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THE INTERNATIONAL RESEARCH GROUP ON WOOD PROTECTION

Section 2 **Test Methodology and Assessment**

Report on COST E37 Round Robin Tests – Comparison of results from laboratory and field tests

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ABSTRACT

A round robin involving 15 European participants was set up in 2006. The round robin consists of both a field test according to the double layer test method and a laboratory test with two different preconditioning methods. When comparing EN 84 preconditioning (two weeks water leaching) with natural preconditioning (1 year in field, above ground) according to CEN/TS 15397, no significant difference could be noted for untreated controls, thermally modified wood or CCA impregnated wood. However, for wood treated with a metal-free organic preservative, a clear difference could be seen where much of the efficacy seen after EN 84 preconditioning is lost when natural preconditioning is used instead. In the field tests, the control pine performs similar in all fields whereas both thermally modified and preservative treated wood performs much better in the Nordic fields than in the Mid- and Southern European fields. The thermally modified wood performs almost as poor as the controls in the Southern European fields, whereas the organic preservative treated wood performs well in these fields. In the six Mid-European fields, the organic preservative treated and thermally modified wood performs equally poor but much better than the controls. The best compliance between field performance and laboratory test results is obtained when comparing the average results from the field tests with results from EN 113 tests with *Postia placenta* after natural preconditioning according to CEN/TS 15397.

Keywords: EN 113, CEN/TS 15397, EN 84, double layer test, thermally modified wood, organic preservative, CCA

1. OBJECTIVES

- To evaluate whether natural preconditioning in field according to CEN/TS 15397 is more relevant than preconditioning in lab according to EN 84 before EN 113 testing
- Ability to test and predict performance of new treatments/materials and thereby fulfil one part of the specific objectives in the MoU of COST Action E37 *("The development of suitable methods of biological and field testing accompanied by round-robin tests for characterising the properties of non-biocidal technologies because the existing methods of test involved for traditional preservative-treated wood often cannot be used for wood treated by new processes - relationship between testing and practice")*
- To collect more data from the Double Layer test set-ups and thereby strengthen the basis for evaluation whether this standard is more relevant and reproducible (especially concerning alternatives to traditional wood preservatives) than other above ground test methods, e.g. ENV 12037 (Lap-Joint test)
- To determine the reproducibility in different laboratories, and thereby, as always in a Round Robin test, to compare laboratories
- To compare above ground performance in laboratory and field of modified wood, i.e. thermally modified spruce, with that of wood treated with metal-free organic preservative and wood treated with traditional preservative (CCA)

2. BACKGROUND

COST, European Cooperation in Science and Technology, is one of the longest-running European frameworks supporting cooperation among scientists and researchers across Europe. The support is channeled through so called COST Actions which usually run for 3-4 years and support meetings and networking according to an approved plan, the Memorandum of Understanding (MoU). Many MoUs for COST actions include setting up and running Round Robin tests of some kind and this was also the case for COST Action E 37 ("Sustainability through new technologies for enhanced wood durability").

As listed above, there were many objectives for the Round Robin test. One of the objectives concerned a comparison of the preconditioning of test specimens according to EN 84 (water leaching for 14 days) with natural preconditioning according to CEN/TS 15397 before decay testing according to EN 113 (the agar-block test). Earlier field tests have indicated that metal free organic preservatives performs much poorer in real field exposure (Jermer *et al.* 1999, Edlund *et al.* 2006) than reported from laboratory testing after EN 84 preconditioning and that natural preconditioning before laboratory testing seems to give more relevant results (Pilgård *et al.* 2013). Very few comparisons have been made with modified wood and therefore such comparisons were included. During the last few years, producers of preservatives have strongly objected to letting the CEN/TS 15397 become a regular EN standard, arguing that it is costly, time consuming and possibly not giving reproducible results in the EN 113 testing afterwards. In the light of this debate, the results from the Round Robin are extra important to publish. It was decided to include three test fungi in the EN 113 test, *Coniophora puteana*, *Postia placenta* (formerly denoted: *Poria placenta*) and *Trametes versicolor* (formerly denoted: *Coriolus versicolor*). Especially the relevance of using *P. placenta* has been discussed since modified wood, especially thermally modified wood, seem to have much lower resistance to this fungus than to other test fungi (Junga and Militz 2005). Junga even calls it "the terminator fungus". Therefore it was included in the Round Robin. The Double layer test (Rapp and Augusta 2004) had been put forward as an alternative to the Lap-Joint test (CEN/TS 12037) that might be more relevant, but more data was needed in order to evaluate this, and therefore this field test method was included in the Round Robin.

