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Utilization of Non -oven Jute felt - A natural Fiber as a Substitution of Wood Veneer for Manufacture of Plywood

S. C. Sahoo, Amitava Sil, P. K. Khatua, C. N. Pandey

***Abstract:** In this study the suitability of using core veneer made from renewable natural fiber i.e. Non-oven jute felt, which is the second most widely used natural fiber for manufacturing of plywood was investigated to minimize the gap between demand and supply of wood veneer. The renewable natural hard jute fibre was impregnated with phenolic resin and was used for the manufacture of plywood. Plywood of 4 mm, 6 mm, 12 mm and 18 mm thick were manufactured by using phenolic resin impregnated jute felt having thickness 16mm of 1850 GSM (approx.) as a core in place of the natural wood veneer. From the study, it can be inferred that PF Resin impregnated Non oven jute felt as a natural fibre can suitably replace the wooden glue core veneer to manufacture ply board up to 80% as an alternative substitute of wood. The physico-mechanical properties such as surface roughness, moisture content, density, water absorption, swelling, compressive strength, tensile strength, static bending strength, glue shear strength, of the plywood manufactured by using jute felt as core veneer with different resin dilution have been studied. Data revels that most of the physico-mechanical properties of the plywood showed satisfactory results meeting the requirement of different grades of plywood tested as per IS: 1734 - 1983. The accelerated study of the glued core after impregnation with jute felt have been carried out for three months before plywood manufacture after storing it in proper temperature and humidity. The data revealed that there is no appreciable change in bond quality and mechanical properties of the plyboard manufactured after storing the veneer up to 30 days. The study concluded that wood substituted jute composites could be an ideal solution with ever depleting forest reserves where utilization of renewable resources will be beneficiary for plywood industries to meet the challenges during scarcity of veneer by reducing the cost of imported veneer.*

Index Terms: ***Indigenous technology Non-oven jute felt, physico-mechanical properties, wood substituted.***

I. INTRODUCTION

Plywood is a universal material in the field of construction and is progressively being used in building and furniture industries along with particle board and block board. It is widely being used in making cabinets, decorative wall paneling and partition walls. The more efficient synthetic resin adhesive had led to the development of weather resistant plywood which are extensively used for exterior applications viz. building construction, concrete shuttering. It is also having an extensive application in construction of railway carriage, bus bodies and ships. Moreover, plywood has a tremendous export potential with continuously being exported to countries like Japan, Middle East, West Asia. There is a greater awareness of the need for materials in an expanding global population and increasing affluence. There are vast supplies of agricultural fiber residues in North America. Bagasse, jute, straws, and sisal appear to hold the most promise for continued development as stated by Maloney [1].

In general, lignocellulosic non-wood fibers are relatively less expensive in alternative to higher quality wood fibers. Composites manufactured by using bagasse are an option for utilization in areas where this material is abundant. Due to large production of sugarcane and other agronomic crops. Louisiana is an ideal place in U.S. for development of agro-based composites. Bagasse is a fibrous by-product from sugar cane processing and has been used to produce hardboard (HB) and insulation board as recommended by Sefain [2]. Composites made from agro-fibers are typically inferior in quality than those made from wood fibers. De-pitying, surface modification, and thermal/chemical treatments have provided comparable mechanical and physical properties for medium density fiberboard (MDF) made from aspen fiber described by Mobarak [3]. Adhesive has an important influence on mechanical and physical properties of agro-based composites. Pizzi [4] suggested that UF (urea-formaldehyde) and PF (phenol-formaldehyde) modified with (20-30)% of pMDI (4,4'-diphenyl methane di-isocyanate) has provided substantially improved physico-mechanical properties of agro-based composites compared to single use of UF or PF application to agro-based composites.

Bamboo (*Bambusoideae* sp.) was introduced in the agro based composite field in the early 19th century. Due to its rapid growth, high bending stiffness and dimensional stability, it has huge potential to use it as raw material for composite panel production.

