PRODUCTION OF CEILING BOARD FROM AGRICULTURAL WASTE (USING THE COMPOSITE OF SAW DUST AND OIL PALM FRUIT (*Elaeis guineesis*) HUSK WITH GUM ARABIC AS BINDING RESINS)

BY

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN AGRICULTURAL & BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

JANUARY, 2011.

DECLARATION

I hereby declare that this project work is a record of a research work that was taken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly reference in the text.

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27/01/2011

DATE

CERTIFICATION

This is to certify that this project entitled "Production of Ceiling Board from Agricultural *Waste* Using the Composite of Saw Dust and Oil Palm Fruit (*Elaeis guineesis*) Husk with Gum Arabic as Binding resin" by Ndukwe, Eme Ndukwe, meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

Engr. Prof. B. A. Alabadan (Supervisor)	24/01/11 Date
Engr. Dr. A. A. Balami (Head of Department)	24/01/2011 Date
External Examiner	13/01/2011 Date

DEDICATION

This project is dedicated to the Almighty God, my entire family, friends for their support and encouragement through all this hustle and bustle of academic pursuit and period of my studies.

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My greatest gratitude goes to God Almighty, for his enabling power to undergo all this stress of academic pursuit and struggle and for granting me good health through out this period of studies. I thank him also for his provisions that had kept me moving even his unmerited favors. I also acknowledge my supervisor for his supervision in the person of Engr, Dr. B. A. Alabadan. I will also like to appreciate all my lecturers and staff of the department for their sincere judgments and encouragement, starting from the HOD Engr Dr. A. A. Balami, Engr Mrs. H. I. Mustapha and my level adviser Mr. J. J. Musa, Mr M. A. Sadeeq. I wouldn't have left my entire family out of the picture of this unique achievement for all their anchor and prayers, I will like take it right from top starting from my dear mother Mrs. Rebecca E. Ndukwe, Engr A. E. Ndukwe, Qs. O. E. Ndukwe, Mrs. Jane Okpara, Mrs. Ucha A. Agwu and every other members of the family that I couldn't mention. I want you all to know that your help, prayers, supports, and most importantly your moral supports throughout this period is acknowledged and appreciated, I say a big thanks to you all and God bless you all, Amen. This achievement would not have been achieved without these men of honors like Ekeh David, Jinadu Nurudeen, Oguche Felix and other of my mates whose name is mention for their support and encouragement all this years of ups and down. I thank you all for everything and I pray that God will reward you for all your efforts and the kindness you have shown me.

ABSTRACT

In this work, ceiling board was produced using palm oil fruit husk and saw dust. The mechanical properties of the boards produced from saw dust were compared with the ones produced from palm oil fruit husk. The different boards where produced using different compositions of saw dust and palm oil fruit husk. The first two boards produced were made up of 100% saw dust and 100% palm oil fruit husk which served as the control board for the other boards. Other boards were produced using the composite of saw dust and palm oil fruit husk in percentage as follows: 60% saw dust to 40% palm oil fruit husk, 40% saw dust to 60% palm oil fruit husk and 50% saw to 50% palm oil fruit husk. The percentages were calculated by mass. Gum Arabic was used as the bonding medium for the boards. When comparing these boards, it was observed that the board produced with palm oil fruit husk required more gum to that produced with saw dust. The 100% palm oil fruit husk is rougher; the 100% saw dust is smoother when compared smoother ceiling boards while the 50%:50% husk to sawdust is coarse when compared to other ceiling boards. They do not burn readily with fire and have high heat resistance.

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CHAPTER ONE

1.0 INTRODUCTION

A ceiling is an overhead interior surface that bounds ("ceils") the upper limit of a room. It is generally not a structural element, but a finished surface concealing the underside of the floor or roof structure above.

Ceilings are classified according to their appearance or construction. A cathedral ceiling is any tall ceiling area similar to those in a church. A dropped ceiling is one in which the finished surface is constructed anywhere from a few inches to several feet below the structure above it. This may be done for aesthetic purposes, such as achieving a desirable ceiling height; or practical purposes such as providing a space for piping. An inverse of this would be a raised floor. A concave or barrel shaped ceiling is curved or rounded, usually for visual or acoustical value, while a coffered ceiling is divided into a grid of recessed square or octagonal panels, also called a lacunars ceiling. A cove ceiling uses a curved plaster transition between wall and ceiling; it is named for cove molding, a molding with a concave curve.

Ceilings have frequently been decorated with fresco painting, mosaic tiles and other surface treatments. While hard to execute (at least in place) a decorated ceiling has the advantage that it is largely protected from damage by fingers and dust. In the past, however, this was more than compensated for by the damage from smoke from candles or a fireplace. Many historic buildings have celebrated ceilings. Perhaps the most famous is the Sistine Chapel ceiling by Michelangelo (Wikipedia, 2010)

1.1 Background of the Study

Since the existence of man, comfort has been the goal of man and survival. He assumed that for him to survival the harsh weather condition of earth, he has to make the earth as much comfortable as possible to suit the earth and its environmental condition.

In other to achieve this comfort, man has been working tirelessly towards achieving this objective. He embarks on several search and research that will facilitate its comfort.

At the early stage of man, roughage was used as the source of building material to reduce the heat effect of the scorching sun. As development proceeds, man began to see other alternatives that could be more attractive and comfortable for his living. Man saw the use of wood as being more attractive and comfortable to using grass which is more prone to fire outbreak compared to wood.

Later in the century, man began to substitute wood to stone as a better, more comfortable, more attractive and more secured means of building shelter.

In the subsequent century, man discovered that there is easier and cheaper way of achieving comfort and making a home more attractive suitable for living. He saw mud as a solution to his problem in his pursuit of comfort and security in life. So, he substitutes all other forms of shelter previously adapted by him to using mud in building his home. After the era of using mud as the building material to reduce the sun effect, concrete was preferably used for its strength, decorative, comfortable and rigidity of the concrete material. It was then that the use of ceiling to cover the upper part of the built concrete structure becomes necessary to further reduce the scorching effect of the direct sun shine falling on the built concrete structure.

Asbestos has in the past many decades known for its fire resistance nature and its ability to withstand high temperature without heating up. Wealthy Persians, who bought asbestos imported over the Hindu Kush, amazed guests by cleaning the cloth by simply exposing it to fire and the cloth was not burnt. This shows the extent to which asbestos could resist fire hazard. It does not only show the resisting power of asbestos to fire but also the absorbing power of asbestos to heat and high temperature. (Robert,1987).

In recent time, the engineers have been working tirelessly to harness and minimize the risk of heaping wastes from agricultural produces and also to reduce the health hazard of asbestos to man by substituting asbestos to the waste from agricultural produces in the production of ceiling board.

Ceiling board has successfully been produced with rice husk, saw dust, bamboo, maize cob, sunflower stalks and wheat straw.

1.2 Statement of the Problem

With the increasing hazardous effect or problems of asbestos to human race, it becomes necessary to find a substitute for it that is health friendly and that can also be environmental friendly.

Asbestos (from Greek ἄσβεστος meaning "unquenchable" or "inextinguishable") is a set of six naturally occurring silicate minerals exploited commercially for their desirable physical properties. They all have in common their asbestiform habit, long, (1:20) thin fibrous crystals. The inhalation of asbestos fiber can cause serious illnesses, including malignant lung cancer, mesothelioma (a formerly rare cancer strongly associated with exposure to asbestos and fiber glass.), and asbestosis (a type of pneumoconiosis). The European Union has banned all use of asbestos and extraction, manufacture and processing of asbestos products. (American Society of Asbestos, 1989).

