Kebony - an Alternative to Teak for Boat Decking

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ABSTRACT

In the struggle for a sustainable society the protection of rainforests is an important issue. One option for saving tropical hardwood is then to replace it with modified wood such as furfurylated European species. An attempt has been made to replace teak with furfurylated Maple (Kebony Maple) in marine applications. Field test with boat decking exposed onboard or at seaside side locations have been met very positively by the end users. This project has aimed to look at different aspects of durability of the Kebony Maple in comparison to teak in pre-fabricated boat decking components. Tests have been carried out on the moisture resistance between the wood and the polyester substrate, the moisture resistance of the adhesion between wood and the sealant used between the wooden ribs and the biological durability of the wooden materials. The results presented in this paper indicate a good weather resistance of the Kebony Maple and a realistic possibility to replace teak in marine applications.

INTRODUCTION

Teak has a long history as a decorative and durable decking material for marine purposes. Due to environmental concern, the deck producers are looking for alternative wood species to replace endangered tropical wood species as teak. Furfurylation of wood result in wood properties similar to those of high quality tropical timbers i.e.; improved dimensional stability, increased hardness, increased decay resistance and aesthetic appearance.

This study is a comparison of high quality teak and Kebony maple used as a boat decking material. The study aim to reveal the gluability and compatibility of the materials in a sandwich construction consisting of wood lamellas separated with a deck caulk and glued to a polyester sheet. Further more, studies of the durability have been performed to ensure that a long service life can be expected.

TEST MATERIALS

The tested teak is imported from Burma, and further processed by Sandøy båtdekk AS. Kebony Maple is produced by Kebony ASA, by furfurylation of Sugar Maple (*Acer saccharum*). The treatment consists of impregnation and curing of Kebony ASA's FA-70 mix. Planks of maple (2"x 6") have been further processed by Sandøy Båtdekk AS into lamellas.

The test material consisted of:

- Sheets of teak, 320 x 500 mm, mounted on the polyester substrate with West System epoxy (105 Resin, 205 hardener) and sealed with the normally used sealant (SIMSON MSR DC), Figure 1. The sheets are produced by Sandøy Båtdekk AS.

- Sheets of Kebony Maple, 320 x 500 mm, mounted on the polyester substrate with West System epoxy (105 Resin, 205 hardener) and sealed with the normally used sealant (SIMSON MSR DC), Figure 1. The sheets are produced by Sandøy Båtdekk AS.

Figure 1 ***Sheet used for test of adhesion between wood and polyester sheet***

- Ribs of teak in dimension 5 x 45 x 600 mm, profiled as shown in Figure 2.
- Ribs of Kebony Maple in dimension 5 x 45 x 600 mm, profiled as shown in Figure 2.

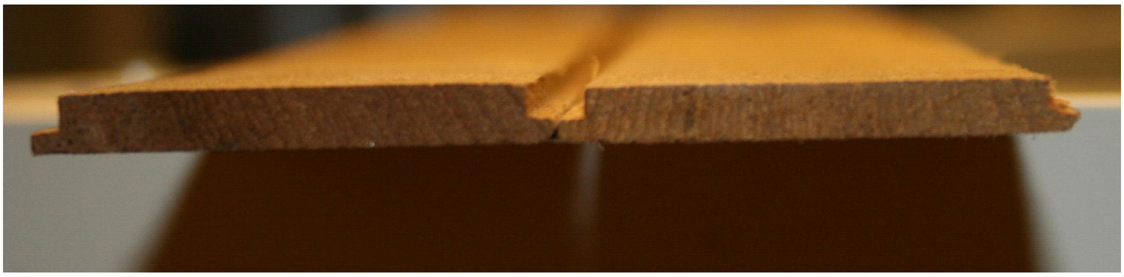

Figure 2: ***Two profiled ribs used for adhesion tests of the sealant***

- Polyurethane sealant "SIMSON MSR DC nåtmassa för däck".

TEST METHODS

Tests of glue-lines

The glue-line between wood and polyester was tested using the European test method EN 314-1. This method is intended for tests of gluing quality of plywood. Specimens with a width of 25 mm and with two notches 25 mm apart, forming a shear area 25 x 25 mm, see Figure3, were prepared from the wood-polyester sheets.

