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Investigation on The Physical and Mechanical Properties of Kanyin (*Dipterocarpus*) Plywood Making by Using Urea Formaldehyde and Phenol Formaldehyde Resins


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Abstract

Plywood is made of three or more thin layers of wood veneer bonded together with an adhesive. Each veneer of wood or ply is usually oriented with its grain running at angles to the adjacent layer to reduce the plywood's shrinkage and strength. Plywood was produced 3-ply and 5-ply by using veneers of *Dipterocarpus alatus* or *Diptercarpus turbinatus* with urea-formaldehyde resin and phenol formaldehyde resin manufactured as per Indian standards (IS 303), In this study, a comparative analysis of Sample Boards has been conducted on the moisture content and density (IS 1734 – Part I and II), water resistance (IS 1734 – Part IV), and the physical and mechanical properties of plywood according to (IS 1734).

Results of this study, the density of 3-plywood with phenol formaldehyde was higher than 3-plywood with urea formaldehyde. Therefore, the mechanical properties of 3-plywood with phenol formaldehyde are a bit higher than 3-plywood with urea formaldehyde. However, the density of 5-plywood with phenol formaldehyde was equal to 5-plywood with urea-formaldehyde, and the mechanical properties of 5-plywood with phenol formaldehyde are a bit higher than 5-plywood with urea formaldehyde. The water resistance of urea formaldehyde resin could not complete all three cycles at 60°C boiling water test for 6hrs MR grade plywood. In case of PF resin three cycle of 100°C boiling water for 8hrs successfully pass the desired requirement and does not delaminate. Hence, the utilization of particular plywood can be prioritized upon the requirement of specific strength as it will promote the concept of sustainability because judicious utilization of resources is also conservation.

This study opens up the scope for future studies. A combination of both species can be used to determine the strength properties.

Keywords: Plywood, Physical and Mechanical Properties, MOR, MOE, and IS

ကညင်သစ်ပါးလွှာများကိုဖီနောဖော်မယ်ဒီဟိုက်ကော်နှင့် ယူရီယားဖော်မယ်ဒီဟိုက်ကော် တို့ကို အသုံးပြု၍ အထပ်သားပြားများပြုလုပ်ခြင်းနှင့် ၎င်းအထပ်သားပြားတို့၏ ရုပနှင့် အင်အား ဂုဏ်သတ္တိများကို စမ်းသပ်လေ့လာခြင်း

စုမြင့်သန်း၊ လက်ထောက်သုတေသနအရာရှိ
သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်း

