Performance of Douglas fir in real outdoor use conditions

Magdalena Kutnik
FCBA Institut Technologique

IRG/WP 10-20472

THE INTERNATIONAL RESEARCH GROUP ON WOOD PROTECTION

Section 2 **Test Methodology and Assessment**

Performances of Douglas fir in real outdoor use conditions

Magdalena Kutnik[1], Sylvain Lepetit[2], Serge Le Nevé[1]

[1] FCBA Technological Institute
Timber Construction Group
Allée de Boutaut BP 227
33028 BORDEAUX Cedex, France

[2]France Douglas Safran
2 avenue Georges Guingouin CS 80912 Panazol
87 017 Limoges Cedex 1, France

Paper prepared for the 42nd Annual Meeting
Queenstown, New Zealand
8-12 May 2011

IRG SECRETARIAT
Box 5609
SE-114 86 Stockholm
Sweden
www.irg-wp.com

Performances of Douglas fir in real outdoor use conditions

Magdalena Kutnik[1], Sylvain Lepetit[2], Serge Le Nevé[1]

[1] FCBA Technological Institute, Timber Construction Group, Allée de Boutaut,
BP 227, 33028 BORDEAUX Cedex, France,

[2]France Douglas Safran, 2 avenue Georges Guingouin, CS 80912 Panazol,
87 017 Limoges Cedex 1, France

ABSTRACT

The European standard EN 350-2 classifies Douglas fir as moderately resistant to fungal decay on the basis of standardized laboratory and field tests. However, the lifespan expectancy of outdoor structures such as cladding, decking and elements of wood construction carpentry may also vary according to environmental conditions (climate, exposure to weathering), maintenance and design. An investigation of approximately thirty wooden structures made of Douglas fir and installed in various locations in France over the period of several decades was performed and their performance in terms of resistance to decay was studied. The results show that outdoor above ground structures made of Douglas fir seem to be less susceptible to fungal decay than could be deduced from its natural durability classification. The evidence provided by this study proves that both the sapwood and heartwood of Douglas fir perform better in real outdoor use conditions than predicted by standardized tests, promoting its use without any preservative treatment for a wide range of outdoor purposes. Furthermore, it makes a valuable contribution to the ongoing French and European studies investigating the possibilities of applying recently developed service life prediction methodologies.

Keywords: Douglas fir, Service Life Prediction, natural durability

1. DURABILITY OF DOUGLAS FIR

The timber species *Pseudotsuga menziesii* (Douglas fir), which originates from Northern parts of America (mainly the US states of Oregon and Washington and British Columbia in Canada) was introduced in Europe in 1827. Today, France holds the largest resource of Douglas fir of all European countries. Douglas fir grown in France is one of the most common softwood timber species present on the wood construction market, where it is extensively used for structural applications (traditional and glue-lamed carpentry elements) and for cladding. Douglas fir is quite unique among all softwood species as its dimensional stability is particularly good.

In terms of biological susceptibility, Douglas fir is generally classified as having moderately durable heartwood (durability class 3 to 4 with regard to fungal decay, as reported in the European standard EN 350-2), which means that its longevity without any preservative treatment for outdoor purposes may be limited. For many years, the attribution of a natural fungal durability class (resistance to Basidiomycete and Ascomycete fungi) to the heartwood of timber species was based only on standardized laboratory and field tests, which are usually well adapted to evaluate the durability of wood that is in constant contact with the ground (in the situation of class 4 as defined in the standard EN 335) but may be regarded as too stringent for assessing the durability of wood used above ground (use classes 3.1 and 3.2). Currently, in order to predict the

