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THE SUBJECTIVITY OF THE ESTIMATION OF NATURAL WOOD'S RESISTANCE TO DESTRUCTION BY TERMITES BASED ON VISUAL ASSESSMENT IN LABORATORY TESTS

This study concerns visual assessment of the degree of damage done to Pinus sylvestris L. wood blocks by Reticulitermes lucifugus Rossi, in an experiment conducted according to ASTM D 3345-08:2017. The six evaluators made their assessments individually. The differing results obtained from the evaluators are a cause for concern. Visual assessment of the degree of wood damage can vary significantly from person to person. Measurement of weight loss seems to be a better way of evaluating the degree of damage done to wood samples by termites in laboratory tests.

Keywords: termites, wood degradation, research procedure, visual assessment

Introduction

The subterranean termite is considered to be the most dangerous to building constructions [Forschler and Jenkins 2000; Shupe and Dunn 2000], because this insect destroys not only wood and wood-based materials, but also electrical installations and air-conditioning devices. Two types of tests are used to estimate the resistance of wood to subterranean termite attack: field tests [Grace et al. 1996; Ncube et al. 2012; Shanbhag and Sundararaj 2013] and laboratory tests [Schultze-Dewitz 1958; Becker and Petrowitz 1971; Becker et al. 1972; Unger 1978; Grace and Yamamoto 1994; Forschler and Jenkins 2000; Shupe and Dunn 2000; Kard et al. 2007; Krajewski et al. 2015]. Laboratory tests on subterranean termites are conducted according to two basic procedures: ASTM D 3345--08:2017 and PN-EN 117:2013. In both procedures, *Reticulitermes* sp. is given

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as the test species. The procedure described in ASTM D 3345-08:2017 is suitable mostly for laboratory estimation of the resistance of wood and other cellulose-based materials. The procedure described in PN-EN 117:2013 is typically applied to the testing of wood preservatives used against *R. lucifugus*. In both laboratory procedures, a visual estimation of the degree of damage to wood samples is made. The problem of the subjectivity of such estimation has been noted in earlier research [Krajewski et al. 2015; 2016; 2018]. The present study was undertaken with the aim of addressing this problem.

Materials and methods

The experiments were performed according to the ASTM D 3345-08:2017 standard. Sapwood of Scots pine (*Pinus sylvestris* L.), of medium grain and with average density 0.498 g/cm^3 (0.416-0.575 g/cm^3), was used. Samples 25.4 × 6.4 mm in size were extracted from groups of samples taken from seven different trees. The moisture content of the wood was 7%.

In the experiments, each sample was placed individually at the bottom of a testing container (a glass container 450 ml in volume) and covered with 200 g of screened, washed and heat-sterilized white sand. The sand was humidified with distilled water, in accordance with the procedure in ASTM D 3345--08:2017. The only deviation from the procedure was the non-use of benzalkonium chloride solution as an antiseptic.

Biological experiments were conducted on the subterranean termite *Reticulitermes lucifugus* Rossi as a forced test, in accordance with the procedure of ASTM D 3345-08:2017. 1 ± 0.05 g of termites were placed in each testing container with one wood sample. Over 90% of the individuals in each container were pseudergates. The containers with the termites and the wood samples were kept for 4 weeks in an incubator at a temperature of 27°C, and the humidity of the sand in the containers was supplemented weekly.

The degree of wood damage, a decisive factor in the evaluation of wood's resistance or susceptibility to termite attack, was classified based on the visual rating system and photos given in ASTM D 3345-08:2017, namely: 10 – sound, surface nibbles permitted; 9 – light attack; 7 – moderate attack, penetration; 4 – heavy attack; 0 – failure. The estimation of the degree of wood damage in the 21 samples was performed independently by six evaluators. In ambiguous cases, a midpoint index was taken, e.g. 10/9 = 9.5, 7/4 = 5.5, 4/0 = 2. The average degrees of wood damage for the 21 samples were calculated based on the estimations of each evaluator (No. I-VI). The significance of the differences between the calculated average values of the estimations of each evaluator was statistically verified using Chebyshev's inequality. If the difference between the average values resulting from two evaluations was greater than or equal to three times the standard error of the average values of wood damage, i.e.:

$$|\bar{x}_1 - \bar{x}_2| \geqslant 3 \cdot \varepsilon(\bar{x}_1 - \bar{x}_2)$$

then the difference between the two evaluations was classified as statistically significant. Otherwise, it was classified as accidental. In addition, the mass loss of dry wood caused by termite attack was determined.

