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Influence of Furnish Characteristics on Strength Properties of Date Fiber Ceiling boards

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Abstract

The objective of this study was to evaluate the density, water absorption, modulus of elasticity and rupture from static bending, and tensile strength of medium-density fiberboards manufactured using Date fiber virgin pulp. Chemo-thermo-mechanical pulping of the Date fibers furnished pulp samples which were further blended with waste papers obtained from newspaper vendors which were earlier soaked in water for 24 hours and pounded into waste paper paste. CMC was equally prepared and incorporated in the mixture as the binder in the research work. The panels' mechanical properties were affected due to the fiber wall characteristics of the Date fiber virgin pulp and interaction with waste paper paste and CMC. Various samples of Medium Density Fiber/ ceiling boards were produced by varying the compositions of the furnished mixtures. To compare the properties of different board samples produced and predict their end use performance criteria, the boards were formed into sheets and tested for strength characteristics using the FIIRO Instron testometer. Testing was carried out at 20^{o}C and 65% relative humidity; the board samples were conditioned in this atmosphere for about 3 ½ hours before testing. The results observed for tensile and flexural properties revealed that Date fiber can furnish building boards with remarkable strength properties. The overall results obtained from research investigations conducted affirms that date fiber offer considerable potentials in the production of good quality MDF boards that meet the requirements for structural engineering application, but other studies should be carried out.

Keywords: Date fiber, Fibre board, Lignin, TAPPI standard, Screen yield, CMC, Density

1.0 Introduction

The date palm is a tall, beautiful and majestic tree that is known for its edible sweet fruits, the dates. The tree belongs to the arecaceae family and the genus phoenix. The Date palm produces true real dates. It is the second most known and most useful palm tree in the world after the coconut palm tree. The date palm is a sub-tropical, dioecious palm which reaches an average height of 60 to 100 feet. There are several varieties peculiar to each producing country. Dates are grown in Iraq, Persia, Egypt, Arabia and North Africa. The palm is very hardy and will grow under the most arid condition where few other plants can survive, but it prefers a blackish or salty clay soil. Commercially the date palm is grown for its fruits, but for local market it is also the source of the strong alcoholic drink, Arak **(Barreveld, 2007)**. The date fruit is one of the most important sources of nutrition for the people in the Middle East. It is considered to be a delicacy. The date is a good source of sugar, potassium, fat and minerals. Only a female tree can form dates. Usually it starts producing fruits after 5-8 years. They may be eaten fresh or dried. The fruits can be stored for several years. The dates are also used as secondary products to make wine, syrup, vinegar, cakes and cream **(Chandra, Anju and Gupta, 2002)**. The chemical constituents of wastes generated from date palm processing are carbon, oxygen, hydrogen, ash (largely silica). They are composed of cellulose; starch, sugar, and lignin, which act as an adhesive for cellulose **(Maheswarappa and Rao, 2004)**.

In the building and construction industry, fiber board is a basic material. The development of a well-developed machineries to produce it has been largely responsible for contributing to the provision of adequate shelter throughout the world **(F.A.O., 2003).** About 50% of the total cost of all constructions can be accounted for by building materials alone, and in low-income shelter, the value of building materials could be as high as 80% of total cost because of the relatively low requirements for other inputs, such as equipment, installations and specialized skills. This trend of rising costs and falling supplies of materials can be reversed, if the system of production is based on locally available resources **(Elinnwa and Buba, 2006)**. The responsibility for improving these situations rests, to a large extent, on the ability of the construction industry to meet the demands for basic physical investment in the built environment. Given this pivotal role of construction in national development, the building materials constitute the single largest input in construction.

Building materials have been a cause for inadequate construction output, high construction cost, abandonment of construction projects and sometimes inadequate building maintenance in developing countries. This situation has come about because majority of our basic building materials are imported at enormous cost to the economy. And because of scarce foreign exchange, costs are prohibitive and supply is limited **(Elinwa and Uba, 2003).** Economic growth of a nation is directly related to the level and efficiency of capital formulation. Typical indicators of underdevelopment are inadequacies in physical infrastructure, shelter and related amenities. Nigeria is faced with many problems in which shelter provision is one of them, and so the next twenty to fifty years, the construction industry will still remain very viable and thus will need a lot of building materials as inputs **(Elinwa and Mangvwat, 2004)**.

This research work aims at furnishing various ceiling board samples from Date fibers and investigate their strength properties and suitability for structural industrial application and also compare their strength properties with those of commercially available similar market products.

2.0 Materials and Method

The raw material investigated in this research work is Date palm. This was sourced during post-harvest processing at oke-ira in Ebute-metta (west), mainland local government area of Lagos State.
Methods developed by Technical Association of the Australian and New Zealand Pulp and Paper Industry Inc.,**(APPITA,2006)** and the Technical Association of Pulp and Paper Industry **(TAPPI,2004)**, were adopted.

