

Effect of surface-applied treatments on the above-ground performance of simulated timber joinery

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Summary

We examined the effect of surface-applied treatments on the above-ground decay resistance of the tenon of mortice-and-tenon timber joints designed to simulate joinery that is exposed to the weather. Joints made from untreated radiata pine, Douglas-fir, brush box, spotted gum and copper-chrome-arsenic (CCA) treated radiata pine were exposed to the weather for 9 y on above-ground racks at five sites throughout eastern Australia. Results indicate (1) a poorly maintained external paint film generally accelerated decay, (2) a brush coat of water-repellent preservative inside the joints often extended serviceability (in some cases by a factor of up to seven times that of untreated joints) and (3) the level of protection provided by a coat of primer applied inside the joint varied and in most cases was not as effective as the water-repellent preservative treatment.

Keywords: service life; durability; decay; wood preservation; joinery; surface treatment; waterproofing

Introduction

A timber species is chosen for a particular application based on its natural durability, which determines in part how long it may perform. During construction, builders will often apply paint to joints believing the paint coat will provide increased protection against decay. A timber species' resistance to biodeterioration is called its natural durability and is defined in the Australian Standard on natural durability as *the inherent resistance of a timber species to decay or to insect or marine borer attack* (Australian Standard AS 5604-2005). The standard sets categories for probable life expectancies (resistance to decay organisms only), based on material from the outer heartwood of a timber species (Table 1) (Australian Standard AS 5604-2005). The sapwood of timber is considered to be not durable. Timber susceptibility to attack by termites and powder post beetles (lyctine species) is also defined in Australian Standard AS 5604-2005. Durability classes are allocated to more than 200 timber species for use above ground or in contact with the ground (Australian Standard AS 5604-2005). Variability in biodeterioration hazard throughout the country is allowed for in the standard by defining the categories according to a range of service life values. The range of service life values also takes into account variation in wood properties between trees within timber species, and within trees.

Table 1. Natural durability classification (Standards Australia 2005)

Durability class	Probable in-ground life expectancy (y)	Probable above-ground life expectancy (y)
1	> 25	> 40
2	15–25	15–40
3	5–15	7–15
4	0–5	0–7

In the case of above-ground natural durability, the durability classification (probable life expectancy) allocated to a timber species by Australian Standard AS 5604-2005 is based on expert opinion, data from Cause (1994) and more recent unpublished data.

The performance of unpainted and painted timber joints was examined by exposing 35 mm × 35 mm L-joint specimens to the weather out of ground contact at 11 sites across Australia (Cause 1994). Deterioration of the exposed pieces was enhanced by using a joint system, and although painted material was included, only the outside of the test specimens were coated. As the trial progressed, the need to evaluate the effect of internal treatment of the joint became apparent and a further trial was established by M.L. Cause (unpublished) in 1995. The trial used five species of timber and four treatments exposed at five sites throughout eastern Australia. This paper describes that research and presents interim results of the evaluation of decay in exposed joints.

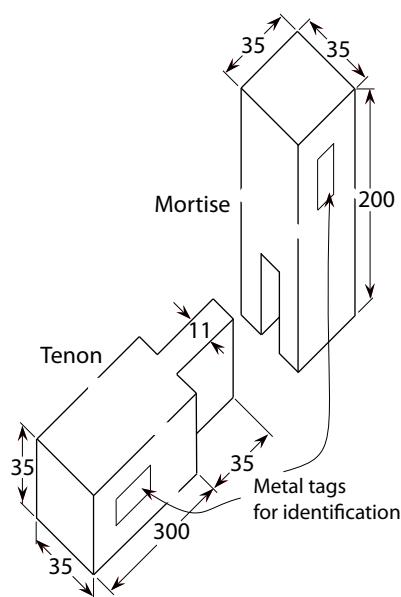
Materials and methods

Timber species

The effect of treatments on each timber species was tested using L-joint exposure specimens. A mortice-and-tenon jointing system was prepared from 35 mm × 35 mm stock and all joints were a machined fit (Fig. 1). The timber species were selected according to their current durability classification (Australian Standard AS 5604-2005) to represent a range of natural durability (Table 2).

