Research Journal of Agriculture and Forestry Sciences ISSN 2320 – 6063
Vol. **8(2),** 21-26, April **(2020)** *Res. J. Agriculture and Forestry Sci.*

Feasibility studies on finger jointing of plywood sections

Asharam Nagar, Navneet Singh Sirswal, D.P. Khali, N. Ismita, V.S. Kishan Kumar* and Sachin Gupta
Forest Products Division, Forest research Institute, Dehradun, 248006, India
kishankumarv@yahoo.com

Available online at: www.isca.in, www.isca.me
Received 29th October 2019, revised 6th December 2019, accepted 19th January 2020

Abstract

This study explores the feasibility of end joining short pieces of commercial plywood through finger joints. The joints were glued with urea formaldehyde and poly vinyl acetate (PVAc) adhesives. It was observed that both the adhesives resulted in similar bending strengths of around 25N/mm^2 showing no glue effect. This was attributed to the absence of glue penetration into individual veneers which already had exposure to enough adhesives during manufacture of the plywood. The bending strength efficiency was in the 53%-61% range depending on the direction of face veneers. All jointed samples resulted in very high MoE efficiencies in the range of 84% to 97% as is seen in solid woods usually. The actual values ranged between 4440 N/mm^2 and 6240 N/mm^2 in two directions. Overall, the study demonstrated the potential of using finger joints for saving plywood offcuts that are wasted by the furniture manufacture industry to make longer sections with more than half of bending strength and very high elasticity compared to original unjointed plywood.

Keywords: Finger Joint, MoR, MoE, Plywood, Poly Vinyl Acetate (PVAc), Urea Formaldehyde.

Introduction

Wood and composite products of wood, including particleboard, plywood, and MDF are widely used in the manufacture of products used inside buildings such as furniture, flooring, doors, and cabinets[1]. A study conducted in Turkey showed that panel products are widely used in furniture manufacture, and out of the total wastage resulting from such industries, more than 96% was being used in heating homes and work places[2]. The wastage pattern in Australian furniture industry reports that offcuts from plywood as well as other panel products like MDF also contribute to wood wastage[3]. According to this study, most of such plywood offcuts are being used for charity purposes by many companies. However, those who mix such plywood and MDF offcuts with other solid wood waste actually cause contamination to the total waste resulting in lesser re-utilization.

Thus it becomes imperative to find ways of utilizing such small sections of plywood and other panel products. One way would be to join the short waste portions and utilise the joined sections in the furniture industry. Reports on joints of plywood sections are generally available for dowelled and lap joints. The bending strength of 4-6 inches pin hole dowel joints ranged between 18.2N/mm^2 and 38N/mm^2 according to one study[4]. Bending strength of 40N/mm^2 has reported for half lap joints of blockboards[5]. However, lap jointing is not advisable since a lot of material will be further wasted during the joint manufacture. A long list of items that can be made out of waste portions of plywood furniture which were designated as upcycling of plywood furniture wastes has been given by Deo[6]. These include wall mounted kitchen shelves, indoor hanging swings, fancy book/magazine shelves etc. Though these are attractive ideas, the strength parameters vis-à-vis requirements were not touched upon.

When 12mm (5-ply) thick Sugi and Karamatsu plywood specimens were loaded with a CN75 nail, it was found that though the grain direction of the surface veneer considerably affected the stiffness, the maximum load was only negligibly affected under embedment resistance[7]. In a test on lap jointed 4mm thick plywood of spruce (3 ply) with different adhesives, only 2.7 N/mm^2 of tensile strength could be acheived[8]. Frolovs et al. reported that the orientation of plywood surface layer had only minor influence on the shear and tensile strength of edge-to-surface joints made with 4mm, 6.5mm and 9mm thick birch plywood sections using poly vinyl acetate glue[9]. In a study on adhesive reinforced dowel joints on different commercial plywoods, it was found that sufficiently strong joints could be made for furniture applications[10]. In a study on staple joints, ply grain orientation was shown to have no effect on staple withdrawal strength from the plywood[11]. In another study, double pair metal-plate joint was shown to result in 50% more stiffness compared to single pair metal-plate joint in OSB furniture frames[12].

