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INNOVATIVE APPLICATION OF SAWDUST WASTAGE USED AS ALTERNATIVE SUSTAINABLE CONSTRUCTION MATERIAL

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ABSTRACT

This paper presents a preliminary experimental study which carried out in the purpose to determine the potential of natural fiber from sawdust used as alternative green construction material. The concrete mix ratio 1:2.25 was prepared using water-cement ratio of 0.35 with 0% to 70% sawdust replacement as partial replacement for fine aggregate. Four variable parameters were investigated namely; concrete quality, exposure period, size specimen and curing period. The experiment result indicated that the compressive strength, Ultrasonic Pulse Velocity (UPV) and density values decreased with increasing of sawdust replacement. However, the strength obtained at 30% of sawdust inclusions have meet the minimum specified requirement of 40 Mpa for high strength lightweight aggregate concrete at 28 days. Thus, preliminary results show that using with or without sawdust can be opted as construction material with acceptable strength and density properties of concrete.

Keywods:- *Natural Fiber, Construction Material, Sawdust, Lightweight, Cement Composite.*

I. INTRODUCTION

Currently, construction sector is focusing in developing sustainable, green and eco-friendly building. Construction materials including bricks, wood, cement, aggregates, steel, aluminum, cladding and partitioning materials are increasing in demand due to rapid growth of construction activities for housing and other building. The current world economic circumstances are unstable because of the world currencies are very high and the cost of building materials also soared. This situations led to several ongoing construction projects are having trouble in getting materials at lower cost [1]. Therefore, there are need to search an alternative material in order to fulfill the constructions demand while maintaining cost at minimum level as well as sustainable material.

There are several innovations in building construction, especially in concrete material and technology which involves new construction techniques and utilization of waste materials for cement and aggregate replacement. In recent years, some researcher carried out the past used natural fibers such as core fibers (jute, flax, hemp, ramie and kenaf), leaf fibers (abaca, sisal and pineapple), seed fibers (coir, cotton and kapok), grass and reed fibers (wheat, corn and rice) and other types (wood and roots), has attracted much attention in the material and engineering discipline [1].

In considering the renewable and sustainable nature, natural fiber is growingly being used in composite material especially in building construction. Natural fiber generally offers low production cost, friendly processing, low tool wear and less skin irritation, and good thermal and acoustic insulation properties [2]. Sawdust is one of natural fiber that used as filler. Sawdust is collected of fine particle of hard and soft woods. This material is produced from cutting of wood with saw. In United States, sawdust has been used as an aggregate for more than 50 years for floor, wall and roof units, but not widely. In recent years, some researcher carried out the past used wood waste as a replacement for aggregate in concrete or mortar mixtures; it showing the great improvement in mechanical properties [3]. Turgut [4] show the feasibility of producing artificial limestone brick with wood sawdust. Bouguerra et al. [5] including wood chipping size 3-8 mm in cement and clay matrix and tested the composite material is a good thermal and insulation properties. Coatanlem et al. [6] described the physio-chemical properties of wood chipping proposed highly water absorption on sawdust. The addition of natural fiber also reduces the thermal conductivity of the composite specimens and yielded a lightweight product [7-10].

Several past studies [11-16] were reported that the use of sawdust as a partial sand replacement material in concrete at all levels of sand replacement ranged between 5% and 30% reduces compressive strength of mortar mix produced relative to neat conventional cement brick for all curing aging. Adebakin et al. [11] had studied about partial replacement of sand in concrete blocks by use of sawdust waste materials. The fine particle of sawdust passed through 4.76 mm test sieve British Standard. They produced hollow blocks used mix ratio 1:8 (cement:sand) at different replacement level of sand and sawdust (100:0, 90:10, 80:20, 70:30, 60:40). The water/cement ratio used 0.5, 0.54, 0.55, 0.56 and 0.57. They have found that the replacement of sand should not more than 10% to achieve the best result use of sawdust in block production. If attempt made

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by using the 50 % replacement of sand was not successful because there are weak bonding. They prove that the present of tannin in sawdust acts as retarded and adversely affecting the blocks. While Boob [12] investigated the performance of sawdust in cement sand-crete blocks using 1:6 cement and sand mix with 15% sawdust replacement gives strength of 4.5N/mm^2 which is reasonable and economical to be used for partition walls in frame structure multi-storey building. Turgut and Algin [13] they used a combination of cotton wastes (CWs) - limestone powder wastes (LPWs) and combinations wood sawdust waste (WSWs) and limestone powder wastes (LPWs) for producing low cost and lightweight composite as a building material. They found compressive strength, flexural strength, ultrasonic pulse velocity (UPV), unit weight and water absorption values are satisfied according to International Standard (IS). The results, found that lighter weight composite having potential to be used for walls, wooden board substitute, an alternative to concrete block, ceiling panels, sound barrier panels and others.