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Many studies have evaluated the properties of bamboo based composites such as oriented strand board by Lee [5], medium density fiberboard by Yusoff [6], bamboo fiber reinforced cement boards by Sulastiningsih [7] and bamboo fiber/thermoplastic composites by Jindal [8]. From the research work done by Mobarak [3], it may be accepted that longer fibers obtain an increased network system by themselves and result in increased bending properties of composites. Processing variables i.e. plate clearance, plate size, and material moisture greatly influence on fiber sizes. Fiber sizes correlate to total surface area, which affects resin efficiency.

For particles, a smaller percentage of fine fractions lowered the strength properties of composites as stated by Hill [9]. The strength loss was due to the relatively larger surface area (up to 88% increased surface area) of the fine materials. However, most studies have not focused on the property enhancement of a multi-fiber layer system for agro-based MDF. Indian plywood Industries Research & Training institute has also done a lot of work on impregnated jute for making of composite along with wood veneer as done by Naha [10].

II. EXPERIMENTAL METHOD

A. Materials

1) Phenol (C_6H_5OH) - 99%
2) Formalin (HCHO) having Formaldehyde content 37%.
3) Sodium Hydroxide (NaOH) of Commercial Grade
4) Non Oven Jute Felt of thickness 12mm and16mm GSM - 1650 -1850 (Jute felt collected from local market in roll form having different width up to 2m. The required size has been used for the study).

B. Synthesis of PF Resin (Resol Type)

70 Kg. of Phenol was charged into resin kettle followed by 126 Kg of formalin and stirred. 5.6 kg NaOH was dissolved in 11.2 Kg water and cooled up to room temperature before adding into resin kettle. NaOH solution was added slowly and rise in temperature was observed. Heating started up to 55^{0}C by steam, then steam was cut off the and cooled by passing cooled water in the jacket. In spite of cooling, the temperature went up to 90 ±2^{0}C. When the temperature stabilized, water was removed from the jacket and the temperature was maintained at 90 ±2^{0}C. The reaction was continued till the flow time when measured in B_4 Cup of IS: 3994 comes to (15-16) sec in hot condition and water tolerance up to 1:1.6. The reaction mixture was cooled and the batch was then discharged. The resin was characterized by checking the parameters like pH, flow time, solid content as given in table I (A) and table I (B). The prepared resin was diluted with water in the ratio 1.0 to 2.0 on W/V Basis.

C. Dilution of Resin

The above resin having around 50 percentage solid content was diluted with water in the ratio 1:0 to 1:2:0 v/v basis.

D. Impregnation of Resin

(i) Non-Oven jute felt having 16mm thickness and 1850 GSM (aprox.) was cut according to the size 1ft x 1ft.

(ii) The weighed jute felt was soaked in different dilution PF liquid resin for (2-3) minutes for fully absorption of resin in a tray.

(iii) Then it was squeezed to remove excess resin two times by glue spreader.

(iv) The resin consumption on liquid and dry basis has been calculated as per formula given below and the data are given in table II (A) and table II(B).

$$\text{Resin consumption (Liquid)} = \frac{B - A}{C}$$

$$\text{Resin consumption (Solid)} = \frac{(B - A) * \text{Solid Content}}{C * 100}$$

Where,

A= Weight of jute felt
B = Weight of Jute Felt and Resin
C = Total resin dilution

E. Manufacture of Plywood

(i) The squeezed impregnated jute felt was kept overnight in open air for drying and subsequently sun dried for (3-4) hrs to bring down the moisture content up to (8-10) % .

(ii) Core and Face Veneer was cut according to the size of jute felt and dried up to moisture content (6 -8) %.

(iii) Individual jute felt has been compressed in cold press at pressure 12Kg.cm^2 for 10 minutes to minimize the thickness.

