

THE UTILIZATION OF JUTE FELT AS A SELF-ADHESIVE CORE VENEER FOR THE FABRICATION OF PLYWOOD REPRESENTS AN INNOVATIVE APPROACH IN PLYWOOD MANUFACTURING PROCESS

Abstract

This research explored using jute felt, a strong natural fiber as a replacement for traditional wood veneer in making plywood. The jute fiber, strengthened with phenolic resin, was used to create plywood sheets of various thicknesses (4 mm to 18 mm). In this study, more than 60% of the materials used to make plywood were natural fibers, offering a sustainable alternative to wood. The Plywood were tested different properties like how rough the surface was, moisture content, density, water absorption, strength under compression and tension, and how well it held screws and nails. The results showed that the plywood met the requirements for different grades according to industry standards. Additionally, it showed increased resistance to pests and weathering. We also tested the glued core made with jute felt for three months before making plywood, and it held up well under different conditions. This study suggests that using jute instead of wood in plywood can be a great solution, especially as forests are getting smaller. Using renewable resources in plywood production can help when there's a shortage of wood and reduce costs associated with importing veneer.

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I. CHAPTER SUMMARY

This investigation aimed to evaluate the feasibility of incorporating core veneer made from a renewable natural fiber, specifically non-woven jute felt—a highly durable natural fiber, ranked second only to cotton—in the plywood manufacturing process. The sturdy jute fiber, impregnated with phenolic resin, was utilized in plywood fabrication. Plywood sheets ranging in thickness from 4 mm to 18 mm were manufactured using phenolic resin-impregnated jute felt with a thickness of approximately 16 mm and a weight of 1850 GSM (approximately), serving as a substitute for natural wood veneer. In this study, more than 80% of the materials used in plywood production comprised natural fiber, offering an alternative to wood and bridging the gap between demand and supply. Various physico-mechanical properties, including surface roughness, moisture content, density, water absorption, swelling, compressive strength, tensile strength, static bending strength, glue shear strength, and screw and nail holding strength, were analyzed for plywood produced with jute felt as the core veneer and different resin dilutions. Data analysis revealed that the majority of these physico-mechanical properties met the requirements of various plywood grades according to IS standards. Moreover, the plywood exhibited increased resistance to termites, borers, and weathering under both dry and wet conditions. An accelerated study of the glued core, post-impregnation with jute felt, was conducted over three months before plywood fabrication, with suitable storage conditions of temperature and humidity. The data indicated high-quality bonding after plywood production. In conclusion, this study suggests that jute composites, as alternatives to wood, could offer an ideal solution, particularly in the face of diminishing forest reserves. The use of renewable resources in plywood industries proves advantageous in addressing challenges during veneer scarcity and reducing costs associated with imported veneer.

II. INTRODUCTION

Plywood is universally essential in the construction field, gaining increasing usage in building and furniture industries, in conjunction with particle board and block board. Its applications span across the construction of cabinets, decorative wall paneling, and partition walls. The development of more efficient synthetic resin adhesives has enabled the production of weather-resistant plywood, widely applied in exterior uses like building construction and concrete shuttering. Moreover, plywood is extensively utilized in constructing railway carriages, bus bodies, and ships. Additionally, plywood demonstrates substantial export potential, with continuous exports to countries such as Japan, the Middle East, and West Asia.

Jute is an attractive natural fibre for use as reinforcement in composite because of its low cost, renewable nature and much lower energy requirement for processing. Since jute is a lignocellulosic material, it has an ample scope to make composite material in wood based panel industry for making composites with wood

There is an increased recognition of the demand for materials due to a growing global population and rising affluence. North America possesses abundant reserves of agricultural fiber residues. Bagasse, jute, straws, and sisal are identified as having significant potential for ongoing development, as highlighted by Maloney (1993) and Li et al. (2000).

Typically, lignocellulosic non-wood fibers serve as a relatively cost-effective alternative to higher-quality wood fibers. Composites produced with bagasse present a viable option for areas abundant in this material, particularly due to the substantial production of sugarcane and other agronomic crops. Bagasse, a fibrous by-product from sugar cane processing, has been employed in the manufacture of hardboard (HB) and insulation board, as documented by Sefain et al. (1978) and Atchison and Lengel (1985).