In Plywood frame corner joints with glued-in hardwood dowels, the bending capacities of the joints corresponding to modulus of rupture of the jointed glulam beams of about 30 N/mm^2 were obtained for both closing and opening moments for the small cross sections whereas, about 22N/mm^2 was obtained for larger cross sections[13]. The permissible limit of moisture content was found to be between 30-60% for better shear strength in 5 layer green-glues plywood[14]. In another interesting study, it is also reported that thick plywood with longitudinally scarf jointed veneers can have practicable bending performance, if the longitudinal joints of veneer are restricted to the inner layers[15].

Looking at the absence of finger jointing technology being adopted so far, a study was taken up to join plywood pieces using finger jointing so that short pieces of waste plywood in any furniture production unit can be efficiently utilized. It is pertinent to note that the usefulness of finger jointing technique in end jointing of solid woods is already established. There are reports on three African hardwoods, where efficiencies ranging from 72 to 94% have been achieved using melamine formaldehyde adhesive[16]. With Resorcinol formaldehyde adhesive, these hardwoods showed efficiencies in the range of 43–94% depending on the finger parameters and the end pressure used during joint mating[17]. Bending strength efficiencies of 34% to 42% and 23% to 35% only could be obtained for Eucalyptus when sections were joined with Urea Formaldehyde and PVA adhesives respectively[18]. However, up to 60% efficiency in MoR for eucalyptus with UF adhesive is reported by others[19]. It is to mention that near 100% efficiency in bending strength has been reported for mango wood using UF adhesive[20]. Thus it becomes imperative to investigate the strength of finger-jointed sections of commercially available plywood from utilization point of view for various end-uses.

Materials and methods

A commercial plywood (make DURO – all weather grade) by M/S Sarda Plywood industry was used in the present study. Finger jointed and control samples were prepared from four boards of size 203mm x 102mm x 18mm. samples were prepared in two directions: along and perpendicular (across) the grains of the face veneers.

For finger jointing, a profile with finger length of 20mm, pitch of 5mm and tip width of 0.8mm was used. Fingers were profiled parallel to the plain top surface. For jointing purpose, 250g of 100% Urea Formaldehyde (UF) in powder form was mixed with 180ml of water. For hardening purpose 5g (2% of resin) of ammonium chloride was added to the above to get a viscous solution of approximately 58.6% solid content. For reconfirmation of results, another two sets of finger jointed samples were prepared with a commercial PVAc adhesive also. Two sets of control samples (in two directions with respect to the face veneers) also were prepared for testing.

After applying the glue, the fingers were pressed on finger pressing vice at an end-pressure of 6N/mm^2 for a short period of time of 3-4 seconds. The jointed fingers were allowed to cure at room temperature for 48 hours. The numbers of samples thus prepared are given in Table-1.The broad directions given in IS: 1734 were followed in conducting the bending tests[21]. A uniform span of 450mm was adopted for all samples[22] which was more than 24 times the thickness of the plywood and all samples had a length of 500 mm.

Table-1: Details of plywood samples

Sample type	Adhesive	Sample name	No. of samples
Along the grain of face veneer	Control	CAlG	35
Across the Grain of face veneer	Control	CAcG	35
Along the grain of face veneer	UF	UFFjAlG	35
Along the grain of face veneer	UF	UFFjAcG	35
Along the grain of face veneer	PVAc	PvFjAlG	22
Along the grain of face veneer	PVAc	PvFjAcG	20
Total			182

Static Bending test was carried out on an automatic Universal Testing Machine (UTM). The specimen was placed at the middle such that it was at the right angle to the load. The load was applied on the joint which is the weakest section of the specimen. For control specimen, the load was applied at the centre.