In the best of worlds, all parties in the Round Robin would have done both the laboratory and field tests, including the natural preconditioning. In reality, only seven parties agreed to participate in both the laboratory and field tests, whereas the majority could only participate in either the laboratory or the field tests. In order to be able to start the tests at the same time and to have the results from the laboratory test part of the RR ready within the time frame of COST E 37, it was decided that one party, SP, prepared not only the test specimens but also the rigs and exposed all laboratory test specimens that should undergo natural preconditioning in one of SPs test fields.

3. MATERIALS AND METHODS

3.1 Wood material

The test material was Scots pine sapwood (*Pinus sylvestris*) from Unnared Sawmill in Southern Sweden and Norway spruce (*Picea abies*) from Finland. The Scots pine was used as untreated control for the field test and internal control for the laboratory tests. Furthermore, the pine was used for preparing the reference preservative specimens (for the laboratory tests one organic preservative in two retention levels and for the field tests the same organic preservative in the same retention levels plus a CCA preservative in two retention levels).

3.2 Thermal modification

Large spruce boards were thermally modified according to the standard ThermoWood D process (212°C peak temperature) and a non-standard process at lower treatment temperature (200°C peak temperature, in the following denoted TMT-UC2) by a company commercially producing ThermoWood. Both batches were produced specifically for the Cost E37 Round Robin tests. The ThermoWood D is aimed for Use Class 3 (UC3) and will in the following be denoted TMT-UC3, whereas the timber treated at lower temperature was an attempt to produce a UC2 grade TW, (denoted TMT-UC2), and thereby designed to fail in the Round Robin tests. The test stakes for field test and specimens for the EN 113 test were prepared from the larger thermally modified timber boards.

3.3 Reference preservative treatments

All preservative treatments were done by SP.

An experimental organic preservative (a non-commercial product intended to resemble typical organic preservative products on the European market) was formulated by Janssen Pharmaceutical BV and delivered to SP. As active biocides it contained triazoles, IPBC and insecticide (Permethrin). It was used to treat (by full cell process) test specimens (field stakes, ribs for natural preconditioning and EN 113 specimens) to two retention levels, 1.6 and 3.9 kg/m³ of the product, intended to simulate levels expected to be suitable for UC3 and UC4, respectively.

For the core group (participating in both laboratory and field tests) references treated with a commercial CCA preservative was also included. It was only used to prepare extra reference field stakes at two retention levels, 4 and 7 kg/m³ (dry salt retention).

3.4 Preconditioning of the wood specimens for EN 113 test

Half the material for the EN 113 tests in form of end-sealed 500-mm ribs with 15x25mm x-section was naturally preconditioned one year in SP's field according to CEN/TS 15397 option for superficially treated wood. The reason for choosing this set-up although fully treated wood was included in the round robin was that it would be less harsh. After the natural preconditioning, the ribs were cut into 50mm test samples. The other half of the material, in form of EN 113 test samples, was simply kept in a climate room during the year while the first half was exposed in the field. Duplicate sets, one consisting of non-preconditioned and the other of field-preconditioned test specimens, were packaged and sent to each laboratory participating in the EN 113 part of the Round Robin test. Finally, each lab themselves did the preconditioning according to EN 84 (two weeks leaching in water) of the test samples that had not been field exposed.

