WOOD RESEARCH
59 (2): 2014
343-350

EFFECTS OF POST-TREATMENT WITH CA AND CCA ON SCREW WITHDRAWAL RESISTANCE OF WOOD BASED COMPOSITES

Cihat Taşçioğlu*, Çağlar Akçay, Mesut Yalçin, Halil Ibrahim Şahin
Düzce University, Faculty of Forestry, Department of Forest Products Engineering
Düzce, Turkey

(Received March 2013)

ABSTRACT

The screw withdrawal resistances of three commercially available wood based composites (WBC), medium density fiberboard (MDF), particleboard (PB), and plywood (PW) were investigated after vacuum-impregnated with copper azole (CA) and chromated copper arsenate (CCA). Two different concentrations were used from both preservatives to obtained above-ground and ground contact retention levels. In addition to the untreated control specimens, a set of only water treated control specimens were utilized to differentiate effects of water (carrier) since both preservatives are water based. Screw withdrawal strengths of the treated boards were determined perpendicular to grain direction after fixation and conditioning periods.

The experimental results show that post-treatment with water-only significantly reduced screw holding strength of MDF and PB tested in the study. The CA and CCA treatments, however, did not cause any further reductions rather than reductions resulted from water-only treatments. The post-treated plywood, on the other hand, seems to be unaffected by water, CA and CCA treatments at all retention levels tested exhibiting the same level of screw holding strength after the post-treatments. The reductions in screw withdrawal strength need to be taken into account when and if such WBC treated with water-based preservative chemicals.

KEYWORDS: Copper azole, chromated copper arsenate, post-treatment, screw withdrawal strength, wood-based composites.

INTRODUCTION

Wood-based composites (WBC) are complex materials exhibiting important anisotropic properties (Bucur 2010). Such products are becoming more widely utilized for replacements of solid wood in today's building structures. Structural and non-structural engineered wood composites, such as oriented strand board (OSB), plywood (PW), particleboard (PB), medium density fiberboard (MDF) and laminated veneer lumber (LVL), are now used in both interior and exterior applications (Laks 2002; Kirkpatrick and Barnes 2006). Since their major component is wood, such composites are prone to biodeterioration and biodegradation by wood-destroying organisms (fungi, insects, termites etc.). Therefore their protection has become an important issue (Gardner at al. 2003; Larkin et al. 2008). WBCs can be protected by various methods such as in-line treatment (addition of biocides during the production process) or post-treatment (treated with biocides after the production of composites). Nevertheless each method has its own advantages or disadvantages when effects on mechanical properties, distribution of biocide chemical and challenges in the manufacturing process are considered (Baileys et al. 2003; Kirkpatrick and Barnes 2006). While the most practical method is the post-treatment, it has adverse effects on dimensional stability, mechanical properties and requirements on re-drying. Mitchoff and Morrell (1991) who studied effects of plywood source and preservative chemicals (CCA and ammonical copper zinc arsenate, (ACZA)) on treatability noted that ACZA post-treatment was found better than CCA in penetration and retention values without any change of mechanical properties. Gardner et al. (2003) reported that post-treatment of yellow-poplar LVL with creosote did not result any detrimental effect on preservative distribution, bending modulus of elasticity (MOE), and shear strength in adhesive line. In addition, glued laminated beams (Glulam) made from hardwood and bonded with resorcinol-formaldehyde resin showed no negative effect on bond quality and mechanical properties after impregnating process with creosote. Although adhesives are generally used in permanent joining of wood materials, screws and nails are also indispensable tools for wood construction (Ozciftci and Doganay 1999). The material density, screw diameter and depth of penetration are well known important factors affecting screw withdrawal strength of wood-based composites (Herzog and Yeh 2006). Unfortunately, the effects of post-treatments on screw withdrawal strength of wood-based composites had not been studied. Although CCA had been phased out from residential constructions, it was chosen as a reference chemical since it was heavily utilized before 2004. The CA, on the other hand, represents a new generation preservative chemical and maintains much higher pH (around 8.5) when compared to CCA (pH around 3) which allows us to compare effects of the two values which are on the opposite sides of the pH spectrum. The aim of this study is to investigate effects of post-treatments with CCA and CA chemicals on screw withdrawal resistance of commercial wood-based composites (MDF, PB and PW). Effects of increased retentions and treatment with only carrier (water) were also evaluated against withdrawal strength.