သစ်ပါးလွှာလေးများကို သုံးလွှာနှင့် သုံးလွှာထက်ပို၍ ကော်ဖြင့်အလွှာလိုက် ကပ်ဖိထားခြင်းဖြင့် အထပ်သားပြားပြုလုပ်ပါသည်။ အထပ်သားပြား၏ ကျုံ့မှုနည်းစေခြင်းနှင့် အင်အား ဂုဏ်သတ္တိတို့ကို မြင့်မားစေခြင်း အလို့ငှာ ၎င်းသစ်ပါးလွှာတစ်ခုနှင့် တစ်ခု ထပ်ရာတွင် သစ်ပါးလွှာ၌ပါရှိသော သစ်ကြောများကို ထောင့်မှန်အနေအထားဖြင့် ထပ်၍ ပြုလုပ်ရပါသည်။ ယခုစမ်းသပ်မှုတွင် ကညင်သစ်ပါးလွှာ(ဖြူ/နီ)တို့ကို ဖီနောဖော်မယ်ဒီဟိုက်ကော်နှင့် ယူရီယား ဖော်မယ်ဒီဟိုက်ကော်တို့ဖြင့် ကပ်၍ သုံးလွှာ အထပ်သားပြား နှင့် ငါးလွှာအထပ်သားပြားတို့ကို (IS 303)အရ ပြုလုပ်ထားပါသည်။ ရုပနှင့် အင်အား ဂုဏ်သတ္တိများကို စမ်းသပ်လေ့လာရာတွင် နမူနာအရွယ်အစားနှင့် စမ်းသပ်နည်းကို (IS 1734)အရ လည်းကောင်း ၊ အစိုဓါတ်နှင့် သိပ်သည်းဆတို့ကို (IS 1734 – Part I and II)အရ လည်းကောင်း၊ ရေစိမ့်ဝင်မှုကိုခုခံနိုင်ခြင်းကို (IS 1734 – Part IV)အရလည်းကောင်း ဆောင်ရွက်ခဲ့ပါသည်။ စမ်းသပ်လေ့လာမှုများအရ ဖီနောဖော်မယ်ဒီဟိုက်ကော်ဖြင့် ပြုလုပ်ထားသော သုံးထပ်သားပြား၏ သိပ်သည်းဆသည် ယူရီးယားဖော်မယ်ဒီဟိုက် ကော်ဖြင့် ပြုလုပ်ထားသော သုံးထပ်သားပြားထက် များနေကြောင်း တွေ့ရှိရပါသည်။ ထို့ကြောင့် ဖီနောဖော်မယ်ဒီဟိုက်ကော်ဖြင့် ပြုလုပ်ထားသော သုံးထပ်သားပြား၏ အင်အား ဂုဏ်သတ္တိသည် ယူရီးယားဖော်မယ်ဒီဟိုက်ကော်ဖြင့် ပြုလုပ်ထားသော သုံးထပ်သားပြားထက် များနေကြောင်း တွေ့ရှိရပါသည်။ ငါးထပ်သားပြားတွင် သိပ်သည်းဆ တူညီနေသော်လည်း ဖီနောဖော်မယ်ဒီဟိုက်ကော်ဖြင့် ပြုလုပ်ထားသော ငါးထပ်သားပြား၏ အင်အားဂုဏ်သတ္တိသည် ယူရီးယားဖော်မယ်ဒီဟိုက်ကော်ဖြင့် ပြုလုပ်ထားသော ငါးထပ်သား ပြားထက် အနည်းငယ် များနေကြောင်း တွေ့ရှိရပါသည်။ ဖီနောဖော်မယ်ဒီဟိုက်ကော်ဖြင့် ပြုလုပ်ထားသော အထပ်သားပြားများသည် ရေစိမ့်ဝင်မှုကို ခုခံနိုင်ခြင်းစမ်းသပ်မှုတွင် အောင်မြင်မှု ရှိပါသည်။ သို့သော် ယူရီးယားဖော်မယ်ဒီဟိုက်ကော်ဖြင့် ပြုလုပ်ထားသော အထပ်သားပြားများသည် ရေစိမ့်ဝင်မှုကိုခုခံနိုင်ခြင်း စမ်းသပ်မှုတွင် အောင်မြင်မှု မရှိပါ။ ထိုသို့ လေ့လာ ဖော်ထုတ်ခြင်းအားဖြင့် တိကျသော သီးခြားလက္ခဏာများနှင့် ဂုဏ်သတ္တိများအရ လိုအပ်ချက်ပေါ်မူတည်၍ အထပ်သားပြား၏ အသုံးချခြင်းကို ဦးစားပေး ဆောင်ရွက်နိုင်ပါ သည်။

Investigation of the Physical and Mechanical Properties of Kanyin (*Dipterocarpus alatus* or *D. turbinatus*) Plywood Making by Using Urea Formaldehyde and Phenol-Formaldehyde Resins

1. Introduction

Plywood is a material (wood) manufactured from thin layers or "plies" of wood veneer that are glued together with adjacent layers having their wood grain rotated up to 90 degrees to one another. There are two types of plywood: softwood plywood and hardwood plywood. Softwoods generally correspond to coniferous species. The most commonly used softwoods for manufacturing plywood are firs and pines. Hardwoods generally correspond to deciduous species. For hardwood plywood, commonly used wood species include *Dipterocarpus alatus* (Density 2.39g/cm^3), *Dipterocarpus tubinatus* (Density 2.1239g/cm^3) and Teak in Myanmar.

In Hardwood plywood the outer layers (face and back) surround a core which is usually laminated lumber, veneer, particleboard, or medium density fiberboard. The plywood thickness you choose depends on the needs of the project. Different types of plywood are available in a dizzying array of sizes. Very thin plywood is appropriate as an underlayment between subflooring and tile. However, thicker plywood is needed for the actual subfloor, or for structural sheathing fastened to the framing members on a new shed. Building codes should be followed.

Phenol formaldehyde and Urea Formaldehyde were used as the adhesives. A phenol-formaldehyde (PF) resin was used as wood adhesive for plywood. It is especially desirable for exterior plywood, owing to their good moisture resistance. Urea Formaldehyde (UF) is widely used glue for plywood, particleboard, wood panels and bent laminations. Importantly it is not an expensive adhesive hence, cost-effective. Keeping environmental prospect, formaldehyde emission is a major problem that a lot of researchers have reported.