Paramaswam et al. [14] in their study of sawdust concrete obtained some encouraging results. Compressive strength values of up to 31 N/mm^2 at 28 days were obtained in a mix proportion of 1:1 that is one part by volume of cement to one part by volume of sawdust. When the mix proportion was changed to 1:2, the 28 days compressive strength reduced to 8.5 N/mm^2 and a mix ratio of 1:3 (cement/sawdust) by volume reduced the 28 day strength value further to only 5 N/mm^2. Ravindrarajah et al. [15] they conducted experiments on concrete mixes containing sawdust as an air-entraining admixture in order to develop sawdust concrete for sand-crete block making. Volume proportion was used to determine the quantity of individual components in the experimental mix. They observed from the results obtained that sawdust concrete for sand-crete block making, with a sawdust content of 3% by volume and a wet density of 1920 kg/m^3 produced best results for compressive strength. Jr. [16] found the highest compressive strength is gained by 7 day sample which not cured in 7, 14 and 28 days and strength of sawdust concrete decrease as water-cement ratio less than 0.45 curves is dropping down, which shows the sawdust concrete not workable. The sawdust-gravel-cement concrete showed 10% reduction in weight than conventional concrete which got about 40% weight. Due to mixing the concrete with waste material, the workability and consistency parameter are varied from conventional concrete and sawdust waste material is cheaper than the fine aggregate.

Previous research indicated that natural fiber has limited by its low compressive strength and need to understand their limitations before use it. The advantages of natural fiber are offers considerable reduction in weight of structure, thereby reducing the dead loads transmitted to the foundation, high economy when compared to and normal weight concrete, reduce damage and prolonged life of formwork due to lower pressure being exerted, easier handling, mixing and placing as compared with other types of concrete, improved sound absorbent properties due to its high void ratio and improved thermal insulation because the incorporation of wood aggregates in concrete decreases its thermal properties. Thus, this research investigates great potential use of sawdust wastes in order to produce the desired lightweight composite and sustainable green construction material.

II. EXPERIMENTAL PROGRAM

The experimental program was planned to investigate the effect of sawdust for mixing targeting to gain in strength of different percentages of sand replacement. This study includes determination of compressive strength, Ultrasonic Pulse Velocity (UPV) and density of cement composite blocks in curing period of 7 and 28 days.

1. *Material*
    a. Cement: Ordinary Portland Cement (OPC) ASTM Type I was used for mixing of mortar cement complying with specifications in ASTM Standard C150.
    b. Silica fume: Ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production.
    c. Aggregate: sand as fine aggregates was used with passing through 5.00 mm BS test. The specific gravity of 2.67
    d. Sawdust: Sawdust is composed of fine particles of wood with passed through 5.00 mm BS test sieve.
    e. Superplasticizer: Type of water reducing admixture was incorporated into the mortar mixtures at required dosage in order to maintain a desired level of workability.
    f. Water: Fresh water was collected from the laboratory complying with the requirement of the

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British Standard BS EN 1008.

2. *Pre-treatment*
The samples were washed with sodium hydroxide (NaOH) to lose some amount of lignin. Sawdust was soaked in NaOH solution at 2% concentrations for two hours. Then washed several times using fresh water. Sawdust was dried in oven at 100ºC for one night.

3. *Mixture proportioning*
The mix ratio of 1:2.25 and water/cement ratio was used 0.35 were maintain constant for all the mixtures. The percentage replacements of sand by sawdust were varied from 0% to 70% by volume. Silica fume was used as admixture at level of 3% by cement weight. Superplasticizer was dosed at 1.5% for all mixes to maintain workability of mortar mixes.

