COMPARISON OF API, RF AND MUF ADHESIVES USING A DRAFT AUSTRALIAN/NEW ZEALAND STANDARD*

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ABSTRACT

Tests were done using MGP15 slash pine (i.e. non-standard) with an aqueous polymeric isocyanate (API), a resorcinol (RF) and a melamine-urea (MUF) adhesive to AS/NZS4364:2007 (Int), for hydrolytical stability, shear block strength, delamination and creep. The API was found to have a durability intermediate between that of the RF and the MUF adhesives. The draft standard needs to be improved by deletion of the hydrolytic test that involves water bath and oven treatment of specimens. The delamination test could also be deleted as it gives information that is essentially the same as the boil/freeze/dry shear block test. The creep test needs modification to prevent specimens buckling.

BACKGROUND

An interim version of AS/NZS 4364 has been published. This standard is for use by manufacturers to classify glues for durability. Previously it was specific to phenolic and aminoplastic adhesives which are the traditional resorcinol and melamine-based adhesives, but it has been amended to include a test for creep. This test was introduced with polyurethane and isocyanate adhesives in mind as these are believed to be susceptible to creep at elevated temperatures. The standard gives options from American and European standards and the tests selected from AS/NZS4364 were:

- Hydrolytic stability, using the method of ASTM 4502.
- Resistance to shear in the dry and wet states by compression.
- Hydro-mechanical response or resistance to delamination during exposure to wetting.
- Resistance to creep under static shear loading during exposure to high humidity, heat and combined heat and moisture.

SPECIMEN PREPARATION AND TESTING

Timber supplied for the tests was 600 mm lengths of MGP15 Radiata and slash pines in 90 x 35 mm dimension. To achieve members of the required size, some initial lamination using resorcinol adhesive was necessary.

Briefly, the tests involve the following:

HYDROLYTIC TESTS

280 modified conventional shear block specimens are made, each consisting of two pieces of timber 38 mm along the grain, 25 mm across the grain and 8 mm thick, glued together with a 6 mm overlap. Groups of 50 of these specimens are placed in water baths at temperatures of 60, 70, 77.5, 85 or 100 °C, or in ovens at 120, 130, 145, 160 or 170 °C. Groups of 10 specimens are removed at intervals, reconditioned to EMC and tested in shear.

SHEAR BLOCK TESTS

90 conventional shear block specimens are made, each consisting of two pieces of timber 45 mm along the grain, 50 mm across the grain and 20 mm thick, glued together with a 5 mm overlap. 30 specimens are tested dry, 30 are wetted by vacuum/pressure soaking, and 30 are subjected to seven boil/dry/freeze cycles with a final boil cycle. They are tested in shear in the condition they are when the conditioning is complete.

DELAMINATION TESTS

Six specimens are made, each consisting of six laminations 19 mm thick, 140 mm across the grain and 75 mm along the grain. The specimens are subjected to three cycles of vacuum/pressure wetting and oven drying. Delamination in the gluelines on the end grain surfaces is measured.

CREEP TESTS

Six specimens are prepared as described in AS/NZS4364. These are placed under a constant compressive load using a spring loaded cage. Two loaded specimens are conditioned at 20°C and 95% relative humidity (RH) for seven days then loaded (treatment A), two are conditioned at 20°C and 65% RH then loaded at 70°C and ambient RH for seven days (treatment B), while two are vacuum/pressure soaked, wrapped in clear flexible film to prevent moisture loss and loaded at 50°C for 28 days (treatment C). Creep in the gluelines is measured.

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RESULTS

HYDROLYTICAL TESTS

Times to 75% of control strength were calculated from the regressions fitted to the strength/time data (Figures 1 to 3). The regressions were forced to an intercept value of unity.

Table 1 gives the times to 25% strength loss at 20°C as predicted from the Arrhenius plots (Figures 4 to 6). These results are not credible because a life of 310 million years is not believable, even for solid wood. Also, MUF yielded better life predictions than did RF. There is a further problem when it comes to interpolating between the dry and wet estimates for intermediate moisture contents because the moisture condition for the wet tests is unknown. Therefore this test is not recommended.