3.5 EN 113 test

Ten specimen packages were received by the 10 participants of the Round Robin test and each of the laboratories performed the testing according to the standard.

3.6 Field test

The field test (Figure 1) is based on the Double Layer test (Rapp and Augusta 2004). A package with a dissembled test rig, geo-textile, test specimens and spacing bars (unmodified spruce stakes) included were sent to each of the 12 participants in the field test. The test was with a few exceptions started in late fall 2006.

An Index of Decay (IoD) value was calculated for each group of test stakes by multiplying the average rating with 25, thereby obtaining results ranging from 0 (all stakes within the group sound) to 100 (all stakes within the group have failed).

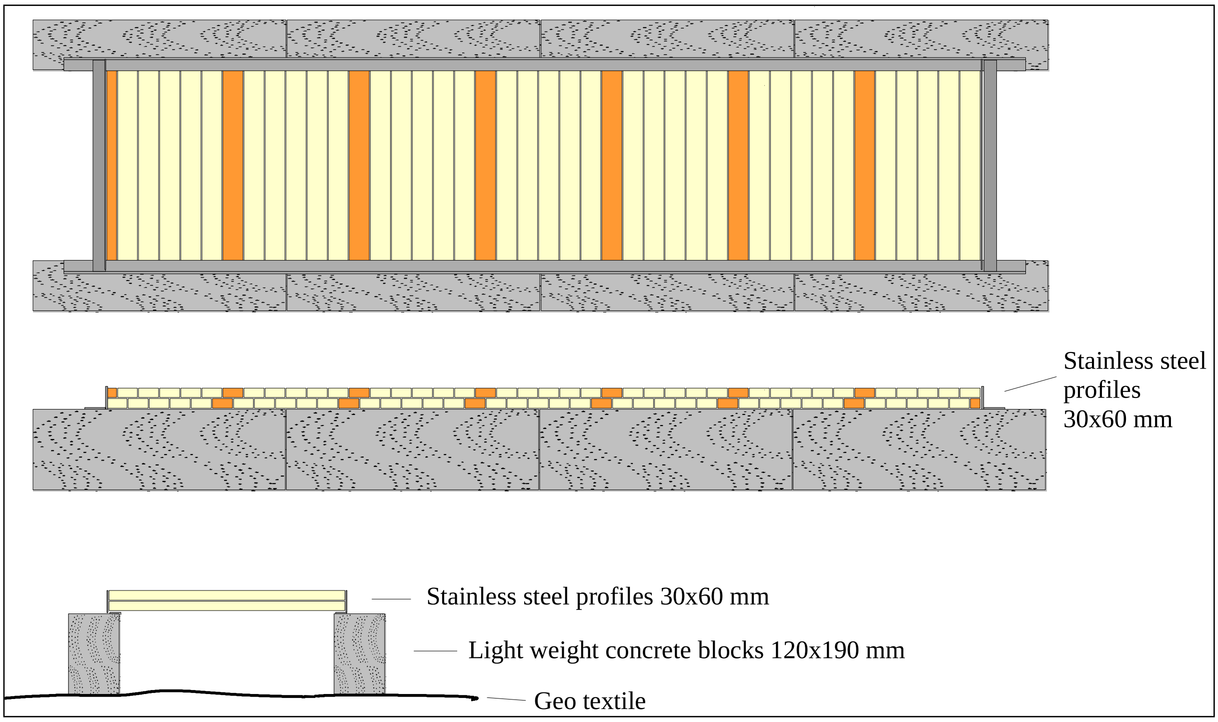

Figure 1. Test rig for double layer test.

3.7 Participants

The participants and their involvement are listed in Table 1. Totally 15 participants of which 7 participated in both laboratory and field tests, 5 only in the field test and 3 only in the lab test.

