LABORATÓRIO NACIONAL
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CONFIDENTIAL

TESTS OF NATURAL AND ACQUIRED DURABILITY OF SUGI TIMBER AGAINST SUBTERRANEAN TERMITES

Characterization of azorean sugi timber

REPORT 228/**2015 – DE/NCE**
English translation

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AZORINA – Sociedade de Gestão Ambiental e Conservação da Natureza, S.A.

Lisbon • April 2015

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Title

TESTS OF NATURAL AND ACQUIRED DURABILITY OF SUGI TIMBER AGAINST SUBTERRANEAN TERMITES

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TESTS OF NATURAL AND ACQUIRED DURABILITY OF SUGI TIMBER AGAINST SUBTERRANEAN TERMITES

Characterization of azorean sugi timber

Abstract

The current report presents the results for natural and acquired durability of *Cryptomeria japonica* (Thunb. ex L.f.) D. Don timber to the subterranean termite *Reticulitermes grassei* attack. The sampling of the pieces was done by AZORINA according to the sampling plan established in the Technical Report 1/2014-DE/NCE.

This document was produced within a project settled with AZORINA, Sociedade de Gestão Ambiental e Conservação da Natureza, SA.

Keywords: Azores / Sugi / *Reticulitermes grassei*

ENSAIOS DE DURABILIDADE NATURAL E ADQUIRIDA DE MADEIRA DE CRIPTOMÉRIA CONTRA TÉRMITAS SUBTERRÂNEAS

Caracterização da madeira de criptoméria açoriana

Resumo

O presente relatório apresenta os resultados de ensaios de durabilidade natural e com tratamento de madeira de *Cryptomeria japonica* (Thunb. ex L.f.) D. Don ao ataque por térmitas subterrâneas da espécie *Reticulitermes grassei*. A amostragem das peças foi realizada pela AZORINA de acordo com o protocolo estabelecido na Nota Técnica 1/2014-DE/NCE.

Este documento foi elaborado no âmbito do projecto estabelecido com a AZORINA, Sociedade de Gestão Ambiental e Conservação da Natureza, SA.

Palavras-chave: Açores / Criptoméria / *Reticulitermes grassei*

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1 | Introdution

1.1 Objectives

The contract with the Azorina, Sociedade de Gestão Ambiental e Conservação da Natureza, SA (Environmental Management Society and Nature Conservation, SA.), by direct award nº 36/Azorina/2012, covers the purchase of services for development of a standard for a visual strength grading standard of sugi for structural purposes, according to European standards, and evaluation of its durability after being subjected to different treatments to protect against subterranean (*Reticulitermes grassei*) and dry wood (*Cryptotermes brevis*) termites.

This report refers to the assessment of the durability of sugi wood, with and without treatment, to the attack by subterranean termites of the *Reticulitermes grassei* species. The study includes sugi wood from the islands of São Miguel and Terceira provided by Azorina. - Sociedade de Gestão Ambiental e Conservação da Natureza, S.A.. The sampling of the material was done by Azorina in accordance with the principles defined in the Technical Note 1/2014 - DE/NCE [1].

1.2 Subterranean termites

Subterranean termites present in continental Portugal belong to the species *Reticulitermes grassei* (Clément, 1978). In continental Portugal this species occurs naturally throughout the country and is recognized as a pest of construction timber.

They are social and polymorphic insects living in family groups of large-scale, having individuals with various morphological forms or castes, with division of labor: reproducers (nymphs and alate) with reproductive and dispersion functions; the workers, who are the most numerous caste, and whose function is to feed the colony and to construct and repair the colony structures; and finally the soldiers whose function is to defend the colony.

After the dispersing flight, the alate reproducers lose their wings and begin the partner search process, to which follows the nest building and formation of a new colony. The female lays eggs that develop into totipotent larvae, meaning with the ability to turn into any of the casts, according to the time of year, the food available and the pheromones emitted by the rest of the colony. The workers have the ability to turn into soldiers or ergatoids (secondary reproducers) in the presence the right stimulus from the colony (Figure 1.1). The nymphs may become nymphoids (secondary reproducers) or alates, developing about two years after the founding of the colony and at specific times of the year.

