DESIGN, DEVELOPMENT AND TESTING OF ARECA LEAF PLY AND DESIGN AND ANALYSIS OF A SHOE RACK CONSTRUCTED WITH ARECA LEAF PLY

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Abstract - *Plywood is a manufactured board with a wide variety of applications and advantages but Plywood are not cheap to manufacture and needs trees to be cut down to do so. Thus introduction of material such as areca ply would reduce stadium on wood for plywood and is a lot more economical. In this project we designed a ply made of areca leaves which is a product that is abundantly available in tropical areas such as India. In order to get the best directional properties of the ply, the layers of the areca leaves need to be oriented correctly. In order to find the best orientation, Minitab software was used. In Taguchi feature of Minitab we obtained multiple orientations and after inserting the directional properties of the orientations, the result was that the best orientation was figured out to be leaf layers to be placed angled at 90° to each other. After the orientation have been selected, construction started. Construction process had many steps like water treatment, drying, peeling etc. After the construction tests recommended by the Indian Standards were conducted on the specimen and properties were determined. The tests conducted on the Areca ply is screw and nail withdrawal test, determination of variation of density of specimen, determination of variation of density of specimen and determination of static bending strength (MOR and MOE). After analyzing the test results we designed a shoe rack among many suitable products made with areca ply and did analysis on it. The analysis done on the Areca ply are total deformation, maximum principle stress, maximum shear stress, maximum shear elastic strain. We were able to successfully design a product that is capabl*e of replacing plywood in a wide variety of applications.

Key Words: *MOR, MOE, CREO, Finite Element analysis*

1. INTRODUCTION

Plywood is wood veneers bonded together to produce a flat sheet. An extremely versatile product, plywood is used for a wide range of structural, interior and exterior applications - from formwork through to internal paneling. The normal product consists of at least 3 plies, with the grain in the alternate plies running at right angles. Plywood offers all the inherent advantages of the parent wood plus enhanced properties in its laminated structure. Being a wood based material, plywood has the ability to accommodate the occasional short-term overload; up to twice the design load. The woods used for plywood are expensive, it is difficult to transport and most importantly causes deforestation. As we are reminded by the scientists all around the globe, the effects of deforestation are so severe in the long run that our own existence will be at risk. This is where the idea of 'areca leaf ply' comes in. Areca leaves are abundantly available in the southern part of India like in Kerala, Karnataka and Tamil Nadu. Areca nut is cultivated extensively in the state of Karnataka in an area of 2.61 lakh hectares with annual production of 3.82 lakh tons. About three million farmers are dependent on areca nut directly/ indirectly for their livelihood. It generates enormous employment and income for the people who are deriving livelihood from this enterprise. Areca leafs are also not considered to be very useful. Of-late due to technological innovations, it has become possible to put leaf sheaths for better use for manufacturing leaf plates, bowls and spoons of different dimensions. These products are biodegradable and eco-friendly. A Shoe Rack, is commonly used to hang and display footwear in retail stores for the purpose of space efficient storage and to present footwear to customers Shoe Rack is made up of Areca leaf fly .It has contain 3 layers, for the protection from water sources it is coated with creosote. Creosote is a category of carbonaceous chemicals formed by the distillation of various tars and pyrolysis of plant-derived material, such as wood or fossil fuel. They are typically used as preservatives or antiseptics

2. CONSTRUCTION OF ARECAPLY

In regular plywood, each layer of wood, or ply, is usually oriented with its grain running at right angles to the adjacent layer in order to reduce the shrinkage and improve the strength of the finished piece. Most plywood is pressed into large, flat sheets used in building construction. The structure of areca leaf is such that linear go along the length of the leaf. As the thickness of the leaf vary from 0.7mm to

3mm, about three layers are needed to create a typical 5mm thick ply. The orientation of the layers should be such that mechanical properties of the material should be highest in all directions. It was found out that 90° is the optimal angle of orientation of layers of areca leaves in areca ply as well.

Areca ply construction is even though simple has a few steps that are really important to be done with care. The steps in production are

- Collection of the leaf.
- Water treatment.
- Peeling.
- Straightening the leaf and drying.
- Cutting.
- Gluing.
- Cold pressing.
- Baking

2.1 Collection of areca leafs: In areca nut farming, the nut bearing starts after 5 years of planting. Generally, nuts are harvested when they are three quarters ripe. The number of harvestings will vary from 3 to 6 in 1 year depending upon the season and place of cultivation. Although areca leaf falls all throughout the year, during the harvesting period will the best time to collect leaves due to the availability of labor.

