Production of Fire-Resistant Ceiling Board from Agro-Based Fiber

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Abstract: This project "Production of Fire Retardant Ceiling Board from Agro-based Fiber" was carried out basically using some raw materials which were locally sourced. Some are materials sourced from the ground while some are from agricultural wastes and others are fire-resistant chemicals which are thermally stable inorganic salts like aluminum trihydrate or borate ester in addition to boric acid. A fire-resistant and environmentally-friendly ceiling board was produced by blending a mixture of two embodiments i.e. embodiments A and B. Embodiment A is a mixture of starch water, fire clay, sodium silicate and Zinc borate. This initial mixture is heated to form a gel. Fiber glass is then added to the gel to form a pulp which constitutes the core material. Embodiment B is a mixture of fire-resistant glass fiber meshes, virgin fiber pulp (agro-wastes) and magnesium compound. Embodiment B was used to reinforce embodiment A in a single layer forming a pulp. The pulp was fed into trays and pressed to form slabs. The slabs were then dried and finished into tiles. The panels were completely cured within 24 hours instead of 10 days by using the forced air circulation oven operating at 105^{o}C for 5 to 6 hours. The ceiling board samples produced were tested for structural and fire performance/rating. 550^{o}C max., and 200^{o}C min., fire performance/rating standard were set. Sample D1 exhibited structural failure @ 316^{o}C after 26 minutes maximum fire duration time and this outcome came about because D1 was unable to support its own weight when maximum fire duration exceeded 26 minutes @ 316^{o}C. R2 exhibited structural failure @ 297^{o}C. After enduring 296^{o}C furnace temperature for 22minutes, bending strength dropped to 1.3145N/mm2, a remarkable strength property with good impact toughness. The use of waste materials and no gas emission manufacturing process combined to make this panel an eco-friendly product which offers a rating 22 minutes maximum fire duration time, though R2 was unable to support its own weight when the maximum fire duration exceeded 22 minutes @ 296^{o}C. Fiber exhibited structural failure @ 255^{o}C after 21 minutes maximum fire duration time while POP exhibited structural failure @ 220^{o}C after 25 minutes maximum fire duration time. The four (4) samples were rated as follow: D1-315^{o}C/26minutes, R2-296^{o}C/22minutes, Fiber-254^{o}C/21 and POP-219^{o}C/25minutes. Decrease in the percentage of agro-waste increased the hardness of the board which is the property of a material that enables it to resist plastic deformation, usually by penetration. This was observed in R2 and D1 with 20% and 10% agro-waste content respectively, exhibiting higher strength properties compared to POP and Fiber with 40% and 30% agro-waste content.

The compressive strength which is the capacity of a material to withstand axially directed pushing forces was highest with D1 followed by R2, Fiber, and then POP. At ambient temperature, D1 displayed 3.5875N/mm2 Bending Strength at Peak/Yield and after enduring 315oC fire resistance test for 26 minutes, it dropped to 1.3849N/mm2 high.
Keywords: Ceiling board, Agro-based fiber, Fire-resistant, Flexural strength.

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Introduction

A ceiling board is a horizontal slab covering the upper section of a room or internal space. A ceiling board is generally not structural but is a shell concealing the details of the structure above. In modern buildings, electric lights, smoke detector, security cameras and signage are commonly attached to ceilings.

In the past, ceiling boards were produced using Asbestos, a fiber present naturally in rocks. It was used because of its high tensile strength, poor heat conductivity and high fire resistance. However, asbestos causes asbestosis, which leads to cancer. As a result of this problem, manufacturers of ceiling boards went into research to find out substitutes that can be used in the production of ceiling boards. This substitute includes shredded wood (natural fiber) from the forest which is becoming increasingly scarce due to increasing urban requirement for wood bringing us into a world where virgin pulp sources are scarce and environmental concerns require reduction in cutting down green forest, a world where agricultural wastes constitute environmental nuisance and a nightmare to farmers who either landfilled or burned them to no beneficial purpose constituting a colossal loss of natural resources and environmental hazard. These known pitfall can no longer be tolerated in a world were environmental friendliness is a law. Therefore, by incorporating a highly combustible agricultural wastes into a combination of unburnable materials would not only furnish building ceiling board composition with good fire rating to help provide fire safety in buildings but also prevent environmental nuisance these wastes constitute during post-harvest, abate air pollution caused by unnecessary burning of these wastes and discourage the act of deforestation by substituting the use of wood for agro-wastes thereby converting wastes to wealth.