Asbestos became increasingly popular among manufacturers and builders in the late 19th century because of its sound absorption, average tensile strength, and its resistance to heat, electrical and chemical damage. When asbestos is used for its resistance to fire or heat, the fibers are often mixed with cement or woven into fabric, or mats. Asbestos was used in some products for its heat resistance, and in the past was used on electric oven and hotplate wiring for its electrical insulation at elevated temperature, and in buildings for its flame-retardant and insulating properties, tensile strength, flexibility, and resistance to chemicals.

Amosite and crocidolite are the most hazardous of the asbestos minerals because of their long persistence in the lungs of exposed people. Tremolite often contaminates chrysotile asbestos, thus creating an additional hazard. Chrysotile asbestos, like all other forms of asbestos, has produced tumors in animals. Mesotheliomas have been observed in people who were occupationally exposed to chrysotile, family members of the occupationally exposed, and residents who lived close to asbestos factories and mines.

Asbestos exposure becomes a health concern when high concentrations of asbestos fibers are inhaled over a long time period. People who become ill from inhaling asbestos are often those who are exposed on a day-to-day basis in a job where they worked directly with the material. As a person's exposure to fibers increases, because of being exposed to higher concentrations of fibers and/or by being exposed for a longer time, then that person's risk of disease also increases. Disease is very unlikely to result from a single, high-level exposure or from a short period of exposure to lower levels. Smoking combined with asbestos exposure may increase the health risk dramatically. (European Union on Asbestos Regulation, 1995)

1.3 Objectives of the Study

The objectives of this project are:

1. To produce ceiling board with the composite of saw dust and palm oil fruit husk.
2. To compare the mechanical properties of the boards produced from saw dust to that produced from palm oil fruit husk.

1.4 Justification of the Study

As long as development is concerned, ceiling board has been a talk of all times in the building industries. A house without a ceiling board covered under its roof is like an incomplete house. Not only that ceiling board gives a house its unique beauty but it also gives a house its comfort nature and makes a house as homey as possible. Ceiling board as every other material made of wood product, will reduce the high demand of wooden material if successfully substituted with some agricultural by-products or waste which will not only make the material for the ceiling production readily or easily available but will also reduce the cost of production and the health implications involved when other materials for the production of ceiling board is used to minimum.

1.5 Scope of the Study

Ceiling board in this particular project is produced with saw dust and the husk from palm oil fruit which is a waste or by-product from an agricultural produce using Gum Arabic as the binding resin in place of the conventional synthetic one. The husk and the saw dust are separately pounded to obtain a more-smooth and uniform or fine particle of the húsk that will make the product to have a very smooth surface. The fine husk and saw dust obtained is dried, sieved and tested for its moisture content before mixing it with the binding resin. The husk and the saw dust are separately mixed with the binding resin (for 100% mixture of individual material) and then (50:50% mixture, 60:40% mixture, and then 40:60% mixture of both materials) are poured respectively into a locally made wooden mould sized (0.35x 0.31x 0.006m).The mat-formed method is chosen for this operation for its convenience, simplicity and its less cost implication suitable for small and medium scale operation.

This project is embarked to know or determine the suitability of using agricultural by-products (palm oil fruit husk and saw dust with Gum Arabic as binding resin) in the production or manufacturing of ceiling board to relief and to serve as a substitute to the ever deteriorating forest for timber which the building and furniture industries have subjected it to. This purpose is achieved by reducing the moisture content of the material and also checking and testing its mechanical properties for strength, durability, resistance to fire and heat, compatibility e.t.c of the product.

1.6 Limitation of the Study

Though the industrial and the laboratory methods of production may share quite a similar processes or steps, but still this project maintains its stands in the laboratory research method alone. The industrial method in some ways varies with the laboratory method for its complexity as regards the technologies and materials involved in the industrial production. The industrial method may require a high skill which may take a lot of resources and time to accomplish if it be the method to be adopted in this particular project which will be beyond the capability of the student involved in this project. So the method used in this project is the cold mat pressing method which eliminates high pressure and temperature involve in using other techniques like the conventional or the industrial method.

The binding resin which is also an agricultural by-product is used to make the project agriculturally oriented and to show that agricultural by-products can also be useful again in the production of ceiling board and other useful products that could be useful to human life. Gum Arabic has a high holding or binding ability though susceptible to fungi attack is used in order not to contradict the purpose of this project work which is to use agricultural waste. The fungi attacking effect can still be eliminated by adding some additives to the product which will form and give the product a protective layer or surface against fungi. Painting the surface of the produced product can as well help to eliminate the fungi attack thereby making it successively possible to use husk from palm oil fruit waste as a substitute or an alternative to a known industrial raw materials used in the manufacturing of ceiling board.

CHAPTER TWO

2.0 LITERATURE REVIEW

Ceiling board production and use is as a result of benefits and comforts the engineers foresee and due to the fact that the human era is always looking for a better days and environment that eases life and promotes human comfort and stability.

Ceiling board have been in used for decades but just that the engineers cannot just stop finding or looking for a better days or some improvement that can give a modern home the comfort and beauty it truly deserved. Since they can not keep their hands crossed allowing only the same kind of product to remain or to be the only alternative, they have to work harder to make their way to the top and to draw the line between the poor and the rich which brings the idea of designing the ceiling board in different decorative shapes fashions that looks appealing to the eyes which will as well make a home look more cute and suitable for living. The board have been produced with different types of materials which include; sawdust, shavings, chips, rice husk, groundnut shell, wheat straw etc.

The ceiling board has the same or similar characteristics and the same production procedure with the particle board. They are or can be produced with the same kind of material the only disparity between them is their thickness and the size of particles used (i.e. their fineness modulus). While particle board has thicker and coarser particles forming the board, the ceiling has lesser thickness and finer particles that formed the board. They are being bound together with a synthetic resin which serve as their adhesive and which help to glue or hold the particles of the waste material together in form as a unit that makes up the board and gives it the required shape and texture.

In the production process, the composite or waste material to be used undergoes a grinding or hammer milled process to reduce the particle size of the material into smaller or finer particles of uniform sizes after which the dissolved adhesive is mixed with the ground material and the mixture introduced into a mould that will give the board its required shape and thickness. The mixture in the mould is pressed to a certain pressure to form a unit solid board.

The characteristics and properties of the board formed in the mould depend strictly on the type, quality and quantity of adhesive used, the quantity of pressure applied, the type of material-waste used as the basic material and the molding method chose. The board quality is affected by the softness, quantity and the nature of the cellulose content present in the cell of the fibrous materials. Other properties of the board such as nail and screw holding properties are determined by the quality of the resin that glues the particle readily and it is recommended that smaller nails or screws be used since the board has a small diameter or thickness in which long nails may damage the board.

2.1 Binding Resins

In the production of ceiling board especially when using agricultural material with high cellulose and lignin content in their fibers as in the case of composition of palm oil fruit husk and saw dust, the choice of the type of binding resins to be use must be considered.

Binders are mainly chemical substance that under goes chemical reaction to form a solid bonds or structure with the material they react with, thereby serving as gluing medium or adhesive. Adhesive or binder is available in different type such as synthetic resins (e.g. Urea formaldehyde, Melamine formaldehyde and phenol formaldehyde) gum resins (e.g. Gum Arabic, sugar molasses from sugar cane) and timing adhesive etc. The choice of this binding agent is greatly determined by cost, nature and quality of the product required, preservative to be added and safety of the chemical.

This project work considers Gum Arabic as the binding resin for the composition of palm oil fruit and saw dust. This is because it is cheap, highly glossy, and odorless and has good ink retention.