2.1 Digestion of Date Palm Residues

3kg of air-dry chips of the sample (Date fiber) was loaded into the digester. The sample was covered with the cooking liquor of about 17% sulphidity, and the lid of the digester was firmly bolted to prevent leakage. The digester was switched on and the time of rise of temperature and pressure was noted at intervals of five (5) minutes. The pulping temperatures rose gradually up to 138^{o}C during a period of 71 minutes and remain steady. The temperature however did not exceed 138^{o}C. The initial pH of the pulping liquor was recorded at 6.0. The digester's initial temperature, pressure and starting time were all noted, and the various changes in parameters were also recorded. Drop in the value of temperature of the operating digester indicated cessation of pulping operation. The digester was switched off, allowed to cool below 60^{o}C and the content blown down. The resultant pulp was subjected to thorough washing with plenty of water. When it was observed that subsequent washing resulted in no further change in color, the pulp was transferred into the valley beater for processing into a more refined pulp. Study of the values recorded during the pulping operation indicated that the over-all cooking time was about 105minutes.

2.2 Formulation of Board Samples

The raw materials for this composite material were obtained locally. Waste papers obtained from newspaper vendors were soaked in water for 24 hours after which they were removed from water and disintegrated into waste paper paste. CMC prepared in readiness for application as the binder in this research work was blended with the waste paper paste. This mixture was then blended with the pulp obtained from digestion of Date fiber in the proportion shown in Table 1 and cast in 400mm x 400mm x 40mm mold for water absorption, as well as 75mm x 75mm x 450mm for tensile and flexural strength tests.

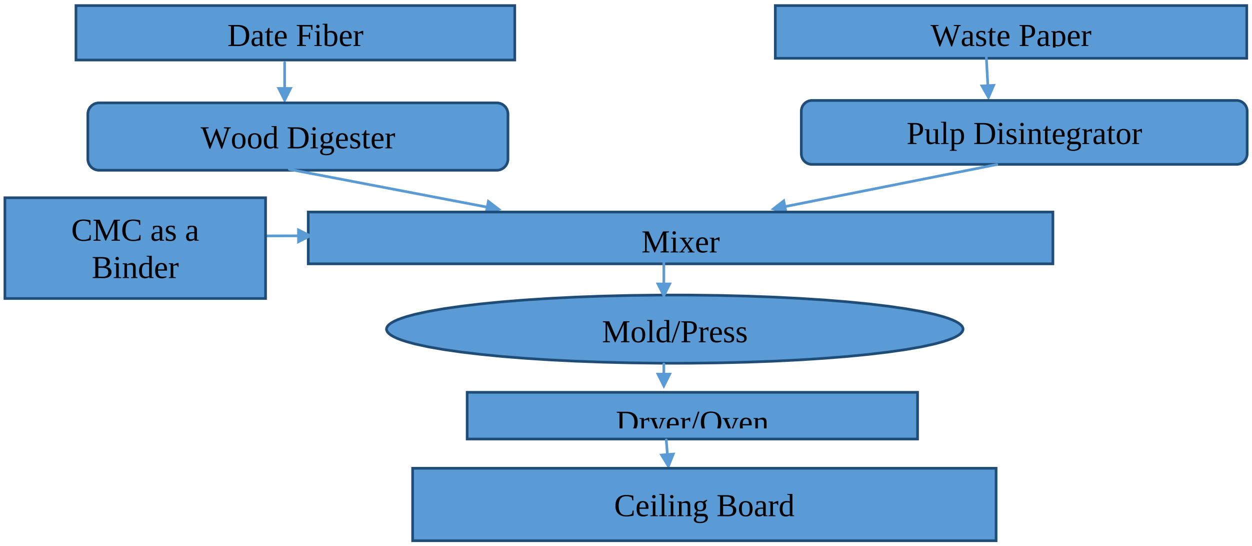

Figure 1: Schematic of the production process

Table 1: Composite Material Mix Proportion

Main Material Components of Ceiling Board	Board Samples			
	Wood Plastic 2	**Dele 1**	**Petopeg 2**	**Mojirin**
Date Fiber Pulp (wt. %)	60	50	40	Not Available
Waste Paper (wt. %)	40	50	60	

Four samples each were prepared for each test at the composite mix percentages and oven dried under a temperature of 80°C for 24 hours. These test samples were removed from the mold and allowed to cool for 24 hours. The samples were then tested for water absorption, tensile and flexural strength properties using FIIRO Instron Testometer (Instron 4260 universal testing machine) . Figure 1 shows the schematic of the laboratory production of the composite samples.

Figure 2: Commercially Available Mojirin

Figure 3: PETOPEG 2 from FIIRO

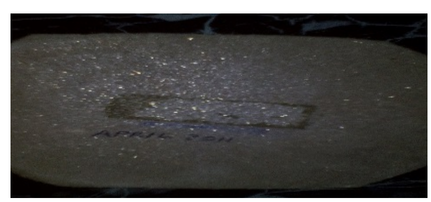

Figure 4: Wood Plastic 2 from FIIRO

Figure 5: Dele 1 from FIIRO

2.3 Measurement of Density

For density measurement of Date fiber boards, EN 520 standards was used, where dimensions of samples were 400 × 300 mm^2. All samples were of specified dimensions and weight, density was calculated as per following equations: Volume, V = a × b × c (m^{-3}), while Density = Mass/Volume, m/v. ($kg \cdot m^{-3}$)

2.4 Water Absorption Test

Water absorption is used to determine the amount of water absorbed under specified conditions. Factors affecting water absorption include: type of material, additives used, temperature and length of exposure. The data sheds light on the performance of the materials in water and humid environments. The equipment used is Mettler balance.

