Andreas O. Rapp[1], *Ulrike Augusta* [2]

The natural durability of industrial important European wood species in different use classes*

Prirodna postojanost industrijski važnih europskih vrsta drva u različitim kategorijama uporabe*

Izvorni znanstveni rad • Original scientific paper
Prispjelo - received: 17. 04. 2003. • Prihvaćeno - accepted: 21. 04. 2004.
*UDK 630*814.1*

ABSTRACT • *The natural durability of important European wood species has been tested on 3970 specimens in field trials. The wood was exposed at five test fields in Germany with different climates at each site in European hazard class 4 and 3 (with and without soil contact). Within EHC 3 three different expositions were tested: end grain sheltered, unsheltered and with water trap. The test has now been running for 3 years. The results have shown that the type of exposition (EHC 3 or EHC 4) has a strong influence on both: the decay activity and the durability determined as the quotient of decay of tested species and Scots pine sapwood. The test site had a strong effect on decay activity and time to failure, whereas the effect on durability was lower. Up to now it has not yet been possible to calculate the final durability classification, but so far the field tests in soil have confirmed the natural durability given in EN 350 (with the exceptions of* Quercus robur *and* Robinia pseudoacacia*, both being less durable than said in the standard). Whereas so far the above ground tests have revealed a higher durability than classified in the standard EN 350 for all soft-wood species with coloured heartwood (heartwood of larix, pseudotsuga and pinus). It is obvious that the current classification of natural durability is only valid for use in soil contact. Future amendments of the standard EN 350 seem to be reasonable. It is proposed that durability class shall be listed separately for in ground and for above ground use in the future.*

Key words: *natural durability, hazard classes, European wood species, field tests*

SAŽETAK • *Prirodna postojanost važnih europskih vrsta drva provjeravana je na 3 970 uzoraka u terenskom testiranju. Drvo je bilo izloženo na pet probnih lokacija u Njemačkoj, s različitim klimatskim uvjetima na svakoj od njih, i to prema europskim kategorijama štetnosti 4 i*

[1]The author is professor at the Federal Research Centre for Forestry and Forest Products, Institute for Wood Biology and Wood Protection, Germany. [2]The author is assistant at University of Hamburg, Department of Biology, Germany
[1]Autor je profesor u Saveznom istraživačkom centru za šumarstvo i šumske proizvode, Njemačka.[2]Autorica je asistentica na Sveučilištu u Hamburgu, Zavod za biologiju, Njemačka
* Dio ovog rada predstavljen je na savjetovanju "Drvo u graditeljstvu - suvremena kretanja", Zagrebački velesajam, 11. travnja 2003.

3 (uz kontakt s tlom i bez njega). U sklopu EHC 3 testirane su tri različite vrste izlaganja: zaštićenim čeonim presjekom, nezaštićenim čeonim presjekom i vodenom zamkom.
Test se provodi već tri godine. Rezultati pokazuju da vrsta izlaganja (EHC 3 ili EHC 4) znatno utječe na brzinu razgradnje i na postojanost koja se određuje kvocijentom razgradnje testiranih vrsta i bjeljike bijele borovine. Mjesto izlaganja također uvelike utječe na jačinu razgradnje i vrijeme pojave greške, dok je utjecaj na postojanost nešto slabiji.
Do sada još nije bilo moguće dati konačnu klasifikaciju postojanosti, ali dosadašnji terenski probni testovi u tlu potvrdili su prirodnu postojanost navedenu u EN 350 (s izuzetkom Quercus robur *i* Robinia pseudoacacia*, koji imaju slabiju postojanost od one navedene u normi). Premda su testovi iznad tla potvrdili veću postojanost drva od onih klasificiranih normom EN 350 za sve vrste mekog drva s obojenom srževinom (srževina* Larix*,* Pseudotsuga *i* Pinus*), očito je da sadašnja klasifikacija prirodne postojanosti vrijedi samo za drvo u dodiru s tlom. Dopune i izmjene norme EN 350 u budućnosti se čine realnima. Predlaže se da se postojanost ubuduće vrednuje zasebno za drvo koje se rabi u tlu i ono iznad tla.*

Ključne riječi: *prirodna postojanost, kategorije štetnosti, europske vrste drva, terenski pokusi*

1 INTRODUCTION
1 UVOD

The natural durability is determined according to EN 350-1 (1993) by lab tests and field tests exclusively in ground contact. However large quantities of wood are used outside soil contact.

Several investigations in above ground situations lead us to the assumption that it is not easily possible to transfer conclusions on durability from field test in soil contact and lab tests on durability in hazard class 3 (Rapp et al., 1998; Derbyshire and Carey, 2001). Obviously different moisture content in wood creates in addition to natural biocides, other decay conditions in soil contact than in above ground situation.
The research presented here aims at contributing to clarifying the question, whether there are differences in natural durability of some European wood species between EHC 3 and EHC 4. Therefore field tests were installed. The wood samples were tested in typical situations in and out of soil contact. The results of still ongoing trials aim at contributing to modify the durability classification. A basis for decisions on the correct use of wood in hazard classes can be developed according to these conclusions.

2 MATERIALS AND METHODS
2 MATERIJALI I METODE

2.1 Materials
2.1 Materijali

The trials included nine different materials from three origins (Table 1).