Table 1. Estimation of times to 25% strength loss at 20°C.

		Slope	Intercept	Time to 75% strength at 20°C (Years)
Dry	API	6.5984	-14.7488	161,462
	RF	7.7728	-17.44	3,360,401
	MUF	9.7518	-22.229	310,244,217
Wet	API	5.2847	-13.9509	33.4
	RF	3.9493	-9.9085	10.2
	MUF	6.7772	-18.908	45.7

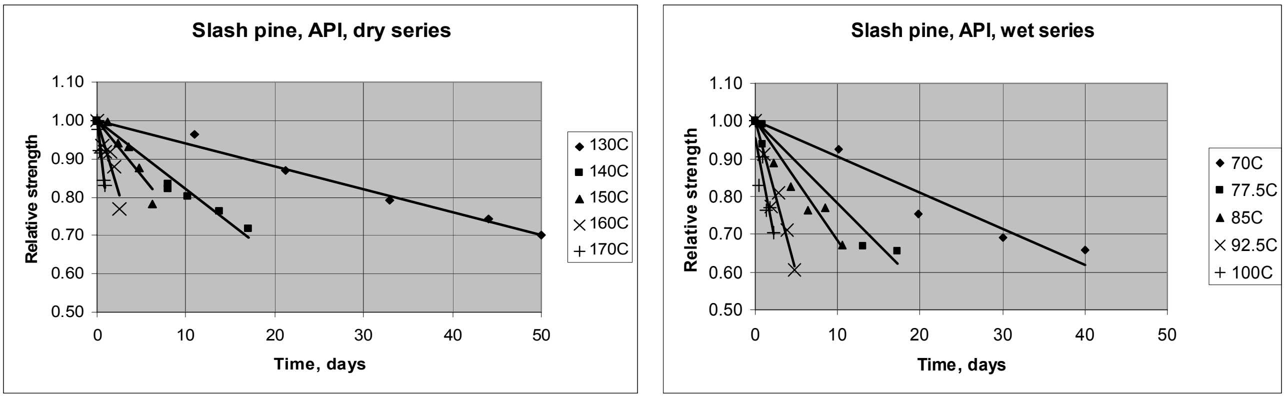

Figure 1. Strength/Time plots for API

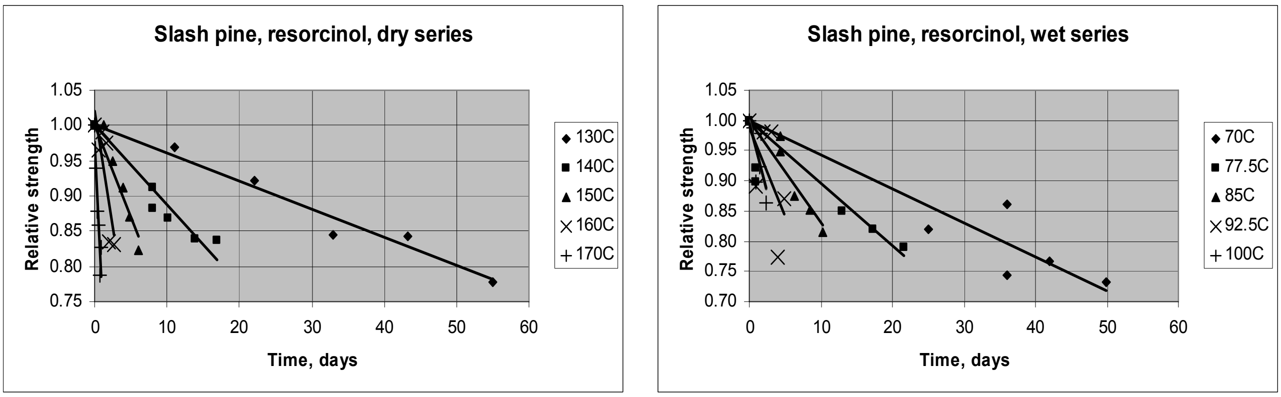

Figure 2. Strength/Time plot for RF

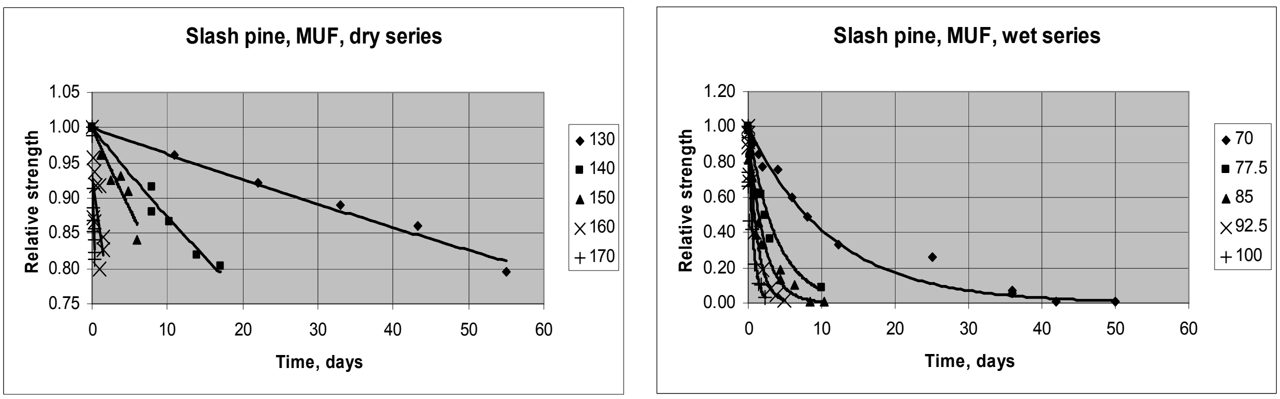

Figure 3. Strength/Time plot for MUF

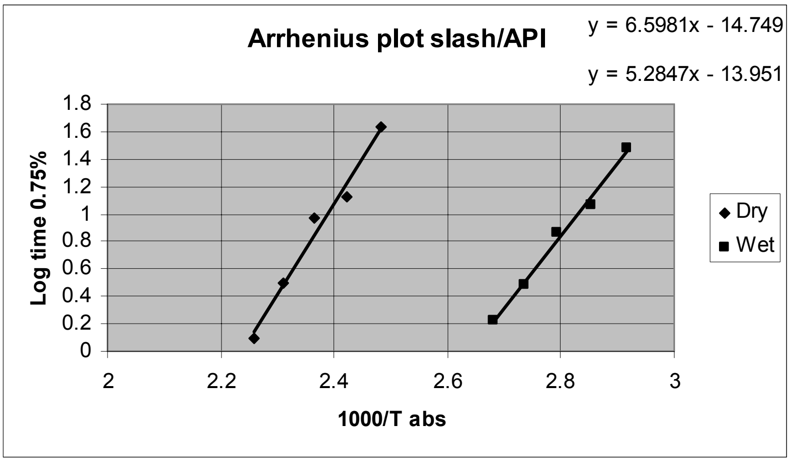

Figure 4. Arrhenius plot for API adhesion

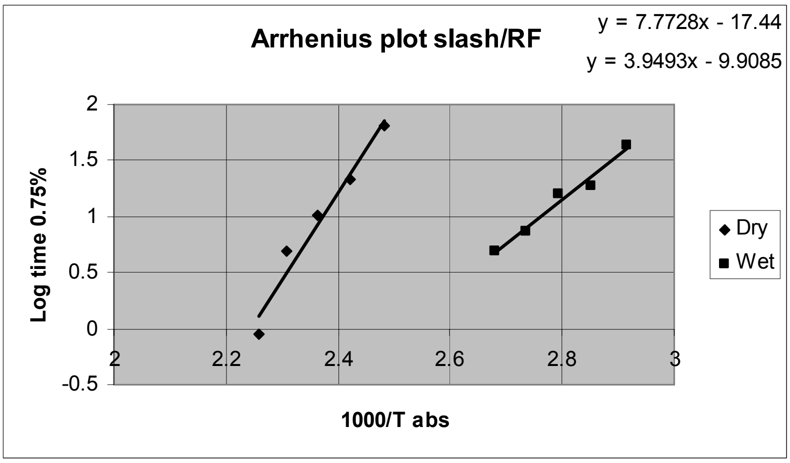

Figure 5. Arrhenius plot for RF adhesion

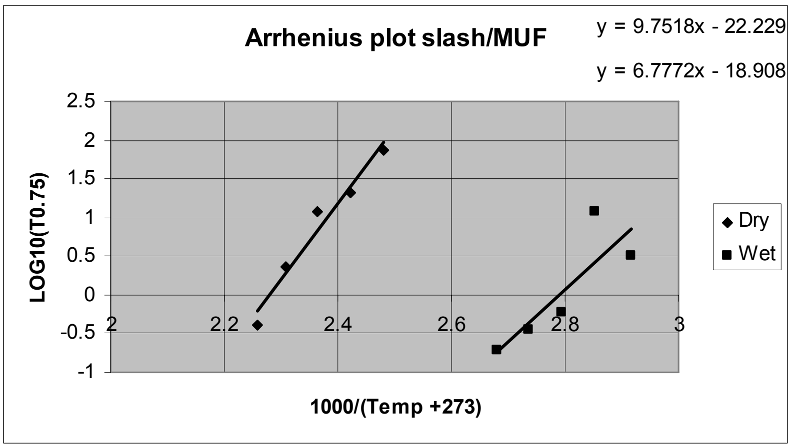

Figure 6. Arrhenius plot for MUF adhesion

SHEAR BLOCK TESTS

The median strengths and median and lower quartile wood failure results from the shear block tests are given in Table 2.

