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ANALYTICAL AND EXPERIMENTAL STUDIES ON STRESS CAPACITY WITH MODIFIED WOOD MEMBERS UNDER COMBINED STRESSES

H. Abdolzadeh [1,♠], Gh. Ebrahimi [2], M. Layeghi [3], M. Ghassemieh [4]

ABSTRACT

The stress capacity of joints made of modified wood members under loading can be affected by design of joints and type of adhesive. Hence, these factors were addressed in this study by assessment of stress capacity variations in corner joints under diagonal applied compressive load induced combined stresses. The joints with mitered and butted design were constructed by application of epoxy and polyvinyl acetate (PVAc) adhesives from furfurylated wood samples with two weight percentage gains (WPGs), i.e., 20% as low level and 60% as high level. Results indicated that stress capacity in both corner joints was not significantly decreased with increasing polymerization of furfuryl alcohol (FA) in wood. Despite the high compression strength in mitered joint, the induced compression stresses were low in comparison with butted joint. The stress capacity in mitered joint bonded with epoxy adhesive enhanced with increasing the level of furfurylation. This was true for shear stress parallel to grain as well. Generally, it could be concluded that mitered joint made of furfurylated members and bonded with epoxy adhesive would be stronger than other corner joints.

Keywords: Corner joint, Dowel, epoxy adhesive, furfurylation, stress capacity.

INTRODUCTION

Dowel-type timber connections are the most common connections applied in timber structures. The singularity of this type of timber connections is associated to the combination of very distinct materials and to the high anisotropy of wood. The knowledge of the mechanical behaviour of these dowel-type connections (e.g. load–slip relation, stress distribution, ultimate strength and failure modes) is important for their rational application. This complex behaviour is governed by several geometric, material and load parameters (e.g. wood species, dowel diameter, end and edge distances, space between connectors, number of connecters, clearance, friction and load configuration) (Itany and Faherty 1984). Some methods of analysis have been developed to assess the relationship between the involved parameters on mechanical behaviour of connectors and joints in different timber structures (Albin 1989, Eckelman 1989, Eckelmann and Rabiej 1985, Loferski and Gamalath 1989, Ozcifci 1995, Martins *et al.* 2013).

On the other hand, timber structures like furniture products and house frames in outdoor applications are subjected to varying outer forces and environmental conditions because of different service conditions. Dimensional instability and susceptibility to biodegradation are critical limitations of wood and wood-based composite materials exposed to weather. There are several approaches to cell wall modification, depending on what property is to be modified. For example, if the objective is water repellency, then the approach might be to reduce the hydrophilic nature of the cell wall by bonding on hydrophobic groups. If dimensional stability is to be improved, the cell wall can be bulked with bonded chemicals, or with a polymer as furfuryl alcohol (FA). The chemical modification of wood has been the subject of research for many decades (Banks and Lawther 1994, Kumar 1994, Lande *et al.* 2010, Rowell 1983, Stamm and Tarkow 1947, Thygesen *et al.* 2010).

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Furfurylation of wood results in polymer formation in wood cell lumens and cell walls. Because of the permanent bulking and grafting of FA polymer to the cell structure, furfurylation will also affect the stiffness, strength and brittleness of the wood (Lande *et al.* 2004).

Adhesive bonding technology has played an essential role in the development and growth of the conservation and repair of timber structures. The ability of a structural joint to maintain satisfactory long-term performance, often in severe environments, is an important requirement of a structural adhesive joint, as the joint should be able to support design loads, under service conditions, for the intended life time of the structure. A number of factors determining the durability of structural adhesive joints have been identified and can be grouped in three categories: environment, materials and stresses. The environment is dominated by temperature and moisture. The materials category includes the adherent, the adhesive, and the inter-phase between them. The last category refers to the stresses to which the bond is subjected during or after exposure to service environment which affects both longevity and residual strength (Custódio *et al.* 2009).

In this work some efforts were made to provide a general understanding on the effects of adhesive type and joint design on stress capacity, fracture behavior and mechanical strength of corner joints made of furfurylated beech wood for different outdoor usages. The main aim of this paper is comparison of stress capacity of corner joints constructed with modified members under combined stress using experimental and analytical methods.

MATERIAL AND METHODS

Materials

Joint members and fasteners

Furfurylated beech wood (*Fagus orientalis*) was selected as the member material for the joints.