Report on research investigation on agricultural wastes worldwide from the following four aspects: characterization, reuse, treatment and management, has proved that agricultural wastes has the potential to replace wood as good sources of natural fiber for the production of various types of ceiling board which can meet the demand for a wide range of use requirement in the tropical regions of the world where crops are grown. Ceiling boards from natural fiber constitutes parts of the elements of building construction but they are highly combustible materials.

Building Regulations and supporting documentation require elements of structure and other building elements to provide minimum periods of fire resistance, expressed in minutes, which are generally based on the occupancy and size of the building. Fire resistance is defined in BS

476: Part 20: 1987 as 'the ability of an element of building construction to withstand exposure to a standard temperature / time and pressure regime without loss of its fire separating function or loadbearing function or both for a given time. While in accordance with ASTM E 119, Standard Test Method for Fire Tests of Building Construction and Materials, Fire Resistance or time fire rating is the ability of a structure to remain in place and prevent the spread of flames and heat when exposed to fire conditions.

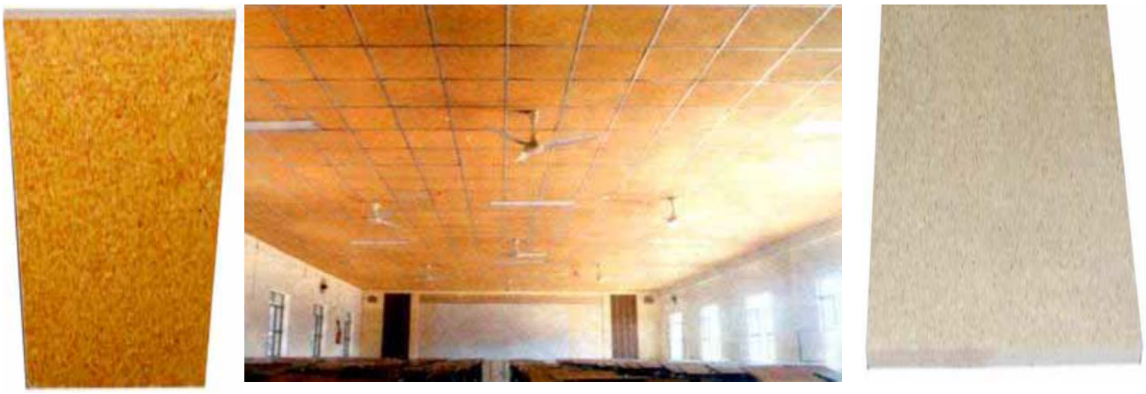

Figure 1. Ceiling Board Sample and its Application in Building Construction

According to Benichou *et al.*, 2001, Stability failure is defined as the loss of load-bearing capacity of structural members. To meet the stability criterion, without structural collapse, the structural element must perform its load bearing function and carry the applied loads for the duration of the test. In the case of the furnished fire resistant board samples, inability of the sample to bear/support its own weight is an indication of stability failure. Integrity failure is defined as flames or hot gases penetrating through the components (Benichou *et al.*, 2001).

To meet integrity criterion, the test specimen must not develop any cracks or fissures which allow smoke or hot gases to pass through the material. Integrity criteria intended to test the ability of a barrier that is to prevent fire spreading from the room of origin. In the case of the furnished fire resistant board samples investigated, if the board cracks or develop any sign of fissure at a particular furnace temperature, it's a clear sign of Integrity failure. All fire rated construction elements must meet one or more of these criteria. The choice of materials for ceilings can significantly affect the spread of fire and its rate of growth, even though they are not likely to be the materials first ignited.

The specification of ceiling material is particularly important in circulation spaces where surfaces may offer the main means by which fire spreads, and where rapid spread is most likely to prevent occupants from escaping. Two properties of ceiling materials that influence fire spread are the rate of flame spread over the surface when it is subject to intense radiant heating, and the rate at which the ceiling material gives off heat when burning. To help provide maximum fire safety in buildings, certain building elements need to be constructed of non-combustible materials.

The objective of this research work is to produce a fire-resistant and environmentally-friendly ceiling boards by incorporating highly combustible natural fibers (agro-based fiber) into unburnable composition in varying proportions in order to obtain the composite that would furnish a fire rating to prevent rapid fire spread, which could trap occupants in the building and reduce the chance of fires becoming large, which are more dangerous-not only to occupants and fire service personnel, but also to people in the vicinity of the building.