Table 1: Participants in the Round Robin test of Cost Action E37

Participant	Country	Lab test	Field test	Field Region	Responsible
BRE	UK	X	X	Mid Europe	Ed Suttie
CATAS	IT	X	-	-	Elena Conti
CNR-Ivalsa	IT	-	X	South Europe	Sabrina Palanti
DTI	DK	X	X	Nordic	Morten Klamer
LNEC	PT	-	X	South Europe	Lina Nunes
LS IWC	LV	X	-	-	Ilze Irbe
NTI	NO	-	X	Nordic	Per Otto Flaete [a]
Poznan Univ.	PL	-	X	Mid Europe	Bartłomiej Mazela
SHR	NL	X	X	Mid Europe	Jos Creemers [b]
SP	SE	X	X	Nordic	Mats Westin
TI (form. BFH)	DE	-	X	Mid Europe	Eckhard Melcher [c]
TU-Zvolen	SK	X	-	-	Ladislav Reinprecht
UGOE	DE	X	X	Mid Europe	Antje Gellerich
VTT	FI	X	X	Nordic	Hannu Viitanen
Dr Wolman	DE	X	X	Mid Europe	Ralf Möller
Total	**15**	**10**	**12**	**12**	

[a] *Initially started by Fred Evans* [b] *Initially started by Bas Holleboom* [c] *Initially started by Andreas Rapp*

4. RESULTS AND DISCUSSION

The most important objective is to evaluate whether the tests are appropriate and can be used for predicting performance in real applications. In order to be able to achieve this, comparison of the results from laboratory and many years in field tests are needed. Six years of field exposure may be a bit on the short side for full comparisons, but we believe that already after 6 years some trends can be presented and comparisons be made.

4.1 Laboratory test

Differences between EN113 results when using the two different preconditioning standards

There are no significant differences with any of the test fungi, in results between the EN84 leached and the field exposed (CEN/TS 15397) groups for unmodified, thermally modified (TMT) and CCA-treated wood (comparing the "EN 84 leached" columns with the "Field exposed" in Table 2).

Table 2:** **Average results (expressed as % Mass Loss) for all laboratories for each type of test group and test fungi

	Coniophora puteana				*Postia placenta*				*Trametes versicolor*			
	EN 84 leached	Field exposed	Control		EN 84 leached	Field exposed	Control		EN 84 leached	Field exposed	Control	
Int. Control	34	34	34	33	29	29	29	30	23	21	24	21
Organic Low	2	14	41	40	2	12	35	30	4	7	21	20
Organic High	0	7	41	42	0	5	34	32	1	3	25	23
TMT-UC2	6	7	39	40	19	18	30	32	4	3	21	21
TMT-UC3	3	5	43	40	11	13	36	34	2	3	20	20
CCA Medium	0	0	41	46	5	9	37	35	1	1	32	23
CCA High	0	0	46	44	1	1	41	37	0	0	23	20

However, for wood treated with the organic preservative, there is a clear difference between the groups that have been preconditioned in two different ways – after EN 84 leaching the performance is almost as good as for the CCA-treated wood (2% ML with the brown rot fungi at the low retention level and 0% at the high level) whereas after field exposure the performance is dramatically poorer (12-14% ML with BR fungi at the low retention level and 5-7% ML at the high retention level). These results are to some extent in line with the results presented by Pilgård *et al.* (2013), where the natural preconditioning was performed in a German test field. These trials and earlier field tests indicate that the active biocides are degraded and/or leached out during one year natural preconditioning to an extent that results in significant fungal decay. Furthermore, this indicates that one year preconditioning in field before EN 113 is more appropriate than the EN 84 preconditioning when testing organic preservatives when also comparing with earlier experiences from field tests (Johansson *et al.* 1999, Edlund *et al.* 2006). However, the EN 84 (together with EN 73) is currently required for approval of new preservatives according to EN 599-1. It should be noted that in the Cost E37 RR, all natural weathering took place in one test field (Borås, Sweden), and it would, of course, have been better if the natural weathering had taken place in a field nearby each of the test laboratories. If the natural weathering had indeed been performed in test fields in the different European regions, we might have seen larger variations in the resulting mass loss values.