2.1.1 Types of Binding or Adhesive

(a) Synthetic resin/adhesive: This is a combination of urea and formaldehyde that makes up the resins and it is the cheapest and easiest to use. It is use for most non-water resistant boards. Others are melamine formaldehyde resins which are more expensive and are use for moisture resistant, phenol formaldehyde also fairly expensive, dark colored and highly durable. But has been classified by WHO as human carcinogen with 99.99% of this chemical contained in board curing process (WHO 2008)

(b) Vegetable-starch adhesive: Obtained from cassava, when the chips are grinded sieved and allowed to settle in water. It is then decanted and dried to prevent it from bacteria attack. Other adhesives like casein adhesive made from .curd of soured mill (FAO, 1963)

(c) Animal adhesive: It is obtained from animal hides, skins, horns and bones by burning them in limited supply of air to form a gelatinous substance.

(d) Plant resin/adhesive: These are substance obtained from plant bark or trunk of trees through distilling wood, extract from plant body by solvent, e.g. sugar molasses from sugar cane. Most of which are soluble in water.

(e) Cement: These are inorganic type made from calcium trioxocarbonate IV clay, sand and other materials.

2.1.2 Characteristics of Adhesive

Adhesive can be used if it has the following characteristics

a) Have low moisture content

b) Resistant to creep at high temperature

c) Easy to apply and require no special fixing equipment

d) Dehydration of binding area

e) Fast grab attack

f) Flexibility on application

The selection of an adhesive depends on the following

a) Heat and safety factors

b) Economic factors

c) Its life span

d) Effect on materials to be bonded

e) Flammable and toxic nature to the materials chosen

f) Availability in commercial quantities (Galdius, 1977).

2.2 Botanical Consideration of Gum Arabic of Gum Acacia

Gum Arabic or Gum Acacia source and predominant supply have been linked with Kordafan on the East and Senegal on the West of Africa. History has also linked the commodities transfer to Europe through Arabian traders, from where its name may have been originated from. The Gum appears on the stem and branches during the prevalence of dry desert winds, which blows in the winter or harmattan after the close of the raining season. and the flow is aided by certain methods of treatment.

The small tree Acacia Arabic, one of the sources of Gum Arabic is recognized by the triple spine at the base of the branch chalets. Similar to it is the Acacia dungeon with occasional third spine meeting within Acacia latex. The gum exudates from this acacia tree and other species of acacia trees containing Arabin. The finest quality of this gum is obtained from acacia Senegal also found in Southern Mozambique, Acacia Arabica found in the red dry region of North-west Africa and in some Northern part of Nigeria e.g. (Maiduguri, Zamfara, Bida-Niger state) e.t.c.

2.3 Chemical Composition and Structure of Gum Arabic

Gum Arabic is an odorless, colorless and tasty gum and quite soluble in water. The best quality ones take, one and half times their weight of water to form thick viscous mucilage. Like other resins, Gum Arabic is a gelatinous substance with a chemical composition which is highly branched polymer of gelatos, rhamose, arabinose and glucoronic acids.

These complex organic acids also called gum acids, when hydrolyzed it forms galactose, xylose, and simple acids which are useful polysaccharides or their derivatives that hydrates in hot or cold water to form viscous solutions that harden when dry. Classified as natural gums, Gum Arabic serves as base for mucilage in cloth finishing, calico printing and emulsifying constituents in medicine and cosmetics it is used also as adhesives for thickening inks in textile industries, stabilizer and binder in low calories food stuff.

They are found in certain calcium, magnesium and potassium salt with molecular weight of 240,000. Highly soluble in water and insoluble in alcohol and hydrates to form viscous solution (Peter, 1985)

2.4 Botanical Consideration of Wood (Saw Dust)

Wood is a hard, fibrous tissue found in many plants. It has been used for centuries for both fuel and as a construction material for several types of living areas such as houses. It is an organic material, a natural composite of cellulose fibers (which are strong in tension) embedded in a matrix of lignin which resists compression. In the strict sense wood is produced as secondary xylem in the stems of trees (and other woody plants). In a living tree it transfers water and nutrients to the leaves and other growing tissues, and has a support function, enabling woody plants to reach large sizes or to stand up for themselves. Wood may also refer to other plant materials with comparable properties, and to material engineered from wood, or wood chips or fiber.

People have used wood from millennia for many purposes, primarily as a fuel or as a construction material for making houses, tools, weapons, furniture, packaging, artworks, and paper. Wood can be dated by carbon dating and in some species by dendrochronology to make inferences about when a wooden object was created. The year-to-year variation in tree-ring widths and isotopic abundances gives clues to the prevailing climate at that time.

Classification and Characteristics of Wood (Hard and soft woods)

Engineered wood products have properties that usually differ from those of natural timbers. There is a strong relationship between the properties of wood and the properties of the particular tree that yielded it. For every tree species there is a range of density for the wood it yields. There is a rough correlation between density of a wood and its strength (mechanical properties). For example, while mahogany is a medium-dense hardwood which is excellent for fine furniture crafting, balsa is light, making it useful for model building. The densest wood may be black ironwood.

It is common to classify wood as either softwood or hardwood. The wood from conifers (e.g. pine) is called softwood, and the wood from dicotyledons (usually broad-leaved trees, e.g. oak) is called hardwood. These names are a bit misleading, as hardwoods are not necessarily hard, and softwoods are not necessarily soft. The well-known balsa (a hardwood) is actually softer than any commercial softwood. Conversely, some softwood (e.g. yew) is harder than many hardwoods.

The saw dust is a by-product gotten from sawed wood when the wood is passing or undergoing through either a reduction or a finishing processes. As the wood is being sawed to a desired shape and size, the dust is being accumulated giving rise to the accumulation of saw dust which is considered as a waste good only for trampling by foot, pig pen or poultry house and for making fire alone.

The wood is dried to considerable moisture content before sawing of the wood is possible. By drying the wood to considerable moisture content, this allows for better gripping of the jack plane used as the sawing equipment of the wood during finishing process and saw used for size reduction of the wood to suit its use or purpose. Without the moisture reduction, sawing of the wood would be almost impossible as the moisture will make or cause the jack plane to slip over the surface of the wood reducing the contact or frictional effect of the jack plane over the wood surface.

The size of the saw dust is already in fine particles in which little or no further size reduction could be possibly needed in the production of the ceiling board. But the size reduction could still be necessary to obtain a uniform size of the sawed particles when the material undergoes sieve analysis processes.

2.5 Botanical Consideration of Oil Palm (Focus on Palm Oil Fruit Husk)

The African oil palm (Eleas guinessis) is of the same botanical family with the coconut (Arecaceae) and they give the highest yield of oil per acre than any other oil seed crop. This plant oil palm produces palm oil from the fleshy mesocarp of the fruit and palm kernel oil from the seeds. The chaff from the fleshy mesocarp after processing the fruit is called the husk. It is used locally to make fire and industrially for rope or fiber production.

History has shown that the oil palm is a nature of west Africa and is grown in the coastal areas, but its plantation has spread to the south-east Asia the American tropics and the west Indies, with world statistics showing the leading producers as Malaysia (7,220, 410t), Indonesia (3,890,000t), Nigeria (950,000t), Columbus, Thailand, Brazil and other countries in the west African zone. And Nigeria as the largest exporter of palm oil, palm kernel oil to the United Kingdom, Germany, the Netherlands, France and the Middle East countries. The heavy biomass of waste generated, is the concern of this project work, converting these raw materials into useful product like the production of ceiling board in composition of saw dust.

