

Cellulose Nanofiber Effect on Bonding Strength of PUR and PVAc Glued Wood Joint in Shear Loading

Gourav Kamboj, Milan Gaff, Anil Kumar Sethy, Fatemeh Rezaei

Czech University of Life Science - Prague

Introduction:

Adhesives play an important role in the wood industry and mechanical performance of wood adhesive bonds is of fundamental importance. Development of high performance material using nanoparticle or nanofiller has become a prominent area of research in academia as well as in industry. Cellulose nanofiber (CNF) has been reported to be relatively safe, even in its dry form and it is one of the most abundant material on the earth. High tensile strength and Young's modulus make cellulose nanofiber one of the suitable reinforcing material for nanocomposites. In this study, cellulose nanofiber was added in PVAc (polyvinyl acetate) adhesive at various proportion (0-3% based on weight). Lap joints were prepared using beech (*Fagus Silvatica*) wood samples and glue shear strength was assessed. However with PUR adhesive proper dispersion of CNF could not be achieved due to higher viscosity. Hence the result with PUR could not be complied as the experiment is still under progress.

Materials

- Test samples from beech (*Fagus silvatica* L) wood having cross-sectional dimension (150mm x 20mm x 5mm) were prepared from defect free and straight grain pieces.
- Dry cellulose nanofiber, sourced from University of Maine was used in this study.
- PVAc (Ag-Coll 8761/L D3) having a viscosity of 7,000 to 13,000 mPas at 23 °C and density ranging between 0.9-1.1 g/cm³ was used.

Methods:

- CNF suspensions with a solid content 0.5w%, 1w%, and 2w% were prepared by mixing dry cellulose nanofiber with 50ml water at room temperature using a high speed homogenizer (T 18 digital ULTRA-TURRAX® IKA-Werke, Staufen, Germany) followed by sonication (SONOPLUS HD 3100, Berlin, Germany).
- One part of CNF suspension was added to two part of PVAc adhesive and mixed thoroughly using high speed homogenizer followed by sonication. For comparison, reference was also prepared by adding one part of water (without CNF) with two part of PVAc adhesive and thoroughly mixed.
- Wood samples were properly to get even surface.
- Glue was applied at a rate of 150 – 180 g/m² through brush coating, assembled and pressed (0.5MPa) at ambient temperature for 30min.
- Pressed samples were conditioned at 20 °C and of 65% RH for 7 days before to test.
- Bond strength was assessed using tensile shear test as per EN 205 - 2003 using universal testing machine (TIRA System GmbH, Schalkau, Germany).
- Glue failure was assessed by visual observation .

Results

Dispersion of CNF with pure PVAc adhesive was difficult, hence CNF mixed with water and then dispersed with PVAc adhesive. Figure 1 shows the shear strength of joints bonded with pure PVAc, PVAc with water (PVAc_W) and CNF reinforced PVAc. Addition of water to PVAc adhesive caused a significant decrease (28.7%) in the shear strength of the joints. However addition of CNF dramatically improved the shear strength of the adhesive joints. Among the three concentration of CNF studied, 1% CNF addition gave the best results in terms of bond strength. The increase in bond strength with 1% CNF addition was 35% higher as compared to PVAc_W and 9% higher as compared to pure PVAc. With increase in the CNF content to 2% the values showed a decline and this might be due to the presence of more water inside the cured resin because of the higher water retention by CNF.

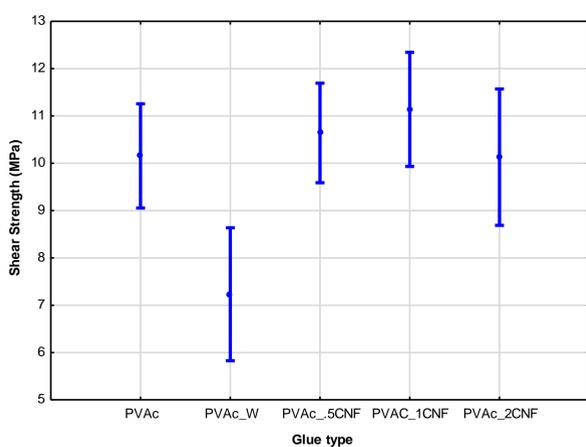


Fig.1 Shear strength of joints bonded with PVAc and percent content of cellulose nanofiber

Table.1 shows the effect of different glue types on the shear strength values of the joints. It is evident that the improvement in shear strength is highly significant due to the addition of CNF when compared with PVAc_W. However, the improvement was not significant when compared with pure PVAc adhesives.