risk of fungal decay experts rely not only on the wood's inherent characteristics (density, chemical composition, growth rate, and moisture uptake) but increasingly also on exterior parameters such as climate, exposure to UV radiation, wind and rain, maintenance and design (Eslyn et al. 1985, Highley 1995, Hazleden & Morris 1999, Brischke & Rapp 2010).
Compared to many other softwood species, Douglas fir displays unique behavior in terms of response to moisture. It is well-known that it is a refractory species and that both its sapwood and heartwood are difficult to impregnate with water, even under pressure. Several studies have demonstrated that the water uptake of Douglas fir, when used outdoors and exposed to rain or high humidity rates, is very slow and that its moisture content remains low even after long exposure. A French study (Dirol & Déglise 2001) showed that after 21 days of exposure to use class 4 moisture conditions Douglas fir heartwood reached 5% relative humidity (as compared to 15% for the maritime pine and 8% for the Scots pine) and sapwood reached only 10%, which is much less than the other studied species (65 to 75% for the Scots pine and 45% for spruce). A comparison between the Radiata pine and Douglas fir performed in New Zealand by the NZ Douglas fir Association also showed that after seven days of exposure to rainfall the Radiata pine reached a moisture content of 27% (enough to initiate decay) and remained well above that moisture content level for the next 48 days, whereas the moisture content of Douglas fir samples never approached the minimum moisture content required for initiating fungal decay throughout the whole period of the test. A second test confirmed that Radiata pine sapwood rapidly attained moisture content conducive to decay, while Douglas fir did not, confirming its refractory reputation.

2. WOOD SERVICE LIFE

2.1 Durability prediction factors

An acceptable level of durability can be reached by using naturally durable timber species (as defined in the EN 350-2 standard) or timber treated with biocidal substances. However, to last for long periods, both solutions require the wooden elements to be properly designed and maintained.
Many different standards dealing with rules of wood construction and preservation exist in Europe and at the national level in France. In order to homogenize approaches to wood durability and sustainability, the French Standardization Committee initiated a project aiming to achieve a Documentation Fascicle which will compile different parameters influencing the longevity of outdoor above-ground wooden structures and propose an estimation of expected service life to those structures on the basis of selected parameters.
The main parameters influencing the durability of wooden elements taken into account in the document are design, climatic conditions inducing wood moistening, thickness of the wooden pieces, and use class conditions as defined in the EN 335 standard.

2.1.1 Design of wooden compounds

Depending on its design, a wooden element used outdoors and exposed to rainfall will present different levels of risk of being moistened to a level promoting fungal decay. In order to avoid water accumulation and facilitate drainage, designers should pay attention to specific details, such as orientation of the fibres, exposure of the end grain, joinery details, and geometrical positioning of the wooden element in the whole structure. Three classes of designs have been defined based on the ability of the wooden element to trap or eliminate water:

- water draining design: vertical elements with no water traps
- intermediate design: horizontal elements with no water traps
- water trapping design: elements with local design details allowing water trapping, such as wood-to-wood contact zones, deep shrinks or unprotected end grain

Lifespan expectancy is supposed to be strongly affected by the selected design, the water-trapping design being obviously the most prone to decay. A few examples of different designs are presented on Fig. 1.

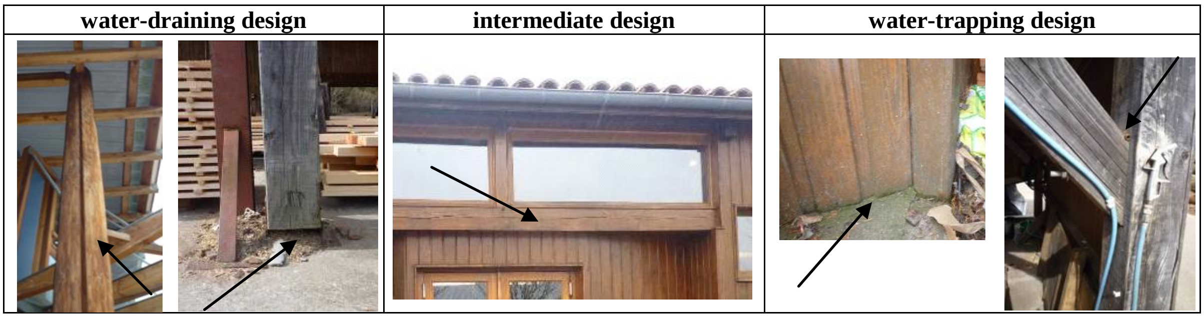


Figure 1: Examples of water-draining, intermediate and water trapping designs

2.1.2 Climatic conditions

Climatic parameters such as heat, rain, wind and UV radiation strongly affect the esthetic durability and susceptibility to fungal decay of wood used outdoors. The risk for wood components to be moistened due to rainfall or high relative humidity of the air depends on local climatic conditions (Scheffer 1971). In France, the following three levels of humidity have been defined to characterize climatic conditions (Fig. 2):

