BUILD SIMUL
DOI 10.1007/s12273-013-0153-4

The multiphysics modeling of heat and moisture induced stress and strain of historic building materials and artefacts

Natalie Williams Portal[1] (✉), A.W.M. van Schijndel[2], Angela Sasic Kalagasidis[1]

1. Department of Civil and Environmental Engineering, Chalmers University of Technology, Sven Hultins Gata 8, Göteborg, Sweden
2. Department of Building Physics and Services, Eindhoven University of Technology, 5600MB Eindhoven, the Netherlands

Abstract

The basic structure of historic sites and their associated interior artefacts can be damaged or even destroyed by climate change. The evaluation of combined heat and moisture induced stress and strain (HMSS) can predict possible damage-related processes. In this paper, the development of one- and two-dimensional HMSS models of building materials and artefacts in COMSOL Multiphysics Version 4, a commercial finite element software, is presented. The validation of the numerical models is revealed using analytical, numerical and experimental solutions. As a result, the HMSS model was shown to be an adequate predictive tool to determine possible damage-related processes in building assemblies and artefacts.

Keywords

heat,
moisture,
mechanical stress,
multiphysics modelling,
predictive tools,
historical buildings

Article History

Received: 16 October 2012
Revised: 6 May 2013
Accepted: 5 August 2013

1 Research aims

The aim of this paper is to present a two-dimensional numerical model that can be used to study coupled heat and moisture induced stresses and strains in materials and objects, which include artefacts that are exposed to varying hygrothermal loads in indoor and outdoor environments.

2 Introduction

Thermal and moisture durability of materials and items inside a building is one of the main research topics in building physics science. Numerical models and tools that have been developed for that purpose considerably help in understanding deterioration and degradation processes that take place in buildings. Advanced building physics tools, which are capable of combined thermal and mass (i.e. water, air, salt) analyses in porous media, are required for durability studies (Hagentoft 1998; Nicolai et al. 2007; Sevilgen and Kilic 2011; Woloszyn and Rode 2008). However, the structural performance of a material is typically not included in the building physics tools even though hygrothermal loads have been shown to induce stresses and strains in porous media in (Mihoubi and Bellagi 2009; Kowalski and Smoczkiewicz-Wojciechowska 2007; Kowalkski and Rybicki 2004). For instance, displacements, dimensional change or cracking are typical issues associated with wooden structural elements exposed to indoor and outdoor hygrothermal loads. These induced changes, in turn, modify the mechanical properties of the given media and as such alter its long-term behaviour. The implementation of a multidisciplinary approach can lead to a more comprehensive understanding, analysis and prevention of hygrothermal-induced problems in buildings (Burke 2009).

Numerical tools from the structural engineering research field, though offering advanced non-linear finite element analyses of the structural performance of a material, are often of limited applicability in building physics investigations. Structural tools typically provide options to prescribe constant, simplified or even uncoupled moisture and thermal

E-mail: Natalie.williams@chalmers.se