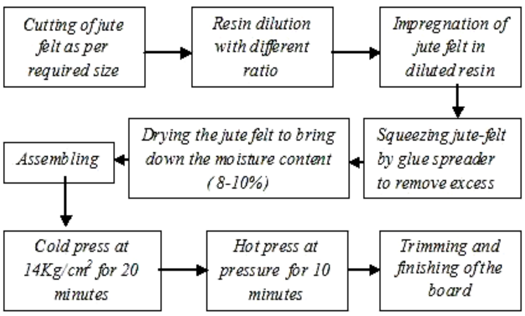
(iv) Assembling of jute felt, core veneer and face veneer was done as per opposite grain direction of wood veneer as required.

(v) Plywood having various thicknesses was prepared by adopting the pressure condition. The detail of plywood construction is given in table X.
Temperature = (140-145) ^{0}C
Pressure = 14 Kg/cm^2.
Time Period = As per desired thickness.

(vi) Ply board after trimmed, sanded and finished were taken for study of Physico -mechanical properties.

F. Process Flow Chart

A processing flow chart of ply board manufactured by using jute felt as core veneer is shown below:



G. Testing

Different physico-mechanical properties of ply board incorporating non oven jute felt has been studied as per relevant Indian standards.

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The test for Static Bending Strength, Compressive Strength, Tensile Strength were carried in Digital Universal Testing Machine of 10 Ton capacity with two interchangeable load cell having capacity 1KN and 10 KN. Test parameters for Moisture Content, Density, Water Absorption and Cyclic Test were determined using Digimatic vernier caliper, Hot air oven, Boiling Water Bath. All the samples were pre-conditioned at 27 ± 2^0C and 65 ± 5% RH in a conditioning chamber before testing.

H. Static Bending Strength

Mechanical testing for evaluating static bending strength (central load) viz parameters like modulus of rupture and modulus of elasticity of each sample were carried out as per IS: 1734-1983 (Part -11).

I. Tensile strength

Tensile strength perpendicular and parallel to the grain were conducted in 10Ton UTM in tension mode and were calculated as per eq (4) as per IS : 1734-1983 (Part 9).

J. Compressive strength

Compressive strength was evaluated at elastic limit were conducted in 10Ton UTM in compression mode and were calculated as per eq (5) as per IS : 1734-1983 (Part 10).

K. Retention of resin media by Jute Felt

Jute felt was impregnated with different resin dilution for two minutes and retention of resin in 12 and 16 mm jute felt was calculated for different dilution.

L. Percentage compression of impregnated Jute Felt

Jute fiber felt taken after impregnation in media and drying was studied for its compression at different specific pressures and at fixed temperature of about 145°C.

M. Tensile strength of compressed impregnated Jute Felt

Jute fiber felt was studied for finding its tensile strength after impregnation and subsequent compression in hot press at different specific pressures and at fixed temperature of 145°C.

N. Accelerated stability study of Resin-jute reinforced composite veneer

The jute felt with resin (1:1.5 dilution) reinforced composite veneer has been kept at the temperature 27±2^0C and RH for 7, 15, 30, 45 and 60 days. Ply board has been prepared by using it as self adhesive core veneer. Bond quality and mechanical properties were then studied.

III. RESULTS AND DISCUSSION

Ply board of different thickness have been manufactured by using jute felt as core veneer to replace the wooden glue core whose data are depicted in table X**.** The quantum resin intake capacity by the jute felt has given in table II (A) and II(B) for both Lab scale and pilot scale study respectively. From the data it has been observed that the resin intake capacity by the jute felt decreases as the dilution ratio increases, however Mechanical properties like static bending strength, tensile strength etc value decreases. The comparison of thickness of jute felt and tensile strength has given in table III and table IV respectively. The mechanical properties of different composition are given in table V(a), V(B), V(C), VI(a), VI(B), VI(C) & VII. Comparative study of Physico-mechanical properties of plywood manufactured from jute felt and commercial plywood and accelerated study has depicted in table VIII and table IX respectively.