2.5.1 Fiber Characteristics of Palm Oil Fruit Husk

There are four varieties of the palm and they can be distinguished on the basis of their morphological nature and fruit structure, especially the thickness of the endocarp. Var macrocapa, 40-60 percent shell, var dura 20-40 percent shell, var tenera 5-20 percent shell and var pisifera a shell-less form. The best considerations are the last two with lower percentage of shell which implies that their pulp composition are very high giving rise to a larger husk(chaff) as waste after processing and their fiber characteristics are similar to the coconut (family Arecaceae) as shown in the table 2.0 below. The palm kernel oil is the widely known use, but little is known of the husk (chaff), that it can also be used in the building industry. The only known use of the palm oil fruit husk (chaff) being that of making fire in the rural communities or areas.

Table 2.0 average composition of palm oil fruit

Composition	Percentage
Carbonhydrate	48.00
Oil	5.00
Protein	19.00
Fiber	13.00
Ash	4.00
Water	11.00

Source: Opeke, 2005

2.6 Manufacturing Step of Ceiling Board

The production or manufacturing of ceiling board starts by sourcing for the raw materials to be used and taking them through the process of size reduction into a very fine and smooth particles. The reduced particles are sieved into uniform sizes and dried to obtain uniform moisture content, before mixing with binder (adhesives). The mixture are then compressed to proper density and cured under heat and pressure. The curing process that results into the ceiling boards can be achieved through two major methods;

(a) Extrusion method (which is highly technical and expensive)

(b) Cold/hot mat-formed method (simple and less sophisticated)

In the extrusion method, the extruded board is homogeneous (single layer) in structure and manufactured by mixing wood particles or flakes together with resin and forming the mixture into sheets. The raw material to be used is fed into disc chipper with radially arranged blades and resin in liquid form is sprayed through nozzles into the particles, the flakes are then spread by an air jet which throws finer particles further than coarse one. Two such jet, reversed, allow the particle to build up from fine to coarse and back to fine. The mixture is made into sheets by an oil heated metal plate serving as a weighing device, that compresses the spread of the mixed particle on a continuous sheet of moving belt into sized thickness and width. This is done at a pressure of 2-3 mega-Pascals and temperature between 140^0C -220^0C. The process sets and hardens the glue. All aspects of the entire process are done carefully controlled machines. The final boards are then cooled, trimmed and then sanded and they can also be covered with wood veneer or laminated with paper for quality finishes.

The mat- formed ceiling board method on the other hand, consolidates and formed as flat panel consisting of building particle of wood together with synthetic resin. Lignins are treated from the particle by digestion which gives an advantage of protection against bingo-celluloses attack. In this method, a layer structure can be made. The single layer board has the advantage of forming a solid structure when great pressure is applied while the three layer structure increase the bending strength and stiffness of the board.

The fiber in the above method can be processed by mechanical or chemical means.

(a) Mechanical processing

This method, involves blending and applying pressure up to about 6.9Mpa at a temperature of 200^0C. The blended finished mats become very loose particles, as its thickness are gradually reduced by the applied pressure until the final density achieved.

(b) Chemical processing

In this processing method, lignin are removed from fiber mixture by adding pulping chemical which greatly reduce them (i.e. the three dimensional polymer formed from cyclic alcohol to prevent cellulose from hydrolysis) and hemi celluloses in the fiber. This is seen as an advantage of lesser application of pressure on the mixture and disadvantage of cost of production than the mechanical method.

2.6.1 Properties of Ceiling Board

The properties of ceiling boards produced have greatly depend on the morphological nature and structure of the raw material used, amount of adhesive and method of forming. For high quality board, some properties must be possessed by these boards which invariably will depend on properties of the raw material and they include;

(a) Tensile strength

Tensile strength is the resistance of a body to tensile forces that tend to pull it apart. It can also be referred to as maximum tensile strength which is the force per unit cross-section area that a body can resist before it ruptures. The relationship between stress and strain in particular material, this determined by means of tensile test (Shukar, 1977)

(b) Hardness

This is the ability of a solid substance to resist surface deformation or abrasion. It can be measured by capacity for bending through a definite angle one or more time without fracture. The hardness of a material does not relate to the strength, durability and toughness of that material, rather it is the material ability to resist fracture by bending.

(c) Abrasion test

This is the measure of scratch that a material can withstand. This is alone by scratching the smooth surface of the material to be tested, by comparing the result with reference to hardness scale, the relative hardness is found. A better test is by means of a level attacked to a vertical pillar and taking the pillar by bond, to make a scratch. The weight in grams required to produce a scratch of standard depth gives a measure of hardness (Gladius, 1977)

(d) Plastic limit

The moisture content at which a board becomes too dry to be in a plastic condition is determined by the plastic limit test.

(e) Nailing test

Nailing of a ceiling board is the ability of the material to withstand nailing or stretching without splitting or disintegration of the binder used. Nailing test is done in order to ascertain the holding strength of the material. Ceiling board should have a minimum holding force of not less than 178N (40Pa).

(f) Moisture content

This is the weight of water contained in a given sample of a particle. It is expressed in percentage. It is the ratio of weight of wet sample minus weight of dry sample divided by weight of dry sample minus weight of container all multiplied by hundred.

(g) Density

This is a measure of strength of material, depending on the pressure applied per unit, volume expressed in kilogram per meter or in the ratio of the mass of a body to it volume.

Relative density is obtained by dividing the weight in air by the loss of weight when the body is immersed in water. There are recommended density for ceiling board, (Low density 160kg/m^3- 500kg/m^3 and high density 550kg/m^3- 1200kg/m^3).

(h) Fire resistance

This is the ability of a material to withstand the effect of fire for a particular period of time before it starts burning. This varies in different materials and it depends largely on the composition of the materials. Some additives have been known to increase the fire resistance of ceiling board; hence can be added in the mixing process.

(i) Compressive strength

This is the ability of a material to resist compressive force before collapsing. And is the ratio of the failure under compressive load to the multiple of the length of the breath of the material and its thickness measured in kg/cm2.

(j) Static bending

This is the ability of a material to withstand a static load. The static bending of a material results either from a purely dead load from a variable load. It is very important test enabling one to ascertain the maximum allowable load on materials. The bending can be achieved if density of the materials is satisfied (Gladius, 1977).

2.6.2 Finishing Processes of Ceiling Board and Uses

Ceiling board products are used in various forms and come in different forms. It can come as suspended, gypsum, tile, and asbestos e.t.c. The building industries account for a larger use though it can also be used as a sound proof for coating walls, cabinet, kitchen cabinets, notice board etc. But ceiling boards can also be used along side with metal products in the automobiles, refrigerators and trucks, exteriors, television cases and in the construction industry. Therefore a high quality finished and semi-finished product is needed for different industrial uses. Some of the processes are as follows;

(a) Sanding

The quality of ceiling boards such that surface sanding is not normally required. However sawed edges, machined surface scratches can be dressed up by normal wood sandy procedures. Also precision sanding to close tolerance can be done.

(b) Machining

Machining can be achieved same as other wood products such operation as shaping, routing and planning gives best result if tools are kept sharp. Absence of grain in ceiling board allows uniformly fine machining without splintering.

(c) Laminating

This process is done to give ceiling board resistance against dampness and change in color as a result of fungi attack. The board is laminated with paper or covered with veneer. This gives the board an esthetic look, more strength and other times no need for painting.

(d) Sawing

Sawing the ceiling board can be achieved with the use of hand or power saw. But for high quality product the second option should be used to avoid edge cut or breaking of the board and saw must be carbide-tipped.

(e) Screwing and Bolting

Special fasteners are can be designed to be used in holding the board other than nail where nail is not readily available for the holding of the ceiling board and where ordinary screw and nails will not provide the correct holding power over time. Threads may strip; portions of the ceiling board may blow out when stressed. Therefore smaller nails should be used instead of screws for proper holding and to avoid part of the ceiling board being blown away as a result of screwing the board.

