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Physical and Mechanical Properties of Composite Fiber Boards for Wall Surface Finishing

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Abstract: ***The housing deficit situation in Ghana keeps worsening each day, this is partly due to the rise in cost of construction materials like cement, sand, roofing sheets etc. The development of alternative local construction materials that will cut down the quantities of these components needs much attention. Two different composite boards made from the combination of cement, sand, sawdust and coconut fibers on one hand and cement, sand, sawdust and rubber fibers on the other hand. Physical properties of the boards such as density, water absorption, scrubbing, fire resistance and retaining of moisture were evaluated after the boards were made. Mechanical properties like the dropping (impact) and flexural bending were also investigated into. The physical properties that were obtained from the boards were consistent with the ASTM C1186-08 – 2012 standards. The boards made from the rubber fibers performed better with respect to the Flexural Bending test and the drop test.***

Keywords: flexural, Mechanical, fibers, composite, deficit

1. Introduction

The housing deficit situation in Ghana is gradually becoming worse day by day, a 50kg bag of cement cost GHC33, a standard size (1.1x2.4, width 0.4mm) steel roofing sheet also cost GHC23 as at the close of 2015[1].The housing deficit in the country is 1.7million houses as at 2013 as reported by the Ministry of Water Resource Works and Housing[2]. If the country's housing needs are going to be realized then the local construction industry should put much efforts into finding ways to develop cheaper building materials and methods for building. This will facilitate the reduction in the total cost of building; with this, more houses can be built each year from the limited resources available to us.

Sand and cement are among the most predominant building materials found in the construction industry in Ghana. Sand winning aside its devastating effect on the environment [3] has become an expensive business these days; trucks have to travel long distances to get sand. This in effect affects the price of sand day in and day out. The price of sand is also driven by changes in fuel prices, vehicle maintenance as well as the scarcity of the resource [3]. On the other hand the price of cement is also controlled by importation of clinker, energy, exchange rate and the like. These factors indirectly drives the cost of building in the country high.
Much effort should therefore be put into finding alternative building materials that can replace or reduce the quantity of these materials used for walling units and concrete works. Areas that have attracted some attention includes recycling of waste concrete into course aggregates and recovery of steel bars from broken down concrete structures. Alternative and cheaper binders should also be researched into. Pozzolana from ash and clay has been established to have binding properties [4], it is also established that the amount of cement to be used can be cut from 10% to 40% if Pozzolana cement is employed [5].

The processing of Sawdust, wood chips, coconut husk, plies and other plant waste into useful building materials is one area that has not received urgent attention in the country. Waste polyethylene has also been researched into as a possible addition to the mixture used in making composite particle boards [6]. This nevertheless has a wide range of products to offer, this may include ceiling panels, sawdust cement boards, furniture, floor panels, doors etc. This concept will not only offer low cost raw materials but it will also reduce the amount of timber used for all these products. Traditional cement boards (used for wall installations in place of plastering) are made from sand and cement, the introduction of any saw dust will reduce the amount of sand needed whiles offering other advantages like light weight and easy installations. It is against this background that this study is being carried out.

1.1 Aim

The aim of this study is to develop a useful building material that will reduce the amount of sand and cement for construction.

1.2 Objectives

- To make a cement board from sand, cement and sawdust using coconut husk for reinforcement.
- To make a cement board from sand, cement and sawdust using rubber fiber as a tensile reinforcement.
- To test and compare the mechanical and physical properties of the cement boards with different reinforcement.

1.3 Methodology

This study will employ the use of quantitative and qualitative analysis for the collection of data.

1.4 Scope

The scope of the study will be limited to construction materials.

2. Experimental Techniques

2.1 Cement, Sand, Sawdust and Coconut Fiber Boards

These boards were made with a material ratio of 25% cement, 25%fine sand, 40%sawdust and 10%coconut fiber by volume. Since they are intended for wall installations in place of plastering, the fiber was introduced to improve the tensile properties of the concrete. [7] This provides added advantages in case the boards will be used in load bearing situations. The coconut husks were obtained from coconut sellers who treat them as waste. The husks were then beaten into fibers with a hammer or mallet. Cocoanut fibers contain an organic fluid which is made up of chemicals that have the tendency of reducing the effect of cement during hydration and bonding processes. These chemicals were removed from the fibers by soaking them in water for at least 24hrs. [8] After which the fibers were dried to make them ready for the mixing process.