Table 1
Materials included in trials
Tablica 1.
Materijali uvršteni u istraživanje

Wood species – *Vrsta drva*	**Latin name –** *Latinski naziv*	**Short cut** *Kratica*
Spruce sapwood *bjeljika smreke*	*Picea abies* Karst.	SpS
Spruce heartwood *srž smreke*	*Picea abies* Karst.	SpH
Fir - *jelovina*	*Abies alba* Mill	Fir
Scots pine sapwood *bjeljika bijeloga bora*	*Pinus sylvestris* L.	PS
Scots pine heartwood *srž bijeloga bora*	*Pinus sylvestris* L.	PH
Douglas fir heartwood *srž duglazije*	*Pseudotsuga menziesii* Franco	Dou
Larch heartwood *srž ariša*	*Larix decidua* Mill. and *larix japonica*	La
English oak heartwood *srž engleskog hrasta*	*Quercus robur* L.	Oak
Black locust heartwood *srž crnoga bagrema*	*Robinia pseudoacacia* L.	Rob

Sapwood and heartwood of spruce and pine were taken from the same logs. The wood was dried at a temperature not higher than 60 °C after cutting. Altogether 3970 samples were sawed from the logs and planks. Then they were planed on the four sides. All samples were 500 mm x 50 mm x 25 mm in dimension as specified in EN 252. The test pieces had no cracks, no discoloration, no infestation by insects or fungi.

2.2 Test sites
2.2 Izlagališta

In the spring of 2000 the material was installed in Germany at five test sites with different climates.

Test site *Izlagalište*	**Average of temperature** *Prosječna temperatura* °C	**Total precipitate** *Količina oborina* mm	**Total sunshine hours** *Broj sunčanih sati*
Rhön	5,8	1 050	1 550
Stuttgart	10,0	679	1 752
Freiburg	10,3	903	1 808
Hamburg	8,4	714	1 630

Table 2
Mean climatic data of many years of the test sites
Tablica 2.
Višegodišnji prosječni podaci o klimatskim obilježjima izlagališta

Table 2 shows the mean long-time climatic data of the test sites. In Hamburg two test fields were built close together (150 m), but with strong differences in the micro climate. One was completely in the shade of trees and the other was completely in the open.

Test site - *Izlagalište*	**Soil type -** *Tip tla*	**PH**	**Rate of C/N** *Omjer C/N*	**Humus, %** *Humus, %*
Rhön	Sandy loam *pjeskovita glina*	6,2	11:1	4,4
Stuttgart	Sandy loam *pjeskovita glina*	7,1	13:1	3,7
Freiburg	Strong loamy sand *izrazito glinasto pjeskovito*	5,4	10:1	3,0
Hamburg	Slight loamy sand *slabo glinasto pjeskovito*	6,4	10:1	3,1
Hamburg "baumschatten"	Slight loamy sand *slabo glinasto pjeskovito*	5,6	11:1	2,9

Table 3
Characteristics of soils at different test fields
Tablica 3.
Obilježja tla na različitim ispitnim poljima

At all test fields the samples were integrated in EHC 3 and 4. Additional soil investigations were carried out for a better characterisation of the soils. Table 3 illustrates the results.

In addition to the soil test the samples were installed at other sites showing typical constructions. For this purpose in EHC 3 three different expositions were chosen:

- horizontal samples in double layer with water trap
- vertical single samples with unsheltered end grain
- vertical single samples with end grain sheltered.

2.3 Data analyses
2.3 Obrada podataka

The assessment of each wood sample was carried out every year in September. The decay of wood was determined according to the standard EN 252 (1989). The rating scheme for the visual inspection is shown in Table 4.

The results of the ratings from field tests were calculated to mean decay ratings for each type of wood.

The natural durability is the resistance of wood against wood destroying organisms. It is defined as relative value between the wood and a reference wood (Scots pine sapwood or beech sapwood). Natural durability was determined and diagrammed as a relative decay rating. This was calculated from the quotient of decay rating of tested species and of decay rating of Scots pine sapwood.

3 RESULTS
3 REZULTATI

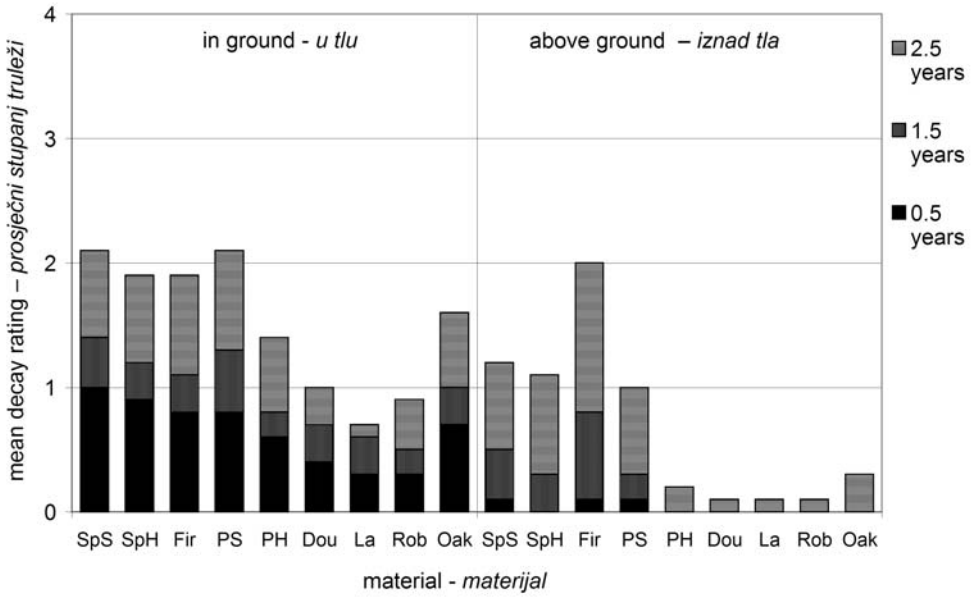
3.1 Influence of exposition on durability
3.1 Utjecaj izlaganja na postojanost

After the evaluation, every year in autumn, the mean decay rating of wood species was calculated from decay rating from field tests. Figure 1 compares mean decay ratings of wood in different hazard classes. The times of evaluation are described by diverse patterns. One bar contains results from 150 samples.