Agro-fiber composites generally exhibit lower quality compared to those composed of wood fibers. However, through processes such as depithing, surface modification, and thermal/chemical treatments, comparable mechanical and physical properties to medium density fiberboard (MDF) made from aspen fiber have been achieved, as demonstrated by Mobarak et al. (1982) and Iñiguez-Covarrubias et al. (2001).

The adhesive plays a crucial role in influencing the mechanical and physical properties of agro-based composites. The incorporation of (20-30)% pMDI (4,4'-diphenylmethanediisocyanate) into UF (urea-formaldehyde) and PF (phenol-formaldehyde) has resulted in significantly enhanced mechanical and physical properties in agro-based composites when compared to the individual application of UF or PF in agro-based composites, as documented by Pizzi (1994), Hse and Choong (2000), Grigoriou (2000), and Simon et al. (2002).

In the early 19th century, bamboo (*Bambusoideae* sp.) emerged as a significant contributor to the agro-based composite sector. Due to its rapid growth, high bending stiffness, and dimensional stability, bamboo stands out as a promising raw material for the production of composite panels. A multitude of studies has explored the properties of bamboo-based composites, encompassing oriented strand board (Lee et al. 1997), medium density fiberboard (Yusoff et al. 1994, Zhang et al. 1997), bamboo fiber-reinforced cement boards (Sulastiningsih et al. 2002), and bamboo fiber/thermoplastic composites (Jindal 1986, Jain et al. 1992).

There is a widely acknowledged consensus that longer fibers inherently establish a more extensive network system, leading to heightened bending properties in composites, as discussed by Mobarak et al. (1982) and Li et al. (2000). Processing variables, such as plate clearance, plate size, and material moisture, have an impact on fiber sizes. The sizes of fibers are linked to the overall surface area, subsequently influencing resin efficiency.

In particles, a smaller percentage of fine fractions lowered the strength properties of composites (Hill and Wilson 1978). 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.

IPIRTI has also done a lot of work on impregnated jute for making of composite along with wood veneer [P.Naha et al,2008]. A patent on the work “Warp and weather resistance solid core wood door and method of making” has been patented on one United State patent [R.Phillip etal,2002].

The main objective of this research work is to utilize jute felt as a substitute to core veneer for manufacturing plywood to narrow the gap between demand and supply of wood and to increase productivity and thus saving large quantity of wood used in panel industry by getting rid of dependency and to reduce depletion of forest .

III. MATERIALS AND METHOD

1. PF Resin Manufacture and Quality Assessment: This research is based on manufacture of plywood and evaluation of mechanical properties of plywood by using different veneer species like Dipterocarpus(Gurjan), Shorea assamica(Makai) and non oven jute felt (compact type of thickness ,12mm and 16 mm and of GSM 1850(appx.)) has been taken for core replacement of plywood, Phenolic resin which is one of the first synthetic resin exploited commercially has been used for impregnation of jute felt because of its high heat resistance, excellent fire resistance, low smoke emission and compatibility with jute fiber.

- Phenol – C_6H_5OH -99%
- Formalin - $HCHO$ – 37% Formaldehyde content.
- Sodium Hydroxide – $NaOH$ (Commercial Grade)
- Non –Oven Jute Felt – Thickness – 12mm and 16mm

GSM - 1850 -1900 (Jute felt collected from local market in roll form having different width up to 2m. The required size has been used for the study).

2. Synthesis of PF Resin (Resol Type): Raw Materials

- Phenol – C_6H_5OH -99%
- Formalin - $HCHO$ – 37% Formaldehyde content.
- Sodium Hydroxide – $NaOH$ (Commercial Grade)

A resin kettle was charged with 70 kg of phenol, followed by the addition of 126 kg of formalin, and the mixture was stirred. A solution of 5.6 kg of $NaOH$ dissolved in 11.2 kg of water was prepared, cooled to room temperature, and slowly added to the resin kettle. The temperature was maintained at $90 \pm 20^\circ C$, and the reaction proceeded until the flow time, measured in a B4 Cup according to IS: 3994, reached (15-16) seconds in hot conditions, with a water tolerance of 1:6 or 7. Subsequently, the reaction mixture was cooled, and the batch was discharged. The resin's characteristics were assessed by examining parameters such as pH, flow time, solid content, etc. (Refer to Table No:1(b)). The prepared resin was further diluted with water at a ratio of 1.0 to 2.0 on a weight/volume (W/V) basis.