2.2 Cement, Sand, Sawdust and Rubber Fiber Boards

These boards were made using the ratio mentioned above but this time around 10%rubber fiber (nylon fibers) was added to the mixture not coconut fiber. Cheap nylon robes were purchased from a hardware shop (waste polymer ropes can be recycled and used as well) [6].The robes were then combed to remove the strands. Waste rubber fibers from construction sites are desirable for this purpose since cost is of prime essence here.

2.3 Board Preparation Process

2.3.1 Sand Sieving

The sand to be used was sieved in order to remove unwanted materials and particle sizes. Fine sand is preferable as this will improve plasticity, workabilitycompressive strength and bonding with the saw dust [9].An electric vibrator was used for the sieving process, the sieves were arranged according to their numbers in the following order 10, 12, 16, 20, 40 followed by 50. The sand that was retained in the sieve numbered 50 after the vibration process was used in making the boards. The vibration period for each sieve size was 2minutes.

2.3.2 Mixing process

The ratios of the cement, fine sand, sawdust and coconut fiber or rubber fiber as stated above was measured by volume and made ready for mixing. The mixture was done with the help of a trowel on a wooden platform. Water is then added to the mixture to help it become plastic and workable. Too much water will destroy the mixture so water should be added with care. After the addition of water the mixture is turned inside out several times to ensure uniformity.

2.3.3 Moulding Process

After the mixing process is the moulding process, where a rectangular metal case of predetermined sizes of 400mm x300mm x15 mm was used as the mould. In other for easy removal of the boards form the platform, the wooden platform was lubricated with grease before the mixture was poured on it (a paper can also be used to prevent sticking of the board to the platform). The mixture was then fetched and poured into the mould until the mould was well filled. The trowel was then used to dress the edges and the surfaces to eliminate voids and cracks in the materials.

2.3.4 Curing

The curing process was next after moulding the boards, during curing the boards were left under shade and water was poured on them twice daily (in the morning and evening for 8days). This was done to enhance the hydration process between the cement and the water during bonding. The curing process helps to improve upon the strength of the boards[10].

The boards were then left to dry after 8days of curing. The drying process was done by arranging the boards in direct sunlight for 21days in order for the cement to attain its maximum strength.

2.3.5 Finishing

The boards were at this stage painted to give them good appearance. Design patterns can also be pressed on the surface of the boards during moulding to improve upon their appearance.

2.4 Materials Testing Techniques

Several tests were performed to determine the physical properties of the boards; among these tests were density test, moisture content test, bending or flexural test, water absorption test, drop test, scratch test and fire resistance test.

2.4.1Density Test

The boards were dried for 21days to maximize the bonding strength of the cement. After this the water displacement density method was used to determine the average density (ρ) in g/cm^3 of the boards. For this test the rubber fiber boards were labeled RA1 and RA2 and the coconut fiber boards were also labeled CA1 and CA2.

The boards were then weighed under water after they were immersed for 48hours, the saturated weight in air was also measured. They were then dried to a constant weight in an oven at 90± 2˚C in order to obtain the dry mass. The density was calculate with the formula

$D = [W/(B - S)]\, X\rho w$[11].In accordance to Standard Specifications ASTM C1186-08(2012) whereD=Density kg/m3, W=Dry weight of specimen kg, S=Saturated weight kg,B=Suspended weight kg, and ρw=Density of the water.Average Density of the boards were therefore calculated as follows;$A\rho = (\frac{RA1 + RA2}{2})$ and $A\rho = (\frac{CA1 + CA2}{2}) = \rho g/cm^3$.