4. *Variable parameter*
   a. Concrete quality: Control mix as reference namely N and seven different percentages of replacement of sand namely D10 to D70 were used. The relevant information of the concrete mixes is given in Table 1.
   b. Curing period: Test specimens were tested periodically after the specified curing periods of 7 and 28 days in fresh water curing.
   c. Size of specimen: Cube specimens of size 100mm x 100mm x 100mm were cast and the compressive strength of the concrete was determined according to ASTM C39.
   d. Curing environment: Concrete cube specimens were cast in the laboratory. At the end of casting, the specimens were kept at room temperature for 24 hours. After demolding, all the specimens were cured in fresh water for 7 and 28 days. After the specific period of exposure, the specimens were taken out from curing tank for compressive strength test, ultra-pulse velocity and density testing.

III. RESULT AND DISCUSSION

The averaged test results with curing age for different percentages of sand replacement with sawdust are presented in Table 1. The result of compressive strength, ultra-pulse velocity and density of cement composite blocks and its trend with reference to age of curing are represented in Fig. 1 to 5.

	7 days			28 days		
Mix	Compressive Strength (N/mm^2)	Ultra Pulse Velocity (m/s)	Density (kg/m^3)	Compressive Strength (N/mm^2)	Ultra Pulse Velocity (m/s)	Density (kg/m^3)
Normal	33.8	4118.3	2229.8	44.5	4265	2267.5
D10	31.39	3853.3	2176.8	49.34	4057	2236.9
D20	32.68	3853.3	2196.9	43.64	3985	2207
D30	30.34	3853.3	2162.5	39.82	3932	2164.5
D40	27.06	3590	2101.6	31.21	3652	2110.5
D50	25.1	3406.7	2057.4	30.62	3503	2068.9
D60	21.9	3260	2005.3	26.85	3365	2020.8
D70	22.1	3166.7	1955.3	26.1	3235	1965.7

Table 1: Test results

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1. Compressive strength

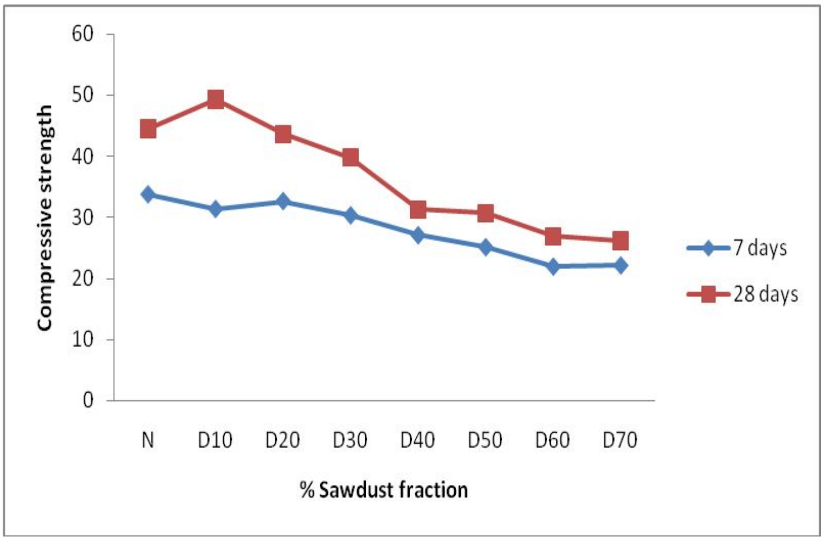

Fig. 1: Compressive strength of cement composite

The compressive strength values of cement composite block are shown in Fig. 1. Three cube specimens are tested per mixture for compressive strength testes at 7 and 28 days. The compressive strength reduces with increase in sawdust percentage from 10% to 70% and with curing and concrete age. Values of 49.34 N/mm^2, 43.64 N/mm^2, 39.82 N/mm^2, were obtained for compressive strength with 10%, 20% and 30% sawdust as partial sand replacement.