Nowadays, most manufacturing of veneers industries have produced 60% to 80% veneers. Therefore, they faced waste veneers from 20% to 40%.

Therefore we will forward the future research which will reduce the formaldehyde emission and will promote the value added products of plywood from the waste veneers.

2. Objectives

We studied to get the destinations as follows;

(i) To identify the value added plywood from the waste veneers use as core layer and

(ii) To compare the physical and mechanical properties of the manufacturing plywood by using phenol formaldehyde and urea formaldehyde Resins

3. Materials and Methods

3.1 Materials

We used veneers of Dipterocarpus species of face (Density 0.4g/cm^3) with a thickness 0.2 mm and core **(**Density 0.4g/cm^3) with a thickness 2mm from the Co, Ltd.,. The wood veneers were cut in the dimensions of 0.45 mm× 0.45mm.

The thickness of the final plywood product will be depending on the thickness of individual veneer used while manufacturing.

(b) Phenol formaldehyde

The adhesives used were composed of Phenol formaldehyde (specific gravity 1.14; pH 9; solid content 5.2%. PF resin was prepared in composite wood laboratory as per Indian Standards (IS 1508).

(c) Urea formaldehyde

The Adhesive of Urea formaldehyde was specific gravity 0.9; pH 8; solid content 4.7% for plywood manufacturing. UF resin was prepared in composite wood laboratory using resin preparing assembly following Indian Standards (IS 1508).

3.2 Methods

3.2.1 Process of plywood making:

After procuring raw material from different sources, plywood was manufactured as per Indian standards (IS 303). Detailed process has been described below:

1. Dipterocarpus species veneers were dried for different time period depending upon the thickness of the veneers (Fig7). Higher moisture content affects the gluing procedure and ultimate strength of the final plywood product. Therefore, veneers were air dried and moisture content was brought up to the optimum range (12%).

2. Determination of the moisture content of Dipterocarpus veneers was done after regular time interval using oven dry weight method (Fig8).

3. Preparation of the adhesives was done as described above and immediately used after its preparation (Fig9).

4. Resin was applied on both sides of the core and cross bands i.e. Number two sheets in case of three ply-boards, two and four in five ply-boards. Resin was speeded using resin brushes with hands (Fig10).

5. The Resin veneers of PF were air dried for one hour (Fig11).

6. Sheets were assembled orthogonally or in cross-graining direction (Fig12). (Note: boards comprising an even number of plies, the direction of grain of the veneer in adjacent plies shall be at right angles to each other, in all cases, the grain on both faces of the assembly boards shall run in the same direction.)

7. After this, assembled veneers were hot pressed as per the following plan (Fig.13):

   (a) The temperature at hot press was kept100-120℃ for UF resin and 140-150℃ for PF resin

   (b) Pressing time was kept 10 minutes for 3 ply-board and 12 minutes for 5ply-board

   (c) Optimum pressure was used depending upon the area of the plywood. Optimum pressure was calculated using the following formula:

   Formula= (width × length/ 15.4) ×200

   ***Note:** 15.4 is the area of one piston.

8. Final step of the plywood manufacturing was finishing, which includes trimming and sanding followed by marking of the samples Markings of the manufactured plywood were done in following way:

Table1. Combinations of Dipterocarpus ply

No.	Species	Resin	No. of Veneers	Replications
1.	Dipterocarpus spp	PF	3 ply	4
2.	Dipterocarpus spp	PF	5 ply	4
3.	Dipterocarpus spp	UF	3 ply	4
4.	Dipterocarpus spp	UF	5 ply	4

3.2.2 Plywood Testing:

For comparison of the plywood testing was necessary. After completing the manufacturing process, plywood boards were couriered to conduct the tests. (Fig14)

Following tests were conducted at Forest Research Institute:

(i) Physical Testing

a) Determination of density and moisture content.

b) Determination of water resistance.

c) Test of Adhesion of plies.

3.2.2.1 Physical testing of manufactured plywood

Samples were prepared for physical testing accordingly with IS: 1734 (1983) as shown in Fig 15 and 16.

a) Determination of density and moisture content

Objective

The determination of moisture content is necessary since it has a bearing on several important mechanical properties of plywood.

Test Specimen

Each test specimen was of the full thickness of the material and 75 mm wide and 150 mm long. Smaller specimens may be used when deemed necessary. The dimensions of the test specimens were measured to an accuracy of not less than ± 0.3 percent.

