CWPA Proceedings, 2009, 262-271

PERFORMANCE OF PARTICLEBOARDS TREATED FOR FIRE RESISTANCE

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Summary

The fire-retardant performance of wood particleboards treated with boric acid at three percentages (8, 12 and 16%) was determined. The treatment was conducted during particle blending. Fire-retardant properties were measured according to ASTM D3806 Standard Test Method of Small-Scale Evaluation of Fire-Retardant Paints, (2-Foot Tunnel Method). Particleboards treated with 16% boric acid showed the best fire-retardant properties, particularly in terms of mass loss and flame spread speed after-flaming. The use of internal bark of white birch as dispersant also improved particleboard mass loss during fire testing. The use of boric acid not only decreased the flame spread speed but also greatly improved the internal bond and thickness swelling of manufactured particleboards over controls.

Keywords: boric acid, fire-retardant properties, internal bond, thickness swelling

1. Introduction

To make wood flame resistant, it should be treated with a fireproofing agent. Many studies have been conducted on wood treatments for fire resistance. For example, the use of a solution containing urea, phosphoric acid and ethanol to treat wood against fire imparted a high degree of fire retardation (Basson and Conradie, 2001). Saka et al., (1992) treated western hemlock with silica gel and found that treated wood displayed greater resistance to burning compared to untreated wood. Pereyra and Giudice, (2009) used flame-retardant impregnants based on alkaline silicates to treat wood which displayed high fire-retardant efficiency as well as high water insolubility after treatment.

The main objectives of this study were to:

- Manufacture particleboards with added boric acid as a fireproofing agent;
- Investigate the fire-retardant properties, the internal bond and thickness swelling of the produced particleboards.

2. Method

Boric acid powder was added to wood particles during blending. Fine internal bark particles of white birch *(Betula papyrifera)* were mixed with boric acid powder to thoroughly disperse it in the fine wood particles used to manufacture particleboard surface layers.

Statistical analyses were performed with SAS using a factorial experiment method in a complete randomized block design (CBD). Two factors were taken into account. The first was the dispersant agent (bark particles) percentage, assumed to be a qualitative factor at two levels: 30% versus 20%. The second was the percentage of boric acid added to wood particles, assumed quantitative at three levels: 8, 12 and 16%. Blocking was used to prevent nuisance factor from known and controllable sources of variability (Montgomery 1997). A total of 6 particleboard types were generated. Each type was replicated three times for a total of 18 particleboards. Three control (untreated) particleboards and 3 particleboards treated with 16% boric acid but without bark particles were also manufactured for comparison.

After blending stage, mats were manually formed in a frame prior to hot pressing, using a conventional steam-heated Diffenbacher press equipped with a Press-Man monitoring system (ARC). Particleboards were conditioned at a temperature of 21°C and 65% relative humidity until they reached equilibrium moisture content (four weeks) before testing.

3. Results and Discussion

Results of complete block analysis are summarized in Table 1. Figures 1 to 6 show the effects of treatment on internal bond strength (IB), thickness swelling (TS), weight loss (WL), thickness loss (TL), flame spread speed (FS) and sample temperature at the end of testing, respectively. Results of multiple comparisons using the least significant difference (LSD) test are also shown. The LSD test was used only to compare the properties of 6 manufactured particleboard types with those of control particleboards.

Table 1. Summary of variance analysis (ANOVA) [**DF** = degree of freedom, **IB** = internal bond, **TS** = thickness swelling, **FS** = flame spread speed, **WL** = weight loss, **TL** = thickness loss (measured at the point directly above the burner), **T** = temperature]

Source of variation		**(F values)**		**Fire-retardant performance (F values)**			
	df	**IB**	**TS**	**FS**	**WL**	**TL**	**T**
Block	2	0.43 ns	1.55 ns	0.44 ns	2.47 ns	1.00 ns	0.02 ns
%B	1	8.34*	0.61 ns	0.06 ns	76.59**	4.81 ns	0.03 ns
%BA	2	7.20*	22.61**	2.15 ns	47.50**	0.03 ns	0.43 ns
%B × %BA	2	2.93 ns	0.46 ns	0.93 ns	0.41 ns	0.36 ns	2.77 ns
Contrasts							
%B	1	8.34 ns	0.61 ns	0.06 ns	76.59**	4.81 ns	0.03 ns
%BA-L	1	13.30**	41.50 ns	2.88 ns	79.39**	0.01 ns	0.77 ns
%BA-Q	1	1.11 ns	3.72 ns	1.42 ns	15.61**	0.05 ns	0.09 ns
%B × %BA-L	1	4.47 ns	0.91 ns	1.64 ns	0.82 ns	0.02 ns	4.9 ns
%B × %BA-Q	1	1.39 ns	0.02 ns	0.22 ns	0.01 ns	0.71 ns	0.61 ns