Table 2 shows that the MUF adhesive could not withstand the boil/dry/freeze treatment, otherwise all three adhesives passed these tests.

DELAMINATION TESTS

The observed delamination results are given in Table 3.

The maximum delamination permitted in any one glueline is 1% of the total glueline length, i.e. 13 mm, so none of the adhesives passed but the use of a non-standard species would have had an effect. However, it is apparent that the RF performs better than API which performs better than MUF.

Table 2. Shear block results summary

	Strength, MPa		Wood failure, %			
	Median	Standard	Lower Quartile	Standard	Median	Standard
API						
Dry	13.50	10	100	85	100	75
Vac/Press Soak	4.52	5.6	100	85	100	75
Boil/Dry/Freeze	3.08	3.5	100	85	100	75
RF						
Dry	13.88	10	100	85	100	75
Vac/Press Soak	5.92	5.6	100	85	100	75
Boil/Dry/Freeze	2.40	3.5	100	85	100	75
MUF						
Dry	13.71	10	100	85	100	75
Vac/Press Soak	5.61	5.6	100	85	100	75
Boil/Dry/Freeze	0	3.5	0	85	0	75

Table 3. Delamination results summary

	Maximum delamination in any one bond line (mm)		
Adhesive	**API**	**RF**	**MUF**
Max	64	20	130

CREEP TESTS

Under conditions A and B all the specimens of all adhesives showed zero creep but under condition C they collapsed as shown in Figure 7. The API-glued specimens showed some failure in the gluelines while the RF- and MUF-glued specimens showed failure only in the timber adjacent to the gluelines.

The specimens that collapsed showed no creep, i.e. where the gluelines were intact there was no displacement of the knife cuts that had been made across the gluelines prior to loading. The specimens that had survived treatment A were given treatment C and these collapsed. The specimens from treatment B were given treatment C, but in the loading cage shims were inserted to prevent buckling. These specimens survived.