Apparatus: Oven and balance were required for the test is given in Fig 16.

Procedure

The test specimen was weighed. The specimen was then dried in an oven at a temperature of 103 ± 2°C until approximately constant mass was obtained. The specimen was weighed to an accuracy of not less than ± 0.2 percent according to IS: 1734 (Part 1) - 1983

Calculation

The density was calculated as follows:

Density, in g/cm3 = Mo/LWt
Where
Mo = oven dry mass of specimen in g,
L = length of the specimen in cm,
w = width of the specimen in cm, and
t = thickness of the specimen in cm.
The moisture content was calculated as follows:
Moisture content, percent = (M1- Mo / Mo) × 100

Where
M1 = initial mass of specimen, and
Mo = oven-dry mass of specimen.

b) Determination of water resistance

Objective

This test is intended to determine the acceptability of plywood panel glued by Phenol Formaldehyde in exterior conditions subjected to alternate drying and wetting or high humidity.

Test Specimen

From each board at least 4 test specimens each approximately 250 mm × 250 mm were cut from different positions in the board such that the grain of the face veneer was parallel to the length of the piece.

Apparatus

Water bath and thermometer are required to be used in test is given in Fig17 and 18.

Procedure

I). Boiling Water Immersion Test

The specimens were kept submerged in a boiling water bath at 95°±5°C for 8 hours as per IS: 1734 (Part 6) - 1983). Then the test specimen were removed and cooled at room temperature for 16 hours. This process was repeated three times in total.

II). Moisture Resistance Test

The specimens were kept immersed in warm water at 60 ± 2°C for a period of 3 hours. These test pieces were removed from the water and cooled down to room temperature by plunging them in cold water. These wet pieces while still in wet condition were tested for ‘glue shear strength’ and ‘adhesion of plies’ according to methods laid down in IS: 1734 (Part 4)-1983* and IS: 1734 (Part 5)-1983† respectively.

c) Test for adhesion of plies

Objective

This test is intended to estimate the tenacity with which the bonding material holds the adjacent plies together.

Test Specimen

The test specimens were of the full thickness of the material and at least 250 × 250 mm. The specimens were preconditioned to a constant mass at a relative humidity of 65 ± 5 percent and at temperature of 27 ± 2°C.

Apparatus

1. The type of knife required to be used in the test. It may be made from a file. The cutting edge should be kept chisel sharp.

2. The test was carried out on a stout table to which is screwed a wooden batten against which the edge of the test piece.

Procedure

The knife was inserted with its cutting edge parallel to the grain of the outer veneer and worked into, or if possible, along glue line and the veneer is prized upward. A hard and dense species of plywood requires considerable force to affect entry and to prize the veneer. In a soft timber, the knife tends to follow an easy course through the wood in this case it is essential that the knife be firmly guided along the glue line. (According to IS: 1734 (Part 5) – 1983)

Examples of cases when the bond just passes the requirements as indicated and this is judged by the relative amounts of wood fiber left on the core veneer, and the area prized off. The grading is assessed chiefly on the appearance of the break, but it was a concomitant requirement that force was needed to effect separation.

The bond is excellent, when it was difficult to find the glue line and impossible to keep the tool within it for more than 3 to 6 mm without cutting into adjacent wood. On prizing upwards, the veneer usually breaks off over a width only slightly greater than that of the tool.

The bond is poor, when the knife met little opposition in the glue line and the prize results in the easy removal of almost all the veneers from one side of the test piece. The separated veneers are usually almost free from adherent fiber.

3.2.2.2 Mechanical Testing

a) Determination of static bending strength of manufactured plywood:

Mechanical testing of samples is necessary to find out the strength properties of plywood (Fig 20 and Fig 21). In this study, Static bending testing procedure was used following Indian Standards (According to IS: 1734 (Part 11) – 1983).

Procedure:

The span was kept 48 times the nominal depth when the grain direction of the face plies of the test specimen is parallel to the span and 24 times the nominal depth when the grain direction of the face plies is perpendicular to the span.

The load was applied through an appropriate loading block for centre loading with a continuous motion of the movable head throughout the test till a failure is indicated. The rate of application of load shall be such that the unit rate of fibre strain is equal to 0.001 5 cm/cm of outer fibre length per minute within a permissible variation of ± 25 percent. The rate of motion of moving head may be calculated as follows:

$$N = zL^2 / 6d$$

Where

N = rate of motion of moving head in cm/min,
z = unit rate of fibre strain in cm/cm of outer fibre length per minute = 0.001 5,
L = span in cm, and
d = depth of beam in cm.