3. Impregnation of Resin

- Non-Oven jute felt having 16mm thickness and 1800 GSM (appx.) was cut to the size 1' x 1'.
- The weighed jute felt was soaked in different dilution PF liquid resin for 2 to 3 minutes.

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- It was squeezed to remove excess resin by passing it through squeezer.
- The resin consumption on liquid and dry basis has been calculated as per formula given below. {Ref : Table -2(a)} .
 - Resin consumption (Liquid) = $B - A/C$
 - Resin consumption (Liquid) = $(B - A) \times \text{solid content} / C * 100$
 - A= Wt. jute felt
 - B = Jute Felt + Resin
 - C = Total resin dilution
- The squeezed impregnated jute felt was kept overnight in open air for drying and subsequently sundried for 3 to 4 hrs to bring down the moisture content up to 8 to 10 % .
- Core Veneer and Face Veneer was cut according to the Size of jute felt and dried up to M/C 6 to 8 % .
- Individual jute felt has compressed in cold press at pressure 12 Kg./cm² for 10 minutes to minimize the thickness.
- Assembling of jute felt, core veneer and Face veneer was carried as per opposite grain direction of wood veneer as per required.
- Plywood having various thicknesses was prepared by hot press as per following hot press condition. The details of plywood construction is given in Table No- 10 .
 - Temp = 140-145 °C, Pressur = 14 Kg/cm². Time Period = As per thickness.
- The ply board were then trimmed& evaluated for Physico mechanical properties, The results are given in table no -5,6,7 respectively .

IV. PROCESS FLOW CHART

A processing flow chart of **plywood** manufactured by using jute felt as core veneer in fig-1

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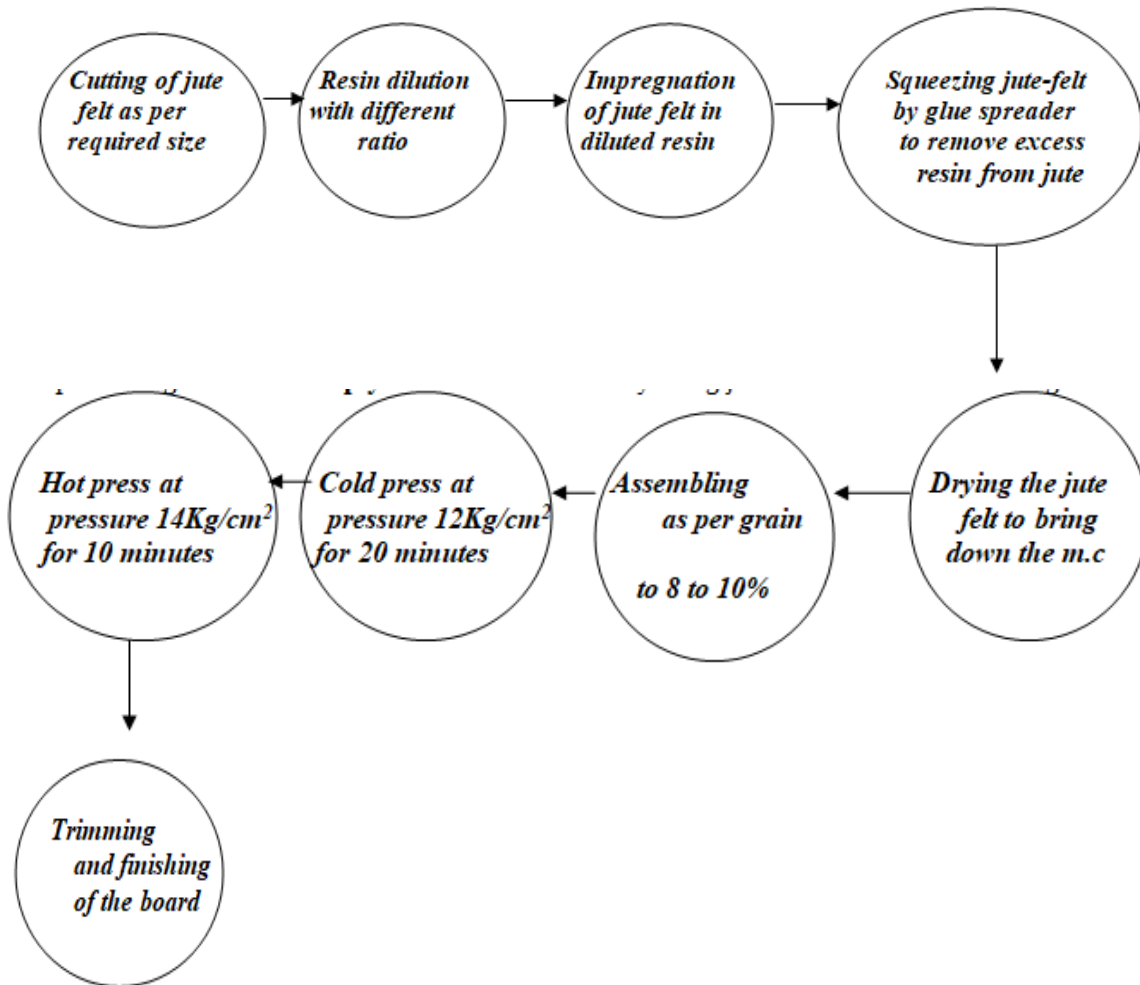


