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Natural durability of selected larch and Scots pine heartwoods in laboratory and field tests

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A B S T R A C T

The aim of this study was to compare natural durability of Siberian larch heartwood grown in Siberia and Sweden as well as European larch and Scots pine heartwood grown in Sweden. The study was based on standard in- and above ground tests lasting 12 years but laboratory decay tests with white and brown rot fungi was also included. Field test results showed that Siberian larch heartwood from Siberia was the most durable among the studied heartwoods with a decay index of 60 after 12 years in Simlångsdalen (Sweden), while European larch heartwood grown in Sweden, was decayed to failure before the end of the test. Scots pine heartwood was found to perform similarly to Siberian larch from Siberia. No relationship could be established between natural durability of examined heartwoods and their water absorption behavior; however, strong correlation to the total amount of extractives was observed. Scots pine and Siberian larch heartwood from Siberia had 12.7 and 19.6% total extractives content respectively but the extractives composition differs. The study revealed also that lignin and monosaccharide content could not explain the variations in decay resistance of the studied heartwoods. No similarities in the natural durability revealed by laboratory and field tests were observed.

1. Introduction

Larches are industrially important wood species found predominantly in the Northern hemisphere and typically represented by *Larix sibirica* Ledeb. and *Larix decidua* Mill. Larch stock in Sweden counts c. 980 000 m^3 (Persson, 1996) and is found in the Southern and Northern parts of the country. Recently, many wood-working companies, e.g. the one in Vimmerby, started to import and process Siberian larch timber for high quality joinery products. The interest to larch has also increased in Finland, Norway and Germany (Kewenter, 1998).

Natural durability of larch wood, defined sometimes as decay resistance, is a debatable issue. According to the European Standard EN 350-1, natural durability of wood is defined as “the inherent resistance of wood by attack wood destroying organisms”. It is generally known that wood biological resistance depends on the extractives (Scheffer and Morrell, 1998; Hinterstoisser et al., 2000; Schultz and Nicholas, 2002; Yang, 2009; Singh and Singh, 2012; Kirker et al., 2013; Nascimento et al., 2013). It is proven that larch wood has a high concentration of water soluble extractives (Hakkila and Winter, 1973; Maksis and Kharuk, 2004). Heartwood has more stored extractives than sapwood. Viitanen et al. (1997) found that the main part of larch heartwood extractives consists of arabinogalactan, a water soluble oligomers consisting of the monosaccharides arabinose and galactose. Côté et al. (1966) studied the distribution of arabinogalactan in larch wood and reported that its content varied between 5 and 30%, but served as nutrient for microorganisms rather than protective agent. Flavonoids in the larch heartwood were found to be about 3.5% (Babkin et al., 2001; Gierlinger et al., 2004). Resin and fatty acids as well as triacylglycerols constitute only a little part in the extractive content (Viitanen et al., 1997). However, the role of the various chemical compounds is not differentiated when larch durability is concerned.

Research on larch wood decay resistance has been carried out since the sixties of the last century (Kharuk, 1961; Shaltyanene, 1962; Bazhenov and Kharuk, 1967). Average service life of larch wood poles was found to be 19–24 years (Bazhenov and Kharuk, 1967). First sign of degradation has appeared after 4 years of use; 10–20% of the telegraph poles have been decayed after 15 years in ground contact. However, 50% of the poles have still been in use after 25 years of exploitation. Comparative data on the resistance of spruce and larch wood poles were shown by Gorshin (1977) where spruce poles had an average service life of 7–8 years while larch poles served 15–25 years. High decay resistance of larch wood has

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also been revealed by Varfolomeev (1995) and Gorshin and Cherntzov (1966).

Although it can be concluded that larch is a very durable wood species, some drawbacks can hinder the interpretation of results for usage of larch in Europe. Most of the studies were carried out on Siberian larch tested in Siberia, a place with rather cold and specific climate particularly in the winter, thus making the conclusions irrelevant for the same species exposed elsewhere. Wide variation of decay resistance within the same wood species has also been observed (Viitanen et al., 1997). According to the authors, decay resistance depends on both genetic and environmental factors.

Chubinsky (2003) showed that water-soluble extractives of Siberian larch heartwood do not provide any fungi inhibiting effect themselves but correlate best and negatively with the mass losses caused by wood destroying fungi. This is an interesting finding having in mind that the carbohydrates are those compounds easily extracted in water rather than phenolic compounds. It is suggested that Siberian larch heartwood is not more durable than Scots pine heartwood but it seems that the wood has some specific defending mechanism against decay fungi, although it contains significantly more arabinogalactan than Scots pine heartwood, i.e. a carbohydrate which acts as a nutrient for the microorganisms.