Table 4
Rating scheme for evaluation wood samples in field test
Tablica 4.
Razredbena shema vrednovanja drvenih uzoraka na ispitnim poljima

Rating *Razred*	**Description -** *Opis*	**Definition -** *Definicija*
0	SOUND *ZDRAV*	no evidence of discoloration, softening or weakening caused by micro-organisms *nije primijećena promjena boje, omekšanje ili oslabljenje prouzročeno mikroorganizmima*
1	SLIGHT ATTACK *BLAGI NAPADAJ*	limited evidence, no significant softening or weakening up to 1 mm depth *jedva zamjetne promjene, beznačajno omekšanje ili oslabljenje do dubine 1 mm*
2	MODERATE ATTACK *UMJERENI NAPADAJ*	explicit evidence, with areas of decay (softened or weakened wood) from 2 to 3 mm depth *jasno zamjetne promjene s trulim područjima (omekšano ili oslabljeno drvo) dubine 2 do 3 mm*
3	SEVERE ATTACK *JAKI NAPADAJ*	strong evidence, extensive softening and weakening, typical fungal decay at large areas from 3 to 5 mm or more depth *jako zamjetne promjene, znatno omekšanje i oslabljenje, tipična trulež na velikom području na dubini 3 do 5 mm i više*
4	FAILURE *POTPUNO TRUL*	after a beat test sample break through *nakon testiranja uzorak se slomio*

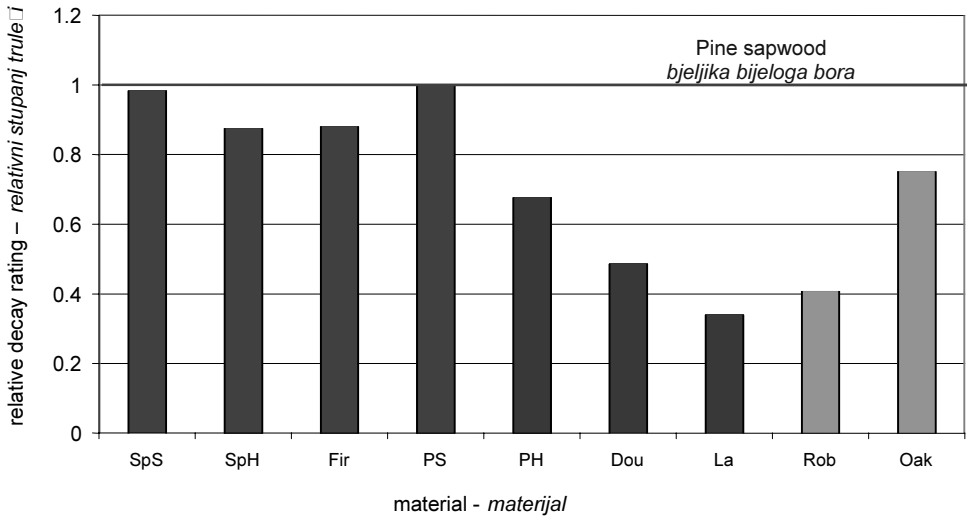
Figure 1
Mean decay rating of wood in different hazard classes (in ground and above ground)
Slika 1.
Prosječni stupanj truleži drvenih uzoraka prema različitim razredima štetnosti (u doticaju s tlom i iznad tla)



In soil contact the decay of wood was stronger than in above ground situations (double-layer test). This applies to all tested wood species with the exception of fir, which showed somewhat stronger decay in double-layer tests than in soil contact.
Figures 2 and 3 shows a first impression of natural durability. For the present the durability was expressed as the quotient of mean decay rating of tested wood species and mean decay rating of Scots pine sapwood. In the Figures this index is calculated as decay rating relative to pine sapwood. One bar contains results from 150 samples.

The relative decay rating of spruce (sap- and heartwood) and fir was lower in soil contact than in the double layer test (above ground). In contrast to spruce and fir the decay rating relative to pine sapwood was minor in above ground situations than in soil contact for larch, douglas fir, Scots pine heartwood, black locust and English oak. A continuation of this trend would result in a longer mean time to failure and also a longer mean time to failure relative to Scots pine sapwood in EHC 3. That means that these materials were more durable above ground than in soil contact and would therefore obtain a better durability classification in EHC 3.

Figures 4 and 5 illustrate the relative frequency of samples in the rating steps (according to EN 252) after 2.5 years in field. One bar contains results from 150 samples. In above ground situations most samples resided in rating step 0 (Figure 4).



SpS - Spruce sapwood - *bjeljika smreke*, **SpH** - Spruce heartwood - *srž smreke*, **Fir** - Fir - *jelovina*, **PS** - Scots pine sapwood - *bjeljika bijeloga bora*, **PH** - Scots pine heartwood - *srž bijeloga bora*, **Dou** - Douglas fir heartwood -*srž duglazije*, **La** - Larch heartwood - *srž ariša*, **Oak** - English oak heartwood - *srž engleskog hrasta*, **Rob** - Black locust heartwood - *srž crnoga bagrema*

Figure 2
Relative decay rating as the quotient of mean decay rating of tested species and mean decay rating of Scots pine sapwood after 2.5 years in ***ground contact***
Slika 2
Relativni stupanj truleži kao kvocijent srednjeg stupnja truleži ispitivanih uzoraka i bjeljike bijelog bora nakon 2,5 godina izlaganja u doticaju s tlom