Figure 1: Testing

The physico-mechanical properties of plyboard incorporating non-oven jute felt were assessed in accordance with relevant Indian standards. Tests for Static Bending Strength, Compressive Strength, and Tensile Strength were carried out using a Digital Universal Testing Machine equipped with a 10-ton capacity and two interchangeable load cells of 1 kN and 10 kN capacity. Test parameters for Moisture Content, Density, Water Absorption, and Cyclic Test were determined utilizing a Digimatic digital caliper, Hot air oven, and Boiling Water Bath. All sample specimens underwent pre-conditioning at $27 \pm 2^\circ\text{C}$ and $65 \pm 5\%$ RH in a conditioning chamber. The results are presented in Tables 5, 6, 7, and 8, respectively.

V. RETENTION OF RESIN MEDIA BY JUTE FELT

Jute felt underwent impregnation with different resin dilutions for a duration of two minutes, and the resin retention in 12 mm and 16 mm jute felt was assessed for various dilutions. Detailed information is presented in Table 2(a).

- 1. 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. Compression data is shown in Table -3
- 2. 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. Data is shown in Table -4 .
- 3. Accelerated stability study of Resin-jute reinforced composite veneer:** The jute felt with resin (1:1.5 dilution) reinforced composite veneer was stored at a temperature of 27±20°C and RH -65% for 7, 15, 30, 45, and 60 days. Subsequently, plywood was manufactured utilizing it as a self-adhesive core veneer. The bond quality and mechanical properties were then examined. The results are presented in Table -9..

VI. RESULT AND DISCUSSION

Plyboard of varying thicknesses was produced by employing jute felt as the core veneer, substituting the traditional wooden glue core [Refer to Table-10]. The resin absorption capacity of the jute felt is presented in Table 2(a) and 2(b) for the laboratory-scale and pilot-scale studies, respectively. The comparison between the thickness of jute felt and tensile strength is provided in Table-3 and Table-4.

The investigation suggests that PF Resin-impregnated Non-oven jute felt, acting as a natural fiber, can effectively substitute the wooden glue core veneer in plywood manufacturing up to 80%, providing an alternative to wood to address the gap between demand and supply for wood veneer. Table-2 illustrates that the 16 mm non-woven jute felt, with approximately 1800 GSM, exhibits a resin intake capacity of 68 gms (approx.) in a 1:1.5 (resin to water dilution) ratio on a solid basis, while the resin intake capacity for a 6 mm thickness of jute felt is 27 gm per sq ft. This implies that, even with three 6 mm jute felts, a single 16 mm jute felt can be utilized to minimize resin consumption and, consequently, reduce the density of the plywood board. From Table-4 and Table-4, it is evident that the impregnated jute felt was compressed to 75-80% of its thickness at a specific pressure of (13-16) kg/cm², a factor considered in the calculation for manufacturing various thicknesses of plywood. Tensile strength results for the impregnated jute felt under different pressures show promising outcomes. The mechanical properties of the jute felt composite plywood board, presented in Table-5 and Table-6, reveal superior Static Bending Strength and Tensile Strength compared to IS-303 BWR grade plywood prepared from 100% wood veneer. Plywood manufactured by compressing impregnated jute felt with a dilution ratio of 1:2.0 exhibited notably low mechanical properties, while an improvement was observed when a combination of jute felt was utilized as a core veneer for maximum replacement. Although no significant change was noted in glue shear strength, water absorption, and density remained consistent compared to commercial plywood [Ref- Table-8].

