EASEC-6：第６回東アジア構造工学会議（1998年1月）

鋼板と鋼床版で補強したＳＷ桁の破壊載荷実験について

On Experimental Study of Steel Stiffened Wooden Beams

Noboru Watanabe[1], Seizou Usuki[2], and Osamu Watanabe[3]

1)Depertment of Civil Engineering, Hokkaido University, Sapporo, Japan
2)Depertment of Civil Engineering, Akita University, Akita, Japan
3)Civil Sekkei Consultant Co.Ltd., Kawasaki, Japan

ABSTRACT

This paper reports the experimental results of steel stiffened laminated lumber beams. All laminated lumber beams used in this experiment were 10.8m long and had cross sections of 40cm by 80cm. *Specimen No.1* was not stiffened with steel. *Specimen No.2* was stiffened with two steel plates: one was inserted in the top of the wooden beam and the other was inserted in the bottom. *Specimen No.3* was stiffened with steel plate and orthotropic steel deck. The steel plate was inserted in the bottom of the wooden beam and the orthotropic steel deck was put on top of the beam by connecting mutually with shear connectors. All specimens were measured stress-strain and centrl deflection of the beam using 100-ton and 600-ton capacity compression testing machines.

INTRODUCTION

Steel stiffened wooden continuous beam bridge, namely SW Continuous Beam Bridge, is stiffened with steel plate and orthotropic steel deck as shown in Fig.1. The steel plate is inserted in the bottom of the wooden beam and the orthotropic steel deck is put on top of the beam by connecting mutually with shear connectors. Laminated lumber and steel plates are united with adhesive epoxy glue. Merits of SW Continuous Beam Bridge are as follows:

(1) The SW Continuous Beam Bridge, compared to prestressed concrete bridge and previous wooden bridge, proves to be the most economical structure.

(2) Utilizing orthotropic steel deck, the SW Continuous Beam Bridge is designed to accomodate the burden of full 25-ton trucks and can be expected to have a life span of greater than one hundred years.

(3) The laminated wooden beams are protected from corrosion by the steel deck which provides an surface impervious to rain. As this protection eliminates the need for an artifical preservative to be applied to the wood, the SW Continuous Beam Bridge is not harmful to the environment.

(4) Because the pre-tensioned concrete bridge does not allow for a continuous beam, the number of joints is inherently large. The SW Bridge, on the other hand, takes advantage of the steel deck to provide for a continuous beam, resulting in a strong to negative bending moment.

(5) The lightness of the SW Bridge (the specific gravity of wood is 0.6 and that of concrete is 2.4) is influenced less by earthquakes and allow for foundations which, economically, compare favorably to those of the concrete bridge.

(6) The speed of construction is much quicker than that of the post-tensioned concrete bridge whose construction must be done by hand on site where, additionally, quality control is difficult.

(7) The cost of changes or dismantlement in the future are economical compared to those of the concrete bridge. Houryu-ji temple in Nara demonstrates the durability of wooden structures, and both the wood and steel used for the SW Bridge are recyclable.

(8) The main beam of the SW Bridge is wood which, if the handrail is also of wood, gives the entire bridge the appearance of a wooden structure, therefore the SW Bridge gives soft and warm image.

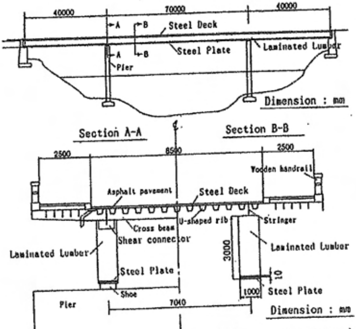


Fig. 1 Steel stiffened wooden bridge (SW Bridge)

TEST SPECIMENS

All laminated lumber beams used in this experiment were 10.8m long and had cross sections of 40cm by 80cm. Specimen No.1 was not stiffened with steel. Specimen No.2 was stiffened with two steel plates: one was inserted in the top of the wooden beam and the other was inserted in the bottom. The steel plates were 10.8m long and had cross-section of 2cmx30cm. Specimen No.3 was stiffened with steel plate and orthotropic steel deck. The steel plate was inserted in the bottom of wooden beam and the orthotropic steel deck was put on top of the beam by connecting mutually with shear connectos. Laminated lumber and steel plates are united with adhesive epoxy glue. The tests were performed with simple support conditions. Strain gauges were placed at suitable locations to measure stress-strain in each specimens. All specimens were tested using 100-ton and 600-ton capacity compression testing machines. The central deflection of the beam was measured using dial gauges.

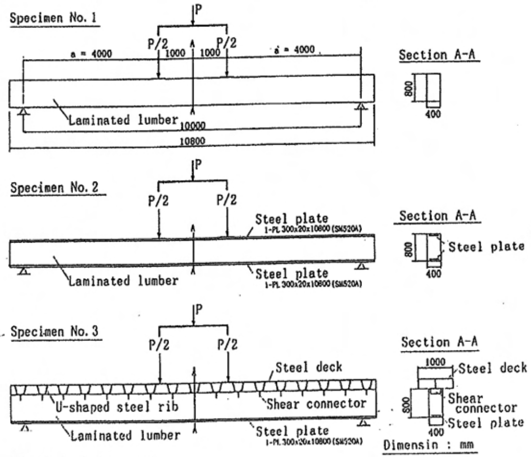
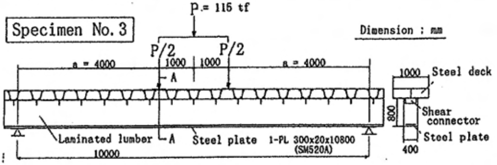


Fig. 2 Test specimens

COMPARISON OF ANALYSIS AND EXPERIMENTS

Analytical stress distribution of the specimen No.3 applied P=115 tf are shown in Fig.3. When young's modulus of steel E_s=2.1x10^{6}kgf/cm^2, young's modulus of laminated lumber E_W=1.05x10^{5}kgf/cm^2, and the ratio E_W/E_s =1/20, the bendingstress of wood is 1/20 times as much as steel at the border with steel as shown by point a or point b in Fig.3.



