No	(πdL) (mm^2)	Weight of Sample (Kg)	Crushing load (KN)	Average splitting Tensile Strength (MPa)
1:1:1	A	141371.67	10.71	155.08	2.194
1:2:2	A	141371.67	10.59	124.97	1.768
1:3:3	A	141371.67	10.61	107.51	1.521

Table 5: Static modulus of elasticity

Mix ratio	The density of Sample in (mm^2)	Weight of Sample in (Kg)	Crushing load in (KN)	Compressive Strength (MPa)	Average Static modulus of elasticity(MPa)
1:1:1	1586.17	5.4	233.59	10.36	9.41
1:2:2	1569.38	5.3	205.3	9.13	8.75
1:3:3	1541.36	5.34	98.1	4.36	6.56

Table 6: Poisson Ratio Test Results for Sawdust – Quarry dust composite

Mix ratio	The density of Sample in (kg/m^3)	Crushing load in (KN)	Compressive Strength (MPa)	Tensile Stress (MPa)	Average Poisson Ratio (μ)
1:1:1	1586.17	233.59	10.36	2.194	0.21
1:2:2	1569.38	205.3	9.13	1.768	0.19
1:3:3	1541.36	98.1	4.36	1.521	0.35

Table 7: Shear Modulus Test Results

Mix ratio	The density of Sample in (mm^2)	Tensile Stress (MPa)	Compressive Stress (MPa)	Static modulus of elasticity	Poisson Ratio μ	Average Shear Modulus (GPa)
1:1:1	1586.17	2.194	10.36	9.41	0.21	3.90
1:2:2	1569.38	1.768	9.13	8.75	0.19	3.68
1:3:3	1541.36	1.521	4.36	6.56	0.35	2.43

Table 8: Flexural and Shear Strength Test Results for Sawdust – Quarry dust Composite Beams

Mix ratio	Sample No	Cross-Sectional Area (mm^2)	Weight of Sample in (Kg)	Crushing load in KN	Flexural Strength (MPa)	Average Flexural Strength (MPa)	Shear Strength (N/mm^2)	Average Shear Strength (MPa)
1:1:1	A	90000	16.2	24.98	2.22		0.278	
1:1:1	B	90000	16.08	25.95	2.31	2.32	0.288	0.290
1:1:1	C	90000	15.9	27.4	2.44		0.304	

1:2:2	A	90000	15.9	22.78	2.02	2.04	0.253	0.255
1:2:2	B	90000	16.02	24.01	2.13		0.267	
1:2:2	C	90000	15.75	22.1	1.96		0.246	
1:3:3	A	90000	16.02	20.45	1.82	1.84	0.227	0.230
1:3:3	B	90000	15.69	20.3	1.80		0.226	
1:3:3	C	90000	16.02	21.38	1.90		0.238	

Table 9: Results of workability test for Sawdust – Quarry dust composite.

W/C Ratio	0.55			0.65			0.75		
Mix Ratios	1:1:1	1:2:2	1:3:3	1:1:1	1:2:2	1:3:3	1:1:1	1:2:2	1:3:3
Ave Slump Value (mm)	77	50	37	100	77	52	125	102	75

Table 10:Average Values of Structural characteristics of Sawdust-Quarry dust composite

Mix ratio	Compressive Strength (MPa)	Dry Density (Kg/m^3)	Shear Strength N/mm^2	Poison ratio μ	Flexural strength N/mm^2	Split Tensile Strength N/mm^2	Shear Modulus (GPa)	Static modulus elasticity (GPa)
1:1:1	10.38	1586.17	0.290	0.21	2.32	2.194	3.90	9.26
1:2:2	9.13	1569.38	0.255	0.19	2.04	1.768	3.67	8.69
1:3:3	4.36	1571.36	0.230	0.35	1.84	1.521	2.72	6.83

Table 11: Results of 28th-day flexural strength test for plain Sawdust – Quarry dust composite slab

Mix ratio	Sample Sizes (mm)	Average(MPa)
1:3:3	1200 X 900 X 100	0.699
1:3:3	1200 X 900 X 125	0.818
1:3:3	1200 X 900 X 150	1.063
1:3:3	1200 X 900 X 175	1.287

Table 12: Results of 28th-day deflection tests for plain Sawdust – Quarry dust composite slab (without Plywood laminate).

