EMPIRICAL VERIFICATION OF DIFFERENT BRANDS OF CEMENT ON THE COMPRESSIVE STRENGTH OF PAVING STONES MADE FROM PERCENTAGE REPLACEMENT OF SAND WITH SAWDUST

[1]YUSUFF, A.Q.; [1]ALUKO, A. K.; [2]USMAN, S.; [1]ADEDEJI, M.S. & [1]ADAMS, O. T.
[1]Federal College of Forestry, Ibadan, Nigeria.
[2]Forestry Research Institute of Nigeria
yusadeq9@gmail.com; +23480 3663 5343

ABSTRACT

The research was carried out to determine the best and the most appropriate brands of cement that gives the most appropriate strength of paving stone made from *Milicia excelsa* and *Gmelina arborea* sawdust. Stonedust, sawdust and cements were combined in different ratio respectively to form 12 specimens with 5 replicates. Paving stones were tested for their weight and compactible strength. The mean weight value obtained had the highest value cement D + stonedust and lowest value cement B + stonedust. The data collected was subjected to Analysis of Variance (ANOVA) to determine the differences in the weight of pavers. The result showed that there was significant difference between the specimens of compressive strength with brands of cement, Stonedust + Cement B + *Milicia excelsa* had the highest crushing strength of 4269.5KN and was not significantly different from other specimens except Stonedust + Cement B, Stonedust + Cement B + *Gmelina arborea*, Stonedust + Cement C, Stonedust + Cement C + *Gmelina arborea* and Stonedust + Cement D +*Milicia excelsa*. This makes Stonedust + Cement B + *Milicia excelsa* perform better than other specimen. It was recommended that the water absorption of pavers containing sawdust increased and have absorption rate, which means it will be able to withstand environment stress and reduce the cost of production.

Keywords: ANOVA, Cement, CRD, Paving stones, Sawdust.

1.0 INTRODUCTION

Hardscape refers to hard landscape materials in the built environment structures that are incorporated into a landscape (Catriona, 2003). From an urban planning perspective, hardscapes can include very large features, such as paved roads. Most water features are hardscapes because they require a barrier to retain the water, instead of letting it drain into the surrounding soil (Wikipedia, 2020). Pavement in construction is an outdoor floor which include asphalt, concrete, stone such as flagstone, cobblestone, and setts, artificial stone, bricks, tiles, and sometimes wood.

Cement has been restricted to adhesives used to bind stones, bricks, tiles etc. in the construction of buildings and other civil works (Ian, *et al.,* 2009). In the last decade, construction industry has conducted various researches on the utilization of waste products in concrete in order to reduce the utilization of natural resources (Sekar *et al*., 2011). The demand for natural sand is quite high in developing countries since the available sand cannot meet the requirement of the construction sector (Verra, 2010). Because of its limited supply, the cost of natural sand has incredibly increased and its consistent supply cannot be guaranteed so there is need to improvise other materials such as sawdust, palm kernel etc. in the production of pavers. Nonetheless, accumulation of unmanaged wastes especially in developing countries has resulted in an increasing environmental concern. However, the increase in the popularity of using environmental friendly, lightweight construction materials in building industry has brought about the need to investigate how this can be achieved by benefiting environment as well as maintaining the material requirements affirmed in the standards. Since a large demand has been placed on building material industry especially in the last decade owing to the increasing population that causes a chronic shortage of building materials, the civil engineers have been challenged to convert the industrial wastes to useful building and construction materials (Turgut, 2007).