As shown in Figure 1 wood dowels were made of beech wood, measured 10 mm x 30 mm (diameter x length), and were used as mechanical fasteners to assemble the members (Figure 1).

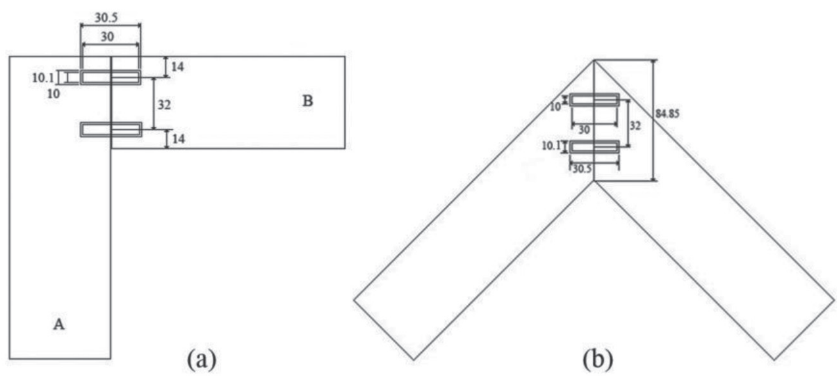

Figure 1. Dowel position and its dimensions (mm) in (a) butted joint and (b) mitered joint.

Moisture content (MC) and density of impregnated wood and control samples were measured according to ISO 3130 and ISO 3131(ISO standard 1975, ISO standard 1975).

Table 1. Density and moisture content (MC) of beech wood and wood polymer (wood-furfuryl alcohol).

Test materials		MC (%)	Density (kg/m^3)
Beech wood (*Fagus orientalis*)	Control	9,27 (0,32)	610 (59)
Wood-Polymer	Low	6,26 (0,43)	640 (41)
	High	4,61 (0,5)	710 (75)

The values in parentheses are standard deviations

Mechanical properties including static bending, tension perpendicular to grain, compression parallel and perpendicular to grain, shear parallel to grain and hardness of test materials were determined in accordance to ASTM D-143 (ASTM Standard 1994). Results are summarized in table 2.

Table 2. Mechanical properties of beech wood and wood polymer (wood-furfuryl alcohol).

Test materials		Static bending (MPa)		Compression parallel to grain (MPa)		Tension perpendicular to grain (MPa)	Compression perpendicular to grain (MPa)	Shear parallel to grain (MPa)	Hardness (KN)
		MOE	MOR	Max stress	E_L				
Beech wood (*Fagus orientalis*)	Control	11045 (2923,2)	94,21 (10,42)	36,45 (1,97)	3666 (357,8)	4,62 (1,44)	9,5 (5,28)	17,43 (3,49)	4,44 (0,46)
Wood-Polymer	Low	12971 (2898,9)	116,5 (23,85)	44,51 (7,11)	5369 (829,55)	3,36 (1,03)	11,84 (1,88)	27,85 (0,81)	7,72 (1,70)
	High	15575 (1930,4)	140,5 (27,08)	59,19 (14,08)	6375 (734,22)	2,23 (0,69)	14,54 (2,33)	32,43 (1,14)	9,15 (0,04)

The values in parentheses are standard deviations

Adhesive

Polyvinyl acetate (PVAc) adhesive and two component epoxy adhesive (Jalasanj 797C) were used in joint making process. Both adhesives were used at room temperature.

Methods

Furfurylation

Sound, straight-grain beech samples 60 mm × 30 mm in cross section and 160 mm in length were treated by a full-cell impregnation process in a lab-scale impregnating vessel. Two different furfuryl alcohol (FA) concentrations were used: 70 and 30%. Ethanol (95%) concentrations of 30 and 70% for high and low levels, respectively, were used for dilution of the samples. Specimens were impregnated with FA (98%, Merck) and 1,5% citric acid (98%, Merck) as a catalyst using the following procedure: (1) Pre-drying-Samples were dried at 60 ºC for 24 h and then weighed; (2) Impregnation-Samples were placed in a cylinder filled with FA solution, and a vacuum (0,10 bar) was applied for 45 min followed by a pressure of 6 bar for 2 h using compressed air. After removal from the cylinder, excess liquid was wiped from the samples; (3) Curing-Treated specimens were wrapped in aluminium foil and subjected to a temperature of 103 ºC for 16 h to cure; and (4) Drying-The foil was removed, the samples were kiln-dried for 168 h at 40 ºC, and the samples weighed before conditioning at 20 ± 1 ºC and 65 ± 3% RH. The weight percentage gain (WPG) was determined as an average of 20 and 60%, ranked as low and high levels of furfurylation, respectively.