Different resin dilutions with water were explored to improve economic viability. Adhesion and mechanical properties underwent changes based on the resin dilution, following the sequence: 1:0 > 1:1 > 1:1.5 > 1:2. The optimal levels of static bending strength

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and tensile strength fell within the range of 60-80 N/mm² and 40-42 N/mm², respectively [Refer to Fig 4 and Fig 5].

The accelerated study of the jute resin composite veneer reveals that there is no significant alteration in the bond quality and mechanical properties of the plyboard, even after storing the veneer for up to 30 days. In other words, the self-adhesiveness property remains unchanged. Plyboard manufactured using the self-adhesive core veneer underwent testing according to IS:303-2003, and the results align with the standards for BWR grade [Refer to Table-9].

VII. CONCLUSION

The use of wood-substituted non-oven jute felt composites in plywood manufacturing emerges as an optimal solution, particularly in the face of diminishing forest resources. The utilization of renewable resources proves advantageous for plywood industries, addressing challenges during the scarcity of wood veneers and reducing the landed cost of imported wood material. In this study, over 80% of the wood materials used in plywood fabrication are sourced from natural fiber, serving as an alternative substitute for wood and narrowing the gap between demand and supply through 100% indigenous technology. This approach contributes to foreign exchange savings for our country. From an economic standpoint, while it may be on par or slightly more expensive than conventional plywood, it showcases superior mechanical properties and maximizes wood replacement to minimize the demand-supply gap. In conclusion, the study recommends the use of a resin-to-water dilution of 1:1.5 for achieving enhanced bond quality and mechanical properties, considering both economic aspects and suitability for BWR Grade.

Table 1: Properties of Resin

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 2: Retention of resin by Jute Felt (Soaking time 2 min) of size 1ft x 1 ft & 16mm thk

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	206
1:1	199.0	687.0	398.5	99.62
1:1.5	187.5	493.5	306	68
1:2.0	201.5	489.5	288	36

Table 3: Percentage thickness compression of impregnated jute felt for 5 mints at pressure 14Kg/cm²

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 4: Physical and Mechanical properties of 6 mm thick plywood

Sl. No	Resin Dilution	Moisture Content (%)	Density (kg/mm ³)	Water Absorption (%)	Modulus of Rupture (N/mm ²)		Modulus of Elasticity (N/mm ²)		Tensile Strength (N/mm ²)		Wood Replacement (%)
					Along	Across	Along	Across	Along	Across	
1	1:1	6.2	1253	10.25	102.14	25.60	11302	1308	44.30	31.26	88
2	1:1.2	6.5	947	11.16	86.91	21.25	11729	1177	43.12	30.16	86
3	1:1.5	6.8	812	10.74	80.80	50.53	12004	4699	40.80	29.66	88
4	1:2.0	7.6	804	11.34	73.15	43.83	9614	6234	32.53	19.69	85

Table 5: Physical and Mechanical properties of 12 mm thick plywood

Sl. No.	Resin Dilution	Moisture Content (%)	Density (kg/mm ³)	Water Absorption (%)	Modulus of Rupture (N/mm ²)		Modulus of Elasticity (N/mm ²)		Tensile Strength (N/mm ²)		Comp Strength (N/mm ²)	Wood Replacement (%)
					Along	Across	Along	Across	Along	Across		
1	1:1	6.17	1241	10.2	177.70	47.05	22220	3524	47.88	30.64	19.70	68
2	1:1.2	6.45	938	11.1	94.81	59.89	14914	6163	42.81	29.53	18.40	66
3	1:1.5	6.81	807	10.7	87.45	37.28	13720	3909	40.87	30.27	18.20	69
4	1:2.0	7.63	804	11.3	47.05	25.60	3525	1308	34.19	21.49	17.50	61