2. Research Methodology

2.1.0 Materials

Most of the raw materials used in this research study were obtained locally. These materials include starch water, fire clay (consisting of 30% ball clay, 35% feldspar and 20% silica), Fiber glass, and fire-resistant glass fiber meshes processed in the Solid Minerals and Ceramic Research Laboratory of the Federal Institute of Industrial Research, Oshodi (F.I.I.R.O.), Lagos-Nigeria, and virgin fiber pulp (agro-wastes) i.e. rice straw, obtained from a rice mill in kagara, Niger State, Nigeria. While others are sodium silicate (Na2SiO3), Zinc borate, magnesium compound, kerosene stove, laboratory mesh-sieve, Instron 4260 universal testing machine, charpy impact testing machine–capacity 300J Samuel Benson Limited, Hydraulic Press–serial No. 94030626 Cat C 43/2, Paterson scientific digital balance Sartorius laboratory LC 120003 (MCl), measuring cylinder, stirrer, iron mold, polyethylene sheet, weighing scale, clean bucket, stop watch, vernier caliper, meter rule, thermometer, and scale balance meter.

2.2.0 Methods

A building material is designated as non-combustible if it satisfies performance criteria when tested in accordance with the following British Standards:

BS 476: Part 4: 1970 (1984) Non-combustibility test for materials.

BS 476: Part 11: 1982 (1988) Method for assessing the heat emission from building materials.

By Authority of the United States of America, materials that meet the criteria of ASTM E 136, Standard Test Method for Behavior of Materials in a Vertical Tube Furnace, and/or ASTM E 119: Standard Test Methods for Fire Tests of Building Construction & Materials. Page 1 are classified as being noncombustible. The failure criteria for the full-scale tests were from CAN/ULC-S101-M89 and ASTM E119. By this test standards, the material is considered to have failed if there is passage of flame or gasses hot enough to ignite it. The three failure criteria for fire resistance testing are stability, integrity and insulation.

2.2.1 Production of Fire Retardant Board Samples

Fire-resistant and environmentally-friendly ceiling board was produced by blending a mixture of two embodiments i.e. embodiments A and B. Embodiment A is a mixture of starch water, fire clay, sodium silicate and Zinc borate.

This initial mixture is heated and mixed with Fiber glass to form a gel which constitutes the core material. Embodiment B is a mixture of fire-resistant glass fiber meshes, virgin fiber pulp (agro-wastes) i.e. rice straws and magnesium compound. Embodiment B was sandwiched in between embodiment A to reinforce it in a single layer forming a pulp. The pulp was fed into trays and pressed to form a Tile. The Tiles were then dried and completely cured by using the forced air circulation oven operating at 105oC for 4 to 6 hours. Figure 2 shows the schematic of the laboratory production of the composite material.

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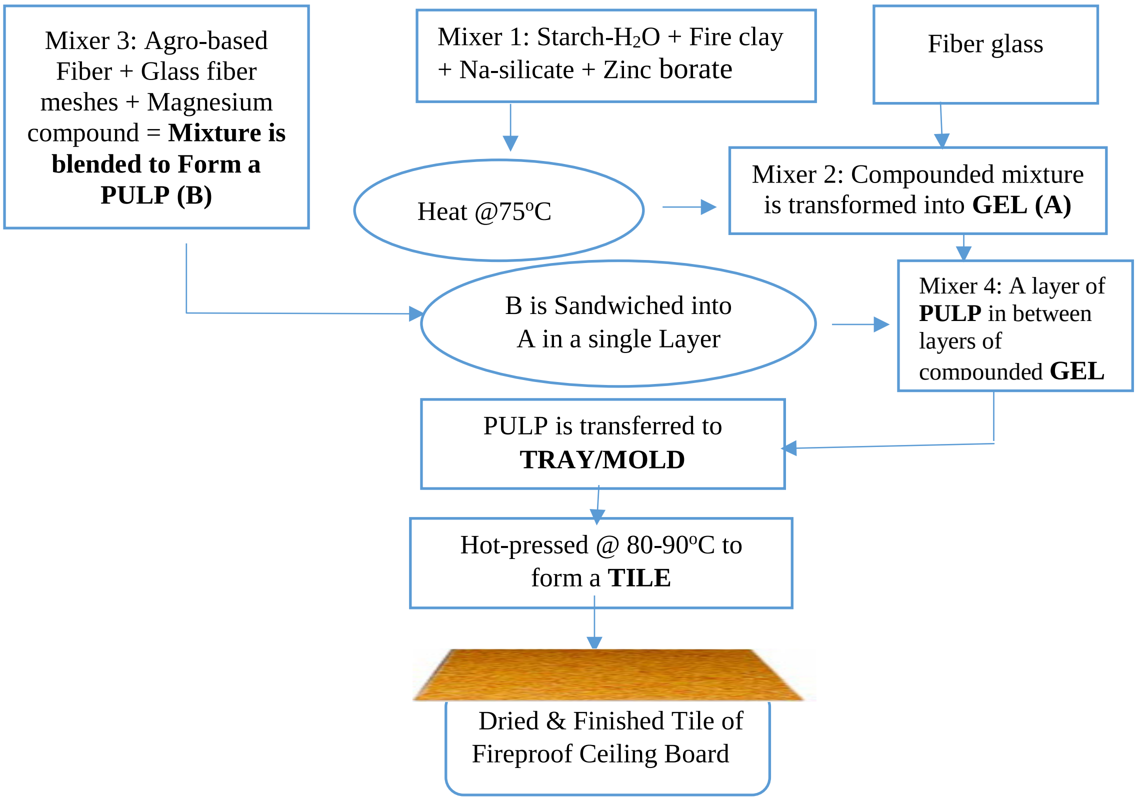