For the water absorption test, the specimen was submerged in water for about six (6) hours and dried in a forced air circulation oven at 105^{o}C for 2 to 3 hours and then placed in a desiccator to cool before weighing. This process was repeated until constant weight was achieved. The material was then immersed in water at 23^{o}C for 6 hours (until equilibrium was esterblished). The specimen was removed and weighed. Water absorption is expressed as increase in weight percent.

Percentage water absorption = [(Wet weight – Dry weight) / Dry weight] × 100

3.0 Results and Discussion

3.1 Analysis of Water Absorption Test Results

The various ceiling board samples investigated, exhibited different water absorption behavior. The water absorption trend showed positive correlation reflecting a proportional increase in water absorption as the proportion of waste paper in the composite increases. In other words, the proportion of water absorbed by waste paper in the composite is greater than the proportion absorbed by the Date fiber virgin pulp itself.

From the results in Table 2, the water absorption recorded the highest value, 23.45% in the commercially available ceiling board from Mojirin, Ibadan, followed by Petopeg 2, which recorded 19.4 then Dele 1 recording a value of 19.40% and lastly, Wood Plastic 2 with a record value of 16.25%. From the trend of these results, it is observed that the more the proportion of waste paper in the composite mixture the more the capacity of the composite to absorb water.

It is however suspected that the Mojirin ceiling board purchased from Mojirin industries, Ibadan consist of high proportion of waste paper which resulted in the high water absorption value it recorded.

3.2 Analysis of Flexural and Tensile Test Results

The bending modulus (flexural modulus) is an intensive property computed as the ratio of stress to strain in flexural deformation. This is the tendency of the board samples to resist bending force. Wood Plastic 2 recorded the highest resistance to bending force, recording a value of 1993.7N/mm2 and second to only Dele 1 when it comes to exhibiting bending strength at peak or yield. These probably has come about because of the proportional ratio of Date fiber virgin pulp to waste paper paste present the ceiling board samples investigated. Increase in weight percent (wt. %) of Date pulp in the composite mixture increased the hardness of the board which is the property of a material that enables it to resist plastic deformation, usually by penetration.

The effect of increase in the proportion of Date Fiber virgin pulp in the ceiling boards investigated was observed in Wood Plastic 2 with 1993.7N/mm2 bending modulus, 2.2760N/mm2 bending strength at peak or yield, 195.10N force at peak or yield and Modulus of elasticity value of 43.664N/mm2 exhibiting the highest strength properties amongst the four (4) ceiling boards investigated

Table 2: Effect of Composite material mixture proportion on Water Absorption

Ceiling Board Samples	DFP:WP	Water Absorption (%)
Dele 1 from FIIRO	50%:50%	17.01
Petopeg 2 from FIIRO	40%:60%	19.40
Wood Plastic 2 from FIIRO	60%:40%	16.25
Mojin Ceiling Board, from Mojirin Industry Ibadan	Not Available	23.45

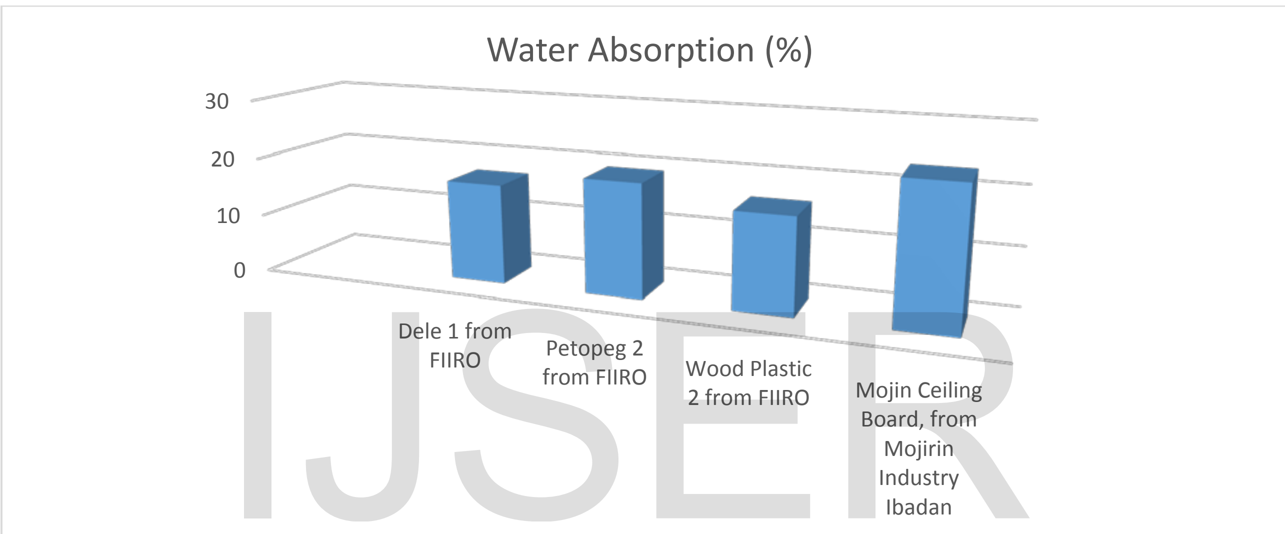

Figure 6: Water Absorption Behavior of Various Ceiling Boards Investigated

Table 3: Flexural Test Result of Wood Plastic 2

Material: Ceiling Board
Sample: Wood Plastic 2
Ref No: 4
Operator: FIIRO

Test: Flexural
Test Type: 3 Point Flexural
Test Speed: 040.00 mm/minute
Span: 150.00 mm
Sample Type: Rectangular