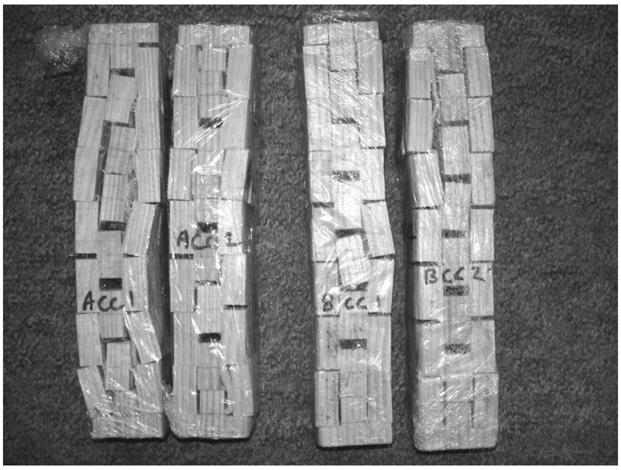

Figure 7. The API creep specimens that collapsed under 50°C conditions.

DISCUSSION

HYDROLYTICAL TESTS

These tests are not difficult to do but they are very time-consuming and give unrealistic answers. As commented earlier, the analysis requires an assumption to be made as to what is the relevant moisture content of the specimens in the water bath tests. The observation that the MUF adhesive gave longer predicted life than the RF adhesive is also a puzzle. There is an alternative method specified in ASTM D 4502 where the specimens are placed in sealable aging jars above saturated salt solutions and subjected to heat. This may be more realistic in that the specimens are not subjected to liquid water and thus the treatment is more representative of actual environmental conditions. It is recommended that this test be deleted from the draft standard.

SHEAR BLOCK TESTS

These tests are simple to perform and give definite answers.

DELAMINATION TESTS

These tests are also simple to perform and gave answers which agreed with those from the shear block tests.

CREEP TESTS

It appears that this test may need modification to ensure that the specimens cannot buckle under treatment C.

COMPARISON BETWEEN TESTS

The standard aims to define accelerated tests to determine how adhesives will perform under three service class conditions of:

- Service Class 1: Indoor, subject to seasonal fluctuations of temperature and humidity but not subject to wetting.
- Service Class 2: Indoor or outdoor, subject to seasonal fluctuations of temperature and humidity but protected from direct sun and rain.
- Service Class 3: Outdoors or in ground contact subject to outdoor climate.

The tests do not enable a decision to be made as to whether an adhesive is suitable for Service Classes 1 and 2, only whether or not it is suitable for Service Class 3. This is a deficiency in the draft standard that needs to be addressed.

Another problem with these tests is that a variety of species may be used. This brings in an unnecessary unknown effect. In these tests slash pine was used so it begs the question as to whether or not the results were affected by the timber. If results are to be compared internationally then the same species of timber must be used for all adhesives.

The shear block tests and the delamination tests both ranked the adhesives as RF being more durable than API which was more durable than MUF. Both the API and MUF were affected by treatments that used water baths rather than high humidity. The shear block and delamination tests can be considered to provide the same information and therefore one of these could arguably be deleted.

The creep test was introduced specifically for adhesives like API and PUR which do not set hard and are believed to creep under conditions of high temperatures. The creep tests conducted in this study show that the details of the equipment need to be modified to prevent buckling. Apart from that, under treatment C, the API appeared to fail in the gluelines as well as in the wood adjacent to the gluelines, while the RF and MUF appeared to fail in the wood only. This test is very time-consuming, mainly because of the intricacy of the specimens. A simpler specimen design is desirable.

CONCLUSIONS

- The hydrolytical test involving ovens and water baths should not be an option in the draft standard because it is open to different interpretations, is very time-consuming, and gives unrealistic answers.
- The shear block and delamination tests are quick and simple to do and give answers that are essentially equivalent which suggests that one of the tests could be deleted.
- The creep test needs modification to prevent specimens buckling.
- The API adhesive showed durability intermediate between that of RF and MUF.
- The durability of both the API and the MUF adhesives were significantly reduced in the presence of liquid water, as distinct from water vapour.