The load was applied continuously throughout the test such that the movable head of the testing machine moves at 2.5mm/min. The readings of deflections corresponding to progressively applied loads were recorded automatically in a computer connected to the UTM. This process was continued until the samples broke and the loads at which the joint failure took place were also recorded for each sample. Graphs were generated with the deflections in mm recorded on the abscissa and corresponding load in N on the ordinate for each sample.

The UTM used had in-built software facility to determine the limit of proportionality and deflection corresponding to this point. Hence, the output of the UTM had all values calculated using the standard formulae given below:

$$MOR = \frac{3P'l}{2bh^2} \text{ N/mm}^2 \quad (1)$$

$$MOE = \frac{Pl^3}{4Dbh^3} \text{ N/mm}^2 \quad (2)$$

Where: P = load at limit of proportionality (N), P' = maximum load (N) at joint failure, l = span of sample (mm), b = breadth of sample (mm), h = height (thickness) of sample (mm), D = the deflection corresponding to the limit of proportionality (mm).

Statistical analyses were carried out using the SPSS package.

The efficiency of each strength parameter was calculated using the following formula:

$$Efficiency\ (\%) = \frac{\text{Mean of Parameter determined for jointed plywood section}}{\text{Mean of Parameter determined for unjointed corresponding section}} * 100 \quad (3)$$

Results and discussion

The calculated Modulus of Rupture (MoR) and Modulus of Elasticity (MoE) of unjointed as well as jointed samples are discussed separately.

MoR and MoE of Control (unjointed) samples in two directions: It was seen that the MoR of the 35 control (un-jointed) samples ranged between 31.8 and 62.6N/mm^2 for along the grain with a mean of 48.4N/mm^2. For the 35 across the grain un-jointed samples, the MoR was between 23.1 and 56.1N/mm^2 with an average value of 41.3N/mm^2. Usually, the strength values are reported to be higher along the grain. The strength values measured across the grain for 16mm plywood made of *Eucalyptus grandis*, *Fagus orientalis* and a hybrid poplar were nearly half of the values measured for along the grain samples[23]. It is to be noted that the MoR values claimed by the manufacturer are 50N/mm^2 along the grain and 30N/mm^2 across the grain[24]. Thus one can see that the values obtained in the study are almost in agreement with those claimed by the manufacturer. However, the difference of 20N/mm^2 claimed by them is not observed in the study with the strength across the face veneer grain showing high values. It is pertinent to note that a commercial plywood of marine grade showed absence of difference in the bending strength values along and across the grain for a range of 12-25mm thickness[25].

The mean values of MoE are 6807N/mm^2 for along the grain which ranged from 5078 to 8171N/mm^2 and 4931N/mm^2 which ranged between 3967 and 5502N/mm^2 for across the grain samples. Thus the MoE across the grain seems to be quite smaller. The MoE values measured along the grain are similar to that of 16mm plywood made of hybrid poplar[23]. A similar trend of reduced MoE values for three types of 9-veneered plywoods made out of birchwood is also reported[22]. The MoR values claimed by the manufacturer are 7500N/mm^2 along the grain and 4000N/mm^2 across the grain[24]. The values obtained in the present study almost agree with these claimed values. Higher MoE values in the range of 6000-90000N/mm^2 for 18 mm ply of beech wood have been reported which also had higher values in the along the grain direction[26].

MoR and MoE of finger-jointed samples in two directions: The MoR values of finger jointed (joined with UF adhesive) samples measured along the grain ranged between 18.5 and 33.7 N/mm^2 with a mean of 25.8 N/mm^2. The values of across the grain of this set of finger jointed samples ranged between 17.5 and 34.8N/mm^2. Average value of MoR of finger jointed samples across the grain is 25.3N/mm^2. This shows that there are huge reductions in the MoR values of finger jointed samples compared to the control samples in both along and across the grain direction when joined with UF. But what is more interesting is the fact that there seems to be practically no difference in the strengths of the sections joined with UF adhesive. As explained earlier, a set of samples were joined with PVAc adhesive also. The mean value in either direction in this case was 25.8N/mm^2 with standard deviation of just 5N/mm^2 in each case. Thus, the adhesive used to join the sections through finger jointing does not seem to have any effect on the resulting reduced strength.