2.4.2 Flexural Bending Strength

The axil bending strength of the boards were also evaluated using the flexural bending test. In this test the samples were labeled as RB1, RB2 and RB3 for the rubber fiber boards and CB1, CB2 and CB3for the coconut fiber boards. The samples were supported over a span of 280mm and loading is done at rates to obtain failure (figure 2.1).

The flexural strength was therefore determine with the formula; $S = \frac{3PL}{2bd^2}$ in accordance with ASTM C1186-08. [11]Where S= Flexural Strength, psi, P=Maximum load, (N) L=Length of span (mm), b =Width of the specimen (mm), d =Thickness of the specimen (mm).

Average Flexural bending of the rubber fiber boards = ($\frac{RB1+RB2+RB3}{3}$) = A psi.

Average Flexural bending of the coconut fiber board = ($\frac{CB1+CB2+CB3}{3}$) = A psi.

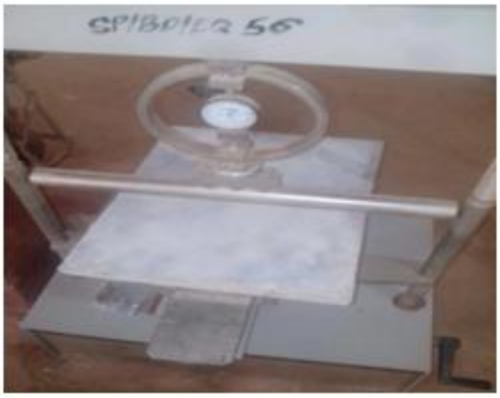


Figure 2.1: Picture shows how the specimen was subjected

2.4.3 Water Absorption Test

To assess the amount of water each type of board can absorb the water absorption test was conducted. For this test the samples were marked RC1 and RC2for the rubber fiber boards and CC1 and CC2 for the coconut fiber boards. The boards were dried of 21days in temperatures fluctuating from 27ºC to 32ºC before this test was conducted. The dry weight of the boards were then determine after which the boards were totally soaked in water for 48hrs. The wet weight of the boards were then measured and the percentage water absorption was calculated using the formula; W1-W2/W2 X 100% with respect to the Standard Specification ASTM C1186 – 08.[11]

There average water absorptions for the various boards were therefore calculated as below;

Average water Absorption of the rubber fiber board= ($\frac{RC1+RC2}{2}$) =%

Average water absorption of the coconut fiber board= ($\frac{CC1+CC2}{2}$) =%

2.4.4 Moisture Content Tests

The amount of moisture each board can retained was also verified. The rubber fiber boards were labeled RD1 and RD2 whiles those made up of coconut fiber were labeled CD1 and CD2. After drying the boards for 21days, they were weighed to determine their initial weight (W1). The boards were then placed in an electric oven where the temperatures were raised to between 110ºC to 120ºC. These temperature condition were maintained for 12hours after which the boards were weighed again to determine the oven dry weight (W2). The amount of moisture content in percentage was calculated using the formula (W1-W2)/W2 X100%.where WI=Initial weight, W2=Oven dry weight[11].

The average moisture contents of the boards were therefore determined with the formular below;

Average moisture content of rubber fiber board= ($\frac{CD1+CD2}{2}$) =%
Average moisture content of coconut fiber board= ($\frac{RD1+RD2}{2}$) =%.

2.4.5 Scrubbing Test

The scrubbing test was done in order to check the resistance of the boards to abrasion. In this test the samples were marked RE1 and RE2 (for the rubber fiber boards) and CE_1 and CE_2 (for the coconut fiber boards)

The initial weight (W1) of the boards were measured, after which the surface of the boards were scratched 120times with a wire brush. The scratched boards were then measured again to determine the final weight (W2). [11] The final weight loss (WL) is therefore determined by$WL = \frac{W2 - W1}{W_2} \times 100$.
The average weight loss by the samples were therefore determined by;
Average weight of rubber fiber boards = ($\frac{RE_1 1+RE_2}{2}$) =%
Average weight of rubber fiber boards = ($\frac{CE_1 1+CE_2}{2}$) =%

2.4.6 Drop Down Test

The drop down test is a destructive test that is conducted to evaluate the extent to which a material will undergo failure if dropped from a particular distance. One board from each category was selected for this test. [12] Each board was dropped from two different positions using the human body as a reference point; that is theshoulder level (4.86ft) and waist level(3ft).The extent of failure was assessed after the boards were dropped from these heights.