Fig 1- Bundled areca leaves after collection

2.2 Water Treatment : After collection the areca sheaths that already lost most of their moisture is soaked areca sheaths in the freshwater for 20 minutes. This allows the areca sheaths to be flexible in their shape and can be moulded into the desired sheets

2.3 Peeling: There exist a fine membrane underneath the areca sheaths that prevents the layers from sticking to each other effectively. These membranes can easily be removed by hand. This process must be done before drying because once the sheaths dry the membranes also get dried up and removing dried membrane is really difficult.

2.4 Straightening the leaf and drying: After the water treatment and cleaning of the sheaths, the shape flexible sheaths are placed on a comparatively clean open floor with weighted objects placed at ends of the sheath. This is done so as to prevent the sheaths curling into a tube once again. These are placed on an open floor because the preferred method of drying the areca leaf sheaths is sun drying.

Fig. 2 - Sun drying areca leaves

2.5 Cutting: Different areca leaf sheaths are of different dimensions, thus a standard size is fixed and all sheaths are cut into that standard dimension (usually 300mm*150mm) for ease of assembling the sheaths into a plywood form.

2.6 Gluing: In production of manufactured wood materials such as plywood and particle board is 'Urea-formaldehyde'. This is the most important step in production of areca leaf ply. After setting and hardening Urea Formaldehyde resins forms an insoluble, three-dimensional network and cannot be melted or thermo-formed. The glue needs to be applied evenly throughout the sheath with almost care

2.7 Cold Pressing and Baking: After the application of urea-formaldehyde, the ply should be cold pressed with a pressure of 7.6-13.8 bar in order for the glue to set and permanently bind the sheets of areca leafs together. At high pressures with the help of heating the pressing can be done within the 2 to 3 minutes. But at lower pressures the pressing process takes at least 6 hours to complete the binding process. The finished ply is placed in a high temperature oven in order to bake the ply to remove any moisture that remains in the product before doing the finishing touches.

3. EXPERIMENTS AND RESULTS

3.1 SCREW AND NAIL WITHDRAWAL TEST

3.1.1 SCOPE

This standard (Part XIV) covers screw and nail withdrawal test.

3.1.2 TEST SPECIMEN

The length and width of the test specimen shall be 150mm and 75mm respectively. The thickness shall not be less than 30mm, two or more thickness of the board may be bonded together with suitable adhesive or clamped. Two wood screws no.8 and 50mm length shall be threaded into the specimen at right angle to the face up to the half of their length in a for 2.5mm.The holes should be preferably at mid width at about 5cm from the ends of the specimen. If the screw holding capacity of the edge of the specimen is required, the screw shall be threaded in a similar way on the edge. Care shall taken that sample may not split during driving of the screws in the specimen.

In the nail withdrawal resistance test, two nails of 50mm long and 2.5mm shank shall be driven in the specimen in the similar way as screw, but without any . Nails shall be bright, galvanized, diamond pointed and shall have plain heads .Each screw or nail shall be used only once.

3.1.3 PROCEDURE

The assembly for the screw or nail withdrawal test is shown in figure 5.1.3.The specimen holding fixture shall be attached to the lower platen of the testing machine. The specimen shall be inserted in the fixture with the head of the screw or nail up .The load applying the fixture which is equipped with a slot for easy management of the head of the screw

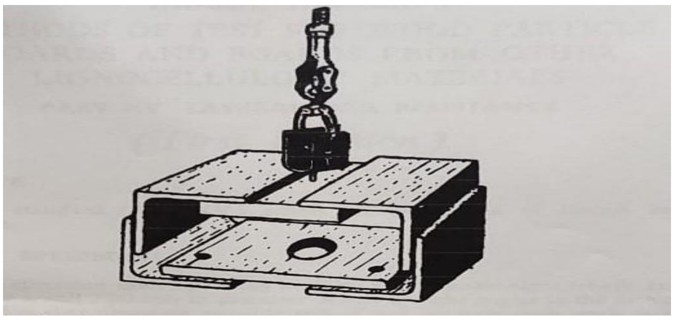

Fig 3- The assembly for manufacturing the resistance of screw and nail to direct withdrawal

Rate of loading shall be applied to the specimen through the test by a uniform motion of the movable head of the testing machine at a rate of 1.5 mm per minute.

3.1.4 MOISTURE CONTENT

After the test a section 50mm long and of the full width of the specimen shall be cut from the body of the specimen for moisture content determination in accordance with IS:238 (partIII)-1977*.

3.1.5 TEST DATA AND REPORT

The maximum load required to withdraw the screw or nail shall be the measure of resistance of the material to direct withdrawal of screw or nail and shall be included in the report. The moisture content shall also be reported.