MATERIAL AND METHODS

Wood-based composites

The experimental specimens (75 x 75 x thicknesses) were prepared from commercially available wood based composites; medium density fiberboard (MDF), particleboard (PB) and plywood (PW). MDF and PB were purchased from a major manufacturer in Turkey (Kastamonu Entegre Inc). PW were obtained a local manufacturer in Ankara, Turkey. Oven-dried densities of the composites were calculated as 0.54, 0.54 and 0.57 $g.cm^{-3}$ for MDF, PB and PW, respectively. The manufacturing details, raw materials and adhesives of the wood based composites tested were given in Tab. 1. The cut ends of specimen boards were coated with a two-component epoxy to simulate full size board treatment conditions. All specimens were conditioned at 20 ± 2°C and 65 % relative humidity (in laboratory conditions) for 2 months until they reach stable weight before and after the treatments.

Tab. 1: Some features of wood – based composites tested.

Composite	Thickness (mm)	Density ($g.cm^{-3}$)	Adhesive	Raw material
MDF	19.3	0.54	UF*	Mixed fibers (beech 55, oak 25 and pine 15 %), 3-layered (2+15+2 mm)
PB	18.9	0.54	UF*	Mixed particles (pine 70, poplar 30 %), 3-layered (4+10+4 mm)
PW	19.4	0.54	PF**	Shell plies okoume, core plies poplar and beech, 11 plies (1+2+2+2+2+2+2+2+2+2+1 mm)

*UF, Urea formaldehyde; **PF, Phenol formaldehyde (boiled-water resistant for exterior)

Preservative chemicals

Chromate copper arsenate (CCA) and copper azole (CA) were supplied from a national wood preservative chemical supplier. Both preservatives are water based and initial pH values of experimental solutions were approximately 3.57 and 9.04 for CCA and CA, respectively. The chemical compositions of preservatives solutions were given in Tab. 2.

Tab. 2: Chemical compositions of wood preservatives tested.

Preservative	Chemical composition	
CCA-C	Chromium as CrO_3	47.5 %
	Copper as CuO	18.5 %
	Arsenic as As_2O_5	34.0 %
CA-A	Copper as Cu	49 %
	Tebuconazole as $C_{160}H_{23}ClN_3O$	2 %
	Boric acid as BH_3O_3	49 %

Treatment

Two different treatment schedules were applied depending on permeability, density profile and glue-line interaction of wood-based composites tested. Before the actual treatments, a series of treatments were conducted with distilled water to determine solution uptake ability of wood-based composites. Based on these preliminary findings, solution concentrations were calculated to achieve the target retentions. Details of treatment schedules used were given in Tab. 3. Both treatment processes were applied in a full size treatment retort. Eight specimens for each composite type (MDF, PB and PW), preservative type (CA and CCA) and retention level (low and high) were treated. Based on the 3 x 2 x 2 experimental design, the number of treated specimens was 96. A total of 144 specimens were tested including untreated and water treated controls. The retention values of CCA and CA were calculated from mass difference of each treated material before and after treatment. The epoxy coatings were removed and a six-week post-treatment conditioning period was applied before the subsequent screw withdrawal strength test. The retention for each treatment solution was calculated following formula

$$R = \frac{G \times C}{V} \times 10 \tag{1}$$

where: R-the retention amount of treatment solution,
G-(T_2-T_1) is the grams of treating solution absorbed by the composite (initial weight of composite subtracted from the initial weight plus the treating solution absorbed),

C-the grams of preservative or preservative solution in 100 g of the treating solution;
V-the volume of composite material.

Tab. 3: The details of post-treatment schedules applied.