Test No.	With (mm)	Thickness (mm)	Force @ Peak/Yield (N)	Deflection @ Peak/Yield (mm)	Bending Strength @ Peak/Yield (N/mm^2)	Energy to Peak/ Break (N.m)	Bending Modulus (N/mm^2)	Force @ Break (N)
14	50.000	15.000	133.80	0.6290	2.6760	0.0242-0.0857	1993.7	1.90000

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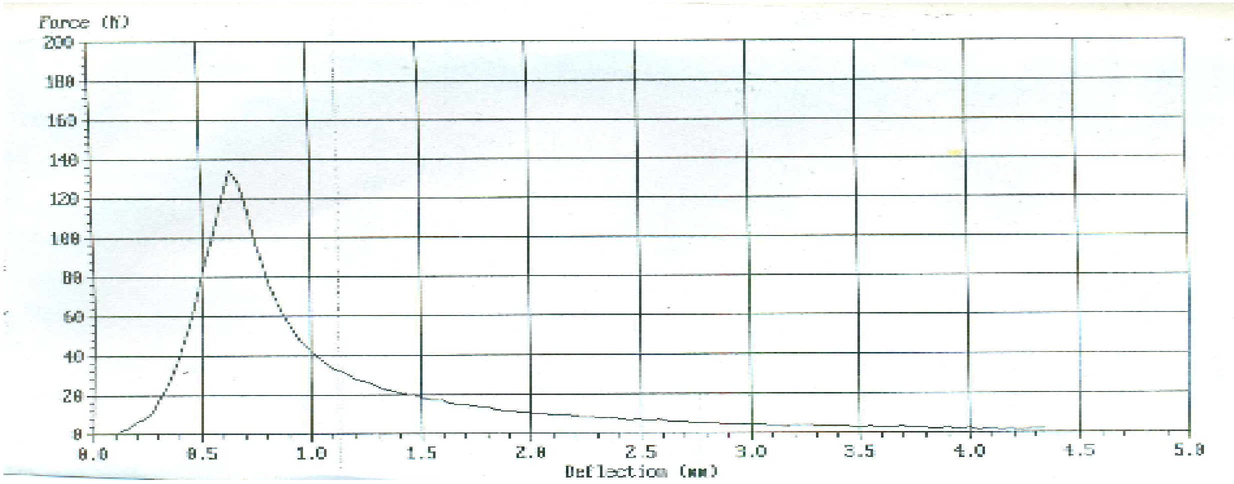

Figure 7: Flexural Strength, Energy Absorption and Stretch Measurement of Wood Plastic 2

Table 4: Tensile Test Result of Wood Plastic 2

Material: Ceiling Board
Sample: Wood Plastic 2
Ref No: \5
Operator: FIIRO
Sample Type: Irregular

Test: Tensile
Test Type: Tensile
Test Speed: 100.00 mm/minute
Sample Length: 200.00 mm

Test No.	Area (mm^2)	Force @ Yield/ Peak (N)	Elong. @ Yield /peak (mm)	Stress @ Yield/ Peak (N/mm^2)	Energy to Peak/ Break (N.m)	Force @ Break/ Yield (N)	Youngs Modulus (N/mm^2)
15	320.00	213.20 - 313.40	6.3630 - 10.186	0.6662 – 0.9794	1.5766 – 2.4779	187.80 – 213.20	25.875

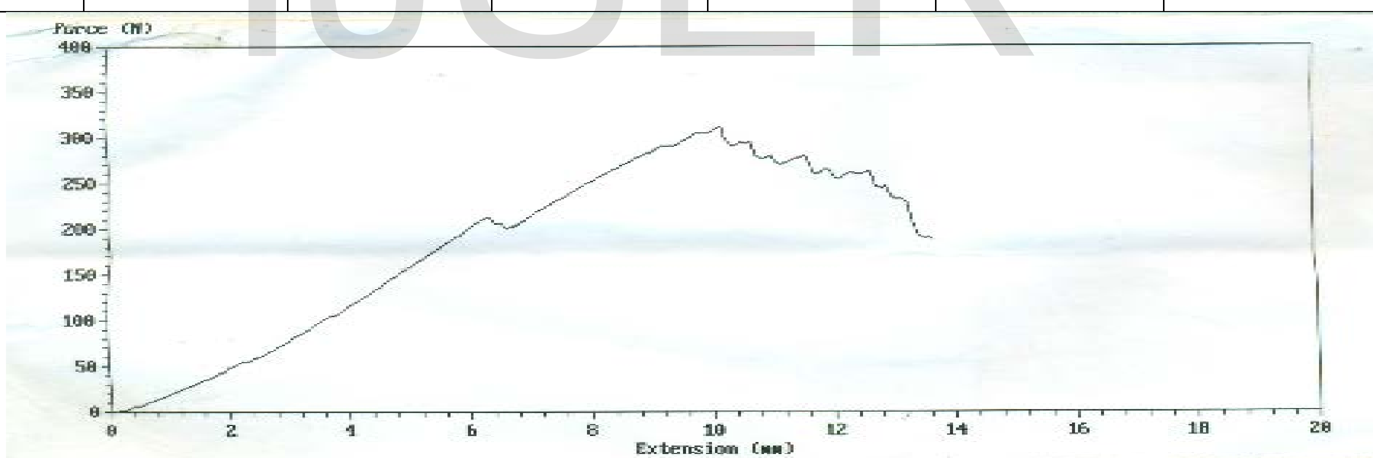

Figure 8: Tensile Strength, Energy Absorption and Stretch Measurement of Wood Plastic 2

