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Experimental Evaluation of a Hybrid FRP-Concrete Bridge Superstructure System under Negative Moment Flexural Loads

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ABSTRACT

Fiber Reinforced Polymer (FRP) bridge systems are gaining wide acceptance among bridge engineers. At the same time, FRP bridge systems are relatively expensive when compared to traditional reinforced concrete bridge systems. In this study, the concept of the hybrid FRP-concrete structural systems is applied to a bridge superstructure. The hybrid FRP-concrete superstructure system is intended to have durable, structurally sound and cost effective hybrid system that will take full advantage of the inherent properties of both FRP materials and concrete.

The primary objective of this study is to examine the structural behavior of an FRP-concrete hybrid bridge superstructure system subjected to negative moment flexural loads through experimental procedures. The experimental results showed that the design of the hybrid FRP-concrete bridge superstructure under a negative flexural moment is found to be stiffness- driven instead of strength-driven.

Keywords: Evaluation, Hybrid FRP-Superstructure, Negative Moment Flexural Loads, Concrete Bridges.

1. BRIDGE SUPERSTRUCTURE CONFIGURATIONS

The test specimen is a one-fourth scale model of the 18.288 m hybrid FRP-concrete bridge superstructure. The proposed hybrid FRP-concrete model is a simply supported single span with a width of 1.067m and a depth of 0.275m. The bridge model has a length of 4.572m. The model is comprised of trapezoidal cross-sections surrounded by an outer shell, as shown in Figure (1). Each trapezoidal section consists of two layers of laminates: the inner tube laminate and the outer tube laminate. Each trapezoidal box section was fabricated individually by the hand lay-up process. Three trapezoidal sections were then assembled together by using vacuum bag process. The three trapezoidal sections were wrapped with the outer-most laminate.

To achieve good composite action between GFRP laminates and concrete, shear keys were staggered at the interface of GFRP laminates and concrete. Each shear key has a length of 0.275 m for the side trapezoidal section and of 0.145 m for the middle trapezoidal section in the transverse direction. They were installed on the top surface of the inner tube laminate and on the bottom surface of the outer tube laminate with an interval of 0.762 m. These shear keys are also made of GFRP composites.

2. THE NEGATIVE FLEXURAL TEST

There is no published information that specifically relates to an experimental investigation of the negative moment region of hybrid FRP-concrete bridge superstructures. The test specimen was tested under negative flexural loadings to examine its resistance to negative moments.

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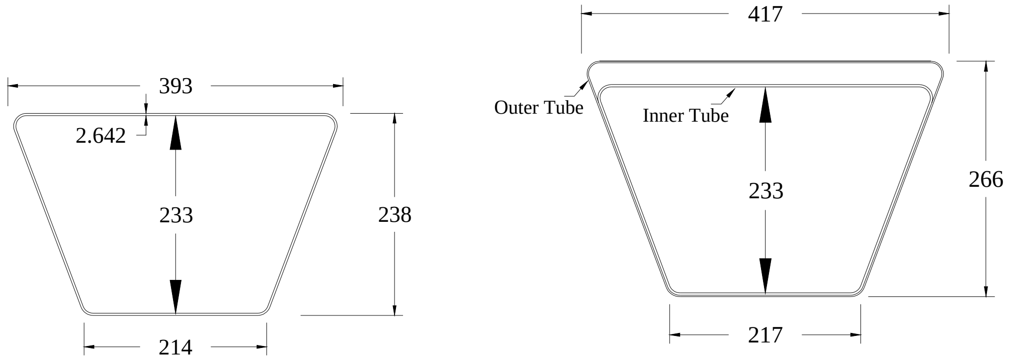
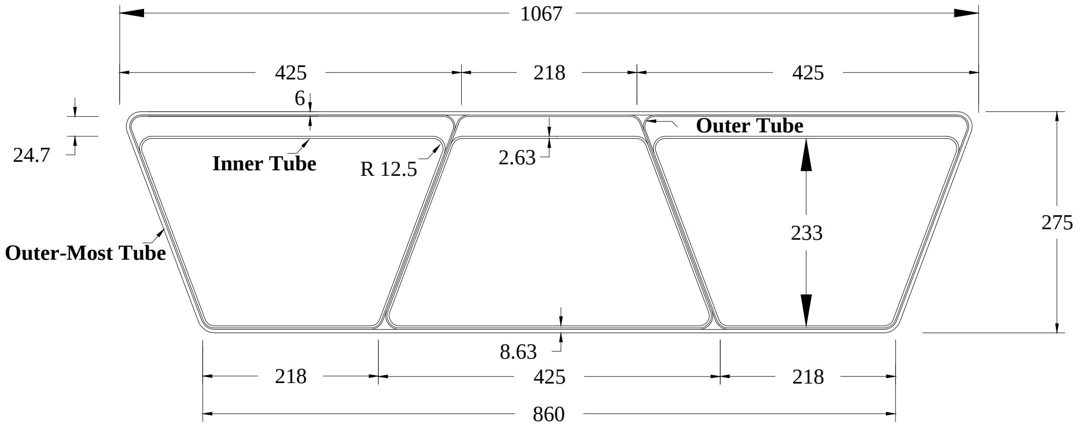