The first problem in the control of subterranean termites is their detection. Subterranean termites live in the soil and feed inside the timber, which hampers their visual detection thus they are usually only detected at an advanced stage of the attack. One way of detection is the visualization of the

characteristic mud tunnels at ground level, in walls of buildings and/or the presence of wings or alates during the time of dispersion flights (which typically occurs in the spring). Another effective way to detect an attack by subterranean termites is by observing the characteristic aspect of damaged wood.

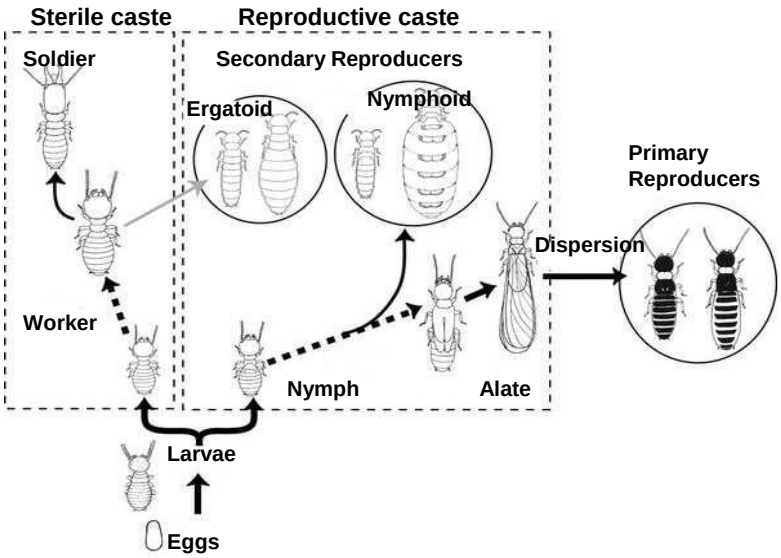

Figure 1.1 – Life cycle of Reticulitermes spp termites.

2 | Methods and Materials

2.1 Evaluation of the natural durability against subterranean termites

The natural durability of Azorean sugi was evaluated in accordance with the draft European Standard prEN350:2014 [2].

Termites

For these tests *Reticulitermes grassei* Clément (Isoptera: Rhinotermitidae) termites were used.

The termites were collected from fallen logs from a forest area of *Pinus pinaster* Aiton, located N 38º32.436 'W 009º07.848' at an 18 m elevation. They were kept in Petri dishes with moistened filter paper inside a conditioned room at LNEC (temperature: 24 ± 2 ° C; relative humidity: 80 ± 5%), having been used in trials, on average, a week after collection.

Wood

All assays were performed with *Cryptomeria japonica* (L. F.) D. Don var. sinensis Sieb heartwood. In most trials "pink" sugi from two different locations was used: Terceira and São Miguel islands in the Azores. From each of the islands, heartwood test specimens were collected from three different trees of "pink" sugi, cut in two different locations. "Black" sugi wood from the island of São Miguel was also tested but with unknown exact origin. For each "pink" sugi sampled tree, 10 replicates were assayed and also 10 replicates of "black" sugi.

Termite virulence testing was also performed using for this purpose the untreated sapwood of a timber species of known susceptibility, maritime pine (*P. pinaster*) (7 replicates).

All test specimens had the approximate dimensions of 50 × 25 × 10 mm and the average initial moisture content of a set of six test specimens was calculated by origin following the procedures described in the Standard NP EN 13183-1: 2013 [3].

Method

As recommended in prEN350: 2014 [2] the natural durability against the attack by subterranean termites was determined according to EN 117: 2005 [4].

In each of the 750 ml glass bottles used as test containers, a layer of about 6 cm loose fill and humidified (4 volumes of sand to 1 litter of distilled water) sand was placed in the bottom. A glass ring (20 mm height, 20 mm diameter) was also placed close to the wall of each container and buried till the middle.

To each of the containers, 250 workers were added as well as some soldiers and nymphs in the same proportion that existed in the colony from where the workers were removed (1-3 soldiers and up to 5 nymphs). After installation of the termites in their respective containers, the test specimens were placed over the glass ring (Figure 2.1).

Figure 2.1 – Image from the start of test (EN 117:2005) using heartwood of sugi (*Cryptomeria japonica*).