Composites	Vacuum/pressure time	Conditions
MDF, PB	15 min (vacuum)	600 mm Hg
PW	15 min (vacuum) 60 min (pressure)	600 mm Hg 8 kPa.cm^{-2}

Screw withdrawal resistance test

The screws were manually inserted into specimens according to ASTM D-1037 standard (ASTM D-1037 2005; Altinok and Kilic 2003) Fig. 1. A screw tip penetration of about 12 mm was maintained. The sample with a screw was then fixed in the testing machine such a way to deliver axial withdrawal force. The details of experimental setup were given in figure. The rate of withdrawal was set 1.5 mm.min^{-1}. The flathead type screws were used in 4 mm diameter (21 x 40 mm) and made of low carbon steel. The maximal force (F_{max}) required to withdraw the screw from the specimen was recorded at the end of each test. Based on these data, the screw withdrawal resistance of the composites was calculated according to the following formula:

$$\sigma sw = \frac{F}{A2\pi rh} \qquad (2)$$

where: F - applied force (N),
A - the surface area of the screw into the sample (mm^2),
r - radius of the screw (ASTM D-1037, 2005).

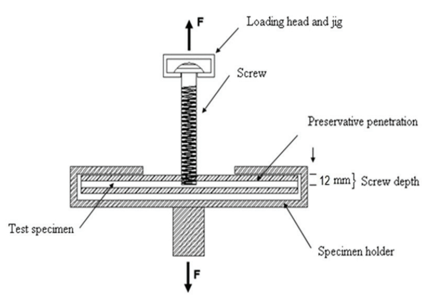

Fig. 1 : Experimental setup for screw withdrawal strength test.

RESULTS

Retentions

CA and CCA retentions in the treated wood-based composites were shown in Tab. 4. While the highest retention was recorded for PB specimens with 30.18 kg.m^{-3}, the PW specimens exhibited the lowest retentions which ranged from 11.54 to 20.65 kg.m^{-3}. The retention values of MDF were between the values of PB and PW.

Tab. 4: Mean retention (kg.m^{-3}) values of CA and CCA treated wood-based composites (numbers in parenthesis are standard deviations).

Preservative and its concentrations	MDF	PB	PW
CCA 2.4 %	11.43 (0.50)	15.18 (0.21)	12.16 (0.59)
CCA 4.8 %	21.57 (0.34)	30.18 (1.08)	17.46 (5.40)
CA 2.4 %	11.75 (0.73)	15.21 (0.41)	11.52 (1.96)
CA 4.8 %	22.47 (0.51)	30.18 (0.70)	20.65 (5.47)

Screw withdrawal strength

Effects of water-only treatments and different concentrations of wood preservative treatments on screw holding strengths of wood-based composites were shown on Tabs. 5, 6 and 7. The highest reductions in screw withdrawal strength were recorded for post-treated particleboards (PB) as 41.5 and 40.3 % in low-retention CA and high-retention CCA treatments, respectively (Tab. 5). The major reductions in withdrawal strength of MDF boards were recorded as 20 and 25.4 % for water-only and high retention CCA treatments, respectively. Post-treatment of PW with water and preservative chemicals, on the other hand, did not resulted in significant reductions in screw withdrawal strength.

DISCUSSION

Retentions

As expected there are variations in retention values due to permeability differences of composites tested (Tab. 4). Based on density profiles of wood-based composites tested, PB is known with the highest permeability in its core section therefore it resulted in the highest retentions with water and both preservative chemicals.

Screw withdrawal strength

In general, there are considerable reductions on screw withdrawal strength of all composites after the treatments with an exception of PW (Tab. 5). The different characters (*a*, *b*, *c*, *d*) given in the same row indicating significant differences between the means of withdrawal strengths based on SPSS statistical analysis (SPSS 2010). Statistical comparisons among CCA and CA retention levels did not reveal any linear relation between the increase in retentions and decrease in screw withdrawal strength properties of post-treated PB and MDF boards (Tabs. 5, 6, and 7) (Ozkan et al. 2011).

Tab. 5: Effects of CCA and CA post-treatments on screw holding strength (N.mm^{-2}) of PB.