(f) Drilling

Ceiling board does not really need drilling during installation because of the thickness of the board. Nailing can give it all the hold ability properties the board could ever need.

(g) Nailing

The only common and usual way of installing ceiling board is by nailing. There is no alternative means or ways of holding the board on the wooden frame of the roof other than nailing. So, nailing is seen as the only suitable means of ceiling board installation in the building industry.

(h) Painting the ceiling board

To paint the ceiling board required no much sophistication as any method could be used to achieving the finishing touches using brushes, spray or rollers. Also interior – wall panels require no special sealer, however if sealer are to be applied, rubber or vinyl-base whiter sealer are good choice oil paint. Clear varnish or resin sealers should not be used as first coat. Instead transparent filler-sealer, natural paste wood filler or clear-drying white vinyl-glue can be used.

(i) Staples of ceiling board

Best stapling is achieved through a narrow screw and divergent point (branding out in different direction) along side a hammer – types stapler or air gum spacing of 3.5" or as recommended. The length of staplers should be at least 1" plans the thickness of the board.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Materials/Equipment

Materials and equipment used for the production and characterization of ceiling board from agricultural by-products are given in table 3.0 and 3.1 below. This is to give the material use and source of the materials as well as their botanical name and comments

Table 3.0 materials used for the project.

Materials	Sources	Botanical name	Comments
Saw dust	Timber shade, Bosso Minna		Dried and crushed into smaller particles
Palm oil husk	Local Restaurants, Minna	Elaesis guinieesis	Dried and crushed into Smaller particles
Gum Arabic	Bida Market	Arabino gelactan	Shredded, crushed, sieved and dissolved.
Water	Soil Lab Fut Minna	Tap water	Washing items

Table 3.2 Equipment used for the project

Material	Sources	Research code
Manual square press	Mallam Billiaminu	
Steel pallet cover and bottom steel	Processing workshop	
Plate size 0.35x0.31x0.006	Minna	
Electronic weighing balance	Saunter England	Digital calibration in (g)
Stop watch	Made in Nigeria	
Measuring cylinder	Eit England	BS 410 1986
Cylindrical steel container	Eit England	Metal
Grinding Machine	Made in Nigeria	
Mortal and Pestle	Made in Minna	Wooden frame
Oven	Eit England	BS 410 1988
Local sieve	Made in Minna	Wooden frame
British standard sieve	Eit England	BS 410 1986
Milk can	Soil and water lab	C1, C2, C3
Rammer	Eit England	BS 410 1986
Nails and screw	Made in Nigeria	

3.2 Preparation of Saw Dust with Gum Arabic Mixture, Palm Oil Fruit Husk (Chaff) with Gum Arabic and the Composite of the Two Materials Saw Dust and Palm Oil Fruit Husk Core (Mould) with Gum Arabic (Binder)

The separate mixture and the composite of saw dust and palm oil fruit husk samples used in production of the ceiling board were taken through some series of processes to obtain a 850µm particle size before being molded into a sheet of ceiling board. The particles of both the saw dust and palm oil fruit husk were obtained from a Carpenter from Tudun Fulani and palm oil fruit husk from the local restaurants around mobile, Minna, Niger state. These raw materials were dried for four days under the sun. The dried materials were pounded using mortal and pestle to break them into size of fine particles (dust). And it was further reduced using grinding machines. These particles were again sun dried for two days to further reduce the moisture content to about 5% m.c. an experiment to determine the moisture content of the sample was taken (See table 4.1 and 4.2)

200g of saw dust and 200g of palm oil fruit husk were taken in two different cans labeled sample A and sample B. The weight of the can when empty was taken with an electronic weighing balance, then the weight of the can and the sample were taken. The can with the sample were put into the electric oven and left for 24 hours at 27^0C. After 24 hours of oven drying, the can with the sample were removed. The weight of the can with the sample was weighed again to obtain the dry weight of the sample. The moisture content of the two samples were computed by subtracting the weight of wet sample + can – the weight of the dried sample + can divided by the weight of the dried sample + can – weight of empty can for dry basis (i.e. moisture content W $= \frac{W_w - W_d}{W_d - W_e} \times 100$

The summary of the final preparation of these raw materials are given below;

1. The saw dust and palm oil fruit husk were sun dried separately for some days to aid easy pounding and serving.
2. The saw dust and palm oil fruit husk were reduced into particle sizes of dust, splinters and saw dusts using the manual pounding method of mortal and pestle to achieve the particle of both saw dust and palm oil fruit husk.

3. The particles were sieved using British standard sieve to determine particle size to be used to form homogeneous mixture. N.B. The finer the particles size the better the quality of the ceiling board produced.
4. The retained particle sizes were sun dried for several days to reduce the moisture content to about 5%.
5. A moisture content test was conducted in the laboratory to keep the particle below or within the 5% M.c after sun drying.
6. About 50g of the treated acacia extract was mixed with about 0.2Lit of hot water at temperature of 100^0C for 30 minutes. To obtain homogeneity, the mixture was agitated until a stable viscosity was obtained. It is then cooled in a water bath until the temperature drop to about 27^0C. And was mixed based on composition mixtures as given in the appendices.
7. The sample of saw dust and palm oil fruit husk particle sizes were weighed using electronic saunter balance into 5(five) separate samples "A, B, C, D and E" each and keep labeled.
8. The wooden mould and flat steel sheets were greased with oil on sides, bottom, surface and cover to obtain reduced frictional resistance created during forming operation and to avoid the sticky of the sample on the mould or rammer during compaction.
9. A separate sample "F, G, H, I and J" of the composites of both saw dust and palm oil fruit husk at a mixed ratio of 100, 100, 70:30, 30:70 and 50:50 in percentage respectively was prepared from the samples "A, B, C, D and E" above.

3.3 Manufacturing Process of Ceiling board

The sample F of the composite of both saw dust and palm oil fruit husk particle were pounded into an open steel container in damped condition.

The liquid Gum Arabic at 27^0C hot condition was added to the composite particles and mixed thoroughly for about 5 minutes to form thick slurry of flares called "stuck". This loose but damped material (particle mixture) was forces spread to achieve a uniform compaction into a greased mould of internal size 0.35 x 0.31 x 0.006m (thickness). The board was shaped to the required size as the stuck was compacted several times using a standard rammer on top of steel pallet cover in strokes to achieve a particular pressure. The formed ceiling board was left to dry under atmospheric condition for several days. The mould was removed, 30 minutes after placing and compacting process. The same procedure was repeated for sample G, H, I and J.

N.B. coloring, anti-fungi agent and fire-resistance additives were not added due to the scope of the project and of the laboratory work.

3.3.1 Conditioning (Curing)

The production of the ceiling board was done after mixing and compacting were, due to pressure. The wooden was removed leaving behind the formed board to dry in open air at room temperature for several days. The purpose of the conditioning is to equalize the moisture content throughout the board.

3.3.2 Characterization of the board

The produced ceiling board attained the required pressure and density which is within the range of $700kg/m^3$ – $1400kg/m^3$ for low density board. The standard requirements are based on plywood and wood-based panels provided by F.A.O. To determine the efficiency of the boards made from the composite of saw dust and palm oil fruit husk with Gum Arabic, it is necessary to establish the minimum standard of blending and tensile strength and other properties.

3.3.3 Observation of formed board

In this project, five ceiling boards were produced given sample A with 100% composition of saw dust, sample B 100% palm oil fruit husk, sample C with 50:50% composition, sample D with 60:40% composition and sample E with 40:60% composition respectively with the same particle size 850μm and 850μm. The holding ability of the gum Arabic varies with composition and type of material used. The holding ability was strongest on the 100% saw dust composition followed by the 60:40% composition of saw dust and palm oil fruit husk and least in the 100% palm oil fruit husk.