Figure 2. Schematic of the production process

2.2.2 Water Absorption/Resistance 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.

For the water absorption test, the specimen was dried in a forced air circulation oven at 105oC 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 23oC until equilibrium. 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

2.2.3 Determination of Fire Performance of Board Samples (Fire Resistant Test)

In this test, the material samples were placed in the test furnace and its flaming time and the furnace temperature were measured. Tests were performed by recording specimen temperature. The temperature of 500ºC was selected as the critical temperature. The temperature of all specimens before testing were ambient. The temperature of the board sample started to rise on the average in 5 minutes and at 16 minutes the temperature of 90ºC has been recorded. Tensile and Flexural strength investigation were conducted on all samples investigated at various temperatures ranging between 205 and 305oC over periods of 15, 20, 25 and 30 minutes.

Modulus of Elasticity (MOE) characterizes the resistance of the material to a primary deformation and its capacity to return to its initial shape, so long as the material is not irreversibly deformed. Properties such as modulus of elasticity, force at peak/yield, bending

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strength at peak/yield, energy at peak/yield and bending modulus amongst others were conducted on all board samples investigated in this research study using FIIRO Instron Testometer model 4260 universal testing machine.

3.0 Result and Discussion

3.1 Water Absorption Test

In the water absorption test, D1 recorded the lowest value, 7.0% after 6hours due to poor water tightness brought about by the low content of agro-waste incorporated. The water absorption trend took the following increasing order: D1 (7.0%) < R2 (9.6%) < POP (11.7%) < Fiber (12.2%).

Table 1. Water Absorption Test Results of furnished composite material mix proportion

Furnished Ceiling Board Samples	Embodiment A	Embodiment B	Water Absorption (%)
			After 6 hours
POP	60	40	12.2
Fiber	50	50	11.7
R2	40	60	9.6
D1	30	70	7.0

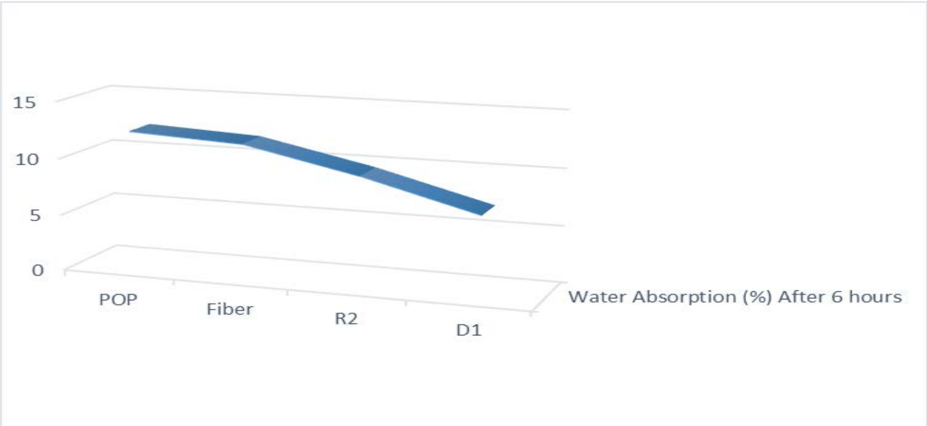

Figure 3. Water Absorption Behavior of Various Fire Retardant Ceiling Boards Investigated

As presented in table 7, the water absorption trend showed positive correlation with the proportion of virgin fiber pulp present in the board samples. After 6 hours, it was observed that D1 with the lowest proportion of virgin fiber pulp recorded the lowest water absorption values which increased as the virgin fiber pulp content increased. Fiber recorded the highest water absorption value, 12.2% and offered the poorest resistance to deterioration which was observed for 2 weeks at 3 days intervals. This was due to poor water- tightness, resulting into increased water permeability, and eventual deterioration which occurred gradually over a period of 8 weeks.