Table 6: Physicomechanical Properties of veneer jute composite and Commercial Plywood

Sl. No	Test Parameter	Plywood	Jute veneer composite
01	Thickness(mm)	12	12
02	Density gm/cc	0.798	0.804
03	Water absorption,24 hrs(%)	12	14
04	MOR N/mm ²	42.6	87.4
05	MOE N/mm ²	4500	13720
06	Tensile Strength(N/mm ²)	42.6	40.87
07	Glue shear Strength,Dry(N)	1300	1250
08	Thickness swelling(%)	3	4
09	Compressive strength(N/mm ²)	25	18.20

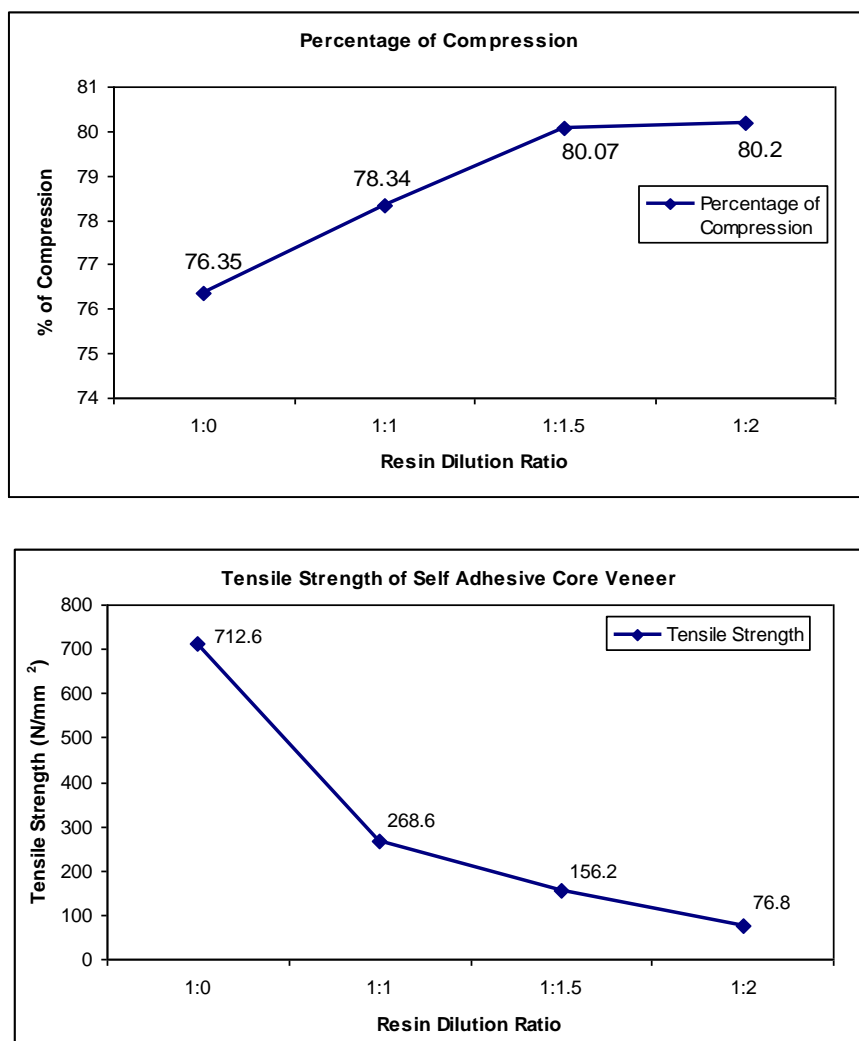


Figure 2: Percentage of Compression and Tensile Strength of Self Adhesive Core Veneer at different resin dilution

