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Second Generation Hybrid Composite Beam Span: Preliminary Assessment at Facility for Accelerated Service Testing

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Summary

Transportation Technology Center, Inc. (TTCI), Pueblo, Colorado is evaluating advanced materials and designs for use in railroad bridges. As part of this process, TTCI recently began testing a commercially produced 42-foot hybrid composite beam (HCB) span in the state-of-the-art concrete bridge at the Facility for Accelerated Service Testing (FAST).

Observations so far include:

- Advancements in fabrication and design of this second generation HCB span are evident by marked improvements in span performance compared to the previous laboratory produced 30-foot prototype HCB span.
- The new HCB span is performing well after more than 30 million gross tons (MGT) of heavy axle load (HAL) traffic.
- The 42-foot HCB span weighs about the same as a 30-foot prestressed concrete span, enabling it to be handled with many existing cranes in cases where the longer span length does not affect the lifting radius.
- The HCB span weighs about 57 percent of the prestressed concrete span it replaced.
- The reduced span weight is hoped to enable replacement of timber spans on a 3-for-1 basis, compared to the 2-for-1 basis common with prestressed concrete. These spans are also being considered as replacements for some steel spans.
- An innovative, lightweight, modular polymer concrete ballast curb is performing well. These lightweight ballast curbs contribute significantly to the weight reduction.
- Maximum deflection was only 67 percent of the American Railway Engineering and Maintenance-of-Way Association recommended maximum, compared to 91 percent for the previous prototype HCB span.

TTCI previously tested a 30-foot laboratory produced prototype HCB span at FAST. The prototype performed satisfactorily while accumulating 237 MGT of HAL traffic during two years of testing at FAST.^{1,2}

Future plans call for the new span to be tested for up to two years at FAST. Then it will be installed in revenue service on a local BNSF Railway line where it will be monitored for long-term performance and maintenance requirements.



INTRODUCTION

For many years, North American railroads have been replacing aging timber bridges, often with precast prestressed concrete spans. Typically, a concrete span can replace two timber spans. Longer concrete spans tend to be too heavy to handle with the on-track cranes owned by most railroads.

TTCI is researching new designs and materials for use in railroad bridge spans. If the cost per foot of new bridge can be reduced, then more aging bridges can be replaced to improve network capacity by reducing slow orders and weight restrictions. The 42-foot HCB span is a new design using both conventional bridge materials (concrete and steel) as well as an alternative material (fiberglass). These spans are being considered as an alternative to some steel spans.

The HCB system consists of a tied concrete arch encased in a fiberglass beam shell (Figure 1). The concrete arch carries compression, and steel prestressing tendons carry tension. The fiberglass shell and diagonal reinforcing stirrups provide shear strength.

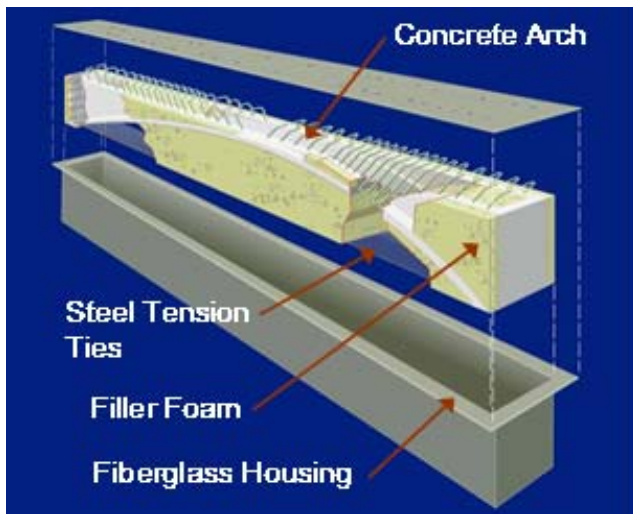


Figure 1. Schematic Drawing of HCB Span

The HCB span is designed to be used as a 3-for-1 or a 4-for-1 replacement of timber spans, rather than the 2-for-1 replacement that is typical using concrete spans. This 42-foot HCB span is designed so it could replace three 14-foot timber spans.

Previously, a 30-foot laboratory produced prototype HCB span was installed and tested under HAL for 237 MGT.