From the study, it can be inferred that PF Resin impregnated Non oven jute felt as a natural fiber can suitably replace the wooden glue core veneer to manufacture ply board up to 80% as an alternative substitute of wood to minimize the gap between demand and supply of wood veneer. From the table II (A), it is observed that 16 mm non woven jute felt having 1800 GSM (approx), the resin intake capacity of jute felt in 1:1.5 (resin to water dilution) is 60 gms (approx.) on solid basis, where as the intake capacity of resin of 6 mm thickness jute felt is 27 gm per sq ft. So it can be concluded that in spite of using three nos. of 6 mm jute felt, single 16 mm jute felt can be used to minimize the resin consumption and hence to minimize the density of ply board. From the table III, it is observed that impregnated jute felt was compressed to 75-80 % in thickness at specific pressure of (13-16) kg/cm^2 which can be taken during calculation for manufacture of different thickness of ply board. Tensile strength of the impregnated jute felt as given table IV having different pressure shows encouraging results. From the mechanical properties of the jute felt composite ply board, it shows that static bending strength and tensile strength results are far apprehensive compared to those prepared from 100% wood and veneer. Ply board prepared by compressing with impregnated jute felt having dilution ratio 1:2.0 yielded very low mechanical properties. Improvement in mechanical properties was observed when combination of jute felt used as a core veneer for maximum replacement. No appreciable change was however noticed in glue shear strength. From table VIII, it has been observed that there is no change in water absorption and density in compared to commercial plywood**.**

Different dilution of resin with water has been studied to make it economically cheaper and getting low condensed resin having suitable drainage of resin through the jute felt. The adhesion and mechanical properties were changed according to resin dilution. The order is as follows: 1:0 > 1:1 > 1: 1.5 > 1: 2. From figure 3(a), 3(b), 4(a), 4 (b), higher values of static bending strength and tensile strength were obtained in the range (60-80) N/mm^2 and (40-42) N/mm^2 respectively.

From the accelerated study of jute resin composite veneer, it has been observed that there is no appreciable change in bond quality and mechanical properties of the ply board manufactured after storing the veneer up to 30 days i.e. the self adhesiveness property remains unaltered. Ply board manufactured by using self adhesive core veneer were tested as per IS:303-2003 and results conforms as per BWR grade as depicted in table IX.

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IV. CONCLUSION

It may be concluded that the wood substituted non oven jute felt composite from manufacture of plywood would be an ideal solution with ever depleting forest services. Utilization of renewable resources will beneficial for plywood industries to meet the challenge during the scarcity of wood veneers and reduce the landed cost of imported wood material. In this study, more than 80 % of the wood materials used in making plywood are taken as natural fiber as an alternative substitute of wood to minimize the gap between demand and supply. From the economic point of view though it is equal or little more costlier than the existing conventional plywood, it exhibits better mechanical properties and wood replacement up to maximum level to minimize the gap between demand and supply. Finally from the study it is recommended to use 1:1.5 diluted resin with water to achieve better bond quality, mechanical properties keeping in view of economical aspects suitability for BWR Grade.

TABLE I (A)

PROPERTIES OF RESIN (LABORATORY SCALE)

Resin Formulation	Quantity	Properties of Resin
Phenol	100 gms	Flow time in B_4 cup as per IS :3499 is 28 sec
Formalin (37%)	180 gms	Water tolerance = 1:6
Sodium hydroxide	8 gms	Solid content = 49%
Water	16 ml	pH = 10.5

TABLE I (B)

PROPERTIES OF RESIN (PILOT SCALE)

Resin Formulation	Quantity	Properties of Resin
Phenol	70 Kg	Flow time in B_4 cup as per IS :3499 is 26 sec
Formalin (37%)	126 Kg	Water tolerance = 1:6
NaOH	5.6 Kg	Solid content = 49%
Water	11.2 Lts.	pH = 10.5

TABLE II (A)

RETENTION OF RESIN BY JUTE FELT OF SIZE 1FT X 1FT & 16MM THICKNESS FOR SOAKING TIME TWO MINUTES (LABORATORY SCALE)

Resin dilution	Int. wt of jute felt (gm)	Resin + wt of jute felt (gm)	Liquid resin (gm)	Solid resin (gm)
1:0	196.7	608.7	412.0	201.8
1:1	199.0	687.0	488.0	119.5
1:1.5	187.5	493.5	306.0	59.9
1:2.0	201.5	489.5	288.0	47.04