Face	763
Edge	360

Table 1- screw and nail test table

3.2 DETERMINATION OF VARIATION OF DENSITY OF SPECIMEN

3.2.1 SCOPE

The standard covers the method of test for the determination of variation in density of the specimen.

3.2.2 OBJECT

The object of this test to determine the density of plywood which is an indication of the properties of timber series.

3.2.2 TEST SPECIMENS

Specimen 1: Specimen of thickness 7mm of length 75mm and width 150mm.

Specimen 2: Specimen of thickness 7mm of length 200mm and width 100mm.

Specimen 3: Specimen of thickness 7mm of length 300mm and width 300mm.

Specimen 4: Specimen of thickness 7mm of length 125mm and width 100mm.

3.2.3 APPARATUS

A balance to weigh a specimen with ±0.2 percent. The accuracy and sensitivity of the weighing balance shall be checked frequently.

3.2.4 PROCEDURE

The test specimen shall be weighted. The specimen shall be weighted to an accuracy of not less than ±0.2 percent.

3.2.5 PRECAUTIONS

Care shall be taken to prevent any change in moisture content between the cutting of the sample and first weighing and also between two removal from the oven and subsequent weightings. The specimen may be wrapped in an aluminum foil or polyethylene film to prevent moisture changes after cutting between concentric weighing. The density so obtained is based on the volume at test. If desired the density may be obtained on volume basis.

3.2.6 REPORT

The density of the specimen shall be reported.

Calculation of density

Specimen 1

Density= $\frac{mass}{volume}$

Volume=B×L×T

B=Breadth=150mm

L=Length=75mm

T=Thickness=7mm

W=Weight=0.076N

g=9806.

Volume=150×75×7=$\underline{78750 mm^3}$

Mass =$\frac{W}{g}$ =$\frac{0.076}{9806}$=$\underline{7.750\times 10^{-6}}$

Density=$\frac{7.750\times 10^{-6}}{78750}$=$\underline{9.84\times 10^{-11}}$

Specimen 2

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

Volume=B×L×T

Breadth=B=100mm

Length=L=200mm

Thickness=T=7mm

Weight W=0.092N

g=9806

Volume=100×200×7= $\underline{140000 mm^3}$

Mass=$\frac{W}{g}$=$\frac{0.092}{9806}$= $\underline{9.38\times 10^{-6} kg}$

Density=$\frac{9.38\times 10^{-6}}{140000}$= $\underline{6.70\times 10^{-11} kg/mm^3}$

Specimen 3

Density=$\frac{mass}{volume}$

Volume=B×L×T

Breadth=B=300mm,L=Length=300mm,T=Thickness=7mm, W=Weight=0.098N,g=9806

Volume=300×300×7=$\underline{63000 mm^3}$

Mass=$\frac{w}{g}$=$\frac{0.098}{9806}$=$\underline{9.99\times 10^{-6} kg}$

Density=$\frac{mass}{volume}$=$\frac{9.99\times 10^{-6}}{63000}$=$\underline{1.56\times 10^{-11} kg/mm^3}$

Specimen 4

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

Volume=B×L×T

B=Breadth=100mm

L=Length=125mm

T=Thickness=7mm

Weight=W=0.085N, g=9806

Volume=100×125×7=$87500 mm^3$

Mass=$\frac{W}{g}=\frac{0.085}{9806}$=$8.66\times10^{-6}$kg

Density=$\frac{8.66\times10^{-6}}{87500}$=$9.906\times10^{-11}$ kg/mm^3

3.3 DETERMINATION OF STATIC BENDING STRENGTH (MODULUS OF RUPTURE AND MODULUS OF ELASTICITY IN BENDING)

3.3.1 SCOPE

This standard (Part IV) covers method of determination of static bending strength of boards.

3.3.2 TEST SPECIMEN

Each test specimen shall be 75 mm in width if the nominal thickness is greater than 6 mm, and 50 mm in width if the nominal thickness is 6mm or less. The thickness shall be the thickness of the material. The length of each specimen shall be 50 + 24t mm where t is the nominal thickness of the board in mm. The width, length and thickness of each specimen shall be measured to an accuracy of not less than ± 0.3 percent. One half of the test specimens shall be prepared with the long dimension parallel and the other half with the long dimension perpendicular to the long dimension of the board in order to evaluate directional properties. The specimen shall be weighed correct to ±0.2 percent. Long span specimens are desired for tests in bending so that the effects of deflections due to shear deformations will be minimized and the values of modulus of elasticity obtained from the bending tests will approximate the true modulus of the materials.