Table.1 Statistical Evaluation of Factors Influencing the Shear Strength

Glue Type	PVAc	PVAc_W
PVAc		0.000785
PVAc_W	0.000785	
PVAc_5CNF	0.537306	0.000188
PVAc_1CNF	0.240655	0.000056
PVAc_2CNF	0.971585	0.000693

Glue failure:

Figure 2 shows the percentage glue failure of joints bonded by PVAc, PVAc with water and CNF reinforced PVAc. Dilution of PVAc adhesive with water resulted in a poor bonding as shown by maximum glue failure. With CNF reinforcement, the bond quality improved resulting in reduced glue failure. This confirms that addition of CNF make PVAc glue line of stronger causing failure in wood rather than in glue line. The results of CNF reinforcement on glue failure was similar to that of shear strength as 1% CNF addition gave the best results (least average glue failure percentage).

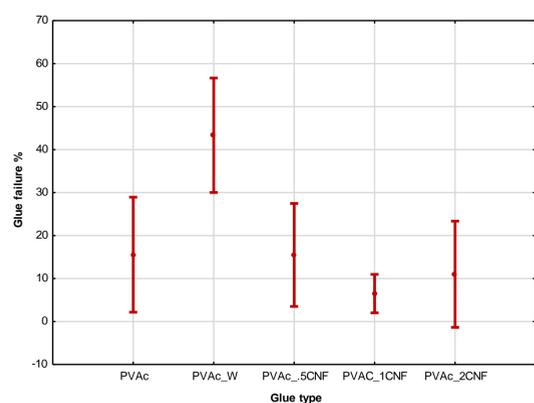


Fig. 2 Glue failure of joints bonded with PVAc and percent content of cellulose nanofiber

Figure. 3 shows elastic stiffness of joints bonded with pure PVAc, PVAc with water and CNF reinforced cellulose nanofiber. Addition of water to PVAc resulted in significant decrease in the stiffness of the joints. However, with addition of CNF, stiffness of the joints increased and became comparable or even marginally better (8 to 17%) as compared to pure PVAc adhesive.

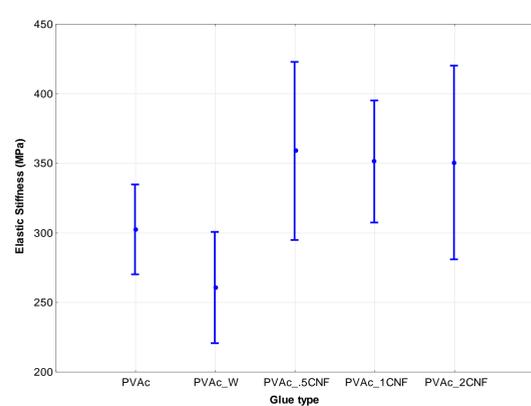


Fig. 3 Elastic stiffness of joints bonded with PVAc and percent content of cellulose nanofiber

Conclusions:

- Addition of cellulose nanofiber to PVAc adhesive, improved the shear strength and elastic stiffness of the joints.
- Among the three concentration of CNF reinforcement studied, 1% addition was found to be optimum in terms of shear strength and elastic stiffness.
- The bonding ability of CNF reinforced PVAc improved as evident by the reduced percentage glue line failure.
- In the present study dispersion of CNF was ensured by premixing with water, which in turn caused a dilution of the resin. In spite of that, the results are quite encouraging. If an alternate method of CNF dispersion in PVAc is followed which may not cause adhesive dilution, then the reinforcing ability of CNF can be better realized.