Accoya® wood flooring and decking in extreme environments

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ABSTRACT

For the first commercial production of acetylated wood in 2007, Accsys Technologies utilised acetylation technology on Radiata Pine (*Pinus radiata* D. Don). This is sold under the brand name Accoya® wood and has been used for many applications worldwide; among which windows, doors, cladding and decking. Recently Accoya® Alder was launched commercially, encompassing the acetylation of Red Alder (*Alnus rubra*) and European Alder (*Alnus glutinosa*). Other wood species are under investigation.

The commercial Accoya® species offer slightly different product attributes. This paper describes testing of these species for a range of particularly demanding flooring and decking applications in which traditional wood products, with the exception of the increasingly scarce old growth Burmese teak, have performed poorly.

INTRODUCTION

Besides aesthetics, the main properties of solid wood flooring are sufficient surface hardness, dimensional stability, skid resistance and resistance against wearing. For interior use, many wood species are able to meet the minimum requirements and, with different coatings, one species can provide a wide scope of appearances. Exterior flooring places an additional set of demands on wood flooring, with perhaps the most severe situation being yacht decking. Dimensional stability, surface smoothness, high skid resistance and low thermal heat gain are critical to successful service in these severe applications which are mainly in utility class 3 and 4 according to EN 335.

Burmese teak is commonly used for yacht decking. However, there is some general acceptance that availability of sustainable Burmese teak is set to diminish. Kollert *et al*. (2012) conclude that a maximum sustainable supply of quality teak from Myanmar is likely to be in the order of 400,000 m^3/year or less. In future it can be expected that the sustained production of teak logs from natural forests will be further limited due to increasing deforestation and increasing pressure related to environmental factors. Hence, the supply trend points to a continuing decline in the volume and quality of natural teak. An extra influence on direct availability has the Burmese export ban of logs starting on 1 April 2014. As the material becomes scarcer, prices are likely to rise.

Based on several literature studies plantation Teak is no real alternative. Durability and dimensional stability of faster grown plantation wood have been determined as inferior to the old growth timber. Wolfsmayr *et al.* (2008) mention that: 'fast grown teak trees from a growth site in Costa Rica were harvested at an early growth stage, consisted entirely of juvenile wood and had a high proportion of sapwood. It was expected therefore that such conditions should not lead to high durability that is typical for teak. However the study revealed the same durability class (1, very durable) as mature natural grown teak for the outer part of the heartwood from plantations. The inner heartwood was slightly less durable (class 2, durable) but this fact is also known for natural teak.'
Separate ground contact stake trial testing at SCION (Simpson *et al.* 2013) indicates that Solomon Islands plantation teak grown on an 80 year rotation has durability which exceeds western red cedar but is some way below CCA H4 which can broadly be regarded as equivalent to Class 1 durable, and further again below Accoya after 8 years.

