The use of non-destructive methods for the evaluation of fungal decay in field testing by dynamic vibration

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Abstract

This study investigated the suitability of dynamic MOE measurements for an evaluation of the durability in field tests under use class 3 conditions. The decay of specimens was assessed by the so called "pick-test" (EN 252) and the determination of the dynamic modulus of elasticity (MOE_{dyn}). Furthermore the evaluation of the influence of wood moisture content on the accuracy of the measurements was investigated.

The results show the feasibility of dry and wet specimens to reliably determine the MOE_{dyn}. Storing specimens in water, thus using (wet specimens) saves time during field tests. The determination of strength losses by means of MOE_{dyn} provides additional information to pick-test and visual assessments of wood particularly in early stages of decay.

1 Introduction

In field tests, a periodical evaluation of the wood specimens is required to determine the infestation of micro-organisms, particularly wood destroying fungi. Basic visual assessments such as the "pick-test" with a sharp pointed knife or blows with a hammer (EN 252) are widely used. Since those methods lack objectivity, results are often difficult to compare. Furthermore fungal attack causes strength loss of the wood specimens even before a degradation becomes visible according visual rating schemes (Grinda and Göller 2005). The fungal decay must not necessarily become visible on the wood surface in early stages, but can cause significant losses in strength (Tsuomis 1993). Therefore the use of non-destructive strength evaluation (Stephan *et al.* 1996) and dynamic methods for the determination of the modulus of elasticity (MOE_{dyn}) can be an effective complement (Machek *et al.* 1997, Pfeffer *et al.* 2008). The dynamic methods are based on resonant vibration excitation or ultrasonic pulse excitation of the test specimens (Görlacher 1984).

The objective of this study was to investigate the suitability of resonant vibration excitation for an evaluation of outside field tests under use class 3 conditions. Therefore, the measurement of MOE_{dyn} is compared to the evaluation of the specimens by a conventional pick-test. Furthermore the influence of wood moisture content on the accuracy of the measurements is investigated.

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2 Material and methods

2.1 Measurement of MOE_{dyn} depending on different wood moisture conditions

It is shown that the MOE is influenced by the moisture content (mc). In field tests, the mc can vary. To guarantee a mc above fibre saturation, samples must be wetted. Prior to measuring the MOE_{dyn} the specimens were soaked in water for different durations (Table 1) in order to investigate the influence of the wood moisture content. Twenty replicates per wood species were used to determine the MOE_{dyn}. They were submerged (held down by weights) in tap-water in plastic boxes, separated according to wood species.

Table 1: Moisture condition for measurements of MOE_{dyn}

Wood species	Specimen size [mm³]	Moisture condition
Scots pine sapwood (*Pinus sylvestris* L.) Beech wood (*Fagus sylvatica* L.)	20 x 30 x 300	20°C / 65% RH Water storage for 24h, 48h, 72h, 7d Vacuum pressure impregnation with water (30min vacuum at 60mbar, 2h pressure at 12bar)

Each specimen was supported horizontally on two sponge rubber pieces located equidistant at 0.224 x length from the ends of the specimen (67.2mm). The measuring device was a GRINDOSONIC MK 4-1 (J.W. Lemmens N.V., Belgium). Slightly tapping the center of the specimen with a hammer initiates the vibration energy into the specimen, a transducer in contact with the specimen quantifies the resulting vibration. The MOE_{dyn} calculation was based on the following formula, derived by Hearmon (1966), shown in Equation 1.

$$MOE_{dyn} = \frac{4 \times \pi^2 \times L^4 \times f^2 \times \rho \times A}{m_l^{\,4} \times I} \times \left(L + \frac{I}{L^2 \times A} \times K_l \right) \qquad \text{Equation 1}$$

I = moment of inertia [mm⁴]
A = area of the cross section [mm²]
f = frequency [kHz]
r = density [g/mm³]
L = length [mm]
K_l = 49.48
m_l = 4.72

2.2 Block-test

In the last decades, several test methods where developed to predict the durability of wood in used class 3. However, even the nowadays used European standards (EN 330, CEN/TS 12037) bare some important short time outcomes. From this reason, several other methods are under development (Rapp and Augusta 2004). One of the promising approaches is the so named “block test”. This test is described in Pfeffer *et al.* 2008. Wood specimens with a size of 20 x 30 x 300mm³ are used. They are arranged to blocks and placed on exposed aggregate concrete with to avoid direct contact between wood and concrete to exclude any influence of the concrete's pH-value. Each block was encased by a rack covered with a water permeable textile mesh to protect the specimens against fast drying by airflow and direct sunlight. One block comprises 40 wood specimens:

- 20 test specimens (one wood specie)
- 10 references, Scots pine sapwood (*Pinus sylvestris*) for softwood or European beech (*Fagus sylvatica*) for hardwood
- 10 specimen of Norway spruce (*Picea abies*) to initiate decay (feeder stakes)

Reference specimens, feeder stakes and test specimens are arranged alternately in the block to increase the risk of a biological attack. An overview about the positioning of the specimens in the block is given in Figure 1.