Description of abbreviations : **%B** = bark percentage used as boric acid dispersant; **%BA** = percentage of boric acid; **%B×%BA** = interaction between (%B) and (%BA); **%BA-L** = linear effect of boric acid percentage; **%BA-Q** = quadratic effect of boric acid percentage; **%B × %BA-L** = contrast bark percentage **versus** linear effect of boric acid percentage; **%B × %BA-Q** = contrast bark percentage **versus** quadratic effect of boric acid percentage; **ns** = non significant, ***** = significant at 0.05 probability level; ****** = significant at 0.01 probability level

3.1 Internal bond (IB)

IB values are presented in Figure 1. All particleboards met the standard requirements for M-1 type particleboards. ANOVA results show no significant interactions between bark particles and boric acid for IB (Table1). However, a highly significant linear effect of the increase in boric acid percentage on IB improvement was found. The highest IB value was obtained for particleboards made with 16% boric acid dispersed in wood particles with 20% bark particles. LSD results show a significantly higher IB over control particleboard (Figure 1).

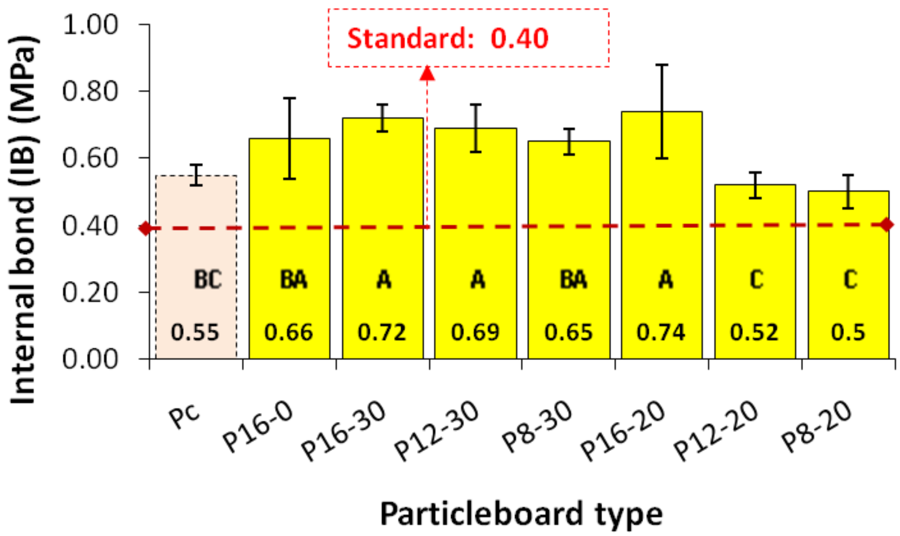

Figure 1. Internal bond (IB) (mean values and standard deviation) (**Legend**: $\mathbf{P_c}$ = control particleboard; $\mathbf{P_{x\text{-}y}}$ = particleboard with x% boric acid and y% bark particles of white birch)

Letters in histograms represent LSD results. This test compares the internal bond of particleboards to control particleboards (Pc). Thus, particleboards sharing the same letters with control particleboard (Pc) did not statistically differ from controls

3.2 Thickness swelling (TS) after 24h water immersion

TS values are presented in Figure 2. ANOVA results show no significant interactions between bark particles and boric acid for TS (Table1). LSD results show that the use of boric acid significantly improved the TS of treated particleboards over control particleboards. Particleboards with respectively 12% and 16% boric acid showed the lowest thickness swelling values (Figure 2).

