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Section 4 **Processes and Properties**

The resistance of high performance acetylated wood to attack by wood-destroying fungi and termites

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ABSTRACT

The resistance of high acetyl solid timber (Accoya®) and medium density fibreboard (Tricoya®) to attack by wood-destroying fungi and termites was investigated under both laboratory and field conditions. Laboratory studies were conducted in Japan, New Zealand and USA. Field studies were conducted in Australia, Japan, New Zealand, Thailand and UK. The results of the laboratory and field studies against decay fungi support previously published work showing that high acetyl timber is highly resistant to attack by wood destroying fungi. The laboratory and field studies against termites have improved knowledge of the resistance of acetylated wood to attack by termites; it has been demonstrated that Accoya® is highly resistant to attack by two species of the highly destructive *Coptotermes* genus. It would be expected that Accoya® would exhibit excellent long-term performance against wood destroying fungi and termites in most regions in the world.

Keywords: acetylation, Accoya®, Tricoya®, MDF, fungi, termites

1. INTRODUCTION

The acetylation of wood to improve its dimensional stability and durability has been studied for over 60 years (Tarkow *et al* 1946, Goldstein *et al* 1961, Peterson and Thomas 1978, Militz 1991, Bongers and Beckers 2003, Papadopoulos 2010). Considerable research has been conducted to determine the effect of acetylation on the resistance of modified wood to fungal degradation (Peterson and Thomas 1978, Nilsson *et al* 1988, Rowell *et al* 1989, Takahashi *et al* 1989, Beckers *et al* 1994, Rowell *et al* 1997, Ohkoshi *et al* 1999, Suttie *et al* 1999, Birkinshaw and Hale 2002, Papadopoulos and Hill 2002, Hill *et al* 2006), and there is generally good agreement amongst researchers that, at least above weight percent gains (WPG) of 15-20%, acetylated wood shows marked resistance to attack by most wood destroying fungi. Recently published data from long running in-ground stake studies (18 years) have confirmed that long term durability against fungal decay is only likely to be achieved at WPG of 22% or above (Larsson-Brelid and Westin 2010).

Compared with research on the resistance of acetylated wood to fungal decay, relatively few studies have been published on the resistance of acetylated wood to attack by wood destroying termites. Furthermore, those that have been published only contain data for a limited number of

termite genera or species from a limited number of countries, and results are not all in agreement. In Japan, Imamura and Nishimoto (1986, 1987) investigated the resistance of three acetylated softwoods to attack by *Reticulitermes speratus* (Kolbe) and *Coptotermes formosanus* Shiraki. Acetylated timbers exhibited a high resistance to attack by *R. speratus* in both laboratory and field tests, whereas *C. formosanus* consumed up to 30% of acetylated spruce (20% WPG) in field tests. Papadopoulos *et al* (2008) investigated the resistance of acetylated Corsican pine to attack by *Reticulitermes flavipes* (Kollar) under laboratory conditions. They observed that a WPG of 16% significantly reduced wood consumption, but at 30% WPG there was apparently still appreciable attack and mass loss (ca. 7%). Rowell *et al* (1997) conducted field tests with acetylated composite board stakes in the USA and Indonesia. A WPG of 20% afforded acceptable protection against termite attack in most cases, even after a number of years' exposure; the species of termite present at the field sites was not reported.

Accsys Technologies has developed a commercial scale production process for the manufacture of high acetyl WPG solid timber (Accoya® wood) and has adapted its proprietary acetylation technology to enable the production of high acetyl wood elements (Tricoya® wood elements) for use within panel products such as MDF. The exploitation of Tricoya® is now carried out by Tricoya Technologies Limited, a joint venture between Accsys and INEOS Industries Holdings Limited. As part of its due diligence, the company has commissioned a number of laboratory and field studies around the world to assess both the fungal and termite resistance of its products. The latest results from these studies are reported here.