- dry: $N < 100$ days
- moderate: $100 \leq N < 150$ days
- wet: $N \geq 150$ days

N being the average number of days per year of wood's exposure to rain.

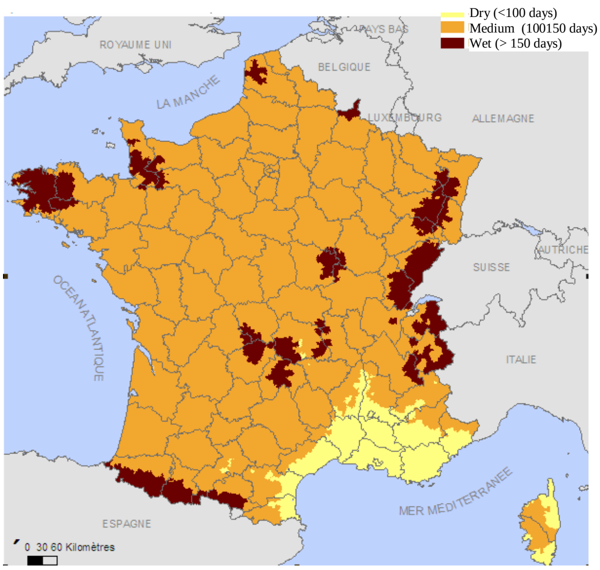


Figure 2: Average number of days per year with precipitation > 1 mm
as recorded between 1971 and 2000

The map above shows the geographical distribution of the defined climatic areas. However, in some locations high ambient humidity (which may be a consequence, for example, of the proximity of water sources such as rivers or oceanic coasts, topography, or frequent fog) may may negatively influence correct identification of the climatic conditions at a given site. In contrast, sites located above the altitude of 900m may benefit from dryer conditions than can be deduced from rainfall frequency.

2.1.3 Thickness of the wood elements

The thickness of a wooden element influences its ability to dry after having been exposed to rainfall, thinner pieces drying quicker than thicker ones. Three levels of thickness have been defined for solid and glue-lamed wood: low, medium and high (Table 1).

Table 1: Levels of thickness defined for solid and engineered wood

thickness (e)	solid wood / end-jointed solid wood	glue-lamed wood with lamellae > 35 mm	glue-lamed wood with lamellae ≤ 35 mm
low (cladding, decking …)	e ≤ 28 mm		e ≤ 28 mm
medium (beams…)	28 mm < e ≤75 mm	e ≤150 mm	28 mm < e ≤210 mm
high (poles, beams …)	75 mm < e	150 mm < e	210 mm < e

Engineered products such as glue-lamed beams are manufactured with wood lamellae dried in advance to reach moisture content <15%. They are less susceptible to shrinkage than solid wood of equivalent dimensions, which considerably reduces the risk of the appearance of water traps.

2.2 Correlation between the parameters influencing service life and the assignation of use classes conditions to outdoor above-ground wooden elements

Two methodologies of assigning real use class conditions to wooden structures have been developed for wood used outdoors, depending on the wood's natural durability, the thickness of the element, the design of the structure and the exposure to weathering. The assigned use classes are designed as 3.a, 3.b and to 4, according to the previously defined parameters and in relation to the general definitions of use classes given in the EN 335 standard as follows:

- Use class 3.a: a wood product located outdoors, above ground and partly covered by a structure.
- Use class 3.b: a wood product located outdoors, above ground and not structurally covered.
- Use class 4: a wood product located outdoors in contact with the ground or fresh water.