Figure 1: Positioning of specimens in a block

All specimens were climatised at 20°C and 65% relative humidity before outdoor exposure. An overview of the wood specimens in the exposed and analysed blocks is given in Table 2.

Table 2: Overview of the specimens

Blocks	Wood species		Beginning of outdoor exposure
1 (B1)	Norway spruce	feeder stakes	12 / 2002
	Scots pine sapwood	references	
	Scots pine heartwood	test specimens	
2 (B2)	Norway spruce	feeder stakes	12 / 2002
	European beech	references	
	Common oak	test specimens	

Afterwards, the MOE_{dyn} is measured. Subsequently, the specimens were soaked in water for a minimum of 24h in order to obtain wood moisture content above the fibre saturation.

Additionally, the surface of the specimens was assessed with a sharp pointed knife to reveal softened areas on all surfaces. The evaluation criteria of the so called “pick-test” were adopted according to the guidelines of EN 252 (1989). The decay rating of the pick-test is shown in Table 3. The MOE_{dyn} was determined as described above.

Table 3: Decay rating of the pick-test

Rating	Description	Definition
0	Sound	No evidence of decay. Any change of colour without softening has to be rated as 0.
1	Slight attack	Visible signs of decay, but very limited in intensity or distribution: changes which only reveal themselves externally by very superficial degradation, softening of the wood being the most common symptom, to an apparent depth in the order of one millimetre
2	Moderate attack	Clear changes to a moderate extent of decay according to the apparent symptoms: changes which reveal themselves by softening of the wood to a depth of approximately 2 to 3 millimeters over more than 1 cm^2
3	Severe attack	Marked decay in the wood to a depth of more than 5mm or 3-5 millimetres over a wide surface (more than 20 cm^2)
4	Failure	Failure of the stake

3 Results and Discussion

3.1 Measurement of MOE_{dyn} depending on different wood moisture conditions

In order to minimize the influence of the variety of wood moisture content, the specimens have to be either climatized before measurement of MOE_{dyn} or the wood moisture content has to exceed fibre saturation point. The experience during the long time exposition showed, that there is no indication for a reduction of fungal vitality caused by the soaking of specimen. The influence of different moisture conditions of the MOE_{dyn} measurement was investigated. The result showed that after 24h of water storage, the wood moisture content was above fibre saturation (Table 4 and 5).

Table 4: Wood moisture content depending on different moisture conditions for Scots pine sapwood

	20°C/ 65% RH	24h	48h	72h	7d	Vacuum-pressure
Mean value of wood moisture content [%]	10	45	51	54	71	148

Table 5: Wood moisture content depending on different moisture conditions for European beech

	20°C/ 65% RH	24h	48h	72h	7d	Vacuum-pressure
Mean value of wood moisture content [%]	10	31	38	42	61	97

The results displayed the MOE_{dyn} to be decreasing at wood moisture contents above fibre saturation. The MOE_{dyn} was reduced by a mean value of 4000N/mm² (Figure 2 and 3) compared to values at 20°C and 65% relative humidity. These results correspond to findings of former investigations (Grinda and Göller 2005, Kufner 1978). The standard deviation was slightly decreased at measurements with wood moisture contents above fibre saturation, as well. A vacuum pressure impregnation did not significantly change the MOE_{dyn} value compared to the values after water storage. However, the wood moisture content was increased significantly, indicating the absence or limitation of the effect of moisture content on results measured above fibre saturation. Furthermore the excitation of the vibrations was more difficult in water saturated specimens compared to those with wood moisture contents slightly above fibre saturation (Niemz 2003).

