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Bond Quality, Mechanical and Physical Properties of Wood - Polyethylene Reinforced Plywood

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Abstract **– An experimental study has been carried out to investigate the quality of adhesion, mechanical and physical properties of plywood produced from bonding Eucalyptus wood veneers with polyethylene (LDPE) sheet as a reinforeced material. All plywood samples were assessed by physical and mechanical strength tests and the results were recorded. The results are matched with the requirements of plywood for general purpose as per Indian standard IS 303: 1989. The results showed that the reinforcement of wood veneers with polyethylene sheets proved to be intact and showed good strength properties. Overall it proved that bonding of wood veneers with polyethylene (LDPE) sheets can be achieved to produce plywood which may be used for general purpose.**

Keywords **– Plywood, Polyethylene (LDPE), Glue Shear Strength, Mycological Test.**

I. INTRODUCTION

Plywood composites have extensively been used for furniture making, office cabinets and other house hold products. These are produced bonding wood veneers with formaldehyde based resins due to it's low cost and avaibility factors. The people at different levels right from plywood plant workers to the consumers are exposed to formaldehyde gases released form panels. The studies over the years have shown that the exposure to formaldehyde can cause human health hazards (Ki-Huan et al 2011). Alternative resins and production techniques which are at affordable cost and free from carcinogenic gases are in demand in the present scenario.

Likewise the growing dependency on petroleum – derived plastic materials and the rising environmental and sustainability concerns have motivated researchers to explore new materials to replace conventional plastic in various applications (Sarufuddin and Ismail 2015). Wood plastic composites (WPCS) are relatively new material class that covers a broad range of composite materials utilizing an organic resin binder (matrix) and fillers composed of cellulosic material. Over the last few years, WPCS have received considerable attention from the wood and plastic industries (Balasuriya et al 2001;Shebani et al 2012).The properties of WPCS differ from solid wood and pure plastic in the sense that they combine the advantages of both materials, which makes it a good replacement material for some applications (Kazemi-Najafi et al 2012). WPCS possess the further advantage that they can be made from the waste from the forestry/ wood industry and recycled plastic obtained from household waste (Teuber et al 2013). The polymer matrix of WPCS are frequently comprises of polyolefins, such as low density poly ethylene (LDPE) or polypropylene of poly vinyl chloride, whereas the wood fillers are soft wood fibers that have a well-known chemical composition and uniform configuration (Schneid--er 2007). Wood is an organic and natural composite of cellulose fibers embedded in a matrix of lignin and rich functional groups with numerous hydroxyl groups. In recent times, the increased use WPCS for structural and exterior applications has resulted in the need to understand their durability better (Stark and Matuana 2007) It has been shown that the performance of WPCS as a structural material depends mainly on the quality of the stress transfer at the interface (Lee et al 2007). The interface is the region between the fiber and polymer matrix and poor interaction between the two materials reduces the adhesion between them (Niska and Sain 2008). Improvement of the interphase adhesion improves WPC properties, such as tensile strength, toughness, impact, rate of water absorption, and other. Consequently, a better understanding of the interfaci--al properties and characteristics will help to evaluate the overall properties of WPC (Lee et al 2007).

Therefore, in the present research, an experimental study has been carried out by bonding wood veneers with polyethylene sheets to study possible adhesion and mechan--ical and physical properties to replace formaldehyde based resins for plywood manufacturing and utilizing the polluting polyethylene as binding materials.

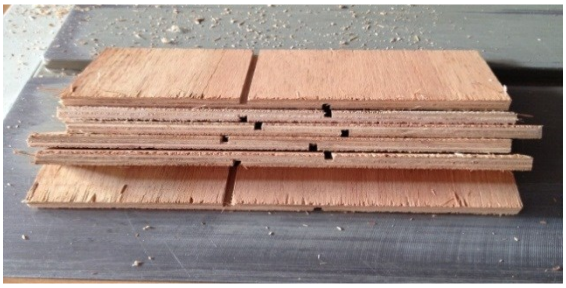
II. MATERIALS AND METHODS

For the study, Eucalyptus veneers of the thickness 1.8 mm were taken to produce plywood of 600 x 600 mm². Veneers were sun dried to remove any extra moisture before pressing. LDPE (Low Density Polyethylene) sheets of approximately 0.5 mm thickness and of density of 23 g/sq.ft. were purchased from local markets. The LDPE sheet cut into required size of 600 x 600 mm² and placed in between Eucalyptus veneers to produce plywood of 9 mm thickness by using 5 layers of veneers as shown in fig. 1. Aluminum Cauls were used to put the assembled Eucalyptus veneers and LDPE sheets into the hot press. The temperature of the press was set at 130 ±5° C and the specific pressure was kept at 10-12 kg/cm². The assembly kept in hot press for 15 minutes as shown in fig. 2 and then cooled down to room temperature before taking it out. Once the pressed plywood taken out from the press, it cutdown from all four sides as shown in fig. 3. The samples were taken as shown in fig. 4 and pre-conditioned as per test requirements.