2. MATERIALS AND METHODS

2.1 Laboratory Testing

2.1.1 Fungal bioassays

Japanese test
The performance of Accoya® Radiata pine against attack by wood-destroying brown and white rotting fungi was evaluated in accordance with JIS K 1571 (2004), and compared with that of untreated radiata pine (*Pinus radiata* D. Don) and Japanese cedar (*Cryptomeria japonica* (L.f.) D. Don) sapwood. The test specimen size was 20 x 20 x 10 mm. The fungi used in the study were *Formitopsis palustris* (brown rot) and *Trametes versicolor* (white rot). Test specimens were weathered prior to inoculation with the fungi, and maintained at 26℃, 70% relative humidity (RH) for 12 weeks. Performance of the test materials was determined by measured mass loss.

USA test
The tests were performed in accordance AWPA E10-06 (2009). The brown rotting fungi used were *Gloeophyllum trabeum*, *Neolentinus lepideus* and *Postia placenta*. The materials tested against these fungi included Accoya® Radiata pine (from New Zealand and Chile), Accoya® Southern Yellow Pine (SYP), untreated radiata pine (from NZ and Chile) and untreated SYP. The white rotting fungi used were *T. versicolor*, *Irpex lacteus* and *Phanerochate chrysosporium*. The materials tested against these fungi included Accoya® Radiata pine (from NZ), Accoya® SYP and untreated poplar (*Populus* spp.). The duration of the tests was 12 weeks. Performance of the test materials was determined by measured mass loss.

2.1.2 Accelerated soil contact / Fungal cellar

Japanese test
The performance of Accoya® Radiata pine against attack by wood-destroying fungi was evaluated in accordance with JIS K 1571 (2004), and compared with that of untreated radiata pine and Japanese cedar sapwood. The test specimen size was 20 x 20 x 100 mm (thickness x width x length). Test specimens were buried in soil, collected from the forest floor and containing a wide variety of naturally occurring and active decay fungi, to a depth of 80 mm and maintained at 26℃, 70% RH. The condition of specimens was rated after exposure for one year.

New Zealand test
The performance of Accoya® Radiata pine against attack by wood-destroying fungi was evaluated in comparison with that of untreated radiata pine and kwila (merbau) (*Instia bijuga* (Colebr.) Kuntze). Test specimen size was 10 x 5 x 160 mm (thickness x width x length). 10 replicates of each material were installed in soil beds in the fungus cellar facility at Scion, Rotorua in March 2005. The chambers in this facility are maintained at 27℃, 85% RH. The condition of stakes in the test have been assessed regularly since they were installed, using a decay assessment scale similar to that described in ASTM D1758. The most recent inspection occurred after eight years' exposure.

USA test
The evaluation was conducted in accordance with the AWPA E23-09 accelerated method of evaluating wood preservatives in soil contact. The materials tested included Accoya® Radiata pine (from NZ and Chile), Accoya® SYP, untreated radiata pine (from NZ and Chile) and untreated SYP. Test specimen size was 3 x 14 x 150 mm (thickness x width x length). Nine replicates of each material were installed in soil beds maintained at 100% water holding capacity at a temperature of between 22 and 28℃. The condition of the test specimens was determined after 15 months' exposure using a decay rating scale similar to that described in ASTM D1758 (2006).

2.1.3 Termite bioassays
Laboratory termite bioassays were conducted in both Japan and the USA. In both cases the test termite used was *C. formosanus*.

Japanese test
The performance of Accoya® Radiata pine against attack by *C. formosanus* was evaluated in accordance with JIS K 1571 (2004). The performance of the Accoya® was compared with that of untreated radiata pine and Japanese cedar sapwood. The test specimen size was 20 x 20 x 10 mm (thickness x width x length). Each test specimen was exposed to 150 workers and 15 soldiers in an individual container for 21 days. Any dead termites were removed during the test period. Performance of the test materials against attack by *C. formosanus* was determined by measured mass loss. Any termite mortality at the conclusion of the test was also recorded.

Two separate bioassays were conducted, one investigating the performance of Accoya® Radiata pine taken randomly from supplied samples, the other investigating the performance of Accoya® Radiata pine taken from the outer and inner portions of supplied samples.

USA test
A termite resistance test was performed in accordance with the AWPA E1-09 (2009). The choice method was used, consisting of leached and un-leached Accoya® Radiata pine, Accoya® Southern Yellow Pine (SYP), untreated radiata pine and SYP samples. Choice samples were

comprised of SYP sapwood. Accoya® Radiata pine and untreated radiata pine samples were comprised of material grown in both New Zealand (NZ) and Chile. All test specimens measured 25 x 25 x 6.4 mm (thickness x width x length), and contained 4 to 6 growth rings per 25 mm.