The moisture content of the specimen and the temperature at the time of test shall be recorded.

Modulus of elasticity and modulus of rupture was calculated using following formulae (N/mm^2):

$$MOE = PL^3 / 4bh^3 \Delta$$

$$MOR = M3\,P'L / 2\,bh^2$$

Where,

P = load in N at proportional limit;
L = span in mm;
b = width of the specimen in mm;
h = thickness of the specimen in mm;
P' = maximum load in N;
Δ = deflection at proportional limit in mm

4. Results and Discussion

Comparative analysis was done in order to know the physical and mechanical properties of plywood manufactured by two different Adhesives (Phenol Formaldehyde PF and Urea Formaldehyde UF). Here we compared these two adhesives in respect to their number of ply (veneers) that is 3ply and 5ply. The boards were prepared using pressure 150psi of 3 ply for 12minutes and 5 ply boards for 16 minutes respectively. The temperature were maintained in hot press 100-120°C for UF resin and 140-150°C for PF resin. All the boards were tested and physio-mechanical properties were compared as per IS 303 general purpose plywood. The prepared board was tested for different physical and mechanical properties and the results are presented in different subheads as given below:

4.1. Physical and mechanical properties of plywood using 3 Ply 5 Ply Dipterocarpus species with UF and PF resin (DUF3 and DPF3)

The prepared plywood was tested for physical properties such as density, moisture content, water resistance Moisture Resistance (MR Grade) for UF resin based board, Boiling Water Resistance (BWR Grade) for PF resin based board and Knife test and mechanical test such as Modulus of Elasticity (Along and across) and Modulus of Rupture (Along and across). Table 3 presents mean observations of these physical and mechanical properties of Plywood.

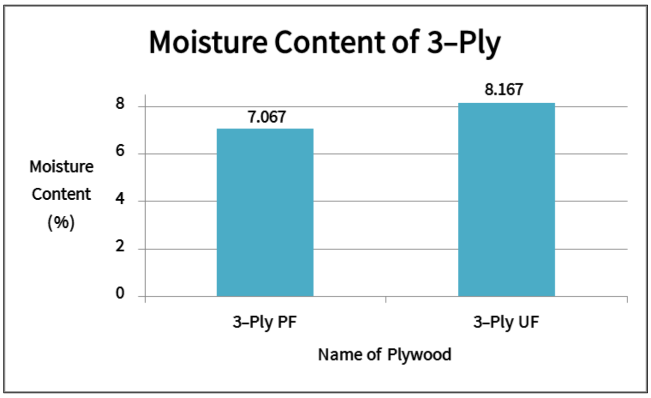

Figure 1. Mean Moisture Content of 3 Ply Dipterocarpus plywood

Higher moisture content affects the gluing strength of the final plywood product. Mean moisture content was found to be DPF5 (7.067%) lower than DUF5 (8.167%).

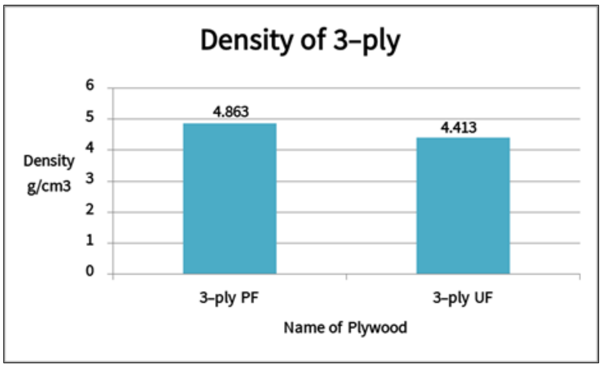

Figure 2. Mean Density of 3 Ply Dipterocarpus plywood

Density was observed more in PF plywood as compare to UF plywood. There are not too much different.