2.4.7 Fire Resistance Test

This test is one of the most essential tests when it comes to safety. Oneboard from each category was selected for this test. The samples from the rubber fiber. The samples were exposed to open flames for time intervals of 20minutes and 60minutes within which the extent of damage were evaluated at each time interval. The main properties that were checked and analyzed were flame advancement and crack developments in the material.

2.4.8 Drilling Properties of the *Boards*

This test was done to verify how easily the installation of these boards using screws will be. A concrete drill was used to drill five holes through each type of board. The boards were laid on a flat surface and held in position whiles the holes were been made. The inspections would be based on the presence of cracks made around the drilled holes and the ease of drill.

3. Result and Analysis

3.1 Density Test

The boards made from the cocoanut fibers (CA) had a higher average density of 2.589g/cm^3 than those from the rubber fibers (RA) which had an average density of 2.497 g/cm^{3}as can be seen in figure 3.1. The reason for this variation is attributed to the disparity in weight of the coconut fibers and the rubber fibers: the weight of the coconut fibers were higher than that of the rubber fibers.

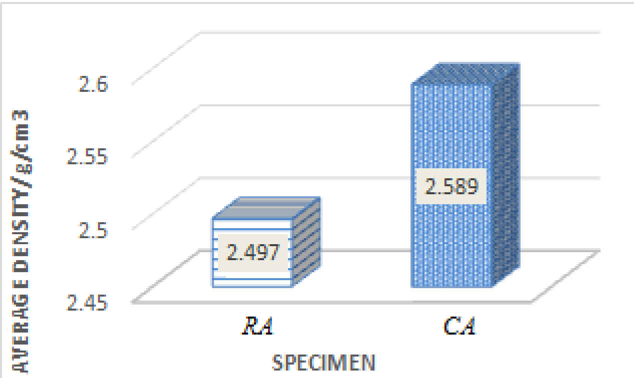


Figure 3.1: Showing the densities of the various boards

3.2 Moisture Content Test

Coconut fibers by nature absorbs and retains water in them,[13] this was proven when the moisture content examination was carried out after the boards were hardened. This test was carried out to ascertain the rate at which the boards can retain moisture in them during usage. The boards from the coconut fiber (CD) showed a higher amount of moisture retained in them after the drying period; it had retained a moisture content of 63.85% as can be seen in figure 3.2

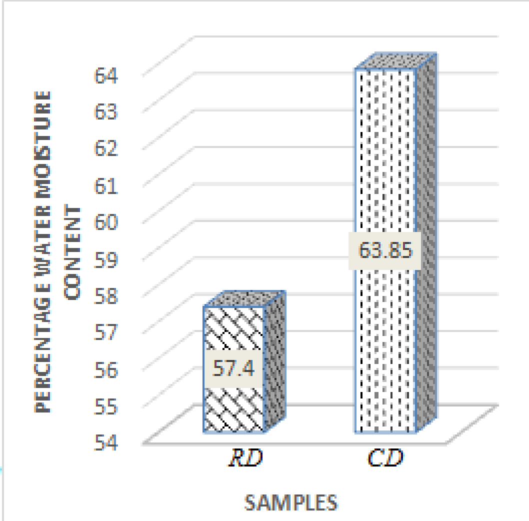


Figure 3.2: Shows the moisture contents of the two types of the boards that were subjected to the moisture test

On the other hand since rubber doesn't retain water in them the moisture content in the boards with the rubber fibers (RD) had a lower moisture content of 57.4%.

The moisture in the board nevertheless is not only attributed to the moisture in the fibers but also the moisture in the cement-sand-saw dust mixture as well. The higher the moisture content the boards can retain the higher the risk of growing fungi and bacteria on them. This can be prevented by coating the surfaces of the boards with an anti-fungi/bacteria agent or a water resistant paints. [14]

3.3Water Absorption Test

This test was also conducted to verify the amount of water each board can absorb when soaked in water for a period of time. According to figure 3.3, the coconut fiber (CC) boards as usual had the highest capacity when it comes to water absorption, it was able to absorb 20.15% water inside it whiles the rubber fiber (RC) board held 18.53% water.