Five replicates of each sample type were included in the test. Each testing jar contained 150 g of autoclaved sand and 30 ml of distilled water. A test specimen was placed in each jar on top of the sand on an aluminium foil barrier to prevent any chemical leaching. Quantities of *C. formosanus* were aggregated and collected from the Brechtel State Park (Algiers, La) and 1.76 g of termites (400 individuals) were introduced into each jar on the side opposite the test specimen. The test duration was four weeks. Performance of the test materials against attack by *C. formosanus* was determined by measured mass loss and assignment of a visual rating. Any termite mortality at the conclusion of the test was also recorded.

2.2 Field Testing

2.2.1 Above-ground

Australian test

The performance of Accoya® Radiata pine, Accoya® Alder, Accoya® Beech, and Tricoya® medium density fibreboard (MDF) (manufactured from both radiata pine and spruce (*Picea* spp.) fibre) against attack by Australia's most economically important species of subterranean termite, *Coptotermes acinaciformis* (Froggatt), was evaluated in a Hazard Class H3 field trial. The performance of the acetylated materials was compared with that of the sapwood of untreated radiata pine, alder (*Alnus* spp.) and European beech (*Fagus sylvatica* L.), untreated exterior grade MDF, and the naturally durable heartwood of kwila (merbau), spotted gum (*Corymbia maculata* (Hook.) K.D. Hill & L.A.S. Johnson) and western red cedar (*Thuja plicata* Donn ex D.Don). Solid timber test specimens measured 35 x 35 x 100 mm and MDF test specimens measured 105 x 100 x 12 mm.

The test methodology used was in accordance with that specified in the AWPC Protocols for Assessment of Wood Preservatives (2007). Prior to exposure in the field test specimens were first leached in water for seven days, and then artificially weathered in vacuum ovens for five days at 40°C and 0.05 mBar to remove any residual volatiles. Test specimens were contained within stainless steel exposure chambers with equal volumes of susceptible bait-wood, the latter present in order to attract and maintain the presence of the target termite species. Exposure chambers were connected to active galleries of *C. acinaciformis* in live, standing trees, and removed from the field once all susceptible material had been consumed and termites had vacated the chambers; the exposure period was five months. Seven replicate test specimens of each sample were exposed in the field trial against seven different colonies of *C. acinaciformis*. The test site was located at Humpty Doo, Northern Territory, Australia.

UK test

An L-joint field trial based on the European standard EN 330 (1993) was established at the BRE Garston exposure site in Watford, UK in 1998. Three L-joints were made from (uncatalysed) acetic anhydride acetylated Scots pine sapwood (*Pinus sylvestris* L.), and three other L-joints were made from Scots pine sapwood treated with alkenyl succinic anhydride (ASA). Analysis indicated that the acetylated samples were treated to the core whilst with the ASA only a thin envelope treatment was achieved. The treated L-joints were coated with a medium build opaque gloss solvent-borne alkyd-based paint and the ends were treated with a two pack water proof end-seal. Since its installation the trial has been inspected regularly, with the condition of test

specimens assessed using the EN 330 rating system. The most recent inspection occurred after 15 years' exposure.

2.2.2 In-ground

Japanese test
The performance of Accoya® Radiata pine against attack by *C. formosanus* was evaluated in accordance with JIS K 1571 (2004) in an in-ground vertical stake field trial at a site located in the Kyushu region, Japan (it should be noted that the termite species *R. speratus* is also present at this location). The performance of the Accoya® was compared with that of untreated radiata pine. Untreated Japanese red pine (*Pinus densiflora* Siebold & Zucc.) sapwood stakes were included in the trial as susceptible bait-wood to attract termites into the test site. The test stakes measured 30 x 30 x 350 mm (thickness x width x length), and their condition was evaluated after one and two years' in-ground exposure using a visual rating system. Five replicate test specimens of each sample were exposed in the field trial.

