Overview of Research Project on Double Composite Steel Bridge

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Summary

Steel girder bridges are commonly designed to take advantage of composite action with the concrete deck slab to improve the load carrying capacity and performance of the girder. This idea can be extended to “double-composite” behavior by including a concrete slab in the plane of the bottom flange in the negative moment region of the girder. In addition to the potential savings in replacing steel flange material with less costly concrete, this concept offers the potential for further savings due to increased stiffness over the piers with a corresponding favorable redistribution of moments, reduced deflections and improved fatigue performance.

The subject research was a cooperative effort between the University of South Florida, URS Corporation and Florida Department of Transportation (FDOT) Structures Research Center. The goal of the project was to provide FDOT with the necessary evaluations, testing and verification to clarify the mode of failure for this particular structural configuration and to provide design guidelines for implementation of the double composite concept in future projects.

1. Test Specimen Design

The final testing layout involved placing the double-composite steel box girder test specimen nearly symmetrical about a center support within the confines of the testing facility. Load actuators are applied 25 ft. from the center support on the right side of the girder and at the opposite end of the girder uplift was restrained by a floor-mounted hold-down assembly located 23 ft. from the center support, as shown in Fig. 1 and 2.

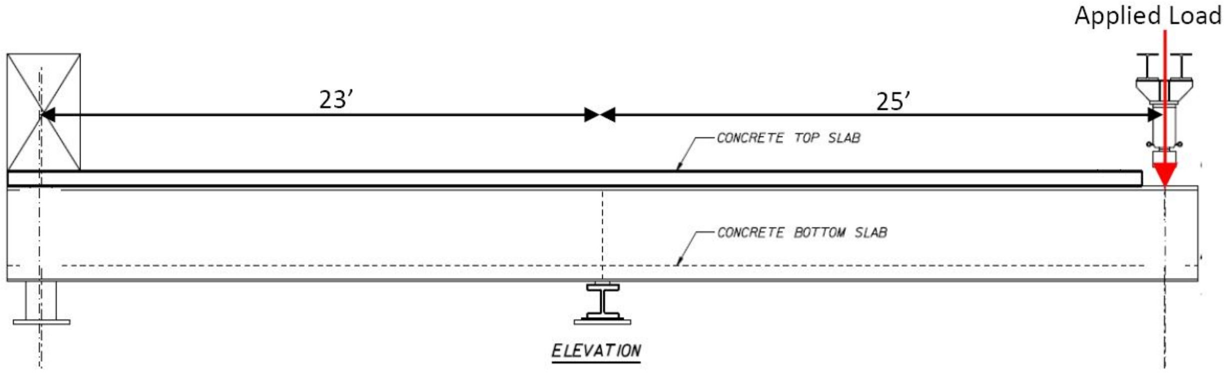

Fig. 1 Test Set-Up

The test specimen was tested under fatigue limit state, serviceability limit state and strength limit state loadings, with the last loading cycle to failure. The results of all limit state conditions were also investigated analytically with finite element modeling to gain insights into the behavior and

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subsequent design recommendations were developed. These design recommendations pertain to bridge superstructures comprised of fabricated straight steel tub sections in a continuous bridge of moderate length whose negative moment areas incorporate a composite concrete bottom slab. Based on the findings of this research, it is recommended that the design of this type of structure be based on the AASHTO LRFD Bridge Design Specifications as modified by the recommendations below.

Fig. 2 Test Girder in FDOT Lab

See reference [1] for additional design detail, and for construction guidelines.

2. Recommendations

Fatigue Limit State: The test findings showed no significant deviation in behavior within the limitations of the testing. Therefore, using the current AASHTO LRFD specifications for shear connector design appears to be valid.

Service Limit State: Based on the testing, the AASHTO LRFD criteria of providing an amount of steel equal to 1% of the total cross sectional area of the deck, with two-thirds located in the top layer, appears to be adequate. However, when utilizing Grade 70 steel, designers should check that the stress in the top slab reinforcement is less than nominal yielding at Load Combination Service II.

Strength Limit State: For strength design, it is recommended that a double composite box girder be evaluated as a non-compact section and must satisfy the following additional requirements:

- The maximum longitudinal compressive stress in the concrete bottom slab at the strength limit state, shall not exceed $0.6f'_c$.
- In order to prevent premature crushing of the concrete, the section shall satisfy the ductility requirement: $D_p < 0.42\ D_t$, where D_p = distance from the bottom of the concrete bottom slab to the neutral axis of the composite section at the plastic moment (in.) and D_t = depth of the composite section measured from the top layer of reinforcing to the bottom of the concrete bottom slab (in.)
- The steel bottom flange must meet AASHTO LRFD criteria for box flanges for all stages of construction, including limiting the deflection to L/360.
- It is recommended that a bottom layer of reinforcing steel be provided in the bottom slab to reduce cracking due to shrinkage.

3. References

[1] SEN, R., STROH, S., and PAI, N. "*Design and Evaluation of Steel Bridges with Double Composite Action*", Final Report submitted to Florida Department of Transportation, November 2009.