Sawdust as an industrial waste in the timber industry constitutes a nuisance to both the health and environment when not properly managed (Elinwa *et al*, 2011). Sawdust wastes are accumulated from the countries all over the world and cause certain serious environmental problems and health hazards. It is one of the major underutilized byproducts from sawmilling operations. Generation of wood wastes in sawmill is unavoidable hence a great efforts are made in the utilization of such waste (Zziwa1 *et al.*, 2006). *Milicia excelsa* (Africa teak) is a large deciduous tree 30-50 m high, with a diameter of 2-10 m; bark thick, pale, ash grey to nearly black, then brown, usually fairly rough and flaking off in small scales, but seldom fissured; slash thick, fibrous, cream coloured with brown spots, exuding white latex; trunk lofty, straight and cylindrical, up to 20 m or more to the 1st branches, usually with short, blunt buttresses; crown high, umbrella-like and growing from a few thick branches; branchlets thick, rather zigzag and angular, all more or less horizontal (Orwa *et al.*, 2009). *Gmelina arborea* (Beech wood) is an unarmed, moderately sized to large deciduous tree with a straight trunk. It is wide spreading with numerous branches forming a large shady crown, attains a height of 30m or more and a diameter of up to 4.5m. Bark smooth, pale ashy-grey or grey to yellow with black patches and conspicuous corky circular lenticels. Inside surface of bark rapidly turns brown on exposure and exfoliates into thick woody plates or scurfy flakes. The wood seasons well without degrading, but it is slow to dry both in the open and in a kiln. Where it is indigenous, it is regarded as a valuable general-purpose wood because of its dimensional stability. The natural durability of the wood is about 15 years. Uses include the manufacture of furniture, plywood core stock, mine props, matches and timber for light construction (Orwa *et al.*, 2009).

The flexural strength of concrete produced with sand increased from 1.43 N/ mm^2 at 7 days to 2.24 N/mm^2 at 28 days for control slab (i.e. about 57% increment). However, the strength of the 25% replacement by sawdust showed increase in flexural strength from 1.15N/mm^2 at 7 days to 1.67 N/mm^2 at 28days (45% increments) (Olutoge, 2010). Similarly, the 50% replacement of sawdust showed an increase from 0.89 to 1.12N/mm^2 between 7 and 28 days. It is also seen that the reduction in cost up to 7.43% can be achieved for every cubic meter of paving stones produced with use of sawdust (Dilip *et al.,* 2014). Thus, it is more important to investigate the potential use of wood sawdust wastes to produce a low-cost and lightweight composite for construction and engineering purpose. In order to cut down the exploitation of natural resource and environmental damage, it is urgent for us to accelerate the development of the environment-friendly construction materials.

The implementation of waste sawdust can not only decrease environmental damage, but also can save the concrete materials. It has many advantages over traditional concrete, such as low bulk density, better heat preservation and heat insulation property, and lower pollution for our environment, etc. And the implementation of waste sawdust could also be generalized to the use of straw in countryside, which could create more environmental saving profit.

There is need to determine the strength of paving stones produced from various brands of cement available in the market in order to prevent occurrence or frequent collapse of structure due to poor specification. Therefore, this study was carried out to determine the suitability of cement brands on strength of paving stones made from percentage replacement of sand with *Milicia excelsa* sawdust and *Gmelina arborea* sawdust.

2.0 METHODOLOGY

2.1 PRE – TREATMENT METHOD OF SAWDUST

Sawdust was pre-treated by soaking it in hot water which attained the boiling point of 100^0C, for five hours (Usman *et al.*, 2012) and later rinsed with water and sun-dried so that inhibitory substances and extractives such as tannin, gum and resin in the sawdust can be removed. It also removed the water soluble extractives and improved its binding ability with cement. This pre – treatment was carried out in order to remove unwanted particles or materials.

2.2 METHOD

Step 1: The moulds were cleaned and lubricated with diesel.
Step 2: The quantity of all aggregates used were weighed by measuring scale.
Step 3: The materials were mixed thoroughly and water was added to the aggregate.
Step 4: Each mix was poured into the tapped mould and vibrated manually.
Step 5: Each mould was placed on leveled ground in an aeration surrounding.
Step 6: The paving stones were demoulded after 48hours (sometimes 24hours).