(a) Inner Tube

(b) Model Unit Cell



(c) Bridge Superstructure Model

Figure (1): Cross-Section of the Hybrid FRP-Concrete Superstructure Model (Units in mm).

The test specimen was supported by steel girder at its center. The support length was 0.305 m. Elastomeric bearing pads were placed on steel girders to allow rotation at supports and to protect the bottom surface of the specimen from damage. The north end of the specimen was tied between two beams as shown in Figure 2(b). Dewidag bars were used to connect the tie-down beam to the strong floor.

Figure (2) shows the support setup for a quasi-static negative moment flexural test. Loads were applied vertically to the top south-end surface of the test specimen by a compression stack beam from the actuators attached to the strong floor. The specimen was instrumented with potentiometer and strain gages at various locations to measure displacements and strains, respectively. Figure (3) shows the instrumentation layout for the negative moment flexural test.

3. TEST RESULTS AND DISCUSSION

No sound of concrete cracking was heard during the negative flexural loading of the hybrid specimen under service load level. Visual inspection after the test revealed no evidence of cracks or delamination in the exterior GFRP laminates. Figure (4) shows the force-displacement relationships obtained at the bottom surface at different locations along the specimen (refer to Figure (3) for measurement locations).

The deformed shapes of the top and bottom surfaces are shown in Figure 5(a) and 5(b). The measured deformed shape of both the bottom and the top surfaces was uniform and the shape was symmetrical about the center point. All the plots show near-linear relationships between force and displacement. The specimen experienced a relatively large displacement ($1.3\times L/800$) when it was subjected to a small force (0.5 × tandem load). In this case, a consideration to increase the bending rigidity of the specimen to satisfy the AASHTO (1998) live load deflection limit should be investigated.

Longitudinal strain variations along the centerline of the top surfaces are shown in Figure (6). It can be seen that the maximum negative strain that occurs at the top surface at section E is much less than the ultimate strain of GFRP composites. This shows that the design of the hybrid FRP-concrete bridge superstructure under negative flexural moment is found to be stiffness- driven instead of strength-driven.

4. CONCLUSION

The superstructure specimen was subjected to a negative moment flexural loading test. The tests results demonstrated the excellent performance of the hybrid FRP-concrete bridge superstructure. The measured force-displacement responses were nearly linear under design loads. As is often the case with GFRP composite bridges, the design of the proposed hybrid bridge superstructure system is stiffness-driven.