		Means		Reduction (%)	Std. deviation	Minimum	Maximum
Untreated		3.37	***b***		0.67	2.72	4.53
Water		2.22	***a***	33.9	0.26	1.81	2.49
CA	2.4 %	1.96	***a***	41.5	0.37	1.21	2.34
	4.8 %	2.40	***a***	33.8	0.31	2.12	3.10
CCA	2.4 %	2.11	***a***	37.1	0.27	1.74	2.49
	4.8 %	2.01	***a***	40.3	0.20	1.66	2.34

Tab. 6: Effects of CCA and CA post-treatments on screw withdrawal strength ($N.mm^{-2}$) of MDF.

		Means		Reduction (%)	Std. deviation	Minimum	Maximum
Untreated		5.55	***d***		0.34	4.91	6.04
Water		4.44	***ab***	20.0	0.63	3.63	5.52
CA	2.4 %	5.11	***cd***	7.9	0.43	4.68	6.04
	4.8 %	4.86	***bc***	12.4	0.46	4.23	5.74
CCA	2.4 %	4.60	***abc***	17.1	1.07	2.72	6.04
	4.8 %	4.14	***a***	25.4	0.33	3.55	4.53

Tab. 7: Effects of CCA and CA post-treatments on screw holding strength ($N.mm^{-2}$) of PW.

		Means	Reduction/Increase (%)	Std. deviation	Minimum	Maximum
Untreated		6.59 ***a***		2.02	3.02	9.44
Water		6.28 ***a***	4.70(-)	1.20	4.68	7.63
CA	2.4 %	6.69 ***a***	1.51(+)	0.79	5.67	7.86
	4.8 %	7.05 ***a***	6.98(+)	1.64	5.06	9.29
CCA	2.4 %	6.81 ***a***	3.33(+)	1.03	5.89	8.84
	4.8 %	6.69 ***a***	1.51(+)	1.60	4.99	9.44

The major reductions in screw withdrawal strength of PB and MDF were recorded on all treatments including water-treated controls. This phenomenon indicates that almost all reductions in withdrawal strength was caused by carrier (water-only) treatment suggesting that active ingredients of both preservatives seemed to have insignificant effect. Previous findings indicated that post-treatment of wood-based composites with water and water-based preservatives caused excessive swelling ranging from 2.28 to 18.55 % depending on composite type and preservative chemical (Tascioglu and Tsunoda 2010). Irreversible swellings due to preservative chemicals or water at this extend could have damaged the integrity of adhesive lines and reduce screw withdrawal strength of the post-treated panels. One possible explanation of this might be related to preservative penetration. Since glue lines in PW play an inhibiting role in biocide distribution, core sections of post-treated PW might not exposed to water and preservative chemicals at calculated retention levels (Van Acker and Stevens 1989; Khouadja et al. 1991). Therefore, screws drawn into composite material came across some partially untreated sections of wood veneers.

In conclusion, post-treatment with water and water-based preservative chemicals (CCA and CA) significantly reduced screw holding strength of PB and MDF composites. Statistical comparisons among CCA and CA retention levels did not reveal any linear relation between the increase in retentions and decrease in screw withdrawal strength properties of post-treated PB and MDF boards. In contrast, there was no detrimental effect on the screw withdrawal strength properties of PW after the post-treatment with water, CCA and CA at any retention level tested. At the same time, the reductions in screw withdrawal strength of PB and MDF should be taken into account when evaluating the performance of post-treated wood-based composites in the engineered wood, construction and furniture industries.

ACKNOWLEDGMENT

The authors acknowledge undergraduate students of Department of Forest Products Engineering, Yasin Ozkan, Kadir Sahin Baskal, Cuneyt Erenturk for their support to conduct this research project as a fulfillment of graduation thesis.