Mix ratio	Sample Size (mm)	Average Deflection (mm)
1:3:3	1200 X 900 X 100	20
1:3:3	1200 X 900 X 125	15
1:3:3	1200 X 900 X 150	10
1:3:3	1200 X 900 X 175	5

V. RESULT DISCUSSIONS

A. Compressive Strength

From Table 2, the average 7th Day compressive strength reduces as the mix ratio increases. Also, from Table 4.6, the average 28th-day compressive strength for the three different mix ratios can be seen. The values of compressive strength for mix ratio 1:1:1, 1:2:2 and 1:3:3 are 10.38MPa, 9.13MPa) and 4.36MPa respectively. The values obtained are less than the minimum value of lightweight concrete at 28-day Strength, which is mostly higher than 17.5MPa for structural concrete. However, the values obtained here are higher than the 1.2MPa to 3.0MPa obtained by [22] using Perlite but lower than 15MPa they obtained using Pumice.

B. Density of Sawdust – Quarry dust composite.

The average density of Sawdust – Quarry dust composite is $1575.64\ \mathrm{Kg/m^3}$As shown in Table 3. This is lower than the $1980\ \mathrm{Kg/m^3}$Obtained by [23]. Comparing with the provisions of [6], this falls within the density of lightweight concrete, which does not exceed$2000\ \mathrm{Kg/m^3}$. Therefore, Sawdust – Quarry dust composite is a lightweight concrete in terms of density.

C. Splitting tensile Strength of Sawdust – Quarry dust composite

The split tensile strength of Sawdust – Quarry dust composite, as shown in Table 4, ranges from $1.546 MPa\ to\ 1.962 MPa$. These values are similar to the$1.58\ \mathrm{N/mm^2}$–$1.74\ \mathrm{N/mm^2}$ obtained by [26] for lightweight concrete using Silica fume and $1.36\ \mathrm{N/mm^2}$–$3.18\ \mathrm{N/mm^2}$ obtained by [17] using Sawdust and sand but lower than the $4.24\ \mathrm{N/mm^2}$–$3.82\ \mathrm{N/mm^2}$Range obtained by [31]using 10% to 40% partial replacement of fine aggregate with Sawdust and Quarry dust. The tensile strength of lightweight concrete, according to literature, ranges from 1.87 to 2.75MPa.

D. Static modulus of elasticity Results

From Table 5, the static modulus of elasticity of Sawdust – Quarry dust composite ranges from 6.83MPa to 9.26MPa. This is lower than the values of 16MPa to 25MPa obtained by [2] for high strength lightweight concrete. The static modulus of elasticity for normal concrete ranges from 21.4GPa to 46.4GPa, which means the values obtained from

Sawdust – Quarry dust composite is less than those of normal weight concrete.

E. Poisson Ratio of Sawdust – Quarry dust composite

The Poisson Ratio of Sawdust – Quarry dust composite, as shown in Table 6, ranges from 0.19 to 0.35. this falls within the range of weak concrete since the Poisson ratio for normal concrete lies within 0.1 to 0.15.

F. Shear Modulus of Sawdust – Quarry dust composite

As shown in Table 7, the average shear modulus of Sawdust – Quarry dust composite beams ranges from 2.43Gpa to 3.90Gpa.

G. Flexural Strength and Shear strength of Sawdust – Quarry dust Composite Beams

The average flexural Strength of Sawdust – Quarry dust composite beams ranges from 1.84MPa to 2.32MPa, as shown in Table 8. This is lower than the 6.9MPa obtained by [31] using 30% and 15% Quarry dust and Sawdust, respectively, as a partial replacement for fine aggregates. Also, the shear strength ranges from$0.226\ to\ 0.304\,\mathrm{N/mm^2}$. The result also falls outside the permissible Stress in bending for concrete, which ranges from 2.5MPa to 16MPa.

H. Workability of Sawdust – Quarry dust composite

From Table 9, it can be seen that at the constant water-cement ratio, the average slump value reduces as the quantity of Sawdust and Quarry dust increases. This implies that the workability of Sawdust – Quarry dust composite reduces with an increase in the quantity of Sawdust. This result is consistent with the results obtained by [27] and [30], who worked on the use of Sawdust as a partial replacement for sand in concrete and brick mortar, respectively.