3.3.3 PROCEDURE

Span and Supports - The span (centre-to-centre distance) for each test shall be 24 times the nominal thickness. The supports shall be such that no appreciable crushing of the specimen will occur at these point! during the test. The supports shall either be rounded or shall be knife-edges provided with rollers and plates under the specimen at these Points.

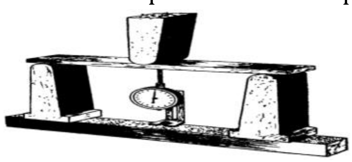

Fig 4- Bend test assembly

When rounded supports, such as those shown in Figure are used, the specimen shall be simply supported, the radius of the rounded portion shall be at least one-and-a-half times the thickness of the material being tested. If the material under test deviates from a plane, laterally adjustable supports shall be provided.

The specimens shall be loaded at the centre of the span with the load applied to the finished face at a uniform rate through a loading block rounded as shown in Figure . The bearing blocks shall be at least 75 mm in width and shall have a thickness (in a direction parallel to the span) equal to twice the radius of curvature of the rounded portion of the loading block. The radius of the rounded portion shall be approximately equal to one and a halftime thickness of the specimen.

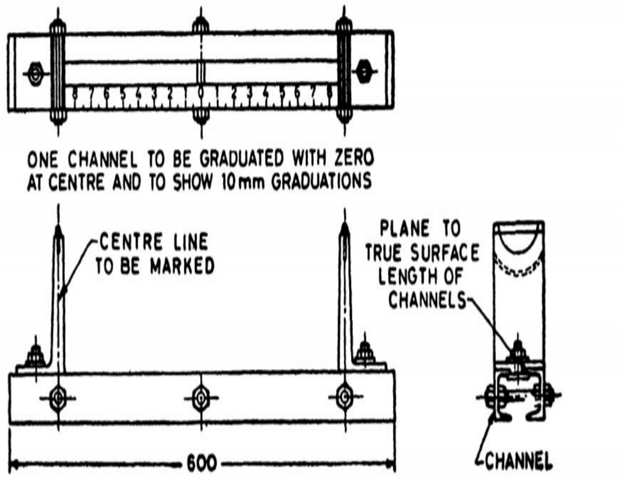

Fig 5-Typical laterally adjustable supports for static bending test

Rate of Loading - The load shall be applied continuously throughout the test at a uniform rate of motion of the movable crosshead of the testing machine as calculated by the following formula :

$$N=\frac{ZL^2}{6t}$$

Where,

N=Rate of motion of moving head in cm/min.

Z == unit rate of fibre strain of outer fibre length per minute = 0·005

L=Span in cm.

t=thickness of specimen in cm

3.3.4 OBSERVATIONS

The deflection of the centre of the specimen shall be measured by measuring the deflection of the neutral axis or alternatively by measuring the deflection of the bottom of the specimen with reference to their respective initial positions. The deflection shall be measured by means of a dial gauge placed suitably below the specimen or by mean of a telescope and scale fixed on the moving head of the testing machine. Readings of deflection shall be taken to the accuracy of 0.1mm deflections shall be measured at convenient load intervals 10 that there are at least six to eight points before reaching the proportional limit, and thereafter the machine shall be kept in balance up to or beyond the maximum load as the case may be and loads will be read at suitable intervals of deflections. The test shall be carried until the specimen completely fails or the deflection is three times the thickness. The character of the failure shall also be observed.

3.3.5 MOISTURE CONTENT AND DENSITY

After the test a moisture content test, 25 mm long and of the full width of specimen, shall be cut from the body of the specimen. The moisture content and density of each specimen shall be determined in accordance with IS: 2380 (Part III)-1977*

3.3.6 CALCULATION AND REPORT

The readings of the deflections and the loads shall be recorded and a load-deflection curve shall be drawn. While drawing a load-deflection curve, the straight line-of proportionality at the initial part of the curve shall be drawn in such a way that maximum number of points lie on the straight line or nearest to it. No consideration need be given to the initial two or three points. A typical load-deflection curve is shown in Figure.

When the straight line does not pass through the origin, a parallel line shall be drawn through the origin and the deflection and load at the limit of proportionality shall be measured on this line. The points beyond the elastic limit and up to maximum load may be connected by smooth curve but the points beyond the maximum load shall be joined from point to point. Load and deflection at first failure and maximum load shall also be noted.

3.3.6.1Modulus of Rupture

The modulus of rupture shall be calculated for each specimen by the following formula, and the values reported. The average values for the lengthwise specimens and the breadth wise specimens shall also be reported separately:

$$R=\frac{3PL}{2bd^2}$$

Where,

R=Modulus of rupture in kgf/mm^3

P=Maximum load in kgf

L=Length of span in mm

B=Width of specimen in mm

d=Depth of specimen in mm.