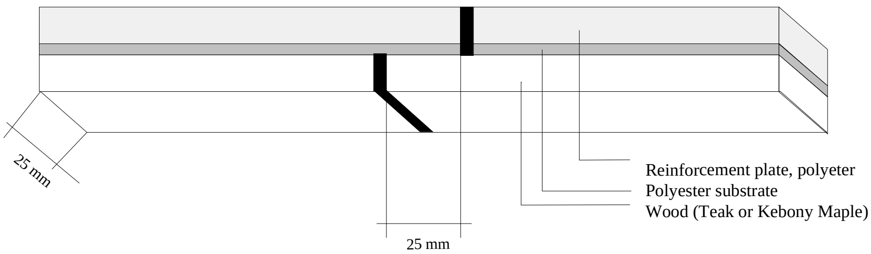

Figure3: The specimen for the glue-lines between wood and polyester substrate.

Before the tests the specimens were divided into three groups pre-treated in three different ways:

- Conditioning in climate 20°C, 65% relative air humidity.
- 72 hours in boiling water
- V313-test according to EN 321 (the specimens are submitted to a cyclic ageing of 3 days in water 20°C, 1 day in freezer (-12°C) and 3 days in heating cabinet 70°C. The cycle is repeated three times)

The pre-treatment with 72 hours in boiling water is the same as used to verify the residual strength for the gluing of veneers in exterior plywood. The V313-test is used to verify the moisture resistance for other types of wood based panels.

After the pre-treatment the specimens are tested in tension shear with a constant rate of deformation. The speed is adjusted to get failure at 60±30 sec. The maximum load for each specimen was recorded and the residual strength calculated according to equation 1

$$\tau_{glue} = \frac{F_{ult}}{l \cdot w} \qquad \text{Equation 1}$$

Where

τ_{glue} Tensile shear strength in the glue line
F_{ult} The maximum load during the test
l The distance between the saw cuts in the specimen
w The width of the specimen

Tests of adhesion of the sealant

The sealant between the ribs was tested with tension tests. The specimens were made from three ribs glued together with the sealant. This means that two joints were tested at the same time and the failure load represents the weaker of two glue lines. Also the stress recorded is the total stress from two joints. Thus a conservative estimation of the failure load as well as the ultimate stress is obtained. Compared to a test with the same amount of sealant line this will result in a lower mean value but also a lower standard deviation. Since the tests are comparative between teak which have been proved to work in practice and Kebony Maple this is acceptable. The test set-up is presented in Figure 4.

Before the testing the specimens were submitted to three different pre-treatments:

- Conditioning in climate 20°C, 65% relative air humidity.
- 2 hours in boiling water
- 72 hours in boiling water

72 hours in boiling water is a pre-treatment for the determination of bonding strength for exterior plywood. Since the residual strength of the sealant in this application was unknown, pilot trials of the adhesion after boiling were made. No load was determined, only the failure patterns between wood and sealant were studied. We could observe a change of behaviour already after an hour of boiling. After that, the failure did not change in any major way between 1 and 72 h of boiling. Also, no obvious difference between the two materials could be observed. Based on this pilot study a third series with a boiling time of two hours was decided.