The test containers were placed in a conditioned chamber at a temperature of 24 ± 2 °C and relative humidity of 80 ± 5% for 8 weeks. After 8 weeks of exposure to the action of the insects, the test speciemens were removed, cleaned, weighed and a visual examination was performed according to the criteria specified in the standard for evaluating the level of attack (0 = no attack; 1 = attempted attack; 2 = slight attack; 3 = moderate attack; 4 = strong attack). At the end of the test the survival rate (expressed in %) was determined as well as the final moisture content [3] and the mass loss (%).

2.2 Evaluation of the acquired durability against subterranean termites

The acquired durability of sugi timber from the Azores after the application of two commercial wood preservatives was also evaluated with the aid of European Standard EN117 [4].

Termites

For these tests, termites of the species *Reticulitermes grassei* Clément (Isoptera: Rhinotermitidae) were used, collected as described above.

Wood

To evaluate the effectiveness of treatments, test specimens of “pink" sugi, randomly chosen from the ones obtained from the selected trees, were used.

Method

Heartwood test specimens were treated with two commercial wood preservatives named for the purpose of these tests Xy and Xz. These products have the active ingredients described in Table 2.1, in an organic solvent. Sugi heartwood test specimens treated only with the solvent (white spirit) were used as controls. For each of the variables (including solvent) 3 replicates were assayed from each sampled island.

The test specimens were treated by immersion for one hour and the absorption calculated by mass variation before and after the treatment *versus* volume. The average absorption values are presented in Table 2.1.

Table 2.1 – Average absorption of the wood preservatives used for treating sugi

Wood preservative	Active ingredients	Average absorption (Kg/m3)	Standard deviation
Xz	Propiconazole: 0.15%; Cypermethrin: 0.07%; Tebuconazole: 0.05%; IPBC: 0.05%	60,72	13,02
Xy	Propiconazole: 0.6%; Dichlofluanid: 0.54%; Cypermethrin: 0.05%	79,28	14,82
White spirit	-	92,32	42,91

Resistance to attack by subterranean termites of the treated test specimens was also assessed according to EN 117: 2005 [4] with the procedure described above.

3 | Results

3.1 Natural durability

Resistance (natural durability) of untreaded sugi heartwood from the two islands and four origins, to attack by subterranean termites was determined through the European Standard EN 117: 2005 [4].

The level of attack (Figure 3.1) was very similar among the tested specimens of Terceira Island, being in general a "1" or a "2", registering only two "3" and one "4". In the sugi test specimens of São Miguel the attack levels were slightly higher, particularly for the test specimens from the tree SM246, with an average attack level of "2.6" (Table 3.1 and Figure 3.1). Regarding termite survival rate and the mass loss of the test specimens, it was very similar in all tested trees. In a large majority of the test containers full mortality was registered and the level of attack was only slightly perceptible by the mass loss of the samples.

In cases where there was survival, it was in a very low percentage and with low mass loss. In the case of the test piece T51-8 a fairly high level of attack occurred, however in other samples of the same tree very low levels of attack occurred. The same occurred with the SM206-3, SM246-6 and SM246-10 test specimens where the attack level was high but in the remaining test pieces of the same tree the attack was very low. For tests with "black" sugi wood the results were very similar to those occurring with "pink" sugi with attack levels between 1 and 2, and 0% overall survival rate of termites, with two exceptions, N3 and N10 test pieces. The mass loss levels were also generally not measurable (Figure 3.4).

In the case of the maritime pine control tests, the attack level was always very high, with the attack level 4 "erosion in more than 1/10 of the sample top surface or attack with more than 3 mm penetration leading to formation of cavities in the test pieces" happening in all samples and with survival rate of termites always higher than 50%. These values allow full validation of the tests.

Table 3.1 – Average results of resistance to subterranean termites obtained with untreated sugi wood.

Wood	Location	Tree	Survival (%)	Final moisture content (%)	Mass loss (%)	Level of attack
“Pink” sugi	P1 -T34	A7	0,48	31,57	0	1,60
“Pink” sugi	P2- T51	A5	2,48	33,56	0,26	1,80
“Pink” sugi	P2 – T45	A2	0	51,90	0	1,30
“Pink” sugi	P1-SM206	A5	2,80	52,05	1,37	2,0
“Pink” sugi	P2-SM222	A1	0	35,57	0,26	1,90
“Pink” sugi”	P2-SM246	A5	4,36	57,49	2,29	2,60
“Black” sugi	SM	-	7,60	32,33	0,11	1,60
Pine (control)	-	-	73,26	49,68	5,37	4

