

# Comparative behaviour of exterior grade wood adhesives for high MC timber gluing

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be perfectly possible by using PRF and MUF fast-setting, as well as by using single application polyurethane (PUR) adhesive bonding one due to its water-induced hardening reaction, but performance. However, the need to maintain the bonded wood to avoid wood distortion indicates that anyone of the three adhesives is the higher rate of setting/curing which determines the capability

However, the existence of the very marked temperature dependence of polyurethane adhesives in the 40°C – 80°C range has been observed. Polyurethanes of higher level of cross-linking for this application are not suitable for use of the current materials.

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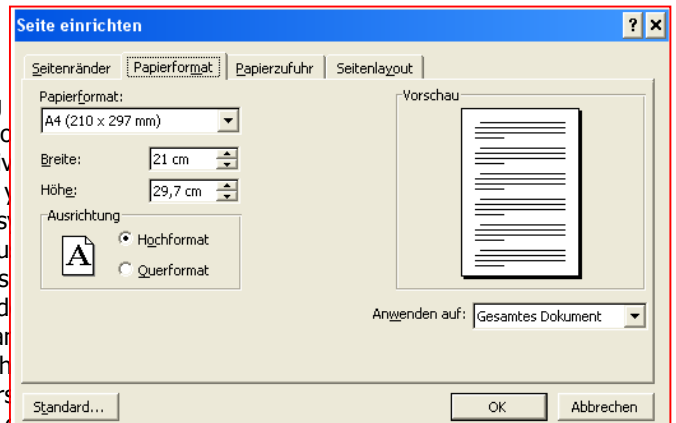
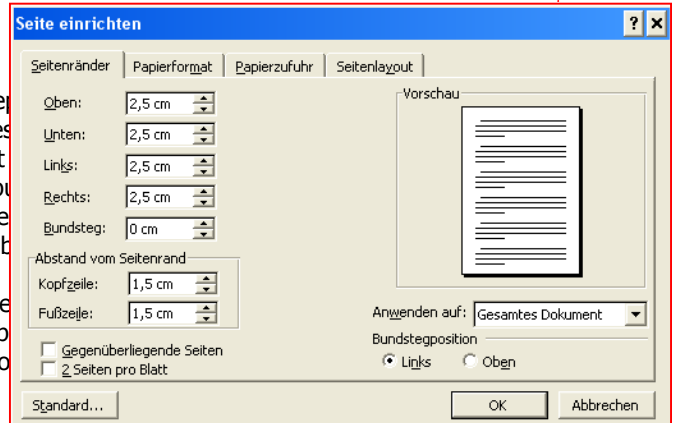
Introduction

Bonding of timber of high moisture content, namely "gluing wet wood" became possible with the industrial introduction of honeymoon formaldehyde (PRF) adhesives. Honeymoon fast-set adhesive systems have now been used industrially for about twenty years. The concept of the honeymoon fast-set system and the initial systems (Pizzi 1989, 1994, Pizzi, Cameron 1984), and are still extensively used. Derived over the years. Thus, to the original PRF/PRF systems, both being fast adhesives of structural marine grade adhesives but at ambient and even lower winter temperatures, and (Pizzi 1989, 1994, Pizzi, Cameron 1984). Variations of the fingerjointing equipment and capable of pot-lives of 48 hours (Pizzi 1989, 1994) were then added. All these adhesives were

Recently however, an honeymoon adhesive for glulam based exclusively on a melamine-urea-formaldehyde (MUF) resin and containing no resorcinol at all has been developed (Properzi, Pizzi et al. 2001a, 2001b). In the same article it was also proven that the use of resorcinol did not improve at all the performance of a top of the range MUF resin used in this new concept honeymoon adhesive system.

Even more recently single application polyurethane systems for "gluing wet wood" have also appeared and been approved for use in structural glulam in at least one country. The main characteristic of reactive polyurethanes, hence still containing reactive isocyanate groups, is that they cross-link in application, such as those used for glulam, is that the presence of water in the wood should set off and accelerate the cross-linking, hardening reaction. In their ease of handling, polyurethane systems are a very interesting proposition for bonding glulam. The main problem all polyurethanes, even cross-linked ones present however, is that of creep. This means that in the past even good polyurethane systems, even those well resistant to water and weather deterioration could not be used for structural application (Fig 1). Considering that the majority of the applications for glulam and fingerjointing is for structural building applications this is a grave defect indeed. It is the existence of this problem which has effectively stopped polyurethanes to be used in glulam applications. As now materials of this class have been accepted in Germany just for structural application, but no results on this have been shown, this paper is aimed at comparing the performance on dry and wet wood of fast setting PRF, MUF and PUR systems on dry wood and on wet wood gluing, as well as checking the temperature-dependent creep and time-dependent creep introduced in wood joints by the use of these three types of adhesives (Tab 1).