Exact definitions of the EN 335 standard are not applied there as the standard is currently under revision. The used terminology (3.a and 3.B) refers to existing French documents.

Wooden elements which are a part of the construction and are partially protected (cladding, outside joinery, etc) are traditionally assigned to use class 3.a. However, the thickness, the design and the conditions of exposure to rain may vary, increasing the risk of water accumulation and thus of fungal decay. In some situation, the use class can therefore be upgraded from 3.a to 3.b or even to 4, for instance, when thick wooden elements are manufactured or assembled in such a way that water traps are created or when they are used in wet climatic conditions (see the red marks in Table 2).

Uncovered outdoor wooden elements exposed to frequent wetting (cladding, pergolas, etc.) are usually assigned to use class 3.b. A use class lower than what the general definition tends to indicate can be assigned when, for instance, thin wooden elements are manufactured or assembled in such a way that water draining is possible and when they are used in dry climatic conditions. Conversely, the use class can be increased when, for instance, thick wooden elements are manufactured or assembled in a way which causes water traps to appear or are used in any of the defined climatic conditions (see the green and red marks in Table 3).

The following tables (Tables 2 and 3) offer an interpretation of the EN 335 standard and assignation of use classes to outdoor wooden elements according to the set of parameters potentially influencing their lifespan.

Table 2: assignation of use class conditions to outdoor above-ground wood components with low exposure to weathering

Wood Thickness	Design	Climate		
		DRY	MODERATE	WET
		Use Class		
low	Water draining	3.a	3.a	3.a
	Intermediate	3.a	3.a	3.b
	Water trapping	3.a	3.b	3.b
medium	Water draining	3.a	3.a	3.b
	Intermediate	3.a	3.a	3.b
	Water trapping	3.a	3.b	4
high	Water draining	3.a	3.a	3.b
	Intermediate	3.a	3.b	3.b
	Water trapping	3.b	3.b	4

Table 3: assignation of use class conditions to outdoor above-ground wood components with high exposure to weathering

Wood Thickness	Design	Climate		
		DRY	MODERATE	WET
		Use Class		
low	Water draining	3.a	3.a	3.a
	Intermediate	3.a	3.b	3.b
	Water trapping	3.b	4	4
medium	Water draining	3.a	3.a	3.b
	Intermediate	3.a	3.b	3.b
	Water trapping	3.b	4	4
high	Water draining	3.a	3.b	3.b
	Intermediate	3.b	3.b	4
	Water trapping	4	4	4

2.3 Service life prediction

Based on:

- the inherent characteristics of the wooden species (natural durability, water uptake ability, etc.)
- the design and thickness of the manufactured wooden components
- the exposure of the components to weathering
- the climatic conditions of the exposition site

expected longevity in real-use conditions has been proposed for outdoor above-ground wooden structures. Four time scales have been defined as follows:

- L3: longevity > 100 years
- L2: longevity between 50 and 100 years
- L1: longevity between 10 and 50 years
- N: longevity < 10 years, which option is regarded as unsuitable

The table below (Table 4) specifies the expected service life for some timber species widely used for outdoor applications.

Table 4: service life expectations for selected timber species

Timber species (2)		**expected time of resistance to decay of the heartwood depending on the use class**					**resistance to wood boring beetles**	**resistance to termites**
common name	**Latin name**	**1**	**2**	**3a**	**3b**	**4**		
European oak	*Quercus petraea & Quercus robur*	L3	L3	L3	L2	L1	yes	no
Black locust	*Robinia pseudoacacia*	L3	L3	L3	L2	L1	yes	yes
Spruce (*)	*Picea abies*	L3	L2	L1	N	N	no	no
European larch	*Larix decidua*	L3	L3	L2	L1	N	yes	no
Scots pine	*Pinus sylvestris*	L3	L3	L1	L1	N	yes	no
Western Red Cedar	*Thuja plicata*	L3	L3	L2	L1	N	yes	no
Fir (*)	*Abies alba*	L3	L2	L1	N	N	no	no
Radiata pine	*Pinus radiata*	L3	L2	L1	N	N	no	no
Southern yellow pine	*Pinus palustris & Pinus elliottii*	L3	L3	L1	L1	N	no	no

