

# PHYSICAL STRENGTH PROPERTIES OF WOOD MODIFIED BY SILANE TREATMENT

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A high degree of water repellency is obtained in wood modified by silanation. However, the degrading effect of HCl, formed as a by-product in the reaction, may not be fully offset by the use of acid acceptors or inert gases in the reaction. Tensile tests on microtome sections of *Pinus nigra* wood, treated variously with dimethyldichlorosilane, clearly show that chemical modification substantially decreases tensile properties of wood. Experiments with large specimens of the same species suggest that silanated zone is only superficial. As a result, most of the strength properties of the large specimens remain unimpaired.

## INTRODUCTION

Wood can be dimensionally stabilized by treatment with silane. However, physical strength properties of wood are likely to be affected by silanation due to the formation of HCl in the reaction (Razzaque 1984). Acid acceptors commonly used in such reactions may be unable to totally eliminate the degrading effect (Rowell 1975, McMillin 1963). Moreover, such chemically modified wood, due to the substitution of silyl compounds for wood hydroxyl groups with consequent reduction in hydrogen bonding capacities, is likely to be more brittle than unmodified wood (Pierce 1968). It was decided, therefore,

to monitor the tensile properties of silanated radial-longitudinal microtome specimens. It is also thought that wood subjected to mild silanation reactions are treated only superficially. Nominal 100 micron thick microtome specimens are, however, likely to be treated through and through. Specimens of one cm cross-sectional width were thus tested for static bending strength.

## MATERIALS AND METHODS

Microtome specimens, 100 micron thick, 1 cm wide and 10 cm long were cut from the radial face of Corsican pine

blocks. These were dried under mild restraint at 20°C and 65% RH and then conditioned to constant weight over P<sub>2</sub>O<sub>5</sub>. They were then subjected to silanation with 1 ml and 5 ml silane vapour for 5 minutes in nitrogen atmosphere. Similarly, in the liquid phase, 1 ml and 5 ml silane in 50 ml CCl<sub>4</sub> were allowed to react with microtome specimens. The same experiment in liquid phase was repeated adding 10 ml Dimethyl formamide (DMF), as acid acceptor. The treated specimens after neutralizing, drying and equilibrating (at 20°C and 65% RH) were subjected to tensile tests over 2 cm span using a Universal testing machine. The load was applied using a cross-speed of 0.5 mm/min. The experiments were replicated using 20 specimens for each treatment condition.

For the static bending tests 16 cm long and 1 cm cross-sectional specimens were used. The specimens were prepared with the radial/longitudinal faces parallel to each other.

Silanation reactions were conducted both in the vapour phase and the liquid phase with dimethyldichlorosilane (DMDCS). Vapour phase reactions were done in a tall reaction vessel using a mild (2 ml silane), a medium (5 ml silane) and a severe (10 ml silane) treatment level. Another set of specimens, pre-treated with DMF, was treated in the vapour phase using 5 ml silane. A 5-minute reaction time was allowed in each case. Similar mild, medium and high level treatments were carried out in the liquid phase also using 5, 10 and 15 ml DMDCS for 5 minutes. In all cases 500 ml toluene was used as a diluent. The high level treatment was repeated with addition of 25 ml DMF in one reaction.

In addition, a control reaction was carried out using solvent (toluene) and acid acceptor (DMF) only.

Liquid phase treated specimens were neutralized and equilibrated to constant weight at 20°C and 65%RH before mechanical testing. Modulus of rupture (MOR), Modulus of elasticity (MOE) and total work done (TWD) were calculated using the standard formulae.

## RESULTS AND DISCUSSION

Results of tensile strength tests and static bending tests are given in Tables 1 and 2 respectively. It is evident that in microtome specimens a high degree of strength loss occurs even on mild treatment. Vapour phase reactions are rather critical. Slight loss of tensile strength occurs with mild vapour phase treatment, whereas, huge amount of strength is lost on rigorous treatment. In liquid phase reactions tensile strength properties are better retained than in rigorous vapour phase reactions. It is clear from the results that the chemical modification taking place drastically decreases tensile strength, suggesting that silanation occurs through the entire thickness of 100 microns of the specimen.

