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Surface mould and blue stain fungi on coated Norway spruce cladding

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ABSTRACT

The study describes the development of surface mould and blue stain fungi on painted wooden claddings exposed to outdoor weathering. The materials consisted of Norway spruce (*Picea abies*) claddings that were processed from inner boards, outer boards, and edge-grained boards with known origin. Heartwood proportion, density, annual ring width, knot diameters and relative knot area were measured, and all boards were coated with the same water-borne alkyd modified acrylic paint system. Most of the tangentially sawn boards were coated on the side facing the pith, but a sub-sample was coated on the opposite side for comparison. The specimens were exposed with a 45° angle of inclination facing south in a field trial in Oslo from 2007 to 2011, and mould growth was evaluated visually according to EN 927-3. The development of mould rating was described with an ordinal logistic regression model. The model predicts expected mould rating to follow a sigmoid curve with some deviation in the first part. Neither wood properties nor manufacturing characteristics had any significant effect on the model, and this may in part be due to the use of a high performance coating system.

1. Introduction

Wooden façades have traditionally been used in family houses in Norway and are increasingly applied also in multi storey and non-residential buildings. The house owners and other end-users demand cladding material with long maintenance intervals and long service life, and some sort of coating or finishing will often be a requirement. Obtaining a desired aesthetical appearance and protecting the wood from water uptake and other external stress are most often the main reasons for coating wood in exterior claddings (Sell, 1975; de Meijer, 2001). Growth of mould fungi with dark-coloured hyphae and spores (blue stain fungi) is a common phenomenon both on coated and uncoated wooden façades. Moulds and blue stain fungi are often considered to be undesirable elements, especially on light-coloured wooden façades, and may reduce the aesthetical service life. Wooden façades are also exposed to physical degradation caused by UV-radiation, rain, temperature, condensation, wind, and high relative humidity, making the surfaces more susceptible to fungal attack (Feist and Hon, 1984; Williams et al., 2000; de Meijer, 2001). The long-time performance of coated wooden claddings will depend on the quality and type of coating products, the wood surface properties, building design, and climatic factors (Browne, 1958; USDA Forest Service, 1999; Gobakken et al., 2008, 2010a; Gobakken and Lebow, 2010; Jermer, 2011).

The coatings and the application of the coating have to accommodate a large variation in the underlying wood substrate, such as variation in wood species, density, growth ring width, mixture of juvenile wood and mature wood, sapwood and heartwood proportions, angle of grains, and number, distribution, and size of knots. All these properties may affect the performance of the coating in one way or another (Browne, 1958; Jourdain et al., 1999; USDA Forest Service, 1999; Williams et al., 2000; Gobakken and Westin, 2008; Gobakken and Lebow, 2010; Sivertsen and Flæte, 2010). A coating cannot change the equilibrium moisture content of the wood; it will only affect the rate at which absorption will occur (Williams et al., 2000). A good coating system will reduce the water transport significantly, but the question is if it can compensate for any difference in wood permeability.

Norway spruce (*Picea abies*) is the wood species most commonly used for cladding material in façades in Norway, partly because of its low permeability. Annual ring width, density, and heartwood content will affect the water sorption properties of the wood (Flæte and Alfredsen, 2004; Bergström and Blom, 2005; Sivertsen and Flæte, 2010; Vestøl and Sivertsen, 2011). Variations in moisture content will cause the wood to shrink and swell, and extensive dimensional changes may cause cracks in film-forming coatings

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(Williams et al., 2000). Furthermore, wood substrates with small swelling and shrinking have been found to have the best paint-adhering performance (USDA Forest Service, 1999). The size, location, shape, and soundness of knots can be decisive for the performance of the coating since knots have lower coating adhesion than wood, and since resin bleeding from knots may discolour the coating (Williams et al., 2000). Heartwood of some wood species contain extractive compounds with fungal resistance (Zabel and Morell, 1992; Eaton and Hale, 1993), and some of these may also cause reduced coating adhesion and discolouration (Williams et al., 2000). The effect of fungal resistance is probably of minor importance in Norway spruce since the content of extractives is low, and there is no difference between heartwood and sapwood (Nylinder and Hägglund, 1954; Assarsson and Åkerlund, 1966). Manufacturing characteristics, such as grain orientation, board selection, and surface roughness, may also influence the coating performance. Due to more tangentially oriented flat-sides and lower proportions of heartwood, outer boards are less dimensionally stable than inner boards and will experience more swelling and shrinkage caused by variation in moisture content. Shrinkage and swelling will stress the coating, and cracks may develop. Movement in the wood can also cause reduced adhesion of the coating, and the coating can start to flake. Radial surfaces are more dimensionally stable than tangential surfaces (Kollmann and Côté, 1968) and will therefore serve as a more stable substrate for any surface treatment. Studies have shown that the roughness and porosity of the wooden surface will influence the coating adhesion (Williams and Feist, 1994; Nussbaum et al., 1998). Furthermore, there are indications that surface roughness and the surface structure of the coating may contribute to the adhesion of fungal spores to the surface (Bardage, 1998; Bardage and Bjurman, 1998; Verran et al., 2000; Gobakken et al., 2010b), and can be decisive for growth of mould and blue stain fungi.

