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Fabrication and Studies on Dimensional Stability of Bentonite Epoxy Laminated Veneer Lumbers

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ABSTRACT
The present manuscript reports an exploratory approach on fabrication and characterization of dimensional stability of Laminated Veneer Lumbers (LVLs).The processes of LVLs fabrication was executed through implication of a series of adhesive formulations (AFs) involving epoxy resin supplemented with various weight fractions of bentonite under four ply arrangements of poplar wood veneers. LVLs were characterized through scanning electron microscopy, water absorption (WA) and thickness swelling (TS) tests. Study reveals that LVLs with 12 mm thickness has shown enhanced density, control over WA and TS. The study demonstrates a viable method of implication of BECs as adhesive for fabrication of LVLs with improved dimensional stability, making them suitable for possible outdoor applications.

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I. INTRODUCTION

Cultivation and harvesting of fast growing varieties of trees for wood production and transformation into structural components has received paramount attention since inception of civilization [1-2]. Because of soft material characteristics, the high proportion of cellulose over lignin make wood as inferior object for structural applications. For such reasons, low grade wood varieties are the subject of modification [3-7] and preservation [8-16] into value added products.

Presently, Poplar is used as fuel, and raw material for pulp & paper industries, fabrication of packaging articles, civil structures and ply boards. However, the physical and biodegradation under humidity, heat, mechanical stress and microbes makes poplar wood as inferior composite materials for high performance applications [3-7].Advancements in polymer science and engineering has made possible to enhance the durability of poplar and alike low grade wood for structural applications through reinforcing polymeric fillers [17-22] and adhesives bonding of veneers [23-27]. Furthermore, the physical and environmental durability of veneers based wood products are conveniently optimized through tuning the chemical composition of adhesives and orientation of veneers [23-27]. Literature survey reveals the fabrication and characterization of a series of sandwiched wood structures derived through adhesive bonding of phenol formaldehyde [27-29], ER [29-31], polyurethane [31-32], polyvinyl acetate [32], urea formaldehyde[25-26, 33-34] and melamine-urea formaldehyde [34] with veneers of rubber [28], black alder [32], beech [34], poplar [25, 27, 29-30], hornbeam [33], P.fortunei [26] and tinussylvestris [31].Efforts has been reported on filler assisted modification of adhesives through implication of carbon fiber [29], nanosilica [33] and montmorillonite [26,34].

In the present investigation, efforts were made on development and dimensional stability assessment of the proposed laminated veneer lumbers (LVLs) through adhesive bonding of poplar veneers with adhesive formulations (ARs) involving ER supplemented with various WF of BN.

II. EXPERIMENTAL

Starting Materials

Epoxy resin (ER, CY 230) and hardener (HT 972) were procured from Huntsman India PVT limited. Bentonite (BN 500 μm) was procured from Himedia private limited India. AFs were prepared through dispersion of various WF of BN ranging 1.0 to 3.0 into ER @ 500 rpm over 20 min .

Fabrication of LVLs

Poplar (*Poplar deltoids*) wood logs of average age of 4 years and diameter of 30±5 cm was procured from Department of Agroforestry of G.B.Pant University of Agriculture & Technology, Pantnagar India. The logs were fabricated into veneers with dimensions of 300X 80x3 mm^3. LVLs was fabricated through laying of AFs (15 mL) over individual veneers in four ply arrangement followed by hot press. The weight fraction of BN into AFs was varied in the range of 1 to 3 wt%. The epoxy bond veneers were cured under hot press at 25°C/ 10 kg/cm^2 over 24h to afford the LVLs.

Characterization

Scanning electron micrographs were recorded over JEOL JSM-6610 LV at 10 to 15 kV ,30X, 500 μm. LVLs and respective veneers were characterized for their density (ASTM D 2397-17), WA (%) and TS (%) (ASTM D1037-12a). Dimensional stability of LVLs and respective veneers was measured at their common sample size of 76x76x12 mm^3 under vertical submersion into deionized water at 20±1°C at 2h and 24h.Their dimensional stability was measured through differential weighing with precision of 0.001g and vernier caliper with least count 0.02 mm.