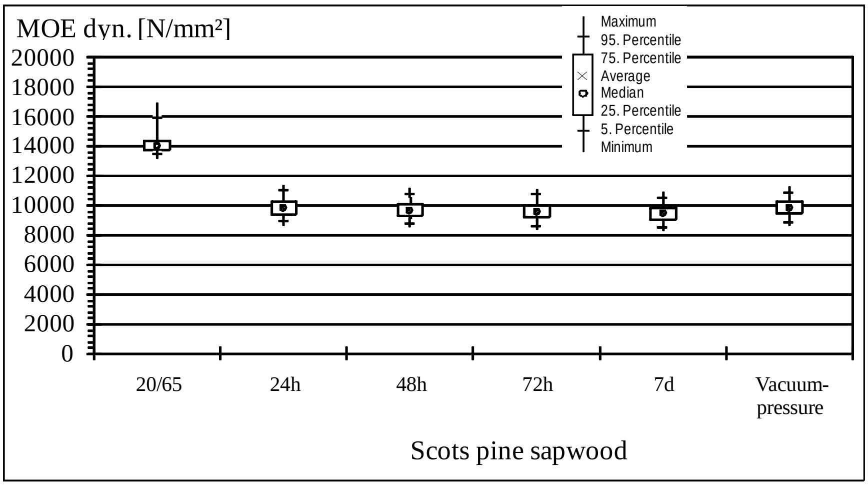

Figure 2: MOE_{dyn} of Scots pine sapwood depending on different moisture conditions

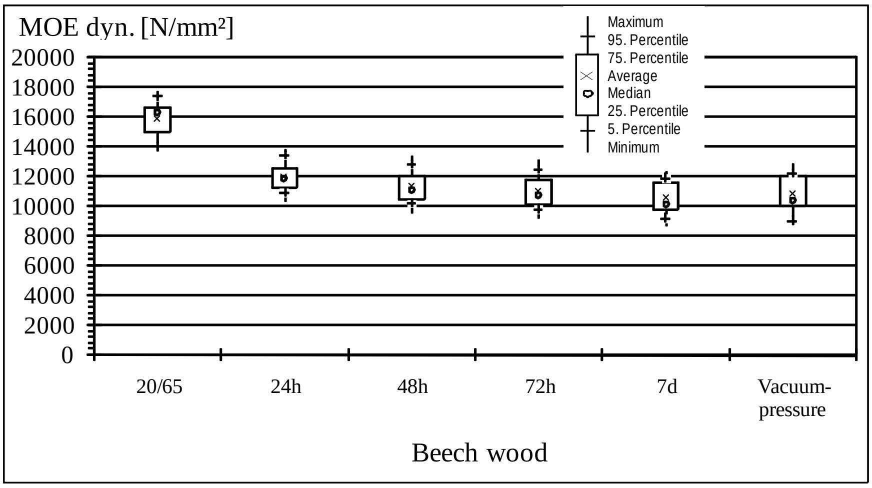

Figure 3: MOE_{dyn} of European beech depending on different moisture conditions

Based on these results the following requirements should be fulfilled for a MOE_{dyn} measurement applied in field tests:

- Water storage for a minimum of 24h is mandatory to guarantee wood moisture contents above fiber saturation.
- No vacuum-pressure impregnation is recommended, to avoid the potential risk of destroying fungal hyphae within the wood tissue to be deteriorated during field tests
- Use of either climatized or water stored specimens for assessing MOE_{dyn}; water storage is less time consuming during field tests

3.2 Determination of MOE_{dyn} in block-test specimens

The results of the pick-test for B1 showed a mean decay rating lower than 1 within the first 30 months for all specimens. After 30 months, the classification rapidly increased, especially in the Norway spruce, and the Scots pine sapwood (Figure 4). The first failure in Scots pine sapwood and Norway spruce was recorded after another 18 months. Compared to the pick-test, the MOE_{dyn} showed a very different behaviour. The MOE_{dyn} of Scots pine sapwood and stakes of Norway spruce decreased during the entire evaluation period. The feeder stakes from Norway spruce showing the highest loss (53%) of MOE_{dyn}. Specimens of Scots pine heartwood displayed a slight decrease of MOE_{dyn} during the whole evaluation period only (15%).

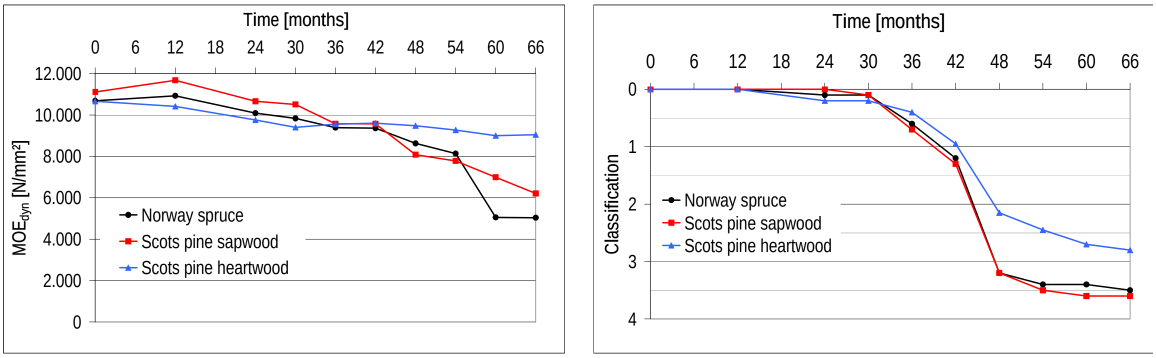

Figure 4: Evaluation of MOE_{dyn} (left) and pick-test (right), mean values of B1