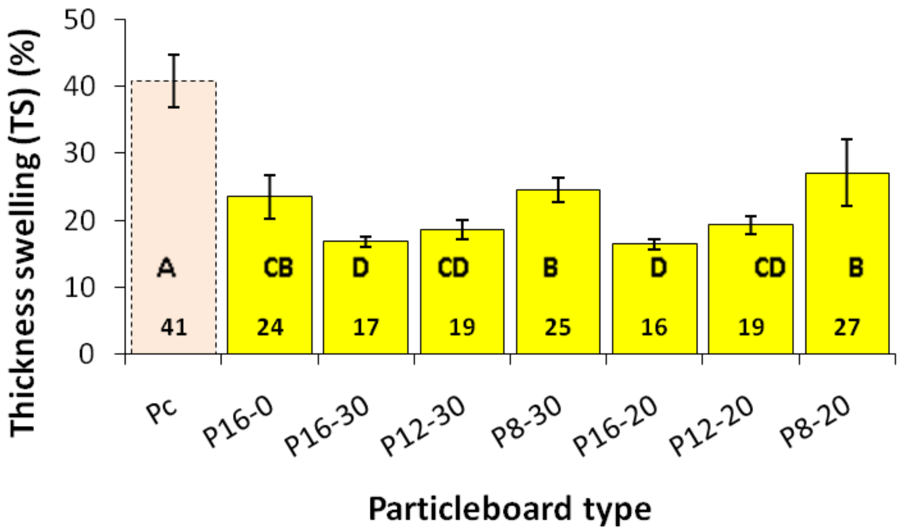

Figure 2. Thickness swelling (TS) (mean values and standard deviation) (**Legend**: $\mathbf{P_c}$ = control particleboard; $\mathbf{P_{x-y}}$ = particleboard with x% boric acid and y% bark particles of white birch)

Letters in histograms represent LSD results. This test compares the thickness swelling of particleboards to control particleboard s (Pc). Thus, particleboards sharing the same letters with control particleboards did not statistically differ from controls]

3.3 Weight loss (WL)

WL values are presented in Figure 3. ANOVA results show no significant interactions between bark particles and boric acid for WL, but show highly significant positive effects of the percentage of boric acid and bark particles (Table 1). These two factors helped to minimize the weight loss of particleboard undergoing fire testing as their percentage increased. The smallest weight loss was obtained with particleboard containing 16% boric acid and 30% bark particles. Another interesting observation is that the use of bark helped to lower weight loss. LSD results show that particleboard with 16% boric acid and without bark particles lost more weight than particleboard with the same percentage of boric acid plus 20% and 30% bark particles.

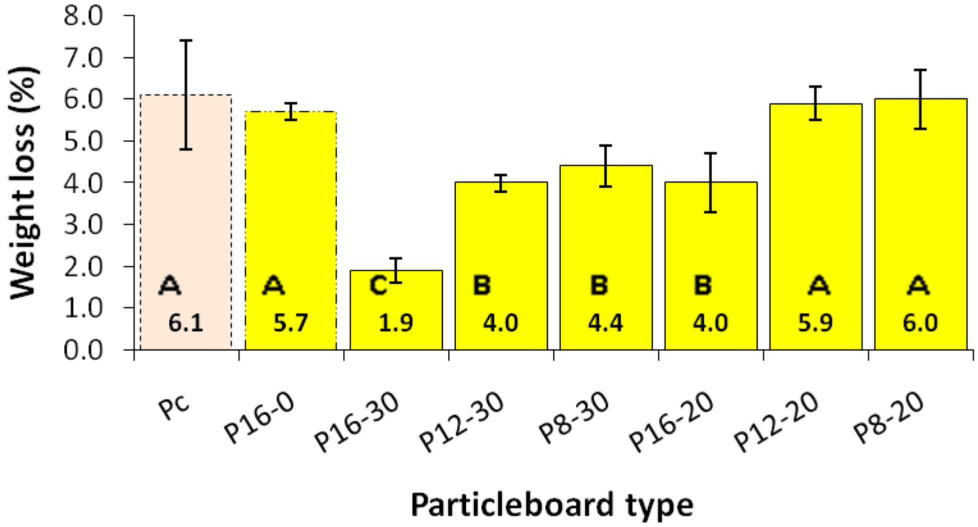

Figure 3. Weight loss (WL) (mean values and standard deviation) (**Legend**: $\mathbf{P_c}$ = control particleboard; $\mathbf{P_{x-y}}$ = particleboard with x% boric acid and y% bark particles of white birch)

Letters in histograms represent LSD results. This test compares the measured weight loss of particleboards to control particleboard s(Pc). Thus, particleboards sharing the same letters with control particleboard did not statistically differ from controls.

3.4 Thickness loss (TL)

TL values are presented in Figure 4. ANOVA results in Table 1 show no significant effects of the percentage variation of boric acid and bark particles on TL. There is no significant interaction between the percentage variation of bark particles and boric acid for TC. LSD results show that TL for all treated particleboards is significantly lower than for control particleboards.