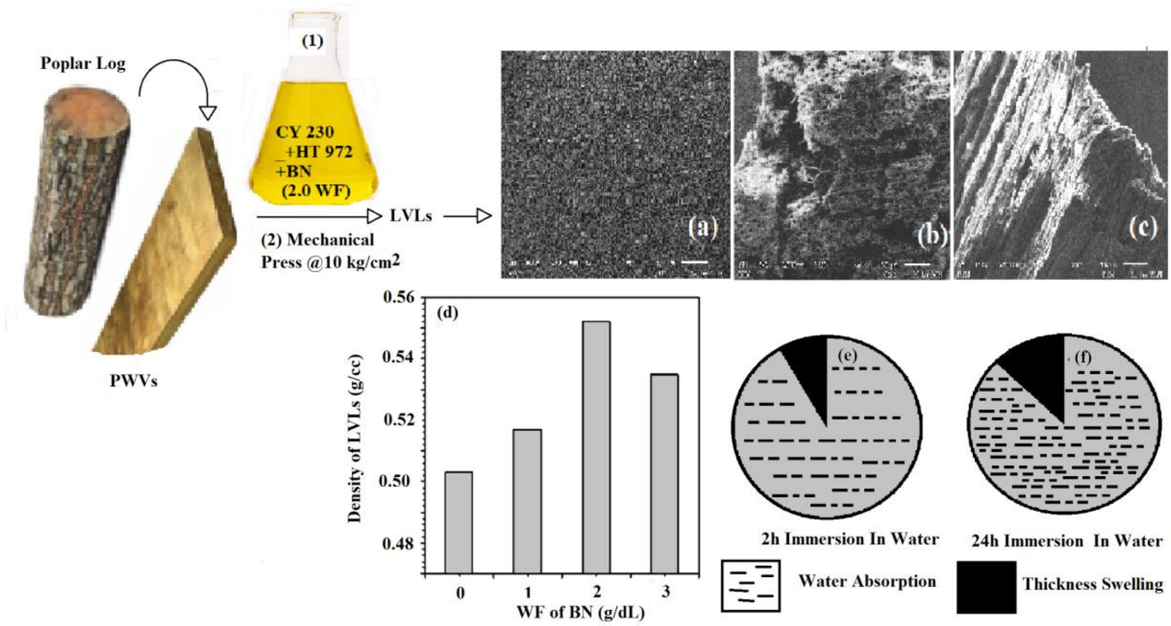

Fig.1: Fabrication and Characterization of LVLs

III. RESULTS AND DISCUSSION

SEM reveals the characteristic particulate morphology of BN (Fig.1a). However, veneers has rendered the porous morphology with distinct voids that were appeared during the tensile test specimens of LVLs. Distinct adhesive bonding and reinforcement of BN was rendered by the SEM of LVLs [35-36].Poplar veneer has rendered the 0.47 g/cc density that was increased with WF of BN into AFs ranging 0.51 to 0.55 with ultimate increase of 17.02 % over poplar veneer (Fig.1d). Early studies reveals the 0.39 g/cc density of LVLs derived through adhesive bonding of poplar veneers with phenol formaldehyde [27]. Adhesive bonding of poplar veneers with phenol formaldehyde and epoxy resins has rendered LVLs with increase (%) in their density to 3.84 [29] and 20.51[30].

Dimensional stability data of LVLs were recorded and separately presented in terms of their water absorption (WA, Fig.1e) and thickness swelling (TS, Fig.1f).Poplar veneers with 12mm thickness has shown 31.61% WA at 2h and 61.71% at 24h respectively .LVLs derived thorough lamination of epoxy has rendered respective WA of 29.60 and 47.31 at 2h and 24h.Modification of epoxy at 1.0 WF of BN has rendered a reduction in WA of LVLs to 17. 07 and 39.11 at 2h and 24h respectively. Further increase in WF of BN to 2.0 has reduced the WA of LVLs to 13.94 and 31.49 at 2h and 24h respectively. Addition of 3WF of BN has however abnormally enhanced the WA of LVLs to 15.32 and 37.31 at 2h and 24 h respectively. The possible reason of such abnormal increase in water absorption of LVLs at 3.0 WF of BN may be associated with increase in viscosity of AFs.

Polar veneers with 12mm thickness has shown TS (%) of 4.61in 2h and 5.57 in 24h.Control over WA has simultaneously affected the TS of LVLs. LVLs derived through adhesive bonding of ER has shown 3.78 mm of TS at 2h and 4.82 mm at 24h in water. Under identical immersion conditions, LVLs has shown gradual decrease in TS to 2.25 at 2h and 4.04 at 244h respectively up to 2.0 WF of BN in AFs. Further increase in WF of BN to 3.0 has raised the viscosity of AFs that has rendered the LVLs with enhanced TS to 3.45 in 2h and 4.36 in

24h respectively. The early reports reveals 48.03% increase in TS of LVLs derived through adhesive bonding of poplar veneers with urea formaldehyde resin within 24h of immersion [26].

IV. CONCLUSION

Laminated veneer lumbers from poplar wood veneers were successfully fabricated through adhesive bonding of epoxy under various weight fractions of bentonite, followed by mechanical press. Scanning electron microscopy reveals distribution of bentonite into porous matrix of poplar wood veneers. With weight fraction of bentonite, the density of LVLs was increased with simultaneous control in their water thickness swelling under immersion in water over 24hours. From the present study this can be concluded that immersion of poplar veneers has rendered 31.61%WA and 4.61% TS in 2h , that was respectively increased to 61.71 and 5.57 in 24h. However, LVLs derived at 2.0 WF of AFs with identical dimensions and length of immersion has rendered substantial reduction in 13.94% of WA and 2.25% of TS in 2h.Further immersion of LVLs to 24h has raised the respective WA and TS to 31.49% and 4.04% respectively. The present exploratory findings prompts for further investigation of physical, thermal and mechanical properties of LVLs for their potential applications in designing and development of durable composite structures for outdoor applications.

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