After 24 months, the evaluation of the pick-test still yielded a decay rating of 0 in case of B2. Six months later, a rapid increase of decay rating occurred (Figure 5). After 54 months, the first European beech and Norway spruce specimens failed. The MOE_{dyn} started to decrease after 12 months and proceeded decreasing during the remaining evaluation period. The loss in MOE_{dyn} reached 36% for Norway spruce and 47% for Common oak. After 54 months, the references of European beech revealed a rather high stiffness loss (89%). The classification of fungal attack on Norway spruce was in both blocks equally, whereas the loss of MOE_{dyn} in B1 was much higher compared to B2 (Table 6).

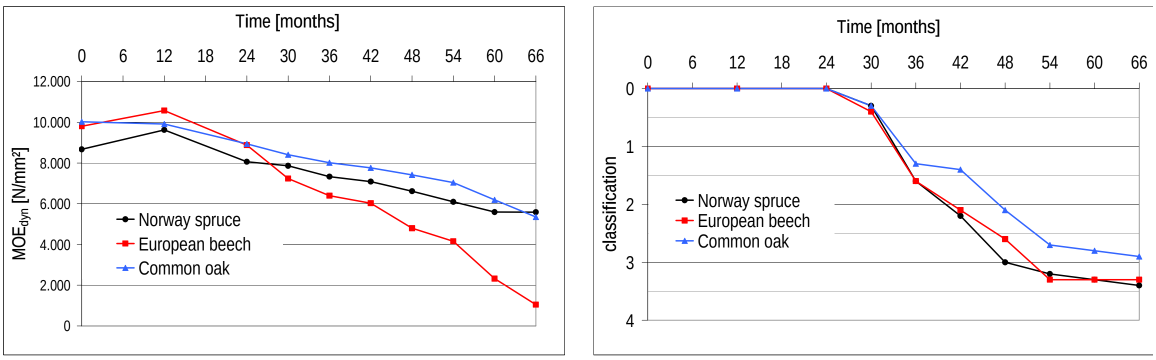

Figure 5: Evaluation MOE_{dyn} (left) and pick-test (right), mean values of B2

Neither in B1 nor in B2 is a correlation between classification data and MOE_{dyn} found.

The differences between the loss of MOE_{dyn} and the result of the pick-test might be caused by several reasons. The location of fungal attack within the stakes is normally not even distributed. At lower attack the pick-test enables the detection of superficial fungal attack mainly. If the fungal attack starts inside the specimen, the surface remains sound and pick test underestimates this attack. In contrast, at measuring MOE_{dyn}, an attack between the bearings (in the centre of the specimen) influences the MOE_{dyn} more than in outer parts (Machek and Militz 2004).

A general shortcome is that the rating according the pick-test has no linear scale (Table 3) and therefore the classification can increase very rapidly within a single evaluation period.

The degradation behaviour of the tested wood species differed to the behaviour what could have been expected following the durability classes (EN 350). Scots pine sapwood and European beech are classified as non durable (class 5, EN 350-2), whereas Norway spruce (class 4), Scots pine heartwood (class 3-4) and Common oak (class 2) are graded into better durability classes. The current classification is based on field (EN 252) and laboratory (EN 113) tests in combination with experienced data and reflects not necessarily the durability in outside testing above ground (Augusta 2007).

Table 6: Ranking of wood species based on test results according pick-test classification and loss of MOE_{dyn}.

	Ranking	
	pick-test (rating)	Loss of MOE_{dyn} (%)
Non durable	Scots pine sapwood (3,6)	European beech (89%)
	Norway spruce B1 (3,5)	Norway spruce B1 (53%)
to	Norway spruce B2 (3,4)	Common oak (47%)
	European beech (3,3)	Scots pine sapwood (44%)
more	Common oak (2,9)	Norway spruce B2 (36%)
durable	Scots pine heartwood (2,8)	Scots pine heartwood (15%)

In general, measurements of the MOE_{dyn} displayed deterioration in earlier stages than visual inspection of the specimens. However, the evaluation of MOE_{dyn} requires more sophisticated equipment to perform the measurements, whereas for the evaluation according the pick-test skilled personal is necessary.

The determination of strength loss is a promising addition to the pick-test and visual assessments of wood, particularly in early stages of decay. To clarify the influence of different form and location (internal or superficial) of fungal decay in the specimen on the MOE_{dyn}, particularly during the later stages of decay, more investigations are necessary and underway.

4 References

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