Table 2. Timber species exposed at the five sites

Timber species	Trade name	Additional information	Above-ground durability classification ^A (1 = highest)
<i>Pinus radiata</i>	Radiata pine	Untreated, sapwood	4
<i>Pseudotsuga menziesii</i>	Douglas-fir	Fast growth, heartwood, imported from North America	4
<i>Lophostemon confertus</i>	Brush box	Outer heartwood	3
<i>Corymbia maculata</i>	Spotted gum	Heartwood	1
CCA ^B -treated <i>P. radiata</i>	Radiata pine	Sapwood treated to H3	1

^AStandards Australia (2005)^BCopper Chromium Arsenic Type C, 0.38% mass/mass (%Cu + %Cr + %As)**Figure 1.** L-joint test unit specifications (Cause 1994). All dimensions are in millimetres.

Treatments

The treatments applied to the L-joints were: unpainted controls, painted (external), painted external and primed in the joint, painted external and water-repellent preservative treated in the joint (Table 3). The internal surfaces of treated joints were painted with an acrylic primer or flood brushed with a proprietary water-repellent preservative (WRP) containing zinc naphthenate, permethrin and waxes and oils dissolved in a hydrocarbon solvent. An acrylic paint system was used to paint joint exteriors to simulate the effect of painting on exposed joinery. First, an acrylic primer was applied to the assembled L-joint specimens, followed by two coats of white acrylic paint. The 35 × 35 mm faces distal to the joint were sealed with adhesive bitumastic building paper to prevent the entry of moisture and micro-organisms. Second, once the paint was dry, each painted L-joint specimen was disassembled to break the external paint film, thus creating a high decay hazard within the joint. Breaking the paint coating at the joint was used to accelerate decay and may simulate joinery where paint systems are poorly maintained. Similarly, the design of the exposure racks on which the L-joint specimens were exposed may simulate joinery in extreme weather-exposed conditions such as the lower joint of an external window.

Table 3. Joint treatment

Treatment	External treatment	Internal joint treatment
1	Unpainted	Nil
2	Painted	Nil
3	Painted	Primed
4	Painted	Water-repellent preservative

Replicates of each timber species × treatment combination were exposed at five sites in eastern Australia. The sites were at South Johnstone (100 km south of Cairns in north Queensland), Beerburrum (70 km north of Brisbane), Dalby (200 km west of Brisbane), Pennant Hills (25 km north-west of Sydney) and Frankston (50 km south-east of Melbourne). Eighteen L-joints of each of the timber species × treatment combinations were randomly allocated to each of the five sites.

Field assay

At each site, the L-joint specimens were placed on exposure racks (Fig. 2) constructed from CCA treated plywood and durable framing timbers, about one metre above the ground (Cause 1994). Specimens of each timber species × treatment combination were randomly distributed amongst the racks. Plastic strips and brackets were fixed to the racks to support the L-joint specimens to prevent them from coming into direct contact with the plywood and to provide consistent spacing between each joint. At all sites the racks faced north and were constructed so that, when in position, the L-joint specimens were oriented 10° backward from vertical. The backward slope caused rain or dew to run toward the joint. Each rack had drain holes at the rear to ensure that water did not remain pooled on the rack.

Assessment

All L-joint specimens were assessed after exposure for 1, 3 and 9 y. In each case, the L-joint specimen was opened and the large faces and shoulders of the tenon were probed firmly using a small knife to detect the presence of decay (Cause 1994). Decay was evaluated by the degree of resistance to probing and assigned a deterioration score from a five-point scale (Table 4) which Cause modified from Carey *et al.* (1981). L-joint specimens of



Figure 2. Dalby exposure site

Table 4. Specimen assessment criteria (Cause 1994)

Deterioration score	Criteria for score (condition of the tenon)
4	Sound
3	Slight surface deterioration (i.e. incipient decay)
2	Small areas of obvious deterioration (< 25% of the assessable surface area decayed)
1	Extensive deterioration (> 25% of the assessable surface area decayed. For lower-durability species, the joint is deemed to be unserviceable.)
0	Joint failure (e.g. sufficient decay through the entire 11-mm thick cross-section of the tenon to allow the assessment probe to pass through)

lower-durability species with a deterioration score of one were deemed to be unserviceable and joints with a score of zero were removed from the trial.

