Bulletin of the *Transilvania* University of Braşov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 6 (55) No.1 - 2013

A COMPARATIVE STUDY ON THE DEGRADATION OF FIR (*Abies alba* Mill.) AND BEECH (*Fagus sylvatica* L.) IN UC 3

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Abstract: *The paper presents a comparative investigation of fir (Abies alba) and beech (Fagus sylvatica) degradation after 7 years exposure in outdoors, above ground conditions (UC3), in a modified L-joint test. It refers only to the complex degradation of untreated samples revealed by non-destructive and destructive evaluation. Almost a similar degradation of fir and beech was observed by non-destructive evaluation of exposed faces and tenons. In contrast, destructive evaluation of the longitudinally sliced samples highlighted distinct differences between the two wood species. Inner biological degradation of beech was far more advanced than for fir, revealing its lower natural durability compared to fir, even in these out of soil contact conditions. Therefore, utilisation of beech in UC3 applications should be carefully considered alongside adequate efficient treatments.*

Key words: *fir, beech, outdoor exposure, UC3, natural durability.*

1. Introduction

Use class 3 (UC3) refers to all the applications of wood in outdoors, above ground conditions under the direct action of climatic factors, but not in contact with soil. Window frames and blinds, exterior doors and building cladding elements, as well as garden furniture, are only a few examples of common applications of wood in UC3, which highlight the importance of this use class and the necessity of studying the complex degradation of wood in these conditions [2], [3], [4], [7], [8], [9], [15], [16].

Biological attack generally follows a stepwise sequence from mould fungi and staining fungi to rot fungi (*Basidiomycetes*), respectively the degradation phenomena will evolve from surface discolouration (colour changes and spots without affecting the mechanical strength) to inner structural damage (decay drastically reducing cohesion and strength) [4], [5]. Degradation by common wood boring insects is also possible, though not typical.

Wood in UC3 is also exposed to weathering, a complex, long-term process resulting in colour change to grey, roughened texture and cracks [12], [13]. This occurs under the action of UV light and water.

Fir (*Abies alba* Mill.) and beech (*Fagus sylvatica* L.) are the most common wood species in Romanian forests, representing 5% and respectively 30% as surface (http://www.appr.org.ro/documente.htm/).

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Beech is often present in natural fir forests as dominant species [6]. Moreover, natural regeneration of beech forests in Europe is very high, about 80% (http://sl.life.ku.dk/English/research/forest). Briefly these two species have the same growth conditions as altitude, soil, etc. [17].

However, the wood properties of these species, from density, swelling coefficients to mechanical strength and natural durability are quite different.

The main physical properties and natural durability characteristics of these two species that are of maximum importance for outdoors, above ground applications are presented in table 1.

Fir wood is often employed in outdoors applications from structural elements for constructions to windows, doors, fences, up to garden furniture [18].

In contrast with fir, beech is only seldomly used in UC 3 applications. Its high hygroscopicity, dimensional instability and the low natural durability explain this situation [10].

It is exactly this difference in properties and utilisation, as well the lack of data referring to their behaviour in outdoor conditions which motivated the selection of these species for an experimental comparative study.

Table 1

Experimental wood species and literature data on some physical and properties and durability

Species	Density at 12-15% MC, g/cm^3	Total shrinkage coefficients, [%]		Total swelling coefficients (calculated), [%]		Durability (data from EN 350/2)	Permeability (data from EN 350/2)
		Ra	Tg	Ra	Tg		
Fir	0.35-0.45.-0.75	2.9-3.8	7.2-7.6	2.9-3.9	7.7-8.2	4-5, SH_{Hy}, SH_A, S_T	2-3H, 2vS
Beech	0.69-0.71-0.75	4 -6.8	10-12.5	4.1-7.2	11.1-14.2	5F, SH_A, S_T	1 (4 red heart)

Note:

Durability: 4-slightly durable to fungi, 5- not durable to fungi

S –susceptible to insects attack (sapwood only), SH- susceptible to insects attack (both sapwood and heartwood); Hy – *Hylotrupes, A -Anobium,* T- termites

Impregnability: 1- impregnable, 2 – moderately impregnable, 3 – difficult to impregnate, 4 – not impregnable; H heartwood, S- sapwood, v – high variability

The paper presents a comparative investigation of fir and beech degradation after 7 years exposure in outdoors, above ground conditions in a modified L-joint test. This research is a part of an extensive research project related to the application and utilisation of this modified L-joint method in Romania for evaluating the performance of wood and the efficiency of different treating technologies in UC3 conditions [1], [10], [11], [12], [14].

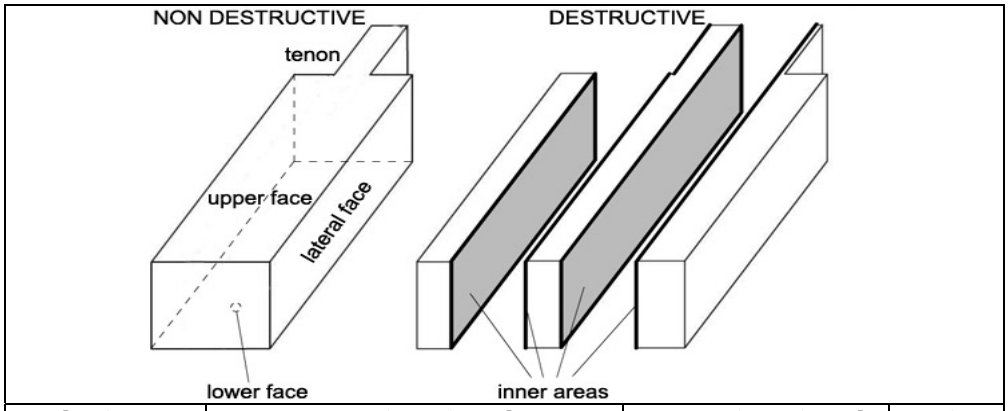
The present paper refers only to the complex degradation of untreated fir and beech wood as result of the combined action of the biotic and non-biotic factors active in the UC 3 conditions. Non-destructive and destructive macroscopic evaluations were performed. Fungal colonisation and other associated phenomena (discoloration and decay) of the external and internal surfaces, alongside non-biotic degradation aspects (wood cracking and weathering effect) were evaluated comparatively for these wood species.

2. Materials and Method

Fir and beech wood samples exposed for 7 years in a modified L-joint test described in earlier publications of the authors [10], [11], [12], [13], [14] were investigated in this research. No preservation or finishing treatments were applied. The methodology is schematically presented in Figure 1.

Non-destructive evaluation of samples took into consideration both the inner joint area (tenon) and the whole external exposed surface (upper, lateral and lower faces). Experiments were carried out on three replicates and an average value was calculated for each determination (discolouration, decay, cracks in wood), the rating system being the one presented in Figure 1.

Destructive evaluation followed non-destructive evaluation and implied splitting of the samples into three parts. Examination considered the same aspects on the whole surface of the inner areas of the 3 slices (totally 4 faces as presented in Figure 1).



Evaluation type	Areas investigated		Aspects investigated	Rating
Non destructive	External exposed surfaces: - Upper face - Lateral faces - Lower face	Tenon area	Discolouration (C) Decay (D) Cracks in wood (CW) Weathering effect	0-3 0-4 0-4 -
Destructive	Inner surfaces revealed by splitting		Discolouration (C) Decay (D)	0-3 0-4

Fig.1. *Testing samples and aspects investigated during non-destructive and destructive evaluation*

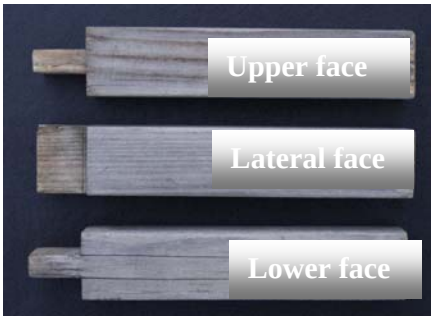
3. Results

3.1. Non-destructive evaluation

Non-destructive evaluation of the test samples revealed the different degradation phenomena specific for untreated wood in outdoors exposure: biological discolouration, decay, weathering effect (grey colour and roughed surfaces) and wood cracking for both fir and beech (Figure 2).