Title 1: Assembling.
Plate 1: veneers and LDPE sheets assembly.

Title 2: Pressing.
Plate 2: Hot pressing of veneers and LDPE sheets.

Title 3: sawn composite board
Plate 3: Ripping from all sides



Title 4: sampling.
Plate 4: Preparation of Glue shear strength samples.

Water Resistance Test:

The water resistance test was performed on the samples of size 250 x 100 mm in a hot water bath as per IS 303 Indian Standard. The samples kept in hot water at a temperature of 60 ± 2°C for 3 h and then dried for 8 h in a hot air oven. This was repeated for another two cycles. After the third cycle, the samples were taken out and subjected to further examination.

Adhesion to Plies:

A knife used in this test and the test carried out on a stout table of sample size 250 x 100 mm. The knife was inserted with its cutting edge parallel to the grain of the outer veneer and worked into a glue line and the veneer is prised upward. The tare in the wood fibre grain should be assessed with visual examination.

Glue Shear Strength:

Samples of 150 x 25 mm and full thickness were cut according to is 1734 glue shear strength with notches as shown in fig. 4. Each test specimen gripped symmetrically at the two ends in the jaws of a Universal testing machine as shown in fig. 5, and pulled apart. The distance between the notches on the test specimen and the end of the gripping jaws of the testing machine was between 10 mm and 20 mm. The pull was in the Centre line of the central veneer. The grain of the Centre ply shall be perpendicular to the direction of application of load.

Title 5: Glue shear strength.
Plate 5: Fixing the sample in UTM for testing

During the test, the load applied to the test specimens as uniformly as possible, and so adjusted as to increase at a rate lying in the range of 1300 ± 500 N/min. The maximum load at the time of complete failure of each specimen was recorded. The record made as whether failure in wood or in glue by visual examination of the area under shear and the percentage wood failure shall also be recorded as shown in fig. 8.

Bending Strength:

The span length (*L*) of the test of MoE & MoR was kept at 48 times the thickness (*d*) of the plywood for along the face grain sample and 24 times the thickness for the across the grain sample. Before the test, the samples were conditioned to a constant mass at a temperature of 27 ± 2 ºC and a relative humidity of 65 ± 5 %. The load applied through a loading block as shown in fig. 6 for Centre loading with a continuous motion of the movable head throughout the test till a failure is indicated. The rate of application of the load (N) was at the unit rate of fiber strain (z) = 0.0015 cm/cm and calculated by the formula $N = \frac{zL^2}{6d}$ cm/min.

$$\text{Modulus of rupture} = \frac{3P'L}{2bd^2}\ \text{N/mm}^2$$

$$\text{Modulus of elasticity} = \frac{PL^3}{4bd^3\Delta}\ \text{N/mm}^2$$

Where P is load in N at proportional limit, L is span in mm, b is width of the specimen in mm, d is thickness of the specimen in mm, P´ is maximum load in N and Δ is deflection at proportional limit in mm;

Title 6: Bending Strength Test
Plate 6: Application of load during test.

Table I: The test resluts on Bond quality, physical and mechanical properties of WPP

S. no	Tests	Requirements as per IS 303-1989	Test results
1.	Water resistance	Min. pass standard	Pass
2.	Adhesion to plies	Min. Pass standard	Pass
3.	Glue shear strength	Not applicable	751
4.	Bending strength (Along the face grain) Modulus of rupture Modulus of elasticity	 30 4000	 40.53 10477
5.	Bending strength (Across the face grain) Modulus of rupture Modulus of elasticity	 15 2000	 41.07 2354
6.	Moisture content, %	5 - 15 %	8.35
7.	Mycological test	Min. Pass standard	Pass

Moisture Content:

The test specimen of size 150x 75 mm weighed within ± 0.2 percent. The specimen then dried in an hot air oven at a temperature of 103 ± 2°C until approximately constant mass was obtained. The moisture content calculated as for the formula

Moisture content, percent = $\frac{M1-Mo}{Mo} \times 100$

Where $M1$ = initial mass of specimen, and
Mo = oven dry mass of specimen in g,

Mycological Test:

The samples of size 250 x 100 mm were kept in a enameled dish, which was filled with saw dust mixed with sugar water. The samples maintained at a temperature of 27 ± 2°C for a period of three weeks after which the test pieces removed. Samples were washed in water at room temperature and examined visually for any delamination of layers due fungus attack.

