

# Hydroxymethylated Resorcinol (HMR) Primer to Improve the Performance of Wood-Adhesive Bonds – A Review

## - Electronic Supplementary Material -

**Table ES-1:** Compression shear strength (CSS) values or tensile shear strength (TSS) values, and the corresponding wood failure percentage (WFP), for different wood-adhesive systems with or without HMR treatment.

Adhesive	Wood species	Additional information	Test Type	Standard	[N/mm <sup>2</sup> ]		WFP [%]		Source
					untreated	HMR	untreated	HMR	
EP	Sitka spruce	/	CSS / dry	ASTM D 2559	8,6	9,9	67	90	[27]
EP	Sitka spruce	/	CSS / dry	ASTM D 2559	9,5	8,6	97	100	[43]
EP	Sitka spruce	/	CSS / dry	ASTM D 2559	9,7	8,1	98	100	[43]
EP	Sitka spruce	/	CSS / dry	ASTM D 2559	9,6	8,5	94	100	[43]
EP	Douglas Fir	/	CSS / dry	ASTM D 2559	8,5	7,5	95	97	[43]
EP	Douglas Fir	/	CSS / dry	ASTM D 2559	8,1	8,8	99	100	[43]
EP	Douglas Fir	/	CSS / dry	ASTM D 2559	8,5	8,0	88	98	[43]
EP	Southern pine	CCA-treated	CSS / dry	ASTM D 2559	9,3	11,5	46	83	[44], [45]
EP	Maritime pine	/	CSS / dry	/	8,1	14,0	37	84	[46]
EP	Maritime pine	/	CSS / dry	/	8,5	9,9	45	86	[46]
EP	Maritime pine	/	CSS / weathered	/	10,1	14,8	44	94	[46]
EP	Maritime pine	/	CSS / weathered	/	9,3	11,2	50	91	[46]
EP	Iroko	/	CSS / dry	/	7,5	10,8	45	77	[46]
EP	Iroko	/	CSS / dry	/	6,6	7,4	37	67	[46]
EP	Iroko	/	CSS / weathered	/	9,3	12,8	54	88	[46]
EP	Iroko	/	CSS / weathered	/	4,1	5,5	22	44	[46]
EP	European oak	/	CSS / dry	/	8,0	11,6	29	62	[46]
EP	European oak	/	CSS / dry	/	6,0	6,0	26	30	[46]
EP	European oak	/	CSS / weathered	/	10,3	13,2	48	73	[46]
EP	European oak	/	CSS / weathered	/	1,6	6,3	4	30	[46]
EP	Yellow poplar	/	CSS / dry	ASTM D 2559	11,3	10,5	93	97	[43]
EP	Yellow poplar	/	CSS / dry	ASTM D 2559	10,9	11,1	100	100	[43]
EP	Yellow poplar	/	CSS / dry	ASTM D 2559	10,3	11,4	70	93	[43]
EP	Yellow birch	/	CSS / dry	ASTM D 2559	10,5	14,9	12	86	[43]
EP	Yellow birch	/	CSS / dry	ASTM D 2559	15,8	16,9	86	77	[43]
EP	Yellow birch	/	CSS / dry	ASTM D 2559	9,4	15,8	29	89	[43]
EP	Eucalyptus	/	CSS / dry	ASTM D 2559	3,5	3,7	72	80	[51]
EP	Eucalyptus	/	CSS / wet	ASTM D 2559	1,1	1,3	56	59	[51]
1C-PUR	Norway spruce	End-Grain	TSS / dry	/	8,3	17,5			[58]
1C-PUR	Norway spruce	Planed, tangential cut	TSS / A4	EN 302-1	3,5	5,7	/	/	[52]
1C-PUR	Norway spruce	Planed, radial cut	TSS / A4	EN 302-1	3,9	5,6	/	/	[52]
1C-PUR	Norway spruce	Sanded, tangential cut	TSS / A4	EN 302-1	5,3	6,0	/	/	[52]
1C-PUR	Norway spruce	Sanded, radial cut	TSS / A4	EN 302-1	4,5	5,3	/	/	[52]
1C-PUR	Douglas Fir	Planed, tangential cut	TSS / A4	EN 302-1	4,3	7,5	/	/	[52]
1C-PUR	Douglas Fir	Planed, radial cut	TSS / A4	EN 302-1	3,6	6,7	/	/	[52]
1C-PUR	Douglas Fir	Sanded, tangential cut	TSS / A4	EN 302-1	5,6	7,2	/	/	[52]
1C-PUR	Douglas Fir	Sanded, radial cut	TSS / A4	EN 302-1	5,2	7,3	/	/	[52]
1C-PUR	Douglas Fir	/	CSS/ dry	ASTM D 905	11,4	13,3	/	/	[48], [49], [50]
1C-PUR	Douglas Fir	/	CSS/ dry	ASTM D 905	11,6	12,6	/	/	[48], [49], [50]
1C-PUR	Douglas Fir	/	CSS/ wet	ASTM D 905	6,3	6,1	/	/	[48], [49], [50]
1C-PUR	Douglas Fir	/	CSS/ wet	ASTM D 905	6,4	6,4	/	/	[48], [49], [50]
1C-PUR	European larch	Planed, tangential cut	TSS / A4	EN 302-1	3,2	6,2	/	/	[52]
1C-PUR	European larch	Planed, radial cut	TSS / A4	EN 302-1	3,1	6,5	/	/	[52]
1C-PUR	European larch	Sanded, tangential cut	TSS / A4	EN 302-1	3,3	2,6	/	/	[52]
1C-PUR	European larch	Sanded, radial cut	TSS / A4	EN 302-1	3,0	3,2	/	/	[52]