I. Flexural strength and Deflection of plain Sawdust – Quarry dust composite slab

From Tables 11 and Table 12, the Flexural Strength of the composite ranges from 0.699 – 1.287Mpa for slab thicknesses of 100 – 175mm. Also, the Deflection ranges from 20mm to 5mm over the same range of slab thickness. This significantly increased with an increase in slab thickness.

VI. CONCLUSIONS

The average compressive strength of Sawdust – Quarry dust composite ranges from 2.26MPa to 5.50MPa at 7days and 4.36MPa to 10.38MPa at 28days. These values are below recommended value for normal structural concrete but are within the nominal concrete value, which has its maximum of 10MPa. This grade of concrete can be used for lintels, non-load bearing partition walls, and as toppings for slabs.

The average density of Sawdust – Quarry dust composite is$1575.64\,\mathrm{Kg/m^3}$; from literature, the density of lightweight concrete should not exceed $2000\,\mathrm{Kg/m^3}$. Therefore, Sawdust – Quarry dust composite is a lightweight concrete in terms of density.

The split tensile strength of Sawdust – Quarry dust composite ranges from 1.521MPa to 2.194MPa, but the tensile strength of lightweight concrete, according to literature, ranges from 1.87 to 2.75MPa. Therefore, the split tensile strength of Sawdust – Quarry dust composite is okay for lightweight concrete.

The static modulus of elasticity of Sawdust – Quarry dust composite ranges from 6.56MPa to 9.41MPa, while the static modulus of elasticity of normal concrete ranges from 21.4Gpa to 46.4Gpa. The value obtained from the experiment is less than the value for normal concrete. This means that this composite cannot be used as structural concrete.

The Poisson Ratio of Sawdust – Quarry dust composite ranges from 0.21 to 0.35 while that of normal concrete ranges from 0.1 to 0.15. The Poisson ratio is within limits as those of normal concrete.

The shear strength results range from 0.230 to 0.29MPa, while the shear modulus ranges from 2.43 to 3.9.

The workability of Sawdust – Quarry dust composite reduces with an increase in the quantity of Sawdust. This is related to the high percentage of water absorption of Sawdust.

The average flexural Strength of Sawdust – Quarry dust composite beams ranges from 1.84MPa to 2.32MPa.

The average flexural Strength of plain Sawdust – Quarry dust composite slab ranges from 0.699 to 1.287Mpa for slab thickness in the range of 100 to 175mm. Also, the Deflection at failure, which reduces from 20mm to 5mm, means that better structural properties such as that can be managed to obtain a relatively stable structure.

REFERENCES

[1] ASTM C 330(2009)., Standard Testing method for Determining Density of Structural Lightweight Concrete. ASTM International West Conshohocken, PA, (2014).

[2] Bogas A.J, Gomes A. (2012).Static and dynamic modulus of elasticity of structural lightweight and modified density concrete with and without Nano silica–characterization and normalization, International Journal of Civil Engineering., Transaction A: Civil Engineering., 12(2),(2014),268 – 278.

[3] BS 882. (1978). “Specifications for aggregates from natural sources for concrete.” British Standard Institute. London.

[4] BS 3797.,Lightweight aggregate for concrete. British Standard Institute.,(1976).

[5] BS 5328., (1990)., Specification for the procedures to be used in Producing and Transporting concrete: Part 3. British Standard Institute. London.

[6] BS 5328 (1997).Guide to specifying concrete: Part 1, standard British Institute.

[7] BS 8110. (1997).,Structural use of concrete: - Code of practice for design and Construction: Part 1. British Standard Institute. London.

[8] BS 1881-121 (1983).Testing Concrete. Method of determination of static modulus of elasticity in compression". British Standard Institute London.

[9] BS EN 197 (2000)., Cement. Composition, specifications and conformity criteria for common types of cement: Part 1, British Standard Institute London.

[10] BS EN 932. (1997).,Test for general properties of aggregate: Method of sampling. Part 1. British Standard Institute. London.

[11] BS EN 1008 (2002).,Mixing water for concrete: - Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete". British Standard Institute London.