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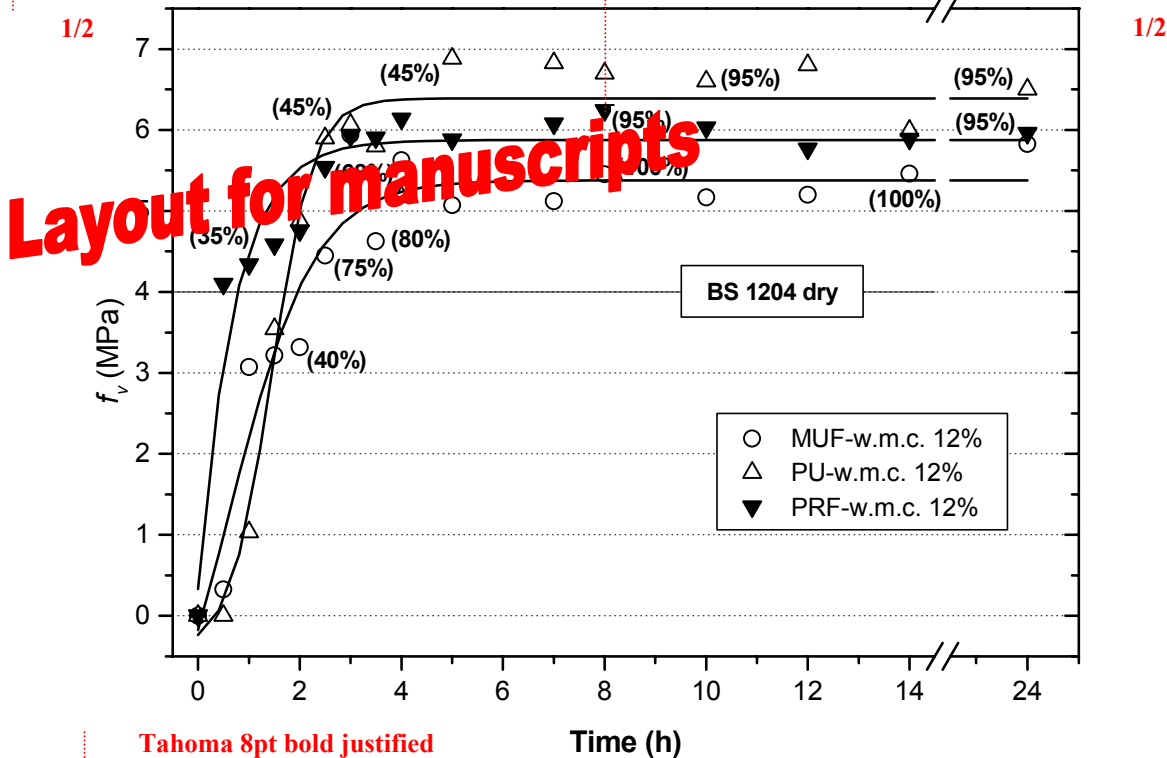
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- 2 Experimental **Tahoma 9pt bold**
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- 2.1 Breadboard construction **9pt bold**
- 2.1.1 First step **9pt**

Three different industrial resins were used and compared to bond dry wood at 12% equilibrium moisture content (e.m.c.) and wet wood at the high moisture content of 22% e.m.c. The three wood adhesives used were (i) two commercial polyurethane (PUR) adhesives both approved for exterior structural grade use in Germany. (ii) A high setting speed phenol-resorcinol-formaldehyde (PRF) commercial honeymoon separate application fast-set adhesive approved for structural exterior grade applications in countries such as Australia and South Africa the formulation of which has already been reported (Pizzi 1983, 1989, 1994) .....



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**Fig 1 – Tensile Strength increase as a function of time of beech joints (BS 1204, Part 1) bonded with PRF- and MUF-based separate application honeymoon adhesive systems and with single polyurethane (PU) adhesive system using beech wood of 12% equilibrium moisture content (e.m.c.) (reference: Müller, Smith 1999)**

The behaviour changes somewhat in the bonding of wet timber at 22% moisture content (Fig 2). All the three adhesives present strength increase rates as a function of time which are slower with the polyurethane being the faster of the three, followed by the PRF and then the wet joint passes the requirements of the standard for an adhesive that is set by the reaction of its residual

- 2.1.2 High-speed photographs

In-situ high-speed photographs of the Excimer laser process can be distinguished from the visible part of

- 0...1µs after laser pulse: absorption of the laser on the surface,
- 1...200µs after laser pulse: plasma expansion,
- 200µs...1ms after laser pulse: burning of gas process

**Absatz**

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1...200µs after laser pulse: plasma expansion.