Other interesting aspects when discussing the durability variations of larch heartwood are the age and density of the material. Siberian larch heartwood at age of 120 years showed 30–50% lower mass loss than that at age of 60 years (Chubinsky, 2003). The composition and the increased amount of extractives with the age can shed light on this difference. The basic density was also found to correlate significantly and negatively with the mass loss. This result is somewhat unexpected and contradicts the findings of similar previous studies (Boutelje and Nilsson, 1985). Koch et al. (2007) also showed that a direct relationship between raw material density and mass loss caused by decay fungi on larch wood collected from three sites in Siberia could not be established unequivocally. It was concluded that the natural durability of larch is highly dependent on the amount of extractives.

Despite the origin and larch species, larch timber is always marketed and sold in Sweden under the name “Siberian larch”. This can be highly misleading for the customers and can introduce decay problem during the outdoor exploitation. A question arises whether the timber from larch species grown at different growing stands (e.g. Siberia and the Nordic countries) have similar properties and behavior during service. Since larch timber is a “new” material in the Nordic countries, there is a scarcity of information concerning its processing and properties. The objective of the present study is to compare the durability of Siberian larch grown in Sweden and Siberia, European larch and Scots pine heartwoods from Sweden. The study is based on a long-term in- and above ground field tests but a laboratory decay test is included as well. The study is aimed at explaining the nature of durability differences.

2. Materials and methods

2.1. Materials

Siberian larch (*Larix sibirica* Ledeb.) grown in Siberia and Sweden and European larch (*Larix decidua* Mill.) only from Sweden were studied. Sap- and heartwood of Scots pine (*Pinus sylvestris* L.) were used as controls. Stand and log characteristics are shown in Table 1. Three butt logs of each wood species were selected and sawn to 50-mm-thick planks in 1998. After drying in room climate, stakes, lap-joint test samples, samples for water absorption and durability tests were cut from the planks. Sap- and juvenile wood were carefully omitted in all larch samples while Scots pine timber was divided to sap- and heartwood samples.

Table 1
Characteristics of the growth stands.

Characteristics	Stand 1 (near Mariestad, Sweden)	Stand 2 (Gotland, Sweden)	Stand 3 (near Bratsk, Siberia)
Wood species	*Larix sibirica* *Larix decidua*	*Pinus sylvestris*	*Larix sibirica*
Location	58°48′ N, 14°14′ E	57°27′ N, 18°31′ E	–
Height above sea level (m)	62	43	460
Average annual temperature[a], °C	7.4	7.1	−1.5
Annual precipitation (mm)	455	95	409
Site index (height at 100 years of age)	24	22	22
Average trees diameter at breast height, cm	40, 37	39	42

[a] Climate data for 1998.

Number of annual rings per 10 mm and ring width were measured to describe the characteristics of the studied material (Table 2). Specimens with a dimension of 25 × 25 × 100 mm were used to determine the wood density.

2.2. Standard ground and above ground field tests

Durability of larch and pine species was tested in ground contact according to the European standard EN 252. For every species, 20 stakes were exposed in the test fields (Table 3) and revised annually. Two test fields, Simlångsdalen and Uppsala (both in Sweden) were chosen. The above ground test was performed according to the standard ENV 12037 (lap-joint method); it was conducted only in Uppsala. The samples in ground and above ground exposure were set in the fields in 1999. Some characteristics of the fields are shown in Table 3.

2.3. Determination of water absorption/desorption coefficient of the studied species

For each wood species, 40 samples with dimensions of 25 × 25 × 100 mm were cut; 20 samples were used for longitudinal absorption while the others were for transversal absorption test. In total, 200 samples were prepared. The initial moisture content of samples was in the range of 8–12%. Prior to the absorption tests, transversal or longitudinal surfaces were sealed with polyurethane glue to prevent penetration through these areas. For the longitudinal water absorption, each surface was sealed except the end-grain surfaces. The specimens for the transversal water absorption were isolated at the end-grain and at two other parallel surfaces. The wood samples were placed in a container containing

Table 2
Density and annual rings characterization of the studied species.

Wood species	Average number of annual rings per 10 mm	Earlywood (%)	Latewood (%)	Average density (kg m^{-3})[a]
Siberian larch from Siberia	6	64.5	35.5	749.8 (73.0)
Siberian larch from Sweden	6	65.8	34.2	638.6 (40.3)
European larch from Sweden	4	64.8	35.2	557.0 (30.6)
Pine heartwood	6	69.1	30.9	655.6 (68.5)
Pine sapwood	6	67.1	32.9	563.1 (40.8)

[a] Standard deviation in parentheses.