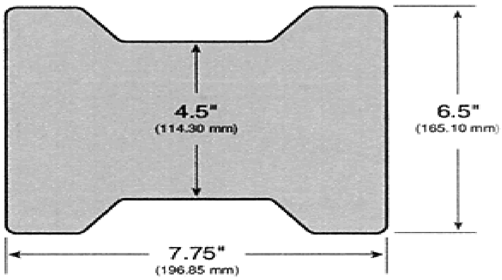

Table 2.3.1. MIXING RATIO (SPECIMEN COMBINATION) FOR THE PRODUCTION (Kg)

Specimen	Stonedust	*Milicia excelsa* sawdust	*Gmelina arborea* sawdust	Cement A	Cement B	Cement C	Cement D
T_1	120			25			
T_2	60	8		25			
T_3	60		8	25			
T_4	120				25		
T_5	60	8			25		
T_6	60		8		25		
T_7	120					25	
T_8	60	8				25	
T_9	60		8			25	
T_{10}	120						25
T_{11}	60	8					25
T_{12}	60		8				25

NOTE: 30kg of stone dust is equal to one head pan of stone dust and 4 kg of sawdust is equal to one head pan of sawdust.

2.2.2 SPECIMEN COMBINATION

T_1: 4:1=Four headpan of stonedust with one headpan of cement A
T_2: 2:2:1=Two headpan of stonedust and *Milicia excelsa* sawdust with one headpan of cement A
T_3: 2:2:1=Two headpan of stonedust and *Gmelina arborea* sawdust with one headpan of cement A
T_4: 4:1= Four headpan of stonedust with oneheadpan of cement B
T_5: 2:2:1=Two headpan of stonedust and *Miliciaexcelsa* sawdust with one headpan of cement B
T_6: 2:2:1=Two headpan of stonedust and *Gmelina arborea* sawdust with oneheadpan of cement B
T_7: 4:1= Four headpan of stonedust with one headpan of cement C
T_8: 2:2:1=Two headpan of stonedust and *Milicia excelsa* sawdust with one headpan of cement C
T_9: 2:2:1=Two headpan of stonedust and *Gmelina arborea* sawdust with oneheadpan of cement C
T_{10}: 4:1= Four headpan of stonedust with one headpan of cement D
T_{11}: 2:2:1=Two headpan of stonedust and *Milicia excelsa* sawdust with one headpan of cement D
T_{12}: 2:2:1=Two headpan of stonedust and *Gmelina arborea* sawdust with one headpan of cement D

2.3 STATISTICAL ANALYSIS

The Compressive strength (MPa), Water absorption and Cost implications were the data assessed. The data obtained was subjected to Analysis of Variance (ANOVA) to determine the significant difference in the weight before and after curing and complete randomized design (CRD) was used.

3.0 MAJOR FINDINGS

Table 3.1: MEAN WEIGHT (KG) OF PAVERS BEFORE AND AFTER CURING

Specimens	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
Mean weight before curing (kg)	2.53	2.16	2.14	2.63	2.26	2.05	2.81	2.46	2.04	3.00	2.28	2.18
Mean weight after curing (kg)	2.93	2.82	2.34	3.01	2.41	2.25	3.06	2.79	2.35	3.10	2.44	2.32
Difference of mean weight (kg)	0.40	0.66	0.20	0.38	0.15	0.20	0.25	0.33	0.31	0.10	0.16	0.14

The table 3.1 shows the difference in value obtained ranges from 0.10 to 0.66 after 48 hours of immersion in water, water absorption increased with increase in proportion of stonedust and sawdust. Specimen 2 has the highest value of water absorption (0.66) followed by T_1 (0.40) followed by T_4 (0.38), followed by T_8 (0.33), followed by T_9 (0.31), followed by T_7 (0.25), followed by $T_{3,}$ T_6 (0.20, 0.20), followed by T_{11} (0.16), followed by T_5 (0.15), followed by T_{12} (0.14) and while T_{10} produced absorption. Paver produce T_2 with Dangote cement + *Milicia excelsa* + Stonedust had high value water with respect to water absorption. This observation agrees with earlier report with Olutoge (2010) and Dilip *et al*. (2014), the fact that pavers produced with sawdust as component could withstand total immersion for 48 hours and its high water absorption rate showed that this product will be able to withstand walkway.

