I －20 BUCKLING OF STEEL-GLUED LAMINATED TIMBER COLUMN

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1. Introduction

Advanced methods of timber construction utilizing composite reinforcements may allow the use of timber in more efficient structural applications. King post truss bridge is a classical type but it has advantages of reducing the bending moment of beam and of using upper chord members as compression members. If chord members are reinforced by high strength materials, the load carrying capacity for buckling could be improved. In addition, the cross sections of the members could be reduced and more larger length of span will be realized.

In the present study a new type of glued-laminated timber column having longitudinal four steel plates inserted vertically into the middle of four surfaces of square cross section and glued by epoxy resin as shown in Fig. 1. In this case the structure has good looking in the aesthetic point of view as well as has high load carrying capacity. Formulas for estimating buckling strength in elasto-plastic columns are presented by using energy method. The predicted buckling load was compared with experimental one and predicted one found within lower limit.

2. Stresses of Columns

In a composite column, as shown in Fig. 1, of axially compression condition by applied force P, the relation between the stresses of steel (σ) and timber (F) can be defined as

$$\sigma = \frac{E_s}{E_w} F \tag{1}$$

It is assumed that the Young's moduli of steel (E_s) and timber (E_w) governing the stress strain relation are expressed by Hook's Law and in the case of plastic state, stresses can be obtained by using following tangent modulus[1)] of steel (E_{ts}) and timber (E_{tw}) as

$$E_{ts} = \frac{d\sigma}{d\varepsilon} = E_s \left\{ 1 - \left(\frac{\sigma - \sigma_p}{\sigma_y - \sigma_p} \right)^2 \right\} \tag{2.a}$$

$$E_{tw} = \frac{dF}{d\varepsilon} = E_w \left\{ 1 - \left(\frac{F - F_p}{F_c - F_p} \right)^2 \right\} \tag{2.b}$$

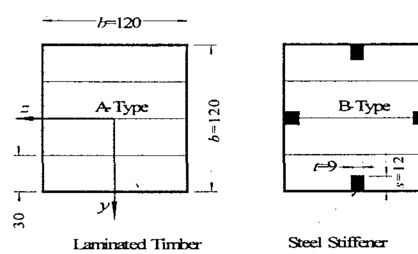

Fig. 1 Cross Section of Composite Columns

where, stress σ_p is proportion to elastic limit and σ_y is yield stress of the steel and σ ranges between σ_p and σ_y where as stress F_p is within elastic limit and F_c is stress in compression of the timber and F ranges between F_p and F_c.

3. Buckling Analysis

In the case of composite column in elastic state, Young's modulus of steel and timber governs the stress-strain relation as in Eq. (1). In the case of plastic state, increment stress-strain relation is obtained using the tangent modulus stated in Eq. (2) and, finally, the following buckling equation in case of both end pinned composite column in elasto-plastic states can be obtained by employing energy method.

$$P_i = \frac{\pi^2 E_{wi} I_{vi}}{(l)^2} \tag{3}$$

where, $$I_{vi} = I_w + \frac{E_{si}}{E_{wi}} I_s \tag{4}$$

In above equations, i = 1 to 3 indicate for buckling of timber and steel in elastic (W.el-S.el) state, timber in elastic and steel in plastic (W.el-S.pl) state and both timber and steel in plastic (W.pl-S.pl) state. E_{si} and E_{wi} are obtained by

$$E_{s1} = E_s\,,\quad E_{s2} = E_{s3} = E_{ts} \quad \text{and} \quad E_{w1} = E_{w2} = E_w\,,\quad E_{w3} = E_{tw} \tag{5.a,b}$$

where, E_{ts} and E_{tw} are given in Eq. (2).

Timber buckling (F_k) and steel buckling (σ_{cr}) equations can separately be written as

$$F_k = \frac{\pi^2 E_{wi}}{\lambda^2},\quad \sigma_{cr} = \frac{\pi^2 E_{si}}{\lambda^2} \tag{6.a,b}$$

λ is slenderness ratio and defined by $\lambda = \dfrac{l}{r}$

where, l is length of the column and r is ratio of gyration as

$$r = \sqrt{\frac{I_{vi}}{E_s / E_w A_s + A_w}}$$

4. Experimental Verification

Average coefficient of Young's modulus E_{yy} is used for the timber as $E_w = E_{yy} = 96.7$ tf/cm^2 by carrying out the bending test and the Young's modulus for the steel (E_s) of SS400 is used as 2.1×10^6 kgf/cm^2.

The graph between buckling strength (P_{cr} or P_k) and slenderness ratio λ for different cross sections are presented in Fig. 2. The buckling strength is being higher as increasing the width of the steel stiffener as shown in Fig. 2.

Comparison has made between the calculated values by present method and tested results of buckling strengths of 28 numbers of 4-types of columns as shown in Fig. 1 and only the results of A-type and B-type of columns are presented in Fig. 3. The figure shows that buckling curve of present method lies below the buckling curve derived by Usuki et al[2] in the case of stiffened column. The average value of ratio of all test results and calculated values is 1.10, which shows the closeness of the calculated values and the test results.

5. Conclusions

The average value of ratio of test results and calculated values is 1.10, which shows the closeness of the present analysis and test results. The performance of glued-laminated timber column loading can be significantly improved by using steel stiffener maintaining the aesthetics of the glued-laminated timber column.

6. References

1. Watanabe, N. (1974), "Structural Engineering 3; Buckling Theory", *Ashakura Book Store*, 1974.
2. Usuki, S., Sharma, M.P., Iijima, Y., Sasaki, T. and Hasebe, K. (2000), "Load-carrying Capacity of Steel –glued Laminated Timber Composite Column", *J. Structtural Engrg., JSCE*, vol. 46A, 217-228.

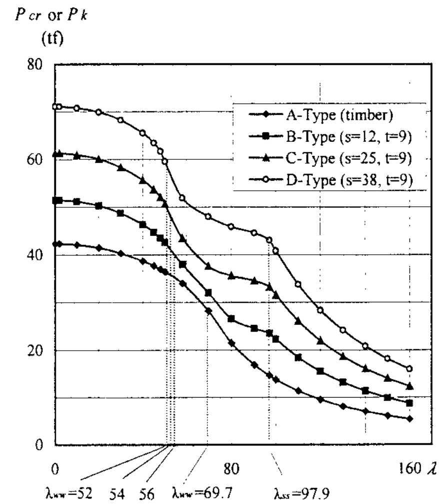

Fig. 2. Buckling Strength of Columns

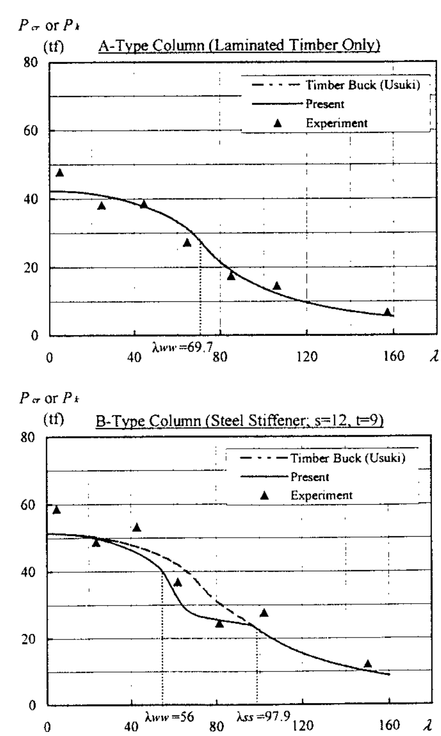

Fig. 3. Comparison of Buckling Strength Results