(*) heartwood and sapwood are difficult to discriminate visually

3. RESULTS OF DOUGLAS FIR CONSTRUCTIONS SURVEY

In 2010, France Douglas, the French Douglas fir Association, performed a survey of about 30 existing wooden structures principally made of Douglas fir. Mainly 10- to 20-year-old buildings or structures located mostly in Central France were inspected (Fig. 3). Several sawmill and farm buildings constructed more that 50 years ago were also examined. A total of 30 buildings and 200 elements made of Douglas fir, mostly untreated and uncoated, were examined for any evidence of fungal decay.

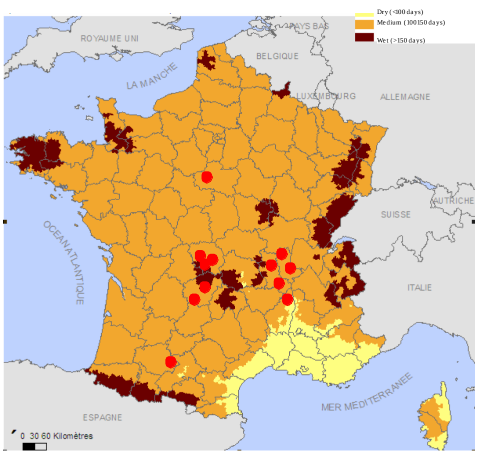
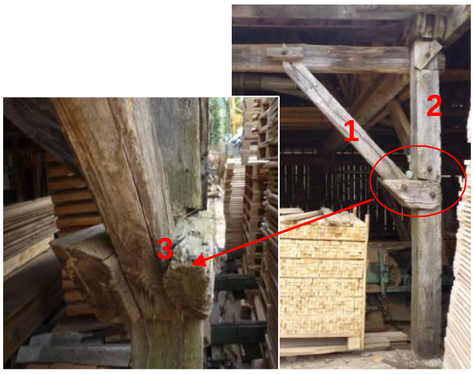
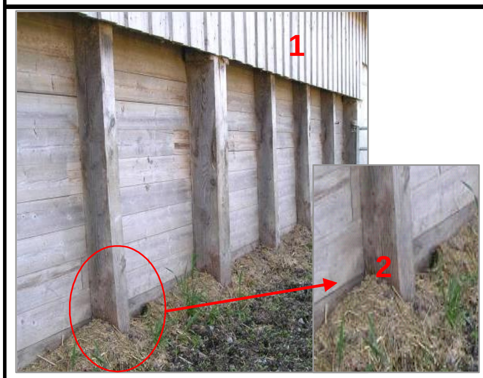
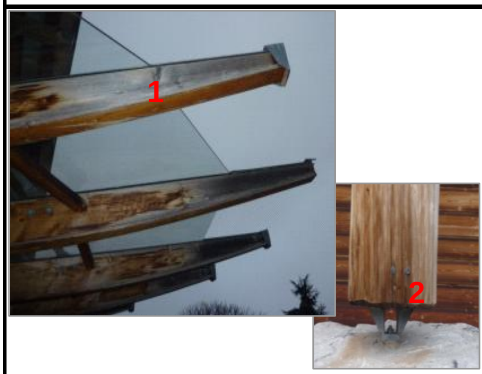


Figure 3: Locations of the examined Douglas fir structures

The results of the examination of the most representative structures are presented in the table below (Table 5).