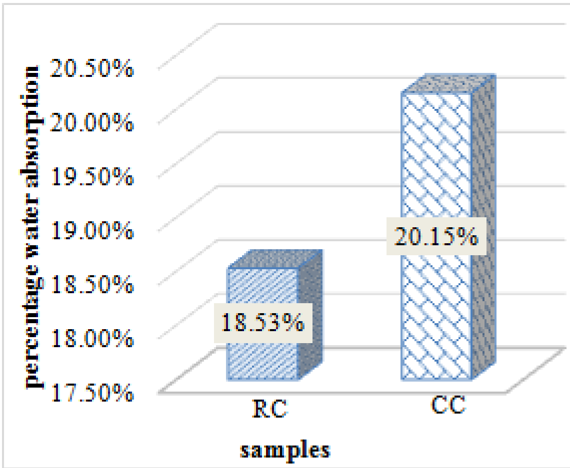


Figure 3.3: Shows the water absorption levels in percentages and the average water absorption of the material.

The non-absorbent rubber fiber added to the mixture (cement, sand and saw dust) lowered the water absorption capacity of the boards.

3.4Flexural Bending Tests

The graph in figure 3.4 indicates that the average bending strength of the boards made from the rubber fibers (RB) was 6.54psi whiles those made from the coconut fibers was 5.54psi, these results meet the ASTM requirements as specified that average load should be ≤ 7.0 KN. This shows that the rubber fibers offer the best tensile conditions in the boards among the two materials. Even though the boards are not for load bearing conditions, this result offers insight into the possibility of increasing the tensile strength of the boards if the area of application requires it.

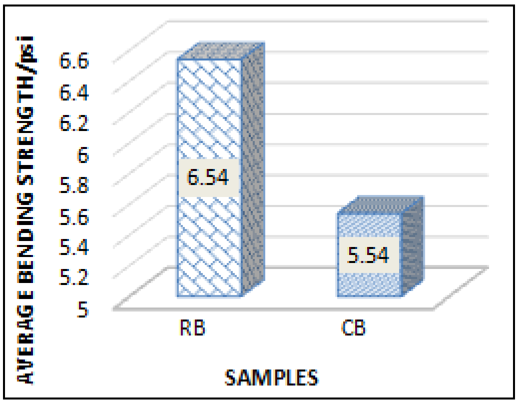


Figure 3.4: Shows the representation of the bending strength of the boards in dry conditions.

One interesting discovery made in the cause of this test was the fact that the boards after failing could not completely separate into two separate pieces but rather the fibers held all the pieces together as shown in figure 3.5 below. This was one major reason why the fibers were introduced as a major component in making the boards. The rubber fibered boards offered the best alternative in this required.

Figure 3.5: Shows the failure state of the Specimen when subjected to flexural bending.

3.5 Scrubbing Test

The samples were subjected to this test to find out how they will fare when subjected to scratching. After scratching each one of them 120times, the average percentage weight loss in the boards made from the Rubber fiber (RA) was 0.14% whiles that from the coconut fiber (CA) was 0.12% as indicated by figure 3.6. This means that the rubber fiber boards are more susceptible to wearing than the coconut fiber boards.

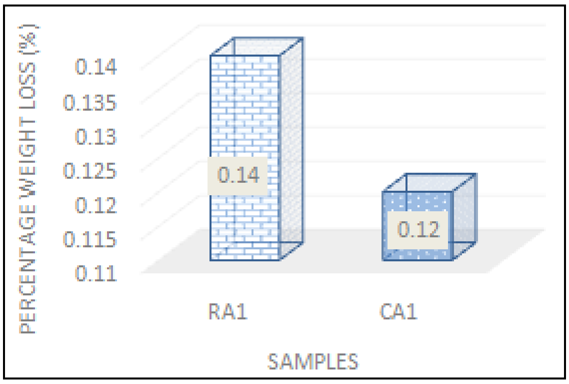


Figure3.6: Presents the percentage weight loss of the boards when scrubbed

This can be attributed to the fact that the boards made from the coconut fibers are denser with fibers than the rubber fiber boards: the coconut fibers are shorter and they are spread out throughout the entire surface of the boards. The short fibers intertwined with each other thereby resisting the wear action. The rubber fibers were however lighter and longer leading to a reduction in their meshing capabilities.

