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Moisture-induced stresses perpendicular to grain in cross-sections of timber members exposed to different climates

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ABSTRACT

In variable humidity conditions, wood absorbs or desorbs moisture from the air. Unless the change in humidity is very slow, this will develop moisture gradients in the wood sections. These gradients will develop stresses due to constrained swelling or shrinkage strains. These stresses are named moisture-induced stresses. The present paper investigates the main parameters affecting such moisture-induced stresses, including the type of climate, the size of the timber cross-section, and the type of protective coating. A first attempt to identify moisture-induced stresses in different European climatic regions was made. For each climatic region, relative humidity and temperature histories were identified, and characteristic and mean values of yearly and daily variations were calculated. Using a finite element model implemented in Abaqus, the moisture content and stress distribution were computed on different timber cross-sections exposed to the climatic regions and protected with different types of coating. A Fickian moisture transfer model was used to compute the moisture distribution, and a mechanical model for time-dependent behaviour of wood was implemented to calculate the corresponding stress distribution. The variation of moisture was found to result in stresses of magnitudes that would probably cause cracking of wood in the perimeter of any uncoated cross-section size. The use of a protective coating, however, reduced considerably the moisture-induced stresses, and can be regarded as an effective protective measure to avoid cracking due to humidity variations. Considering European climates, Northern climates were found to result in higher surface tensile stresses than Southern climates.

1. Introduction

Wood is a hygroscopic material which absorbs or desorbs moisture to maintain equilibrium of the moisture state with the surrounding air [1]. This external exposure of wood structures, termed as the 'humidity load', may be subdivided into various categories such as external conditions, either sheltered or not from precipitation and sun radiation, and interior conditions of heated or unheated buildings. Further subdivisions of the exposure are also possible, as for instance, related to the activity taking place inside the building. This paper is related to the exposure in external conditions in case where there is sheltering from precipitation and solar radiation. The exposure varies according to the climate. Here only European climates are considered.

The moisture content u is an important parameter affecting several physical, mechanical and rheological properties of wood, including durability, shrinkage/swelling, modulus of elasticity, and strength properties [2–4]. A further factor which significantly affects the stress state of wood is the moisture gradient. Moisture diffusion in wood is a rather slow process in comparison to heat flow for instance. Gradients of moisture in the wood sections are created when the humidity load is variable or different from initial equilibrium. These gradients may be high close to the surface of the wood section particularly when air humidity changes are fast. These gradients may also be high in the central parts of the wood sections. Moisture gradients induce differences in shrinkage and swelling of wood, which further induce stresses in the wood sections. These are named moisture-induced stresses and may lead to cracks in the surface or in the central part of the wood sections. The rheological properties of wood, namely creep and mechanosorption, are markedly affected by moisture content and these have an important role in the development of internal stresses as they generally decrease the stress magnitudes [2,5,6].

There is a need to investigate the influence of moisture on the performance of timber structures. Cracks have been observed in timber structures exposed to outdoor conditions and sheltered from rain, in connection regions and adjacent to heat sources [7].

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