Table 5: Examples of application of service life impacting parameters to Douglas fir structures

<table>
<tr><th colspan="2">age and description of the structure</th><th>service life parameters</th><th>result of the fungal decay investigation</th></tr>
<tr><td></td><td><u>sawmill</u>
date of construction:
1950
general description:
outdoor carpentry elements</td><td><table><tr><td rowspan="3">Wood Thickness</td><td rowspan="3">Design</td><td>Climate</td></tr><tr><td>MODERATE</td></tr><tr><td>Use Class</td></tr><tr><td rowspan="3">high</td><td>Water draining</td><td>3.a</td></tr><tr><td>Intermediate</td><td>3.b</td></tr><tr><td>Water trapping</td><td>3.b</td></tr></table>3 1-2</td><td>- posts
wood sound
- post to beam joints
wood sound, some evidence of superficial decay in the wood-to-wood contact zone</td></tr>
<tr><td></td><td><u>farm building</u>
date of construction:
1950
general description:
outdoor carpentry elements</td><td><table><tr><td rowspan="3">Wood Thickness</td><td rowspan="3">Design</td><td>Climate</td></tr><tr><td>MODERATE</td></tr><tr><td>Use Class</td></tr><tr><td rowspan="3">high</td><td>Water draining</td><td>3.a</td></tr><tr><td>Intermediate</td><td>3.b</td></tr><tr><td>Water trapping</td><td>3.b</td></tr></table>2</td><td>- beams
wood sound
- post to beam joints
wood sound</td></tr>
<tr><td></td><td><u>farm building</u>
date of construction:
1950
general description:
outdoor carpentry elements</td><td><table><tr><td rowspan="3">Wood Thickness</td><td rowspan="3">Design</td><td>Climate</td></tr><tr><td>MODERATE</td></tr><tr><td>Use Class</td></tr><tr><td rowspan="3">high</td><td>Water draining</td><td>3.a</td></tr><tr><td>Intermediate</td><td>3.b</td></tr><tr><td>Water trapping</td><td>3.b</td></tr></table>1 2</td><td>- beams
wood sound
- post to beam joints
wood sound</td></tr>
<tr><td></td><td><u>farm building</u>
date of construction:
2000
general description:
cladding outdoor carpentry</td><td><table><tr><td rowspan="3">Wood Thickness</td><td rowspan="3">Design</td><td>Climate</td></tr><tr><td>MODERATE</td></tr><tr><td>Use Class</td></tr><tr><td rowspan="3">low</td><td>Water draining</td><td>3.a</td></tr><tr><td>Intermediate</td><td>3.a</td></tr><tr><td>Water trapping</td><td>3.b</td></tr><tr><td rowspan="3">high</td><td>Water draining</td><td>3.a</td></tr><tr><td>Intermediate</td><td>3.b</td></tr><tr><td>Water trapping</td><td>3.b</td></tr></table>1 2</td><td>- cladding:
wood sound
- bottom part of the posts:
wood sound</td></tr>
</table>

age and description of the structure		service life parameters	result of the fungal decay investigation
	**school** date of construction: 1998 general description: outdoor carpentry elements "pergola-like"	Wood Thickness: high Climate: MODERATE Use Class (by Design): Water draining: 3.a Intermediate: 3.b Water trapping: 3.b 1 2	- horizontal beams wood sound - bottom part of the posts wood sound
	**bridge** date of construction: 2000 general description:	Wood Thickness: high Climate: WET Use Class (by Design): Water draining: 3.b Intermediate: 4 Water trapping: 4 1	- balustrade decay initiated locally (close to the nodes)
	**bridge** date of construction: 1998 general description: glue-lamed structure	Wood Thickness: high Climate: WET Use Class (by Design): Water draining: 3.b Intermediate: 4 Water trapping: 4 1 2	glue-lamed structure: wood sound - post to beam assembly: wood sound

4. CONCLUSIONS

The French and European standards provide keys to proper selection of timber species (EN 350-2), understanding of the biological risks associated with their use (EN 335) and proper treatment if necessary (EN 599). However, the timber construction industry also needs practical guidelines explaining how to improve the expected service life of wooden products by taking into account parameters such as climate, exposure and design details.