Making experimental specimens

As mentioned earlier, solid beech dowels were used for mechanical connection of members. Epoxy and PVAc adhesives were used as gluing materials. A double-spread method was used where adhesive was applied to both the dowel hole and the surface of the dowels. After this, L-shaped test specimens were assembled as butted and mitred corner joints. The assembled test joints were clamped for 24 h to allow the adhesive to cure. In butted joints, member A had dimensions of 160 mm × 60 mm × 30 mm and member B had dimensions of 100 mm × 60 mm × 30 mm. However, in the mitred joints, both members had the same dimensions, 160 mm × 60 mm × 30 mm.

Testing procedure

As shown in figure 2 the corner joints were subjected to compression force causing a bending moment tending to close the joint. The load versus displacement curves were plotted by a computer of a testing machine for all tests.

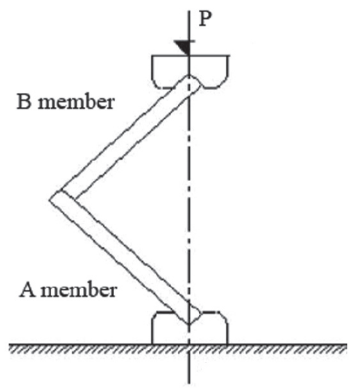

Figure 2. Test apparatus in diagonally loading corner joint (Tankut and Tankut 2009).

Tests were carried out at room temperature with a 30 KN loading capacity load cell on a universal testing machine (Instron 4486) at a speed of 5 mm/min (Tankut and Tankut 2009).

Experimental verification of the equations

Corner butted joint (α=0º) and mitered joint (α=45º) are illustrated in figure 3. The maximum stress induced on the joint surface (DE) by a force P is given by equations (1) to (7). The stress distribution in joints induced by variation of bending and axial forces was calculated as equations (6) and (7).

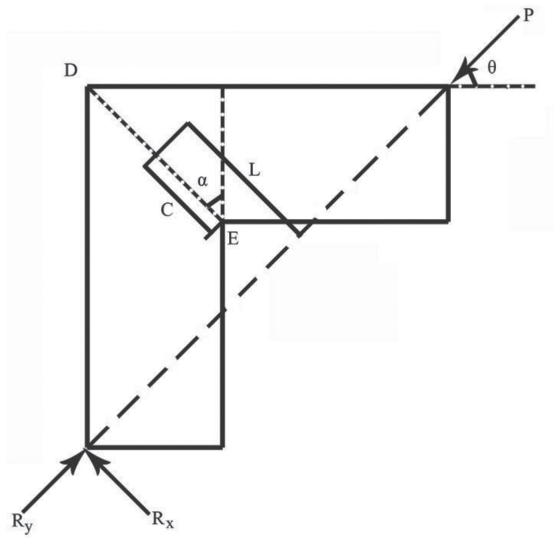

Figure 3. Schematic design of corner butted joint and mitred joint showing the applied force and support reaction forces.

$$M = P\,L \tag{1}$$

Where L = 70,71 mm

$$C = \frac{b}{2\ \cos\alpha} \tag{2}$$

$$I = \frac{tb^3}{12\ \cos^3\alpha} \tag{3}$$

Therefore maximum axial stresses (parallel to the grain), σ_a, in joint members are calculated as follows

$$\sigma_a = \frac{P\cos\theta}{tb} \pm \frac{MC}{I} \tag{4}$$

$$\sigma_a = -\frac{P\cos\theta}{tb} \pm PL\left(\frac{b}{2\cos\alpha}\right)\frac{12\cos^3\alpha}{tb^3} \tag{5}$$

$$\sigma_{a)_D} = -\frac{P\cos\theta}{tb} + \frac{6PL\cos^2\alpha}{tb^2} \tag{6}$$

$$\sigma_{a)_E} = -\frac{P\cos\theta}{tb} - \frac{6PL\cos^2\alpha}{tb^2} \tag{7}$$

As shown in figure 3 the shear stresses perpendicular to the grain of joint members, τ, in the member are given by

$$\tau = -\frac{P\sin\theta}{tb} \tag{8}$$

Failure load, P, of each joint was measured. Combined fiber stress, σ_a, and shear stress, τ, were calculated by the following value of α and θ into equations (6), (7), and (8) respectively.