REFERENCES

1. Altinok, M., Kiliç, A., 2003: Determination of some mechanical performances of particle board covered with roll (continue press laminate) laminate. (Rulu laminanti continue press laminate ile kaplanmis yonga levhanın bazı mekanik performanslarının belirlenmesi). Gazi University Journal of science 16(3): 559-566, ISSN 1303-9709 (in Turkish).
2. ASTM-D 1037, 2005: Standart test method for evaluating properties of wood base fiber and particle panel materials.
3. Baileys, J.K., Marks, B.M., Ross, A.S., Crawford, D.M., Krzysik, A.M., Muehl, J.H., Youngquist, J.A., 2003: Providing moisture and fungal protection to wood-based composites. Forest Products Journal 53(1): 76-81.
4. Bucur, V., 2010: Delamination detection in wood – based composites, a methodological review. Proceedings of 20th International Congress on Acoustics, 23-27 August, Sydney, Australia, 1-5: 835-843, ISBN: 978-1-61782-745-7.
5. Gardner, D.J., Tascioglu, C., Wâlinder, M.E., 2003: Wood composite protection. In: Wood Deterioration and Preservation: Advances in Our Changing World. American Chemical Society, Goodell, B., Nicholas, D., and Schultz, T.P. (eds.), Washington D.C.. Pp 399-419.
6. Herzog, B., Yeh, B., 2006: Nail withdrawal and pull-through strength of structural use panels. Proc. 9th World Conference on Timber Engineering 6 – 10 August 2010, Portland, Oregon, Technical presentation. Pp 110.
7. IBM SPSS Statistics, 2010: 19.0 version.
8. Khouadja, A., Barnes, H.M., Lyons, D.E., 1991: Properties of CCA treated southern pine plywood after redrying. Proc. Am. Wood. Pres. Assn. 87: 82-89.
9. Kirkpatrick, J.W., Barnes, H.M., 2006: Biocide treatments for wood composites—A Review. The International Research Group on Wood Protection, Doc. No. IRG/WP 06 40323, Stockholm, Sweden, 20 pp.
10. Laks, P.E., 2002: Biodegradation susceptibility of untreated engineered wood products. In: Enhancing the durability of lumber and engineered wood products. FPS Symposium Proceedings, Forest Products Society: Madison, WI. 7298(7249): 125-130.
11. Larkin, G.M., Merrick, P., Marek, J., Gnatowski, M., Laks, P.E., 2008: In: process protection of wood composites: An Industry Perspective. ACS Symposium Series, Washington. 982(27): 458-469.
12. Mitchoff, M.E., Morrell, J.J., 1991: Preservative treatment of plywood panels from the Pacific Northwest. Forest Products Journal 41(9): 11-18.
13. Ozcifci, A., Doganay, S., 1999: Screw withdrawal resistances of beech, spruce wood and waferboard. Turkish Journal Agriculture and Forestry. (Etiket Yongalı Levha (Waferboard) ile Doğu Kayını ve Ladin Odunlarının Vida ve çivi Tutma Dirençleri), Turk J. Agrıc. For. 23: 1207-1213 (in Turkish).

14. Ozkan, Y., Baskal, K.S., Erenturk, C., 2011: The effects of post treatment on screw withdrawal resistance in wood based composites. Undergraduate Thesis, Faculty of Forestry, Duzce University, Turkey (Emprenye İsleminin Odun Bazlı Kompozitlerde Vida Tutma Direnci Uzerine Etkisi. Lisans Tezi, Duzce Universitesi, Orman Fakultesi), 31 pp (in Turkish).
15. Tascioglu C., Tsunoda, K., 2010: Biological performance of copper azole-treated wood and wood-based composites. Holzforschung 64(3): 399-406.
16. VanAcker, J.V., Stevens, M., 1989: Treatment of poplar plywood with solvent and waterborne preservatives. The International Research Group on Wood Preservation, Stockholm, Sweden IRG/WP/3538.

Cihat Taşçioğlu*, Çağlar Akçay, Mesut Yalçin, Halil Ibrahim Şahin
Düzce University
Faculty of Forestry
Department of Forest Products Engineering
81620, Düzce
Turkey
Phone: +90 543 778 2
Corresponding author: cihattascioglu@duzce.edu.tr, cihattascioglu@yahoo.co