Both vapour phase and liquid phase treatments bring about loss of strength. From the limited tests carried out, it is not possible to prescribe which method of treatment is most deleterious. Even the process involving the acid acceptor does not change the results to any appreciable degree.

From the static bending tests of larger wood specimens it appears that the level of silanation achieved in these treatments

**Table 1. Tensile strength of silanated microtome specimens (Mean of 40 specimens  $\pm$  standard deviation)**

Specimen treatment	Tensile strength Kg/mm <sup>2</sup>	Loss of strength (basis : control ) %
Control	8.29 (0.67)	-
Vapour phase (mild)	5.55 (1.15)	33
Vapour phase (severe)	1.08 (0.14)	87
Liquid phase (mild)	3.14 (0.31)	62
Liquid phase (severe)	2.18 (0.19)	74
Liq. phase with DMF (mild)	3.09 (0.10)	63
Liq. phase with DMF (severe)	2.60 (0.43)	69

**Table 2. Static bending tests of silanated large specimens (Mean of 12 specimens  $\pm$  standard deviation)**

Specimen treatment	MOR (N/mm <sup>2</sup> )	MOE (N/mm <sup>2</sup> )	TWD (Nmm/mm <sup>3</sup> )
Control	117.86 (7.72)	10,769 (837)	0.2168 (00.4)
Vapour phase (mild)	112.69 (7.27)	11,006 (496)	-
Vapour phase (medium)	104.56 (5.38)	10,453 (588)	0.1876 (0.02)
Vapour phase (severe)	99.17 (5.67)	10,752 (691)	-
Vapour phase with DMF (severe)	115.94 (6.64)	10,780 (880)	-
DMF alone	103.34 (9.88)	12,798 (1372)	-
Liquid phase (with DMF)	107.05 (4.30)	11,328 (715)	-
Liquid phase (mild)	110.12 (8.48)	12,100 (790)	-
Liquid phase (medium)	107.11 (6.38)	9,166 (2869)	0.1715 (0.03)
Liquid phase (severe)	103.50 (3.99)	12,630 (1759)	-

leads to only a slight reduction in bending strength properties. However, it can be seen that as the severity of treatment is increased, a corresponding increase in strength loss is incurred. Comparison of these data with those for the thin strips suggests that the silanated zone is superficial, probably not extending to a depth greater than 1 mm or so. As a result, most of the strength properties of the large specimens remain unimpaired. The modulus of elasticity values do not change much and seem to be inconclusive. Total work done was calculated on the control, one batch of vapour phase and one batch of liquid phase specimens only.

At first sight, these minimal loss of strength data appear to be quite encouraging. That is, in relatively large cross sections the loss of strength caused is less in comparison with naturally occurring strength reducing factors (relative to the strength of clear specimens) such as knots and sloping grain. However, as shown by the strength reduction caused to these sections, such reduction seems to be concentrated in a thin exposed surface zone. It is likely, therefore, that this zone may rapidly erode when exposed directly to weather, leaving unprotected wood at the surface. Under a paint film, the situation may be a little better. In this case the stresses encountered due to any differential movement of wood and paint due to change in atmospheric condition may well lead to shearing of the weak surface layer of modified

wood from the underlying sound material, and effectively detaching the paint film from the wood surface. Hence, the observed strength reduction occurring as a consequence of silane treatment must impart a serious reservation on the possible utility of such wood modifying processes.

## CONCLUSION

Silanation reduces the hydrogen bonding capacity of wood hydroxyl groups. Silane treatment is effected only superficially causing the thin specimens to lose most of their strength on treatment. However, most of the strength properties of large treated specimens are retained. Hence, silanation may be a practical means of imparting water repellency to wood. The long-term behaviour of modified wood needs further study.

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