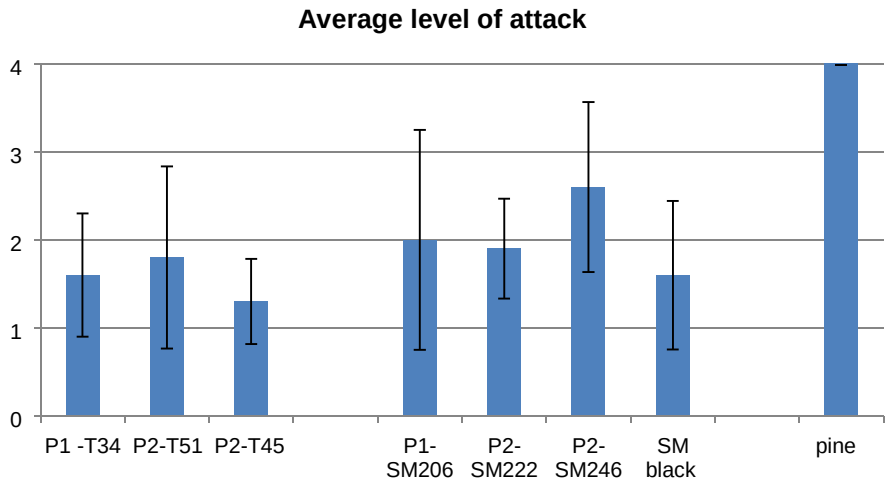

Figure 3. 1 - Summary of the levels of attack recorded in the samples used for verification of untreated sugi wood resistance to subterranean termites.

By comparing the levels of attack on the test pieces of the different trees used, it is verified that the differences are significant, with however a p-value of 0.05, which is the limit for its validation as significant (p-value ≥ 0.05) (Table 3.2). By comparing the values of the levels of attack occurred in test pieces of "pink" sugi from Terceira with the test pieces from the island of São Miguel it is found that there are quite significant differences (p-value ≥ 0.05), with higher values of level of attack in samples originating from the island of São Miguel (Table 3.3).

Table 3.2 – Comparison, through the ANOVA statistical test, of the attack levels of subterranean termites on the wood of the different sugi trees sampled

Variation source	SQ	gl	MQ	F	p
Between groups	10,14	6	1,69	2,23	0,05
Within groups	47,8	63	0,75		
Total	**57,94**	**69**			

Table 3.3 – Comparison, through the ANOVA statistical test, of the attack levels of subterranean termites to the "pink" sugi wood from trees with origin in the islands of Terceira and S. Miguel.

Variation source	SQ	gl	MQ	F	p
Between groups	5,4	1	5,4	6,88	0,01
Within groups	45,53	58	0,78		
Total	**45,53**	**59**			