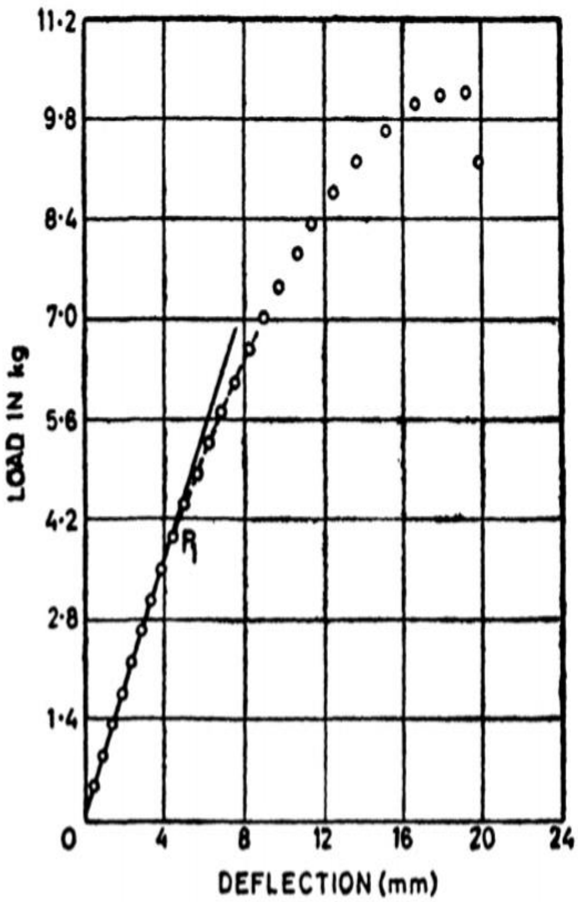

Fig 6 -Typical load-deflection curve for bend test

Load	Deflection
1	2
2	11
3	38
4	67
5	96
6	128
7	158
17	380

Table 2-Modulus of Rigidity

MOR=$\frac{3PL}{2bd^2}$

P=380kgf

L=150mm

b=75mm

d=17mm

MOR=$\frac{3\times380\times150}{2\times75\times17^2}$

=3.94 kgf/mm^2

3.3.6.2 Modulus of Elasticity

The modulus of elasticity shall be calculated for each specimen by the following formula and the values reported. The average for the lengthwise specimens and the breadth wise specimens shall also be reported separately:

E=$\frac{p_1 L^3}{4by_1 d^3}$

Where,

E=Apparent modulus of elasticity in kgf/cm^2

y_1= central deflection at limit of proportionality load in cm

Calculation of Modulus of Elasticity

Load	Deflection
1	28
2	60
3	95
4	163
5	194
6	224
16	451

Table3- Modulus of elasticity

MOE =$\frac{p_1 L^3}{4by_1 d^3}$

P=284kgf

L=150mm

d=12mm

b=75mm

y=142mm

MOE =$\frac{284\times150^3}{4\times75\times142\times12^3}$

=13.020kgf/mm^2

4. ARECAPLY SHOE RACK

A Shoe Rack, is commonly used to hang and display footwear in retail stores for the purpose of space efficient storage and to present footwear to customers. Shoe hangers have secondary functions of providing support for footwear and for displaying key information, such as style and shoe size. Shoe hangers come in a variety of styles for different display purposes and footwear types. The most common styles are wing, hook and clip designs, which are made from plastic.

Wing shoe hangers have an elongated base that terminates at the upper end with a hook. Usually a flat disc appears just below the hook where information about the footwear is displayed. The bottom end of the base terminates into a U-shape. Each arm of the U acts as an element where a shoe can be fitted. These arms often extend and loop back down on each other to create a wing, which offers more support for the shoe. In U-shaped and wing designs, each shoe of the pair is hung adjacent to each other. This design is most commonly used for flat soled footwear such as trainers, sandals, slippers and pumps. Hook shoe hangers are more basic in their design and resemble small clothes hangers. The arms are far shorter and have a hook at their end. This design is commonly used to hang flip-flops or sandals.

5. CONSTRUCTION OF ARECAPLYSHOE RACK

Shoe Rack can be constructed with the help of cad and solid edge software and their analysis can be done by using Ansys software Shoe Rack is made up of Areca leaf fly .It has contain 3 layers, for the protection from water sources it is coated with creosote.