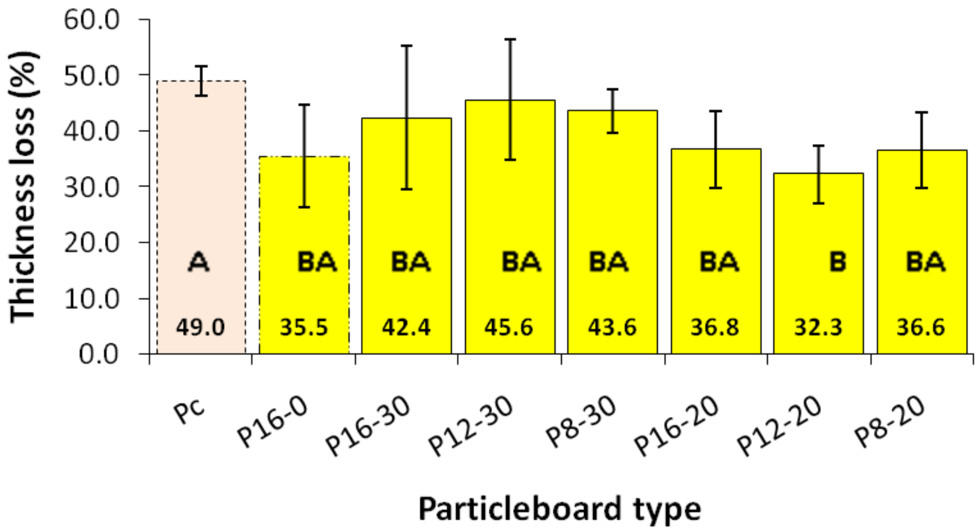

Figure 4. Thickness loss (TL) (mean values and standard deviation) (**Legend**: $\mathbf{P_c}$ = control particleboard; $\mathbf{P_{x\text{-}y}}$ = particleboard with x% boric acid and y% bark particles of white birch).

Note: TL was measured on the sample at the point directly above the burner.

Letters in histograms represent LSD results. This test compares the measured thickness loss of particleboards to control particleboards (Pc). Thus, particleboards sharing the same letters with control particleboards did not statistically differ from controls

3.5 Flame spread speed (FS)

FS values are presented in Figure 5. ANOVA results in Table 1 show no significant effects of the percentage variation of boric acid and bark particles on FS. This interesting result suggests that the use of the smallest proportions of boric acid is sufficient to improve the fire retardation in treated particleboards. No significant interactions were found between the percentage variation of bark particles and boric acid for FS. LSD results show that FS for all treated particleboards is significantly lower than for control particleboard.