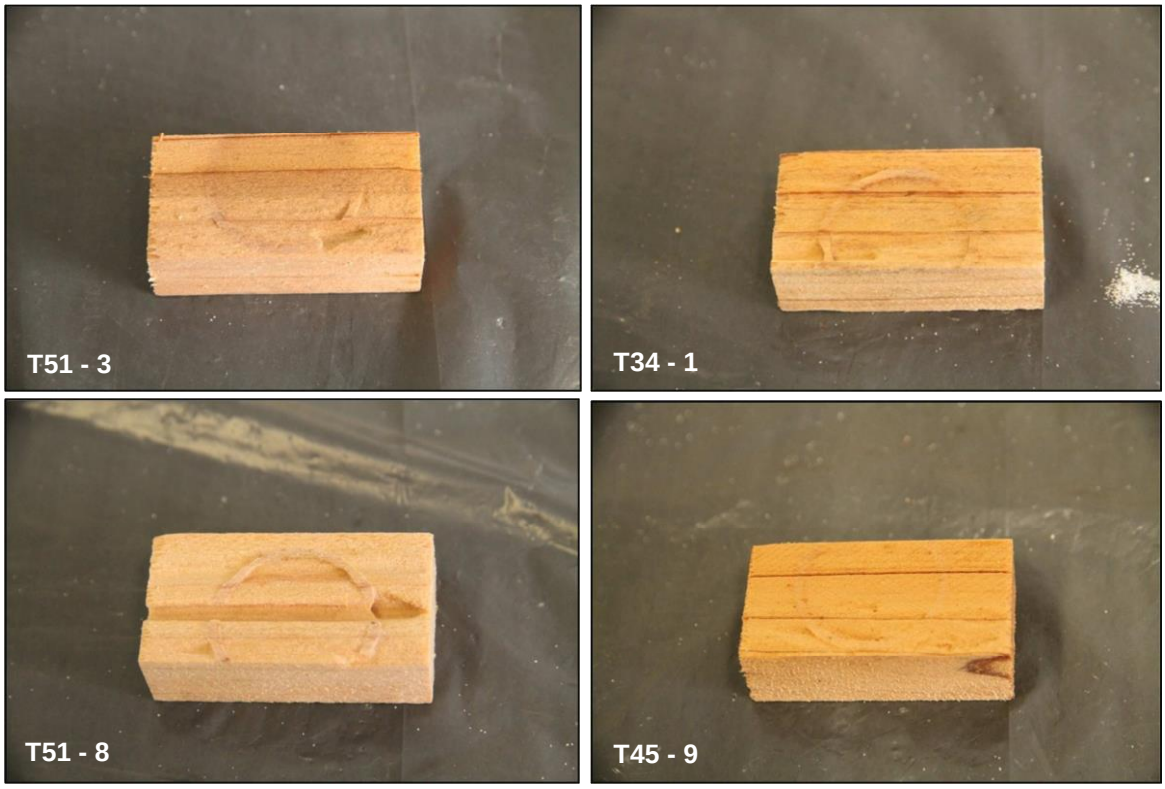

Figure 3.2 – Test samples of "pink" sugi from the island of Terceira.

Figure 3.3 – Test samples of "pink" sugi from the island of S. Miguel.

