AN IMPROVED METHOD FOR CALCULATING FORCE DISTRIBUTIONS IN MOMENT-STIFF TIMBER CONNECTIONS

Sigurdur Ormarsson¹, Mette Blond²

ABSTRACT: An improved method for calculating force distributions in moment-stiff multi-dowel timber connections is presented, a method based on use of three-dimensional finite element simulations of timber connections subjected to moment action. The study that was carried out aimed at determining how the slip modulus varies with the angle between the direction of the dowel forces and the fibres in question, as well as how the orthotropic stiffness behaviour of the wood material affects the direction and the size of the forces. It was assumed that the force distribution generated by the moment action taking place strives to minimize the slip rotation between the separate members of a given timber connection. The results of modified hand calculations and of the corresponding finite element calculations that were performed were found to agree rather closely, and to differ remarkably from the results of conventional hand calculations.

KEYWORDS: Timber connections, FE-simulations, slip modulus, orthotropic material

1 INTRODUCTION

Moment-stiff timber connections formed using multiple metal dowel fasteners are generally a highly critical factor in the design of large timber structures. In the case of complex timber connections exposed to mechanical loading and to changing climatic conditions, it is difficult to predict the stress distribution in the connections, in particular close to the fasteners. Interactions between the fasteners and the wood material involve primarily mechanical contact and friction. In conventional methods for hand calculations of the distribution of forces (in terms of their size and direction) within moment-stiff timber connections, no account is taken of the orthotropic stiffness properties of the material. In contrast, calculations of the load-carrying capacity of single-dowel joints performed in accordance with Eurocode 5 and based on a yield theory presented in [1] take the orthotropic stiffness behaviour of the wood material into account. In [2], force distributions within moment-stiff timber connections determined by use of conventional hand calculations were found to not correspond closely with results of advanced three-dimensional finite element simulations.

¹ Sigurdur Ormarsson, Department of Civil Engineering, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark. E-mail: sor@byg.dtu.dk
² Mette Blond, COWI, Parallelvej 2, DK-2800 Kgs. Lyngby, Denmark. E-mail: metteblond@hotmail.com

2 DOWEL-FORCE DIRECTION

To study how the dowel-force direction in moment-loaded timber connections is affected by the location of the dowels, a simple double-shear gusset plate connection having four dowels in each group of fasteners was analysed. It was investigated how the force direction changes when the locations of the dowels are varied along the circular path shown in Figure 1.

Figure 1: Double-shear gusset plate connections subjected to moment action.

The angle between the fibre direction and the position of the dowel, β, was varied from 5° to 85° in 5° increments. Simulations were done with a full three-dimensional analysis carried out in ABAQUS, the interaction between the fasteners and the wood material being modeled as involving surface-to-surface contact. The contact algorithm employed was based on a penalty formulation of the mechanical constraints allowing small
of the angle between the direction of the force and the fibre direction. In order to be able to refine the hand calculations it would be necessary to know how the slip modulus varies with the angle between the dowel force and the fibre direction. Figure 2 shows variations in the slip modulus found in numerical simulations of moment-loaded connections involving 4 bolts.

4 Refined Hand Calculations

The refined hand calculations obtained are based on the hypothesis that the optimum direction of the dowel force is reached when the dowel group rotation is at its minimum value. Figure 4 shows that the force direction calculated with the refined hand calculation method corresponds rather closely to that estimated on the basis of the numerical calculations.

5 Conclusion

It was shown that the dowel force distribution (in terms both of direction and of size) obtained for connections on the basis of numerical calculations differ from those obtained by means of conventional hand calculations. The differences are due to the conventional hand calculation method failing to take account of the wood materials orthotropic stiffness behaviour. Suggestions were made on how results obtained using the conventional hand calculation method could be improved, this involving a minimizing of the rotation that takes place in the connection. Although such an approach appears reasonable, a better understanding of the slip modulus is needed before it can be developed adequately.

References