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Embedment mechanism in wooden joints and collapse simulation of traditional wooden frames with column-tie beam joints

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SUMMARY

There are many traditional wooden buildings, such as temples and shrines in Japan. Some of them are involved in cultural heritage. Rational seismic evaluation for such traditional wooden buildings is the most important in order to mitigate probable damages caused by great earthquakes in the near future. Therefore, establishing the evaluation method and appropriate seismic reinforcements are urgently required for conservation.

The major seismic resisting elements of the traditional wooden buildings are restoring forces of column rocking, rotational resistances of column-tie beam joints and shear resistances of mud/wood walls. Among them, in general, the column-tie beam joints show the most ductile restoring force characteristics due to embedment and friction at the contact interfaces inside the wooden joints, though their rotational stiffness is rather small. Therefore, the authors made clear the yielding and hardening mechanism of compression and embedment of wood perpendicular to the grain,

Then, the authors proposed Elasto-plastic Pasternak Model (EPM) formulation of the column-tie beam joint, considering the orthotropic properties of wood and the strain softening /hardening behaviour of lateral compression.

However, there are many types of column-tie beam joints which may differ in mechanisms and deformability. Thus, they are classified into some major types and their mechanisms are discussed from a viewpoint of stiffness, strength and deformability. Then, the restoring force characteristics are confirmed by experiments of some major types of joints and simulated by the EPM formulation.

Moreover, the authors formulate the restoring force characteristics of frames with column-tie beam joints, including the deformations of joints and frames. Thick columns have some resistances for horizontal force due to rocking of the column as the positive $P-\Delta$ effect when the horizontal displacement is small. However, if the horizontal displacement increases, the effect leads to collapse of the frame as the negative $P-\Delta$ effect. Thus, the authors consider such effects consistently from small to large deformations. The total restoring forces are obtained by accumulating those of all column-tie beam joints and column rocking resistances.

On the basis of above formulation, collapse simulations of traditional wooden frames are discussed with full scale static and dynamic loading test results. As a result, among many types of column-tie beam joints, the column-*Nuki* joint which penetrates through columns completely has the largest deformability and plays the most significant role for preventing frames from collapse.

Fig.1 Grand Gate of Itsukushima Shrine:
Typical column-*Nuki* joint

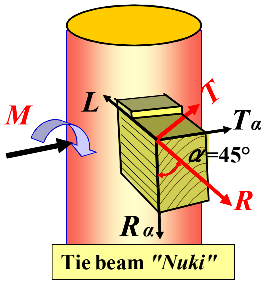

Fig.2 Column-*Nuki* joint

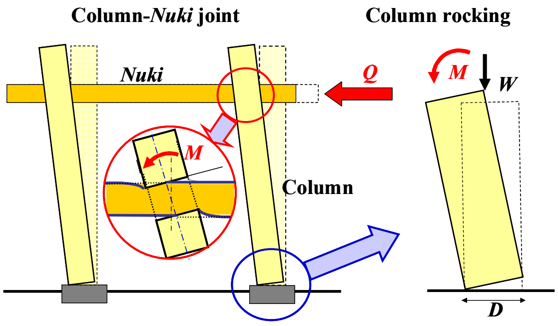

Fig.3 Mechanical model of the column-*Nuki* join
and column rocking resistance

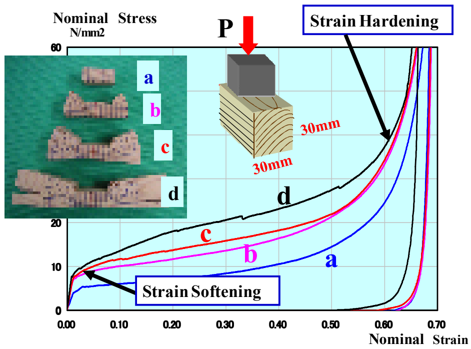

Fig.4 Strain softening/hardening of
wood in lateral compression

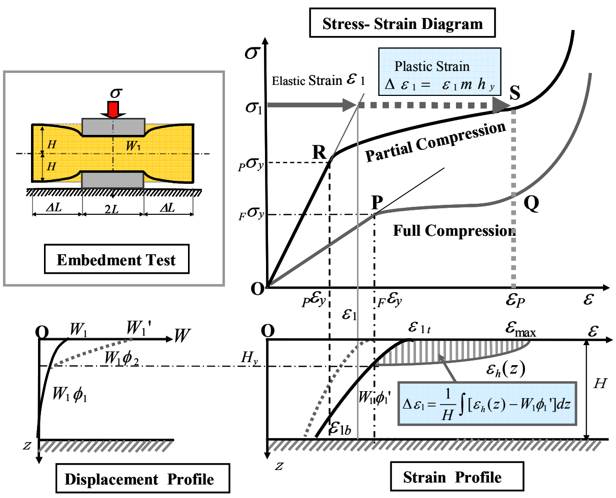

Fig.5 Compressive yielding mechanism of wood
perpendicular to the grain

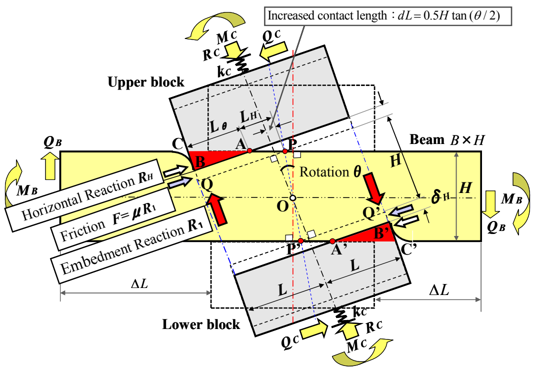

Fig.6 General mechanical model of
column-tie beam joint