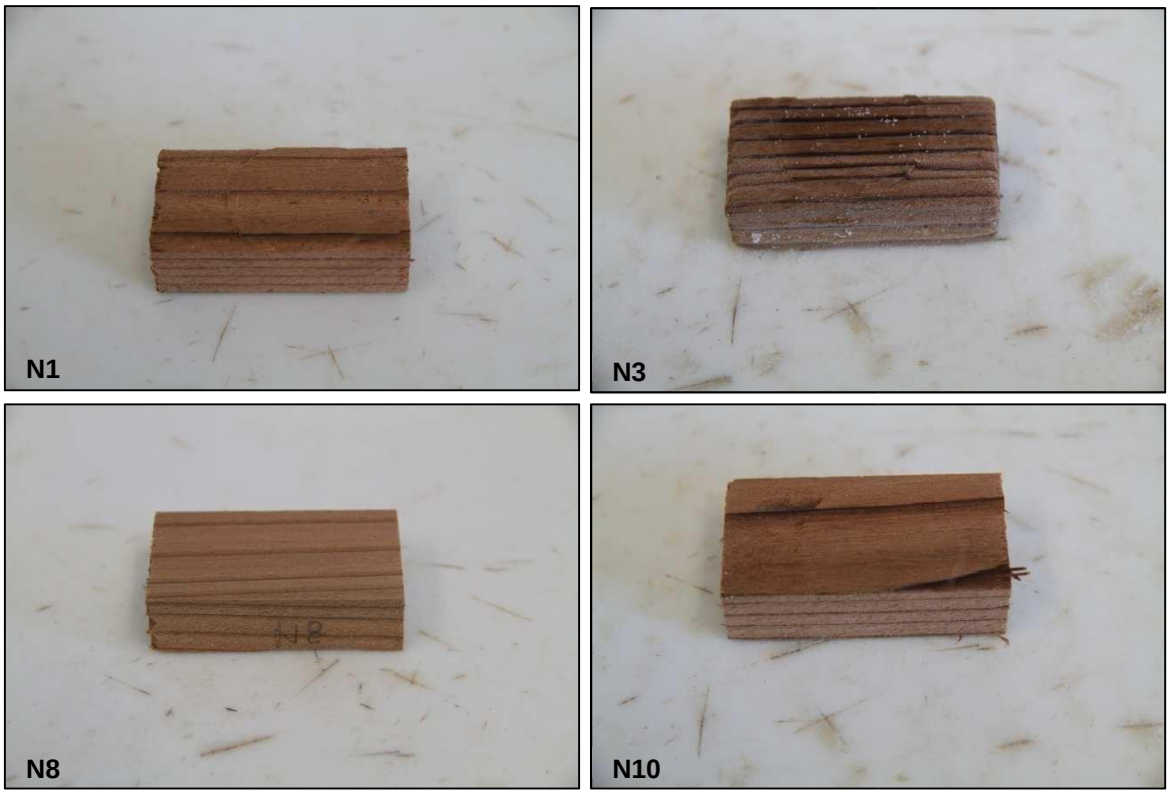

Figure 3.4 – Test samples of "black" sugi from the island of S. Miguel

3.2 Acquired durability

In the sugi test specimens treated with wood preservatives Xy and Xz the survival, the attack level and the consequent mass loss were zero (Table 3.4). In the case of sugi wood treated with only the organic solvent (white spirit) the results were, as expected, of the same magnitude as with untreated sugi (Table 3.4) (figure 3.5).

Table 3.4 – Average results of resistance to subterranean termites obtained with treated sugi wood.

Treatment	Survival (%)	Moisture content (%)	Mass loss (%)	Attack level
Xz	0	47,47	0	0
Xy	0	43,17	0	0
White spirit (control)	15,47	56,22	2,68	3,67
Pine (control)	73,26	49,68	5,37	4

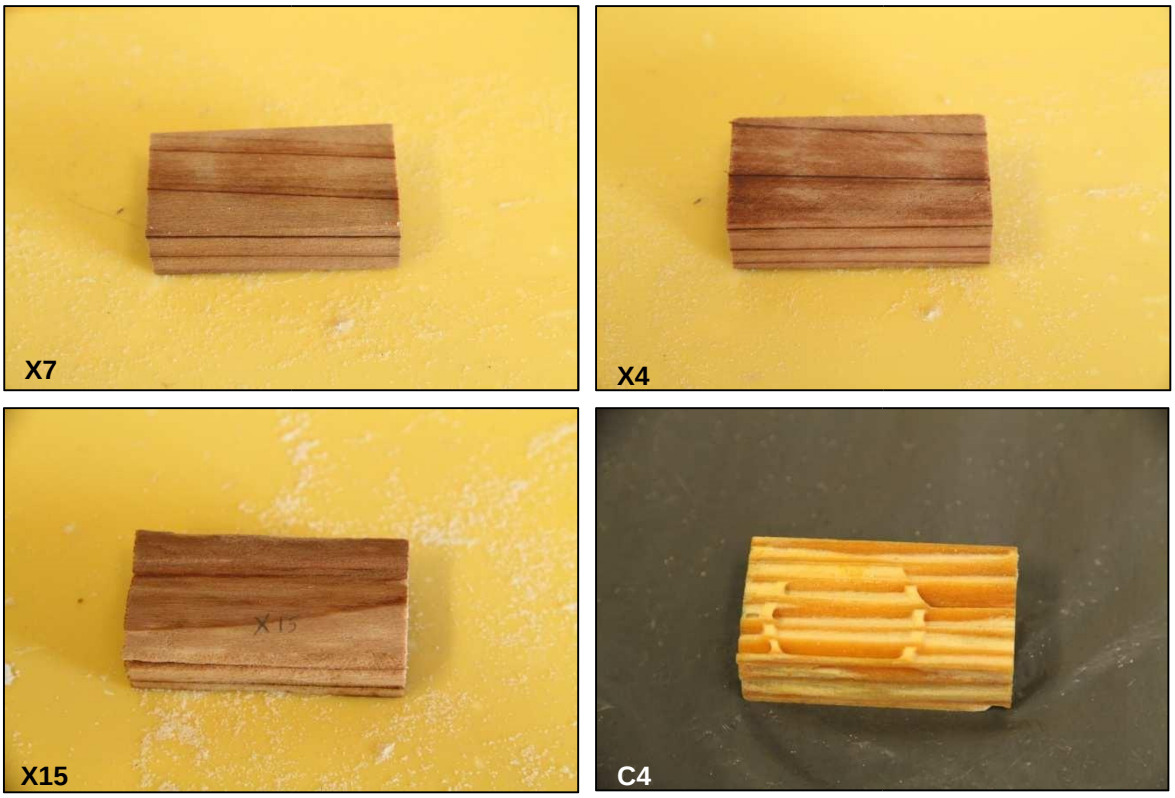

Figure 3.5 – Test samples of "rose" sugi with: Xz (X7) product; Xy (X4) product; and white spirit (X15), and maritime pine control test sample (C4).