The finish product differ in color slightly, texture, weight and density. The change in the physical properties is due to the different composition of the formed board, the variation in their particle size and the different properties of the materials combined together.

The curing steps are as follows:

1. The ceiling board was left to cure at room temperature (27^0C) for 30 minutes to set after which the mould was remove and the board was then conditioned at the same room temperature for several days.
2. The board was then trimmed and shaped to rectangle to finish.

CHAPTER FOUR

4.0 RESULTS & DISCUSSION

4.1 Laboratory Experiment/Test

Laboratory experiment and tests were carried out following method and step prescribed scientifically. This is to ensure that results obtain are based on provable principles which originate from facts and figures which guide engineering principles.

The experiment conducted were on the saw dust and palm oil fruit husk sample to determine the moisture content of the sample and reduce it to appropriate required standard of 5% M.c. Also a sieve analysis experiment was conducted to know the size distribution of the particle, to obtain a homogeneous size particle for proper mixture to ascertain the suitability of the particle to be used.

The experiment procedure, test, observation and results are observed as follows:

Experiment 1

Federal University of Technology, Minna

Department of Agric & Bioresource Engineering

Material testing Laboratory (food and processing section)

Percentage Moisture contents Determination

Assignment: Project Research

Title: Moisture content determination

Aim: To determine the percentage moisture content of the experimental sample of saw dust and palm oil fruit husk

Apparatus:

(i) Samples of saw dust and palm oil fruit husk

(ii) Electronic weighing balance

(iii) Cylindrical steel tin or container labeled A and B

(iv) Electrical oven

Procedure:

The weights of the empty containers were taking as (W1) in each case A and B. Dry sample of saw dust and palm oil fruit husk were put in each can with saw dust and palm oil fruit husk labeled A and B respectively. The weight of the can and wet sample were weighed and recorded as (W2). The samples were then placed in the oven at 105^0C for twenty four (24) hours. The oven dry sample and container were weighed and recorded as (W3). The obtained data were used to calculate the percentage of moisture content of the samples based on BS 1377 of 1975 which is given as follows:

$$\frac{W_2-W_3}{W_3-W_1} \times \frac{100}{1}$$

Precautions

1. The container was cleaned with dry cloth.
2. Moisture or water was avoided from coming in contact with dried sample before and during weighing.
3. Dried sample were allowed to cool before taking their weight to avoid expansion and contraction effect.
4. Results were quickly and carefully collected as stated in Table 4.1

Table 4.1 moisture content analysis

% Moisture content	Test 1 (sample A)	Test 2 (sample B)
Weight of container (W_1) g	24.90	24.02
Weight of wet sample + container (W_2) g	52.12	50.64
Weight of dry sample + container (W_3) g	50.86	49.39
Weight of moisture (W_2-W_3) g	1.26	1.25
Weight of dried sample (W_3-W_1) g	25.96	25.37
Moisture content W $= \frac{W_2-W_3}{W_3-W_1} \times 100$	4.85	4.93

Uses of the Test

In forming a standard and suitable board, the required moisture content is 5%. Therefore, the test helps to determination the moisture content in the samples which aid the quick solidification of the formed ceiling board. And if higher than 5%, through the oven drying, it is further reduced to the required moisture content which affects the properties of the formed board.

Experiment 2

Federal University of Technology, Minna

Department of Agric & Bio-resource Engineering

Material Testing Laboratory (soil and water section)

Assignment: Project Research

Title: sieve analysis for saw dust and palm oil fruit husk

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Since the advent of ceiling board, different materials have been used in production of the board. The use of Agricultural by-products is a new innovation that is used in recent time, as ceiling board have been produced successfully with rice husk, rice straw, groundnut shell, coconut shell e.t.c. But the newest innovation being explored is the use of compatible composite of agricultural waste. The composite of saw dust and palm oil fruit husk at different composition or proportion has brought about new innovation of producing ceiling board in small quantity which can as well be explored for industrial and massive production for commercial purpose.

About new properties and characteristics of the board produced in terms of strength and usability. The agro-based raw material needed are sufficiently available to support ceiling board manufacturing/production as saw dust and palm oil fruit husk are produced in large quantities in southern part of the country especially palm fruit husk from oil palm. Although some of these material may not be suitable for some geographical zone thereby, affecting the economical variability.

Saw dust and palm oil fruit husk are good alternative source of bio-material with good physical, mechanical and chemical properties that can be used in production of ceiling board. In addition, they possess good handling properties and are environmental friendly. Gum Arabic is another agro-based product that is used in place of the very expensive and chemically based synthetic resin as a binder to form the ceiling board.

Aim: to determine the distribution of particle size of saw dust and palm oil fruit husk using British standard sieve (BS 410), with the aim of selecting the medium, less medium (small) and finest test particle for board production.

Apparatus: (i) Weighing balance

(ii) Wire brush

(iii) Stop watch

(iv) British standard sieve

(v) Sieving machine (vibrator machine)

Procedure: The sieves of the British standard sieve were weighed on the weighing balance each. 1kg of the particle samples of saw dust and palm oil fruit husk each was poured into the top sieve and set on the vibrator machine respectively. The set were set into vibration for 10 minutes for each of the sample respectively. The sieve were arranged in descending order in sizes of 6.70mm, 4.75mm, 2.36mm, 2.00mm, 850µm, 300µm, 180µm, and the bottom pan. After the vibration each sieve and the retained particle were weighed. The result is shown in the table below.

The result of sieve analysis conducted on the saw dust particles is given below showing the weight and percentage retained.

Table 4.2 sieve analysis data of sample A (saw dust)

No	BS/sieve Mesh size	Wt of sieve (Kg)	Wt of sieve + sample (Kg)	Wt of retained sample (Kg)	% Retained	Cumulative % retained
1	6.70 mm	0.50	0.51	0.01	1.00	1.00
2	4.75 mm	0.51	0.52	0.01	1.00	2.00
3	2.36 mm	0.40	0.42	0.02	2.00	4.00
4	2.00 mm	0.50	0.57	0.07	7.00	11.00
5	850 μm	0.40	1.05	0.65	65.00	76.00
6	300 μm	0.36	0.58	0.22	22.00	98.00
7	180 μm	0.39	0.40	0.01	1.00	99.00
8	Pan	0.30	0.31	0.01	1.00	100.00
Total				1.00		391.00

Fineness modulus = cumulative 391/100% = 3.91

The sieve analysis conducted on the palm oil fruit husk particles is given below showing the weight and percentage retained.

Table 4.3 sieve analysis of sample B (palm oil fruit husk)

No	BS/sieve Mesh size	Wt of sieve (Kg) Sample (Kg)	Wt of sieve + sample (Kg)	Wt of retained	% Retained	Cumulative % retained
1	6.70 mm	0.50	0.51	0.01	1.00	1.00
2	4.75 mm	0.51	0.53	0.02	2.00	3.00
3	2.36 mm	0.40	0.43	0.03	3.00	6.00
4	2.00 mm	0.50	0.74	0.24	24.00	30.00
5	850 µm	0.40	1.00	0.60	60.00	90.00
6	300 µm	0.36	0.43	0.07	7.00	97.00
7	180 µm	0.39	0.40	0.01	1.00	98.00
8	Pan	0.30	0.32	0.02	2.00	100.00
Total				1.00(Kg)		425.00

Fineness modulus = cumulative 425/100% = 4.25

Precaution

1. Before the sieve analysis was carried out, the samples were dried for adequate moisture content to have correct weight of sample.
2. Error due to parallax was avoided during reading.
3. The sieve was cleaned with wire brush to avoid retention of the first sample before the second was introduced.
4. The samples were allowed to settle after vibration to avoid loses.
5. Error due to computation was also avoided.

