TRADITIONAL TIMBER FRAMES

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ABSTRACT: Due to its new possibilities traditional timber framing has become increasingly more popular since the beginning of the 21st century. Although traditional timber framing has been used for centuries, the expected mechanical behaviour is not prescribed in building codes or guidelines or text books. Especially the behaviour of joints is of great importance, since the stiffness of the individual members is higher than the stiffness of the joints connecting the members.

This paper deals with experimental research related to traditional timber frame connections. Additionally the stiffness behaviour is modelled by which the mechanical behaviour of traditional timber structures can accurately be predicted.

KEYWORDS: timber, connections, energy balance

1 INTRODUCTION

Traditional timber frames is characterized by a long history. Early timber frames were made rigid by digging holes in the ground for the post to realise a moment resisting connection to the ground. This provides lateral support. A disadvantage is however that the posts rot quickly due to the hazardous environment they are in. To prevent this, posts were placed above ground level. Consequently bracing elements have to be added to the structure to provide lateral stability (creation of semi-rigid frames). This technique was further developed during the middle ages. When settlers immigrated to America, different styles from their home countries were mixed. The mixture of styles in combination with new materials and developments led to a new timber framing style. In all these construction types, mortise and tenon connections are commonly used.

During the industrial revolution, new inventions were made, which resulted into new timber framing methods. These methods met the high demands of that time, being quicker and cheaper as the method of traditional timber framing. As a result traditional timber framing was abandoned. Since the 1970s traditional timber framing has become increasingly more popular. Due to new techniques, production costs have been decreasing since the beginning of the 21st century and consequently traditional timber framing may play a more significant role in the future again.

Mortise and tenon connections are commonly used to connect semi-rigid frames, providing lateral support. Mortise and tenon connections subjected to tensile forces, show different failure modes and, perhaps even more important, lower stiffness than mortise and tenon connections subjected to compression forces. Different failure modes can be distinguished for each type of loading, depending on the dimensional parameters of the joint.

Several models have been developed to predict the strength and stiffness of mortise and tenon joints. The stiffness of the joint can be predicted by using the semi-rigid connection model, in which the contact between structural members and pegs are modelled as springs. The stiffness of these springs can either be determined by using experimental data or mechanical models and theories. In the latter case the peg stiffness is obtained by using a beam-model, the stiffness of the base material is obtained by using the bulb analogy. The bulb analogy is also used for determining the spring stiffness modelling the direct contact between two main members. Finally, the strength of mortise and tenon joints is predicted by using the adapted European Yield Model.

2 STRUCTURE STUDIED

The structure studied is illustrated in figure 1.
A number of experiments on structures as shown in figure 1 are conducted. The specimen were loaded in compression in the knee brace direction. For equilibrium reasons the beam at the joint is subjected to tensile forces.

3 ANALYSES

3.1 FAILURE MODES

The beam in figure 1 is subjected to a tension force. This results into a situation in which the tenon tends to be pulled out of the post and a couple of possible failure modes are observed and described: (1) large peg deformation in bending or shear, (2) a block shear failure of the tenon, (3) wedge tear out and (4) splitting of the beam end near the wedge.

Two additional failure modes are related to the compression in the brace knee: (5) crushing of timber loaded perpendicular to the grain and (6) peg failure in bending or shear.

3.2 STIFFNESS

For the stiffness of the structure shown in figure 1, the structure is schematised as shown in figure 2; linear springs are defined.

The analyses is carried out using an energy balance formulation saying that the internal energy stored in the several springs + the internal energy stored in bending and shear of post and beam equals the work done by the external loading. The calculation of the energy stored in the different elements is based on load-slip analyses of different stress component experiments (e.g. perpendicular to the grain tests, embedment tests, etc.). The work done by the external load calculated by multiplying the load by the load displacement.

4 CONCLUSIONS

As expected, the performance of structure is very sensitive to manufacturing tolerances and shrinkage. The failure modes studied and the energy stored are very dependent on the flexibility of the system which is mainly governed by the connection flexibility.

The model analyses described in 3.2, being linear elastic analyses, seems to perform fairly well up to the load level where proportionality can be expected; for higher load levels, non-linear response is expected which is described by the model less accurately.

REFERENCES