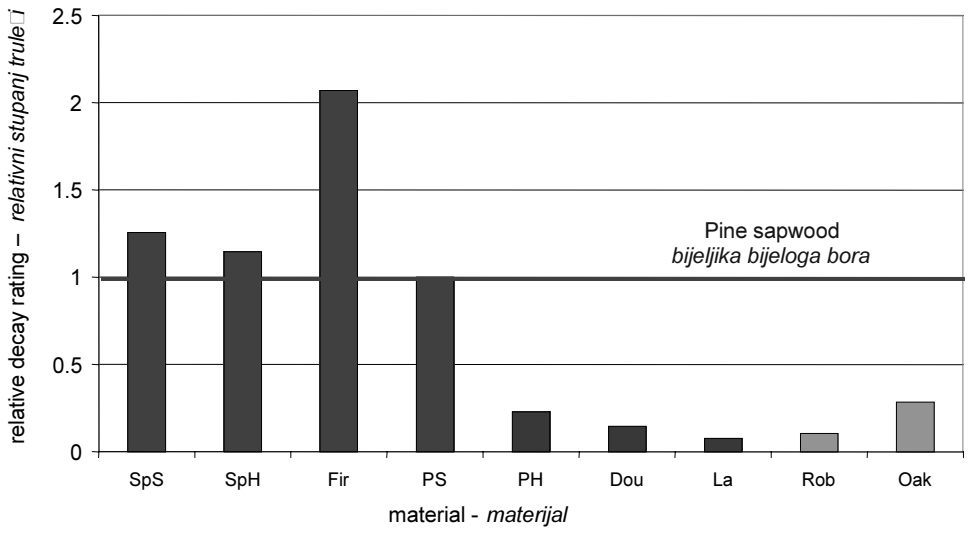


Figure 3
Relative decay rating as the quotient of mean decay rating of tested species and mean decay rating of Scots pine sapwood after 2.5 years in ***above ground*** *situation (double layer test)*
Slika 3.
Relativni stupanj truleži kao kvocijent srednjeg stupnja truleži ispitivanih uzoraka i bijeljike bijelog bora nakon 2,5 godina izlaganja iznad tla (ispitivanje pomoću dvoslojnih uzoraka)

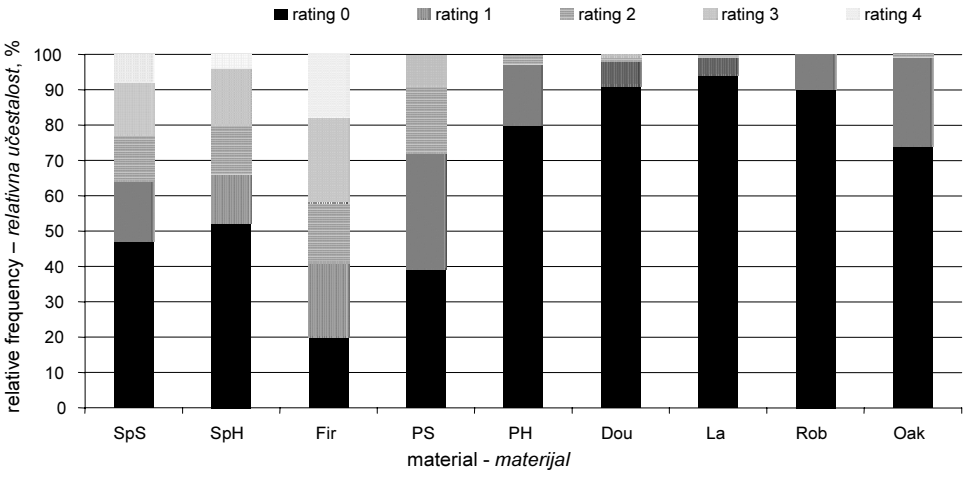


Figure 4
Relative frequency of samples in the rating steps (EN 252) after 2.5 years in ***above ground*** *situation (double layer test).*
Slika 4.
Relativna učestalost uzoraka u razredbenom stupnjevanju (EN 252) nakon 2,5 godina i iznad tla (ispitivanje pomoću dvoslojnih uzoraka)

However, samples from fir were distributed more or less uniformly in all rating steps. Also Scots pine sapwood and spruce were represented in all rating steps. That means that samples were present without decay as well as samples, which were completely destroyed. Softwood with coloured heartwood and hardwood were predominantly sound or slight attacked (rating step 0 or 1). For the same wood species a slight to moderate infestation (rating steps 1 and 2) was established in ground contact (Figure 5).

3.2 Influence of test site and test exposition on natural durability
3.2 Utjecaj izlagališta i izlaganja na prirodnu postojanost

The following Figures 6 and 7 compare the mean decay rating of all wood species at different climatic test sites. For this purpose wood species were classified in wood-groups:

- NH (sapwood and non-coloured soft - wood): spruce sapwood, spruce heart - wood, Scots pine sapwood, fir
  NH (bjeljika i neobojene meke vrste drva):

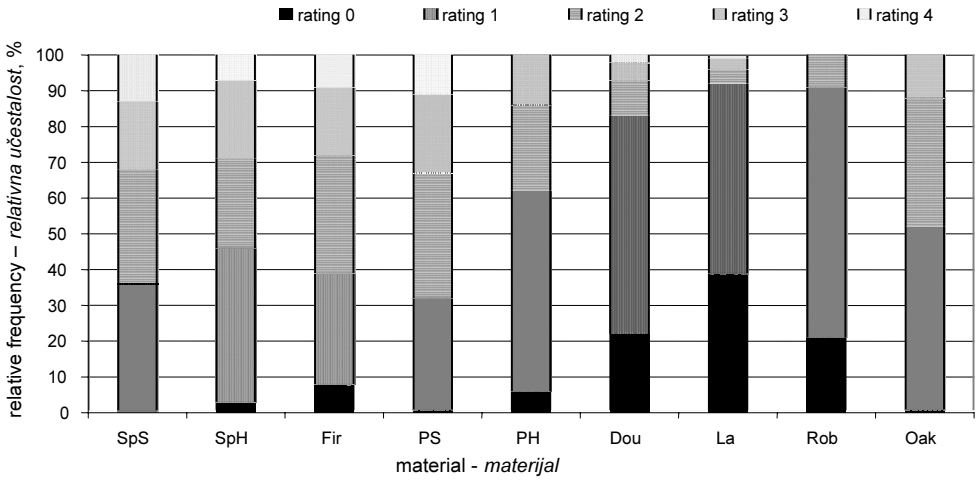


Figure 5
Relative frequency of samples in the rating steps (EN 252) after 2.5 years in ***ground contact***
Slika 5.
Relativna učestalost uzoraka u razredbenom stupnjevanju (EN 252) nakon 2,5 godina i u doticaju s tlom