The mortality rate of the termites was estimated as follows, in accordance with ASTM D 3345-08:2017: slight (0-33%); moderate (34-66%); heavy (67--99%); complete (100%). This was done based on visual estimation of the presence of dead individuals.

Results and discussion

The results of the experiments involving visual estimation of the degree of wood decay by six evaluators are shown in Table 1. In all variants of the experiment, termites carved tunnels in the sand and built galleries above its surface next to the glass walls of the containers. Dead or diseased individuals were not observed. Therefore, the mortality rate of the termites was classified as slight (0-33%).

Table 1. Results of visual estimation of the degree of damage done to Scots pine (*Pinus sylvestris*) sapwood by *Reticulitermes lucifugus*, performed by six evaluators (No. I-VI)

No. of sample	Evaluator No. I	Evaluator No. II	Evaluator No. III	Evaluator No. IV	Evaluator No. V	Evaluator No. VI
1	9	4	7	4	10	7
2	5.5	2	4	7	7	4
3	5.5	2	0	9	9	7
4	4	2	0	7	7	0
5	5.5	0	4	7	8	4
6	8	4	4	4	10	7
7	5.5	2	4	9	7	2
8	5.5	2	4	10	9.5	7
9	5.5	2	4	10	8	4
10	5.5	2	4	10	7	4
11	8	4	4	4	8	7
12	5.5	2	0	7	5.5	4
13	5.5	0	4	7	8	4
14	5.5	2	4	7	7	4
15	7	2	4	4	7	4
16	4	0	0	4	0	0
17	5.5	2	4	2	4	4
18	4	0	0	4	2	0
19	4	0	0	4	0	0
20	5.5	0	0	4	2	4
21	2	0	4	0	0	0
Average value	5.5	1.6	2.8	5.9	6.0	3.7

Statistical verification of the differences between each pair of estimations is shown in Table 2.

Table 2. Statistical verification of the differences between each pair of estimations

Evaluators	For statistical significan $\lvert\bar{x}_1-\bar{x}_2\rvert \geqslant 3\cdot\varepsilon(\bar{x}_1-\bar{x}_2)$	Statistical
No. I and No. II	3.9 > 1.35	significant
No. I and No. III	2.7 > 1.73	significant
No. I and No. IV	0.4 < 2.09	insignificant
No. I and No. V	0.5 < 2.40	insignificant
No. I and No. VI	1.8 < 1.9	insignificant
No. II and No. III	1.2 < 1.66	insignificant
No. II and No. IV	4.3 > 2.05	significant
No. II and No. V	4.4 > 2.34	significant
No. II and No. VI	2.1 > 1.9	significant
No. III and No. IV	3.1 > 2.30	significant
No. III and No. V	3.2 > 2.58	significant
No. III and No. VI	0.9 < 2.2	insignificant
No. IV and No. V	0.1 < 2.84	insignificant
No. IV and No. VI	2.2 < 2.5	insignificant
No. V and No. VI	2.3 < 2.7	insignificant

As is shown in Table 1, four (No. I, II, V and VI) of the six people performing the evaluations used midpoint indices in ambiguous cases. Two evaluators (No. III and IV) did not use this option in classifying wood damage. As mentioned above, the problem of the subjectivity of the results of research on the susceptibility of wood to termite damage based on visual evaluation of the degree of wood damage has been noted in earlier studies [Krajewski et al. 2015; 2016; 2018]. Unfortunately, there are almost no publications investigating the correctness of visual estimation of the degree of damage to samples, with the exception of the above-mentioned paper by the co-authors [Krajewski et al. 2018]. The procedures of both ASTM D 3345-08:2017 and PN-EN 117:2013 are based on visual estimation of the degree of wood damage. ASTM D 3345--08:2017 defines five possible degrees, while PN-EN 117:2013 defines four. A larger number of available degrees may increase the likelihood of divergent evaluations of the degree of damage to the same wood sample when examined by several evaluators. The procedure of ASTM D 3345-08:2017 is thus more suitable for examination of the subjectivity of such evaluations.