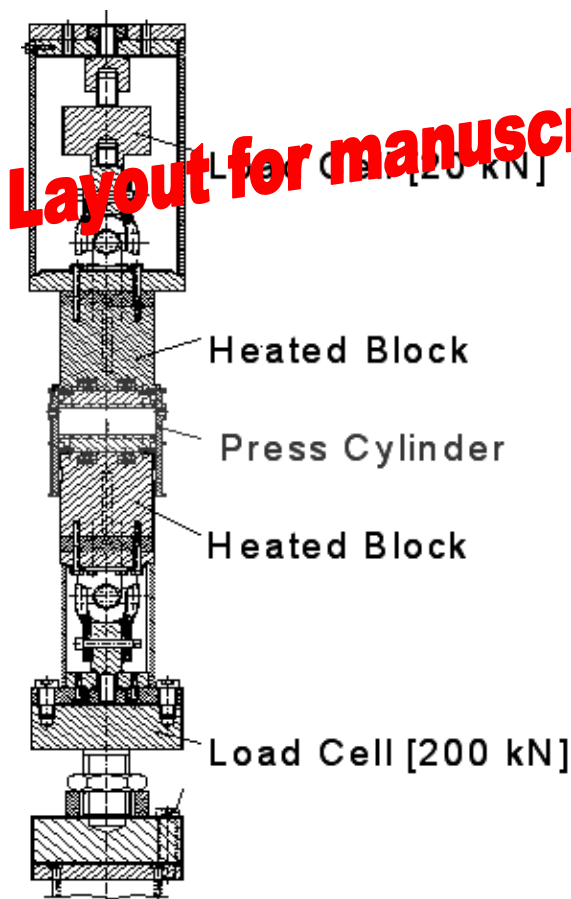
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**Numerierung und Aufzählungszeichen**

Aufzählungen    Numerierung    Gliederung

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To determine adhesive cure of resinated wood fiber and particle mats a specially designed testing device is required. Therefore, the Integrated Pressing and Testing System has been developed (Fig. 1). Wood particle mats are formed, pressed and subsequently, after a range of pre-selected pressing times, destructively tested in tension mode without removing it out of the system. A special adhesive is used to provide the linkage between the press platen and the sample being tested.

Wood composite samples (100 mm in diameter and 5 mm in thickness) can be formed under highly controlled conditions of temperature, thickness and gas pressure within the pressing chamber. Two electrically heated blocks generate the heat which is transferred through the pre-heated steel press platen onto both surfaces of the mat. The linkage between the heated blocks and the press platens is accomplished by t-slots. A pressing cylinder surrounding the wood fiber sample during the pressing sequence prevents transversal strain and maintain pre-selected final mat densities. Prior to the testing sequence the pressing cylinder is pneumatically pushed back.

A servo-hydraulic driven piston provides the load for mat densification and the force for tensile testing of partially cured fiber or particle mats. Both heated blocks are linked with universal joints to the load cells to ensure that no transversal stresses are transferred during the test. The pressing load is measured with a load cell capable up to 200 kN whereas the bond strength is measured with a load cell capable of 20 kN. Because of its limited range the pressing load is transferred through a steel cylinder during the pressing...

Fig 2 - Schematic of the Internal Pressing and Testing System (ipates) (reference: Heinemann 2001)

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Tab 1 - Internal bond strength (IB) of particleboard specimens. Values in parentheses represent the coefficient of variation (%). Different letters show which values are statistically different at the 5% level. (reference: Papadopoulos 2001)

Resin Type	Mat MC (%)	IB (N/mm <sup>2</sup> )	Platen (°C)	IB (N/mm <sup>2</sup> )	Wax (%)	IB (N/mm <sup>2</sup> )
EMDI	7	0.736 A (8.1)	170	0.734 A (10.8)	0	0.871 A (10.2)
EMDI	10	0.765 A (7.2)	180	0.765 A (7.2)	0.5	0.853 AB (6.2)
EMDI	13	0.784 A (9.2)	190	0.771 A (6.8)	1	0.765 B (7.2)
PMDI <sup>1</sup>	7	0.692 A (10.1)	170	0.681 A (11.1)	0	0.846 A (9.9)
PMDI <sup>1</sup>	10	0.717 A (6.5)	180	0.717 A (6.5)	0.5	0.815 AB (6.7)
PMDI <sup>1</sup>	13	0.731 A (8.4)	190	0.729 A (7.9)	1	0.717 B (6.5)

<sup>1</sup> Data from other project (Papadopoulos and Hill, 2001).

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### 3 Characterisation

Furthermore, a method was established to quantify the extent of silylation by infrared spectroscopy. By comparing peak height (or peak area) ratios of Si-O-C and C-O-C absorption bands from the spectra of the modified material with bands from the spectra of the starting material, the percentage of silicon incorporated after silylation can be determined spectroscopically with an accuracy of +/- 0.5 wt% and a noticeable lower measurement error and work. The GC-method developed to determine the amount of bound water in lignocellulosic matter yielded reproducible results. This method allows calculation of the amount of silylating agent consumed by bound water and thereby helps to optimise the reaction conditions needed for complete silylation of the starting material.....

### 4 Conclusions

The present investigations on the silylation of cellulose and wood meal in liquid phase clearly showed, that TMCS, HMDS and BSA were well suited as silylating agents. TMCS, because of it's higher reactivity, led to higher Si-contents than HMDS or BSA. TMCS-reactions of wood meal yielded silicon mass contents of up to 18 wt%. Bond formation between OSC and wood was confirmed by infrared spectroscopy, scanning electron microscopy and solid state NMR spectroscopy.....

### 5 Acknowledgement

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