4 | Discussion / Conclusion

With regard to natural durability of wood, the draft standard prEN350: 2014 [3], based on tests carried out by the method described in the standard EN117: 2005 [2], establishes three durability classes for wood, based on the average level of attack on the test speciemns, as defined in the following table:

Table 4.1 – Wood durability classes according to the draft European Standard prEN350 [3]

Durability Class	Description	Attack levels
D	Durable	>90% “0 and 1” with a maximum of 10% “2”
M	Moderately durable	<50% “3 and 4”
S	Not durable	>50% “3 and 4”

Considering the results of the tests and the differences between the two islands, a summary of the obtained durability class is presented below, derived from the analysis of the attack levels of all samples (see Annex) per island and considering, or not, for São Miguel the tests with "black" sugi.

Table 4.2 – Durability classes of azorean sugi wood to subterranean termites action.

Origin	Level of attack (% of test pieces with level 3 or 4)	Durability Class	Description
São Miguel (“pink”)	30	M	Moderately durable
São Miguel (“pink” and “black”)	27,5	M	
Terceira (“pink”)	10	M	

In Table 4.3 a comparison of the results obtained in this test with the sugi characteristics described in the draft European standard prEN 350 [3] is presented. The density values were obtained from the parallel mechanical characterization of the sugi wood [5].

The results presented in this report lead to the assignment of a natural durability class, in face of subterranean termites, higher than that described in the European standard of reference. Azorean sugi wood can therefore be described as **"Moderately durable"**.

Table 4.3 – Comparison of the durability class results obtained in the present test and the ones described in the draft European Standard prEN350 [3].

Scientific name	Common name	Origin	Density (kg/m³) at 12% MC	Durability class (termites)	Additional data
Cryptomeria japonica	Criptoméria Sugi	East Asia and Europe	280-320-400	S (Not durable)	Treatability and durability of heartwood highly variable
		São Miguel (Azores)	245-338-461	M (Moderately durable)	Durability of heartwood highly variable
		Terceira (Azores)	236-318-444		

However and as also referred to in the Standard, the variability of the results is very high. This natural durability classification should be viewed with some caution particularly for applications with permanent humidification (use class 4 according to NP335: 2013) [6]. Performing tests with ground contact (NP EN 252: 1992) [7] may be a way to adjust this natural durability classification to more demanding applications for wood.

With regard to acquired durability, both products tested, for the levels of absorption obtained, gave full protection to the sugi heartwood. These results should however be confirmed in the future after artificial aging tests (evaporation and leaching).

Lisbon, LNEC, April of 2015

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ANNEX
Total results obtained on the resistance testing to subterranean termites

Table I.I – Results of resistance testing of untreated sugi wood to subterranean termites from three different trees from the Island of Terceira.

Wood	Localization	Tree	Number	Survival (%)	Moisture content (%)	Mass loss (%)	Level of attack
Pink Sugi	P1 -T34	A7	1	0	34,53	0	2
			2	0	31,58	0	1
			3	0	30,2	0	2
			4	0	31,7	0	1
			5	1,6	31,7	0	1
			6	0	29,81	0	2
			7	2,8	29,63	0	3
			8	0,4	33,08	0	2
			9	0	33,58	0	1
			10	0	33,58	0	1
			Average	**0,5**	**31,57**	**0**	**1,60**
Pink Sugi	P2-T51	A5	1	0	35,03	0	1
			2	0	32,15	0,86	3
			3	0	35,52	0	2
			4	0	31,36	0	2
			5	0	32,43	0	1
			6	0	32,09	0	2
			7	0	31,5	0	1
			8	24,8	36,38	1,73	4
			9	0	34,2	0	1
			10	0	34,94	0	1
			Average	**2,5**	**33,56**	**0,26**	**1,80**
Pink Sugi	P2-T45	A2	1	0	62,94	0	2
			2	0	58,07	0	2
			3	0	42,08	0	1
			4	0	36,82	0	1
			5	0	37,55	0	1
			6	0	35,11	0	2
			7	0	66,82	0	1
			8	0	69,4	0	1
			9	0	41,72	0	1
			10	0	68,55	0	1
			Average	**0**	**51,90**	**0**	**1,30**

Table I.II – Results of resistance testing of untreated sugi wood to subterranean termites from three different trees from the Island of São Miguel.