Table 5: Flexural Test Result of Dele 1

Material: Ceiling Board
Sample: Dele 1
Ref No: 7
Operator: FIIRO

Test: Flexural
Test Type: 3 Point Flexural
Test Speed: 040.00 mm/minute
Span: 150.00 mm
Sample Type: Rectangular

Test No.	With (mm)	Thickness (mm)	Force @ Yield/Peak	Deflection @ Yield/Peak (mm)	Bending Strength @ Yield/Peak (N/mm^2)	Energy to Peak/Break	Bending Modulus	Force @ Break (N)

			(N)			(N.m)	(N/mm^2)	
17	50.000	8.500	57.6 – 76.3	3.2200 – 14.977	3.5875 – 4.7522	0.8784-1.3972	1106.8	46.800

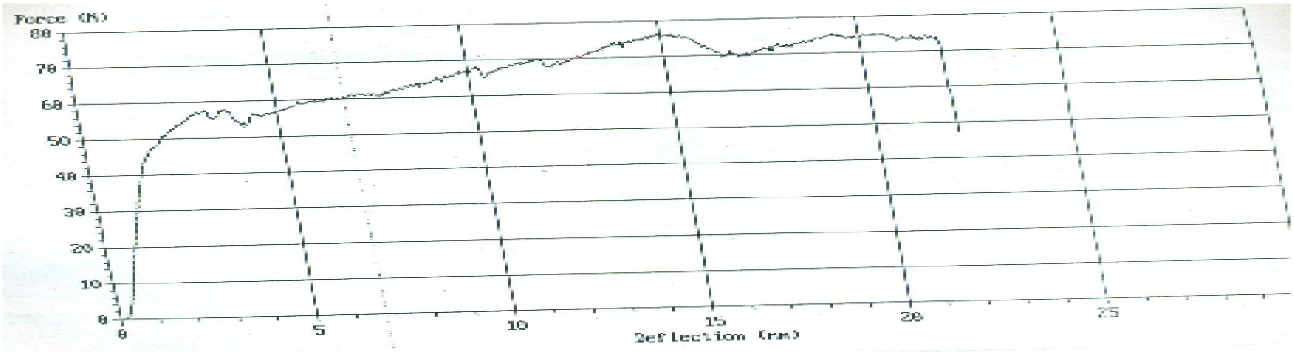

Figure 9: Flexural Strength, Energy Absorption and Stretch Measurement of Dele 1

Table 6: Tensile Test Result of Dele 1

Material: Ceiling Board
Sample: Dele 1
Ref No: 8
Operator: FIIRO

Test: Tensile
Test Type: Tensile
Test Speed: 50.00 mm/minute
Sample Length: 100.00 mm
Sample Type: Irregular

Test No.	Area (mm^2)	Force @ Yield/ Peak (N)	Elong. @ Yield/ peak (mm)	Stress @ Yield/ Peak (N/mm^2)	Energy to Peak/ Break (N.m)	Force @ Break/ Yield (N)	Youngs Modulus (N/mm^2)
18	550.00	277.80 – 328.70	2.4330 – 5.6280	0.5051 – 0.5976	1.4595– 1.6263	252.3 – 277.8	6.1511

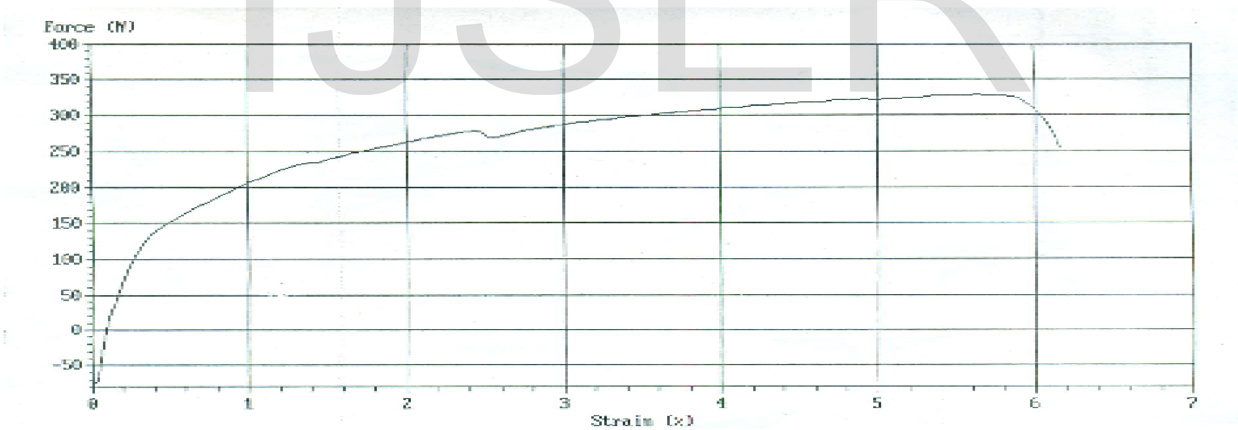

Figure 10: Tensile Strength, Energy Absorption and Stretch Measurement of Dele 1

Table 7: Flexural Test Result of Petopeg

Material: Ceiling Board
Sample: Petopeg
Ref No: 11
Operator: FIIRO

Test: Flexural
Test Type: 3 Point Flexural
Test Speed: 040.00 mm/minute
Span: 150.00 mm
Sample Type: Rectangular

