I −46　A Trial Design of Steel Deck-Glulam Timber Beam Bridge

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1. Bridge concept

The ratio of beam height versus span length is a very important aspect in the design of beam bridges. Choosing carefully this ratio to be comparable to ratios of other types of bridges helps making the timber bridge a viable option for bridge building. The authors proposed a glued laminated timber and orthotropic steel deck hybrid beam bridge structure, for short and medium span bridges, using Douglas fir glulam main beams and ⊥-shaped steel floor beams, with a height-span ratio of h/L = 1/16.

For aesthetic reasons, the authors decided to design a similar bridge, but instead of using Douglas fir for main beams and steel for floor beams, Japanese cedar was considered as the material for both, resulting in a height-span ratio of h/L = 1/17.

2. Bridge system

The cross section of the new hybrid bridge is shown below, in Fig.1. The structure consists of an orthotropic steel deck, attached to two double glulam main beams. The orthotropic steel deck plate has a total length of 15.6 m (span is 15.0 m) (see Fig.2), a width of 6200 mm and a thickness of 12 mm. The deck plate is stiffened by eight U-shaped longitudinal ribs and seven double glulam floor beams of size 180x750 mm each, the latter being arranged with an interval of 2500 mm. The steel deck acts as the top flange of the main beams, having rectangular cross sections. The beam width of a single beam varies from 180 mm to 280 mm at near beam-ends, in order to overcome shear forces developed by reactive forces on the support. The beam depth remains constant, being equal to 900 mm.

The main beams are stiffened by two, vertically inserted, glued-in ribbed steel plates. The size of the upper ribbed plate is 10x130 mm, while the lower one has a cross section of 32x210 mm. After removing mill scale by sandblasting, these steel plates are bonded by epoxy resin. The upper inserted steel plates serve as shear connectors between the deck and the main beams, while the role of the glued-in ribbed steel plates on the lower surface of the beams is to compensate the longitudinal axial strength of beams. Thus a part of the steel deck with effective widths λ_1 = 715 mm and λ_2 = 1730 mm (obtained by applying the Japanese shear lag formula for roadway bridges), the ribbed steel plates and the double glulam beams form a composite beam, therefore the composite beam theory can be used to calculate the bending and shear stresses in the beams.

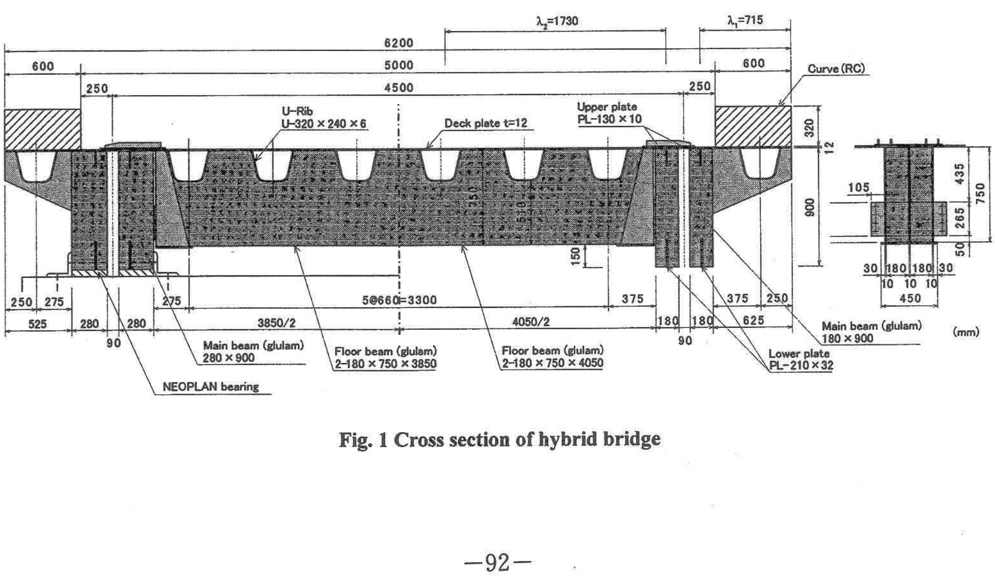

Fig. 1 Cross section of hybrid bridge

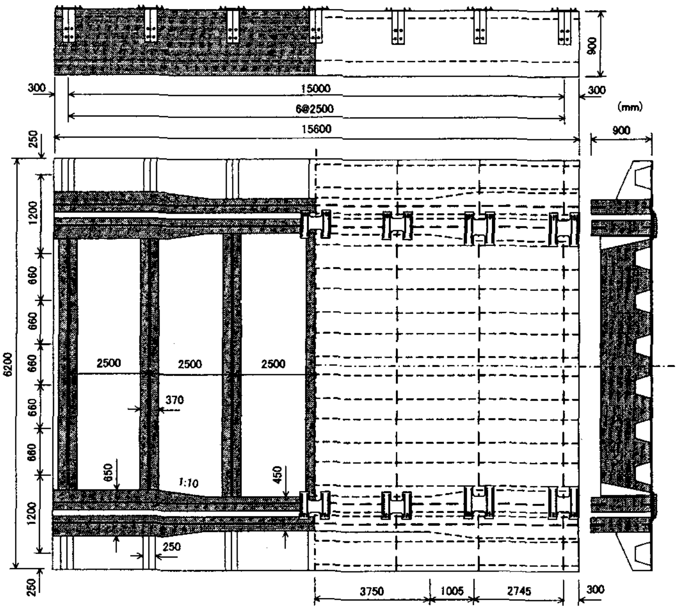

Fig. 2 Side and plan view of hybrid bridge

3. Bridge design

The glued laminated timber material used was Japanese cedar of strength grade E85-F255, while the steel material was SMA400. The value of bending moment capacity of glulam is $\sigma_{y,W}$ = 25 MPa, while the allowable bending stress is equal to 1/3 of this value, i.e. F_b = 8.3 MPa. For design purposes, determined by a size factor, a modified allowable bending stress is used, F_b' = 7.4 MPa. The allowable shear stress is F_V = 0.9 MPa. The Young's modulus of glulam is taken as E_W = 8.3 GPa. The steel material has a yield strength of $\sigma_{y,S}$ = 235 MPa, the allowable bending stress being σ_{ba} = 137 MPa and the modulus of elasticity equals E_S = 206 GPa.

The testing of a 1/3 model will follow the design of the above prototype bridge. The prototype bridge was designed using the concept of transformed section and converting all steel to an equivalent wood area. In order to obtain this modified section, first the ratio of moduli of elasticity is calculated, being $n = E_S / E_W = 25$.

The design bending moment occurs at the midspan of double glulam main beams, having the value M = 1522 kNm. The corresponding maximum bending stress at the bottom of glulam beam is 5.2 MPa and at the bottom of lower inserted steel plate is 130 MPa, both values being under the allowable bending stresses. The neutral axis of the composite section is determined in a way that it lies below the bottom of U-ribs, i.e. the U-ribs are designed to be under compression.

The transverse shear force is checked at a distance from the support, being equal to the depth of the double main beam. The design shear force is V = 376 kN. The cross section of the double main beam considered at this point is changed to an axisymmetric cross section with an equivalent deck plate thickness t' = 13.9 mm. The maximum transverse shear stress of 0.9 MPa occurs at the centroid of this cross section, being equal to the allowable shear stress of glulam. The horizontal shear stress acting on the surface of the inserted steel plate (assuming to have a linear distribution in the direction of plate depth) is also obtained. Its absolute maximum value of 0.4 MPa occurs at the bottom of lower plate, being lower than F_V.