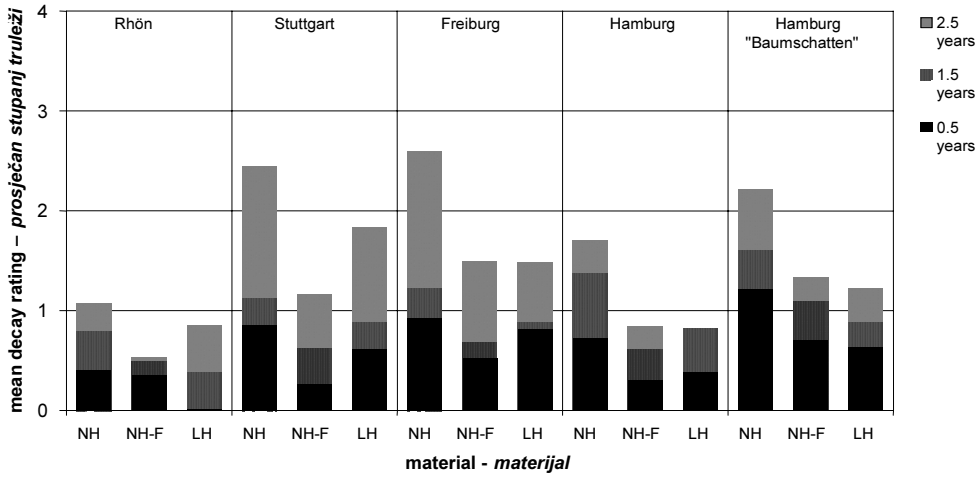


Figure 6
Mean decay rating of wood-groups at five climatically different test fields after 2.5 years in ***ground contact***
Slika 6.
Prosječni stupnjevi truleži grupa uzoraka na pet klimatski različitih ispitnih polja nakon 2,5 godina izlaganja u doticaju s tlom

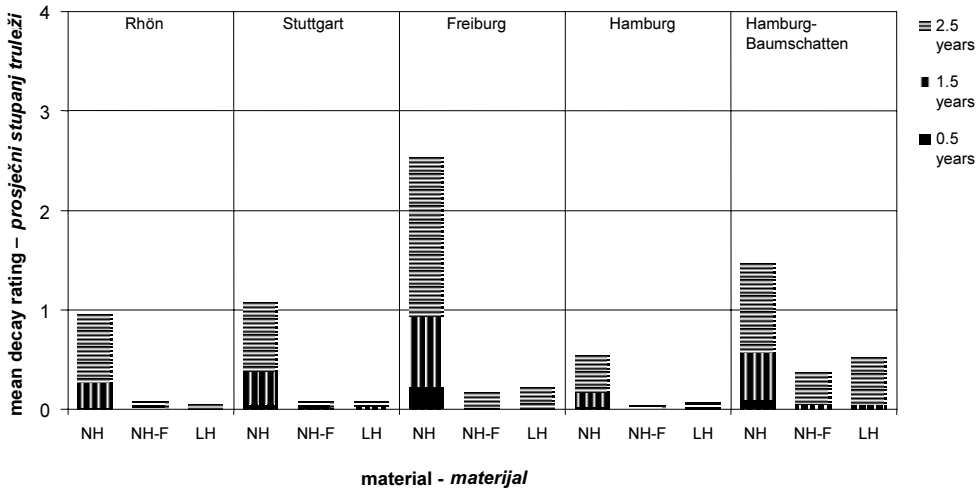


Figure 7
Mean decay rating of wood-groups at five climatically different test fields after 2.5 years in ***above ground*** *situation*
Slika 7.
Prosječni stupnjevi truleži grupa uzoraka na pet klimatski različitih ispitnih polja nakon 2,5 godina izlaganja iznad tla