At the butted joint which θ=45º and α=0º, the stress value, σ_a, is given by

$$\sigma_{a)_D} = -0,7071\ \frac{P}{tb} - \frac{6PL}{tb^2} \quad (9)$$

$$\sigma_{a)_E} = -0,7071\ \frac{P}{tb} + \frac{6PL}{tb^2} \quad (10)$$

And for the mitered joint which θ=45º and α=45º, it is given by

$$\sigma_{a)_D} = -0,7071\ \frac{P}{tb} - \frac{3PL}{tb^2} \quad (11)$$

$$\sigma_{a)_E} = -0,7071\ \frac{P}{tb} + \frac{3PL}{tb^2} \quad (12)$$

The shear stress perpendicular to the grain in butted and mitered joints at θ=45º is given by

$$\tau_{\perp} = 0,7071\frac{P}{tb} \quad (13)$$

Statistical analysis

One-sample Kolmegorov-Smirnov procedure was used to test normal distribution of collected data. Data were then analyzed using analysis of variance (ANOVA). Comparison of the means was carried out employing Duncan multiple range test (DMRT), with a 95% confidence level. All analyses were conducted by SPSS software. All experimental data were obtained with four replica.

RESULTS AND DISCUSSION

Fiber Stress at points D and E of L-type joint

The analysis of variance of the independent factors effects i.e., joint type, type of adhesive and furfurylation levels as well as the interaction between each of the factors on fiber stress at points D and E are given in table 3.

Table 3. Analyses of variance of independent factors effects and interaction between them on fiber stress at points D and E.

Source of variance	Degrees of freedom	Sum of square		Mean square		F value		P < 0,05 Sig.	
	Points D & E	Point D	Point E	Point D	Point E	Point D	Point E	Point D	Point E
Furfurylation	2	80,662	111,896	40,331	55,948	1,543	1,409	0,227	0,258
Joint	1	1672,342	864,703	1672,34	864,703	63,99	21,78	0	0
Adhesive	1	30,467	63,313	30,467	63,313	1,166	1,594	0,287	0,215
Furfurylation* Joint	2	90,303	129,048	45,151	64,524	1,728	1,625	0,192	0,211
Furfurylation* Adhesive	2	95,799	165,752	47,900	82,876	1,833	2,087	0,175	0,139
Adhesive* Joint	1	12,003	30,465	12,003	30,465	0,459	0,767	0,502	0,387
Furfurylation* Joint* Adhesive	2	52,853	89,349	26,427	44,674	1,011	1,125	0,374	0,336
Error	18	940,832	1429,578	26,134	39,711				
Total	24	29394,54	47774,93						

*Indicate interaction effect

According to results of ANOVA, Duncan multiple range test (DMRT) and stress values at points D and E (Table 4), the furfurylation level and adhesive type have no significant effect on stress values under diagonal compression.

Table 4. Effects of independent factors on fiber stress at points D and E.

Materials and process	Mean (MPa)		Standard Error	
	Point D	Point E	Point D	Point E
Control	25,09	-32,48	4,60	4,08
Low level of furfurylation	23,39	-30,52	3,59	2,98
High level of furfurylation	21,91	-28,75	2,58	1,56
Butted joint	29,36	-34,83	1,49	1,77
Mitered joint	17,56	-26,34	0,89	1,34
PVAc	24,26	-31,73	2,65	2,05
Epoxy	22,66	-29,43	3,11	2,71

Fiber stress at points D and E are increased by changing α angle from 45 to 0 degree as obtained from equations 9 to 12. Epoxy adhesive bonded butted joint in control (BCE) gave the maximum stress at points D and E under diagonal compression strength tests, however, epoxy adhesive bonded mitered joints in control (MCE) and also both furfurylation levels (MLE and MHE) gave the minimum stress (Table 5). As shown in figure 4, compression strength at all of the furfurylation levels and both adhesive types in mitered joints achieved the highest values which means that despite of showing high compression performance (joint strength under compression), fiber stress at points D and E had lowest value in this corner joint design.