Acknowledgements

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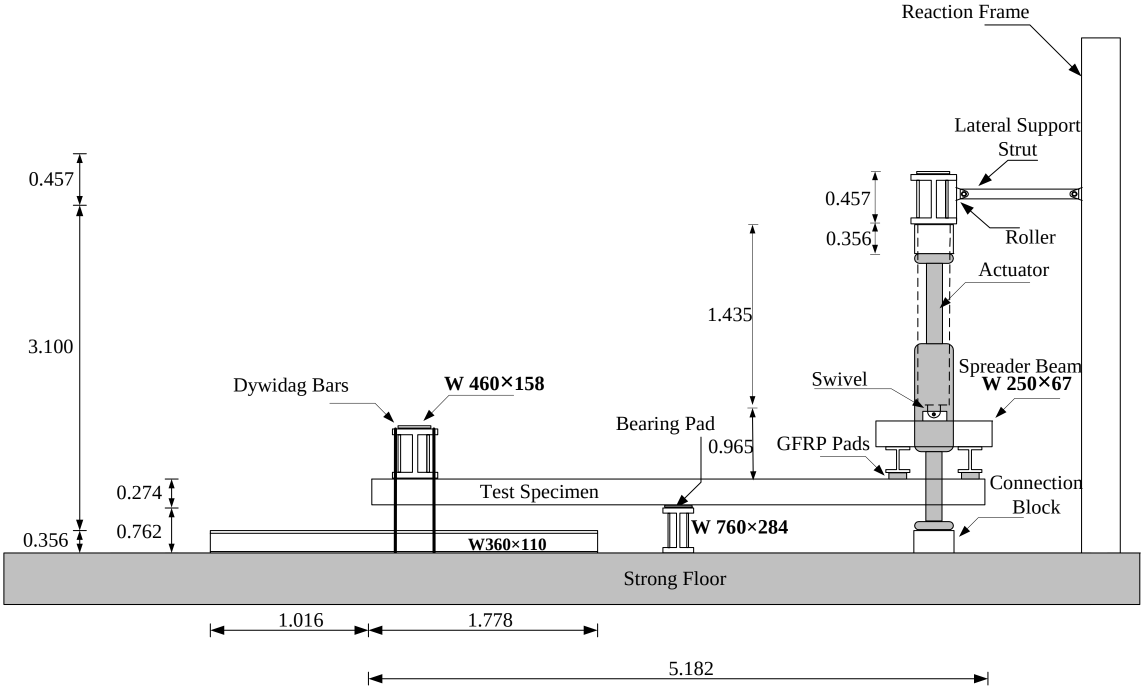
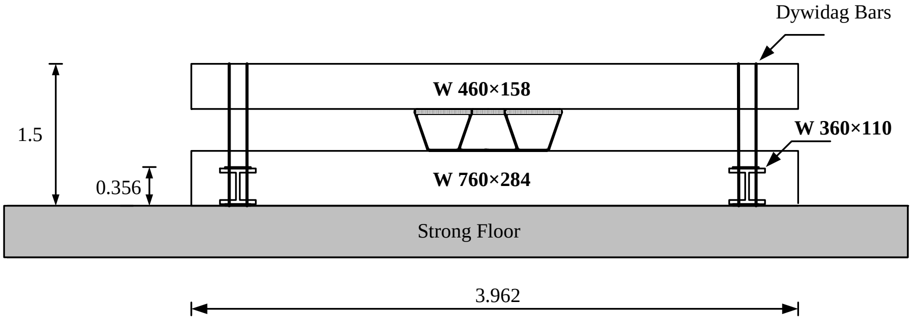
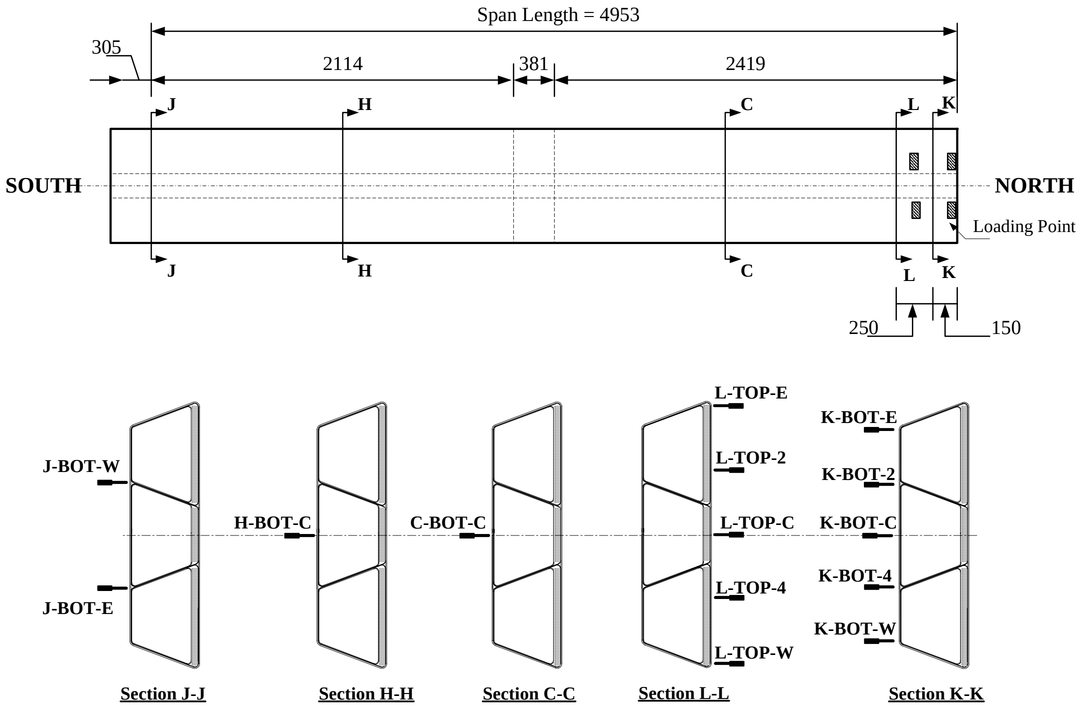