Due to the exposure manner, the upper faces, directly exposed to the climatic factors, were the most degraded, especially in terms of discolouration, weathering and cracking. Incipient decay (rate up to 1) was also present on limited areas. The

differentiation between biological discolouration and the UV induced grey colour was difficult. The lateral faces presented mostly weathering effects, clearly visible, though discolouration was also present. The lower faces revealed discolouration and cracks in wood. The tenon area was the most susceptible to decay (as actually intended by the design of the test). The tenon area for both species presented more or less advanced decay revealed by the presence of white mycelium and soft, friable wood, brownish in colour. Discolouration was also present.



Fir- exposed surfaces

Beech - exposed surfaces

Fir-Tenon area

Beech- Tenon area

Fig. 2. *Pictures revealing the degradation of fir and beech after 7 years exposure*

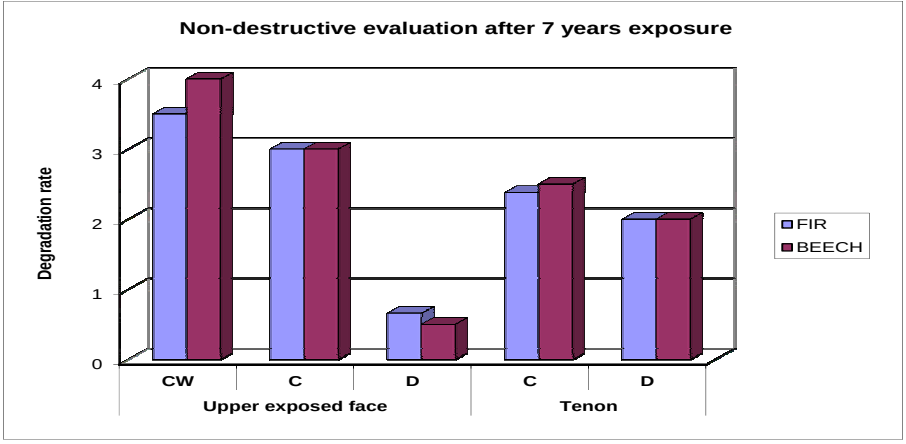


Fig. 3. *A comparative non-destructive evaluations of fir and beech*

The comparative average numerical results for fir and beech are given in Figure 3. It can be observed that fir and beech presented almost a similar rate of degradation after 7 years exposure.

A slight differentiation appears when considering the cracks in wood which were rated at 4 in beech and 3.5 in fir. This is expectable due to the higher dimensional instability of beech comparatively with fir, as resulting from the swelling and shrinking coefficients in Table 1.

Average decay rating on the upper face was slightly higher for fir than beech, respectively 0.66 compared to 0.5, though this could not be considered as significant, due to the reduced number of replicates (only 3) and the general uneven incidence and distribution of decay [15].