Table 5. Results of Duncan multiple range test and mean fiber stress at points D and E according to interaction effects.

Materials and process	Mean (MPa)		Standard Error		DMRTa	
	Point D	Point E	Point D	Point E	Point D	Point E
BCP	31,56	-37,43	1,62	1,92	de	bcd
BLP	32,11	-38,08	1,65	1,96	de	cd
BHP	25,32	-30,03	4,12	4,88	bcd	abc
MCP	20,04	-30,06	1,18	1,77	abc	abc
MLP	19,79	-29,69	0,82	1,23	abc	abc
MHP	16,73	-25,10	2,57	3,86	a	a
BCE	34,02	-40,35	3,80	4,50	e	d
BLE	25,92	-30,74	3,84	4,55	bcde	abcd
BHE	27,26	-32,33	4,06	4,81	cde	abcd
MCE	14,73	-22,10	0,73	1,10	a	a
MLE	15,71	-23,56	0,35	0,54	a	a
MHE	18,35	-27,52	1,07	1,61	ab	ab

C: Control, L: Low level, H: High level, M: Mitered, B: Butted, P: PVAc adhesive and E: Epoxy.

Despite the fact that the butted joint indicated higher stress than mitered joint under diagonal compression, the compression strength value in mitered joint was higher than in the butted joint (Figure 4). These results demonstrate the importance of joint geometry and design in developing stress, so that jointing members in mitered form, resulted in high strength under compression load. Since this configuration induced less stress in this joint in comparison with butted joint, so it led to delay in fracture of dowel and members. This also demonstrates the fact that the connections are the critical locations of timber structures and about 80% of failures observed in timber structures are due to connections (Itany and Faherty 1984).

Indeed strength properties are modified as the result of many of chemical reactions which take place in wood. For example, shear strength parallel to grain was decreased in acetylated wood (Dreher *et al.* 1964), a slight decrease was observed in modulus of elasticity (Narayanamurti and Handa 1953) but no changes in impact strength (Koppers Acetylated Wood 1961) or stiffness (Dreher *et al.* 1964) have been reported. Wet and dry compressive strength (Dreher *et al.* 1964, Narayanamurti and Handa 1953), hardness, stress at proportional limit, and work to proportional limit are often increased due to chemical modification (Dreher *et al.* 1964).