The MoE values in along the grain direction of finger jointed samples (joined with UF) are between 2688 and 7326N/mm^2 with a mean of 5742N/mm^2. This value also seems to have reduced in comparison with unjointed samples. For the across the grain samples, the MoE values were between 3544 and 5429 N/mm^2 with a mean of 4519N/mm^2. Here also there looks to be a general reduction in MoE for the finger jointed samples joined with UF. In the case of samples joined with PVAc, the MoE values were again reduced with means of 6240N/mm^2 for along the grain samples and 4440N/mm^2 for across the grain samples. However, there looks to be very little similarity in the MoE values obtained with the two adhesives unlike in the case of MoR suggesting some role for the adhesive used to finger joint the plywood sections.

For confirmation of the observed similarities, the results were statistically analysed using SPSS.

Statistical analyses: All the 182 MoR values were subjected to one-way ANOVA to understand the statistical differences in the measured mean values. The analysis clearly indicated a very clear difference in the values with $p < 0.001$. Hence the values were further subjected to Duncan's homogeneity test and the results thereof are presented in Table-2.

Table-2: Duncan's subsets for MoR of all samples

Sample type	No. of Samples	Subsets of MoR (N/mm^2)		
		1	2	3
UFFjAcG	35	25.3		
PvFjAcG	22	25.8		
UFFjAlG	35	25.8		
PvFjAlG	20	25.8		
CAcG	35		41.3	
CAlG	35			48.4
Sig.		0.79	1.00	1.00

Table-2 shows that the unjointed plywood samples have slight but significantly higher bending strength when the samples had their face veneers along the grain. This is a usual phenomenon reported for many plywoods. In a recent report on plywood made with different progenies of *Melia dubia*, the mean MoR varied between 53.2N/mm^2 and 71.34N/mm^2 along the grain[27].

Very high MoR values exceeding 90 have been reported for 4 and 5 layered beech and poplar laminated samples made with 5 mm and 4 mm thick veneers using PVAc and Polyurethane adhesives[28].

However, in this study, more important is the behaviour of finger jointed sections of plywood. From Table-2, it is seen that MoR values along and across the grain of the finger jointed plywood samples used in the present study with either adhesive do not differ significantly (p=0.79) at all. It has already been reported that the orientation of plywood surface layer do not influence the shear and tensile strength of edge-to-surface joint made with PVAc[9]. On the other hand, one would have expected the glue used to mate the fingers to play some role in the bending strength. Glues like PVAc consist of long fibrous molecules which reduces their mobility and hence causes lower penetration into the wood[28]. Moreover, UF contributing to higher bending strengths in finger joints of various solid woods is widely reported like mango wood[30] and Eucalyptus[18,31].

Reports on the strengths of adhesive joints of plywood are rather limited. *There is a report on the bending strength of end-jointed blockboards with melamine urea formaldehyde adhesive made out of veneers[5]. Out of the two end to end joints (butt and mitre) studied, they reported that the mitre joint with 27 N/mm^2 was better than butt joint. They could increase the joint strength only by using a very long lap joint which leads to huge material waste.* The plywood that was used in this study is marked as "all weather grade" by the manufacturer which indicates that it is meant even for exterior uses.

Hence, it must have been made with exterior grade adhesives like phenol formaldehyde. Such adhesives which are able to diffuse into the cell walls and their curing in the cell walls results in higher hardness of the cell walls[29].

During the manufacture of the plywood, the wood veneers are almost completely spread with adhesive. Hence during subsequent joining of the sections, the possibility of the new glue (used for joining sections) penetrating the individual veneers is highly unlikely. Mechanical adhesion due to the glue filling up the voids in the surfaces only is expected and hence the low strength of UF joined finger jointed sections is in expected lines. Further, the similarity in MoR values obtained with both UF and PVAc adhesives (Table-2) proves the fact that there has been no diffusion of these adhesives into the wood structure. The absence of adhesive effect is further proven by the similarity of jointed samples' strength irrespective of the grain direction. It should be remembered that the control samples did show a directional effect.