TABLE II (B)

RETENTION OF RESIN BY JUTE FELT OF SIZE 8FT X 4 FT & 12MM THICKNESS FOR SOAKING TIME TWO MINUTES (PILOT SCALE)

No of Jute Felt	Resin dilution	Int. wt of jute felt (gm)	Resin + wt of jute felt (gm)	Liquid resin (gm)	Solid resin /ft^2 (gm)
1	1:1.5	4485	13360	8875	54.3
2		5728	14951	9223	56.4
3		5024	14304	9280	56.8
4		4480	13394	8914	54.5

TABLE III

PERCENTAGE THICKNESS COMPRESSION OF IMPREGNATED JUTE FELT FOR 5 MINUTES AT PRESSURE 14KG/CM^2

Resin dilution	Initial thickness (mm)	Final thickness (mm)	Percentage of compression
1:0	16.08	12.60	78.35
1:1	16.12	12.71	78.84
1:1.5	16.06	12.86	80.07
1:2.0	16.22	13.01	80.20

TABLE IV
TENSILE STRENGTH OF SELF ADHESIVE CORE VENEER AT DIFFERENT RESIN DILUTION

Resin Dilution	Tensile strength (Kg/cm^2)
1:0	712.6
1:1	268.6
1:1.5	156.2
1:2.0	76.8

TABLE V (A)
PHYSICAL AND MECHANICAL PROPERTIES OF 6 MM THICK PLY BOARD

Resin Dilution	Moisture Content(%)	Density (kg/mm^3)	Water Absorption (%)
1:1	6.2	1253	10.25
1:1.2	6.5	947	11.16
1:1.5	6.8	812	10.74
1:2.0	7.6	804	11.34

TABLE V (B)
PHYSICAL AND MECHANICAL PROPERTIES OF 6 MM THICK PLY BOARD

Resin Dilution	Modulus of Rupture (N/mm^2)	Modulus of Elasticity (N/mm^2)	Tensile Strength (N/mm^2)
	Along the Grain		
1:1	102.14	11302	44.30
1:1.2	86.91	11729	43.12
1:1.5	80.80	12004	40.80
1:2.0	73.15	9614	32.53

TABLE V (C)

PHYSICAL AND MECHANICAL PROPERTIES OF 6 MM THICK PLY BOARD

Resin Dilution	Modulus of Rupture (N/mm^2)	Modulus of Elasticity (N/mm^2)	Tensile Strength (N/mm^2)
	Across the Grain		
1:1	25.60	1308	31.26
1:1.2	21.25	1177	30.16
1:1.5	50.53	4699	29.66
1:2.0	43.83	6234	19.69

TABLE VI (A)
PHYSICAL AND MECHANICAL PROPERTIES OF 12 MM THICK PLY BOARD

Resin Dilution	Moisture Content (%)	Density (kg/mm^3)	Water Absorption (%)
1:1	6.17	1241	10.2
1:1.2	6.45	938	11.1
1:1.5	6.81	807	10.7
1:2.0	7.63	804	11.3

TABLE VI (B)
PHYSICAL AND MECHANICAL PROPERTIES OF 12 MM THICK PLY BOARD

Resin Dilution	Modulus of Rupture (N/mm^2)	Modulus of Elasticity (N/mm^2)	Tensile Strength (N/mm^2)
	Along the Grain		
1:1	177.70	22220	47.88
1:1.2	94.81	14914	42.81
1:1.5	87.45	13720	40.87
1:2.0	47.05	3525	34.19

TABLE VI (C)

PHYSICAL AND MECHANICAL PROPERTIES OF 12 MM THICK PLY BOARD

Resin Dilution	Modulus of Rupture (N/mm^2)	Modulus of Elasticity (N/mm^2)	Tensile Strength (N/mm^2)
	Across the Grain		
1:1	47.05	3524	30.64
1:1.2	59.89	6163	29.53
1:1.5	37.28	3909	30.27
1:2.0	25.60	1308	21.49