The performance of Accoya® Radiata pine against attack by wood-destroying fungi was also evaluated in accordance with JIS K 1571 in a similar in-ground vertical stake field trial at the same site located in the Kyushu region of Japan. The test site is located on a slope subject to moisture laden winds coming off the nearby ocean. The warm temperatures and high annual rainfall in excess of 2.3 metres create an environment where severe decay conditions are prevalent for much of the year. The performance of the Accoya® was compared with that of untreated radiata pine and untreated Japanese cedar. The test stakes measured 30 x 30 x 600 mm (thickness x width x length), and their condition was evaluated after one and two years' in-ground exposure using a visual rating system. Five replicate test specimens of each sample were exposed in the field trial.

New Zealand test
The performance of Accoya® Radiata pine against attack by wood-destroying fungi was evaluated in an in-ground graveyard test at the Whakarewarewa outdoor test area at Scion. For comparison stakes made from untreated radiata pine and the heartwood of teak (*Tectona grandis* L.f.), Western red cedar and macrocarpa (*Cupressus macrocarpa* Hartw. ex Gordon) were included in the trial. Test specimen size was 20 x 18 x 500 mm (thickness x width x length). 10 replicates of each material were installed in the trial in 2005. The condition of stakes in the test have been assessed regularly since they were installed, using a decay assessment scale similar to that described in ASTM D1758. The most recent inspection occurred after eight years' exposure.

Thailand test
The test was established in accordance with the AWPA E7-09 standard method of evaluating wood preservatives by field tests with stakes. The performance of Accoya® Radiata pine against attack by wood-destroying fungi and termites was evaluated in in-ground graveyard tests located at five different sites in Thailand. Teak and makha (*Afzelia xylocarpa*) were included as naturally durable reference timbers. Test specimen size was 90 x 22 x 470 mm (thickness x width x length). 20 replicates of each material were installed at each trial site in 2010. The condition of stakes in the test have been assessed regularly since they were installed, using an assessment scale similar to that described in ASTM D1758. The most recent inspection occurred after two years' exposure.

3. RESULTS AND DISCUSSION

3.1 Laboratory Testing

3.1.1 Fungal bioassays

Japanese test

A summary of the mean mass losses for test specimens after exposure to the brown rotting fungus *F. palustris* and white rotting fungus *T. versicolor* in the laboratory for 12 weeks is given in Table 1. Mass losses in the Accoya® were negligible compared with the untreated controls and susceptible reference material.

Table 1: Mean mass losses for test specimens after exposure to the fungi *F. palustris* and *T. versicolor* in the laboratory test according to JIS K 1571 (2004) for 12 weeks.

Material Type	Mean Mass Loss [%]	
	F. palustris	***T. versicolor***
Accoya® Radiata pine	0.0	0.3
Untreated Radiata pine	27.3	25.4
Japanese cedar	41.2	32.6

USA test

Summaries of the mean mass losses for test specimens after exposure to three species of brown rotting fungi and three species of white rotting fungi in the laboratory for 12 weeks are given in Tables 2 and 3 respectively. It is evident that mass losses in the Accoya® materials were negligible compared with the untreated controls and susceptible reference materials.

Table 2: Mean mass losses for test specimens after exposure to three species of brown rotting fungi in the laboratory test (AWPA E10-06 (2009) for 12 weeks.

Material Type	Mean Mass Loss [%]		
	G. trabeum	***N. lepideus***	***P. placenta***
Accoya® Radiata pine (NZ)	-0.1	-0.2	0.0
Accoya® Radiata pine (Chile)	0.3	-0.2	0.0
Accoya® SYP	0.0	-0.4	0.0
Untreated Radiata pine (NZ)	62.3	19.7	28.2
Untreated Radiata pine (Chile)	50.1	19.6	30.5
Untreated SYP	42.5	21.1	28.6

Table 3: Mean mass losses for test specimens after exposure to three species of white rotting fungi in the laboratory test (AWPA E10-06 (2009) for 12 weeks.

Material Type	Mean Mass Loss [%]		
	T. versicolor	***I. lacteus***	***P. chrysosporium***
Accoya® Radiata pine (NZ)	0.2	-0.2	0.1
Accoya® SYP	-0.2	0.1	-0.1
Untreated Poplar	16.4	11.9	4.2

3.1.2 Fungal cellar / Accelerated soil contact

Japanese test

A summary of the mean decay ratings for test specimens after exposure in the fungal cellar test for one year is given in Table 4. There was no evidence of decay in any of the Accoya® test

specimens, whereas the untreated controls and susceptible reference material exhibited high levels of fungal decay.