All the 182 MoE values also were analysed in a similar manner and the results indicated differences in the measured MoE values of different sets of samples. The Duncan's subsets formed are given in Table-3.

Table-3: Duncan's subsets for MoE of all samples.

Sample type	No. of Samples	Subsets of MoE (N/mm^2)				
		1	2	3	4	5
PvFjAcG	22	4440				
UFFjAcG	35	4519				
CAcG	35		4931			
UFFjAlG	35			5742		
PvFjAlG	20				6240	
CAlG	35					6807
Sig.		0.658	1.000	1.000	1.000	1.000

Unlike in the case of MoR, the MoE values do exhibit significant differences in a more spread out pattern with the mean values being grouped into 5 subsets. For the unjointed samples, the values are much more in the grain direction of the face veneers (6807N/mm^2 against 4931N/mm^2). This is in agreement with the report on marine ply where the MoE values were lesser ranging from 3500N/mm^2 across the grain to 4500 N/mm^2 along the grain[25]. But what is more interesting is the fact that MoE is affected in both directions unlike usually found in solid woods. It is too often reported that finger jointing results in good MoE values in the case of solid woods irrespective of the adhesive used. It was argued that the elastic properties are more related to the wood rather than the adhesive bond[32]. Table-3 indicates that MoE has significantly lowered after finger jointing of plywood sections. In addition, the values along the grain direction also show an effect of glue used to join the sections. Those joined with PVAc show higher elasticity. However, in case of across the grain samples, this glue effect is absent.

Efficiency of joints: One of the methods to assess the suitability of finger joints is to evaluate the efficiency of MoR and MoE of the jointed sections against the unjointed sections. The efficiencies of finger jointed plywood samples (using the two adhesives) were calculated with respect to the values of control samples in either direction as described in the materials and Methods section. Table-4 gives the calculated efficiencies of finger jointed plywood section along and across the grain using the two adhesives.

Table-4: Efficiencies (%) of plywood finger joints.

	Along the grain		Across the grain	
	Using UF	Using PVAc	Using UF	Using PVAc
MoR (%)	53.3	53.3	61.3	62.5
MoE (%)	84.4	91.7	91.6	90.0

Table-4 shows that the efficiency of MoR along the grain are same for samples finger jointed with either adhesive. The salient point is that with either of the adhesive, more than 53 % of the original bending strength is retained. On the other hand, for across the grain samples, the efficiency with either adhesive is higher exceeding 60%. This is directly because of the lower strength of the control samples across the face veneers' grain direction. As seen from Table-2, these actually had no difference with the values of along the grain direction. MoR efficiencies in the 40-60% with PVAc adhesive are often reported in solid wood finger joints. A study on beech wood reported an MoR efficiency of 43.6% with PVAc adhesive when joined with smaller fingers of 9mm length[33]. However, Singh et al. have reported a 63% efficiency for finger jointed Eucalyptus sections using a similar finger profile that was used in this study and UF adhesive[34].

In the case of MoE, along the grain and across the grain efficiencies are more than 84% for the finger jointed samples which is very much like the behavior in solid woods. Higher MoE efficiencies are often reported with many adhesives in finger jointed solid woods. Good retention of MoE in the range of 83% to 98% for finger jointed African hardwood sections were reported with resorcinol-formaldehyde adhesive[17]. They attributed this to the fact that stiffness is more of a global phenomenon than MoR and is not very sensitive to joint properties.

The retention of high bending strength in the 50% to 60% range and very high retention of elasticity (>84 %) makes finger joints a potential technology to use up short pieces of plywood that are wasted by the furniture industry which use plywood as a base material.