TABLE VII

GLUE SHEAR STRENGTH OF 6 MM AND 12MM THICK PLY BOARD AT VARIOUS RESIN DILUTION

Resin dilution Ratio	Resistance to water after three cycle	Glue shear strength in Dry State (N)	
		6mm Ply	12mm Ply board
1:1	No delamination	1290	1350
1:1.2	No delamination	1120	1200
1:1.5	No delamination	1100	1150
1:2.0	Delaminated	820	850

TABLE VIII COMPARATIVE PHYSICO-MECHANICAL PROPERTIES OF VENEER JUTE COMPOSITE PLYWOOD WITH COMMERCIAL PLYWOOD

Test Parameter	Plywood	Jute veneer composite
Thickness (mm)	12.0	12.0
Density gm/cc	0.798	0.804
Water absoption (24 hrs)%)	12.0	14.0
MOR, N/mm^2	42.6	87.4
MOE N/mm^2	4500	13720
Tensile Strength (N/mm^2)	42.6	40.87
Glue shear Strength (Dry State), N	1300	1250
Thickness Swelling (%)	3.0	4.0
Compresive Strength (MPa)	25.0	18.20

TABLE IX PHYSICO-MECHANICAL PROPERTIES AFTER ACCELARATED STUDY (STORAGE PERIOD OF 30 DAYS)

Test Parameter	Jute veneer composite
Water absoption after 24 hrs, (%)	13.0
MOR, N/mm^2	72.05
MOE, N/mm^2	11005
Tensile Strength, N/mm^2	32.87
Glue shear Strength (Dry State), N	1100
Thickness swelling, %	3.5
Compresive strength, N/mm^2	15.20

TABLE X
DETAILS OF PLY BOARD CONSTRUCTION

Thickness (mm)	No of Ply	Veneer Assembly
6	4	Face veneer(0.5mm)/**1,4** - 2 nos Jute Felt (12mm)/**2,3** - 2 nos.
9	5	Face veneer(0.5mm)/**1,5** -2 nos Jute Felt (16mm)/**2,4** -2 nos. Core veneer (1.8mm)/**3** -1 no.
12	7	Face veneer(0.5mm)/**1,7** -2 nos Jute Felt (12mm)/**2,3,5,6** -4 nos. Core veneer (1.8mm)/**4** -1 no.
19	9	Face veneer(0.5mm)/**1,9** -2 nos Jute Felt (16mm)/**2,4,6,8** -4 nos. Core veneer (1.8mm)/**3,5,7**- 3 nos

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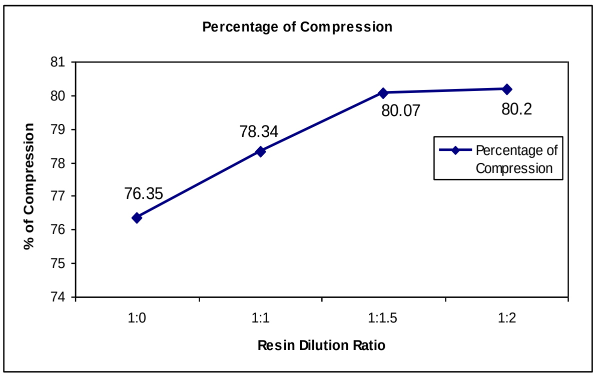

Fig 1(a) : Percentage of Compression of Self Adhesive Core Veneer at different resin dilution

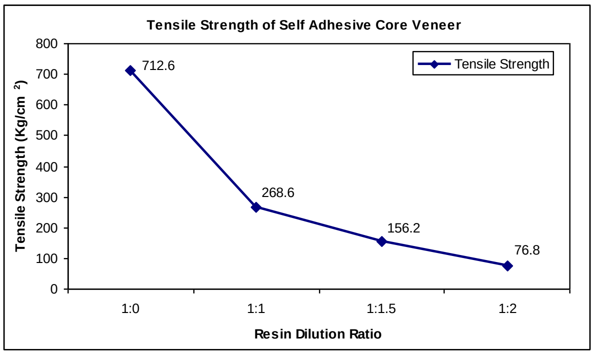

Fig 1 (b): Tensile Strength of Self Adhesive Core Veneer at different resin dilution