Statistical analyses

For each site × timber species combination, the deterioration score after 9 y exposure was analysed using an ANOVA to determine whether there were treatment effects. Comparisons between treatments were done using Fisher's protected least significant difference test (LSD) (GenStat 2002).

An 's' shaped curve was used to model rates of joint deterioration:

$$\ln(-\ln(1-s)) = ax + b, \quad (1)$$

where \ln = natural logarithm, a = slope of the curve, b = intercept on the y axis, s = (mean deterioration score/4), and x = \ln elapsed time (in years).

Curves were fitted as generalised linear models with normal errors, complementary log-log link and points were weighted by the number of L-joint specimens contributing to the means (GenStat 2002). Grouped regression analyses comparing deterioration in joints for treatments were done separately for each timber species × site combination. Differences between the parameter estimates for each of the treatment curves were tested for significance

($P = 0.05$). Pooled estimates were used where differences were not significant (Francis and Norton 2005).

Results and discussion

The assessments revealed that timbers with low durability had either failed (deterioration score = 0) or undergone extensive decay within 9 y. Table 5 shows the number of L-joint specimens remaining in the trial after 9 y for each timber species × treatment combination. The mean deterioration scores (after 9 y) for each timber species × treatment combination exposed at each site are presented in Table 6.

It is important to consider the number of samples remaining after 9 y exposure (Table 5) in conjunction with the mean deterioration scores over the same period (Table 6). At each site, nearly all of the original 18 samples of brush box, spotted gum and treated radiata pine were still in the trial after 9 y exposure. However most of the brush box samples, despite still being in the trial, were scored lower than spotted gum and treated radiata pine samples.

Untreated radiata pine samples show the greatest extent of decay, and in general the external paint plus WRP treatment appeared to provide the most protection.

For untreated radiata pine, external paint plus WRP L-joints had mean deterioration scores that were significantly higher than the

Table 5. Number of specimens remaining after 9 y. Eighteen specimens were initially installed for each combination of timber species × treatment × site.

Site	Treatment ^A	Timber species ^B				
		UTR	DF	BBX	SPG	TRP
South Johnstone	Unpainted	0	10	15	18	17
	Painted	0	2	15	18	18
	Painted + prime	1	4	17	18	17
	Painted + WRP	4	14	18	18	18
Beerburrum	Unpainted	1	5	18	18	18
	Painted	0	9	17	18	18
	Painted + prime	0	11	16	18	18
	Painted + WRP	4	18	17	18	18
Dalby	Unpainted	5	13	18	18	18
	Painted	0	8	18	18	18
	Painted + prime	2	7	18	18	18
	Painted + WRP	5	18	18	18	18
Pennant Hills	Unpainted	5	7	18	18	18
	Painted	1	7	18	18	18
	Painted + prime	0	7	17	18	17
	Painted + WRP	4	18	18	18	18
Frankston	Unpainted	6	10	18	18	18
	Painted	4	9	18	18	18
	Painted + prime	0	12	18	18	18
	Painted + WRP	15	18	18	18	18

^APrime = acrylic primer; WRP = water-repellent preservative

^BUTR = untreated radiata pine; DF = Douglas-fir; BBX = brush box; SPG = spotted gum; TRP = treated radiata pine

other treatments at all sites except Pennant Hills. At every site, all treatments resulted in scores of less than one, with the exception of external paint plus WRP at Frankston.

In general, Douglas-fir L-joints had mean deterioration scores of less than two. The main exception was external paint plus WRP at three sites. External paint plus WRP L-joints were significantly more durable than those with external paint treatment only at all sites, and more durable than unpainted L-joints at all sites except South Johnstone. At three sites, L-joints treated with external paint plus primer were significantly more durable than those with external paint treatment only.