Conclusion

The study reveals that it is possible to join short plywood sections with urea folrmaldehyde or polyvinyl acetate adhesives to obtain pieces with more than half the bending strength of original plywood. The directional difference, if any, observed in the unjointed plywood sections get neutralised in the case of bending strength after finger jointing. High stiffness is retained by the jointed sections like in solid woods. The study points to the fact that finger jointing can be potentially adopted by furniture industries to reduce wastage of short sections of plywood which arise during manufacture of furniture.

References

1. Güneri A. (2005). Handbook of Polymers in Construction. Smithers Rappa, Shrewbury.
2. Top Y. (2015). Waste generation and utilisation in micro-sized furniture-manufacturing enterprises in Turkey. *Waste Management*, 35: 3-11.
3. Daian G. and Ozarska B. (2009). Wood waste management practices and strategies to increase sustainability standards in the Australian wooden furniture manufacturing sector. *Journal of Cleaner Production*, 17 (17), 1594-1602. doi.org/10.1016/j.jclepro.2009.07.008
4. Eckelman C.A., Erdil Y.Z. and Zhang J. (2002). Withdrawal and bending strength of dowel joints constructed of plywood and oriented strandboard. *Forest Products Journal*, 52 (9), 66-74.
5. Nazerian M., Moazami V., Farokhpayam S. and Gargari R.M. (2018). Production of blockboard from small athel slats end-glued by different type of joint. *Maderas. Ciencia y tecnología*, 20 (2), 277-286. DOI: 10.4067/S0718-221X2018005021101
6. Deo R. (2015). Upcycle waste plywood into trendy home furniture. https://www.homify.in/ideabooks/274945/upcycle-waste-plywood-into-trendy-home-furniture (accessed on 22 June 2018)
7. Ogawa K., Harada M., Shibusawa T. and Miyamoto K. (2019). Method for measuring the resistances produced on parallel and perpendicular veneers in plywood under nail embedment loading. *Journal of Wood Science*, 65, 1 doi.org/10.1186/s10086-019-1786-4
8. Brožek M. (2016). Bonding of plywood. *Research in Agricultural Engineering*, 62(4), 198–204. doi:10.17221/ 39/2015-RAE
9. Frolovs G., Rocens K. and Sliseris J. (2017). Shear and tensile strength of narrow glued joint depending on the grain direction of plywood plies. *Procedia Engineering*, 172, 292-299. doi: 10.1016/j.proeng.2017.02.117
10. Zhang J., Erdil Y.Z. and Eckelman C.A. (2002b). Lateral Holding Strength of Dowel Joints Constructed of Plywood and Oriented strand Board. *Forest Products Journal*, 52 (7/8): 83-89.
11. Zhang J., Quin F., Tackett B. And Park S.H. (2002a). Direct withdrawal strength of single-staple joints in pine plywood. *Forest Products Journal*, 52 (2), 86-91.
12. Zhang J., Yu Y. and Quin F. (2016). Bending fatigue life of metal plate connected joints in furniture grade pine plywood. *Forest Products Journal*, 56 (11), 62-66.
13. Jensen J.L., Sasaki T. and Koizumi A. (2002). Plywood frame corner joints with glued in hardwood dowels. *Journal of Wood Science*, 48 (4), 289-294.
14. Lavalette A., Cointe A., Poimmier R. and Legrand G. (2016). Experimental design to determine the manufacturing parameters of a green glued plywood panel. *Holz als Roh-und Werkstoff* 74 (4), 543-551.
15. Shibusawa T., Toda J. and Tanikawa N. (2016). The effect of scarf jointed veneer on Mechanical performance of thick plywood. *Mokuzai Gakkaishi*, 62 (3), 73-79.

16. Ayarkwa, J., Hirashima, Y., Sasaki, Y. and Ando, K. (2000b). Effect of glue type on flexural and tensile properties of finger-jointed tropical African hardwoods. *Forest Products Journal*, 50 (10), 59–68.

17. Ayarkwa, J., Hirashima, Y., and Sasaki, Y. (2000a). Effect of finger geometry and end pressure on the flexural properties of finger jointed tropical African hardwoods. *Forest Products Journal*, 50 (11/12): 53–63.