Stress distribution at section A-A (P=115 tf)

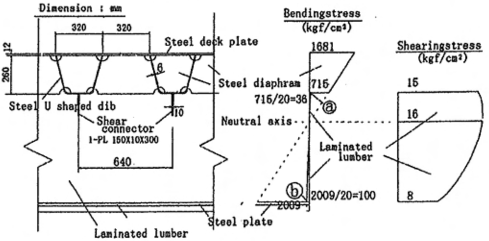
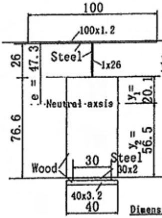


TABLE 1. Allowablestress (kgf/cm^2)

Laminated lumber:Tension	65 - 110
Laminated lumber:Shear	9 - 12
Steel:Tension	1400(SM400)-2100(SM520)
Steel:Shear	800(SM400)-1200(SM520)

Fig. 3 Analytical stress distribution of specimen No. 3



Dimension:cm

	A (cm²)	y (cm)	A·y (cm³)		A·y² (cm⁴)
100x1.2=	120	0.6	72.0		43
				(1/12)x100x1.2³=	14
1x26=	26	14.2	369.2		5243
				(1/12)x1x26³=	1465
40x76.6x(1/20)=	153.2	65.5	10034.6		657266
				(1/12)x40x76.6³x(1/20)=	74909
30x2=	60	104.8	6288.0		658982
				(1/12)x30x2³=	20
40x3.2x(1/20)=	6.4	107.4	687.4		73822
				(1/12)x40x3.2³x(1/20)=	5
	368.6		17451.2		1471769

$e = 17451.2 / 368.6 = 47.3$ cm

Steel eqivalent Momet of Inertia : $I_S = 1471769 - 47.3^2 \times 368.6 = 647104\ \mathrm{cm}^4$

Flexural Rigidty: $EI = E_S \cdot I_S = 2.1\times10^6 \times 647104 = 1.35\times10^{12}\ \mathrm{kgf\cdot cm^2}$

$P = 115$ tf , $P/2 = 57.5$ tf, $Q = 57.5$ tf, $M = 57.5\times4.0 = 230$ tf·m $= 2.3\times10^7$ kgf·cm

$\sigma_e = M\cdot e / I_S = 2.3\times10^7 \times 47.3 / 647104 = 35.54\times 47.3 = 1681\ \mathrm{kgf/cm^2}$

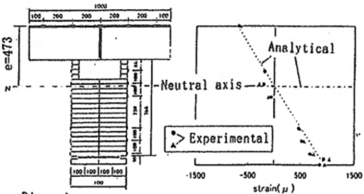
$\sigma_{1s} = M\cdot y_1/I_S = 35.54\times 20.1 = 715\ \mathrm{kgf/cm^2}$, $(\sigma_{1w} = 715/20 = 36\ \mathrm{kgf/cm^2})$

$\sigma_{2s} = M\cdot y_2/I_S = 35.54\times56.5 = 2009\ \mathrm{kgf/cm^2}$, $(\sigma_{2w} = 2009/20 = 100\ \mathrm{kgf/cm^2})$

$\tau_N = (Q/I_S)(S_N/t) = (57500/647104)(100\times1.2\times46.7 + 1\times26\times33.1 + 40\times20.1/20\times20.1/2) / 40$

$= 16\ \mathrm{kgf/cm^2}$

Strains at spancenter of specimen No.3 are shown in Fig.4. Analytical values are in good agreement with the experimental results.



Dimension: mm

Fig. 4 Strains of specimen No. 3

Load-deflection curves of three test specimens are shown in Fig.5 and Fig.6. Fig.5 is experimental, and Fig.6 is analytical. Specimen No.3 with elastic shear connectors in Fig.5 is more flexible than specimen No.3 in Fig.6. Allowable loads of three specimens are P_{a1} =22.4tf, P_{a2}=64.8tf, and P_{a3}=115.0tf.

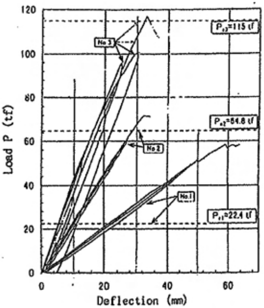


Fig.5 Load-deflection curves

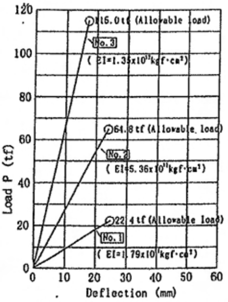


Fig.6 Analytical load-deflection relationship

CONCLUSION

The results of experimental study are as follows:

(1) Steel stiffened wooden beam has high flexual rigidity in comparison with previous wooden beam.

(2) When young's modulus of steel E_S=2.1x10^{6}kgf/cm^2, young's modulus of laminated lumber E_W=1.05x10^{5}kgf/cm^2, and the ratio E_W/E_S=1/20, the bendingstress of wood is 1/20 times as much as steel at the border with steel as shown by point a or point b in Fig.3.

(3)Allowable load of the steel stiffened wooden beam is determined dy bending- and shearingstress of wood at point b shown in Fig.3 comparing with the allowablestress of TABLE 1.