SEMI RIGIDITY OF TRADITIONAL TIMBER FLOORS – MODELLING ASPECTS OF HORIZONTAL DIAPHRAGMS FOR SEISMIC LOADING

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ABSTRACT: The determination of in-plane floor’s stiffness in timber structures allows predicting the distribution of the horizontal forces on the bracing system for seismic applications. Several studies developed mainly simplified numerical models to analyse the wood diaphragms but their domain of application remains limited. In this work, a new FEM modelling approach is proposed. It takes into account the non-linear behaviour of the joints, the contact evolution between the panels and the out-of-plan effect in the timber floors. The numerical model is validated by comparison with full scale tests results.

KEYWORDS: Timber floor, FEM Models, Contacts, Diaphragms, Non-linear joints

1 INTRODUCTION
Shear walls supporting floors and roofs is common system in constructions mainly for timber structures. Under horizontal loading, specifically seismic actions, the floors and roofs have to play the role of horizontal diaphragms. They transfer the horizontal loads to the foundations through the shear walls [1]. In this situation, the horizontal diaphragm with shear walls can be modelled using horizontal short beam on elastic supports (Figure 1) [2]. The distribution of the horizontal load on the shear walls represented by elastic springs is influenced by the relative in-plan stiffness of the horizontal diaphragm ($k_{\text{diaphragm}}$) in comparison with that of the shear walls ($k_{\text{sw}}$). Besides, the mechanical behaviour of the shear walls and the horizontal diaphragms, including the stiffness, is influenced by the non-linearities due to the mechanical joints and the contact evolution between the panels. Several studies have been carried out on different configurations of shear walls, but only few focused on timber floor as horizontal diaphragm [3, 4, 5]. This study presents a new FEM model able to take into account the effects of the nailed connections between the panels and the wood frame, the contact between the panels and the 3D effect mixing the in-plan and out-of-plan behaviours. The aim of the model is to represent accurately the behaviour of various configurations of wooden floors. Thus, the model provides data on the stiffness, the strength and the ductility of the wooden diaphragms. These parameters could be used as input data in the capacity design approaches developed in practice. Small scale tests are performed to provide the real local mechanical parameters of the components to be introduced in the model. The numerical model is validated by comparison with the results of full scale tests.

2 NUMERICAL FEM MODEL
The floor is modelled considering five basics components: the frame, the panels, the frame-panels connection, the chords assemblies and the contact between panels. The wood frame and the panels are modelled using beam and shell elements. The connection between the frame and the panels is modelled using a new approach based on non-linear beam elements (flexural springs). Each connector is
modelled by one vertical element considering the eccentricities between the panels and the frame [6] (Figure 2). The chords splice is modelled using axial non-linear springs. The evolution of the contact between the panels is considered using non-interpenetration conditions (Figure 3).

![Figure 2: Illustration of the panel-frame connection modelling](image)

3 EXPERIMENTAL AND NUMERICAL RESULTS COMPARISON

The numerical model is validated using the results of the experimental campaign on full scale timber floors (2.4x7.2m²) with two different configurations [7] and four points bending (Figure 4). In addition, tests on materials and connections are performed in order to calibrate the input data of the model [8].

![Figure 4: Full scale bending test of the timber floors](image)

Figure 5 shows the experimental and numerical load-deflection curves for one diaphragm. The experimental results highlight the non-linear behaviour of the floor. The comparison of numerical and experimental results shows that the FEM model represents well the global nonlinear behaviour of the floor. However, for a load under 75kN, the numerical model shows a slight underestimation of the global displacement. In terms of secant stiffness, the maximum difference for this model is 17% (for load of 30kN). A numerical parametric analysis shows that the overall behaviour of the floors is highly controlled by the mechanical properties of the panels and the connections between the frame and the panels.

![Figure 5: Experimental and numerical results](image)

4 CONCLUSIONS

The mechanical behaviour of timber floor diaphragms is influenced by many parameters such as the non-linear behaviour of the connections and the contact between the panels. The developed model takes into account the real behaviour of the materials and the connections including the in-plan and the out-of-plan effects. The model showed its capability to represent well the experimental behaviour. This validated model can be used to analyse various configurations of the diaphragms such as floors with hoppers or non-symmetrical floors. Besides, it can be used to analyse a whole building and evaluate the distribution of load in order to carry out a push-over test.

REFERENCES