Table 4: Mean decay ratings for test specimens after exposure in the fungal cellar test in accordance with JIS K 1571 (2004) for one year.

Material Type	**Decay Rating[a]**
Accoya® Radiata pine	0.0
Untreated Radiata pine	2.5
Japanese cedar	4.4

[a] *0 = Sound, 5 = Complete failure*

New Zealand test

A summary of the mean decay ratings for test specimens after exposure in the fungal cellar test for two, four and eight years is given in Table 5. The untreated radiata stakes had failed to decay after 18 months' exposure. In contrast, only one of the 10 Accoya® stakes is exhibiting evidence of slight decay after eight years' exposure. The durable reference timber, kwila (merbau), has decayed steadily over the course of the test, with most stakes now having failed or exhibiting severe levels of decay.

Table 5: Mean decay ratings for test specimens after exposure in the Scion fungal cellar test for eight years.

Material Type	**Decay Rating[a]**		
	2 years	**4 years**	**8 years**
Accoya® Radiata pine	10.0	10.0	9.9
Untreated Radiata pine	0.0	0.0	0.0
Kwila (Merbau)	7.1	4.8	3.4

[a] *10 = Sound, 0 = Complete failure*

USA test

A summary of the mean decay ratings for test specimens after exposure in the accelerated soil contact test for 15 months is given in Table 6. There was no evidence of decay in any of the Accoya® test specimens. In contrast, the untreated radiata pine controls had failed to decay after 15 months, whilst the untreated SYP controls were lightly decayed.

Table 6: Mean decay ratings for test specimens after exposure in the accelerated soil contact test (AWPA E23-09) for 15 months.

Material Type	**Decay Rating[a]**
Accoya® Radiata pine (NZ)	10.0
Accoya® Radiata pine (Chile)	10.0
Accoya® SYP	10.0
Untreated Radiata pine (NZ)	0.0
Untreated Radiata pine (Chile)	0.0
Untreated SYP	8.7

[a] *10 = Sound, 0 = Complete failure*

3.1.3 Termite bioassays

Japanese tests

Summaries of the mean mass losses for test materials exposed for 21 days in the laboratory against *C. formosanus*, together with observations on termite mortality, are given in Tables 7 and 8.

Table 7: Mean mass losses and termite mortality for test specimens after exposure to *C. formosanus* in the laboratory test according to JIS K 1571 (2004) for 21 days (test 1).

Material Type	Mass Loss [%]	Termite Mortality [%]
Accoya® Radiata pine	3	21
Untreated Radiata pine	10	9
Japanese cedar	30	6

Table 8: Mean mass losses and termite mortality for test specimens after exposure to *C. formosanus* in the laboratory test according to JIS K 1571 (2004) for 21 days (test 2).

Material Type	Mass Loss [%]	Termite Mortality [%]	
		Worker	Soldier
Accoya® Radiata pine (outer portion)	3	6	93
Accoya® Radiata pine (inner portion)	3	6	99
Untreated Radiata pine	14	6	20
Japanese cedar	29	7	27

Whilst the Accoya® wood materials were attacked by *C. formosanus* in the laboratory trial, the mass losses were low, being no greater than three percent. In contrast, the mass losses the untreated radiata pine and Japanese cedar samples were much higher, ranging from 10 to 30%. The mass losses of the outer and inner portions of the Accoya® Radiata pine sample were identical, which provides supporting evidence for uniform acetylation of the timber substrate through its cross-section.

USA tests

A summary of the mean mass losses and visual ratings for test materials exposed for four weeks in the laboratory against *C. formosanus*, together with observations on termite mortality, is given in Table 9.

All Accoya® wood materials were attacked by *C. formosanus* in the laboratory trial, with mass losses ranging from one to five percent. However, the mass loss was significantly lower than that incurred by the untreated radiata pine and southern pine samples, which ranged from 12 to 40%. The untreated choice test specimens were preferentially attacked in the jars containing the Accoya® test specimens, whereas the reverse was true in the jars containing the untreated radiata pine test specimens. Leaching did not appear to have a significant influence on the susceptibility of Accoya® materials to attack by *C. formosanus*. The visual ratings supported the mass loss data.