Table 3.2: ANALYSIS OF MEAN WEIGHT (KG) OF PAVERS BEFORE AND AFTER CURING

Specimens	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
Weight before curing	2.532 BC	2.16D EF	2.14 EF	2.63B	2.26 DE	2.05F	2.902A	2.464C	2.036F	3A	2.28D	2.18 DE
Weight after curing	2.934 BC	2.82C	2.34 DE	3.014 AB	2.41 4D	2.25E	3.056A B	2.794C	2.35DE	3.098A	2.44D	2.32 DE

***means with the same letter are not significantly different at 5% level of probability**.

In the result obtained in the weight before curing and weight after curing showed that there is significant effect among the specimens. The highest mean weight was recorded in T_{10} having 3.00 and 3.098kg in weight before and after curing respectively and is not significantly different from T_7. The least mean weight was recorded in T_6 in both weights before and after curing having 2.05 and 2.25kg respectively, according to Dilip *et al*. (2014).

Table3.3: ANALYSIS OF THE COMPRESSIVE STRENGHT (KN) OF THE PAVING STONES

Treatment	Crushing Load	Average Crushing load		Crushing Strength	Average Crushing Strength	
T_1	1000	1125	Abc	3247	3652.5	abc
	1250			4058		
T_2	1000	1075	Abc	3247	3490.5	abc
	1150			3734		
T_3	1200	1275	Ab	3896	4139.5	ab
	1350			4383		
T_4	1000	975	C	3247	3165.5	c
	950			3084		
T_5	1250	1315	A	4058	4269.5	a
	1380			4481		
T_6	1100	1065	Bc	3571	3457.5	bc
	1030			3344		
T_7	1100	1050	Bc	3571	3409	bc
	1000			3247		
T_8	1100	1075	Abc	3571	3490	abc
	1050			3409		
T_9	1050	1031	Bc	3409	3347.5	bc
	1012			3286		
T_{10}	1012	1181	Abc	3286	3834.5	abc
	1350			4383		
T_{11}	1100	1060	Bc	3571	3441.5	bc
	1020			3312		
T_{12}	1150	1250	Ab	3734	4058.5	ab
	1350			4383		
		246.1785			798.9549	

***means with the same letter are not significantly different at 5% level of probability**.

The mean result obtained in the crushing load and crushing strength showed there is significant effect among the different specimens in the crushing load and crushing strength. T_5 had the highest mean crushing load of 1315Kn and is not significantly different from T_1, T_2, T_3, T_8, T_{10} and T_{12}. The least mean crushing load was recorded in T_4 of 975Kn and it is not significantly different from T_1, T_2, T_6, T_7, T_8, T_9, T_{10} and T_{11}.

There is significant difference in the crushing strength with T_5 having the mean highest crushing strength of 4269.5Kn and is not significantly different from other specimens except T_4, T_6, T_7, T_9 and T_{11}. The least mean crushing strength was recorded in T_4 having 3165.5Kn with reference to Ohijeagbon (2008) and Olutoge (2010).

Table 3.4: TOTAL COST OF PRODUCING EACH OF THE SPECIMENS

Specimens	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
Value (₦)	3795	3495	3495	3775	3475	3475	3795	3495	3495	3825	3525	3525

The table 3.4 contains the cost prices that produced paving stones made from four brands of cement (Dangote, Purechem, Elephant and Bua) and two sawdust of different species of wood i.e *Milicia excelsa and Gmelina arborea*. Specimen 5 and specimen 6 have the lowest cost of production with ₦3475 followed by T_2, T_3, T_8, T_9 with ₦3495 followed by T_{11}, T_{12} with ₦3525, followed by T_4 with ₦3775, followed by T_1, T_7 with ₦3795 while T_{10} has the highest cost of production with ₦3825.

4.0 CONCLUSION

This study shows that it is possible to produce paving stones from stonedust that is durable by incorporating *Milicia excelsa* sawdust and brand of cement. It also shows that, comparably, stonedust that has highest compressive strength is a good indicator of durability. The variable, stonedust and *Milicia excelsa* sawdust, used in paving stones production had serous effect on the strength properties examined. Paving stones produced from stonedust and *Milicia excelsa* sawdust can be satisfactory used to produce pavers for the construction of walk ways.