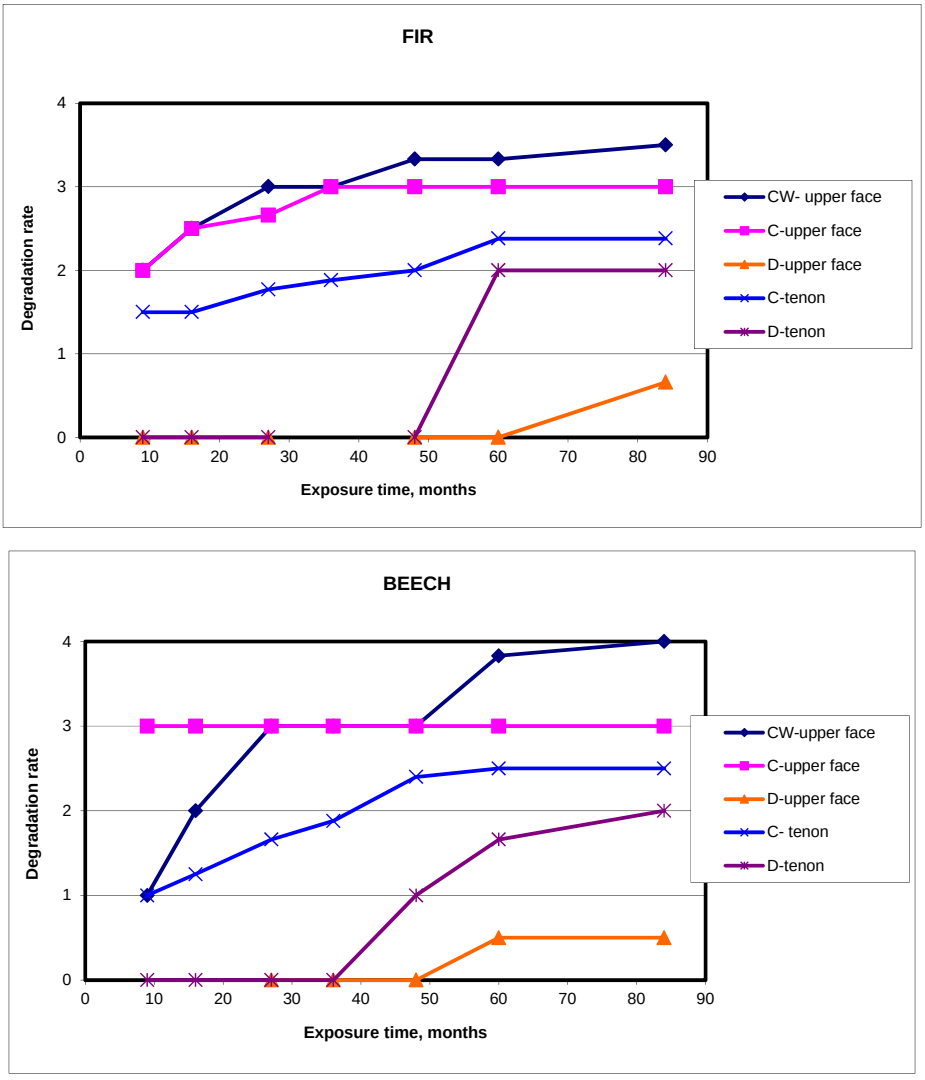


Fig. 4. *Evolution in time of degradation phenomena on the upper face and tenon area*

However, the evolution of degradation in time was somehow different for the two wood species. The diagrams in Figure 4 highlight the different sequences in the complex degradation of fir and beech wood in time and allow estimation of the period of exposure for their apparition. These diagrams are based on the data from 7 evaluations after different exposure periods: 9, 16, 27, 36, 48, 60 and 84 months [1], [10-14].

The first sequence of wood degradation is discolouration due to mould and staining fungi and this phenomenon is very rapid and intense on beech, so that even at the first evaluation after 9 months the maximum rating 3 was reached. For fir wood the rate 3 was obtained after a longer period of exposure of 36 months.

Discolouration was present also in the tenon area after 9 months exposure but not so intense (rate 1 for beech and 1.5 for fir). A further similar evolution of tenon discolouration for fir and beech could be observed.

Wood cracking was also present for both beech and fir samples from the first evaluation after 9 months, being rated surprisingly as 2 for fir and 1 for beech. However, wood cracking evolved in time at different rates for the two wood species, reaching the rate of 3.5 for fir and the maximum rate of 4 for beech, after 84 months.