1C-PUR	Yellow birch	/	CSS/ dry	ASTM D 905	22,0	22,5	/	/	[48], [49], [50]
1C-PUR	Yellow birch	/	CSS/ dry	ASTM D 905	22,0	23,7	/	/	[48], [49], [50]
1C-PUR	Yellow birch	/	CSS/ wet	ASTM D 905	8,4	8,3	/	/	[48], [49], [50]
1C-PUR	Yellow birch	/	CSS/ wet	ASTM D 905	8,0	8,1	/	/	[48], [49], [50]
1C-PUR	European beech	/	TSS / A1	EN 302-1	12,4	13,6	80	87	[34], [47]
1C-PUR	European beech	/	TSS / A4	EN 302-1	6,3	7,0	16	62	[34], [47]
1C-PUR	European beech	/	TSS / A5	EN 302-1	11,4	11,9	62	84	[34], [47]
1C-PUR	Eucalyptus	/	CSS / dry	ASTM D 2559	3,5	3,1	84	75	[51]
1C-PUR	Eucalyptus	/	CSS / wet	ASTM D 2559	1,6	1,7	52	58	[51]
1C-PUR	Eucalyptus	/	CSS / dry	EN 392	18,0	19,1	60	90	[55]
1C-PUR	Eucalyptus	/	CSS / wet	EN 392	10,5	11,9	55	95	[55]
1C-PUR	Eucalyptus	/	CSS / dry	EN 392	13,8	14,5	97	97	[55], [56]
1C-PUR	Eucalyptus	/	CSS / wet	EN 392	8,5	9,6	78	98	[55], [56]
PVAc	Scots pine	/	TSS / A1	EN 302-1	7,7	8,3	100	80	[53], [54]
PVAc	Scots pine	/	TSS / A2	EN 302-1	4,4	6,0	30	60	[53], [54]
PVAc	Scots pine	Silicone treated	TSS / A1	EN 302-1	4,9	5,5	20	10	[54]
PVAc	Scots pine	Silicone treated	TSS / A2	EN 302-1	8,1	8,2	95	75	[54]
PVAc	Scots pine	Wax treated	TSS / A1	EN 302-1	7,8	8,9	27	38	[53]
PVAc	Scots pine	Wax treated	TSS / A2	EN 302-1	1,5	3,5	0	0	[53]
EPI	Southern pine	CCA-treated	CSS / dry	ASTM D 2559	14,5	11,8	92	96	[44]
EPI	Eucalyptus	/	CSS / dry	ASTM D 2559	3,0	2,8	71	68	[51]
EPI	Eucalyptus	/	CSS / wet	ASTM D 2559	1,0	0,9	58	56	[51]
MF	Scots pine	Wax treated	TSS / A1	EN 302-1	7,0	9,4	9	43	[53]
MF	Scots pine	Wax treated	TSS / A2	EN 302-1	2,2	7,1	0	59	[53]
MF	Scots pine	/	TSS / A1	EN 302-1	7,3	9,2	100	100	[53]
MF	Scots pine	/	TSS / A2	EN 302-1	6,7	6,5	100	78	[53]
MF	Southern pine	/	CSS / dry	ASTM D 2559	14,2	13,3	79	56	[57]
MF	Southern pine	CCA-treated	CSS / dry	ASTM D 2559	9,8	13,8	20	32	[57]
MUF	Southern pine	/	CSS / dry	ASTM D 2559	13,4	14,8	90	85	[57]
MUF	Southern pine	CCA-treated	CSS / dry	ASTM D 2559	13,9	14,0	68	86	[57]
MUF	Eucalyptus	/	CSS / dry	EN 392	15,8	15,4	100	99	[55], [56]
MUF	Eucalyptus	/	CSS / wet	EN 392	8,4	9,2	66	86	[55], [56]
PRF	Yellow cedar	snag wood	CSS / dry	ASTM D 2559	11,4	11,0	95	90	[17]
PRF	Eucalyptus	/	CSS / dry	ASTM D 2559	3,4	3,8	77	84	[51]
PRF	Eucalyptus	/	CSS / wet	ASTM D 2559	1,3	1,7	48	61	[51]

