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Hygro-Thermal Modelling of Timber Decks

Authors : Stefania Fortino, Petr Hradil, Timo Avikainen

Abstract : Timber bridges have an excellent environmental performance, are economical, relatively easy to build and can have a long service life. However, the durability of these bridges is the main problem because of their exposure to outdoor climate conditions. The moisture content accumulated in wood for long periods, in combination with certain temperatures, may cause conditions suitable for timber decay. In addition, moisture content variations affect the structural integrity, serviceability and loading capacity of timber bridges. Therefore, the monitoring of the moisture content in wood is important for the durability of the material but also for the whole superstructure. The measurements obtained by the usual sensor-based techniques provide hygro-thermal data only in specific locations of the wood components. In this context, the monitoring can be assisted by numerical modelling to get more information on the hygro-thermal response of the bridges. This work presents a hygro-thermal model based on a multi-phase moisture transport theory to predict the distribution of moisture content, relative humidity and temperature in wood. Below the fibre saturation point, the multi-phase theory simulates three phenomena in cellular wood during moisture transfer, i.e., the diffusion of water vapour in the pores, the sorption of bound water and the diffusion of bound water in the cell walls. In the multi-phase model, the two water phases are separated, and the coupling between them is defined through a sorption rate. Furthermore, an average between the temperature-dependent adsorption and desorption isotherms is used. In previous works by some of the authors, this approach was found very suitable to study the moisture transport in uncoated and coated stress-laminated timber decks. Compared to previous works, the hygro-thermal fluxes on the external surfaces include the influence of the absorbed solar radiation during the time and consequently, the temperatures on the surfaces exposed to the sun are higher. This affects the whole hygro-thermal response of the timber component. The multi-phase model, implemented in a user subroutine of Abaqus FEM code, provides the distribution of the moisture content, the temperature and the relative humidity in a volume of the timber deck. As a case study, the hygro-thermal data in wood are collected from the ongoing monitoring of the stress-laminated timber deck of Tapiola Bridge in Finland, based on integrated humidity-temperature sensors and the numerical results are found in good agreement with the measurements. The proposed model, used to assist the monitoring, can contribute to reducing the maintenance costs of bridges, as well as the cost of instrumentation, and increase safety.

Keywords : moisture content, multi-phase models, solar radiation, timber decks, FEM
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