Termite mortality after four weeks was similar and relatively low for all materials, being in the range 7-12%. There was no significant difference between the Accoya® wood samples and the untreated samples, regardless of whether they were leached or un-leached. This suggests that Accoya® does not have a toxic mode of action against wood destroying insects such as termites.

Table 9: Termite mortality and mean mass losses and visual ratings for test specimens after exposure to *C. formosanus* in the laboratory test (AWPA E1-09) for four weeks.

Material Type	Leached / Un-leached	Mass Loss [%]		Visual Rating[a]		Mortality [%]
		Treated	Untreated Choice	Treated	Untreated Choice	
Accoya® Radiata pine (Chile)	Leached	1	22	8.2	4.6	8
	Un-leached	3	18	7.2	4.0	10
Accoya® Radiata pine (NZ)	Leached	2	26	7.5	4.0	12
	Un-leached	3	26	7.4	4.7	10
Accoya® SYP	Leached	5	28	6.4	4.0	10
	Un-leached	4	25	7.0	4.6	7
Untreated Radiata pine (Chile)	Leached	34	5	4.0	7.7	10
	Un-leached	15	15	4.3	4.7	11
Untreated Radiata pine (NZ)	Leached	40	4	3.2	7.5	7
	Un-leached	35	9	0.8	7.7	12
Untreated SYP	Leached	13	18	7.1	6.4	10
	Un-leached	12	13	7.0	6.5	8
SYP Controls	Un-leached	26		0.5		10

[a] *10=Sound, surface nibbles permitted, 9=Light attack, 7=Moderate attack, penetration, 4=Heavy attack, 0=Failure*

3.2 Field Testing

3.2.1 Above-ground

Australian test

A summary of the mean mass loss data for test materials exposed for five months in the Hazard Class H3 field trial is given in Table 10. At the conclusion of the field trial, all test specimens within the seven exposure containers had evidence of contact by *C. acinaciformis.* All untreated bait-wood had been destroyed. The majority of the susceptible sapwood and exterior grade MDF test specimens were destroyed or severely attacked by *C. acinaciformis*. The mean mass losses for each material type ranged from 74% to 95%. These mass losses, together with the destruction of the susceptible bait-wood, demonstrated that test specimens were subjected to a high level of termite pressure during the field trial. The fact that not all susceptible sapwood and exterior grade MDF test specimens were completely destroyed by termites reflects the typical variability in relative voracity between different colonies frequently observed in field trials.

Table 10: Mean mass loss of test specimens after exposure to *C. acinaciformis* in a Hazard Class H3 field trial (AWPC Protocols for Assessment of Wood Preservatives (2007)).

Material Type	Mean mass loss [g]	Mean mass loss [%]
Accoya® Radiata pine	0.31	0.5
Accoya® Alder	0.42	0.7
Accoya® Beech	0.32	0.4
Tricoya® (radiata pine)	0.99	1.2
Tricoya® (spruce)	0.89	1.1
Radiata pine sapwood	41.01	82.6
Alder sapwood	47.13	83.9
Beech sapwood	71.22	94.6
Exterior grade MDF	64.56	74.3
Kwila heartwood	0.25	0.3
Spotted gum heartwood	1.25	1.0
Western red cedar heartwood	11.47	28.6

The kwila (merbau) and spotted gum heartwood test specimens were highly resistant to attack by *C. acinaciformis*, with mean mass losses of 0.3% and 1.0% respectively. In contrast, three of the seven western red cedar heartwood test specimens were significantly attacked, one being destroyed and a second largely destroyed. The mean mass loss for western red cedar was 28.6%. All of the Accoya® and Tricoya® materials performed similarly to kwila and spotted gum heartwood, having mean mass losses ranging from 0.2% to 1.2%. Any attack by *C. acinaciformis* largely consisted of minor localised grazing on the surfaces of test specimens.

UK test

A summary of the mean decay ratings for test specimens after exposure in the EN 330 L-joint test for five, nine and 15 years is given in Table 11. Over the course of the trial the ASA-treated joints have steadily degraded, and after 15 years all three have now failed. After five years one of the three acetylated joints was assessed to have contained slight levels of decay. However, this was not evident in subsequent inspections, and was attributed to misinterpretation of wood softening due to the presence of excessive moisture at the time of the five-year inspection. After 15 years all three of the acetylated joints are largely sound, showing only discoloration due to fungal attack.