Decay in the tenon area was detected at the minimum level (rate 1 for beech) only after 48 months exposure and was observed after 60 months for fir, but at a higher rate of 2. After 84 months the rate was similar 2 (medium degradation) for both wood species.

Decay on the external surfaces of fir and beech was noticed only after 60 months of outdoors exposure, being still very limited (below rate 1). It represents the fourth sequence of wood degradation.

3.2. Destructive evaluation

Destructive evaluation performed on the samples after their longitudinal slicing revealed net differences in terms of extent of degradation compared to the external faces and pointed out distinct differences between the two wood species.

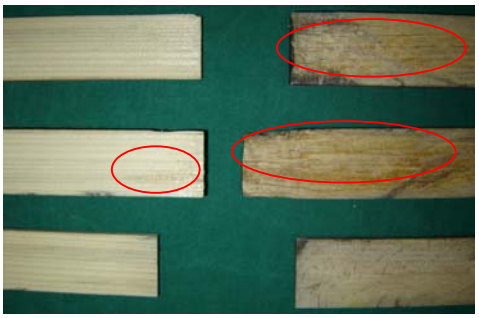


Fig. 5. *Inner degradation of fir (left) and beech (right) revealed after slicing*

The picture in Figure 5 was chosen to show the aspect of the most degraded samples from the three replicates of each species. Fir wood is less degraded than beech. A yellowish spot in central slice reveals the presence of incipient decay on a limited internal area of fir. A brown-yellowish severely decayed area can be observed inside of beech. This decay started from the tenon and extended on more than 50% from the inner area.

The quantitative evaluation calculated as average of three replicates is presented in diagram from Figure 6. Discolouration (C) was rated with 0.83 for fir and 2.27 for beech wood. Rate of decay (D) was 0.38 for fir and 1.5 for beech.

These results clearly indicate that beech is less durable than fir even in these above ground conditions. They also show the more advanced, difficult to observe inner degradation compared to the external one. Therefore, the use of beech in outdoor, above ground conditions should be carefully considered and compulsorily associated with an efficient preservation.

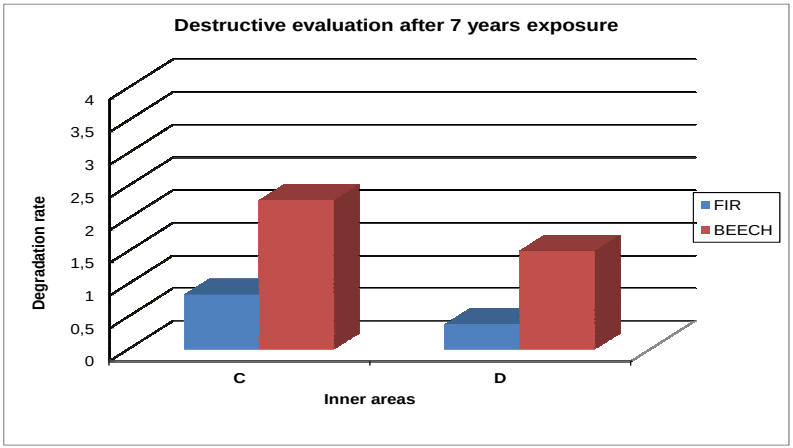


Fig. 6. *A comparative destructive evaluations of fir and beech*

4. Conclusions

The comparative study presented in this research revealed the natural durability differences between fir and beech in the conditions of UC3.

Non-destructive evaluation after 7 years of exposure showed a quite similar externally visible degradation. In contrast, destructive evaluation of the sliced samples highlighted that inner biological degradation of beech was far more advanced than for fir, demonstrating the lower natural durability of beech compared to fir even in these out of soil contact conditions.

This clearly points out the fact that non-destructive evaluation of wooden samples in field tests should be completed with a destructive one in order to correctly assess wood biological degradation and durability.

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