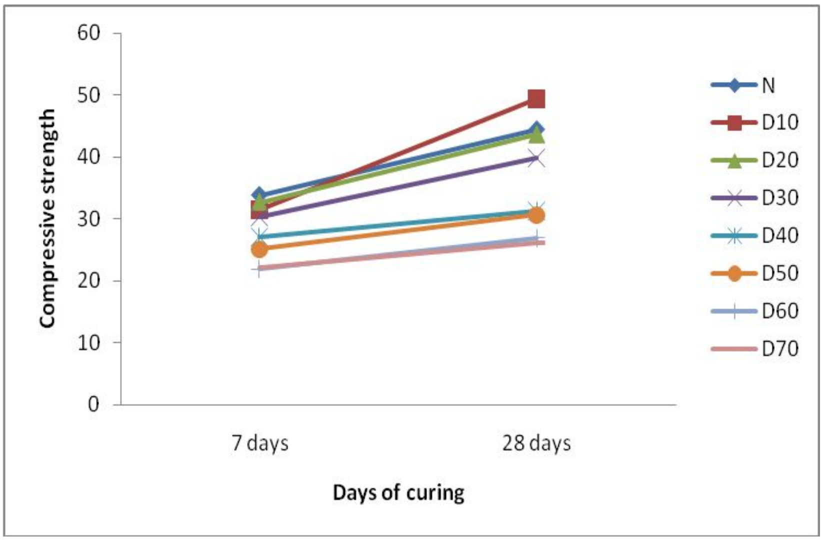

Fig. 2: Average compressive strength of cement composite at curing ages

At 7 days of curing, trend decrease in compressive strength was observed with 10%, 20% and 30% sawdust replacement of sand exhibiting values of compressive strength of 31.39 N/mm^2, 31.39 N/mm^{2}and 30.34 N/mm^2.

At 28 days, the compressive strength of the concrete cube exhibited a trend different percentage sawdust replacement decreased from 49.34 N/mm^2 and exhibited a constant trend of approximately 39.82 N/mm^2 till 40% sawdust replacement then drop to 26.1 N/mm^2 at 70% replacement of sand. However, the strength obtained at various sawdust inclusions has met the minimum specified requirement of 40 Mpa for high

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strength lightweight concrete.

2. Ultra Pulse Velocity (UPV)

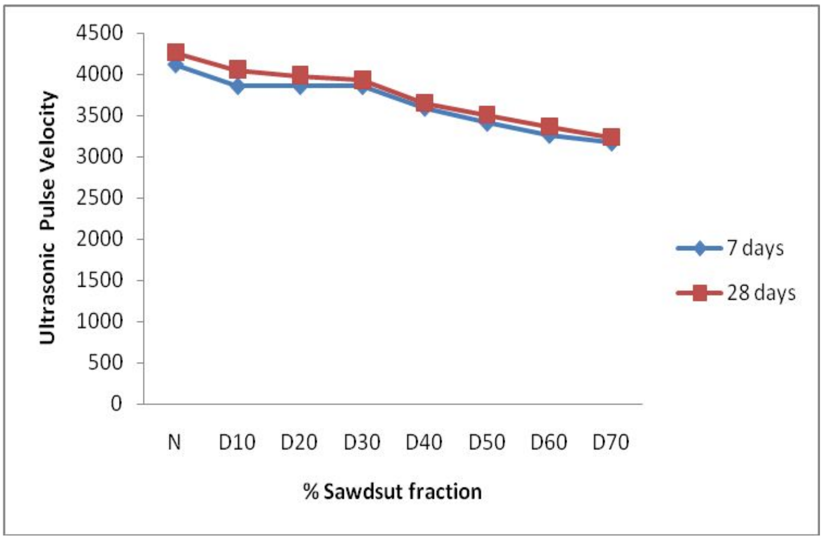

Fig. 3: Ultrasonic pulse velocity of cement composite

UPV values decreased with increasing sawdust replacement for sand at the 7 and 28 days curing periods. Maximum reduction occurred at 70% sawdust replacement and it was 23% and 24% at 7 and 28 days curing period. Minimum reduction occurred at 10% sawdust for 28 days curing period. The UPV values decreased with increasing sawdust replacement percentage. However, reduction in UPV values due to sawdust replacement was much lower than compressive strength. The higher of sawdust replacement, the higher the decrease in UPV values.

3. Density

The result of the densities of the concrete cubes with sawdust as sand replacement as shown in Fig.4. The result showed that there was a decrease in the density of the cube with increasing sawdust replacement of sand in the concrete cubes when compared with each other.