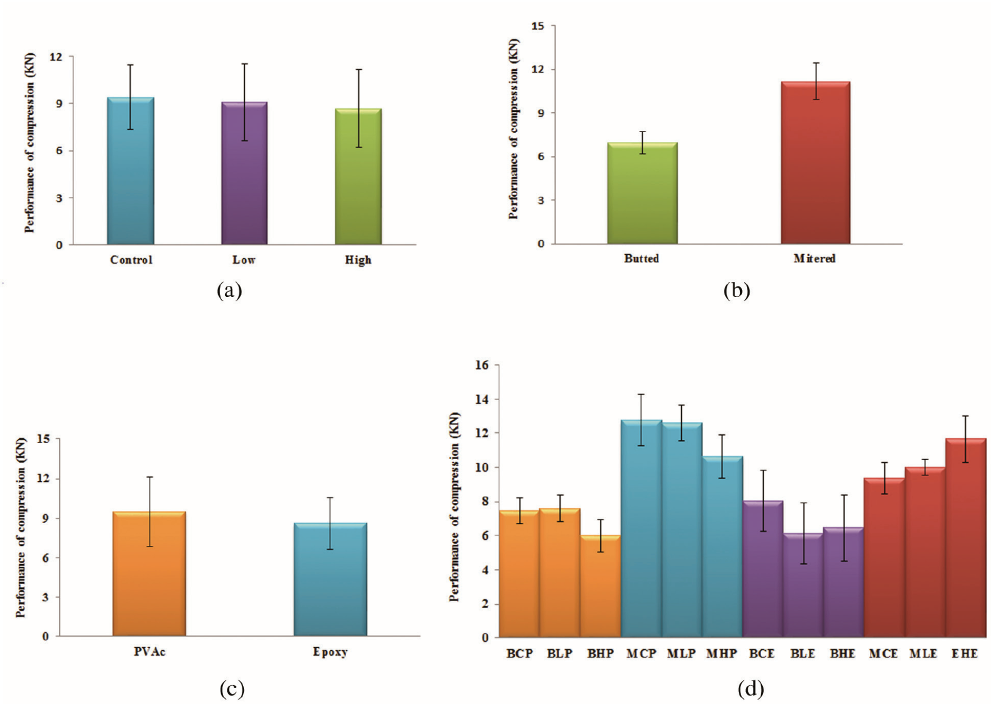

Figure 4. Performance of compression caused by independent effect of furfurylation level (a), type of joint (b), adhesive type (c) and interaction effects between them (d).
C: Control, L: Low level, H: High level, M: Mitered, B: Butted, P: PVAc adhesive and E: Epoxy.

In the butted joint under diagonal compression, members are subjected to tension perpendicular to grain. Drawback of timbers in structural applications is its low tension strength perpendicular to grain and shear parallel to grain. According to results in table 2, most of mechanical properties of furfurylated wood are increased except the tension perpendicular to grain. Tension perpendicular to grain is decreased about 21 to 50 percentage in low and high levels of furfurylation respectively. Compression parallel to grain strength is increased about 22 to 62 percent and compression perpendicular to grain is increased about 24 to 53 percent in low and high level of furfurylated samples respectively.

Since these strengths are influenced by furfurylation, the compression performance in butted joint is decreased. However the mitered joints (α=45º), not only are affected by tension perpendicular to grain of the furfurylated members, but also wood and wood polymer members are simultaneously affected by compression perpendicular to the grain. Therefore compression performance is increased (Figure 4d) by increasing compressive strength in furfurylated members in mitered joints.

Greater combined stress tolerated by the mitered joints would be related to the modes of failure. Figure 5 illustrates some main failure modes of joints under diagonal compression. As shown in figure 5, the modes of failure of the butted joints were tensile type, and for the mitered joints were mixed types of mode. Shear strength parallel to grain was higher than tensile strength perpendicular to grain and it also increased by increasing furfurylation level (Table 2).

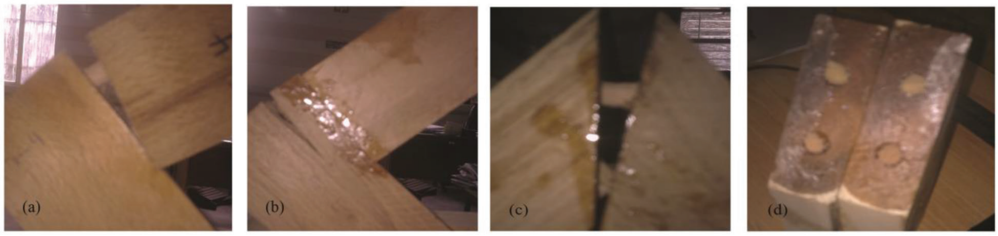

Figure 5. Main failure modes of butted and mitered joints under diagonal compression by (a, c) PVAc and (b, d) Epoxy adhesives on furfurylated members.

According to the above results, it can be claimed that furfurylation of the mitered joint members not only causes an increase in compression performance, but also can considerably affect fiber stress at the corner joint. Stress distribution in joints under diagonal compression is illustrated in figure 6.