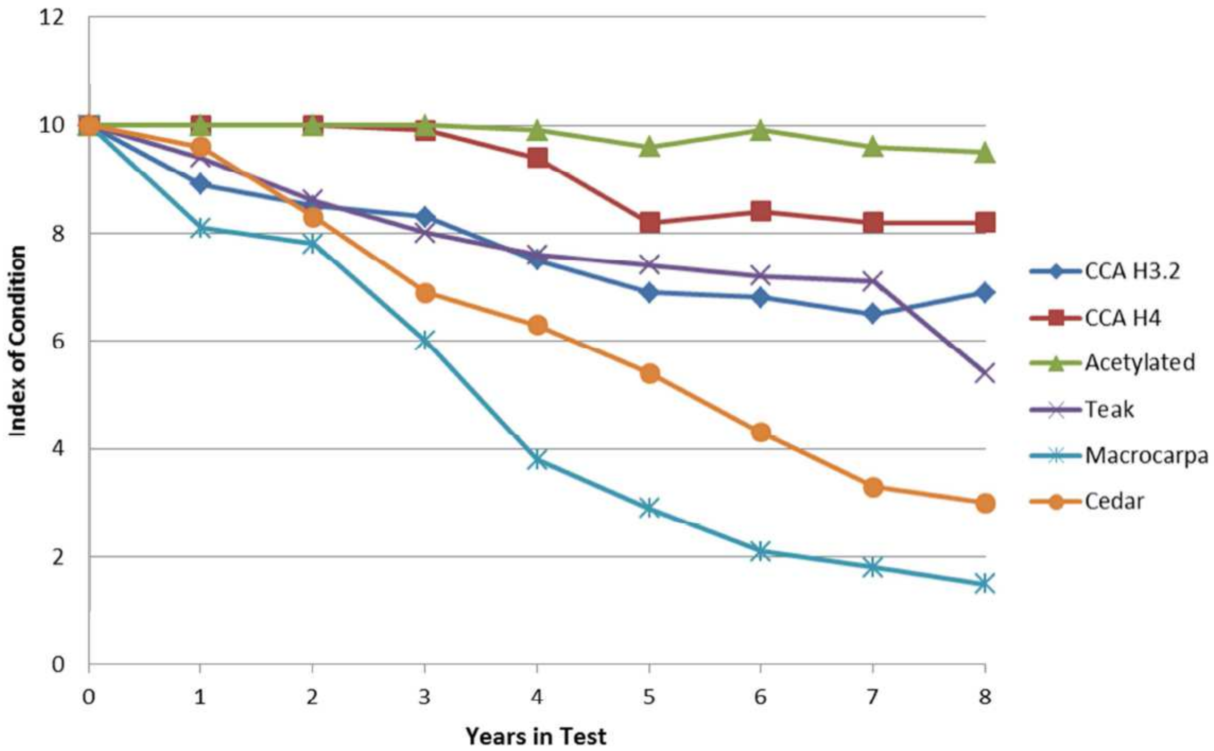


Figure 1: Decay of several variations of wood species or/and treatments (source: Simpson et al. 2013).

Kollert *et al.* (2012) reported that 'almost 77% of planted teak forests falls within the age class from 0 to 20 years, and 18 % in the age class from 21 to 40 years. Only 5% of the planted teak forests are older than 40 years.' Tewari & Mariswamy (2013) reported that Teak plantations between 30 and 32 years have a heartwood proportion of stem wood volume between 37 and 56%.

Accoya® Alder has been evaluated as an alternative to teak for yacht decking in this reported program of work. Accoya® Alder offers a European durability Class 1 rating under EN 350-1 based on results of laboratory tests according to EN 113 and ENV 807. It can be utilised for use classes 1 to 4 and has an 80% improvement in dimensional stability. The bending strength and stiffness is similar to the untreated Alder, but the Janka hardness is increased by circa 30%.

Table 1: Most important wood properties of Teak compared to Accoya Alder. (Sources: Wagenführ 2010, SHR test report 6.322 (2007), Wolfsmayr et al. 2008)

	Teak (Wagenführ)	**African Plantation Teak (D. Louppe)**	**Accoya Alder (SHR)**
Durability class of heartwood	1	2 (but depending on age) **	1
Density oven dry [kg/m³]	630 (440 – 720)	536 – 642	485 (445 – 535)
Shrinkage wet – oven dry radial [%]	2.1 – 3	Depending on growth rate/annual ring width	0.8
Shrinkage wet – oven dry tang [%]	4.2 – 5.8	Depending on growth rate/annual ring width	1.2
Bending strength [N/mm²]	58 – 109	81 - 169	90 *
Bending stiffness* [N/mm²]	9500 -13.200	7600 – 17.500	8700 *
Janka hardness [N]		Side: 3700 – 4890 End: 4065 - 4760	Tangential: 3570 Radial: 3240 End grain: 6050
Brinell Hardness [N/mm²]	Tangential: 28 – 39 End grain: 63 - 71		

** Based on clear samples*
*** Source: Wolfsmayr et al. (2008)*

Wet situations might represent a condition in which external flooring (decking) is most susceptible to damage in service. Accoya structural properties are less affected by high moisture levels compared to unmodified wood (Bongers *et al*. 2013, Marcroft *et al.* 2013). This characteristic ability to retain mechanical properties in wet conditions was extended in this work where Janka hardness was tested for unmodified wood and Accoya in both dry and wet conditions.

EXPERIMENTAL, RESULTS & DISCUSSION

This section describes test methods, demonstration installations, independent research results and sources of literature data given per project/topic.

Wood decking/flooring in exterior use

185 mm wide tongue & groove profiled Accoya® Radiata pine flooring boards were installed to create a 16 m diameter dance floor in a public park 'Fælledparken' in Copenhagen, Denmark. During the summertime the floor is in daily use by different dance groups. The flooring was installed with only 1 mm (0,5% of the board width) gap between the boards. The construction ensures good ventilation underneath the boards. The circular floor is split into 4 quarters for optimal use of the lower longitudinal swelling coefficient. For two and half years the dance floor has been exposed to a range of weather conditions and has been frequent used for dancing. The outdoor floor still remains stable and in very good condition considering the external environment.

