LOAD-CARRYING CAPACITY OF A BUILT-UP STUD FABRICATED WITH SMALL-DIAMETER ROUND TIMBER

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ABSTRACT: Small-diameter round timber is a forestry by-product mainly from thinning of the artificial forest. It is not suitable for direct use as structural members due to the low quality. To make use of the by-product, a built-up stud fabricated with small-diameter round timber was proposed in this paper and was intended to be employed in a shear wall for light wood frame construction. The load-carrying capacity of the built-up stud was investigated experimentally by testing of the specimens under axial compression and testing of the specimens under eccentric compression, respectively. To predict the load-carrying capacity considering buckling, the equation for the modified slenderness ratio of the stud was derived. The predicted load-carrying capacity using the modified slenderness ratio correlated with the test very well. Some suggestions were then given to enhance the load-carrying capacity of the built-up stud. The study provides reference for incorporating the small-diameter round timber into a shear wall of light wood frame construction and thus promotes the application of small-diameter round timber as structural members.

KEYWORDS: Small-diameter round timber, load-carrying capacity, built-up stud, slenderness ratio

1 INTRODUCTION

The small-diameter round timber, referring to the logs with a diameter between 40mm and 160mm in Northeast China or 4cm and 14cm in the rest part of China according to the corresponding code[1], is a forestry by-product mainly from the thinning of the artificial forest. A large quantity of small-diameter round timbers is produced every year, which accounts up to 44% of the total of wood supply. It is not suitable for the small-diameter round timber to be used directly as structural members due to various kinds of natural defects, yet it is not economical to use it merely as raw material for other products.

Light-frame construction is used extensively in the European, American and Australasian market for low and medium rise timber buildings. These buildings are lightweight and with high energy-dissipation capacity due to the ductile behavior of the shear walls, which are made of light frames (stud, top and bottom plates) and sheathing boards nailed together. The cross-sectional area of small-diameter round timber and the dimension lumber are both quite small, a built-up stud fabricated with small-diameter round timber was proposed in this paper and was intended to be employed in a shear wall similar to that made of dimension lumber stud. This is an effort to enhance the efficiency of application of the small-diameter round timber.

Twelve specimens, each consisting of three built-up studs, were manufactured. Six of these were tested under axial compression and the other six were tested under eccentric compression. The equation for the modified slenderness ratio of the built-up stud was then derived, in consideration of shear deformation of the limbs of stud, deformation of the U-shaped nails and the slip of connection between the U-shaped nails and the stud. The load-carrying capacity of the stud with buckling being addressed was predicted based on the modified slenderness ratio, and the predicted result correlated with the test very well. Some suggestions were then given to enhance the load-carrying capacity of the built-up stud. This study provides reference for incorporating the small-diameter round timber into a shear wall of light wood frame construction and promotes the application of small-diameter round timber as structural members.

2 FORMATION OF THE BUILT-UP STUD

As shown in Figure 1, a built-up stud is comprised of two limbs of small-diameter round timber and U-shaped nails are used to link the two limbs. A piece of small-diameter round timber is sawn into two halves to form two semicircle limbs, or it is cut along one side to form one
limb. The U-shaped nails are applied to both sides of the limbs, the angle between the axis of the nails and the stud is about 45 degrees.

![Figure 1: Formation of a built-up stud](image)

(a) Plan view  (b) Section A-A

3 TEST OF THE LOAD-CARRYING CAPACITY OF THE STUD

The wall-type built-up stud model was fabricated with 3 built-up studs, as shown in Figure 2. The stud in the test model can only bend outside the wall plane under vertical load.

Vertical load was applied to the test model via two one-way steel hinges, each installed to one end of the model. By moving the hinge plate to intended position, the vertical load was applied either axially or eccentrically. In order to measure the lateral displacement of test model, 6 LVDT’s were employed. Another 2 LVDT’s were used to measure the vertical displacement.

11 of 12 models buckled under vertical load. The average load-carrying capacity of the stud under axial load was 24.62 kN, of stud under eccentric load was 21.95 kN.

4 PREDICTION OF THE LOAD-CARRYING CAPACITY OF THE STUD

To predict the load-carrying capacity of the built-up stud, the modified slenderness ratio of the stud needs to be worked out. The shear deformation resulted from bending of the limbs, deformation of the U-shaped nails and slip of connections between the U-shaped nail and the studs was taken into consideration. The derived equation is given as

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\lambda_0 = \sqrt{\frac{\pi^2}{12} \lambda_1^2 + \frac{\pi^2}{\sin^2 \alpha} \frac{E_w A}{E_s A_d} + \frac{\pi^2 E_w A}{\sin^2 \alpha K l}}
\]

where \(\lambda_0\) = the modified slenderness ratio; \(\lambda_1\) = unmodified slenderness ratio; \(\lambda_s\) = slenderness ratio of limbs; \(\alpha\) = the angle between the U-shaped nail and the stud; \(E_w\) = modulus of elasticity of wood; \(E_s\) = Young’s modulus of steel; \(A\) = the cross-sectional area of stud; \(A_d\) = the cross-sectional area of the U-shaped nail; \(K\) = the slip stiffness of the connection between the U-shaped nail and the stud and \(l\) = length of the U-shaped nail.

Using Equation (1) and the equations given by GB50005-2003[2], the load-carrying capacity of the stud was predicted either under axial load or eccentric load, which was 24.40 kN for axial compression and 21.08 kN for eccentric compression, respectively. The prediction correlated with the test very well. From the derived Equations (1), it can be found that to increase the slip stiffness of the connection between the U-shaped nail and stud is the most effective way to reduce the value of the modified slenderness ratio and thus enhance the load-carrying capacity of the stud.

5 CONCLUSIONS

A built-up stud fabricated with small-diameter round timber was proposed and the load-carrying capacity of the stud under axial load or eccentric load tested. The equation for the modified slenderness ratio was then derived to predict the load-carrying capacity of the stud. The work provides reference for incorporating the small-diameter round timber into a shear wall for light wood frame construction and promotes the application of small-diameter round timber as structural members.

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REFERENCES