Uses of the Test

The test is important in separating the particle sample of both saw dust and palm oil fruit husk into flake, chips and dust and hence the determination of the suitability of the size to be used. The particles retained in sieves 850μm and those in 850μm and below were selected for homogeneity of the ceiling board.

4.1 CONSIDERATION OF MECHANICAL PROPERTIES

4.1.1 Ceiling Board Density

Table 4.3 shows the density of the ceiling board based on test and calculation carried out on the ceiling board formed as shown in the appendices, for different composition of saw dust and palm oil fruit husk at 100:100%, 60:40%, 40:60% and 50:50% composition respectively. Also putting the sieve size analysis of the particle into consideration shows that the density of the ceiling board formed falls within the range of $700Kg/m^3$ – $1400Kg/m^3$, which has a wide variety of use in insulation and decoration.

4.1.2 Hardness

The formed board was subjected to surface deformation using hammer, it was observed that the board showed a resistance to a force of 5 Newton, which means the board has considerable strength.

4.1.3 Optimum Concentration of the Binder

The concentration of the binding resin or adhesive used is of high viscosity and the result show good retention of adhesion. Therefore, a good binding resins base of this mix composition shown in the appendices.

4.1.4 Nail/Screw Withdrawal Test

The ceiling board of size 0.35 x 0.31 x 0.006m and composition of saw dust and palm oil fruit husk in ratio of 100:100%, 60:40%, 40:60% and 50:50% formed were passed through nail/screw withdrawal test. The five samples A, B, C, D and E ceiling board were subjected to nailing using a 2" nail and hammer. The nail was driven to a depth of 5mm. the ceiling board had a firm grip of the nails which shows that the board satisfied the minimum holding force as specified by (Madoux, 1963). To remove the nail a considerable force was applied.

4.1.5 Tensile Strength

Tensile strength is based on the maximum tensile stress which is the force per unit cross sectional area a body can resist before it ruptures. The board was able to resist a force of 5N without rupture. This shows that the ceiling board has considerable tensile strength as this is always inversely proportional to density which is low in the formed board. (ASTM, 1988)

4.1.6 Moisture Content

From the moisture content experiment, the moisture content of the board is approximately 5% M.C. which is the required standard for a good board production and formation.

4.1.7 Fire Test

The samples were subjected to fire test without additive, to determine the level of their resistance. With all condition kept constant it was observed that sample F has the highest resistance as it took some time to burn and does not burn readily. Sample H and J also show little resistance to fire as it burns slowly after 30 seconds, while sample G and I burns a little earlier than samples H and J. This is as a result of the variation in the quantity of adhesive used.

Table 4.4 Summary of comparative material composition and test result

Material composite	Types of resin binder	Volume of coconut & palm kernel (m3)	Weight of formed particle (Kg)	Density (Kg/m3)	Grade of ceiling board	pressure	Comment on properties of Gum Arabic	General remarks or comments	
Sample F 100% saw dust particle, size (850mm)	Gum Arabic	6.51x10^-4	0.60	921.66	Low density	3313	Medium	Fast dehydration	Room temperature
Sample G; 100% palm oil fruit husk size (850um below)	Gum Arabic	6.51x10^-4	0.58	890.94	Low density	3313	Low	Moderate dehydration	Room temperature
sample H: 60:40% saw dust and palm oil fruit husk	Gum Arabic	6.51x10^-4	0.55	844.85	Low density	3313	Low	slow dehydration	Room temperature
Sample I: 40:60% saw dust and palm oil fruit husk	Gum Arabic	6.51x10^-4	0.47	721.97	Low density	3313	Low	Moderate dehydration	Room temperature
Sample J: 50:50% saw dust and palm oil fruit husk	Gum Arabic	6.51x10^-4	0.50	768.05	Low density	3313	Low	Moderate dehydration	Room temperature

4.3 Discussion of Result

Based on the result obtained from the five samples of the board formed, it is shown that the composite ceiling board has high quality due to combination of properties which can be improved by using a more stronger adhesive. And the 50%:50% and 60%:40% show greater qualities with little differences. But with that of 60%:40% composition preferred. Although with good Gum Arabic mixture and under hot compression with oven dry method the 50%:50% will give best properties. These two samples are good for different uses based on the properties required. Table 4.4 below show a breakdown of the compound properties

Table 4.5 Comparison of properties against ceiling board samples

No	Properties	Sample F (100%)	Sample G (100%)	Sample H (60:40%)	Sample I (40:60%)	Sample J (50:50%)
1.	Fastener holding	High	High	Moderate	Moderate	Moderate
2.	Smoothness	High	Low	High	Low	Moderate
3.	Shrinkage	Low	Low	Low	Moderate	Moderate
4.	Abrasion resistance	High	Low	Moderate	Moderate	Moderate
5.	Swelling	Low	Moderate	Moderate	Moderate	Moderate
6.	Bending	High	Moderate	High	Moderate	Moderate
7.	Rate of burning	Very slow	Fast	Slow	Fast	Moderate
8.	Density	921.66Kg/m3	890.94Kg/m3	844.85Kg/m3	722.00Kg/m3	768.05Kg/m3

4.4 Possible Factors Leading to the Loss in Strength of Ceiling Board

Loss of strength in ceiling board could results based on some factors mentioned below:

1. Nature and Structure of Method: The morphological nature which is based on both Chemical and Physical properties of the material used can caused structural deformation leading to loss of strength which can result into warping, bending, fracture and less inter-particle bond e.g. acid content of the material.
2. Type of Adhesive used: Improper choice of selection of adhesive and amount used can affect the strength of a ceiling board.
3. Method of forming or mould used: the method or mould used may bring about loss of strength, if the process is not effectively applied and design of mould not properly used during composition which can result in variation in shape.
4. Particle sizes: The particle sizes selected to form a ceiling board affect the density and invariability affects the strength of the board formed. Previous experiment formed in test has shown that the smaller the particle sizes, the more effective the inter-particle bond. This provides large surface areas for the binder to reach with and penetrates to form a solid mould.
5. Drying effect: The strength of a ceiling board is directly proportional to its drying effect. The presence of oily surface, very high viscose and oily binder, tend to prevent effective drying. Thereby, reducing the strength of the ceiling board, producing a gummy surface during the drying process. (Saydi, 2007)

The properties of the ceiling board produced in terms of strengths are dependent mostly on board densities this is very important point to note when selecting the design process, type of agricultural by-product to be used in developing the board.

The uses of the board formed can be applied in the following areas:

1. General furniture: - Low density boards are widely used in place of woods, this is because they are expensive; therefore reduce cost and weight of material. They are used in light furniture, like TV, cabinet, shelves, wardrobe, partitioning, particle board, chalk board as well as in the arts industry.
2. Acoustic paneling: - Low densities boards are used in construction where sound proof is desired, like in studios, auditorium, and theatre halls e.t.c. (Madoux, 1963).
3. Insulation: - Based on the nature and structure of the material used in ceiling board production and their low density properties. They are very good insulators use in lagging heating materials where heat loss is not require, also in electronic casing to prevent shock and maintain required environmental temperature.
4. Floor underlay: - Engineered panel or ceiling board can be used as floor underlay, to serve as resilient floor covering.

5.2 Recommendation

On the basis of the result obtain from this project; the following recommendations can be made for further development. The development of a local production plant for the manufacturing of ceiling boards based on the design recommended should include; drying process – milling – mixing process – blending building (core mould) – oven drying – finishing process, thereby, enhancing the recycling of the agricultural by-product and Gum Arabic . This will be a cheap and mass local production of the boards. Thereby reducing the dependence on the forest based product that are use in construction and building industries in Nigeria.