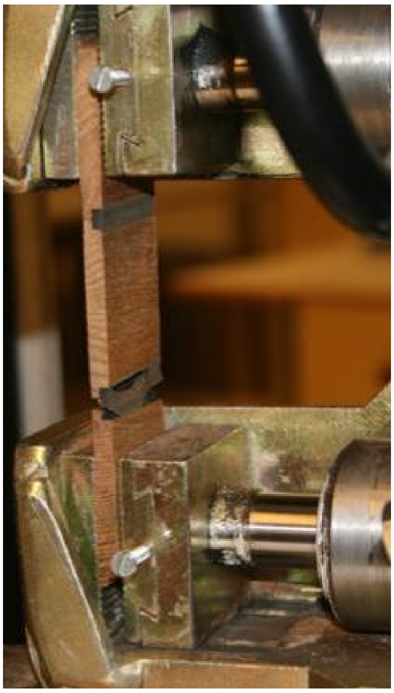

Figure 4: Test setup for adhesive tests of the sealant

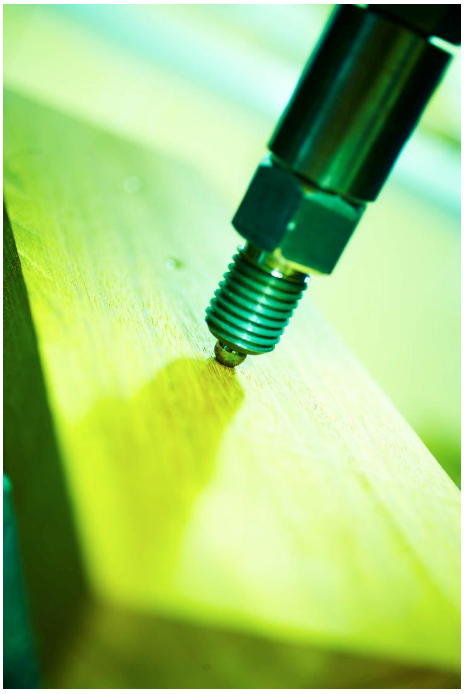

Figure 5: Brinell hardness testing

Hardness testing

Brinell hardness Kebony Maple and unmodified maple was tested according to EN 1534 with 1kN indentation force. Average value of 50 measurement points, mainly in tangential direction, was calculated.

Soil-block test (test of biological durability according to AWPA E10)

Preparation and pre-ageing of test cubes

From larger modified boards (25x100x400mm, end-sealed before furfurylation) smaller test cubes (14 x 14 x 14 mm) were cut. The test cubes were water leached according to EN 84: leaching in de-ionized water 1:5 (sample volume : water volume) for 14 days with 10 exchanges of water, which corresponds to the leaching procedure described in AWPA E10. In total, 25 Kebony cubes (5 per test fungus + 5 for calc of correction value) and 34 control cubes (6 per test fungus + 10 for calculation of correction value) were prepared.

Sterilisation

Test cubes were sterilized by gamma irradiation (min 25 GGy) at the institute of Energy Technology (IFE) at Kjeller, Norway. Soil-jars were steam sterilized twice, second time with two Scots pine sapwood feeder strips (3 x 15 x 30 mm) in each jar.

Fungal test

Fungal species used:

- *Postia placenta* (FPRL 280)
  (*Poria placenta* in EN nomenclature)
- *Coniophora puteana* (BAM Ebw. 15)
- *Trametes versicolor* (CTB 863 A)
  (Coriolus versicolor in EN nomenclature)
- *Irpex lacteus* Fries (ATCC 11245)

Inoculation period: Two weeks

Duration of test: 8 weeks.

Calculation of Durability class

EN 350-1 was used for calculation of "Natural Durability class", by first calculating an x-value as ratio between mass loss of Kebony maple and control maple.

Field exposure

Two field tests/commodity tests have been started with decking made from furfurylated maple (Kebony Maple). The product was installed in one boat late 2007 as well as on rigs for seaside exposure on land during the summer of 2006. The exposure site was close to the factory of Sandøy Båtdekk AS. Both decks have been visually inspected with respect to appearance after weathering, and the deck on the boat has also been evaluated with respect to wear and cleaning ability.

RESULTS

Tests of glue-lines

The results from the test of the glue-line between wood and polyester substrate is given in Table 1. As can be seen in the table the residual strength was slightly higher for the Kebony specimens than for teak. However, both materials show residual strength much better than the required values for glue lines in exterior plywood in EN 314-2.

An observation from the test was also that the failures occurred to a minor part in the glue line. The most common failure was either in the wood material or in the polyester substrate.

Table 1: Residual strength from tension shear tests of the glue-lines between wood and polyester. (mean value and standard deviation from 20 specimens)

Material	**20°C, 65% RH**		**Boiling water 72 h**		**V313-test**	
	Mean value [MPa]	Std dev [MPa]	Mean value [MPa]	Std dev [MPa]	Mean value [MPa]	Std dev [MPa]
Teak	5,4	1,3	3,9	0,7	3,7	1,0
Kebony Maple	6,4	1,5	4,7	0,9	4,4	1,2
Requirement for exterior plywood	1,0		1,0			

Tests of adhesion of the sealant

The results from the tests of adhesion between the wooden ribs are given in Table 2 and Table 3. Also for the adhesion between wood and sealant the difference between teak and Kebony is very small. The stress at maximum load is much larger than what can be expected in service.