5.0 RECOMMENDATION

Stonedust and *Milicia excelsa* sawdust with Dangote cements are good for the production of paving stones which means paving stones with *Milicia excelsa* sawdust can absorb more water and withstand environmental stress. It also reduces the cost of paving stones. That is, it is cheaper in production.

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APPENDIX

Appendix 1: ANALYSIS OF VARIANCE TABLE FOR WEIGHT BEFORECURING

EFFECT	SS	DF	MS	F	ProbF
Treatment	5.73362	11	0.52124	53.6207	3.91E-23**
Residual	0.4666	48	0.00972		
Total	6.20022	59	0.10509		

Appendix 2: ANALYSIS OF VARIANCE TABLE FOR WEIGHT AFTER CURING

EFFECT	SS	DF	MS	F	ProbF
Treatment	5.9152	11	0.53775	32.9874	1.23E-18
Residual	0.7825	48	0.016302		
Total	6.6977	59	0.113521		

Appendix 3: ANALYSIS OF VARIANCE TABLE FOR CRUSHING LOAD (KN)

EFFECT	SS	DF	MS	F	ProbF
Treatment	254205.8333	11	23109.62	1.810224	0.161203
Residual	153194	12	12766.17		
Total	407399.8333	23	17713.04		

Appendix 4: ANALYSIS OF VARIANCE TABLE FOR CRUSHING STRENGTH

EFFECT	SS	DF	MS	F	ProbF
Treatment	2680088.333	11	243644.4	1.811973	0.160817
Residual	1613563	12	134463.6		
Total	4293651.333	23	186680.5		

Appendix 5: COST ANALYSIS OF RENTAGE MATERIALS

Items	Quantity	Unit price (₦)	Amount (₦)	1% of amount
Mould	72	120	8,640	86.40
Shovel	1	1,200	1,200	12.00
Hand trowel	2	150	300	3.00
Bucket	2	350	700	7.00
Labour	1	2000	2,000	20.00
Wheel barrow	1	10,000	10,000	100.00
Total			228.4	

Variable cost of Cement A

Pavers items	Quantities	Unit price (₦)	Amount (₦)
Stonedust	4	300	1200
Cement	1	775	775
Lubricant	1	180	180
Transportation		200	200
			2355

Total production cost = Fixed cost + Total variable cost= ₦228.4 + ₦2355=₦2,583.40

Variable cost of Cement B

Pavers items	Quantities	Unit price (₦)	Amount (₦)
Stonedust	4	300	1200
Cement	1	750	750
Lubricant	1	180	180
Transportation		200	200
			2330

Total production cost = Fixed cost + Total variable cost
= ₦228.4 + ₦2330
= ₦2558.42

Variable cost of Cement C

Pavers items	Quantities	Unit price (₦)	Amount (₦)
Stonedust	4	300	1200
Cement	1	775	775
Lubricant	1	180	180
Transportation		200	200
			2355

Total production cost = Fixed cost + Total variable cost
= ₦228.4 + ₦2355
= ₦2583.4

Variable cost of Cement D

Pavers items	Quantities	Unit price (₦)	Amount (₦)
Stonedust	4	300	1200
Cement	1	825	825
Lubricant	1	180	180
Transportation		200	200
			2405

Total production cost = Fixed cost + Total variable cost
= ₦228.4 + ₦2405
= ₦2633.4

COST OF PRODUCTION

MATERIALS	PRICE (₦)
▪ Stonedust	3,600
▪ Cement (Dangote, Purechem, Elephant &Bua)	6,270
▪ Field book	60
▪ Plastic Moulds (Double Tee -60mm)	3,000
▪ Lubricant (diesel)	360
▪ Compressive strength machine	24,000
▪ Labour and boiling of water for soaking sawdust	5500
▪ Transport	1680
Total	44,920