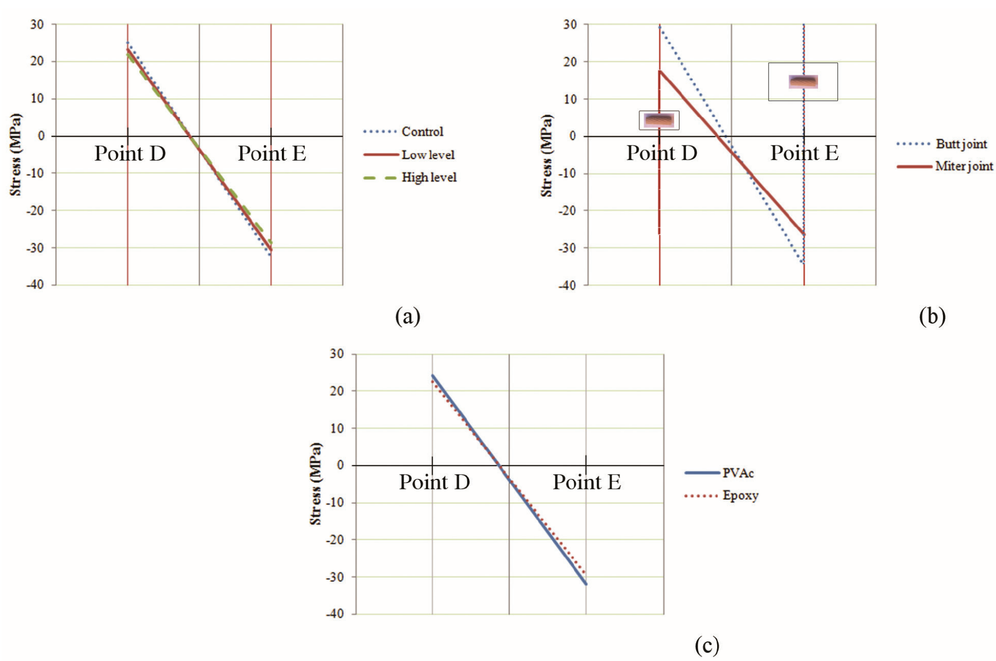

Figure 6. Stress distribution at joint surface (DE) under diagonal compression force in: (a) control and furfurylated members, (b) butted and mitered joint, (c) PVAc and epoxy adhesive as bond line. The distance between points D and E is 50 mm in the butted joints and 70,71mm in the mitered joints.

Experimental results indicated that failure occurred in mitered joints at point where located 26,4 mm far from outer corner of dowel hole. Consequently this is a point where the highest stress concentration occurred. By comparing experimental results with that of analytical findings, it can be concluded that failure will occur near to the outer corner of the second dowel hole where the joint is under tension (Figure 6b). However, stress distribution patterns in both dowels are the same.

These findings are in agreement with previous research in which the joints failures have been attributed to wood weakness in tension.

The performance of compression was decreased by increasing furfurylation level (Figure 4a). Also epoxy used in butted joint (Figure 4b, c) resulted in the reduction of the compression performance. The compression strength value resulting by interaction between independent factors (Figure 4d), shows highest value of strength in MCP, MLP and MHE (12,748, 12,59 and11,67 KN).

Experimental data have shown that, in spite of the negative effects that chemical preservatives bring to the adhesion, many types of modified timber can still be successfully bonded with specially formulated adhesives and by strictly following specific procedures (Tascioglu *et al.* 2003). However, studies about the effects of modification treatments as furfurylation on glue bonds using modern adhesives like epoxy are not practically available. Resins that are water-soluble and depend on a hydrophilic adherent for penetration like PVAc will be less efficient due to the decreased hydrophilic nature of the cell wall resulting from modification. Vick *et al.* (1993), Vick and Christiansen (1993), and Vick (1995) have investigated properties of some adhesives such as polyvinyl acetate (PVAc) in laminating two acetylated softwoods (Scandinavian pine, southern pine, and spruce) (Vick 1995, Vick and Christiansen 1993, Vick *et al.* 1993). Acetylated laminates with PVAc also resisted delamination as long as individual lamellae had equal acetyl content, but the unmodified lamellae performed better. All other wood adhesives develop poorer bonds to acetylated wood than to untreated wood (Davis 1997, Marra 1992, Vick 1999). According to our observations joints with furfurylated members bonded by PVAc adhesive were failed easily at bond line under diagonal compression force, but the same joints bonded with epoxy adhesive were resistant in bond line and fracture occurred in joint members (Figure 5).

The furfurylated members are weak in tension perpendicular to grain and so failures in butted joints of furfurylated members occurred at lower strength than untreated samples. In the mitered joint increased compressive parallel and perpendicular to grain strength could contribute to the furfurylated members' resistance under diagonal compression load. Therefore, in the mitered joint with epoxy adhesive, diagonal compression strength is increased by increasing the furfurylation levels.

Shear stress perpendicular to the grain ($\tau\perp$)

The analysis of variance of the independent and interaction effects of the joint type, type of adhesive and furfurylation levels on shear stresses are given in table 6. Based on the results of shear stress perpendicular to the grain ($\tau\perp$) (tables 6-8), the furfurylation level and adhesive type have no significant effect on shear stress values under diagonal compression. The mitered joints indicated higher shear stress under diagonal compression than the butted joints.