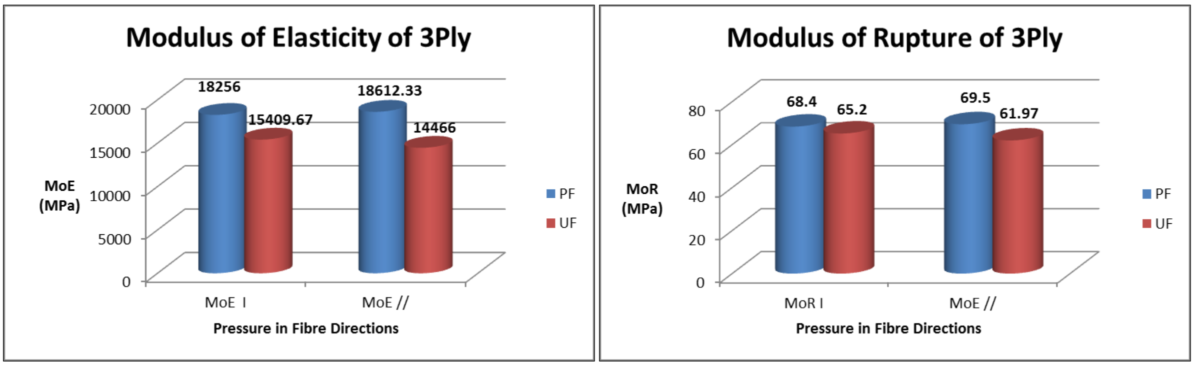

Figure 3. Mean Physio- Properties of MoE and MoR in 3 Ply PF and 3Ply UF

MOE and MOR were found DPF3 higher than DUF3 in both along as well as across the direction. Water resistance, BWR for PF based board passed but MR grade for UF based board could not passed in all the three cycle of the test. Knife test also gave best result in DPF3 boards to meet the IS. Table 2 to 5 present the ANOVA for Physio-Properties of 3 ply PF and UF resins.

Table 2. ANOVA for Moisture of 3 ply PF and 3 ply UF resins

ANOVA					
Moisture 3					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	1.815	1	1.815	9.151	.039
Within Groups	.793	4	.198		
Total	2.608	5			

3 ply in moisture of PF and UF are not sig.

Table 3. ANOVA for Density of 3 ply PF and 3 ply UF resins

ANOVA					
3 Density					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	.304	1	.304	4.956	.090
Within Groups	.245	4	.061		
Total	.549	5			

3 plywood densities in PF and UF are not sig.

Table 4. ANOVA for MoR (Along & Across) of 3 ply PF and 3 ply UF resins

Tests of Between-Subjects Effects					
Dependent Variable: Rupture					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	99.816[a]	3	33.272	2.642	.121
Intercept	53080.301	1	53080.301	4215.510	.000
ply	71.541	1	71.541	5.682	.044
MoR	7.208	1	7.208	.572	.471
ply* MoR	21.068	1	21.068	1.673	.232
Error	100.733	8	12.592		
Total	53280.850	12			
Corrected Total	200.549	11			
R Squared = .498 (Adjusted R Squared = .309)					

Table 5. ANOVA for MoE (Along & Across) of 3 ply PF and 3 ply UF resins

Tests of Between-Subjects Effects					
Dependent Variable: yield					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	38199260.667[a]	3	12733086.889	1.714	.241
Intercept	3341071152.000	1	3341071152.000	449.725	.000
ply	36673040.333	1	36673040.333	4.936	.057
moe	258720.333	1	258720.333	.035	.857
ply* moe	1267500.000	1	1267500.000	.171	.690
Error	59433197.333	8	7429149.667		
Total	3438703610.000	12			
Corrected Total	97632458.000	11			
a. R Squared = .391 (Adjusted R Squared = .163)					

Both 3 ply PF and 3Ply UF are no sig in elasticity and rupture.

The results of both 3 ply PF and 3Ply UF were not be different in MOR and MOE. It means that their strength would be the same.

4.2. Physical and mechanical properties of plywood using 5 Ply Dipterocarpus species with UF and PF resins (DUF5 and DPF5)

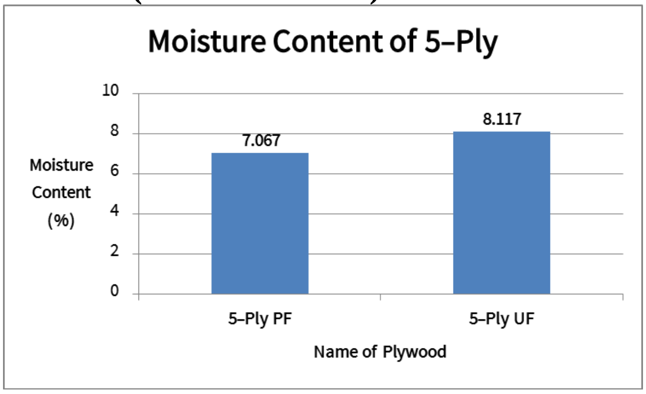

Figure 4. Mean Moisture Content of 5 Ply Dipterocarpus plywood

Mean moisture content was found to be DPF5 (7.067%) lower than DUF5 (8.117%).