Performance of modified wood

The thermally modified wood at a treatment level required for UC3 use (*TMT-UC3*) performs rather well in the EN 113 tests with *Coniophora puteana* and *Trametes versicolor*, resulting in a

Natural durability class 1 (very durable) when the results are used for classification according to EN 350-1. However, this material performs much poorer in tests with *Postia placenta*, resulting in durability class 3 (moderately durable) although the relevance of using this test fungus in EN 113 tests of modified wood has been questioned (Junga and Militz 2005, Welzbacher *et al.* 2005).

Differences between laboratories

The level of average mass loss values for various material groups and test fungi differed between several participants, mainly due to different level of virulence of the actual fungi used. Furthermore, 3-5 laboratories (depending on material tested) had non-valid test results with *Trametes versicolor* due to poor virulence (mass loss values below 15%), and 1-2 laboratories had non-valid test results with *Postia placenta* due to the same reason. However, the relative difference between mass loss values of different materials, and their internal ranking, was more or less the same for the laboratories involved.

4.2 Field test (above ground)

Results for all materials in respective geographic test field region

Table 3: Average results (expressed as Index of Decay) for all fields within a region (Nordic, Mid-Europe and Southern Europe) and at the bottom average for all fields.

Geographic region	**Wood material type**	**Index of Decay (0-100%)** 1 year	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs
Nordic Fields	Control	0,0	1,9	4,4	20,0	34,9	54,2
	TMT-UC2	0,0	1,9	2,5	8,1	13,8	28,3
	TMT-UC3	0,0	0,0	2,5	3,8	6,9	15,0
	Organic Low retention	0,0	0,6	1,3	5,6	10,6	9,2
	Organic High retention	0,0	0,0	0,6	1,3	0,0	4,2
	CCA Medium retention	0,0	0,0	0,0	0,0	0,0	0,0
	CCA High retention	0,0	0,0	0,0	0,0	0,0	0,0
Mid European fields	Control	6,0	16,5	25,0	33,0	45,0	57,5
	TMT-UC2	5,0	13,0	16,3	22,0	26,5	32,5
	TMT-UC3	5,0	8,5	10,0	13,0	21,0	24,6
	Organic Low retention	3,8	5,0	6,3	9,0	17,5	28,8
	Organic High retention	3,3	5,0	7,5	9,5	14,0	24,6
	CCA Medium retention	0,0	0,0	1,3	5,8	8,3	11,3
	CCA High retention	0,0	0,8	3,8	4,2	4,2	3,8
Southern European fields	Control	16,3	16,3	26,3	25,0	37,5	67,5
	TMT-UC2	1,3	7,5	17,5	42,5	55,0	75,0
	TMT-UC3	1,3	6,3	11,3	25,0	40,0	43,8
	Organic Low retention	0,0	0,0	3,8	0,0	2,5	7,5
	Organic High retention	0,0	0,0	0,0	0,0	0,0	5,0
Average, all European fields	Control	5,7	11,1	17,0	27,0	40,2	58,4
	TMT-UC2	2,5	8,0	11,0	18,5	24,3	39,1
	TMT-UC3	2,5	5,0	7,3	10,5	17,3	25,5
	Organic Low retention	1,9	2,5	3,8	6,8	13,3	19,5
	Organic High retention	1,7	2,3	3,3	5,3	7,0	15,5
	CCA Medium retention	0,0	0,0	0,4	2,5	3,6	6,4
	CCA High retention	0,0	0,4	1,3	1,8	1,8	2,1

As can be seen in Table 3, the untreated control pine stakes are in rather similar condition after six years exposure in all test fields (54-67% IoD), although the onset of decay appears earlier the further south in Europe the field is located. The thermally modified and preservative treated wood on the other hand, performs much better in the Nordic fields than in the Mid- and Southern European fields as can be seen from Table 3 and Figures 2 and 3. In the Southern European fields, the thermally modified wood performs almost as poor as the controls (severe decay for TMT-UC2 and IoD=44% for TMT-UC3), whereas the organic preservative treated wood performs well in these fields (none to slight decay).