3.2 Laboratory Furnace Temperature Test

Laboratory Furnace tests were conducted at the Analytical Division of the Federal Institute of Industrial Research, Oshodi, FIIRO, Lagos, to determine the effect of subjecting the samples to heat treatment at various degrees of elevated temperature. According to the test results in Table 2, Fiber exhibited structural failure at when temperature exceeded 219^{o}C after 25minutes heating duration time. POP did not exhibit structural collapse until the temperature exceeded 255°C beyond a heating period of 21minutes. R2 and D1 maintained stability at 286°C and 305°C maximum. It is suspected that the heat resistance of the board samples has come about due to chemical reactions taking place in the board sample at temperature between 100°C and 125°C resulting in the intense water evaporation.

Table 2. Furnace Test Results (Time-Temperature to Failure for board samples in Furnace)

Board Samples	Stability Failure	Integrity Failure	Fire Rating
D 1	Component unable to support its own weight if maximum fire duration exceed 26 minutes @ 306°C.	Structural failure @ 306°C beyond 26 minutes heating period.	315°C/26 minutes
R 2	No structural failure occurred from 0-286°C @ 0 to 25 minutes maximum fire duration time	Structural failure @ 287°C beyond 19 minutes heating period.	296°C/19 minutes
POP	No structural failure occurred from 0-255°C @ 0 to 21 minutes maximum fire duration time	Structural failure @ 255°C beyond 21 minutes heating period.	254°C/21 minutes
Fiber	Component unable to support its own weight if max., fire duration exceed 25 minutes @ 220°C.	Structural failure @ 220°C beyond 25 minutes heating period.	219°C/25 minutes

Board sample contains considerable amount of chemically linked water and it is suspected that upon evaporation, the water consumes thermal energy and in such a way prevents the specimen from overheating. It is also suspected that for the same reason, the specimen temperature remains stable for a certain period (15 to 30 minutes) depending on the board sample. In 15 minutes the temperature starts rising insignificantly. It can be asserted that evaporating water suspended the increase in temperature for close to 10 minutes. In approximately 25 minutes after the beginning of testing, a more rapid increase in the temperature was observed. This could also mean that a major portion of the water evaporated resulting into a constant rise in the temperature which was observed until the temperature of 305°C was reached in the case of D1.

The said specimen has reached such temperature within 55 minutes after the beginning of testing, and was allowed to withstand this temperature for a period between 15 to 26 minutes. This is why D1 is rated 305°C/26 minutes. Same goes for R2 (286°C/19 minutes), POP (254°C/21 minutes) and Fiber (219°C/25 minutes).

3.3 Effect of Agro-based material Composition in FRCB on strength properties

Decrease in the percentage of agro-waste increased the hardness of the board which is the property of a material that enables it to resist plastic deformation, usually by penetration. This was observed in R 2 and D 1 with 15% and 10% agro-waste content respectively, exhibiting higher strength properties compared to POP and Fiber with 20% and 25% agro-waste content. The compressive strength which is the capacity of a material to withstand axially directed pushing forces was highest with D 1 followed by R 2, then POP and Fiber.

3.4 Strength properties investigated on the board samples after Furnace Temperature

Flexural strength, also known as modulus of rupture, or bend strength is a material property, defined as the stress in a material just before it yields in a flexure test. Modulus of rupture, frequently abbreviated as MOR, (sometimes referred to as bending strength), is a measure of a specimen's strength before rupture. The yield point is the point on a stress–strain curve that indicates the limit of elastic behavior and the beginning of plastic behavior. The yield point determines the limits of performance for mechanical components, since it represents the upper limit to forces that can be applied without permanent deformation. Yield strength or yield stress is the material property defined as the stress at which a material begins to deform plastically whereas yield point is the point where nonlinear (elastic + plastic) deformation begins. However, at ambient temperature, D1 displayed 3.2275/ 4.8650N/mm2 Bending Strength at Peak/Yield, but after enduring 305ºC furnace temperature for 26 minutes, bending strength dropped to 1.3849N/mm2, an indicative of the fact that D1 has lost over 70% of its bending strength and as a result, its structural stability and integrity is heavily compromised. The same goes for R2 dropping from 2.8790 N/mm2 to 1.1970N/mm2, POP also compromising its strength property by dropping from 2.4120-3.6510 N/mm2 to 0.8571-0.9061N/mm2 and lastly Fiber dropping in bending strength property from 38.500-39.200N/mm2 to 0.8571-0.9061 N/mm2. The values of Force, Deflection at Peak/Yield, Energy at Peak/Break and Bending Modulus before and after the ceiling boards were subjected to Furnace Temperature are presented in Tables 3, 4, 5, 6 and 7.