Wood	Localization	Tree	Number	Survival (%)	Moisture content (%)	Mass loss (%)	Level of attack
Pink Sugi	P1-SM206	A5	1	0	39,45	2,56	4
			2	0	52,69	0	1
			3	28,0	99,51	11,09	4
			4	0	57,88	0	1
			5	0	40,66	0	1
			6	0	51,21	0	1
			7	0	37,36	0,69	2
			8	0	61,88	0	3
			9	0	36,53	0	1
			10	0	43,31	0,93	2
			Average	**2,8**	**52,05**	**1,37**	**2,0**
Pink Sugi	P2-SM222	A1	1	0	32,91	0,10	2
			2	0	28,73	0,30	2
			3	0	39,02	0	2
			4	0	46,05	0	2
			5	0	32,10	0	2
			6	0	31,05	0	2
			7	0	44,8	0	1
			8	0	33,69	0	1
			9	0	29,4	0	2
			10	0	37,93	2,24	3
			Average	**0**	**35,57**	**0,26**	**1,90**
Pink Sugi	P2-SM246	A5	1	0	39,33	1,64	3
			2	0	35,75	0	1
			3	0	82,07	0	2
			4	0	39,67	0	2
			5	0	61,11	0	2
			6	3,6	44,84	0	2
			7	0	91,38	8,76	4
			8	0	36,96	1,58	3
			9	0	67,10	1,98	3
			10	40,0	76,06	8,98	4
			Average	**4,4**	**57,49**	**2,29**	**2,60**

Table I.III – Results of resistance testing of black sugi wood to subterranean termites

Wood	Number	Survival (%)	Moisture content (%)	Mass loss (%)	Level of attack
Black Sugi	1	0	28,89	0	1
	2	0	34,69	0	1
	3	36,0	40,73	1,56	3
	4	0	27,13	0	1
	5	0	31,73	0	2
	6	0	33,14	0	1
	7	0	30,89	0,51	3
	8	0	25,02	0	1
	9	0	36,64	0	1
	10	40,0	34,45	0	2
	Average	**7,6**	**32,33**	**0,11**	**1,60**

Table I.IV – Results of resistance testing of control wood to an attack of subterranean termites

Wood	Number	Survival (%)	Moisture content (%)	Mass loss (%)	Level of attack
Pine (Control)	1	100	55,6	12,9	4
	2	56,8	30,5	3,2	4
	3	65,2	41,4	4,8	4
	4	68,8	80,0	5,7	4
	5	80,4	58,8	3,0	4
	6	66,4	45,8	3,8	4
	7	75,2	35,6	4,3	4
	Average	**73,3**	**49,68**	**5,37**	**4**

Table I.V – Results of resistance testing of treated sugi wood to subterranean termites from three different trees from two different islands.

Treatment	Localization	Tree	Number	Survival (%)	Moisture content (%)	Mass loss (%)	Level of attack
Xz	P1-SM206	A5	1	0	44,57	0	0
	P2-SM222	A1	2	0	40,10	0	0
	P2-SM246	A5	3	0	66,27	0	0
	P1-T45	A2	4	0	46,00	0	0
	P1-T34	A7	5	0	40,38	0	0
	P2-T51	A5	6	0	47,49	0	0
			Average	**0**	**47,47**	**0**	**0**
Xy	P1-SM206	A5	1	0	43,92	0	0
	P2-SM222	A1	2	0	37,45	0	0
	P2-SM246	A5	3	0	50,79	0	0
	P1-T45	A2	4	0	54,16	0	0
	P1-T34	A7	5	0	34,70	0	0
	P2-T51	A5	6	0	38,03	0	0
			Average	**0**	**43,17**	**0**	**0**
White spirit (Control)	P1-SM206	A5	1	0	35,54	2,14	4
	P2-SM222	A1	2	0	32,97	5,62	4
	P2-SM246	A5	3	24,40	73,06	3,40	4
	P1-T45	A2	4	0	63,92	0	2
	P1-T34	A7	5	11,20	44,00	1,38	4
	P2-T51	A5	6	57,20	87,86	3,53	4
			Average	**15,47**	**56,22**	**2,68**	**3,67**

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