**Table ES-2:** Delamination results for different wood-adhesive systems with or without HMR treatment.

Adhesive	Wood species	Additional information	Standard	Delamination [%]		Source
				untreated	HMR	
EP	Sitka spruce	/	ASTM D 2559	43,7	15,3	[27]
EP	Sitka spruce	/	ASTM D 2559	31,3	12,3	[27]
EP	Sitka spruce	/	ASTM D 2559	55,1	4,5	[27]
EP	Sitka spruce	/	ASTM D 2559	31,2	12,1	[27]
EP	Sitka spruce	/	ASTM D 2559	19,7	4,3	[44], [43]
EP	Sitka spruce	/	ASTM D 2559	30,5	4,0	[44], [43]
EP	Sitka spruce	/	ASTM D 2559	72,8	6,0	[43]
EP	Douglas Fir	/	ASTM D 2559	59,3	4,2	[44], [43]
EP	Douglas Fir	/	ASTM D 2559	49,6	3,7	[44], [43]
EP	Douglas Fir	/	ASTM D 2559	56,4	3,4	[43]
EP	Southern pine	/	ASTM D 2559	27,5	0,8	[27]
EP	Southern pine	CCA-treated	ASTM D 2559	27,6	0,7	[27]
EP	Southern Pine	CCA-treated	ASTM D 2559	88,8	3,0	[44]
EP	Yellow poplar	/	ASTM D 2559	30,9	0,5	[44], [43]
EP	Yellow poplar	/	ASTM D 2559	10,5	0,0	[44], [43]
EP	Yellow poplar	/	ASTM D 2559	76,2	7,0	[43]
EP	Yellow birch	/	ASTM D 2559	97,5	10,8	[44], [43]
EP	Yellow birch	/	ASTM D 2559	27,7	0,0	[44], [43]
EP	Yellow birch	/	ASTM D 2559	99,2	22,9	[43]
EP	Eucalyptus	/	ASTM D 2559	10,0	0,0	[51]
1C-PUR	Douglas Fir	/	ASTM D 2559	47,0	2,1	[60], [48]
1C-PUR	Douglas Fir	/	ASTM D 2559	15,2	2,5	[48]
1C-PUR	Yellow birch	/	ASTM D 2559	17,2	5,8	[60], [48]
1C-PUR	Yellow birch	/	ASTM D 2559	62,8	0,0	[48]
1C-PUR	Eucalyptus	/	EN 391	3,0	1,0	[56], [55]
1C-PUR	Eucalyptus	/	ASTM D 2559	7,8	0,0	[51]
1C-PUR	Eucalyptus	/	EN 391	51,6	0,8	[55]
pMDI	Southern pine	/	ASTM D 2559	78,7	3,5	[44]
pMDI	Southern pine	CCA-treated	ASTM D 2559	73,7	3,7	[44]
EPI	Southern pine	CCA-treated	ASTM D 2559	10,6	1,7	[44]
EPI	Eucalyptus	/	ASTM D 2559	15,6	55,6	[51]
PRF	Southern pine	/	ASTM D 2559	3,4	2,3	[44], [57]
PRF	Southern pine	/	ASTM D 2559	2,1	2,2	[44], [57]
PRF	Southern pine	CCA-treated	ASTM D 2559	4,4	4,1	[44], [57]
PRF	Southern pine	CCA-treated	ASTM D 2559	12,4	2,6	[44], [57]
PRF	Southern yellow pine	CCA-treated	ASTM D 2559	1,6	0,3	[61]
PRF	Southern yellow pine	CA-B-treated	ASTM D 2559	5,5	1,2	[61]
PRF	Southern yellow pine	ACQ-treated	ASTM D 2559	10,8	8,7	[61]
PRF	Yellow cedar	snag wood	ASTM D 2559	3,6	1,4	[17]
PRF	Eucalyptus	/	ASTM D 2559	12,2	0,0	[51]
MUF	Eucalyptus	/	EN 391	24,1	3,1	[56], [55]