Figure 2: Overview of the exterior dance floor. Picture 3: Close up photo of the surface after 3 seasons before cleaning.

Avoiding lift of the board from the substructure when such a small expansion gap is present requires that the timber boards offer an exceptional level of dimensional stability.
For example: Accoya Radiata pine from ambient (4%) to soaked will swell 1.2% in width. Over a width of 185 mm this leads to a maximum expansion of 2.2 mm. This stability level is compared to a range of hardwood timbers used in external deck applications in table 2. The absolute swell of hardwood species is approximately between 2 and 8 times that of Accoya.

Table 2. Swelling of various wood species (Source: SHR report 6.322 (2007), Wagenführ 2010).

Species	**Average radial swell from oven dry to soaked [%]**	**Absolute swell [mm] in a board of 185 mm**
Accoya Radiata pine plain sawn (*Pinus radiata*)	1.2	2.2
Azobe (*Lophira alata*)	7.4	13.7
Bangkirai (*Shorea laevis*)	9.0	16.7
Bilinga (*Nauclea diderrichii*)	4.4	8.1
Ipé (*Handroanthus spp.*)	3.9	7.2
Iroko (*Milicia spp.*)	4.7	8.7
Teak (*Tectona grandis*)	2.6	4.8

Figure 4: Bangkirai test deck, originally with 5 mm gaps totally closed up after being exterior exposed.

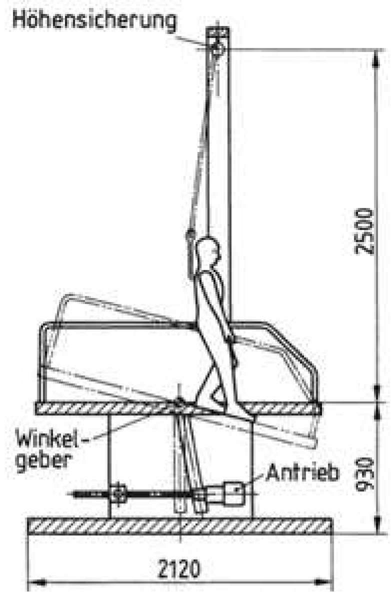
Table 2 indicates a disparity between an average Accoya swell of 2.2 mm over this 185 mm and the installed expansion gap of 1 mm. This indicates that either the Accoya boards never reach a saturated level or that through compression of the wood, the boards are able to cope with some average expansion of between 1 and 2.2 mm.

In the same park Accoya Radiata pine 34 x 198 mm (thickness x width) grooved boards have been used for a 30 m long bridge deck. Over 5 million people have crossed the bridge since its opening and the wood is still performing well. A gap of 5 mm was left between the boards in order that there was sufficient space for the hidden fasteners.

Figure 5: Accoya 34 x 198 mm bridge deck with hidden fasteners.

Skid resistance for the use of wood in public places

There are several standards and principles to measure the skid resistance of a surface. Three methods have been conducted in this review. The first is DIN 51130; DIN 51097 in which a person stands on a tilting surface. The second is JIS A1454 in which a Portable Slip Meter is used and a third is the SIA252:2002 (Swiss method) where a slip meter tests a 60 cm long surface.



Description of the test:
Three different test persons with prescribed shoes stand on a test surface. A lubricant is applied on the surface, 200 ml/m², and under the shoes. The surface tilts with 1°/s. The angle is measured at the point where the test person is not able to stand secure anymore. Test is repeated 3 times per test person and, in anisotropic materials, is tested in both length and perpendicular orientation. A calculation, based on the point the test technician slips is used to derive the classification of skid resistance.

Table 3: Classification of skid resistance according DIN 51130.

Average acceptance angle	Classification of skid resistance	Example applications
6-10°	R9	Internal flooring
10-19°	R10	Public toilets
19-27°	R11	Shop entrances, external public staircases
27-35°	R12	Professional kitchens
>35°	R13	Professional slaughterhouses

Most uncoated wood products perform in category 10/11, although many factors will influence the performance during time, like the use of a coating, moisture content, algae, wearing, etc.
A specific Accoya decking profile was tested in accordance with DIN 51130. The results presented below indicate several permutations of smooth profiled, coated and uncoated are at least equivalent to typical wood results and meet the requirement of both external public stair cases and shop entrances.