Fig7- Development of shoe rack

Fig 8- 3D figure

6. SIMULATION OF ARECAPLY SHOERACK

6.1 MATERIAL PROPERTIES

Density	7.85e-006 kg mm^{-1}
Coefficient of Thermal Expansion	1.2e-005 C^{-1}
Specific Heat	4.34e+005 m J kg^{-1} C^{-1}
Thermal Conductivity	6.05e-002 W mm^{-1} C^{-1}
Resistivity	1.7e-004 ohm mm
Young's Modulus	2.e+005
Poisson's Ratio	0.3
Bulk Modulus	76923

Table 4- Material properties

6.2 MODEL

Shoe Rack is made up of Areca leaf fly .It contains 3 layers, for the protection from water sources it is coated with creosote

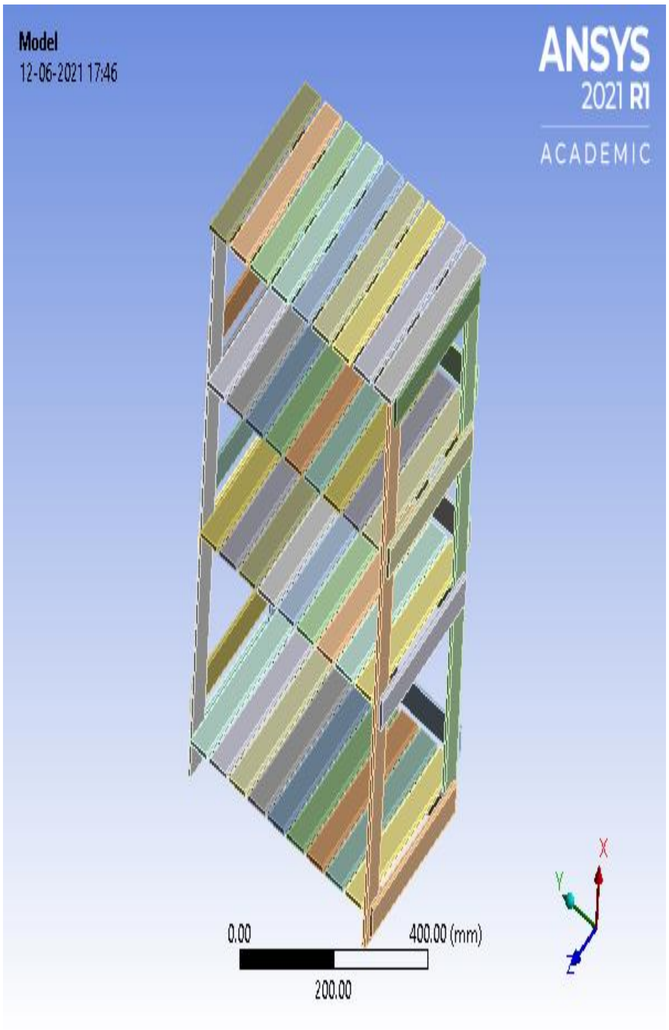

Fig 9- Arecaply shoe rack model

6.4 GEOMETRY

Length Unit	mm
Length X	800mm
Length Y	386mm
Length Z	340.5mm
Volume	8.5039e+006 mm^3
Mass	66.755 kg
Scale Factor Value	1
Analysis type	3D

Table 5- Geometry

6.3 MESH

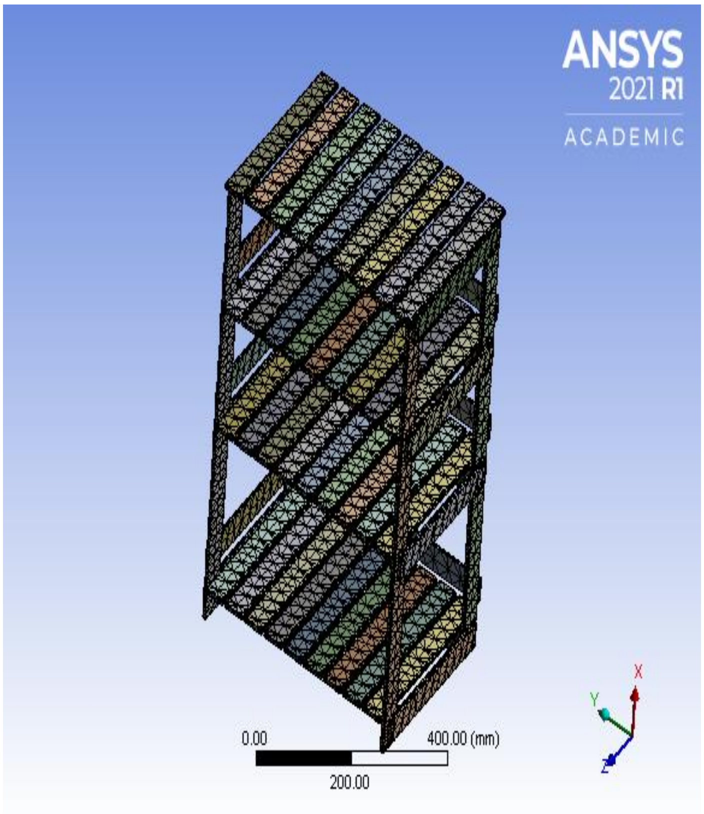

Fig 10-Arecaply shoe rack mesh

6.5 DISPLAY SETTING

Display	Use Geometry Setting

Table 7- display setting

6.6 SIZING

Bounding Box Diagonal	996.06 mm
Average Surface area	5067.4 mm^2
Minimum Edge Length	4.7124 mm