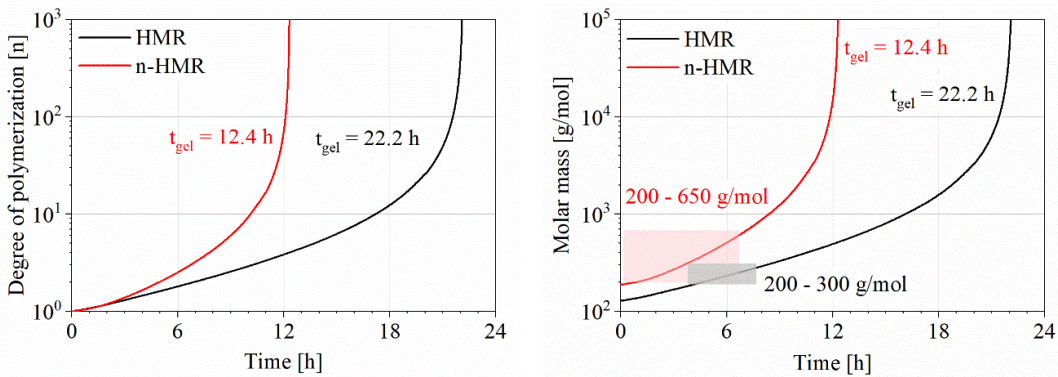
In addition to the results listed in Table ES-2, different GLT production parameters of HMR-primed European beech (*Fagus sylvatica* L.) were compared in delamination tests by Ohnesorge *et al.* [62]. However, due to the difficulty to compare the results, they are excluded from the direct comparison in Table ES-2 and the corresponding figure in the publication.

**Table ES-3:** Comparison of contact angle [°] on wood with and without HMR treatment

Test Liquid	Wood species	Equilibrium		Initial		Source
		untreated	HMR	untreated	HMR	
water	Southern pine	13,2*	3,5*	45,7	30	[98]
water	Southern pine	2,9	0	60,8	54,5	[99]
water	Douglas fir	4,5	0	53	39,3	[99]
water	Eucalyptus	38*	57*	74	75	[51]
Formamide	Southern pine	0	0	28	52,7	[99]
Formamide	Douglas fir	0	0	30,6	33,4	[99]
Ethylene glycol	Southern pine	1,7	0	27,6	41,8	[99]
Ethylene glycol	Douglas fir	0	0	24,8	29,4	[99]
Methylene iodide	Southern pine	19,2	27,2	24,6	41,5	[99]
Methylene iodide	Douglas fir	26,6	36,9	36,7	54,8	[99]
pMDI	Southern pine	18,9	30,3	49,8	57,9	[99]
pMDI	Douglas fir	21	27,6	54,1	58,3	[99]
PF	Southern pine	44,5	51,3	77,2	87,5	[99]
PF	Southern pine	/	/	74,6	93,5	[98]
PF	Douglas fir	50,8	57,2	90,1	93,7	[99]
1C-PUR *	Douglas fir	23	22	/	/	[52]
1C-PUR *	Douglas fir	27	25	/	/	[52]
1C-PUR *	Douglas fir	16	12	/	/	[52]
1C-PUR *	Douglas fir	16	15	/	/	[52]
1C-PUR *	Spruce	21	30	/	/	[52]
1C-PUR *	Spruce	24	20	/	/	[52]
1C-PUR *	Spruce	18	16	/	/	[52]
1C-PUR *	Spruce	16	21	/	/	[52]
1C-PUR *	Larch	23	34	/	/	[52]
1C-PUR *	Larch	24	36	/	/	[52]
1C-PUR *	Larch	23	20	/	/	[52]
1C-PUR *	Larch	22	12	/	/	[52]

\*value from static measurement, taken after 10 seconds

\* Different surface preparation: sanded/planed in radial/tangential direction  
Note: [98] and [51] used static methods, [99] and [52] used dynamic methods



**Figure ES-1:** Based on the data presented in [98], the average degree of polymerization for the original HMR and the n-HMR's B-stage were simulated (left). Based on the degree of polymerization the average-number molar mass,  $M_n$ , was calculated and the values extracted for the time window of effectiveness presented in [98].