Test No.	With (mm)	Thickness (mm)	Force @ Yield/Peak (N)	Deflection @ Yield/Peak (mm)	Bending Strength @ Yield/Peak (N/mm^2)	Energy to Peak/Break (N.m)	Bending Modulus (N/mm^2)	Force @ Break (N)
17	50.000	11.000	45.100	0.6610	1.6773	0.0170-0.0737	1113.7	45.100

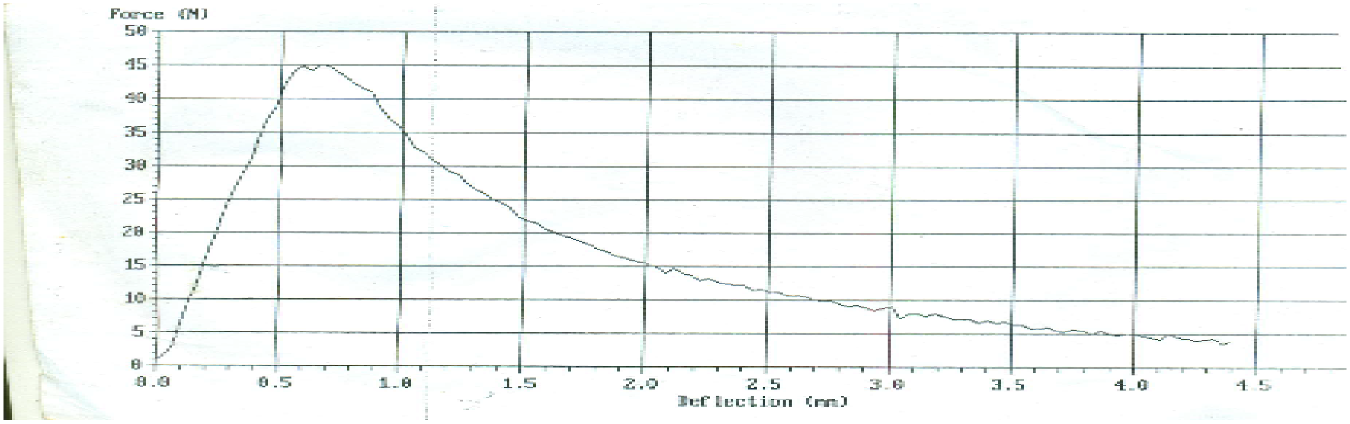

Figure 11: Flexural Strength, Energy Absorption and Stretch Measurement of Petopeg

Table 8: Tensile Test Result of Petopeg

Material: Ceiling Board
Sample: Petopeg
Ref No: 12
Operator: FIIRO

Test: Tensile
Test Type: Tensile
Test Speed: 100.00 mm/minute
Sample Length: 200.00 mm
Sample Type: Irregular

Test No.	Area (mm^2)	Force @ Yield/ Peak (N)	Elong. @ Yield/ peak (mm)	Stress @ Yield/ Peak (N/mm^2)	Energy to Peak/ Break (N.m)	Force @ Break/ Yield (N)	Youngs Modulus (N/mm^2)
18	550.00	195.10	6.2180	0.7562	0.3683– 0.3836	174.7 – 195.10	43.664

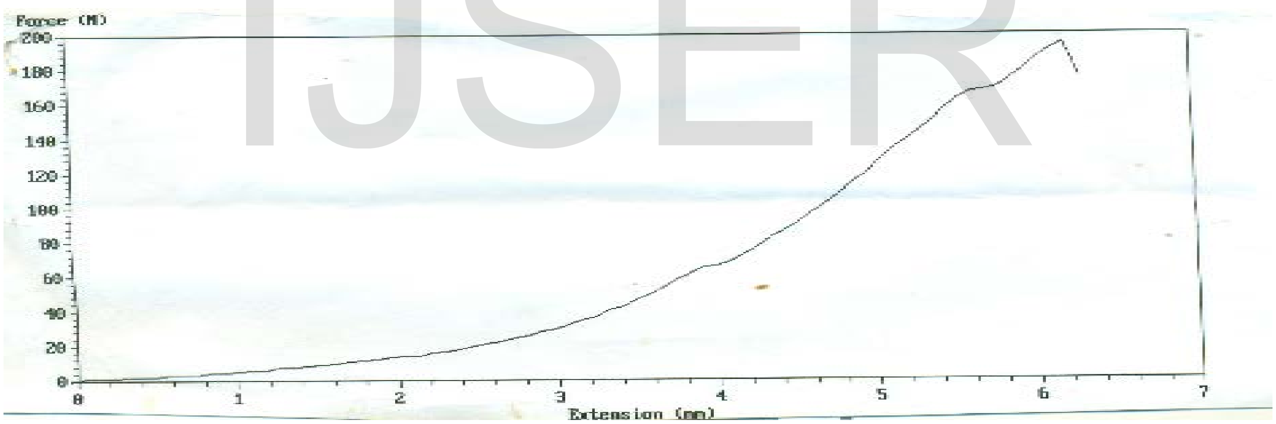

Figure 12: Tensile Strength, Energy Absorption and Stretch Measurement of Petopeg