Table 11: Mean decay ratings for test specimens after exposure in the EN 330 L-joint test for 15 years.

Material Type	**Decay Rating[a]**		
	5 years	**9 years**	**15 years**
Acetylated Scots pine sapwood	1.3	1.0	1.0
ASA-treated Scots pine sapwood	2.7	3.0	4.0

[a] *0 = Sound ,1= Slight attack / discolouration, 2 = Moderate attack, 3 = Severe attack 4 = Failure*

3.2.2 In-ground

Japanese test

A summary of the mean ratings for test materials exposed for two years against *C. formosanus* in the vertical stake field trial is given in Table 12.

Table 12: Mean ratings for stakes after exposure to *C. formosanus* in the field (JIS K 1571) for two years.

Material Type	**Rating[a]**	
	1 Year	**2 Years**
Accoya® Radiata pine	0	0
Radiata pine	46	76
Japanese red pine	Heavy attack	Heavy attack

[a] *0=Sound, 10=Shallow damage on surface, 30=Internal damage, 50=Widespread internal damage, 100=Collapse of stake.*

After two years' exposure in the field Accoya® stakes were in a sound condition. In contrast, untreated radiata pine stakes had been significantly attacked by *C. formosanus*, with three of the five stakes largely destroyed. The Japanese red pine stakes also exhibited heavy attack by *C. formosanus* after both one and two years' exposure, demonstrating that test specimens were subjected to a high level of termite pressure during the field trial

A summary of the mean ratings for test materials exposed for two years against wood-destroying fungi in the vertical stake field trial is given in Table 13. After two years' exposure in the field Accoya® stakes were in a sound condition. In contrast, untreated radiata pine and Japanese cedar stakes were showing signs of widespread decay.

Table 13: Mean ratings for stakes after exposure to wood-destroying fungi in the field for two years.

Material Type	Decay Rating[a]
Accoya® Radiata pine	0.0
Radiata pine	1.7
Japanese cedar	2.0

[a]0 = Sound, 5 = Complete failure

New Zealand test

A summary of the mean decay ratings for test specimens after exposure in the in-ground graveyard test for two, four and eight years is given in Table 14. The Accoya® stakes are exhibiting evidence of very slight decay after eight years' exposure. In comparison the naturally durable reference timbers are showing much higher levels of decay, with teak having extensive decay and both the western red cedar and macrocarpa now being close to complete failure.

Table 14: Mean decay ratings for test specimens after exposure in the Scion graveyard test for eight years.

Material Type	Decay Rating[a]		
	2 years	4 years	8 years
Accoya® Radiata pine	10.0	9.9	9.5
Teak	8.6	7.6	5.4
Western red cedar	8.3	6.3	3.0
Macrocarpa	7.8	3.8	1.5

[a]10 = Sound, 0 = Complete failure

Thailand test

A summary of the mean decay and termite ratings for test specimens after exposure in the in-ground graveyard tests at five sites for two years is given in Table 15. The Accoya® stakes are exhibiting evidence of very slight decay and slight nibbling by termites after two years' exposure. Teak is performing comparably, whilst makha is performing less well, particularly against termites.

Table 15: Mean decay and termite ratings for test specimens after exposure in the graveyard tests (AWPA E7-09) at five sites in Thailand for two years.

Material Type	Decay Rating[a]	Termite Rating[a]
Accoya® Radiata pine	9.4	9.6
Teak	9.1	9.3
Makha	8.2	6.8

[a]10 = Sound, 0 = Complete failure

4. CONCLUSIONS

The results of the laboratory and field studies against decay fungi presented here appear to confirm that highly acetylated timber is highly resistant to attack by wood destroying fungi. Furthermore, the laboratory and field studies against termites have significantly improved knowledge of the resistance of acetylated wood to attack by termites; it has been demonstrated that Accoya® is highly resistant to attack by two species of the highly destructive *Coptotermes* genus. It would be expected that Accoya® would exhibit excellent long-term performance against wood destroying fungi and termites in most regions in the world.

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