Based on the authors' experience, a visual method of evaluation of the degree of damage to samples is easily applied in the case of wood resistant to termite feeding. It has long been known that wood suffering from fungal decay

may attract termites [Grace and Wilcox 1988] and may be more appropriate for their feeding needs than undecayed wood [Unger 1973]. Sapwood of *Pinus* sp., used for comparative purposes in ASTM D 3345-08:2017, even if not exposed to fungal decay, is among the wood types susceptible to destruction by the termite. Unfortunately, even the photographs included in ASTM D 3345-08:2017, showing representative examples of each degree of damage to the wood, do not always make the evaluation easier. Some particular difficulties may arise under certain circumstances. For some wood species it is impossible to extract samples with annual rings situated in the manner required by ASTM D 3345-08:2017. This is the case with narrow pieces of many tropical species of wood, as well as the European *Taxus bacatta* L. Some difficulties also arise during the examination of waterlogged wood [Krajewski et al. 2015], when in many cases it is very difficult to extract samples without ruptures and losses, which may be mistaken for termite damage when the condition of the wood is evaluated at the end of the test. For wood from some species, such as hornbeam [Krajewski et al. 2016], the damage caused by the termite may appear completely different than damage to the sapwood of Pinus sp. used as the comparative species in ASTM D 3345-08:2017.

The results of this study confirmed the problem mentioned in the earlier paper [Krajewski et al. 2018]. Visual evaluation of the degree of damage done to wood samples by the termite may be highly affected by subjective factors. The evaluators in the study appear to be divisible into two groups: the first group (No. II and III) assigning a higher average degree of damage, and the second group (No. I, IV and V) assigning a lower average degree of damage. The first group consisted of scientists with a high or intermediate level of experience in the visual evaluation of certain phenomena tested in wood science, while the second group consisted of one person with some experience with these phenomena and two with no such experience. Within each group, the differences between the average degrees of damage assigned by individual evaluators were statistically insignificant. However, the differences between the average degrees assigned by individual evaluators from two different groups were all statistically significant. The values assigned by evaluator No. VI (with no experience) lay between those of the two groups. The average degree of damage assigned by evaluator VI was statistically different only from the average degree assigned by evaluator II, who had the greatest experience in visual evaluation of the degree of wood damage caused by the termite. Evaluator II rated the degree of wood damage the most severely. However, there is no possibility of verifying whether their evaluation is in fact fully correct.

It should also be noted that visual evaluation of the degree of termite damage to wood is more difficult than visual evaluation of resistance to the growth of mould. In the latter case, the evaluation is performed on a two-dimensional plane based on the percentage of the surface covered with mould, as described in, for example, ASTM D 3273-94, ASTM D 4445-91 or ASTM G21-96. In the case of

ASTM D 3345-08:2017, a three-dimensional loss of varying shape, placement and segmentation is assessed based on a rather imprecise specification from the procedure. For example, it is difficult to decide where the cut-off point lies between light attack (9) and moderate attack, penetration (7), or between heavy attack (4) and failure (0). Termite feeding in pine sapwood caused an average weight loss of 34%.

The subjectivity of such evaluation can be eliminated by determining the mass losses of samples after termite feeding. However, to avoid distortion of the results, wood drying should be applied at a temperature of 105 °C both before and after the test, which is inadvisable. The procedure in PN-EN 117:2013 stipulates that only wood dried at temperatures below 60 °C can be used. Other options include freeze-drying of the samples and taking into account the impact of wood moisture content on the results. Freeze-drying may, however, also cause evaporation of some components of the wood (e.g. terpenes). The possibility of applying such methods should thus be the subject of further research.

Conclusions

The results obtained in this study confirm the doubts expressed by the authors in earlier work, and lead to the following conclusions:

- Visual evaluation of the degree of damage to wood caused by termites may be strongly affected by subjective factors.
- Not only minimal experience in visual evaluation (or lack of such experience) can lead to incorrect results. It seems that the innate ability to perform visual evaluation may also play a role in the process. A method based on the mass loss of wood samples is proposed as a way of excluding the influence of subjective factors on the evaluation.