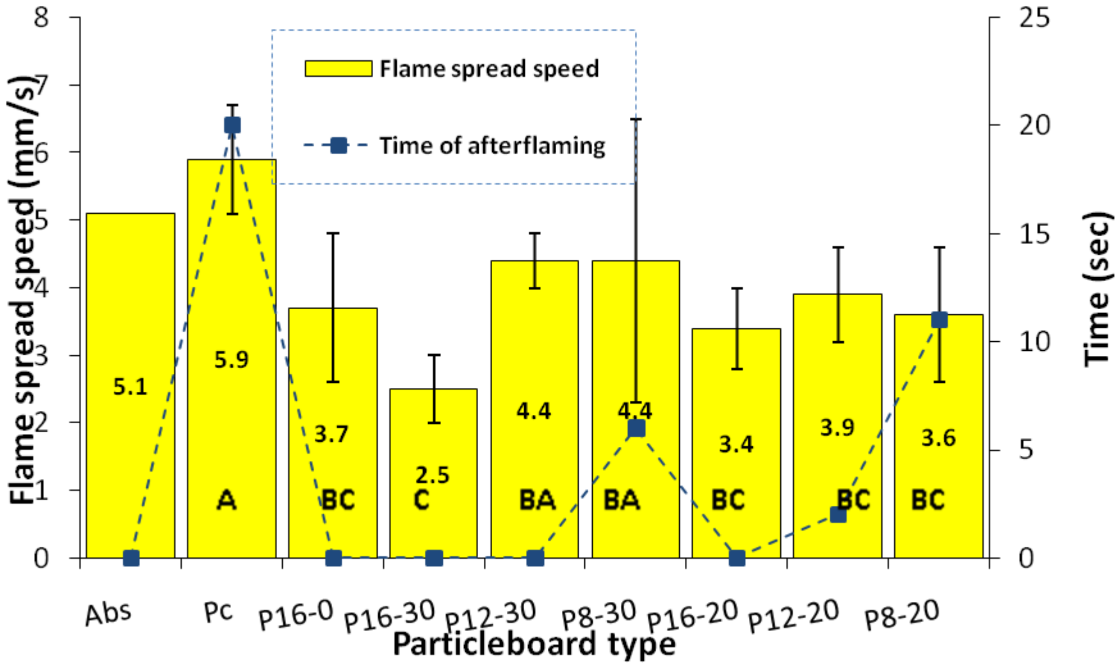

Figure 5. Flame spread speed (FS) (mean values and standard deviation) and after-flaming time

(**Legend**: **Abs** = asbestos-cement board; $\mathbf{P_c}$ = control particleboard; $\mathbf{P_{x\text{-}y}}$ = particleboard with x% boric acid and y% bark particles of white birch)

Letters in histograms represent LSD results. This test compares the measured flame spread speed of particleboards to control particleboards (Pc). Thus, particleboards sharing the same letters with control particleboards did not statistically differ from controls

3.6 Temperature at four different points on the sample back at the end of fire testing

Temperature values are presented in Figure 6. Only the results of the temperature measured at 304.8 mm from the flame source were statistically analyzed. Temperature was measured on the sample side facing away from the flame. ANOVA results (Table 1) show no significant effects of the percentage variation of boric acid and bark particles on temperature. No significant interactions were found between the percentage variation of bark particles and boric acid for temperature. Temperature decreases with measured distance from the burner. LSD results show that only the temperatures of particleboards with 8% boric acid and 20% bark particles and 16% boric acid and 30% bark particles are significantly lower than that of control particleboards.

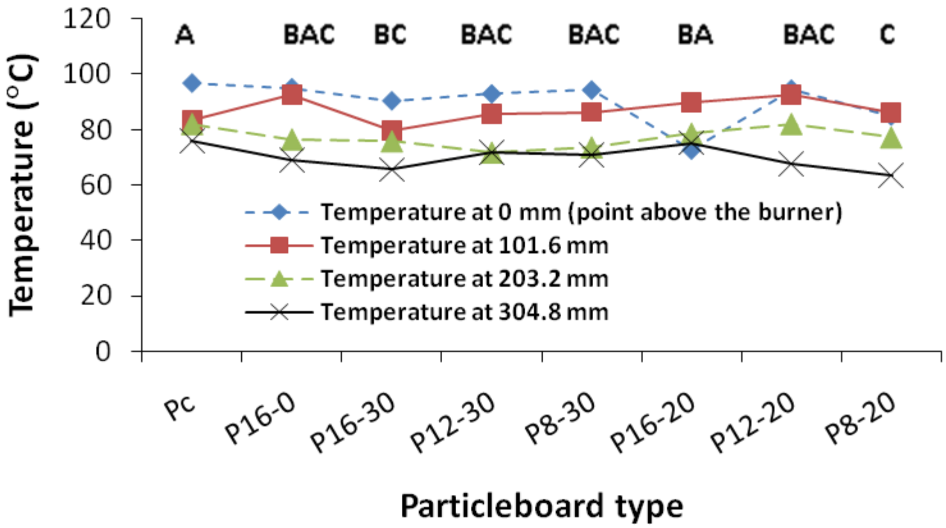

Figure 6. Temperature at different points measured immediately after the burner was extinguished. (**Legend**: $\mathbf{P_c}$ = control particleboard; $\mathbf{P_{x\text{-}y}}$ = particleboard with x% boric acid and y% bark particles of white birch)

Letters above curves represent LSD results. This test compares the measured temperatures of particleboards to control particleboards (Pc). Thus, particleboards sharing the same letters with control particleboards did not statistically differ from controls

4. Conclusions

The results of the present study show that boric acid can be successfully used as a fire-retardant agent in the manufacture of wood particleboard. Increased proportion of boric acid in the particleboard composition led to a significant improvement in fire-retardant properties. Another considerable advantage of this agent is its contribution to the high increase in internal bond and the significant decrease in thickness swelling of manufactured particleboards. The use of internal bark particles of white birch to disperse the boric acid powder in the fine wood particles of particleboard surface layers did not negatively impact any particleboard properties. Instead, this addition improved several properties including weight loss.

5. References

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