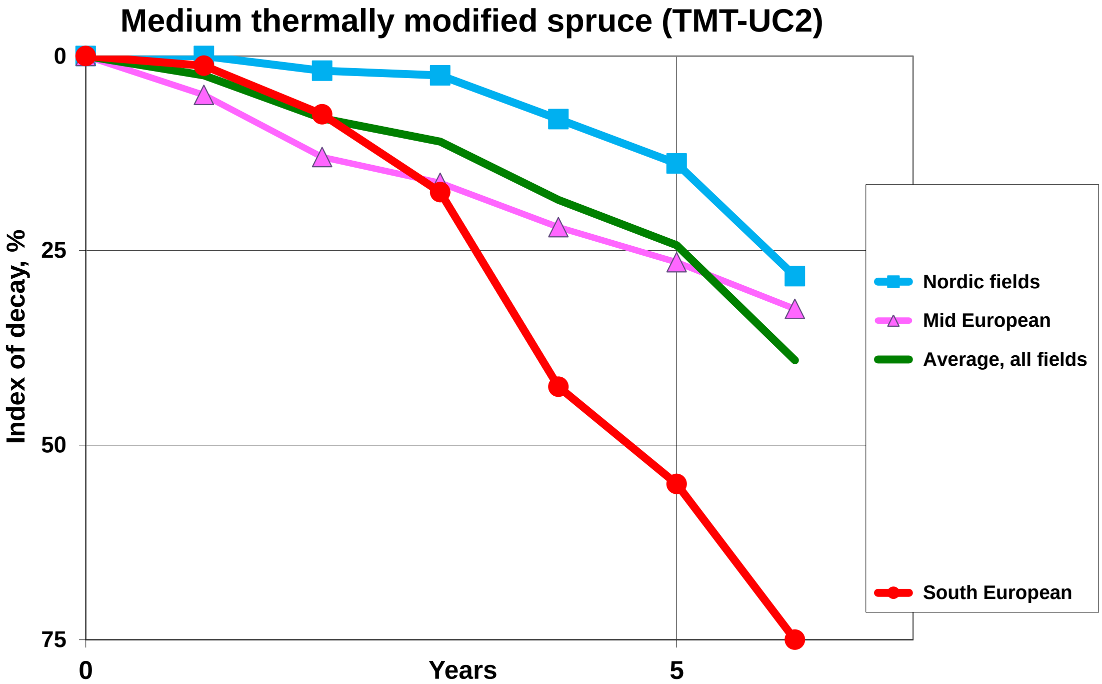

Figure 2. Performance of medium thermally modified spruce (TMT-UC2) in different regions of Europe.