[12] BS EN 1015-1 (1999)., Methods of test for mortar for masonry. Determination of Particle size distribution.,British Standard Institute.

[13] BS EN 12350. (2000).,Testing Fresh Concrete-Slump test. Part 2". British Standard Institute London.

[14] BS EN 12390. (2000).,Testing Hardened Concrete. Shape, dimension, and other requirements for specimens and molds. Part 1, British Standard Institute. London.

[15] BS EN 12390. (2009).,Testing Hardened Concrete: Flexural Strength of test specimens, Part 5. British Standard Institute. London.

[16] BS EN 12390. (2009). Testing Hardened Concrete: Tensile Splitting strength test of specimens. Part 6. British Standard Institute. London.

[17] Chandana P.S and Mynuddin S.A. (2015)., Experimental study on the strength of concrete by partial replacement of fine aggregate with Sawdust and Robosand". International Journal & Magazine of Engineering Technology, Management, and Research. 2(9),(2015), 343.

[18] Fontana, Mario, Andrea Frangi (2002).Fire Behaviour of Timber-Concrete Composite Slabs, Fire Safety Science-Proceedings of the Sixth International Symposium, 891-902.

[19] Ibearugbulem, O.M. (2006).Mathematical models for Optimization of Compressive Strength of Periwinkle Shells-Granite Concrete. .M.Eng Thesis, Federal University of Technology Owerri, Nigeria.

[20] Ibearugbulem, O.M., Ezeh, J. C., Ettu, L.O.(2014). Energy Methods in Theory of Rectangular Plates (Use of Polynomial Shape Functional),. Liu House of Excellence Ventures Owerri, Nigeria.

[21] Ilangovana, R., Mahendrana, N., and Nagamanib, K., Strength and durability properties of concrete containing Quarry rock dust as fine aggregate. ARPN Journal of Engineering and Applied Science.3(5),20-26.

[22] Kakamare M.S, Pudale Y.M, Nair V.V., Light weight concrete. A research paper was presented at the international conference on 'the latest innovations in science, Engineering and Management' The international CenterGoa, Panjim Goa, India. (2017),209.

[23] Kumar R.S. (2012). Experimental study on the properties of concrete made with alternate construction materials, International Journal of Modern Engineering Research (IJMER).,2(5),(2012),3006-3012

[24] Kwesi, A. Okutu., Structural Implications of Replacing Concrete Floor Slabs with Timber in Composite Construction.M.Eng Dissertation, University of Sheffield United Kingdom.,1, (2012).

[25] Lee, A.W.C., and Short, P.H.Pretreating hardwood for cement-bonded excelsior board. Forest Products Journal 39(10),(1991),68-70,

[26] Mydin M.A, Sani N.M, Mohd M.A, Ganesan S.(2014)., Determining the Compressive, Flexural and Splitting Tensile Strength of Silica Fume Reinforced Lightweight Foamed Concrete, MATEC Web of Conferences 17, 01008,(2014),01008 Pp 5.

[27] Olugbenga Joseph Oyedepo, Seun Daniel Oluwajana, Sunmbo Peter Akande., Investigation of Properties of Concrete Using Sawdust as Partial Replacement for Sand, Civil and Environmental Research.,6(2), (2014),35 – 42.

[28] Pramod A.V., Parashivamurthy P., and Yogananda M.R. and Srishaila J.M., Mechanical Properties of Recycled Coarse Aggregate Concrete with Mineral Admixture, SSRG International Journal of Civil Engineering (SSRG - IJCE)., 6(2), (2019),4 – 12.

[29] Ravindra T and Santosh K (2011)."Fiber-reinforced self-compacting concrete." Rheology and compatibility of ingredients. Vol. 1 Chapter 4, pp 45.

[30] Sasah Jonathan and Charles K. Kankam (2017)."Study of brick mortar using sawdust as a partial replacement for sand." Journal of Civil Engineering and Construction Technology. Vol. 8(6), pp. 59-66

[31] Suji D, Narayanan. A. M, Kartic K.M, Perarasan M. (2016)."Experimental study on partial replacement of fine aggregate with quarry dust and sawdust." International Journal of Advancement in Engineering Technology, Management &Applied Science. Vol. 3, issue 6 June 2016. pp 42.