Ultimate Strength Evaluation for Wide-Type Box Girders in Cable-Supported Bridges

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Summary

Wide-type steel box girders that have much larger size of width than depth are widely adopted in cable-supported bridges due to their superb rigidity and advantages in aerodynamics. In design such primary members it is inevitable to evaluate nominal strengths before applying various design parameters. As ultimate strength of wide-type steel box girders subjected to concurrent bending moment and axial force is governed by flanges in compression rather than in tension, separated deck panel system in compression was modeled and analyzed. General-purpose nonlinear finite element analysis program was used to perform evaluation of ultimate strengths of various hypothetical stiffened plate systems with U-ribs. The analyses results have been compared to expected strengths from available design specifications such as Eurocode 3, FHWA (Federal Highway Association), and JRA (Japanese Road Association). New design equations have been developed for ultimate strength as a function of plate and column slenderness parameters of the stiffened deck panel. It has been found that the proposed equations expect ultimate strengths reasonably permitting a way to more economic design than other design guides.

Keywords: wide-type steel box girders; ultimate strength; stiffened plate; U-rib; cable-supported bridges.

1. Nonlinear FE analysis of stiffened plates

In this study, commercial finite element program ABAQUS 6.11-1 was used to assess the ultimate strength of the stiffened plates. The stiffened plate was modelled with the four-node shell element (S4R) which can account for finite membrane strains, large rotations and material nonlinear response allowing thickness change as a function of in-plane deformation (Fig.1~Fig.2). Both geometrical and material nonlinearities are taken into account including two different types of initial imperfection (I. I.) as shown in Figs.3 and 4 along with residual stress. The material behaviour of all elements was considered as elastic-plastic model with a von Mises yield criterion and an isotropic stain-hardening rule. For solving the nonlinear equilibrium equation, modified Riks algorithm was used in ABAQUS.

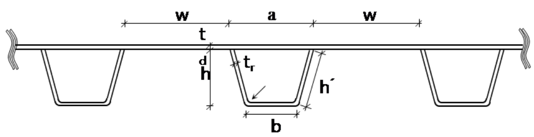

Fig. 1: Hypothetical model

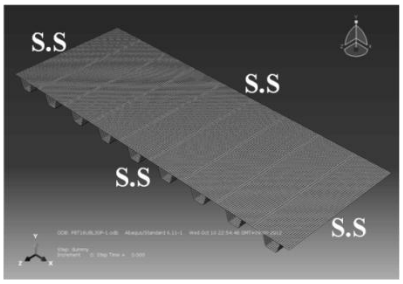

Fig. 2: Modelling by ABAQUS

https://doi.org/10.2749/222137813808627703

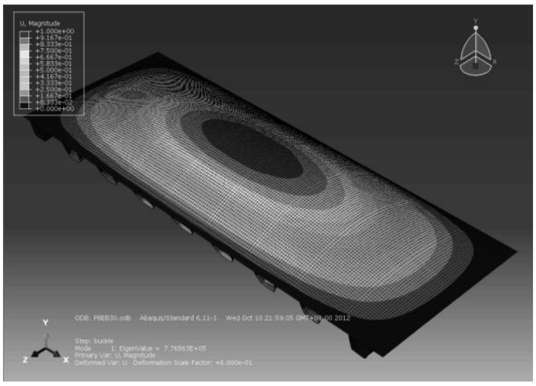

Fig. 3: Global buckling type I.I.

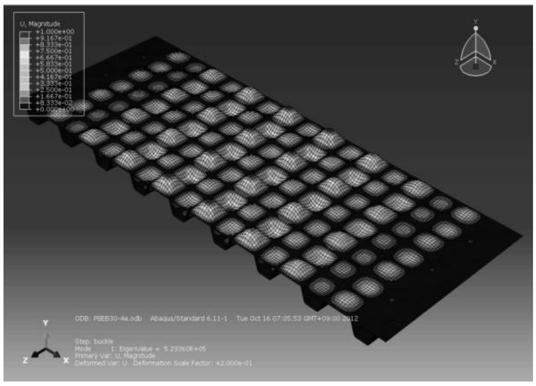

Fig. 4: Plate buckling type I.I.

2. Proposed strength curve

Stiffened plates have two strength curves for present models according to two types of initial imperfection. The strength curves were developed conservatively as the minimum line as shown in Fig. 5. The basis function for strength curve was assumed 2nd order polynomial function with respect to plate and column slenderness parameter. To fit the coefficients to measurements, linear regression method based on the least square errors was used. It seem that the proposed strength curve generally higher than existing code predictions due to more accurate evaluation of stiffened plate behaviours.(Fig. 6)

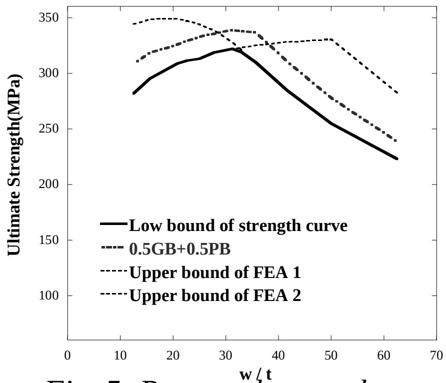

Fig. 5: Proposed strength curve

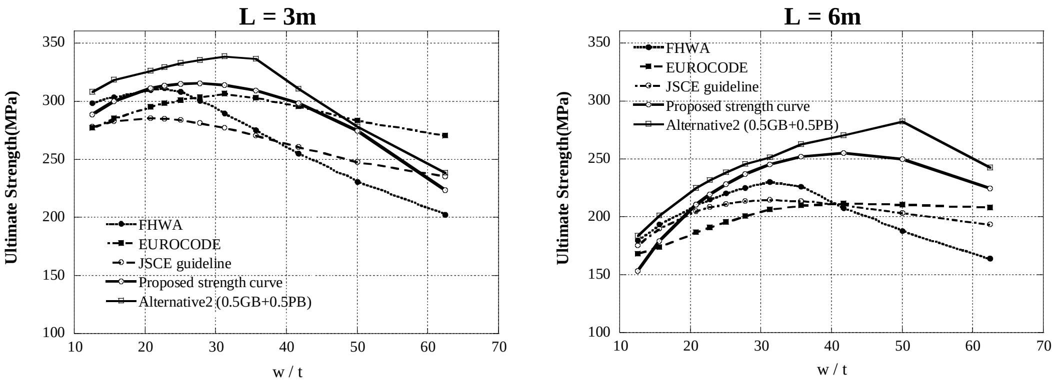

Fig. 6: Strength comparison with proposed method and existing codes predictions

3. Conclusion

Stiffened plates by U-rib were modelled and analyzed using finite element software, ABAQUS. Two types of initial imperfection were considered in the analyses for ultimate compressive strength, the global buckling mode and the plate local buckling mode, respectively. Based on numerical results, strength formulas were derived using linear regression method and the minimum envelopes were proposed for final ultimate compressive strength curves. The proposed method was compared with other existing code predictions. It has been found that the proposed method provides higher strengths than existing codes yet in the conservative side when compared to FE expectations.