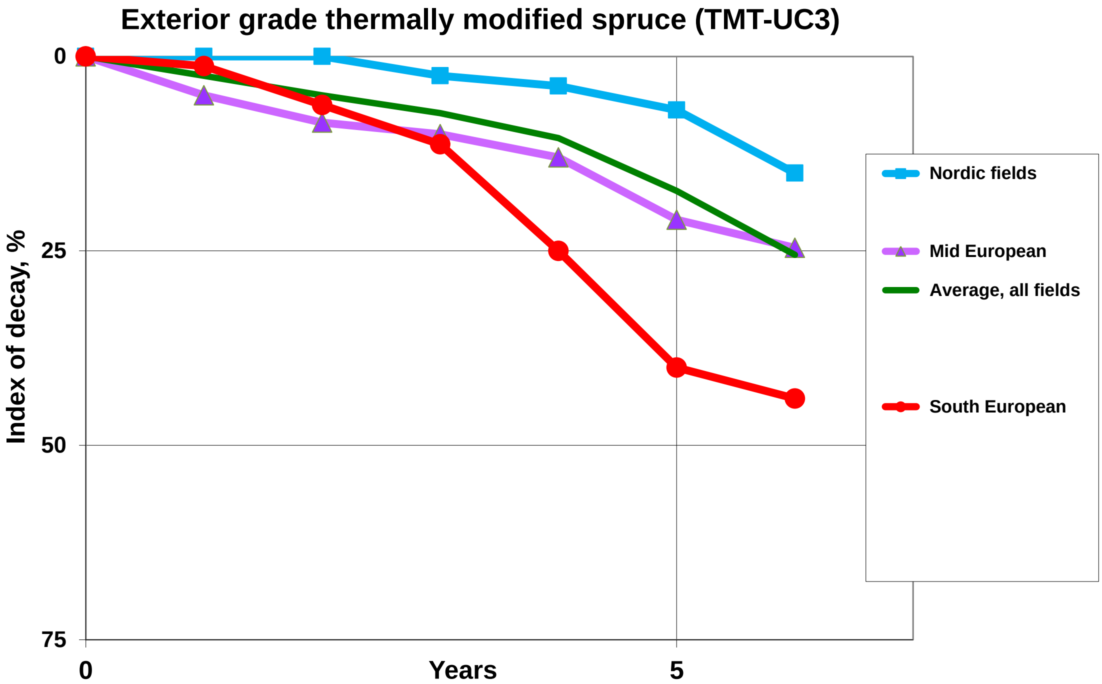

Figure 3. Performance of UC3 grade thermally modified spruce (TMT-UC3) in different regions of Europe.

In the six mid-European fields, the organic preservative treated and thermally modified wood performs equally poor (around 30% IoD for TMT-UC2 and $Organic_{LOW}$, and slight decay for TMT-UC3 and $Organic_{HIGH}$) but much better than the controls (IoD=57.5%).

Figure 4. Decay in TMT-UC2 stakes in deck in Italy and Control stakes in deck in Denmark after 6 years.

In Figure 4 severely decayed medium thermally modified spruce stakes (TMT-UC2) can be seen in the left hand photo and moderately decayed unmodified pine control stakes in the right hand photo.

Figure 5. Top: BRE test deck in the UK and bottom: Opened up Wolman test deck in Sinzheim, Germany.

In Figure 5 the top photo shows what the decks typically looks like on a dry day when not opened up (here represented by the deck at BRE in UK). The bottom photo in Figure 5 shows a deck that has been opened up, here represented by the deck at Wolman’s test site in Sinzheim, Germany.

Average results for all fields for all materials

When plotting the average Index of Decay (IoD) for each material, i.e. average of results from all 12 fields, very nice curves are obtained (see Figure 6). After six years controls are moderately to severely decayed (IoD=58.4%); medium thermally modified spruce, TMT-UC2, slightly to moderately decayed (IoD=39.1%); thermally modified spruce for UC3, TMT-UC3, slightly decayed (IoD=25.5%); Organic preservative treated to "UC3 level", $Organic_{LOW}$, none to slight decay (IoD=19.5%); Organic preservative treated to "UC4 level", $Organic_{HIGH}$, IoD=15.5%; CCA preservative treated to medium retention IoD=6.4%; and finally CCA high retention IoD=2.1%.