(a) Elevation

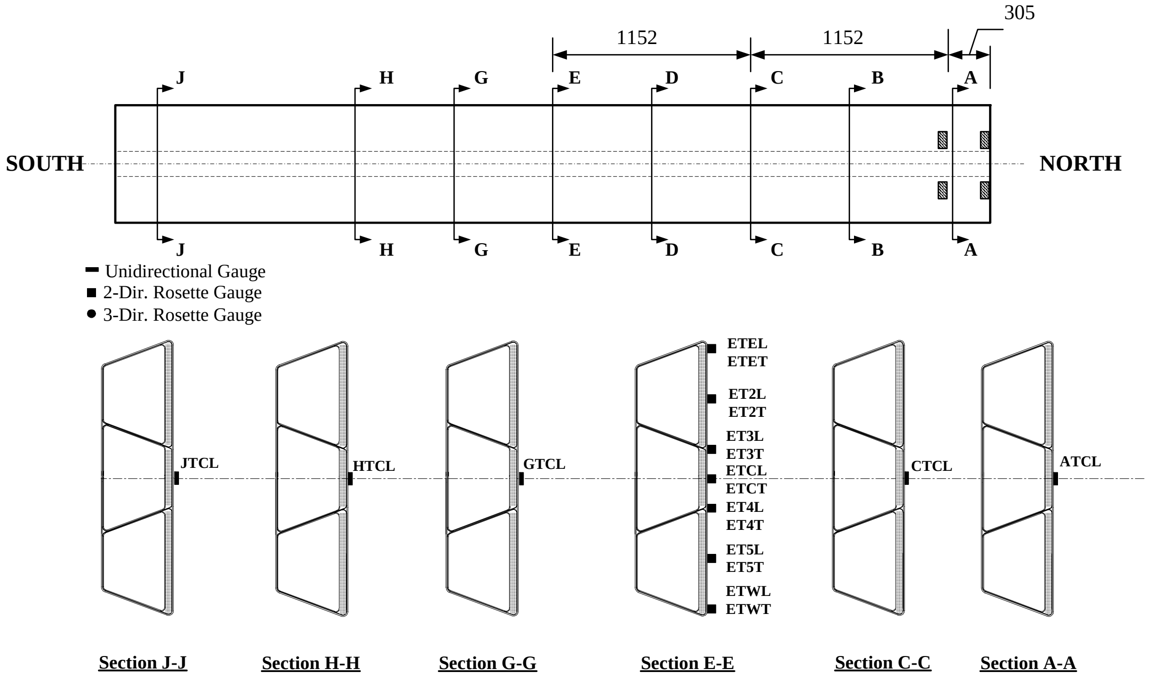


(b) Side View -North End

Figure (2): Test Configuration for Quasi-Static Negative Moment Flexural Test (Dimensions in m).