III. Results And Discussion

The results of quality of bonding, physical and mechanical strengths (Moisture Content, Resistance to Micro – Organisms, Resistance to Water, Adhesion to plies, Glue Shear Strength, Bending Strength) of the Wood Polyethylene Plywood produced by bonding Eucalyptus wood veneers with LDPE sheets are shown in the Table 1.

Title 7: Water resistance test.
Plate 7: check for delamination.

We perfomed three types of tests i.e. water resistance test, adhesion to plies and Glue shear strength to evaluate reinforcement. The bonding of the veneers with the LDPE sheets were intact as expected as shown in fig. 3. While we ripped out all four sides, there was no chipping of veneers which shows the proper reinforcement of wood and polyethylene sheet. The result of the Water Resistance Test as shown in fig. 7 as per IS 303 MR Grade plywood, there was an edge delamination from corners. It may be due to rough sawing of Wood-Polyethylene reinforced Plywood which can be fairly acceptable. Moreover, during the Adhesion to plies test (Knife test), in which the layers were separated by forcing with suitable knife, it retained much of its bonding and showed pass standard as per the requirement. Which can not be possible if the reinforcement was weak. In turn it showed that the bonding was good and retained much of it's reinforcing between wood and polyethylene sheet.

Title 8: Glue shear strength test.
Plate 8: wood failure.

The most important test to investigate reinforcement of wood with polyethylene sheet was Glue shear strength, in which the glue-line was tested by pulling the adjacent layers in the opposite direction. The results were really encouraging and average value was more that 751 MPa. The important investigation in this test was wood failure as shown in the figure 8. It was quite promising because the wood failure was about more than 50 %. Which showed that wood was failed while testing the Glue line. By above three tests the bond quality was adequate and the Wood Polyethylene reinforced plywood can be used as general purpose plywood.

The strong interfacial bonding between wood fibers and polyethylene matrix contributes to mechanical and physical properties of WPP. The MoE and MoR tested as per IS 1734 Method of tests for plywood shown that the strength of the polyethylene reinforced plywood was clearly stand out to be a product, which can be used for manufacturing of furniture and other products without any doubt. Though the strength mainly directly proportional to the wood we used, nevertheless the fortification of wood and polyethylene was intact. Last but not least, while employing this production process, we were eliminated so many stages of the conventional type production. Which was a hectic process to maintain the quality of the plywood. Since there is no liquid based resin involved, we can save a lot of time for assembling of veneers.

However, further studies are to be done about the microscopic analysis of the bonding between wood and the polyethylene sheet. Suitable thickness of polyethylene sheet is to be optimized to ensure the production cost and also to produce higher thickness plywood. Further assessment of other mechanical tests such as Screw and nail holding strength are to be evaluated. An elaborated comparision study also required with other commercial plywood for the suitability of the polyethylene reinforced plywood to replace formaldehyde based resin bonded plywood.

IV. Conclusion

In the experimental study conducted to evaluate the bond quality, mechanical and physical properties of Wood-Polyethylene reinforced Plywood by pressing with LDPE sheet, the following main conclusions can be drawn. The bond quality of the WPP by assessment as per water resistance, adhesion to plies and glue shear strength as required for the general purpose plywood is attained acceptably. The bending strength of the Wood - Polyethylene reinforced Plywood is shown to be promising by bonding with LDPE film. We conclude by saying that we can produce plywood free from formaldehyde emissions and hassle – free manufacturing process.

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Ramesh Karri born in Palasa, Andhra Pradesh on April 20th, 1987 and did his under graduation in Chemistry from Andhra University, Visakhapatnam in 2008. He earned Post Graduate Diploma in Mechanical Wood Industries Technology from IPIRTI (Indian Plywood Industries Research & Training Institute), Bangalore in 2 009. Late--r he joined IPIRTI as JTA on Jan 2011 before working for the plywood industries as Trainee Chemsit and Assistant Chemsit. Currently he is employed with the IPIRTI, a premier research organization as a laboratory technical manager. He pursued M.sc. Chemistry from Madurai Kamraj University in 2018. His major contributions were in obtaining NABL Accreditation to IPIRTI Centre, Mohali. He is a team member in organizing training courses on the topics like testing and standardization of panel products as per Indian Standards, synthesis of Amino and Phenolic resins, estimation of preservatives chemicals and raw materials. He has been visiting various plywood factories to attain knowledge about gluing problems, pressing problems and resin manufacturing. He has tested more than 1000 samples of plywood, particle boards, resins and other raw materials. He participated in many exhibitions as a exhibitor for IPIRTI.