Fewer studies on surface mould growth and blue stain fungi have addressed the interaction between the wood substrate and the coating. When considering both the wood substrate and the surface coating, it is not clear how to distinguish their effects, for instance with respect to providing a reservoir of moisture, supplying nutrients, and inhibiting growth of microorganisms. Gobakken and Lebow (2010) and Gobakken et al. (2010a) showed significant effect of wood substrate on the development of blue stain and moulds on coated wooden claddings, but it was minor both to the effect of the coating itself and to the effect of exposure time. Furthermore, Gobakken and Lebow (2010) found a clear difference in degree of mould growth between various wood species when coated, and the findings indicated that, in general, coated sapwood had more surface mould growth than coated heartwood. The objective of the present study was to analyse the effects of manufacturing characteristics and wood properties on the growth of surface moulds and blue stain fungi on cladding panels of Norway spruce in outdoor exposure.

2. Material and methods

The study included 158 specimens of Norway spruce with known origin, and it was based on parts of the material described by Sivertsen and Vestøl (2010). The materials were sampled from four sites; two sites in relatively productive forests in southern Norway (Larvik), and two others in slow growing forests located at higher altitudes and somewhat farther north (Toten). The trees from Larvik were from 45 to 57 years old and had large diameter- and height growth and small tapering, whereas the trees from Toten were about 150 years old, and were shorter with greater tapering (Sivertsen and Vestøl, 2010).

Five trees with breast height diameter between 27 and 30 cm and five trees with breast height diameter between 32 and 35 cm were sampled from each site. Butt logs of 4–5 m length were split in half through the pith, and two 100 mm wide plain-sawn planks were produced from one half, and a 100 mm wide edge-grained plank was produced from the other (Fig. 1). The planks were subsequently kiln dried and resawn into 19 mm thick and 98 mm wide boards with dry-cut surfaces on all sides.

The inner boards closest to the pith and the outer boards farthest from the pith were used in our study, as well as one edge-grained board (Fig. 1). The boards were cut in two before coating. One half of each inner board was coated on the side facing the pith, whereas the other half was coated on the side facing the bark. The outer boards were coated on the side facing the pith, whereas the edge-grained boards were coated on the side that was closest to a radial direction. The samples were applied with one layer of a red, fully pigmented waterborne alkyd emulsion primer and two layers of a red waterborne acrylic topcoat on the top face and the sides. The primer and the topcoat were commercial products (Jotun Industrial Opaque Primer and Jotun Industri Optimal) and they were applied by spraying in an industrial setup. The mean dry film thickness was measured to 0.18 mm.

The dimensions of the panels were 800 mm by 98 mm by 19 mm. In order to locate the heartwood and the sapwood, the plain-sawn planks were scanned with a medical computer tomographic scanner before drying. The scans were used to calculate heartwood proportions in the middle and 10 cm from each end of the panels, and the proportion of heartwood was calculated as the mean of the three scans (Sivertsen and Vestøl, 2010). Annual ring width and density were measured from a 20 cm specimen taken from each board. Annual ring width was measured as mean width of all complete annual rings in the cross section. Density and moisture content were measured after conditioning to 12% moisture content at 20 °C and 65% relative humidity, and density was adjusted in accordance with EN 384 (2004). Knot sizes and relative knot area were recorded before applying the coating. Mean values are presented in Table 1.

The panels were exposed to outdoor weathering in Oslo, Norway (N 60°01′29.3″, E 10°35′35.7″, 210 m above sea level) from June 2007 until September 2011. The specimens were mounted on 45° in rigs facing south and with the longitudinal direction along the inclination. The test set up was similar to the one described by

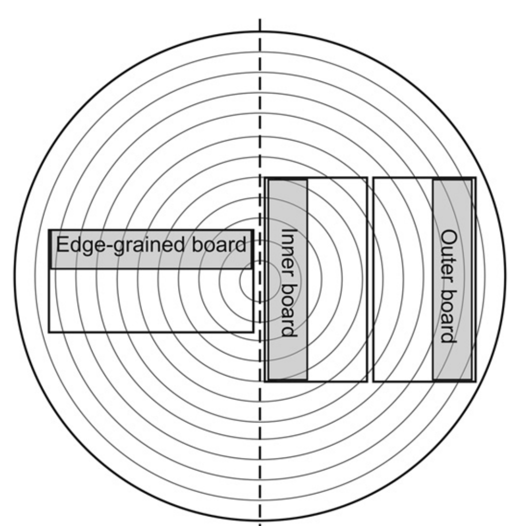

Fig. 1. Sawing pattern in the logs; inner boards, outer boards, and edge-grained boards.