Table 3. Flexural Energy Absorption and Stretch Measurement of D1 after Furnace Test

Material: Ceiling Board	**Test:** Flexural
Sample: D1	**Test Type:** 3 Point Flexural
Ref No: 4	**Test Speed:** 040.00 mm/minute
Operator: FIIRO	**Span:** 150.00 mm
	Sample Type: Rectangular

Test No.	With (mm)	Thickne-ss (mm)	Force@ Peak/ Yield (N)	Deflecti-on @ Peak/ Yield (mm)	Bending Strength @ Peak/Yield (N/mm^2)	Energy to Peak/ Break (N.m)	Bending Modulus (N/mm^2)
14	50.000	11.500	40.700	0.7370	1.3849	0.0171-0.0490	664.98

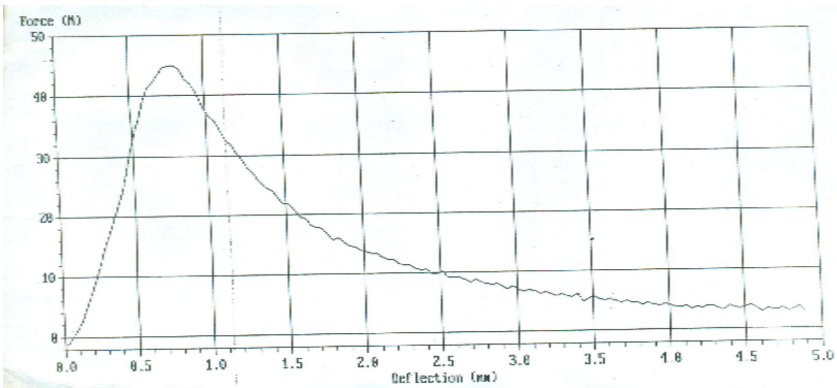

Figure 4. Graph showing 3-point bend strength test of D1

Table 4. Flexural Energy Absorption and Stretch Measurement of R2 after Furnace Test

Material: Ceiling Board	**Test:** Flexural
Sample: R2	**Test Type:** 3 Point Flexural
Ref No: 6	**Test Speed:** 040.00 mm/minute
Operator: FIIRO	**Span:** 150.00 mm
	Sample Type: Rectangular

Test No.	With (mm)	Thickne-ss (mm)	Force @ Peak/ Yield (N)	Deflecti-on @ Peak/ Yield (mm)	Bending Strength @ Peak/Yield (N/mm^2)	Energy to Peak/ Break (N.m)	Bending Modulus (N/mm^2)
14	50.000	12.400	40.900	1.1230	1.1970	0.0222-0.1356	659.95

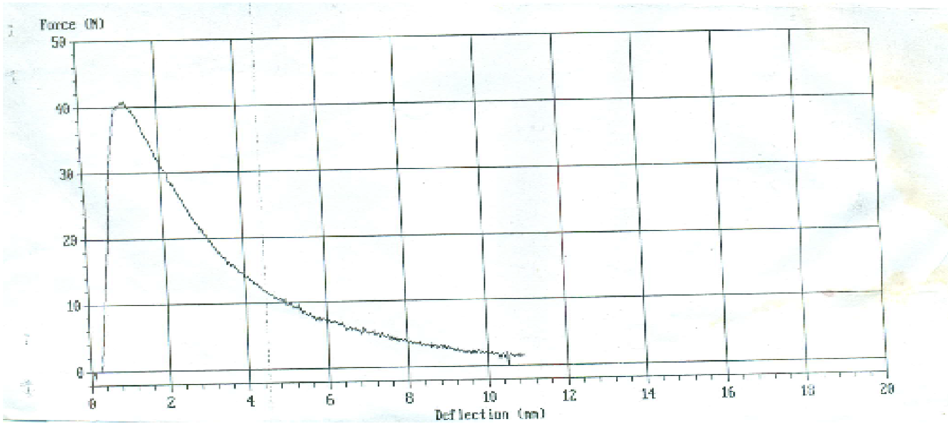

Figure 5. Graph showing 3-point bend strength test of R2

Table 5. Flexural Energy Absorption and Stretch Measurement of POP after Furnace Test

Material: Ceiling Board	**Test:** Flexural
Sample: POP	**Test Type:** 3 Point Flexural
Ref No: 9	**Test Speed:** 040.00 mm/minute
Operator: FIIRO	**Span:** 150.00 mm
	Sample Type: Rectangular

Test No.	With (mm)	Thickne-ss (mm)	Force @ Peak/ Yield (N)	Deflecti-on @ Peak/ Yield (mm)	Bending Strength @ Peak/Yield (N/mm^2)	Energy to Peak/ Break (N.m)	Bending Modulus (N/mm^2)
14	50.000	10.500	21.000-22.200	1.1890	0.8571-0.9061	0.0109-0.0467	437.73