The building industries in the country should be encouraged to use the waste generated from agricultural by-product and products formed from them to reduce cost of production, as a result of high cost of raw materials.

Also, further environmental studies should be done to show the effect of agricultural waste on the environment such as dumping and burning of palm kernel shells, coco nut shell, saw dust, palm oil fruit husk, rice husk, groundnut shells and the burning of other wastes.

The use of Gum Arabic should be further developed in industries, encouraging them to go into the production and improvement of its properties for it to effectively replace synthetic resins or adhesive like the urea formaldehyde which are imported at very high cost into the country. For effective drying, curing in the oven can be employed.

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APPENDICES

Appendix I density Determined

In calculating the density of the dried ceiling board, the weight of the formed board per unit volume is very important.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Sample F (100% saw dust composition)

Weight of ceiling board = 0.60Kg

Volume of ceiling board = 0.35 x 0.31 x 0.006= 6.51 x 10-4m3

$$\text{Density of board A} = \frac{0.60}{6.51 \times 10^{-4}} = 921.66 Kg/m^3$$

Sample G (100% palm oil fruit husk composition)

Weight of ceiling board = 0.58Kg

Volume of ceiling board = 0.35 x 0.31 x 0.006 = 6.51 x 10-4

$$\text{Density of board B} = \frac{0.58}{6.51 \times 10^{-4}} = 890.94 Kg/m^3$$

Sample H (60:40% compositions)

Weight of ceiling board = 0.55Kg

Volume of ceiling board = 0.35 x 0.31 x 0.006 = 6.51 x 10-4

$$\text{Density of board H} = \frac{0.55}{6.51 \times 10^{-4}} = 844.85 Kg/m$$

Sample I (40:60% compositions)

Weight of ceiling board = 0.50Kg

Volume of ceiling board = 0.35 x 0.31 x 0.006 = 6.51 x 10-4

Density of board I = $\underline{\quad 0.47 \quad}$ = 722.00Kg/m3

$$\overline{6.51 \times 10\text{-}4}$$

Sample J (50:50% compositions)

Weight of ceiling board = 0.47Kg

Volume of ceiling board = 0.35 x 0.31 x 0.006 = 6.51 x 10-4

$$\text{Density of board J} = \frac{0.50}{6.51 \times 10\text{-}4} = 768.05\text{Kg/m3}$$

Appendix II Compaction

Using a 38Kg standard rammer with an applied distance of 0.10m iron mould pallet to compact ceiling board mixture, the force of application can be computed as:

$$\text{Compaction Force} = \frac{\text{Mass (Kg)}}{\text{Applied distance}} \times \text{acceleration due to gravity} = 380\text{Kg} \times 10 = 3800\text{N}$$

Pressure

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} \ \text{N/m2}$$

$$= \frac{3800}{(0.35 \times 0.31)} = 35023.04\text{N/m2}$$

Appendix III Mixture Composition

The composition mixture of saw dust and palm oil fruit husk particles with the Gum Arabic is given as:

50Kg of Gum Arabic dissolved in 0.2lit of hot water

Let volume of Gum Arabic be denoted with GA= 200ml = 0.2lit

Volume of the composite shall be denoted as S = 0.35 x 0.31 x 0.006 = 6.51 x 10-4m3

But 1000ml = 1lit = 1m3

$$\text{Composition Mixture} = \frac{GA}{S} = \frac{0.2}{6.51 \times 10\text{-}4} = 307.22$$

G A= 307.22S

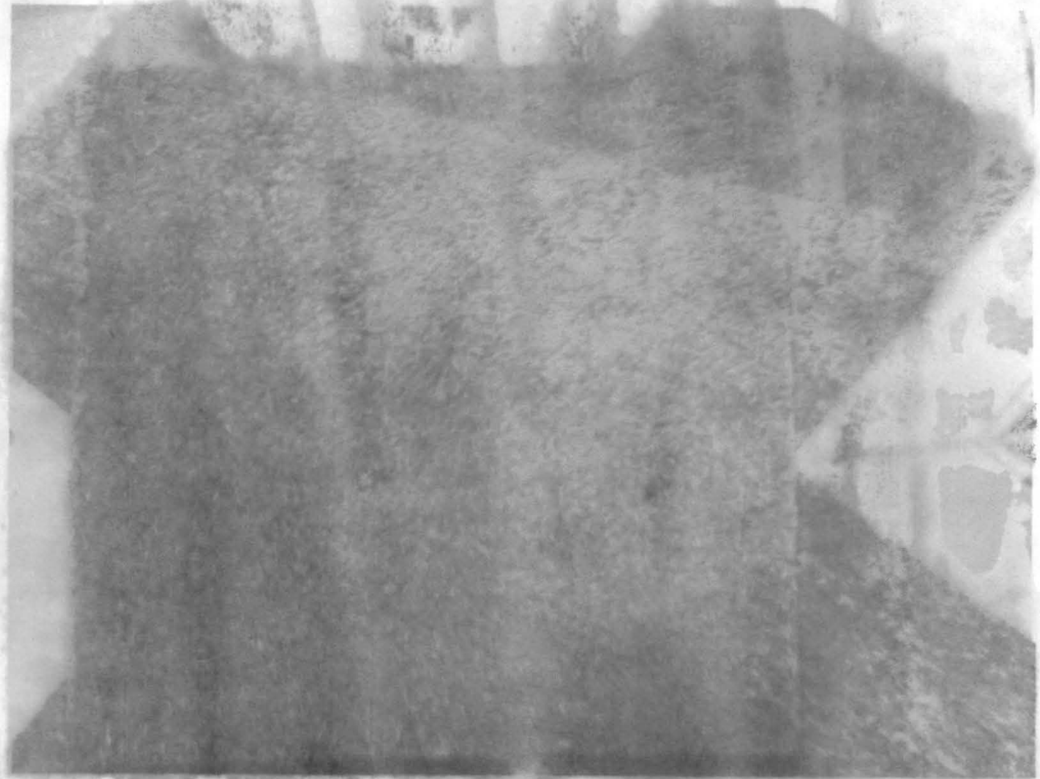

Plate1: 100% saw dust sample

Plate2: 100% palm oil fruit husk sample

Plate3: 60% saw dust to 40% palm oil fruit husk sample

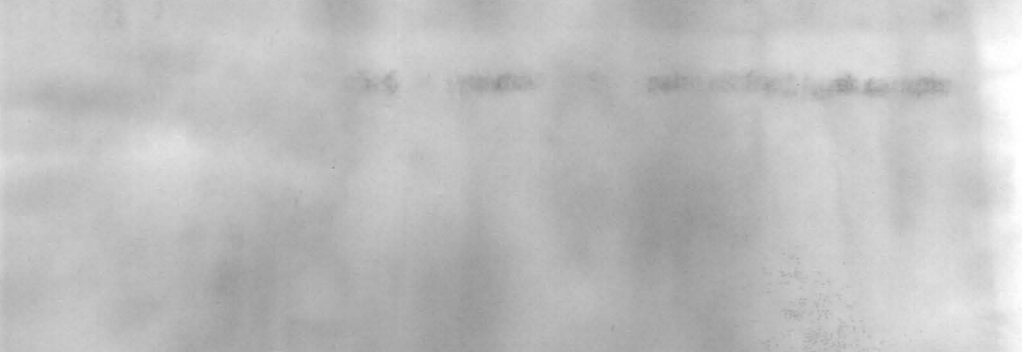

Plate4: 40% saw dust to 60% palm oil fruit husk sample

Plate5: 50% saw dust to 50% palm oil fruit husk sample