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# Mechanical properties of glue bonds in black locust wood treated with ammonia

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**Abstract:** *Mechanical properties of glue bonds in black locust wood treated with ammonia.* Work deals with strength of bonds in smoked black locust wood, glued with MUF, PVAc and EPI glues. Smoking (ammonia treatment) of black locust wood deteriorates strength of bonds, because of lowered wettability, especially with water-based resins of lower solution strength. Best results, in both dry and wet state, were gained with the usage of MUF glue.

*Keywords*: Black locust, smoked wood, bond strength

## INTRODUCTION

Wood is being used by humanity for ages, and in a numerous applications, as a tool, weapon, shelter, toy etc. Such an utilization is caused by ease of use, wide avaiibility and looks – color, pattern, finish and especially natural look. Most precious species of wood are being chosen especially for the visual advantages, which usually come along with exceptional strength and durability properties, especially in exotic species. Some domestic, cheaper wood can be modified to reach visual looks of exotics, being suitably strong for demanding applications such as flooring Hill 2006). Processing of wood in high temperatures or ammonia is especially designed for darkening of lightly colored wood.

Ammonia processing of wood is widely used by carpenters (Tinkler 1921). Treatment may be made with aqua ammonia (ammonia saturated water) (Oniśko and Matejak 1971) or by smoking (in gaseous ammonia) (Weigl *et al.* 2009 a,b). Modification bases on chemical reaction of tannins with gaseous ammonia, which causes darkening of wood, even down to black color. Such processing is usually used with oak wood (*Quercus sp.*), sometimes with black locust (*Robinia pseudoacacia* L.) or sweet cherry wood (*Prunus avium* L.) (Weigl *et al.* 2007, 2009 a,b). Unfortunately, mechanical properies are usually affected along color modification (Bariska 1969, Oniśko and Matejak 1971, Weigl *et al.* 2009 a,b). Amongst other effects lowered wood gluability may occur (Pióro 2009) – causing unquestionable harm to layered wood materials.

Objective of his work was to determine ammonia treatment influence on black locust wood bonds mechanical properties, with MUF, PVA and EPI glues.

METHODIC

Black locust wood (*Robinia pseudoacacia* L.) of density 748 kg/m$^3$, treated with gaseous ammonia (wood smoking) was used for tests. Wood was modified in in gas environment (wood exposed to ammonia fumes). Unmodified black locust wood (*Robinia pseudoacacia* L.), density 711 kg/m$^3$ was also tested as an control samples.

Wetting angle ($\theta$) measurement of test samples was made wit Phoenix 300 goniometer. Wetting angle of all tested specimens was measured after 60 seconds from drop settling.

Wood bonds quality tests were made accordingly to EN 204: 2002 standard - Classification of thermoplastic wood adhesive for non-structural applications and EN 205: 2005 standard - Test methods for wood adhesives for non-structural applications - Determination of tensile shear strength of lap joint. Shear strength tests of bonds were made with dry and 4-day soaked samples (water at 20 ± 1 $^o$C -D3 grade glue test). MUF, PVAc and EPI glues were used for the tests. Glue types and gluing parameters are presented in tables 1 and 2.

Table 1. Glue characteristics and.

| Glue | Durability class | Viscosity | Dry mass |
|---|---|---|---|
| | | [mPas] | [%] |
| **MUF** | D4 | 20000 | 69 |
| **PVAc** | D3 | 12000 | 58 |
| **EPI** | D4 | 10500 | 57 |

Table 2. Gluing parameters

| Glue | Glue spread* | Pressing temperature* | Pressing time* | Maximum unit pressure* |
|---|---|---|---|---|
| | [g/m$^2$] | [$^o$C] | [min] | [MPa] |
| **MUF** | 160 | 20 | 180 | 1,0 |
| **PVAc** | | | 10 | |
| **EPI** | | | 30 | |

* gluing parameters selected according to the manufacturer's glue

Ten tests were made for each combination, T-Student test at significance level 95 % showed statistical importance of the results.

RESULTS

Smoking of black locust caused hydrophobizaton of the wood. Wetting angle: ammonia-modified wood 58$^o$ ± 5$^o$, unmodified wood 16$^o$ ± 3$^o$. Over three times increase of wetting angle has severe impact on water-based glues.

Shear strength tests are presented on figures 1-3. In dry state no statistically important differences were found between smoked and unsmoked wood bonded with all three glues. Shear strength ranged 9,4 – 10,6 N/mm$^2$ (variation coefficient 8 – 18 %) for smoked wood and 10,1 – 10,5 N/mm$^2$ (variation coefficient 14 %) for control samples. D3 grade requires strength of 10 N/mm$^2$ . EN 204: 2002 standard however states only about beech wood. Smoked wood shows fracture in the wood itself in 55 % samples, in control samples this reaches around 80 %.