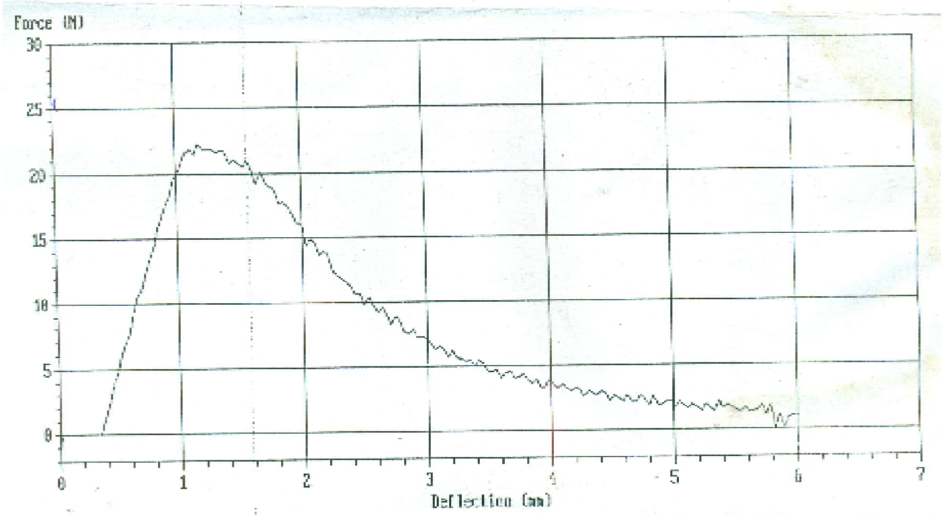

Figure 6. Graph showing 3-point bend strength test of POP

Table 6. Flexural Energy Absorption and Stretch Measurement of Fiber after Furnace Test

Material: Ceiling Board	**Test:** Flexural
Sample: Fiber	**Test Type:** 3 Point Flexural
Ref No: 12	**Test Speed:** 040.00 mm/minute
Operator: FIIRO	**Span:** 150.00 mm
	Sample Type: Rectangular

Test No.	With (mm)	Thickne -ss (mm)	Force @ Peak/ Yield (N)	Deflecti- on @ Peak/ Yield (mm)	Bending Strength @ Peak/Yiel d (N/mm^2)	Energy to Peak/ Break (N.m)	Bending Modulus (N/mm^2)
14	50.000	12.500	38.500-39.200	1.1890	0.8571-0.9061	2.8010-3.0910	164.42

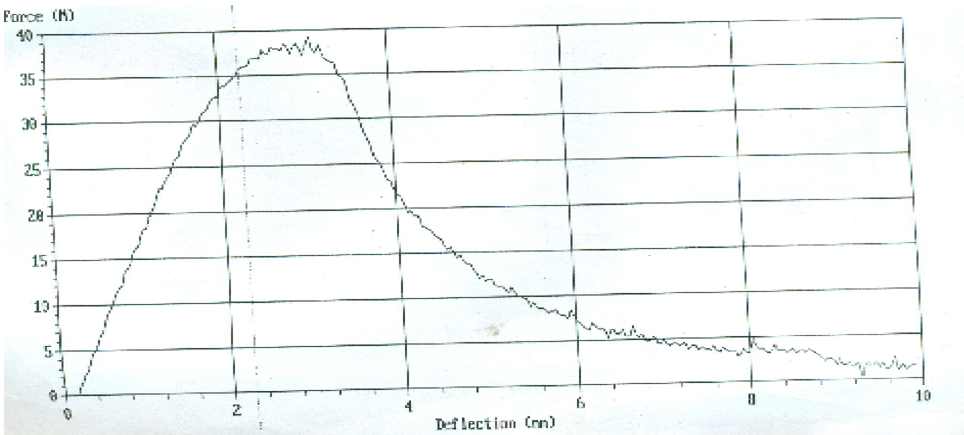

Figure 7. Graph showing 3-point bend strength test of Fiber

Table 7. Summary of Water Absorption, Flexural Strength Properties of Furnished Ceiling Boards before and after Furnace Test