LaBella® Smooth profiled, oil coated Accoya, length orientation: R11
LaBella® Smooth profiled, oil coated Accoya, perpendicular orientation: R11
LaBella® Smooth profiled, uncoated Accoya, length orientation: R11
LaBella® Smooth profiled uncoated Accoya, perpendicular orientation: R12

Another test was performed in Japan according JIS A1454: 2010, using an Ono Portable Slip Meter. Specimens sized 26 x 140 x 140 mm (thickness x width x length) were tested on a dry surface and on a wet surface by applying 400 g/m^2 of ordinary tap water directly before testing. The coefficient of skid resistance (CSR) is measured and listed in table 4. The values achieved for Accoya in the range of product permutations can be compared to the threshold levels for a range of application areas according to Tokyo Government Manual of Building Standards (Table 5). The test results fit within the boundaries for the full range of use situations.

Table 4: Acetylated wood CSR average values.

Acetylated Wood CSR Average Values	X Axis (dry perpendicular to grain)	X Axis (wet perpendicular to grain)	Y Axis (dry along grain)	Y Axis (wet along grain)
A: Uncoated	0.74	0.75	0.77	0.81
B: Coated	0.73	0.74	0.75	0.79
C: Uncoated, Grooved	0.71	0.72	0.77	0.80
D: Coated, Grooved	0.72	0.67	0.78	0.76

Table 5: CSR Values found in Tokyo government manual of building maintenance standards.

C.S.R. Coefficient of Slip Resistance） C.S.R.＝0.00（min）～0.99（max）			
Areas where footwear is worn	Areas where footwear is not worn	Areas where people walk barefoot	Sloped surfaces
0.4～0.9	0.35～0.9	0.45～0.9	0.5～0.9

**Any area of a building where the CSR is below 0.4 is regarded as "slippery and dangerous".*
** It is regarded as dangerous where there is a large difference in CSR on the same floor/plane.*

The third test, appropriate to the Swiss market, is based on SIA252:2002. An automated skid resistance meter called FSC 2000 tests a 60 cm long surface which is treated with a prescribed lubricant. Different types of materials are attached to the resistance meter, such as rubber and a material which represents the human skin. The result is GB 2 which allows profiled Accoya to be used in all public environments including swimming pools surrounds.

Acetylated wood as boat decking

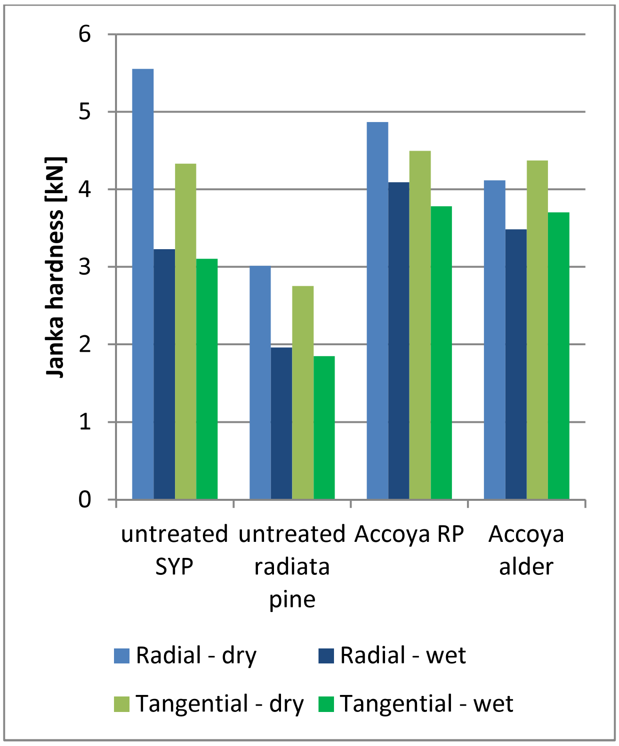
Dimensional stability and rate of that stability change are critical to achieving low caulk squeeze up. A rule of thumb is that the width and depth of the joints between Teak parts must be approximately 10% of the width of the teak parts themselves, with a minimum of 5 mm and a maximum of 10 mm. Normally, maintenance on a deck takes place every 8-10 years where the caulk is replaced.