By contrast, brush box L-joints had mean deterioration scores above two at all sites except South Johnstone. At South Johnstone, L-joints that were unpainted and those that had external paint plus WRP were significantly more durable than those with external paint plus primer and those with external paint treatment only. Similar patterns are evident at the other sites, but less deterioration has occurred at those sites.

For spotted gum, most L-joints had minimal deterioration with mean deterioration scores much greater than two. South Johnstone was an exception, with mean scores falling between 1.5 and 2.1. Though unpainted joints had significantly higher scores than the other treatments at the remaining four sites, these results may not be indicative of long-term performance as minimal deterioration was detected.

The CCA-treated radiata pine L-joints showed very little evidence of deterioration. Except at Dalby, where results suggest that unpainted joints were most durable, there were no significant treatment effects evident after 9 y exposure.

Additional data gathered as the trial progresses are likely to provide further insight into the effects of the surface-applied treatments for the more durable timber species (CCA-treated radiata pine, spotted gum and brush box). For these species, treatment effects could not be reliably distinguished from those of the inherent durability of the timber itself.

Although Douglas-fir and untreated radiata pine are allocated the same durability classification rating under AS 5604:2005, more Douglas-fir samples remained in the trial after 9 y. All 18 Douglas-fir samples that were painted and treated in the joint with WRP remained at all sites except at South Johnstone where 14 remained (average score = 1.5). By comparison, most radiata pine samples had failed and were removed from the trial. This result highlights a limitation with the durability classification system used in the current standard (AS5604:2005) wherein timber species are assigned to one of only four durability classes that represent a wide range of estimated service life.

Timber biodeterioration hazards have been shown to vary considerably throughout the country (Cookson and Trajstman 2002; Leicester *et al.* 2003; Francis and Norton 2005). The last assessment of L-joints in this study showed that the mean score for

Table 6. Mean deterioration score after 9 y (4 = sound; 0 = failure) and least significant difference (LSD) for L-joints exposed at each site

Site	Treatment ^A	Timber species ^B				
		UTR	DF	BBX	SPG	TRP
South Johnstone	Unpainted	0.0 b	1.2 ab	1.8 a	2.1	3.5
	Painted	0.0 b	0.2 c	0.9 b	1.5	3.6
	Painted + prime	0.1 b	0.6 bc	1.1 b	1.7	3.8
	Painted + WRP	0.5 a	1.5 a	1.7 a	2.1	3.8
	LSD (5%)	0.4	0.8	0.5	NS ^C	NS
Beerburrum	Unpainted	0.1 b	0.4 c	3.3 a	3.7 a	3.7
	Painted	0.0 b	0.7 c	1.9 b	2.8 b	3.8
	Painted + prime	0.0 b	1.4 b	2.4 b	3.2 b	3.9
	Painted + WRP	0.6 a	2.3 a	2.3 b	3.1 b	3.8
	LSD (5%)	0.4	0.7	0.6	0.5	NS
Dalby	Unpainted	0.4 ab	1.4 b	3.8 a	4.0 a	3.6 a
	Painted	0.0 b	0.9 b	2.9 b	2.8 b	2.3 c
	Painted + prime	0.2 b	1.3 b	3.0 b	3.0 b	3.2 ab
	Painted + WRP	0.8 a	2.6 a	3.4 ab	3.1 b	2.9 b
	LSD (5%)	0.6	0.8	0.6	0.5	0.6
Pennant Hills	Unpainted	0.3	0.4 b	3.6 a	3.5 a	3.4
	Painted	0.1	0.6 b	2.0 b	1.7 c	3.5
	Painted + prime	0.0	0.7 b	1.9 b	2.6 b	3.3
	Painted + WRP	0.2	1.9 a	2.1 b	2.5 b	3.2
	LSD (5%)	NS	0.6	0.5	0.5	NS
Frankston	Unpainted	0.5 b	1.6 bc	4.0 a	3.9 a	3.8
	Painted	0.4 b	1.1 c	3.0 c	3.1 b	3.9
	Painted + prime	0.0 b	2.2 ab	3.4 b	3.5 ab	4.0
	Painted + WRP	2.0 a	3.1 a	3.7 ab	3.4 b	3.9
	LSD (5%)	0.6	1.0	0.4	0.4	NS