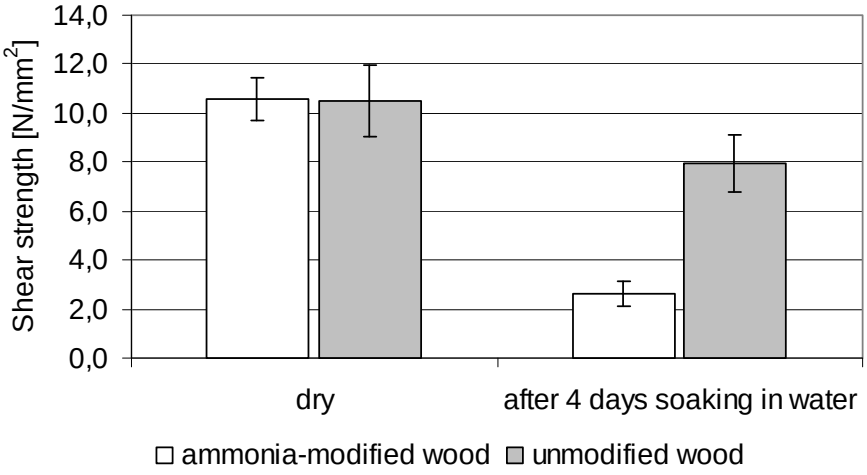


Fig. 1. Shear strength results of Black locust samples glued with MUF.

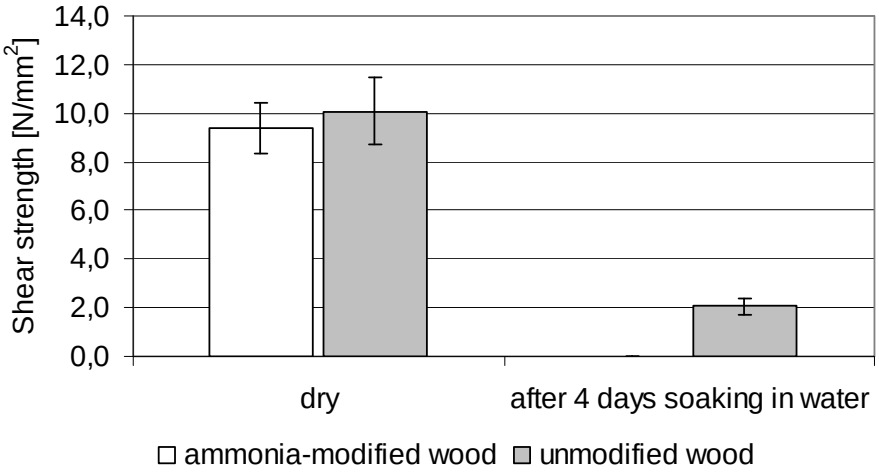


Fig. 2. Shear strength results of Black locust samples glued with PVAc

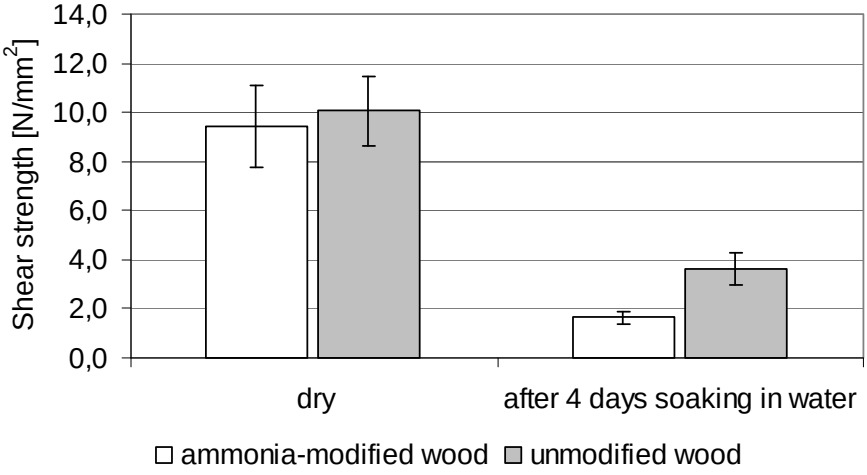


Fig. 3. Shear strength results of Black locust samples glued with EPI

Smoked wood in case of PVAc and EPI glues shows 7% decrease in bond strength. It is probably caused by higher wetting angles. Dry mass of PVAc equals 58 %, EPI – 57 %, and MUF 69 % in comparison to MUF glue, so their penetrating properties may be lower.

In wet state, MUF and EPI glues show statistically important shear strength decrease at 67 % and 56 % respectively, with fracture typically in the bond. PVAc glue applied to unsmoked wood shows 100 % separation after soaking, with shear strength 2,1 $N/mm^2$ level. Minimal shear strength of 2 $N/mm^2$ is required in accordance to EN 204: 2002 standard. Smoked wood shows lower mechanical properties possibly due to increased wood swell in tangential direction (Oniśko and Matejak 1971, Weigl *et al.* 2009 b), which increases tensile strain in the bond to higher values than in unsmoked wood.

## CONCLUSION

Smoking of black locust wood changes its physical properties, decreasing physical strength of bonds made with MUF, PVAc and EPI adhesives. Between all the glues tested, MUF glue shows best results in both wet and dry states, in comparison to other ones.

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**Streszczenie:** *Wytrzymałość spoin klejowych w klejonym drewnie akacji zmodyfikowanej amoniakiem.* W trakcie badań określono wytrzymałość na ścinanie połączeń klejowych wykonanych z drewna akacji modyfikowanej amoniakiem przy zastosowaniu klejów MUF, PVAc i EPI. Wykazano, że modyfikacja drewna akacjowego amoniakiem pogarsza zwilżalność jego powierzchni wodą. W konsekwencji pogorszeniu ulega wytrzymałość spoin wytworzonych z wykorzystaniem klejów na bazie wodnej o mniejszej zawartości suchej masy. Najlepsze właściwości wytrzymałościowe spoin, biorąc pod uwagę oznaczenie na sucho i po moczeniu w wodzie, uzyskano dla kleju MUF.

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