3.6 Drop Down Test Results

The boards were dropped from two different positions waist level (3ft) and shoulder level (4.86ft) this was done to test the mode of failure of the boards when dropped from either positions. When the coconut fiber board was dropped from the waist level, cracks from one end of the board to the other advanced through the board but the board was still held together by the fibers.

(A) (B)

Figure 3.7: The pictures above (Picture A and B) shows the rate of failure of the specimens when they were subjected to impact

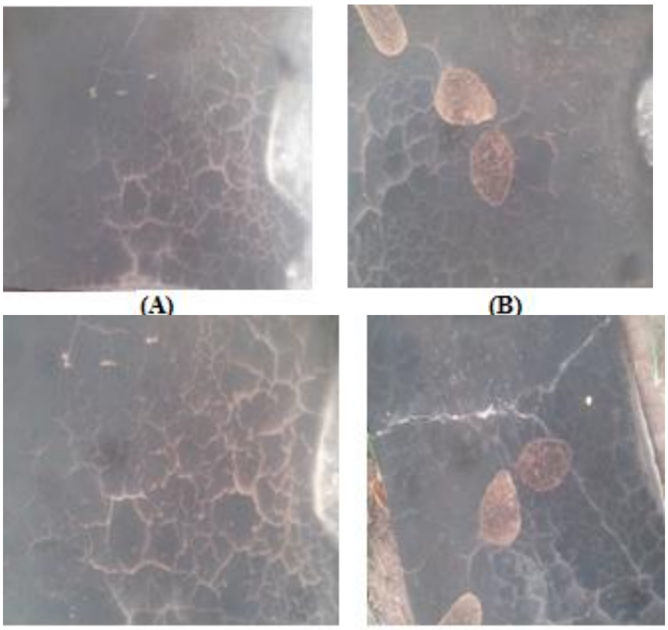
The boards were then dropped from the shoulder level, more cracks were introduced and this time around pieces of the board were completely separated.

The rubber fiber boards were also dropped from the waist level as well, the boards failed with less cracks initiated in it than that of the coconut fiber board. These cracks had just been initiated but had not yet propagated through the entire board. The rubber fiber boards on the other hand showed a little bit of resistance when it was dropped from the shoulder level, unlike the boards from the coconut fibers, no piece from the board was removed but this time around they were held together by the rubber fibers. This observation is consistent with the result from figure 3.4, where the flexural strength of the rubber fiber boards were higher than that of the coconut fiber boards. This proves that the rubber fibers are the best alternative if the tensile strength of the cement boards are to be enhanced.

3.7 Fire Resistance Test Results

When the two boards were subjected to heating, after 20mins (figure 3.8 A), rings of fire appeared on the board made from the coconut fibers. When the heating was continued for 60mins (figure 3.8 B), cracks were formed from ash lines within the material.

The board from the rubber fibers however showed multiple points of attack by the fire at 20minutes (figure 3.8 C). More fire sections and boundaries continued to advance throughout the entire material (figure 3.8 D)as the boards were been heated for 60mins.