Table 8- Sizing

6.7 QUALITY

Target Quality	0.0500

Table 9- Quality

6.8 INFLATION

Transition Ratio	0.272
Maximum Layers	5
Grow Rate	1.2

Table 10- Inflation

6.9 STATISTICS

Nodes	89914
Elements	37271

Table 11- statistics

6.10 CONNECTIONS AND CONTACT

Connection Type	Contact
Scoping Methods	Geometry Selection
Tolerance Type	Slider
Tolerance Value	2.902mm
Face to Face angle Tolerance	75^0
Cylindrical Faces	Include
priority	Include All
connections	150

Table 12-Connections and Contact

7. ANALYSIS AND RESULT OF ARECAPLY SHOERACK

7.1 TOTAL DEFORMATION

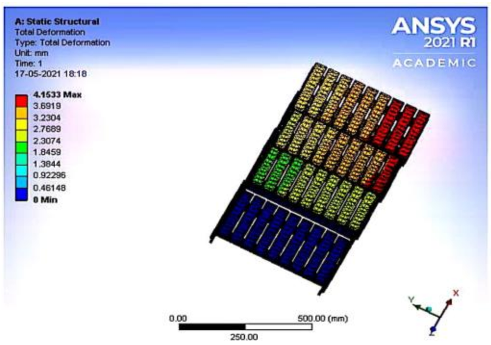

Fig 11-Total Deformation

Object Name	Total Deformation
State	Solved

7.1.1 SCOPE

Scoping Method	Geometry Selection
Geometry	All Bodies

Table 13- scope of Total Deformation

7.1.2RESULT

Minimum	0mm
Maximum	4.1533mm
Average	2.307mm

Table 14- Result of total deformation

7.2 MAXIMUM PRINCIPLE STRESSES

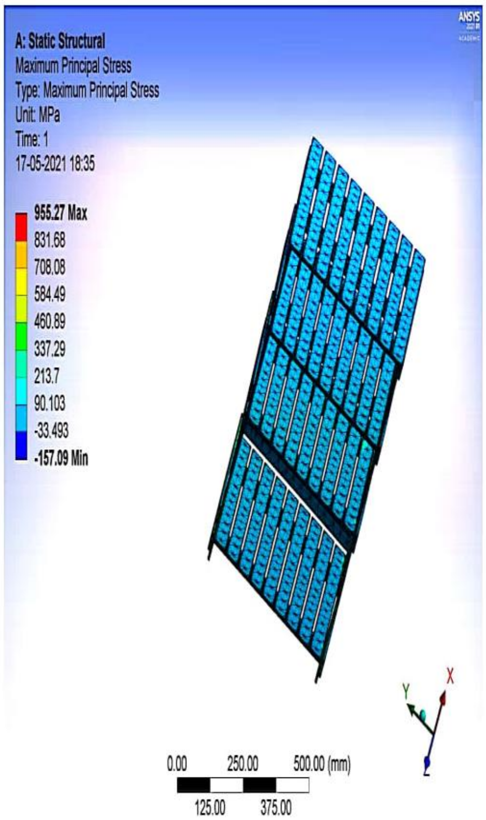

Fig 12-Maximum Principle Stress

Object name	Maximum Principle Stress
State	Solved

7.2.1 SCOPE

Scoping Method	Geometric Selection
Geometry	All Bodies

Table 15- scope of Maximum principle stress

7.2.2 RESULT

Maximum	955.27 MPa
Minimum	-157.09 MPa
Average	399.09 MPa

Table 16- Result of Maximum principle stress

7.3 MAXIMUM SHEAR STRESS

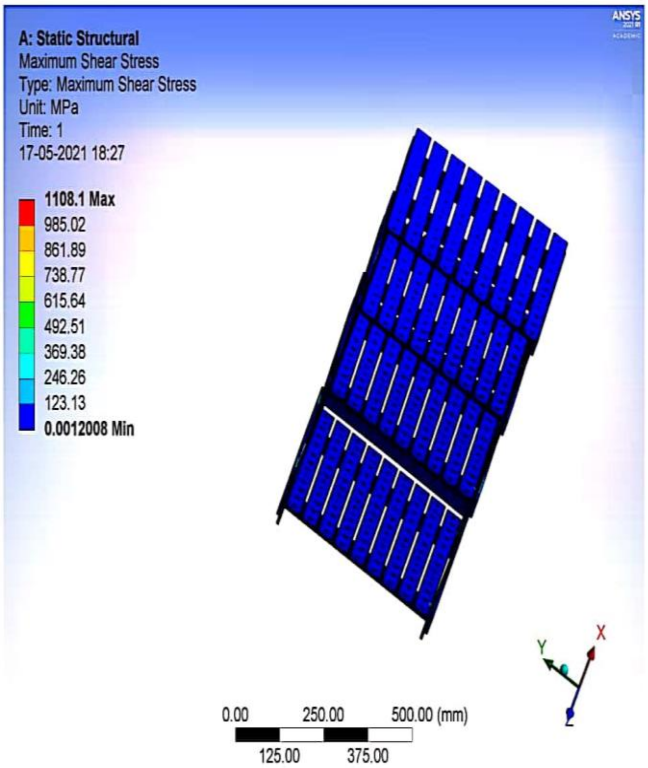

Fig 13- Maximum Shear Elastic Strain

Object Name	Maximum shear stress
State	Solved

7.3.1 SCOPE

Scoping Method	Geometric selection
Geometry	All Bodies

Table 17-scope of Maximum Shear Stress

7.3.2 RESULT

Maximum	1108.1 MPa
Minimum	0.0012008 MPa
Average	554.070 MPa