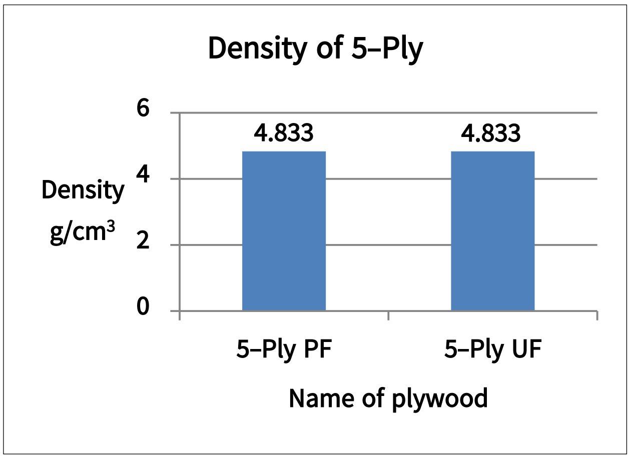

Figure 5. Mean Density of 5 Ply Dipterocarpus plywood

Density was observed in DUF5same as DPF5.

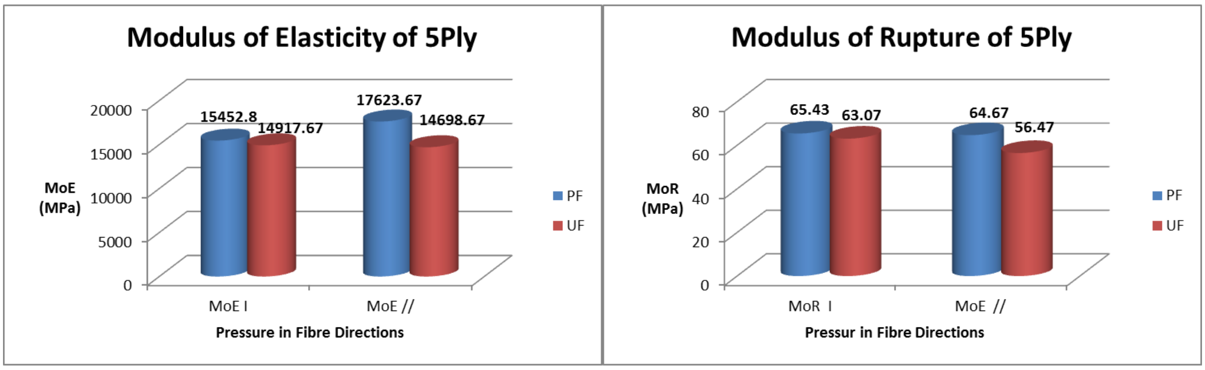

Figure 6. Mean Physio- Properties of MoE and MoR in 5Ply PF and 5Ply UF

The lower MOR and MOE observed in DUF3. Water resistance, BWR for PF based board passed but MR grade for UF based board could not passed in all the three cycle of the test. Knife test also gave best result in DPF3 boards to meet the IS.

Table 6. ANOVA for Moisture of 5 ply PF and 5 ply UF resins

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.654	1	1.654	7.126	.056
Within Groups	.928	4	.232		
Total	2.582	5			

5 ply in moisture in PF and Uf are not sig.

Table 7. ANOVA for Density of 5 ply PF and 5 ply UF resins

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.001	1	.001	.022	.890
Within Groups	.251	4	.063		
Total	.252	5			

5ply wood density in PF and UF are not sig

Table 8. ANOVA for MoE (Along & Across) of 5ply PF and 5ply UF resins

Tests of Between-Subjects Effects					
Dependent Variable: yield					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	16120326.640[a]	3	5373442.213	.685	.586
Intercept	2947790378.880	1	2947790378.880	375.685	.000
pf	8979392.013	1	8979392.013	1.144	.316
moe	2857337.613	1	2857337.613	.364	.563
pf* moe	4283597.013	1	4283597.013	.546	.481
Error	62771465.040	8	7846433.130		
Total	3026682170.560	12			
Corrected Total	78891791.680	11			

a. R Squared = .204 (Adjusted R Squared = -.094)

Table 9. ANOVA for MoR (Along & Across) of 5 ply PF and 5 ply UF resins

Tests of Between-Subjects Effects					
Dependent Variable:					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	149.962[a]	3	49.987	1.232	.360
Intercept	46737.601	1	46737.601	1152.355	.000
ply	83.741	1	83.741	2.065	.189
moe	40.701	1	40.701	1.004	.346
ply * moe	25.521	1	25.521	.629	.451
Error	324.467	8	40.558		
Total	47212.030	12			
Corrected Total	474.429	11			
a. R Squared = .316 (Adjusted R Squared = .060)					

Both 5 ply PF and 5Ply UF are no sig in elasticity and rupture.