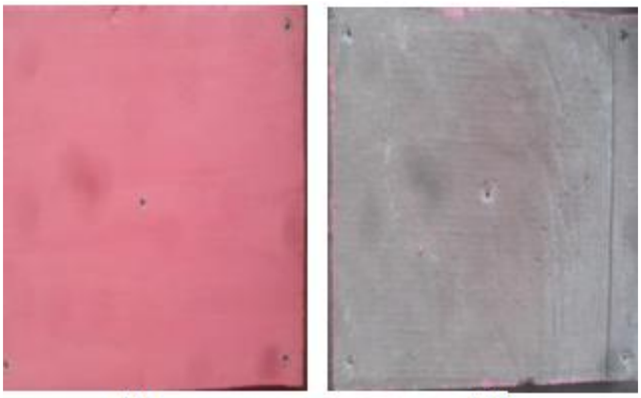
(A) (B) (C) (D)

Figure 3.8: Picture A shows the behavior of the coconut fiber board in 20 minutes, B shows the behavior of the rubber fiberboard in 20 minutes, C shows the behavior of the coconut fibber boards in 60 minutes and D shows the behavior of the rubber fiberboard in 60 minutes.

This board due to the rubber fiber exhibited more flammable tendencies and rapid flame development.

3.8 Drilling Properties of the Boards

The specimens showed good drilling properties when they were drilled by the use of the concrete drill. The specimen showed soft and smooth drilling process and no cracks were developed around the holes as well, this indicates that they can be screwed into position during installations.



(A) (B)

Figure 3.9: Picture (A) shows the front view of a drilled Picture (B) shows the bark view of the drilled board

3.9 Comparison of the TestResults with ASTM standards

The table below reflects on the various parameters that were measured as compared to the standard ranges predicted by ASTM (ASTM C1186-08 - 2012 [11]. As can be deduced from table 3.1, the properties of the boards fall within the established standards.

Table 3.1 Summary of material Test Result table

Test performed	*Materials Averages*		*ASTM C1186-08 (2012) STANDARDS*
	Rubber fiber boards.	*Coconut fiber boards.*	
Density	2.497ρg/cm3	2.589ρg/cm3	1.50-3.50G/cm³ in ≥7mm
Flexural Bending Strength	6.3 psi	3.83psi	≤ 7.0mpa in dry conditions
Water Absorption	22.9%	20.73%	22.0 – 37.72%
Moisture Content	57.4%	63.85%	85% - 90% in 24 hours dry
Scrubbing test	0.14%	0.12%	Loss mass ≤ 0.3%
Drop Down Test	3.5 ft.	3.5ft	≤ 2.00ft will collapse it

4. Conclusion

The boards made from the coconut fibers were denser than those made from the rubber fibers due to the variations in weight. They also absorb and retain more water as compared to the rubber fiber boards; this is as a result of the ability of the coconut fibers to soak and hold water by nature.

With respect to the mechanical properties of the boards the flexural bending strength indicated that the rubber fiber boards can perform better in tensile conditions even though the boards are not designed for load bearing applications.The drop test also gave an insight into the impact performance of the boards, even though the rubber fiber boards performed better once again the coconut fiber boards were not far off. An impressive outcome from this test however was the ability of the fibers to hold the broken pieces of the boards together after failure.

The scratch test indicated that the meshing effect in the coconut fibers are more resistant to wear actions than those in the rubber fibers. This will be more beneficial in applications where wear is inevitable.

With respect to the burning tendencies of the boards, the rubber fiber boards showed a higher tendency for flammability than the coconut fiber boards. On the other hand the coconut fiber boards exhibited the ability to burn intensely with minimum flame levels as compared to the rubber fiber boards.

The comparisons of the various parameters of the boards to ASTM C1186-08 – 2012 [11] shows that the properties of the boards are within the requirements for boards in their category. This proves the viability of this project. They can therefore be used for various applications from plaster works to ceiling works. This can also be facilitated by their ease of installation using drills.

5. Recommendation

This project focused on the making and testing of the boards and not so much on costing and usage. The next phase of the project should focus on these issues in order to come out with a clear cost profile of the boards. This can help do a proper cost comparisons with the other methods of wall finishing. The boards can also be recommended for interior designs, wall and ceilings installations. They offer ease of installations and potential reduction in cost.

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Prof. KwadwoAdinkrah – Appiah is currently the Vice Chancellor of the Sunyani Technical University. He has done more research works in the area of civil engineering where his interest is in structural engineering. He has been involved in major projects in the country and this has established him as a force to reckon with in his area of specialisation.