Table 18- Result of Maximum Shear Stress

7.4 MAXIMUM SHEAR ELASTIC STRAIN

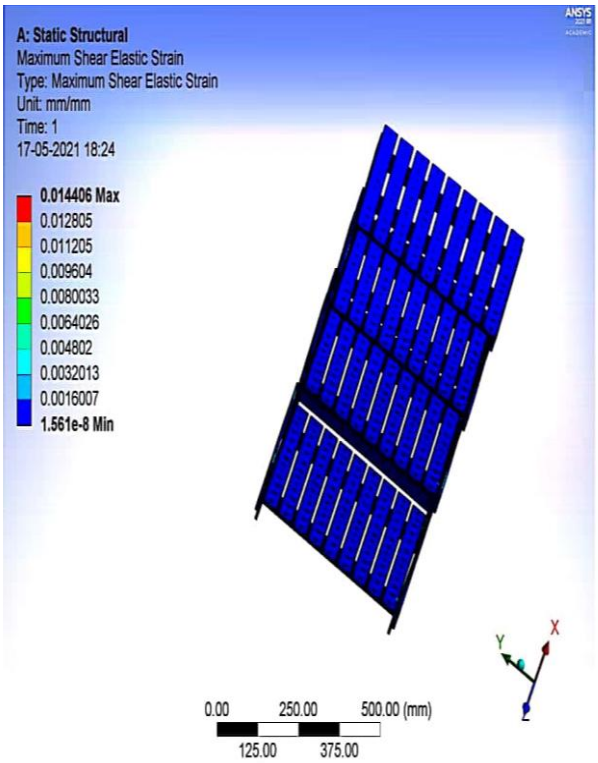

Fig 14- Maximum Shear Elastic Strain

Object Name	Maximum Shear Elastic Strain
State	solved

7.4.1 SCOPE

Scoping Method	Geometric selection
Geometry	All Bodies

Table 19- Scope of Maximum Shear Elastic Strain

7.4.2 RESULT

Maximum	0.014406mm
Minimum	1.561e-8mm
Average	0.02220mm

Table 20- Result of Maximum Shear Elastic Strain

8. CONCLUSIONS

After conducting tests put forth by the Indian standards, the results were satisfactory. We identified all the limitations and strengths of the material and shortlisted a wide range of applications for the material. Shoe racks, book shelves, ecofriendly carrying boxes, cutting boards, etc. are feasible uses of areca leaf ply. We also selected one of those applications which was a shoe rack and did the mechanical analysis on it. The result of this analysis was also satisfactory for the duty of the product.

By further developing and mass manufacturing of this product we can reduce deforestation by a considerable amount. Since manufacturing of areca ply is also more economic than plywood, it will be a good business opportunity. With this project we aimed at producing an alternative to plywood that does not require trees to be cut down since deforestation will lead to a chain reaction of unfavorable events such as decrease of oxygen content in the atmosphere, disasters, soil erosion, draught, etc. This material can replace plywood in a wide variety of applications.

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