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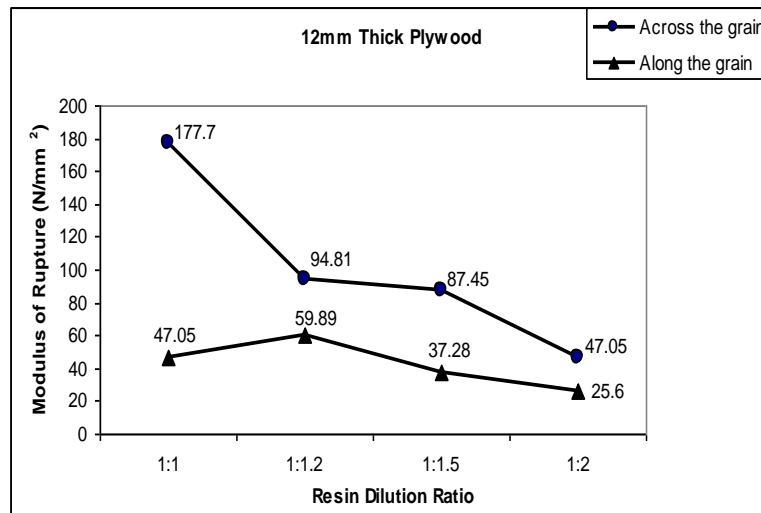
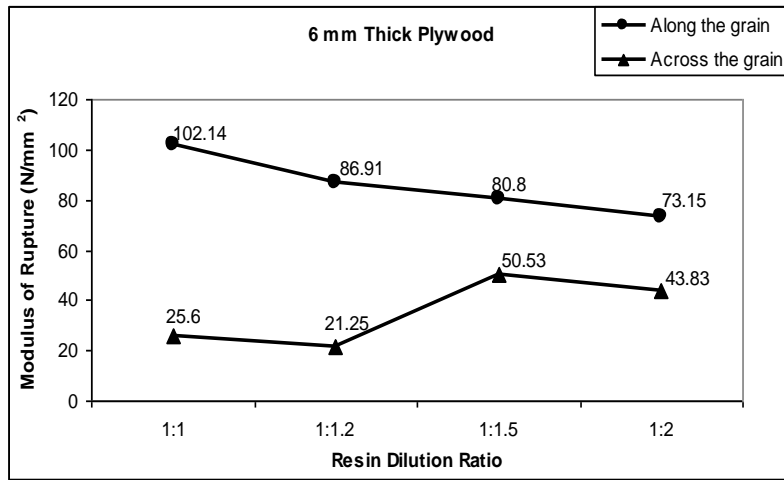
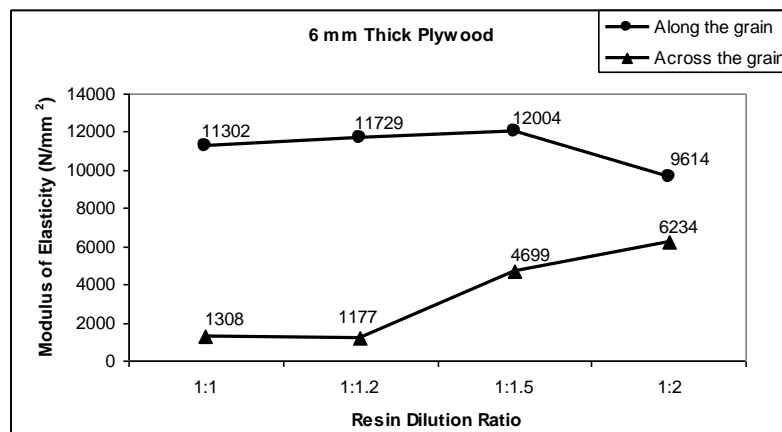


Figure 3: Variation of Modulus of Rupture at various resin dilution for 6 mm and 12mm thick plywood



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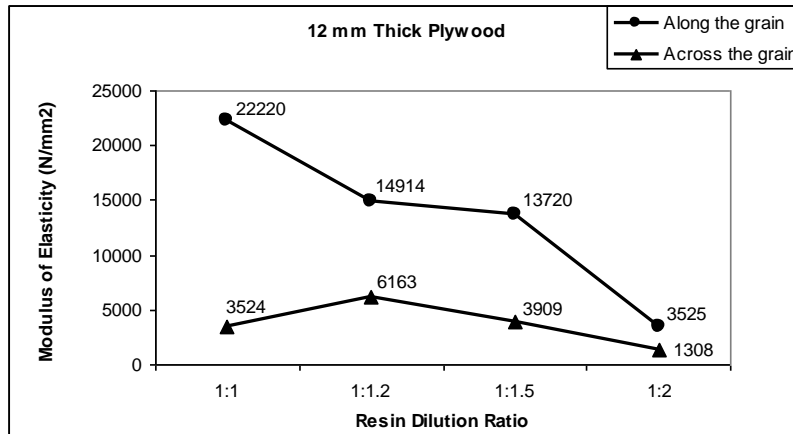