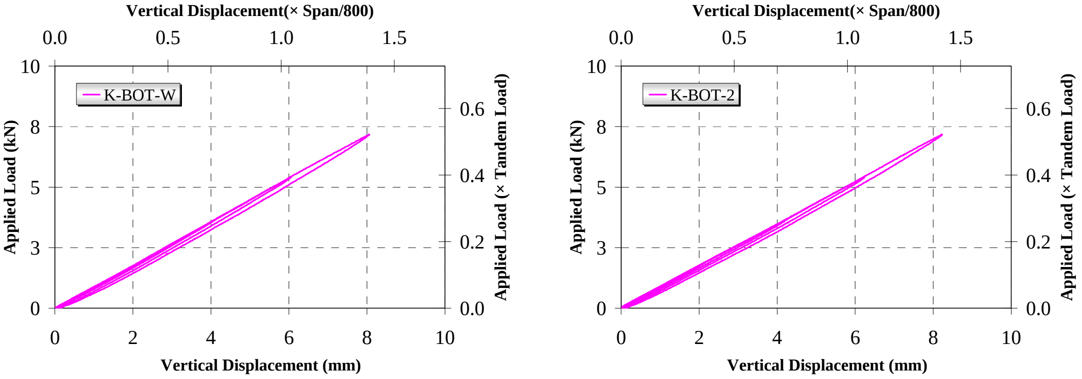


(a) Displacement Measurement



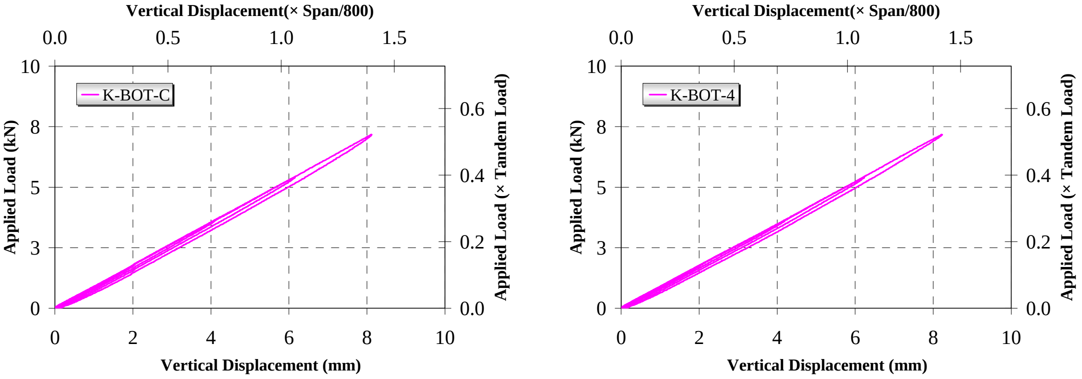
(b) Strain Measurement

Figure (3): Instrumentation for the Negative Moment Flexural Test (Dimensions in mm).