Table 6. Analyses of variance of independent factors effects and interaction between them on shear stress perpendicular to the grain ($\tau\perp$) in compression.

Source of variance	Degrees of freedom	Sum of square	Mean square	F value	P < 0.05 Sig.
Furfurylation	2	0,642	0,321	0,775	0,468
Joint	1	32,996	32,996	79,632	0
Adhesive	1	1,485	1,485	3,584	0,066
Furfurylation* Joint	2	0,866	0,433	1,045	0,362
Furfurylation* Adhesive	2	2,611	1,305	3,150	0,055
Adhesive* Joint	1	1,056	1,056	2,548	0,119
Furfurylation* Joint* Adhesive	2	1,612	0,806	1,945	0,158
Error	18	14,917	0,414		
Total	24	664,657			

*Indicate interaction effect

Table 7. The effects of independent factors on shear stress perpendicular to the grain ($\tau^{\perp}$).

Materials and process	Mean (MPa)	Standard Error
Control	3,70	0,46
Low level of furfurylation	3,57	0,56
High level of furfurylation	3,42	0,57
Butted joint	2,73	0,14
Mitered joint	4,39	0,22
PVAc	3,74	0,46
Epoxy	3,39	0,34

With regard to interaction effects of the independent factors on shear stress distribution, mitered joints with PVAc adhesive as bond line (MCP, MLP and MHP) and high level furfurylated members bonded with epoxy adhesive (MHE) indicated the maximum $\tau^{\perp}$ under diagonal compression strength tests. However, interaction of furfurylation and adhesives in butted joints gave the minimum $\tau^{\perp}$ under diagonal compression strength (table 8). Compression strength value at mitered joint was higher than butted joint as shown in figure 4. Therefore this shear stress values increased by increasing compression diagonal force as specified in equation 8.

According to the above results, it can be said that furfurylation had no directly significant effect on shear stress of the corner joints under compression.

The experimental results demonstrated that mitered joints showed higher shear stress perpendicular to the grain ($\tau^{\perp}$) than butted joints that contribute to members' failure.

Table 8. The results of Duncan multiple ranges test and mean shear stress perpendicular to the grain ($\tau^{\perp}$).

Materials and process	Mean	Standard Error	DMRT[a]
PCB	2,94	0,15	ab
PLB	2,99	0,15	ab
PHB	2,36	0,38	a
PCM	5,01	0,29	d
PLM	4,95	0,20	d
PHM	4,18	0,64	cd
ECB	3,16	0,35	ab
ELB	2,41	0,36	a
EHB	2,54	0,38	a
ECM	3,68	0,18	bc
ELM	3,93	0,09	bc
EHM	4,59	0,27	cd

C: Control, L: Low level, H: High level, M: Mitered, B: Butted, P: PVAc adhesive and E: Epoxy

CONCLUSIONS

The maximum value of stress under diagonal compression with regard to furfurylation level was observed in untreated beech wood as control and low level of furfurylation. The minimum stress occurred in high level furfurylated wood. The butted joints indicated higher stress under diagonal compression than the mitered joints.

With regard to stress distribution, mitered joints made of beech or wood polymer members bonded by either epoxy or PVAc adhesives exhibited lower stress at points D and E under diagonal compression load. However, the compression performances in mitered joint bonded by epoxy adhesive as bond line were increased by increasing furfurylation level. Therefore, it can be concluded that the furfurylation of mitered joint members not only improves the compression performance, but also has considerable influence on stress values at the corner joint.

Interaction effects of furfurylation and adhesive exhibited minimum $\tau^{\perp}$ in butted joints under diagonal compression strength. It was found that compression strength value at mitered joint was higher than the butted joint. Therefore this shear stress value is increased by increasing compression diagonal force. Consequently, it can be concluded that furfurylation had no significant effect on shear stress of the corner joint under compression.

Wood polymers as furfurylated members are used for external joinery, decking, garden furniture, play-ground equipment, marina jetting etc. Therefore, it is necessary for timber constructions to use appropriate geometry and design of joints under different loadings. When the furfurylated members are subjected to combine stress in the joints, it is suggested that the mitered joints with epoxy adhesive as bond line would be the best design option under diagonal compression. This choice would not only ensures best dimensional stability, but also the strength of construction members under diagonal compression would increase by increasing the furfurylation level.

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