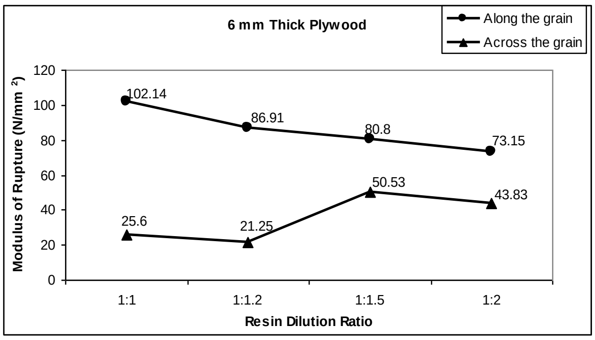

Fig 2 (a) : Variation of Modulus of Rupture at various resin dilution for 6 mm thick plywood

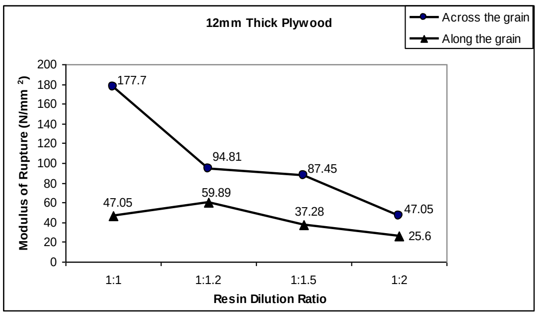

Fig 2 (b) : Variation of Modulus of Rupture at various resin dilution for 12mm thick plywood

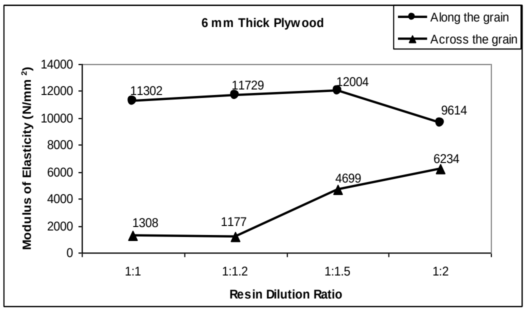

Fig 3(a) : Variation of Modulus of Elasticity at various resin dilution for 6 mm thick plywood

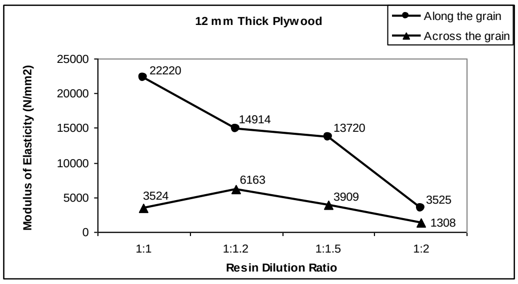

Fig 3(b) : Variation of Modulus of Elasticity at various resin dilution for 12 mm thick plywood

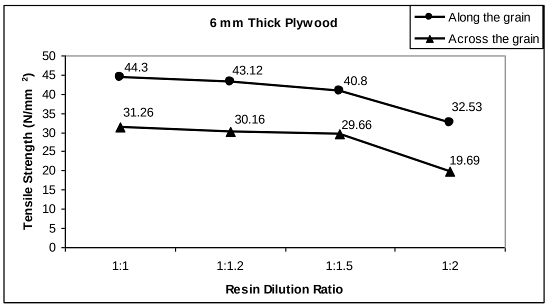

Fig. 4(a): Variation of Tensile Strength at various resin dilution for 6 mm thick plywood