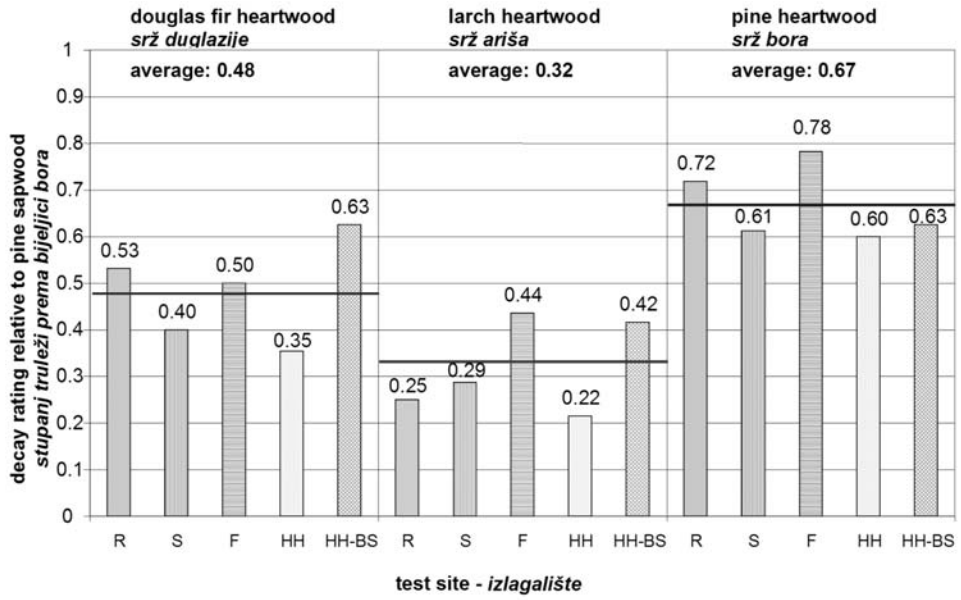


Figure 8
Decay rating relative to pine sapwood of douglas fir, larch and pine heartwood at five climatically different test sites (R - Rhön, S - Stuttgart, F - Freiburg, HH - Hamburg, HH-BS - Hamburg „Baumschatten") in ***ground contact***
Slika 8.
Vrednovanje stupnja truleži duglazije, srži ariša i bora u odnosu prema bjeljici bijelog bora na pet različitih izlagališta u doticaju s tlom

bjeljika smreke, srž smreke, bjeljika bijeloga bora, jelovina

- NH-F (coloured heartwood of softwood): Scots pine heartwood, douglas fir heartwood, larch heartwood
  NH-F (obojena srž mekih vrsta drva): srž bijeloga bora, srž duglazije, srž ariša
- LH (coloured heartwood of hardwood): English oak heartwood, black locust heartwood
  LH (obojena srž tvrdih vrsta drva): srž engleskoga hrasta, srž crnoga bagrema.

ferent mean decay ratings appeared depending on the test site.

The natural durability (decay rating relative to pine sapwood) at different test sites was examined in the heartwood of douglas fir, Scots pine, larch, English oak and black locust. For each of these woods the relative decay rating to pine sapwood varied somewhat from test site to test site. These differences can be seen in different length of the bars in Figure 8 to Figure 11. But considerable variations in relative

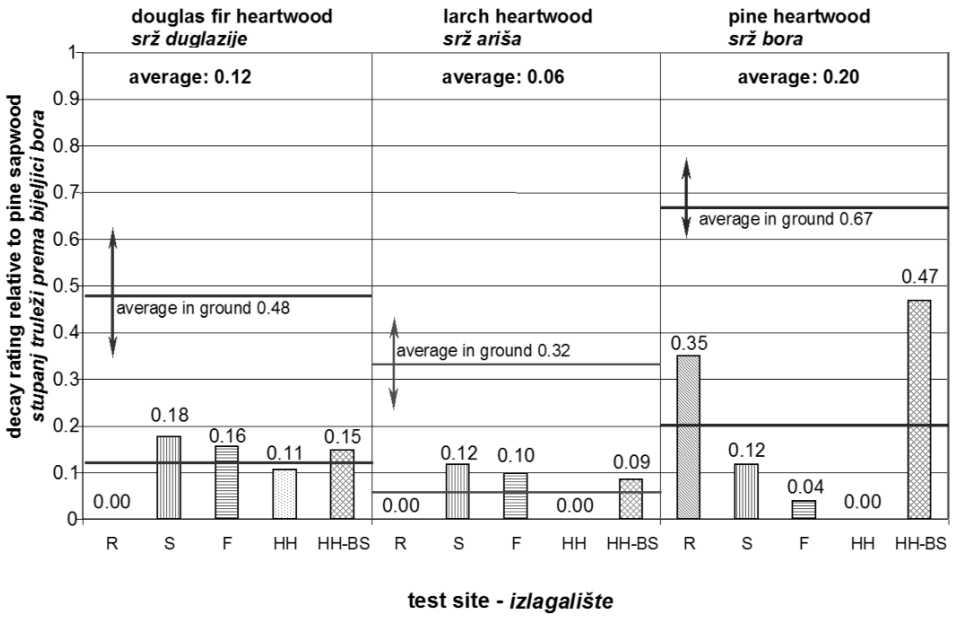


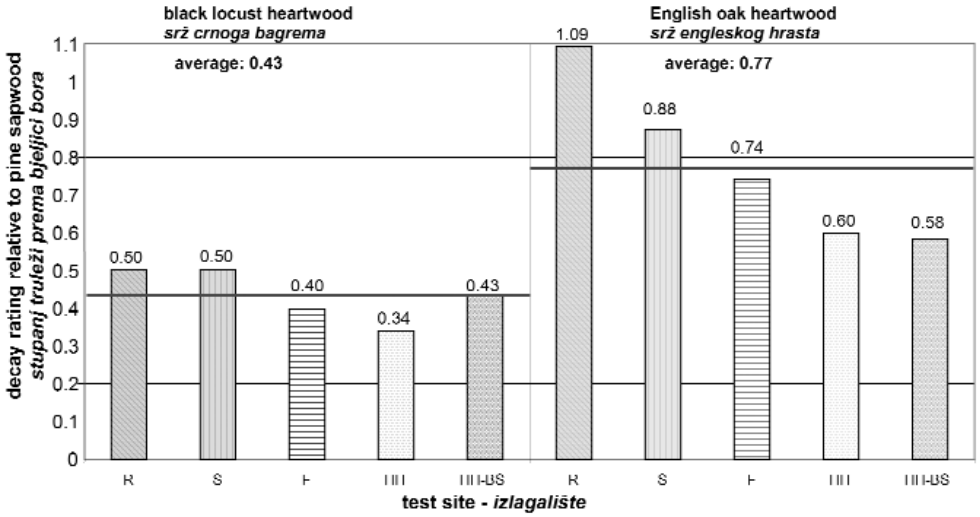
Figure 9
Decay rating relative to pine sapwood of douglas fir, larch and pine heartwood at five climatically different test sites (R - Rhön, S - Stuttgart, F - Freiburg, HH - Hamburg, HH-BS - Hamburg „Baumschatten") in above ground situation: With averages (single line) and variations (arrow) of in ground test
Slika 9.
Stupnjevi truleži duglazije, srži ariša i bora u odnosu prema bjeljici bijelog bora na pet različitih izlagališta iznad tla, s prosjecima (vodoravna crta) i varijancama (strelice)

The mean decay rating of wood-groups in soil contact showed marked variations depending on the test site (Figure 6). For example the mean decay activity in Rhön was lower then in Freiburg.