References

Becker G., Lenz M., Dietz S. [1972]: Unterschiede im Verhalten und Giftempfindlichkeit verschiedener Termiten-Arten gegenüber einigen Kernstoffen (Differences in relation and sensitivity of various termites species to some heartwood substances). Zeitschrift für angewandte Entomologie 71: 201-214

Becker G., Petrowitz H.-J. [1971]: Über die Ursache der abschreckenden Wirkung von Kiefernholz auf Termiten (Causes of repellent effect of pine wood on termites). Zeitschrift für Angewandte Entomologie 68: 180-186

Forschler B.T., Jenkins T.M. [2000]: Subterranean termites in the urban landscape: Understanding their social structures is the key to successfully implementing population management using bait technology. Urban Ecosystems 4: 431-451

Grace J.K., Ewart D.M., Tome Carrie H.M. [1996]: Termite resistance of wood species grown in Hawaii. Forest Products Journal Oct 1996, 46, 10. ProQuest Agriculture Journals 57: 57-60

Grace J.K., Wilcox W.W. [1988]: Isolation and trail-following bioassay of a decay fungus associated with *Reticulitermes hesperus* Banks (Isoptera: Rhinotermitidae). Pan-Pacific Entomologist 64 [3]: 243-249

Grace J.K., Yamamoto R.T. [1994]: Natural resistance of Alaska-cedar, redwood, and teak to Formosan subterranean termites. Forest Products Journal 44 [3]: 41-45

Kard B., Hiziroglu S., Payton M.E. [2007]: Resistance of eastern redcedar panels to damage by subterranean termites (Isoptera: Rhinotermitidae). Forest Products Journal 57 [11]. ProQuest Agriculture Journals: 74-79

Krajewski A., Lisiecka E., Drożdżek M., Witomski P., Wójcik A. [2015]: The susceptibility of Neolithic waterlogged beech wood (*Fagus sylvatica* L.) to destruction by *Reticulitermes lucifugus* Rossi. Drewno. Prace naukowe. Doniesienia. Komunikaty, 58 [195]: 59-68

Krajewski A., Oleksiewicz A., Witomski P. [2018]: Some problems in the results assessment in laboratory evaluation of wood for resistance to termites based on visual ratings of attack on test blocks. Annals of Warsaw University of Life Sciences – SGGW, Forestry and Wood Technology 103: 181-184

Krajewski A., Witomski P., Kotarbiński S. [2016]: Susceptibility of hornbeam and Scots pine woods to destruction by the subterranean termite *Reticulitermes lucifugus* Rossi, 1792 (Blattodea: Isoptera). Polish Journal of Entomology 85: 409-417

Ncube E., Chungu D., Kamden D.P., Musawa K. [2012]: Use of a short field test to evaluate termite resistance of *Eucalyptus grandis* and *Bobgunnia madagascarensis* in a tropical environment. BioResources 7 [3]: 4098-4108

Schulze-Dewitz G. [1958]: Vergleichende Untersuchungen der natürlichen Frassresistenz einiger einheimischer Kernholzarten unter Verwendung von Calotermes flavikollis Fabr. und *Reticulitermes lucifugus* Rossi als Versuchstiere. Holz als Roh- und Werkstoff, 7 [16]: 248-251

Shangbhag R.R., Sundararaj R. [2013]: Physical and chemical properties of some imported woods and their degradation by termites. Journal of Insect Science 13 [63]. Published online 2013 Jun 25. DOI: 10.1673/031.013.6301

Shupe T.F., Dunn M.A. [2000]: The Formosan subterranean termite in Louisiana: Implications for the forest products industry. Forest Products Journal 50 [5]: 10-18

Unger W. [1978]: Über ein Einfluss Zerstörungsaktivitet von Pilzstämmen verschiedener Herkunft auf die Frassintensität von Termiten (*Reticulitermes lucifugus* var. *santonensis* de Feytaud). Holztechnologie 14 [3]: 131-134

List of standards

ASTM D 3273-94 Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber. American Society for Testing and Materials

ASTM D 3345-08:2017 Standard Test Method for Laboratory Evaluation of Wood and other Cellulosic Materials for Resistance to Termites. American Society for Testing and Materials

ASTM D 4445-91 [reapproved 1996]: Standard Test Method for fungicides for controlling Sapstain and Mold in Unseasoned Lumber (Laboratory Method). American Society for Testing and Materials

ASTM G21-96 Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi. American Society for Testing and Materials

PN-EN 117:2013 Środki ochrony drewna – Oznaczanie wartości owadobójczej przeciwko gatunkowi Reticulitermes (europejskie termity) (metoda laboratoryjna). Wood

preservatives. Determination of toxic values against Reticulitermes species (European termites) (Laboratory method)

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