Board Sample	%wt. Agro-based Fiber	%wt. A + Glass Fiber Meshes	%wt. of B without Agro-based Fiber	Water Absorption (%) After 6 Hours	**Flexural Strength Properties**							
					Force @ Peak/Yield (N)		Bending Strength @ Peak/Yield (N/mm^2)		Energy to Peak/ Break (N.m)		Bending Modulus (N/mm^2)	
					Before Furnace Temp. Test	After Furnace Temp. Test	Before Furnace Temp. Test	After Furnace Temp. Test	Before Furnace Temp. Test	After Furnace Temp. Test	Before Furnace Temp. Test	After Furnace Temp. Test
D1	10	20	45	7.0	313.760	40.700	3.2275–4.8650	1.3849	0.8920-1.4930	0.0171-0.0490	2650.50	664.98
R2	15	20	40	9.6	281.254	40.900	2.8790	1.1970	0.7389-1.6390	0.0222-0.1356	2517.40	659.95
POP	20	20	35	11.7	256.980	21.000-22.200	2.4120-3.6510	0.8571-0.9061	0.5120-1.5438	0.0109-0.0467	1490.00	437.73
Fiber	25	20	30	12.2	196.500	38.500-39.200	1.2320-2.1340	0.8571-0.9061	0.3430-0.8920	2.8010-3.0910	1243.90	164.42

A is a mixture of starch water, fire clay, sodium silicate, Zinc borate and Fiber glass while B is a mixture of fire-resistant glass fiber meshes, virgin fiber pulp (agro-wastes) i.e. rice straws and magnesium compound.

The tensile strength of a material is the maximum amount of tensile stress that it can take before failure, such as breaking or permanent deformation while Bending Modulus/Flexural Modulus is an intensive property that is computed as the ratio of stress to strain in flexural deformation, or the tendency for a material to resist bending. In the Tensile Strength investigation conducted, it was observed that D1 displayed higher values of Force at Peak or Yield (313.760N) followed by R2, (281.254N), POP (236.980N) and then Fiber (196.500N) before being subjected to furnace temperature. But after Furnace test, these values decreased as presented in Table 8, loosing over 65% of their strength properties thereby compromising in strength properties. The trend for Elongation at Peak/Yield, Stress at Peak/Yield and Force at Break displayed by the four (4) Ceiling Boards furnished and investigated, including Force at Peak/Yield exhibited positive correlation with the proportion of virgin pulp fiber present in the board samples. These results are summarized in Table 8 below. This result clearly indicated that the increase in the composition of virgin fiber pulp furnished nagative correlation with higher Tensile Strength properties. In tension, the bending strength at peak/yield and bending modulus decreased slowly as temperature rose until flaming which occurred at different temperature depending on the particular sample being investigated. As temperature continued to rise, the decline became more rapid. The modulus of elasticity in compression of the whole fire resistant ceiling boards investigated lose over 75% of their strength in the first 45 minutes at temperature ranging between 210 and 305°C.

Table 8. Summary of Tensile Energy Absorption and Stretch Measurement of Furnished Ceiling Boards before and after Furnace Test

Furni-shed Board Sample	Tensile Strength Properties							
	Force @ Peak/Yield (N)		Elongation at Peak/Yield (mm)		Stress at Peak/Yield (N/mm^2)		Force at Break (N)	
	Before Furnace Temp. Test	After Furnace Temp. Test	Before Furnace Temp. Test	After Furnace Temp. Test	Before Furnace Temp. Test	After Furnace Temp. Test	Before Furnace Temp. Test	After Furnace Temp. Test
D1	313.760	140.700	3.2275–4.8650	1.3849	0.8920-1.4930	0.0171-0.0490	2650.50	664.98
R2	281.254	110.900	2.8790	1.1970	0.7389-1.6390	0.0222-0.1356	2517.40	659.95
POP	236.980	71.000-82.200	2.4120-3.6510	0.8571-0.9061	0.5120-1.5438	0.0109-0.0467	1490.00	437.73
Fiber	196.500	48.500-59.200	1.2320-2.1340	0.8571-0.9061	0.3430-0.8920	2.8010-3.0910	1243.90	164.42

Conclusion and Recommendations

This paper describes tests conducted to evaluate the fire resistant effectiveness of the four different grades of ceiling board sample furnished by impregnating unburnable materials with highly combustible virgin pulp fiber (agro-wastes) to form ceiling boards for building construction application.

Testing showed that the furnished board samples especially D1 and R2 can retard a spreading fire for a period of at least 20 to 25minutes and this is intended to:

• Minimize the risk to the occupants, some of whom may have to remain in the building for some time (particularly if the building is a large one), while evacuation proceeds.

• To reduce the risk to fire fighters engaged on search and rescue operations.
• To reduce the danger to people in the vicinity of the building who may be hurt by falling debris.

Because of scarce virgin pulp resources, this study has provided baseline information on the potentials of agro-base fibers/wastes as an alternative to clear cutting of primeval forest in the tropical regions of the world where they are grown. The strength properties of the boards indicated that agro-wastes could be used in the production of fire resistant ceiling board of flexural strength, medium density, and durability in Nigeria serving as an alternative to sawn timber.

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