^APrime = acrylic primer; WRP = water-repellent preservative

^BUTR = untreated radiata pine; DF = Douglas-fir; BBX = brush box; SPG = spotted gum; TRP = treated radiata pine

^CNS = mean scores not significantly different ($P = 0.05$)

Table 7. Estimated time (y) for tenons to deteriorate from an initially-sound condition to an unserviceable state (a deterioration score of 1)

Timber species	Treatment ^A	Site				
		South Johnstone	Beerburrum	Dalby	Pennant Hills	Frankston
Radiata pine	Unpainted	1.8	2.8	6.1	5.4	5.8
	Painted	1.4	1.5	2.3	2.0	4.7
	Painted + prime	1.7	1.3	3.7	1.9	4.3
	Painted + WRP	6.2	5.5	8.0	4.8	14.6
Douglas-fir	Unpainted	8.1	5.4	13.6	6.0	16.3
	Painted	3.7	4.7	6.4	5.5	9.8
	Painted + prime	4.4	16.7	8.2	7.5	21.2
	Painted + WRP	12.1	ID ^B	24.6	20.9	ID
Brush box	Unpainted	17	ID	ID	ID	ID
	Painted	5.2	31.4	ID	25.4	ID
	Painted + prime	6.9	ID	ID	15.5	ID
	Painted + WRP	14.4	ID	ID	24.7	ID
Spotted gum	Unpainted	29.1	ID	ID	25.7	ID
	Painted	15.8	ID	ID	16.6	ID
	Painted + prime	16	ID	ID	16.6	ID
	Painted + WRP	24.7	ID	ID	34.7	ID

^APrime = acrylic primer; WRP = water-repellent preservative

^BID = insufficient data

unpainted untreated Douglas-fir joints at all sites ranged from 0.4 (>25% of the assessable surface area decayed) at Beerburrum and Pennant Hills to 1.6 (obvious areas of decay) at Frankston. This finding highlights a further limitation of AS 5604-2005, which provides only one range of probable life expectancy values for each species, irrespective of exposure location.

The results of this study might imply that a review of the AS5604-2005 classification of Douglas-fir is necessary. Any review, however, needs to be carefully considered as the trial configuration described in this research was designed to accelerate decay. To be useful for service life prediction, results should be calibrated against actual in-service performance, for example quantification of the performance of Douglas-fir joints compared to cladding. AS5604-2005 is not based on performance criteria, and the differences in biodeterioration hazards for different applications cannot be captured in the standard's current format.

It may be more appropriate to use data obtained from this research to further develop durability models for timber in-service performance.

For the purposes of this paper, it was considered that a score of one represents the point at which a joint in service might require inspection or replacement. The estimated time for each timber species to deteriorate to a score of one (more than 25% of the assessed surface area decayed or deteriorated) was determined from the deterioration model (Equation 1) (Table 7). All fitted

curves for treatment \times timber species \times site combinations had a coefficient of determination (R^2) greater than 0.90.

There was a strong relationship between mean deterioration score for low-durability timbers and elapsed time in years. Consequently for the low durability timbers, the predicted time to achieve a score of 1 (Table 7) provided a good indication of how the various joint treatments can be expected to perform. There were a number of combinations of species \times site \times treatment where there were insufficient data to produce meaningful results. It is expected that more data will become available as deterioration progresses with time.

In most cases the external paint plus WRP treatment effectively extends the expected service life of the low-durability timbers.

The performance of the various surface treatments compared to the performance of unpainted control joints of a nominated species (Table 8) shows the effect on service life of the different treatments. Comparisons have been presented only for those cases where deterioration (a score of three or lower) occurred in the unpainted specimens.

