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# Crack Size and Moisture Issues in Thermally Modified vs. Native Norway Spruce Window Frames: A Hygrothermal Simulation Study

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**Abstract :** The study investigates the impact of cracks in surface coatings on moisture content (MC) and related fungal growth in window frames made of thermally modified (TM) and native Norway spruce using hygrothermal simulations for Ljubljana, Slovenia. Comprehensive validation against field test data confirmed the numerical model's predictions, demonstrating similar trends in MC changes over investigated four years investigated. Various established mould growth models (isopleth, VTT, bio hygrothermal) did not appropriately reflect differences between the spruce types because they do not consider material moisture content, leading to the main conclusion that TM spruce is more resistant to moisture-related issues. Wood's MC influences fungal decomposition, typically occurring above 25% - 30% MC, with some fungi growing at lower MC under conducive conditions. Surface coatings cannot wholly prevent water penetration, which becomes significant when coating is damaged. This study investigates the detrimental effects of surface coating cracks on wood moisture absorption, comparing TM spruce and native spruce window frames. Simulations were conducted for undamaged and damaged coatings (from 1 mm to 9 mm wide cracks) on window profiles as well as for uncoated profiles. Sorption curves were also measured up to 95% of the relative humidity. MC was measured in the frames exposed to actual climatic conditions and compared to simulated data for model validation. The study utilizes a simplified model of the bottom frame part due to convergence issues with simulations of the whole frame. TM spruce showed about 4% lower MC content compared to native spruce. Simulations showed that a 3 mm wide crack in native spruce coatings for the north orientation poses significant moisture risks, while a 9 mm wide crack in TM spruce coatings remains acceptable furthermore in the case of uncoated TM spruce could be acceptable. In addition, it seems that large enough cracks may cause even worse moisture dynamics compared to uncoated native spruce profiles. The absorption curve comes out to be the far most influential parameter, and the next one is density. Existing mould growth models need to be upgraded to reflect wood material differences accurately. Due to the lower sorption curve of TM spruce, in reality higher RH values are obtained under the same boundary conditions, which implies a more critical situation according to these mould growth models. Still, it does not reflect the difference in materials, especially under external exposure conditions. Even if different substrate categories in the isopleth and bio-hygrothermal model or different sensitivity material classes for standard and TM wood are used, it does not necessarily change the expected trends; thus, models with MC being the inherent part of the models should be introduced. Orientation plays a crucial role in moisture dynamics. Results show that for the similar moisture dynamics, for Norway spruce, the crack could be about 2 mm wider on the south side.. In contrast, for TM spruce, orientation isn't as important, compared to other material properties. The study confirms the enhanced suitability of TM spruce for window frames in terms of moisture resistance and crack tolerance in surface coatings.

**Keywords :** hygrothermal simulations, mould growth, surface coating, thermally modified wood, window frame
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