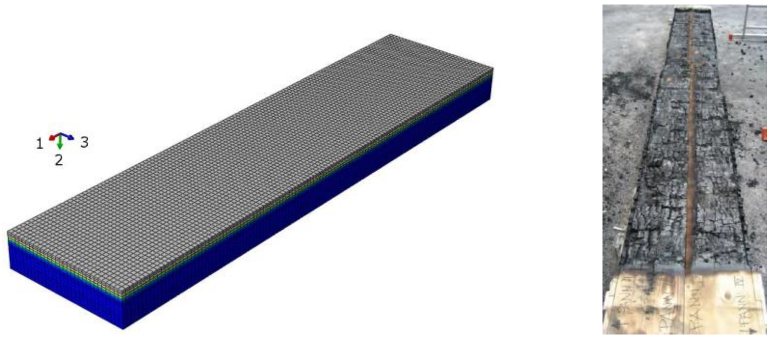
FEM-FIRE



Formation of char after the fire test: (a) numerical and (b) experimental.

Finite Element Modelling of FIRE resistance of timber composite panels

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Context — In residential buildings, the fire is one of the most unpredictable and dangerous accidents that may occur. When wood material is used in buildings for posts, beams and floors, fire protection is typically required and can be determined using building codes. Moreover the timber material is combustible; designers have therefore major concerns about fire safety in wooden structures. But the wood combustion is slowly and regular, and their behaviour becomes predictable. If wood is exposed to fire environment, a thermal degradation process occurs in which the wood is converted to volatile gases and a char residue, and is accompanied by loss in weight and cross-section dimensions of timber beams. The thermal behaviour of wood submitted to high temperatures can be described through the following processes: pyrolysis, ignition, reradiation, char formation. The extent of any thermal degradation depends on both the temperature and the time of the exposure.

Objectives — This present work is in line with the general topics of sustainable development, and the objectives of this study were to investigate the thermomechanical behaviour of wood panels exposed to fire numerically, develop a finite element model describing the behaviour of wood submitted to high temperatures, verifying the finite element model against the experimental tests published in the literature and to examine the impact of uniform heat flux on the process of pyrolysis of wood panels. The modelling of the pyrolysis of wet wood provides more realistic fire scenarios for structural fire design by taking into account variable thermal properties of wood which are beyond the scope of conventional structural fire design codes. The proposed numerical methodology in this study has been implemented in Abaqus software.

Approach — When wood is subjected to fire therefore its thermal behaviour and mechanical strength change. Therefore, the evaluation of the spatial and temporal distribution of temperature and moisture content over the element is the first key phase of the analysis. The process of thermal degradation is observed when the temperature of timber reaches a certain threshold value (around 300°C) which depends on the specie of wood.

The purpose of the study is to develop a three-dimensional coupled thermomechanical model for predicting the behaviour of wood composite panels exposed to fire. Various types of mode failure, such as the temperature profiles, char formation, the charring depths of timber composite panels, will be included. The finite element model can predict temperature, deflection, time-to-failure of composites over a wide temperature range from temperatures of 100° to 600°C. The model has been incorporated into the commercial software Abaqus by user subroutine named UMAT (used for mechanical behaviour) and UMATHT (used for thermal behaviour) for the convenience of engineering application. The material behaviour of wood composites subjected to combined thermomechanical loading has been analysed by the model and the code. A number of two-sided heating tests conducted on different material systems with different stack sequences of fibre orientation and different sample sizes have been simulated and the model has been verified and validated by comparing its results with other numerical results and experimentally measured data, presented by A. Menis in "Fire resistance of Laminated Veneer Lumber (LVL) and Cross-Laminated Timber (XLAM) elements. PhD Thesis, Università degli studi di Cagliari, Italy, 2012".

Key results — A numerical method has been developed to incorporate the effects of heat transfer in a Cross Laminated Timber (CLT) panel exposed to fire. The procedure has been added into the software package Abaqus as a user-defined subroutine (Umatht), and has been verified using both time-and spatially dependent heat fluxes in two- and three-dimensional problems. The aim is to contribute to the development of simulation tools needed to assist structural engineers and fire testing laboratories in technical assessment exercises. The accuracy of the used thermal properties and the finite element models was validated by comparing the predicted results with an available fire test in literature. It was found that the model calibrated to results from standard fire conditions provided reasonable predictions of temperatures within CLT panel exposed to fire.

Main conclusions including key points of discussion — A 3D finite element model is developed to solve the partial differential equations of heat conduction numerically. Accordingly, the user subroutine Umatht has been implemented in Abaqus code to define their thermal constitutive relations in the finite element calculation. According to the predicted results, the validity and effectiveness of Umatht are confirmed. This study lays a foundation for the modelling of fire performance of laminated timber members used in engineering structures.

Future perspectives — Further investigations are now in progress to extend these finite element models with the hope of simulating the thermomechanical behavior of timber structures using various geometrical and loading conditions and to provide more information for engineering applications used in timber construction.

Valorisation —

These developments have been awarded in several occasions, both nationally and internationally. Therefore, there is an obvious interest for the Labex to be associated to the related works, contributing to the promotion of these models and receiving back the acknowledgements in publications and in communications at international congresses.

[1] T.-T. Tran, M. Khelifa, A. Nadjai, M. Oudjene and Y. Rogaume. Modelling of fire performance of Cross Laminated Timber panels. Third European symposium on fire safety sciences (ESFSS2018), September 12–14, 2018 at Nancy, France

The manuscript is also considered for publication in the Proceedings that will appear in Journal of Physics: Conference Series.