The same results were found in above ground situations (Figure 7). Here also, dif-

decay rating were detected in all wood species among the expositions (in ground and above ground situation). That means that the natural durability was lower in ground contact than above ground (Figure 8 to Figure 11).

So far the influence of test exposition



R - Rhön, S - Stuttgart, F - Freiburg, HH - Hamburg, HH-BS - Hamburg „Baumschatten"

Figure 10
Decay rating relative to pine sapwood of English oak and black locust at five climatically different test sites in ***ground contact***
Slika 10.
Stupnjevi truleži engleskog hrasta i bagrema u odnosu prema bjeljici bijeloga bora na pet različitih izlagališta u doticaju s tlom

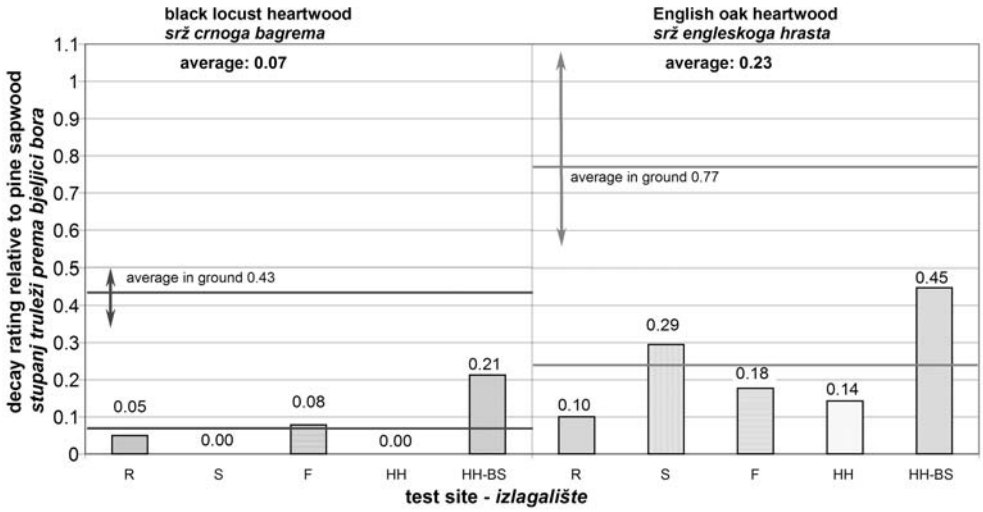


Figure 11
Decay rating relative to pine sapwood of English oak and black locust at five climatically different test sites in above ground situation: With averages (single line) and variations (arrow) of in ground test.
Slika 11.
Stupnjevi truleži engleskog hrasta i bagrema u odnosu prema bjeljici bijeloga bora na pet različitih izlagališta iznad tla s prosjecima (vodoravna crta) i varijancama (strelice).

on natural durability was greater than the influence of the test site. To illustrate this more clearly the average decay ratings relative to pine sapwood (durability) were calculated for individual wood species on all test sites. This average is shown as a line in Figure 8 to Figure 11. The arrows symbolise the variation of data in ground contact. The comparison between the average values of durability in and above ground and their variations clearly show that the differences in durability between the expositions are greater than between the test sites (Figure 8 and Figure 11).

4 DISCUSSION
4 DISKUSIJA

The double-layer test has proven suitable as an above ground test method. In the test period to date, the following advantages have been determined:

- It is a natural exposure (field test).
- It is a typical construction with some similarity to a wooden deck.
- Quick infection by decay fungi is possible (within 0.5 years).
- The decay is objectively assessed even at early stages.
- The construction is not expensive.
- The installation of construction is very fast.
- One size of sample (EN 252) covered for two tests.
- The samples require no end sealing, no cable binders and no clamps.
- The assessment is simple and fast: pick-test or bending (Rapp et al., 2001).

The low durability of spruce and fir in the double-layer test remains as yet unexplained. A possible explanation is the strong stain of pine sapwood. An antagonism between blue stain fungus and Basidiomyces e.g. has been scientifically

proved by Highley et al. (1988) and Shuichi et al. (1991). Such an effect means that a delay in decay of Scots pine sapwood is imaginable. This would result in a lower durability of spruce and fir at present. Another possible reason is the better spore germination at spruce than at pine sapwood (Carey, 2002). Hence it is very important to observe the development of decay in the coming years.

One probable reason for the varying durability of the tested heartwood of coloured softwoods and hardwoods in the hazard classes is their different moisture content. Variations of moisture content in some hardwoods were observed in above ground tests at L-Joints (Suttie et al., 1998). In field tests with Lap-joints Militz et al (1998) found large differences in water absorption between wood species and grouped pine sapwood and spruce as highly absorbent species and larch, douglas fir and pine heartwood as medium absorbent species.

The exposition influenced the moisture content and thus the conditions for decay in wood species. The absorption and desorption of wood can be affected differently depending on the construction-situation (in ground or above ground). For wood in soil contact a relatively high moisture content can be expected. The occasional drying of woods was partly prevented or greatly delayed by soil contact and vegetation. The continuously high wood moisture content in ground contact may have been the reason for low natural durability of English oak (*Quercus petrea*). English oak contains a relatively high concentration of water-soluble polyphenols that can be leached (Sierra-Alvarez et al., 1998).