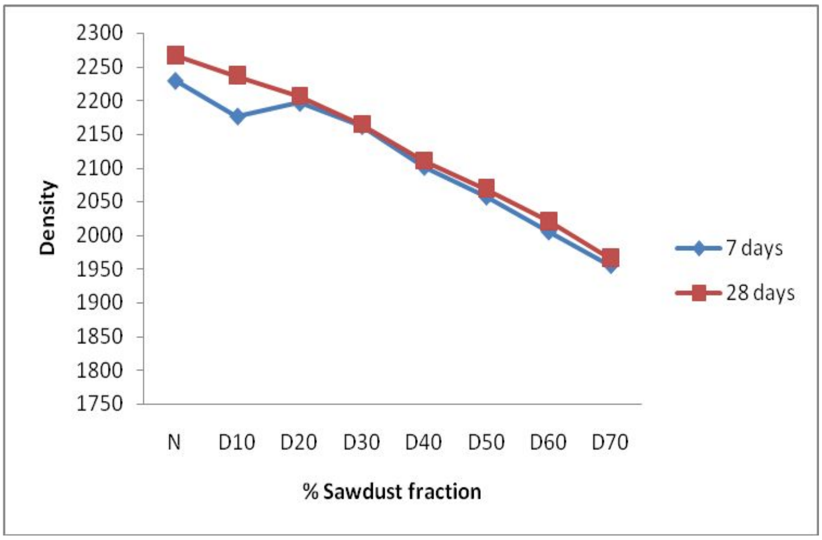

Fig. 4: Density of cement composite

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Similarly, variation in the densities of the concrete cube with different sawdust content was observed in Fig. 5.

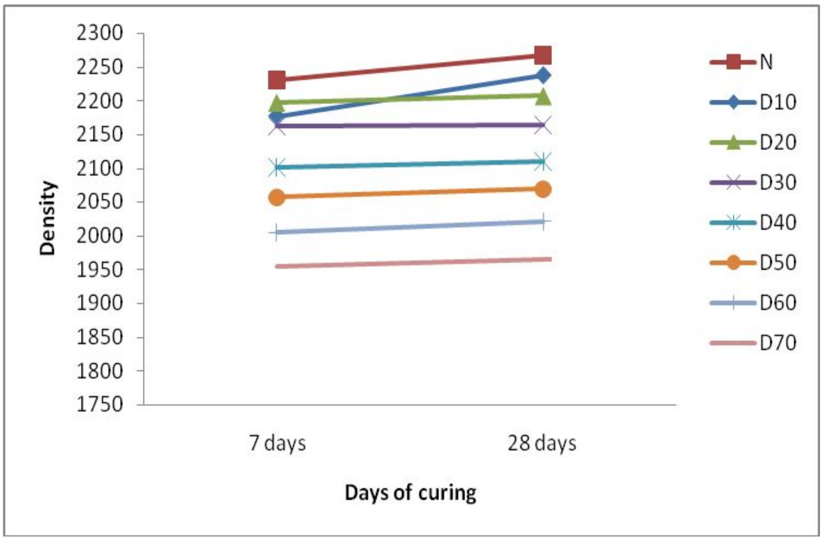

Fig. 5: Average density of cement composite at curing ages

For cube with 0% sawdust replacement the density of the cube was observed to increase with the days of curing with maximum value of 2267.5 kg/m^3 obtained at 28 days of curing. However, cubes with 30% sawdust replacement exhibited a constant trend with densities of 2162.5 kg/m^{3}and 2164.5 kg/m^3 obtained for 7 and 28 days. This variation could be attributed to hydrophilic nature of sawdust (hygroscopic behaviour) in concrete cube. This problem affect the chemistry bonding between sawdust and binder because sawdust contains a large of lignin, sugar, starches, and hemicelluloses which could dissolved with pre-treatment such as alkaline treatment (NaOH) to improve the sawdust matrix bonding [17]. However, the cube density achieved the requirement of ≤2200 kg/m^3 has meet known as lightweight concrete.

IV. CONCLUSION

Cement composite produced using sawdust as sand replacement has affecting on the properties of the concrete. The result of the analysis carried out shows that the workability of cement composite with partial sand replacement with sawdust reduces at constant water cement ratio 0.35. The use of sawdust in concrete at high percentage of sawdust replacement of sand affected the strength of the cement composite as there was a decrease in the strength value, ultra pulse velocity (UPV) and density requirement of ≤2200 kg/m^3 and the compressive strength achieved 40Mpa at 28 days has meet known as high strength lightweight concrete. However, the use of sawdust as sand replacement at 20% by volume gives the same strength requirement when sawdust was not used. Thus, incredibly; using sawdust as partial sand replacement between 0% to 30% will contributes to reduction in sawdust waste without affecting concrete strength and developed green construction material.

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