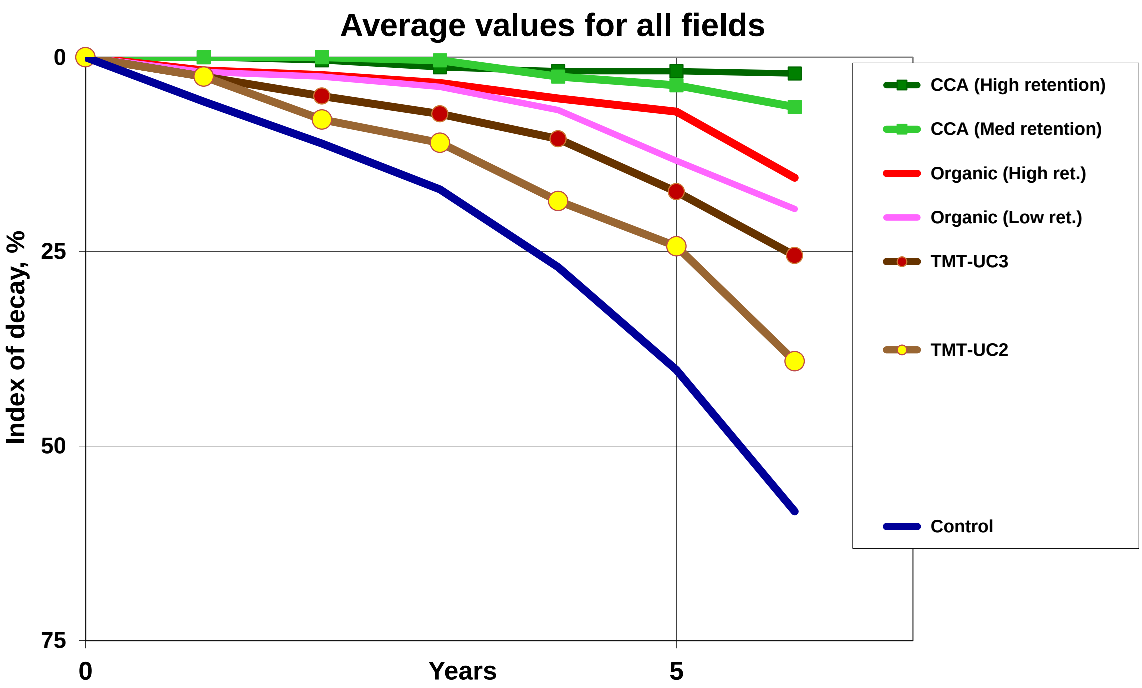

Figure 6. The development of decay in respective wood material. Average values for all fields.

4.3 Comparison of results from laboratory and field tests

First of all it is clear when comparing the columns for "EN 84 leached" specimens in Table 2 with the field performance shown in Figure 6 that the predictability is poor for the performance of both organic preservative treated and thermally modified wood.

If instead the columns for "Field exposed" (naturally preconditioned) specimens in Table 2 is compared to the performance in Figure 6, the predictability is much better – especially when looking at the results with the *Postia placenta* fungus. Furthermore, with *P. placenta*, the ranking order is more or less the same.

When looking at the predictability for field performance in different regions by laboratory testing of naturally preconditioned specimens, the correlation is better for North and Mid-Europe than Southern Europe. In the Southern European fields thermally modified wood performs poorer than in laboratory testing with both pre-conditioning methods.

5. CONCLUSIONS

The round robin tests were successfully set up. In the EN 113 part with two types of preconditioning, the mass loss ranking order was approximately the same for all ten laboratories and test fungi. For the field test part the ranking order was the same, with a few exceptions, for all fields. The exceptions were the fields located in the southern part of Europe where the thermally modified wood performed much poorer and some Mid-European fields were the organic preservative treated wood performed poorer than the thermally modified wood. Finally, an interesting result concerning predictability of above ground field performance is that natural preconditioning in field seems to be more appropriate than preconditioning according to EN 84 before EN 113 testing. However, further investigation of field preconditioning at the different fields should be made before any strong conclusions regarding predictability of actual field performance could be drawn.

6. FUTURE

In order to fully achieve the main objective all field test participants should continue with annual assessment and report back to the first author, Mats Westin, who in turn will continue to compile and write status reports. Hopefully there will be a follow-up paper at least 4 years from now.

7. ACKNOWLEDGEMENTS

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