Figure 4 : Variation of Modulus of Elasticity at various resin dilution for 6 mm and 12 mm thick plywood

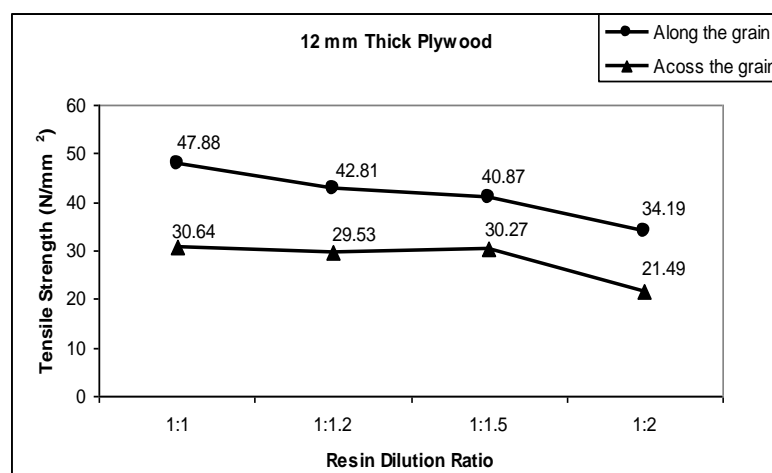
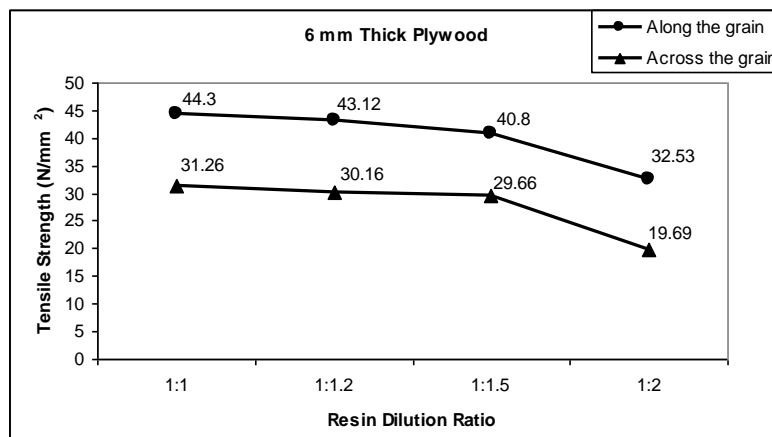


Figure 5: Variation of Tensile Strength at various resin dilution for 6 mm and 12 mm thick plywood

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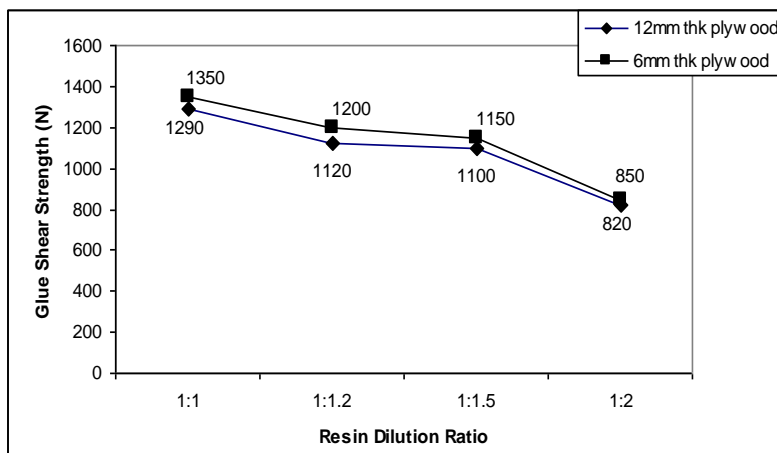


Figure 6 : Variation of Glue Shear Strength at various resin dilution for 6 mm and 12mm thk plywood



Figure 7: Plywood with Gurjan as face veneer



Figure 8: Jute Felt of 12mm thick and GSM 1650 used as a glu core

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