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Numerical investigations on the thermo-mechanical behavior of steel-to-timber joints exposed to fire

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ABSTRACT

A three-dimensional finite element model is developed to predict the thermo-mechanical behavior of steel-to-timber doweled joints in tension parallel to grain exposed to fire. To manage the plastic yielding of the materials, the mechanical model is based on the von Mises criterion for steel and the Hill criterion for timber. In fire, the material characteristics depend on the temperature. Two different meshes are used for the thermal and the thermo-mechanical models. The thermal model is continuous, to take account of the thermal continuity between the joint components. The thermo-mechanical model is discontinuous, to consider the contact evolution between the joint components. The thermal model is used to predict the evolution of the temperature field inside the joint which depend on the gas temperature. It is validated on the basis of measured temperatures during fire tests. The complex transformations in wood during fire are represented by apparent values of thermo-physical characteristics proposed in the bibliography and calibrated on the basis of the experimental measurements. The mechanical model is validated by comparison with the experimental results of joints in normal conditions. The thermo-mechanical model is validated by considering the experimental failure times of some joints. The numerical models showed a good capacity to simulate the behavior of the timber joints in cold and in fire situations. These developed and tested models can be used as a general tool to analyze the behavior of a large variety of joint configurations to constitute a data base that can be used in safe and economic practice of fire engineering of wood joints.

1. Introduction

Exposed structural wood members are commonly used by architects and designers in modern buildings because of their pleasing appearance and environmental aspects. Thus, the wood material confirms the increase of its use in the construction activities. This development requires a high level of knowledge about the behavior of such timber structures in fire situations. In fact, as for the other materials, the timber structure must guarantee the fire resistance necessary to the evacuation of the building occupants by the rescue teams and a safe intervention of the fire fighters. As wood is a combustible material, fire safety represents an important area of investigation for the development of its use in construction. Timber structures exhibit a good behavior in fire. Indeed, wood burns in a controllable way so that it allows the estimation of its stability in fire when the evolutions of its physical and mechanical properties with temperature are known. Then, the resistance of the timber structure depends on the accuracy of the thermo-mechanical behavior of the structural components represented by the floors, the beams, the columns, and the connections.

In timber constructions, the connections are often the weakest zones among the various structural components. In fire situations as well as in normal conditions, they govern the bearing capacity and the mechanical behavior of the structure. Due to their complex geometrical, physical, and material configurations, the behavior of the connections in fire is one of the more difficult to predict. Although experimental and numerical studies exist in the literature [1–3], and although progress has been given by EN1995-1-2 [4] to the design of timber connections, large limitations still exist due to the lack of data. Besides, the design rules developed are based on a limited number of experimental or numerical results [2,3,5]. However, it appears essential, for the understanding of the mechanical behavior of timber connections in fire exposure, to use numerical models validated by testing. Indeed, the numerical models can be used, with limited cost, to study a large number of joints by varying different geometrical and thermo-mechanical parameters. In this context, many researchers [6–9] have initiated a numerical modeling approach to simulate the thermo-mechanical behavior of dowelled timber joints in fire

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