Table 9: Flexural Test Result of Mojirin

Material: Ceiling Board
Sample: Mojirin
Ref No: 13
Operator: FIIRO

Test: Flexural
Test Type: 3 Point Flexural
Test Speed: 040.00 mm/minute
Span: 150.00 mm
Sample Type: Rectangular

Test No.	With (mm)	Thickness (mm)	Force @ Yield/Peak (N)	Deflection @ Yield/Peak (mm)	Bending Strength @ Yield/Peak (N/mm^2)	Energy to Peak/ Break (N.m)	Bending Modulus (N/mm^2)	Force @ Break (N)
17	50.000	10.400	35.500	1.2990	1.4770	0.0197-0.0545	869.50	20.800

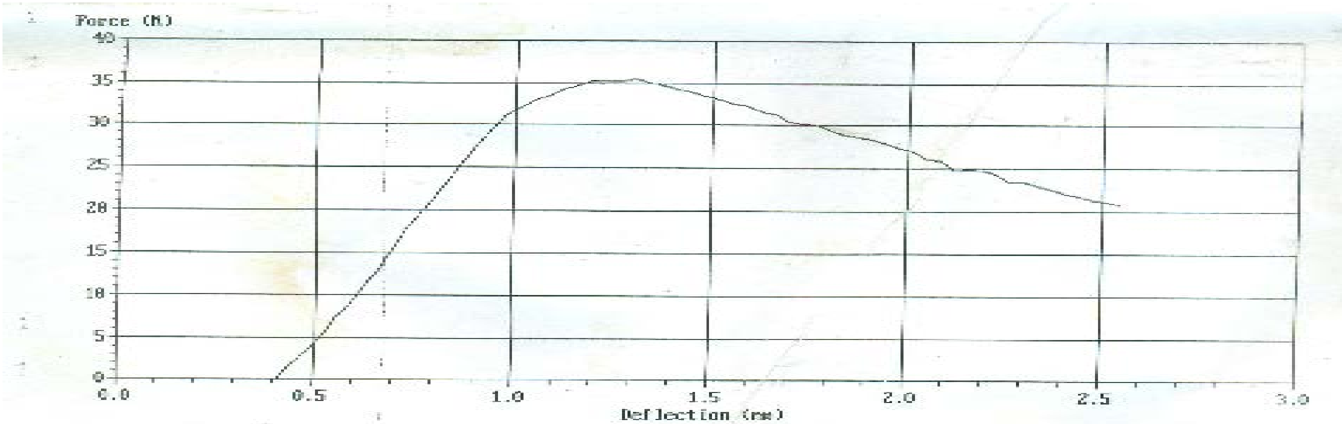

Figure 13: Flexural Strength, Energy Absorption and Stretch Measurement of Mojirin

Table 10: Tensile Test Result of Mojirin

Material: Ceiling Board
Sample: Mojirin
Ref No: 14
Operator: FIIRO

Test: Tensile
Test Type: Tensile
Test Speed: 100.00 mm/minute
Sample Length: 200.00 mm
Sample Type: Irregular

Test No.	Area (mm^2)	Force @ Yield/ Peak (N)	Elong. @ Yield/ peak (mm)	Stress @ Yield/ Peak (N/mm^2)	Energy to Peak/ Break (N.m)	Force @ Yield/Break (N)	Youngs Modulus (N/mm^2)
18	420.00	151.30	6.0140 – 8.0660	0.2807 – 0.3602	0.6150– 1.0371	117.90 - 140.80	35.832