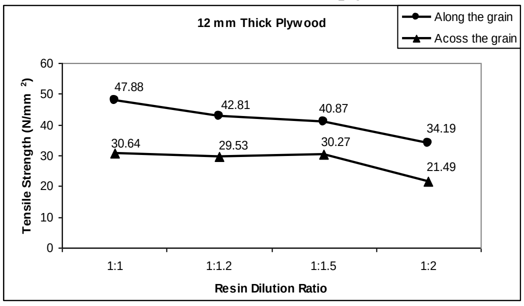

Fig. 4(b): Variation of Tensile Strength at various resin dilution for 12 mm thick plywood

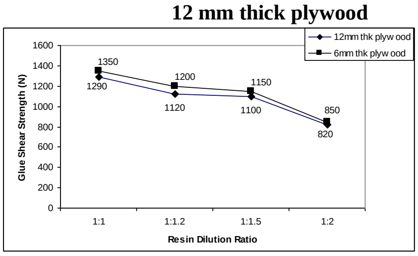

Fig. 5: Variation of Glue Shear Strength at various resin dilution for 6 mm and 12mm thk plywood

Fig. 6 (a) : Plywood with Gurjan as face veneer

Fig. 6(b): Jute Felt of 12mm thick and GSM 1650

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REFERENCES

1. T. M. Maloney, "Modern particle board & dry process fiber board manufacturing, (Book style with paper title and editor)," *Miller Freeman Publications*, San Francisco, CA, USA
2. M. F. Sefain, N. A. Naim, M. Rakha, "Effect of thermal treatment onthe properties of sugar cane bagasse hardboard" *J Appl Chem Biotechn*, 1978, 28(2), pp. 79.
3. F. Mobarak, Y. Fahmy, H. Augustin, "Binderless lignocellulose composite from bagasse and mechanism of self-bonding", Holzforschung, 1982, vol. 36, pp. 131–135.
Pizzi, . Smith, "Advanced wood adhesives technology (Book style)," Marcel Dekker Inc, New York,1994, pp 58–60

A. W. C. Lee, X. Bai, A. P. Bangi, "Flexural properties of bamboo reinforced southern pine OSB beams (Journal style)," *FPJ*, 1997, 47(6), pp. 74–78.

4. M. N. M. Yusoff, A. A. Kadir, A. H. Mohamed, "Utilization of bamboo for pulp and paper and medium density fiber board" (Proceedings style)" National Bamboo Seminar, Kuala Lumpur, Malaysia.

I. M. Sulastiningsih, S. M. Nurwati, S. Kawai, "The effects of bamboo cement ratio and magnesium chloride ($MgCl_2$) content on the properties of bamboo–cement boards (Proceedings style)," ACIAR., Canberra, Australia, 2002, No. 2.

5. U. C. Jindal. Poor, "Development and testing of bamboo-fiber reinforced plastic composites", J Composite Mater, 1986, vol. 20, pp. 19–29
6. M. D. Hill, J. B. Wilson, "Particleboard strength as affected by unequal resin distribution on different particle fractions (Journal style)," Forest Prod Journal, 1978, 28(11), pp. 44–48.
7. P. Naha, S. Sen, J. Nag, "Development of jute overlays for panel products (Report style)", IPIRTI Research Report, 2004, No. 131
8. IS: 1734 -1983 (Part 1 to 20), "Method of test for plywood", Bureau of Indian Standards, New Delhi.
9. L. G. Esteban, P. D. Palacios, F. G. Fernandez, J. Ovies, "Mechanical properties of wood from the relict abuies pinsapo (Journal style)", *FPJ*, 2009, vol. 59 (10), pp. 72-78.

B. Pavithran, P. S. Mukherjee, M. Brahmakumar, A. D. Damodaran, "Impact properties of natural fiber composites (Journal style)", *JMS Fillers*, 1987, vol. 6, pp. 882-884.

10. M. K. Sridhar, G. Basavarappa, S. G. Kasturi, N. Balasubramanian, "Mechanical properties of jute/polyester composites", *Indian Journal of Technology*, 1984, vol. 22, pp. 213-215
11. S. Nangia, S. Biswas, "Jute Composite: Technology & Business Opportunities (Report style)" *TIFAC*.

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