The survey of existing Douglas fir constructions demonstrated that of the 200 examined outdoor wooden elements only 6 showed partial decay, obviously due to poor design and wrong position in the structure. The resistance to fungal decay of Douglas fir's heartwood appears thus to be good enough to allow its use in Use Class 3.1 conditions for periods of time ranging from 50 to 100 years (time L2 as defined in the Documentation Fascicle) and in Use Class 3.2 conditions for periods of time ranging from 10 to 50 years (time L1) (Table 6). However, these performance estimates are rather theoretical as we lack sufficient experience with structures older than 50 years, therefore they should be approached carefully.

Table 6: Lifespan expectancy for Douglas fir structures

Timber species		expected time of resistance to decay of the heartwood depending on the use class					resistance to wood boring beetles	resistance to termites
common name	**Latin name**	**1**	**2**	**3a**	**3b**	**4**		
Douglas fir grown in Europe	***Pseudotsuga menziesii***	**L3**	**L3**	**L2**	**L1**	**N**	**yes**	**no**

Regarding exposure to above-ground conditions equivalent to Use Class 4, the survey reported several cases of heartwood resistance to decay for periods ranging from 10 to 15 years. However, extrapolating from these few observations to infer service life expectancy in real Use Class 4 conditions as defined in the accepted standards (permanent contact with ground or sweet water) is risky. Douglas fir sapwood also performed better than expected from its low natural durability. This good performance may be due to the fact that sapwood is almost as refractory to water uptake as heartwood. Thus it can be assumed that Douglas fir sapwood may reach lifespan durations ranging from 10 to 50 years in Use Class 3.1, which makes it is quite unique among most European timber species.
The study provided evidence which confirmed that both the sapwood and heartwood of Douglas fir perform better in real outdoor use conditions than predicted by standardized tests and demonstrated that good knowledge of how a wooden product should be manufactured and assembled is the key to optimizing its life in service. Douglas fir confirmed its reputation of being a refractory timber species, which means that it resists wetting and has a natural ability to withstand decay for longer time. Douglas fir is also known for retaining its shape and size without shrinking, swelling, cupping, warping, and bowing or twisting (Cown et al. 1999), which considerably reduces the risk of wooden elements becoming wet and suffering damage during their life in service.
In terms of general durability assessment methodology, the survey performed by France Douglas also confirmed that the ability of timber species to absorb/desorb liquid or vapour water is a critical parameter which should be taken into account for optimizing their performances in outdoor use for long periods of time.

5. REFERENCES

Brischke, C., Rapp, A.O. (2010): Service life prediction of wooden components – Part 1: Determination of dose response functions for above ground decay. *Proccedings of the Annual Meeting of the International Research Group on Wood Protection,* Biarritz, France.

Cown, D.J. (1999): New Zealand pine and Douglas-fir: Suitability for processing. *Forest Research Bulletin* **216**, 72pp.

Dirol, D, Déglise, X (2001) Durabilité des bois et problèmes associés. Ed. Hermès.

EN 335-2 (2007) Durability of wood and wood-based products - Definition of use classes — Part 2: Application to solid wood.

EN 350-2 (1994) Durability of wood and wood-based products - Natural durability of wood — Part 2: Guide to natural durability and treatability of selected wood species of importance in Europe.

Eslyn, W.E.; Highley, T.L., Lombard F.F. (1985): Longevity of untreated wood in use above ground. Forest *Products Journal* **35**(5): 28–35.

Hazleden D.G., Morris P.I. (1999) Designing for durable wood construction: the 4 Ds. *Proceedings of the, 8th International Conference on Durability of Building Materials and Components*, Vancouver, Canada

Highley, T.L. (1995): Comparative durability of untreated wood in use above ground. International *Biodeterioration & Biodegradation* 1995: 409–419.

The NZ Douglas-fir Association (Forest Owners and Sawmillers) (2004) Alternative Solution for use of Untreated Douglas-fir (New Zealand Oregon) in external walls. Report.

Scheffer, T.C. (1971): A climate index for estimating poten-tial for decay in wood structures above ground. *Forest Products Journal* **21**(13): 25–31.