18. Kishan Kumar V.S., Sharma, C.M. and Gupta S. (2013). Role of finger tip area on flexural strength properties of finger-jointed sections. *International Wood Products Journal*, 4 (2), 101-106.

19. Uday N.D., Mathews K.C., Mohandas K.K., Jagadish H.N. and Bansal A.K. (2005). Finger jointed timber from plantation species using indigenous machines. *Indian Forester*, 131 (4): 535–542.

20. Kishan Kumar V.S., Gupta S. and l Kothiyal V. (2011). Elasticity and rupture of finger jointed mango wood joined with two adhesives. *Indian Forester*, 137 (1), 88-93.

21. BIS (2005). IS: 1734 (Parts 11) – 1983 Methods of Test for Plywood (Second Revision). Bureau of Indian Standards, New Delhi, pp. 7.

22. Siim K., Kask R., Lille H. and Täkker E. (2012). Study of Physical and Mechanical Properties of Birch Plywood Depending on Moisture Content. 8th International DAAAM Conference, Industrial Engineering“, 19-21 April, Tallinn, 735-740.

23. Bal B.C. and Bektaş I. (2014). Some mechanical properties of plywood produced from eucalyptus, beech, and poplar veneer. *Maderas. Ciencia y tecnología*, 16 (1), 99-108. DOI 10.4067/S0718-221X2014005000009.

24. https://www.duroply.in/pdf/sarda-corporate-brochure.pdf The World of Duro, Vol. 2017. (accessed on 19 September 2019)

25. http://www.robbins.co.uk/pdf%20files/mar_plywood_technical.pdf (accessed on 09 March 2018)

26. Makowski A. (2019). Analytical Analysis of Distribution of Bending Stresses in Layers of Plywood with Numerical Verification. *Drvna Industrija*, 70 (1), 77-88. https://doi.org/10.5552/drvind.2019.1823

27. Khali D.P., Kumar, A., Shrivastava P., Chand V., Mehta N.S. and Kumar S. (2017). Boiling water resistant (BWR) grade general purpose plywood of selected different progenies *of Melia composita* Benth. *J. Timber Development Association of India*, 62-63, 7-18.

28. Kilic M. (2011). The effects of the force loading direction on bending strength and modulus of elasticity in Laminated Veneer Lumber (LVL). *BioResources*, 6 (3), 2805-2817.

29. Follrich J., Vay O., Veigel S. and Müller U. (2010). Bond strength of end-grain joints and its dependence on surface roughness and adhesive spread. *Journal of Wood Science*, 56, 429–434. DOI 10.1007/s10086-010-1118-1

30. Kishan Kumar V.S., Sharma C.M. and Gupta S. (2015). Compression and flexural properties of finger jointed Mango wood sections. *Maderas.Ciencia y tecnología*, 17 (1), 151-160. http://dx.doi.org/10.4067/S0718-221X2015005000015.

31. Ranjan M., Khali D.P., Ismita N., KishanKumar V.S. and Gupta S. (2019). Effect of adding Urea Formaldehyde in Polyvinyl acetate on the bending properties of Finger jointed Wood sections. *International Archive of Applied Sciences and Technology* 10 (1): 160-165. DOI: 10.15515/iaast.0976-4828.10.1.160165

32. Frihart C.R. (2005). Wood adhesion and adhesives. In: Rowell, R.M. (Ed.), *Handbook of wood chemistry and wood composites*, Boca Raton, Fla. CRC Press, 2005: 215-278.

33. Barboutis I. and Vasileiou V. (2013). Strength of finger - jointed beech wood (*Fagus sylvatica*) constructed with small finger lengths and bonded with PU and PVAc adhesives. *PRO LIGNO*, 9(4), 359-364. www.proligno.ro

34. Singh C.P., Gupta S. and Kishan Kumar V.S. (2018). Role of different gluing areas in deciding the bending strength of finger jointed timber. Research Journal of Agriculture and Forestry Sciences, 6 (12): 15-20.