Table 2: Maximum load (N) after three different pre-treatments. Mean value and standard deviation for the weakest glue line of two from 20 – 24 specimens per treatment)

Material	**20°C, 65% RH**		**Boiling water 2 h**		**Boiling water 72 h**	
	Mean value [N]	Std dev [N]	Mean value [N]	Std dev [N]	Mean value [N]	Std dev [N]
Teak	187	34	94	10,7	59	4
Kebony Maple	217	27	103	8,1	66	4

Table 3: Stress (mm) at maximum load after three different pre-treatments. Mean value and standard deviation over two glue lines from 20 – 24 specimens per treatment)

Material	**20°C, 65% RH**		**Boiling water 2 h**		**Boiling water 72 h**	
	Mean value [mm]	Std dev [mm]	Mean value [mm]	Std dev [mm]	Mean value [mm]	Std dev [mm]
Teak	10,0	2,0	8,7	2,0	6,4	1,2
Kebony Maple	15,2	2,1	11,3	1,9	8,1	1,3

Hardness

In figure 6 it can be seen that furfurylation of maple by the Kebony process leads to an increase in Brinell hardness from 3.72 to 5.41, i.e. 45% increase. Furthermore, Kebony Maple has approximately the double Brinell hardness of teak (2.5-2.8 HB in literature).

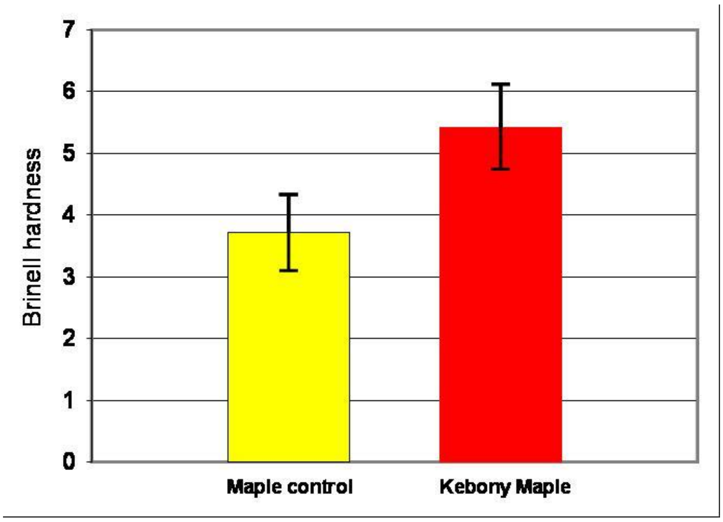

Figure 6: Brinell hardness of unmodified control maple and Kebony Maple

Durability of the wood material

The decay resistance of Kebony Maple against all test fungi (both brown and white rot fungi) was very high. As can be seen in Table 1, the corrected mass loss ranged from below 1% to 4.5% whereas the corrected mass loss due to fungal decay of the untreated maple controls ranged from 34% to 50%, depending on test fungus.

Table 4: Durability classes of Kebony Maple as calculated according to EN 350-1.

Test Fungus	Treatment mix	WPG (%)	Corrected Mass Loss, ML (%)	Controls ML (%)	x-value	Durability Class
Postia placenta	FA70	31	**3.2** (±1.5)	50.4	0.06	1
Coniophora puteana	FA70	31	**2.5** (±1.4)	34.2	0.07	1
Trametes versicolor	FA70	30	**0.9** (±1.1)	33.5	0.03	1
Irpex lacteus	FA70	30	**4.5** (±1.9)	40.4	0.11	1

For all test fungi this resulted in x-values below 0.15 which means durability class 1 (very durable) when calculated according to EN350-1. This is the same natural durability class generally obtained for teak from tropical forests. However, plantation-grown teak has been reported to have lower durability, i.e. durability class 2, durable, to 4 ,slightly durable (Kokutse et al. 2006)

Field exposure

The experience from the field test with respect to visual appearance after weathering, wear and cleaning ability is consistently positive. The Kebony deck ages very similarly to the teak deck, it is further worn more slowly and is easier to clean than teak decks.

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CONCLUSIONS

The product Kebony Maple has a very good potential to be a sustainable alternative to teak as boat decking. None of the parameters studied have shown any disadvantage for the end-user:

- The visual appearance of Kebony has been appreciated by the users. The two materials are similar from the start and after a period of outdoor weathering under marine conditions the similarity of the two materials is even more pronounced
- The biological durability of Kebony Maple is similar or better than that of teak
- The durability of the glue-line between Kebony Maple and is at least equal to the glue-line between teak and polyester substrate
- The adhesion between the Polyurethane sealant and Kebony Maple is at least equal to the adhesion between the Polyurethane sealant and teak
- The hardness of Kebony Maple is double the hardness of teak

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