The observation of the study as follows table:

Species		**Density (Dry) (kg/m^3)**	**MoR (MPa)**	**MoE (MPa)**
Hard wood	Dipterocarpus spp.	440-486	56-65	14000-19000
	Birch	580-620	54-60	13000-15000
	Beech	640-680	52-56	10000-16000
	Oak	650-720	53-65	10000-13000

The Dipterocarpus plywood is lower density and higher MoR and MoE than the other hardwoods.

And we analyzed the variances of strength between PF plywood and UF plywood of Dipterocarpus by the ANOVA one way method. In this study, we explore that the strengths of PF plywood and UF plywood were not be different.

In case, BWR for PF based board passed but MR grade for UF based board could not passed in all the three cycle of the test. Knife test also gave best result in DPF3 boards to meet the IS. Therefore UF based board can be used in interior products only and PF based board can be used in both indoor and outdoor products.

5. Conclusion

Following inferences are drawn on the basis of comparative study on physical and mechanical properties of plywood manufactured from dipterocarpus veneers by using phenol formaldehyde and urea formaldehyde:

All the physical and mechanical properties of the plywood of 3 ply and 5 ply meet the minimum criteria of IS 303 for plywood for general purposes.

The resin of PF based plywood demonstrated good results and completed the Indian Standard. But UF plywood could not give good results.

The density of PF plywood and UF plywood were the same because there were the same species.

It is interesting to note that while the same of density in 5-Plywod, the MOR and MOE across value and along value of 5Ply PF is increasing as compare to 5Ply UF.

In case of PF resin three cycle of 100°C boiling water for 8hrs successfully pass the desired requirement and does not delaminate. The water resistance of UF resin does not compete all the three cycle successful in 60°C boiling water test for 6hrs MR grade plywood.

Knife test to know the adhesion quality also give the excellent results in PF application.

The Dipterocarpus plywood is lower density and higher MoR and MoE than the other hardwoods. Therefore, Compression of wood fibre leads to increase in overall density of the product. Comparative higher MoE and MoR of the other hardwood veneers gave them an extra edge over the other hardwood veneers. After hot pressing, there was subsequent increase in MoE and MoR, which has significant effect on overall strength properties of the plywood product. As a result, most of the combinations Diptetrocarpus plywood outraced plywood of the other hardwood.

Results of this study have shown that utilization of particular plywood can be prioritized based on requirement of specific properties as it will promote the concept of sustainability because judicious utilization of resources is also conservation.

This study opens up scope for future studies. Combination of other softwood species can be used to determine the overall strength properties. Dipterocarpus is natural grown hardwoods, therefore, to reduce excessive pressure on natural forest resources.

Keeping environmental prospect, formaldehyde emission is a major problem that a lot of researchers have reported. Therefore, replacing formaldehyde based chemicals (adhesives) or keeping the concentration up to a tolerable limit will be a challenging task in future.

6. Acknowledgement

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8. Appendix

Fig 7. Measurement of Veneer Thickness

Fig 8. Determination of Moisture Content of Veneer Thickness

Fig 9. Preparation of PF resin

Preparation of UF resin

Fig 10. Resin application

Fig 11. Drying of applied veneer

Fig 12. Assembling sheets

Fig 13. Sample Board produced by hot -press

Fig 14. Sample Board

Fig 15. Sample Boards for MC and Density

Fig 16. Sample Boards for MC by Oven Dry

Fig 17. BWR testing of PF samples

Fig 18. MR testing of UF bonded plywood

Fig 19. Solid Content tests for Two Resins

Fig 20. Samples for Mechanical

Fig 21. Mechanical testing by Shimazu Machine

Mean	Water Resistance	Knife test
3Ply PF	Pass (BWRR)	Pass
3Ply UF	Fail (MR)	Fail
5Ply PF	Pass (BWR)	Pass
5Ply UF	Fail (MR)	Fail