The five in ground test sites show great variations in absolute decay, for example Rhön and Freiburg. The time to failure will probably be developed in the same way. Also Gary et al. (1996) determined relevant differences between the median specimen life values of heartwood specimens at five test sites after more than 25 years in ground contact. The variations in decay in different soil contact test fields depends especially on the local composition and activity of wood decay organisms and not so much on the geographical location. Within one test field the hazards to decay can vary greatly (Edlund, 1998).

Obviously in above ground situations the climatic conditions affect the decay of wood more than in soil contact. The influence of the test site on colonisation and decay by wood-rotting Basidiomycetes was described in treatise on above-ground field tests on untreated wood (Grinda et al., 2001; Preston et al., 1996).

So far our own investigations show that the differences in durability between the expositions are greater than between the test sites.

5 CONCLUSION
5 ZAKLJUČAK

To date it has not yet been possible to calculate the final durability classification.

However the following conclusions can be derived from the developments carried out so far:

1. The test exposition (in or above ground) has a strong influence on the decay activity and the durability determined as the quotient of decay of tested species and of decay of Scots pine sapwood.
2. The above ground tests (double layer test) revealed a higher durability for all soft-wood species with coloured heartwood (heartwood of *Larix*, *Pseudotsuga* and *Pinus*) than classified in the EN 350 standard and than the durability in ground contact.
3. In field tests in soil *Quercus robur* and *Robinia pseudoacacia* were less durable than in above ground situation and than in the EN 350 standard.
4. The test site had a strong effect on decay activity and time to failure.
5. So far the natural durability of heartwood of *Pseudotsuga menziesii*, *Larix decidua / japonica*, *Pinus sylvestris*, *Quercus robur* and *Robinia pseudoacacia* has been influenced more seriously by test exposition than by test site.
6. It is proposed that durability class be listed separately for in ground and for above ground use in the future.

6 REFERENCES
6 LITERATURA

1. *** EN 252, 1989: Field test method for determining the relative protective effectivness of a wood preservative in ground contact. German version, 9p.
2. *** EN 350-1, 1993: Durability of wood and wood-based products - Natural durability of solid wood - Part 1: Guide to the principles of testing and classification of the natural durability of wood
3. *** EN 350-2, 1993: Durability of wood and wood-based products - Natural durability of solid wood - Part 2: Guide to natural durability and treatability of selected wood species of importance in Europe
4. Carey, J. 2002: personally information

5. Derbyshire, H.; Carey, J. K. 2001: Evaluating joinery preservatives: performance prediction using BS EN 330 L-joint trails. IP2/01, BRI, Watford, England, 4pp.
6. Edlund, M. L. 1998: Durability of untreated wood exposed in terrestrical test fields and microcosms. Material und Organismen 32 (4), Dunker & Humboldt Berlin, 253 - 275.
7. Gary, C. J.; Thornton, J. D.; Nguyen, N.K. 1996: An in-ground natural durability field test of Australian timbers ans exotic reference species. XI Results after more than 25 years´exposure. Material and Organismen 30 (3), Dunker & Humboldt Berlin, 219-230.
8. Grinda, M.; Bergman, Ö.; Borck, H. V.; Dickenson, D.; Esser, P.; Gründlinger, R.; Leithoff, H.; Molnar, S.; Paajanen, L.;
9. Highley, T. L.; Ricard, J. 1988: Antagonism of Trichoderma spp. and Gliocladium Virens against wood decay fungi. Material und Organismen 23 (3), Dunker & Humboldt Berlin, S. 157 - 169.
10. Militz, H.; Broertjes, M.; Bloom, C. J. 1998: Moisture content development in Lap-Joints of different wood species in outside exposure trials. Doc. no. IRG/WP/98-20143.
11. Preston, A. F.; Archer, K. J.; Roberts, D. M.; Carey, J.; Bravery, T. 1996: Climate Indices at Work: Above Ground Decay L-Joint Test (EN 330 and AWPA E9) at two Sites 12000 km apart and with Scheffer Climate Indices of 60-65 and 300-330. Doc. no. IRG/WP 96-20095.
12. Rapp, A. O.; Peek, R. D.; Sailer, M. 1998: Feuchteverlauf von Holzproben mit und ohne Oberflächenbehandlung während zwei Jahren Freilandbewitterung. In Vorträgen der 21. Holzschutz-Tagung der Deutschen Gesellschaft für Holzforschung. München, DGfH, 55 - 67.
13. Rapp, A. O.; Augusta, U.; Peek, R. D. 2001: Facts and ideas of testing wood durability above ground. In: proceedings of COST Action E22: Environmental optimisation of wood protection, workshop on optimising treatment levels and managing environmental risks, Reinbek, 8-9 November 2001. Hamburg, Bundesforschungs-anstalt für Forst- und Holzwirtschaft. HTTP://WWW.BFAFH.DE/INST4/43/PDF/3DOUBLAY.PDF
14. Shuichi, D.; Atsushi, Y. 1991: Antagonistic Effect of Trichoderma spp. Against Serpula Lacrymans in the Soil Treatment Test. Doc. no. IRG/WP 1473.
15. Sierra-Alvarez, R.; Le Bayon, I.; Carey, J.; Stephan, I.; van Acker, J.; Grinda, M.; Kleist, G.; Militz, H.; Peek, R. D. 1998: Laboratory testing of wood natural durability in soil-beb assay. Doc. no. IRG/WP 98-20141.
16. Suttie, E. D.; Orsler, R. J. 1998: The natural durability assessments of secondary hardwood species - field trials. Doc. no. IRG/WP 98-10297.

Corresponding address:

ANDREAS O. RAPP, PhD
Federal Research Centre for Forestry and Forest Products
Institute for Wood Biology and Wood Protection
HAMBURG
GERMANY
E-mail: arapp@holz.uni-hamburg.de