(a) K-BOT-W

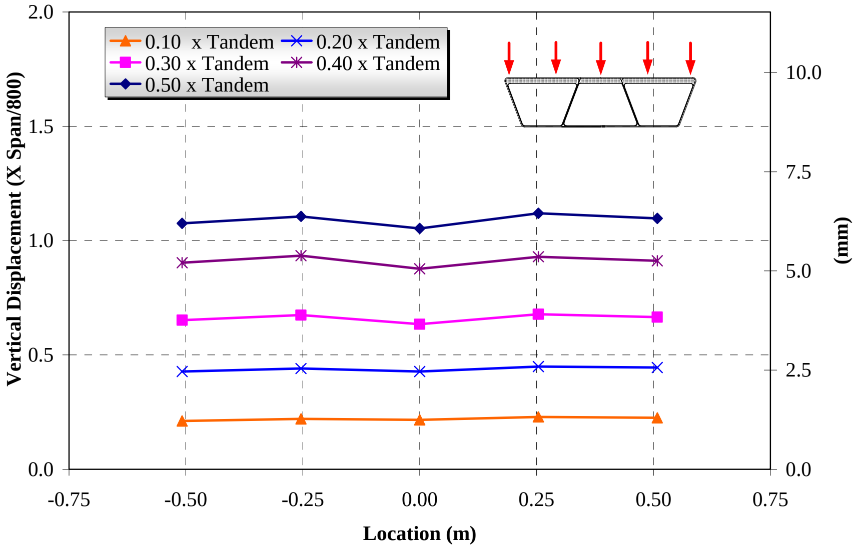
(b) K-BOT-2



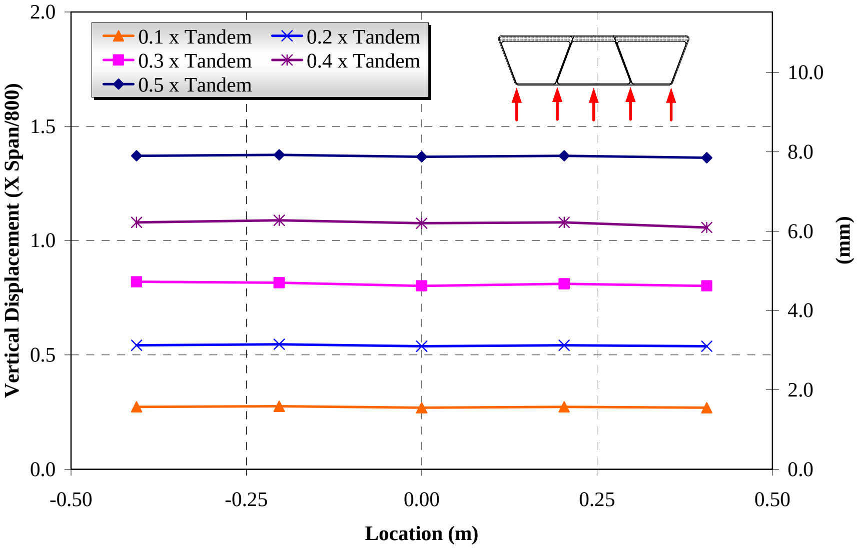
(c) K-BOT-C

(d) K-BOT-4

Figure (4): Forces vs. Displacement at the Bottom Surface (Negative Moment Flexure).



(a) Top Surface



(b) Bottom Surface

Figure (5): Deformed Shapes at Different Load Levels for Hybrid Specimen under Negative Moment Flexure Test.

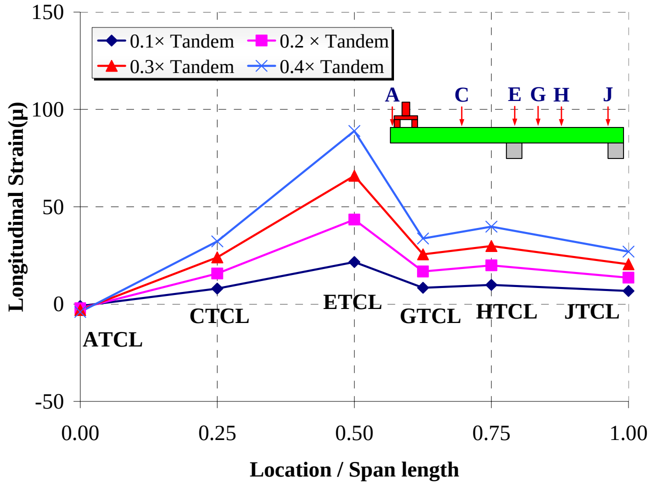


Figure (6): Longitudinal Strain Variations along the Centerline at Top Surface (Hybrid Specimen in Negative Moment Flexure).

REFERENCES

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