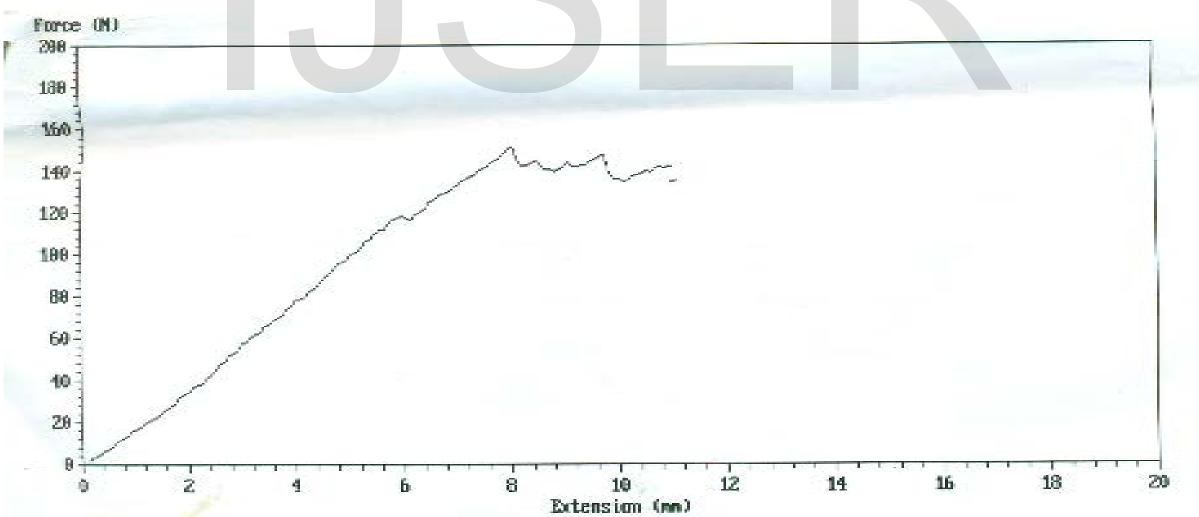

Figure 14: Tensile Strength, Energy Absorption and Stretch Measurement of Mojirin

The trend for Elongation at Yield/Peak, Bending Modulus and Energy to Break displayed by the four (4) Ceiling Boards investigated, recorded the following decreasing order; Wood Plastic 2 (6.3630-10.186mm, 1993.7N/mm2, 1.5766-2.4779N.m); Dele 1 (2.4330-5.6280mm, 1106.8 N/mm2, 1.4595-1.6263N.m); Petopeg 2 (6.2180mm, 1113.7N/mm2, 0.3683-0.3836N.m) and lastly Mojirin (6.2180mm, 869.50N/mm2, 0.6150-1.0371N.m). Slight deviation from this trend was only occurred where Petopeg 2 exhibited slight increase in bending modulus (1113.7N/mm2) over Dele 1 (1106.8N/mm2).

This result clearly indicated that the increase in the content of virgin Date pulp among the samples investigated furnished positive correlation with higher Tensile Strength properties. Wood Plastic 2 and Dele 1 exhibited a remarkable strength property with good impact toughness when compared with commercially available similar product like Mojin ceiling board locally produced by Mojirin Industries Nig. Ltd, Ibadan-Nigeria.

Based on the over-all parameter achieved from the investigations carried out, it seems appropriate to use Date fibre as a cellulose source substitute to wood in the production of fiber-board despite it moisture vulnerability. This asserts that Date fibre has a promising future in the building industry.

Conclusion and Recommendation

The water absorption test carried out showed that CMC reinforced Date Fibre virgin pulp furnished ceiling boards that offer poor resistance to deterioration which was observed for 2 weeks at 3 days intervals. This is due to poor water-tightness, resulting into increased water permeability, and eventual deterioration which occurred gradually over a period of about 5 weeks.

From the results of the strength investigation conducted, it was found that the boards had a good hardness property, compressive strength though lack a special water resistant property. When compared with the commercial standard board, Wood Plastic 2 and Dele 1 are assumed to meet the commercial standard result.

The resultant fiber boards show remarkable strength properties, surface beauty and attractiveness. Wood Plastic 2 requires no further painting when fixed, and low cost, compared to similar existing market products. There is guarantee in the safety of use as the product contains no carcinogenic material in their manufacture.

To discourage deforestation, and reduce the amount of wastes that are being sent to landfill, attention should be directed towards the use of Date fibre in the production of high quality fiber boards. In a world where virgin pulp sources are scarce, and environmental concerns require reduction in cutting down green forest, Date Fiber could become a good source of fiber in the tropical regions of the world where Date Palms are grown.

The demand for ceiling boards in Nigeria is directly proportional to the population actively involved in building and construction. Therefore, the need to develop strategies that would encourage the use of low-cost building materials if they are cheap, durable and affordable, is a welcome development.

References

1. Barreveld, W.H. 1993. Date palm products. Rome: FAO. (FAO Bulletin no. 101)
2. Casey J.P., (2000) Pulp and Paper, Chemistry and Technology, Interscience Publishers, Inc., New York, Pg 389 – 399, 415.
3. Chandra, Anil; Chandra, Anju, and Gupa, I.C., 2002. Date palm research in Tar Desert. Jodhpur (India) : Scientific publishers.
4. Elinwa, A.U. and Buba, S.A. (2003) “Construction cost factor in Nigeria”. Journal of Construction Engineering and Management, 119, 4, 698-714.
5. Elinwa, A.U. and Mangvwat, J.(2001) “Time-overrun factors in Nigerian Construction

industry". Journal of Construction Engineering and Management, 127, 5, 417-424.

6. Elinwa, A.U. and Uba, U.M. (2001) "Failure factors in the Nigerian construction industry". Nigerian Journal of engineering Management, 2,14-22.

7. Maheswarappe, B.S. and Rao, K.S.,2002. Journal literature pf Food Science and technology: A biliometric study. Annals of Library Science and Documentation, Vol. 29, no. 3: 126- 134.

8. Newell S.J. (2000) "Preparation and Treatment of Wood Pulp. Mc Graw Hill Book Company Inc. Volume 1,New York (2006)

9. . Swamy, R. N. (2000) "Designing concrete and concrete structures for sustainable development". Paper presented at the two-day CANMET/ACI International Symposium on concrete Technology for Sustainable Development, Vancouver, BC, Canada, April 19-20. 5.

10. Tropical Woods and Agricultural Residues as Sources of Local Pulp. F.A.O. Papers No. 3, Wisconson, (Sept. 2004).