Painted joints that had no internal joint treatment deteriorated more quickly than unpainted joints under the hazard conditions of the exposure. The results are not as clear for the higher-durability timbers, but we suggest that any trends will become apparent as exposure proceeds and more samples fail. An earlier study indicated that poor maintenance of painted mortice-and-tenon

Table 8. Performance of timber species \times treatment at each site compared with unpainted joints of each species at each site (controls, assigned a value of 1 at each site)^A

Timber species	Treatment ^B	Site				
		South Johnstone	Beerburrum	Dalby	Pennant Hills	Frankston
Radiata pine	Unpainted	1.0	1.0	1.0	1.0	1.0
	Painted	0.8	0.5	0.4	0.4	0.8
	Painted + prime	0.9	0.5	0.6	0.4	0.7
	Painted + WRP	3.4	2.0	1.3	0.9	2.5
Douglas-fir	Unpainted	1.0	1.0	1.0	1.0	1.0
	Painted	0.5	0.9	0.5	0.9	0.6
	Painted + prime	0.5	3.1	0.6	1.3	1.3
	Painted + WRP	1.5	7.2	1.8	3.5	2.7
Brush box	Unpainted	1.0	ID ^C	ID	ID	ID
	Painted	0.3	ID	ID	ID	ID
	Painted + prime	0.4	ID	ID	ID	ID
	Painted + WRP	0.8	ID	ID	ID	ID
Spotted gum	Unpainted	1.0	ID	ID	1.0	ID
	Painted	0.5	ID	ID	0.6	ID
	Painted + prime	0.5	ID	ID	0.6	ID
	Painted + WRP	0.8	ID	ID	1.4	ID

^AData from Table 7, the estimated service life of each combination of species \times treatment \times site, were used as the basis for this table

^BPrime = acrylic primer; WRP = water-repellent preservative

^CID = insufficient data

joints would accelerate joint deterioration (Francis and Norton 2005). Accelerated joint deterioration is probably because moisture entering the joint takes longer to evaporate from under a paint film than if the joint was unpainted.

Conclusions

The major advantage of the trial is that field data are being gathered that represent the long-term performance of L-joints exposed to the weather in a range of climates. The results to date show:

- painting joints followed by induced failure of the paint film can lead to accelerated decay within the joint, compared with unpainted material. Beesly and co-workers (1983) (using flat panels 19 mm × 76 mm × 229 mm) also found that a surface coating accelerated the incidence of decay.
- applying a proprietary WRP is a good technique for extending the life of a housed joint
- painting the tenon of joints with an acrylic primer in most cases did not appear to provide the same level of protection as flood brushing the tenon with a WRP.

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References

- Beesly, J., Creffield, J.W. and Saunders, I.W. (1983) An Australian test for decay in painted timbers exposed to the weather. *Forest Products Journal* **33**(5), 57–63.
- Carey, J.K., Purslow, D.F. and Savory, J.G. (1981) Proposed method of out-of-ground contact trials of exterior joinery protection systems. In: *Proceedings of the 12th Annual Meeting of the International Research Group on Wood Preservation*, IRG WP 2157.
- Cause, M.L. (1994) Major above-ground timber durability trial in eastern Australia. In: Wells, J. (compiler) *Proceedings of the Pacific Timber Engineering Conference*. Gold Coast, Australia, 11–15 July 1994, pp. 412–421.
- Cookson, L.J. and Trajstman, A.C. (2002) *Termite Survey and Hazard Mapping*. Technical Report No. 137, CSIRO Forestry and Forest Products, Clayton South.
- Francis, L.P. and Norton, J. (2005) Above-ground durability estimation in Australia: results after 16 years exposure. In: *Proceedings of the 36th Annual Meeting of the International Research Group on Wood Preservation*. Bangalore, India. IRG/WP 05-20314.
- GenStat (2002) *GenStat for Windows Version 6.1*. VSN International Ltd, Oxford.
- Leicester, R.H., Wang, C.–H., Nguyen, M.N., Foliente, G.C. and MacKenzie, C.E. (2003) Structural durability of timber in-ground contact. Presented to: *36th CIB–W18 Meeting*. Colorado, USA, August. (International Council for Research and Innovation in Building and Construction, Working Commission W18: Timber Structures). Abstract at: <http://www.cmmt.csiro.au/research/papers/abstract.cfm/569>.
- Standards Australia (2005) *Timber — Natural Durability Ratings. Australian Standard AS 5604–2005*. Standards Australia, Sydney.