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Citation	Sustainable humanosphere : bulletin of Research Institute for Sustainable Humanosphere Kyoto University (2013), 9: 25-26
Issue Date	2013-10-31
URL	http://hdl.handle.net/2433/185660
Right	
Type	Departmental Bulletin Paper
Textversion	publisher

Sustainable Humanosphere, vol. 9, p.25-26, 2013

ABSTRACTS (PH D THESIS)

Application of axial performance of pulled-out screw for joint of wooden structure

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A screw is one of the most used fasteners in wooden structure recently. Since the joint with screws has high joint performance and is easy to be dismantled and repaired, it attracts timber engineers' attentions. Especially, nowadays, by using screws improved on its thread shape and size for higher shear and pull-out performance, many joint methods have been developed. However, the performance of the stiffness, maximum strength and failure property of the joint changes variously by not only the shape or number of fasteners, but also the cross-section of a wooden member where the load is applied and the shape of steel plates used around the fasteners. The structural design method corresponding to these conditions has not been established at present. The relationship between the load and displacement of pull-out screw is essential factor to establish the design method, however, it has not been explained well yet. So the design equations are inadequate.

The shear and pull-out performance of the screw have not been evaluated by accounting the shape and diameter of the screw. There are not the suitable equations of stiffness and strength corresponding to the case that the screw with any shape was pulled out from the wood member. Therefore, aiming to apply screws into the joint of the wooden structure more easily, the quantitative evaluation of the screw performance had been conducted in this study considering the case they are sheared or pulled-out. And as an application, the evaluation method for the joints of the wooden structure with screw was established.

As the first step of analysis, estimation by the finite element method (hereinafter called "FEM") was conducted to compare with the experimental results. Fig.1 shows the elastic FEM model for pull-out tests of screws, which was inserted into perpendicular to the grain of wood. The stiffness of the results of FEM were much higher than that of the experimental results. The peculiar deformation of wood under contacting surface with screws was considered as reason. Therefore, the surface deformation was evaluated by the compression tests in the direction of perpendicular to the grain of wood. The surface deformation is quantitatively derived from the difference between the apparent young's modulus obtained from the total strain and the true young's modulus obtained from the strain gage put at the center of the wood surface. By combining the deformation with the result of FEM, the stiffness of the test result was expressed well.

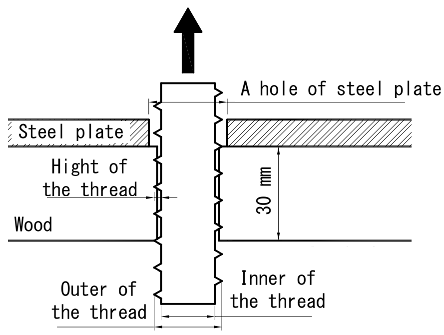

Fig. 1 Outline of test of pull-out screw

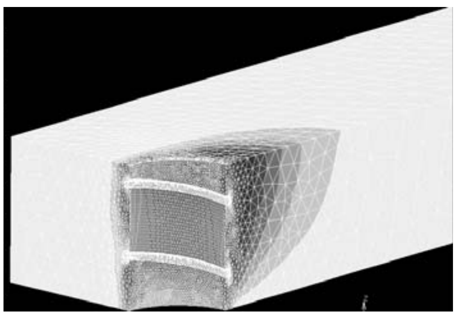

Fig. 2 Deformation distributions in radial direction in FEM

The calculated yield strength derived from the design method on the yield strength by Madsen [1] and Embedment Theory [2] showed good accordance with the test results of the pull-out tests. Therefore it was concluded that the yield strength can be decided by the projected area of the thread, the interval of the thread and the embedment-yield stress of the wood. The maximum strength could be estimated by the reduction of the multiplication of the shear area by shear strength. It was suggested that the ultimate displacement is equal with the interval of the screw thread.

As the next step, by using the characteristic values of pull-out performances of the screw, the method to improve the compression performance in the direction of perpendicular to the grain of the wood was investigated. Here, the pull-out performances of the screws was regarded as the push-in performance of them. It was considered that the screws can reinforce wood by embedding together. Fig.3 shows the models of the area where the screws are to be inserted. The performance of the joint on the wooden structure becomes much higher by improving embedment performance. It is because that the strength of the joint is decided by the wood deformation perpendicular to the grain. The equations to predict the reinforcement effect of a screw were derived. Then, the performance of the joint was predicted. The predicted results showed good agreements with the experimental results as shown in [3] and [4].

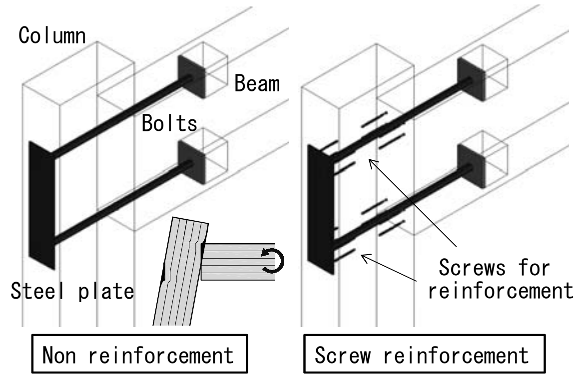

Fig. 3 The models of area where the screws are to be inserted

Finally, by taking the equation of the pull-out screw mentioned above into considerations, the performance of the screw deformed in the wood by shear force was estimated until reaching at the maximum strength. Thus, the performance of structural components of the building such as shear wall is also predicted by using the equation. Fig.4 shows a single-braced shear wall system composed of the joint with the screws. To improve the performance of the end joint of the brace, thick and short screws were effective in terms of transmitting the force into brace-steel-plate. The shear performance of the developed brace system was improved in both loading directions. Consequently, the shear wall showed 3.5 and 3.8 of the shear resistance factor against compression and tension force respectively as indicated in [5].

Fig. 4 Appearance of Shear wall test and its joint

The above-mentioned findings caused not only the improvement of the reliability on the design of the joints with the screws, but also the significant information to promote the more desirable joints.

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