Vertical grain (VG) Accoya Alder (rift sawn) performs better than flat sawn with respect to dimensional stability and is aesthetically more like the traditional boat deck appearance. It is unknown whether the improved dimensional stability of the substrate may also result in an improved scheme regarding maintenance. Vertical grain Accoya Alder was used alongside Burmese Teak to build a number of comparative yacht deck panels by Westport Shipyard, USA (such as Figure 6). These deck panels where situated on the floating dock and outside a workshop door of the shipyard and exposed for between 12 and 24 months. It is clear that initially, VG Accoya Alder is lighter in colour than Teak. Figure 7 shows they weather to similar grey colour after 10 months, and Westport found that the VG Accoya Alder could be cleaned to a more uniform colour after weathering than Teak. The test panel installations, particularly the one outside the workshop door, subject to heavy traffic demonstrated that neither wood type suffered any particular wear or damage over the 24 month period.

Figure 6 and 7: in situ comparison between Burmese Teak and vertical grain acetylated Accoya Alder. Source: Westport shipyard, Port Angeles, WA, USA.

Janka hardness in dry and wet conditions

Samples of different wood species of 50 x 50 x 150 mm (radial x tangential x longitudinal) were tested on Janka hardness in one of two conditions, dry (conditioned to 20°C/65% relative humidity) or wet (vacuum impregnated).



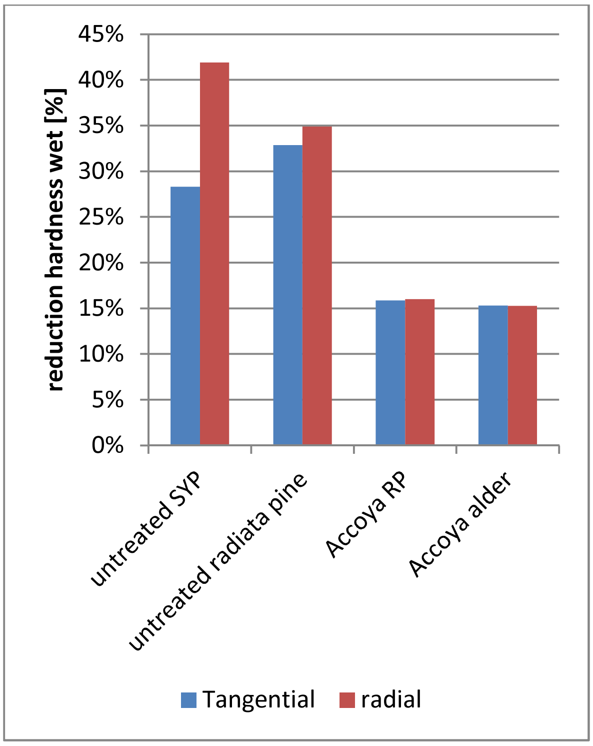


Figure 8: Janka hardness

Figure 9: Percentage of hardness reduction in wet state compared to normal

The results in Figure 9 show that the hardness of Accoya® Radiata pine and Accoya® Alder was reduced by 10 to 15% when soaked compared to 30 to 40% for unmodified softwood common for external decking (SYP and Radiata pine). This additional hardness benefit from the acetylation process extends the fact that Accoya from Radiata pine is already 108% harder than unmodified Radiata pine and 30% harder than SYP in the wet condition, radial orientation which is most appropriate to decking. This reduced deterioration in the wet condition, when wood is most susceptible to damage helps explain the positive assessments from the noted external dance floor and yacht deck pilot application projects.

Radiant heat (thermograph) imagery

A lesser considered but increasingly important measure of deck performance, particularly for the increasing non wood external decking products is surface temperature in services.
Material temperature on decks and terraces is a particular issue in the summer season. A thermogram image analysis was made in Japan by the Hiroshima Prefectural Technology Research Institute to assess differences between Accoya, thermally modified wood and three variants of commercial WPC decking. The ambient temperature during the testing of all decks was 32°C. Deck board dimensions were comparable for all three types:

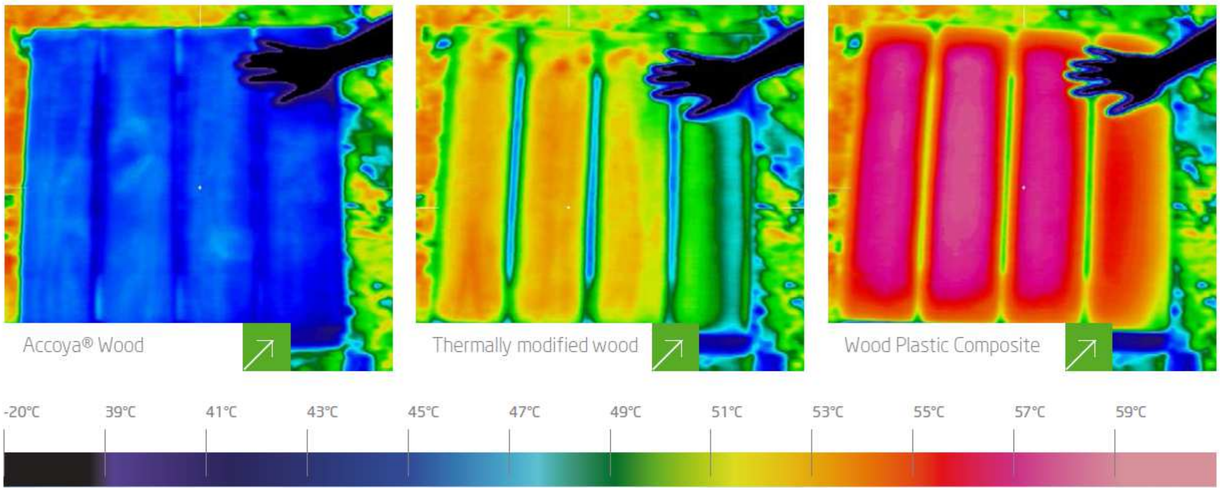


Figure 10: Thermogram images of Accoya, thermally modified wood and WPC.

The thermograms clearly indicate temperatures of the Accoya® surface of about 46° C. This is substantially less than the alternatives tested. The thermal modified Pine ranged between 51 and 54° C whereas WPC reached surface temperatures of more than 55° C.

CONCLUSIONS

Acetylated wood has performed well in the three severe project installations of an external dancefloor, a high traffic foot bride and as yacht decking. This performance is supported by common material factors of hardness and dimensional stability. Further, more application specific factors of hardness in wet conditions, slip resistance and radiant heat have been developed and demonstrate that Accoya performs well by all measures, even when compared with old growth teak. These test results provide a technical insight as to why the product performs well in the installed projects and indicate that it can provide a reliable and sustainable source of wood for such demanding external floors.

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REFERENCES

BM Trada test report TT//F13325 (2013). Janka Hardness Testing.

BM Trada test report TS//F12167 (2014). Establishment of an experimental floor rig and test method for wood floorcoverings intended for use over underfloor heating.

Bongers F., Rowell R. and Roberts, M. (2008). Enhancement of lower tropical wood species. Acetylation for improved sustainability & carbon sequestration. In: *Fortrop 2 international conference*, Thailand, Bangkok.

Bongers, F., Alexander, J., Marcroft, J., Crawford, D. and Hairstans, R. (2013). Structural design with Accoya wood. *International Wood Products Journal* 4(3), pp. 172-176.

Kollert, W., Cherubini, L. (2012). Planted Forests and Trees Working Paper Series.
Teak resources and market assessment 2010 (*Tectona grandis* Linn. F.). Forestry department FAO.

Louppe D., Oteng-Amoako A, Brink M. (2008). *Plant Resources of Tropical Africa: Timbers*. ISBN 9789057822094.

Marcroft J., Bongers F., Perez F., Alexander J., Harrison I. (2013). Structural performance of Accoya® wood under service class 3 conditions. *RILEM Conference. Materials and Joints in Timber Structures – Recent Advancement of Technology*. October 08 – 10, 2013, Stuttgart, Germany.

MT-Qualitest (2013). Prüfung der Gleitfestigkeit von Accoya Holz. Auftraggeber: Holz-Pur AG, Neuenkirch.

Rijsdijk, J. and Laming P. (1994). *Physical and Related Properties of 145 Timbers: Information for Practice*. Springer science. ISBN 978-94-015-8364-0.

Saba, Marine Adhesives Info sheet 203. Sealing teak ship decks with Saba caulk and Saba tack® 780.

Simpson, I., Van der Waals, J. and Singh, T. (2013). The durability of acetylated radiata pine sapwood results from ground contact tests after eight years exposure. *SCION report*.

SHR test report 6.322 (2007). Dimensional stability of Accoya wood under different moisture conditions. Downloadable from the Accoya website.

Tewari, V.P. and Mariswamy, K. (2013). Heartwood, sapwood and bark content of teak trees grown in Karna-taka, India. *Journal of Forestry Research* 24(4), pp. 721-725.

Wagenführ R. (2000). *Holzatlas.* ISBN 3-446-21390-2.

Wolfsmayr U., Terziev N. and Daniel, G. (2008). Natural durability and anatomical features of teak (*Tectona grandis*) from plantations in Costa Rica. *International Research Group on Wood Protection*, document IRG/WP 08-10671.