SPAN CHARACTERISTICS

TTCI is now testing at FAST a 42-foot commercially produced HCB span designed and built for BNSF Railway.

The 42-foot span is comprised of two half-span pieces with a 5-inch concrete deck. Each half-span piece has three HCB cells, and the overall height of the span is 42 inches. The ballast curb is made of prefabricated modular polymer concrete panels bolted to steel supports. This ballast curb is significantly lighter than a conventional reinforced concrete ballast curb, which was used on the 30-foot prototype HCB

span, as well as the prestressed concrete spans in this bridge. Figure 2 shows the ballast curb panels bolted to the steel supports prior to span installation.



Figure 2: View Showing Polymer Concrete Ballast Curb Panels and Steel Supports

BNSF bridge engineers challenged the HCB designers to keep the weight of this 42-foot span comparable to the weight of a conventional 30-foot prestressed concrete span. BNSF wants to handle the longer span with its existing on-track cranes. The designers noted that in the previous span, approximately one-third of the concrete was in the arch, one-third was in the deck, and one-third was in the ballast curb. The ballast curb became an obvious target for weight reduction.

Figure 3 shows the installation of the 42-foot HCB span at FAST. Lifting weight of the half-span section with the deck and ballast curb (27 tons) is about 40 percent lighter than the prestressed concrete double cell box girder section (47 tons) that was removed. Figure 4 shows the completed installation.



Figure 3. Installation of 42-foot Span at FAST



Figure 4. Completed Installation of 42-foot Span at FAST

The second generation HCB span differs from the prototype span previously tested with the addition of an integral concrete fin above the arch, which was used to facilitate placement of the diagonal shear reinforcement during fabrication, as Figure 5 shows. In addition, the fin adds shear strength and reduces deflection in the finished product. The new span also uses standard prestressing tendons rather than sheets of hard wire for the tension reinforcement. (Prestressing tendons are more readily available and their properties are better known to structural engineers.) The fiberglass shells were commercially produced, with numerous quality improvements compared to the prototype span. The new span has three integral cells per half-span piece instead of four cells bolted together, and the new 42-foot HCB span is 8 inches deeper than the shorter prototype 30-foot HCB span.

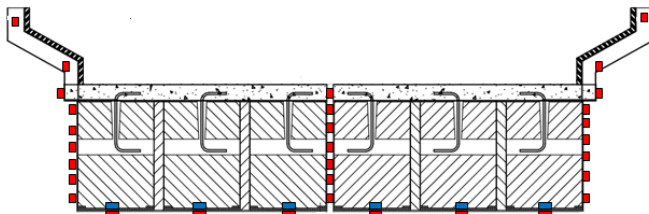


Figure 5. Cross Section showing Integral Concrete Fin and Instrumentation on HCB Span

Compared to the 42-foot prestressed concrete span that was originally in this location, the HCB span is 6 inches deeper. Design of HCB spans for railroad loadings, like steel spans, tends to be governed by deflection rather than strength, requiring a deeper section. A 2-inch track raise was used to provide the minimum recommended ballast depth of 8 inches beneath ties on this span. The track on this span uses timber ties with Safelok elastic fasteners. The precast concrete span previously in this location had a ballast mat, 12 inches of ballast, and concrete ties with Safelok elastic fasteners.

PERFORMANCE TESTING

During normal train operations, the HCB span is subjected to HAL traffic. The train at FAST is made up of about 110 cars,

with most of them at 315,000 pounds gross rail load, and operates at approximately 40 mph. The FAST train does not normally have any wheels producing significant impacts from wheel tread defects. Wheels are typically removed when impacts exceed 80,000 pounds.

The HCB span was installed at FAST on a 5-degree curve with 4 inches of superelevation. Ballast depth below ties is 8 inches at the low rail and 12 inches under high rail. The deck of the span is level. Figure 6 shows the train at FAST passing over the HCB span.



Figure 6. Train at FAST Passing over HCB Span at FAST

INSTRUMENTATION

Strains and deflections were measured on the HCB span under normal HAL traffic at FAST. Thirty-eight strain gages and six string potentiometers were installed. Figure 5 is a cross section showing the strain gage locations in red and the string potentiometers (for vertical deflections) in blue.

DEFLECTIONS

Figure 7 shows vertical deflection measurements of the 42-foot HCB span under HAL traffic. Deflections are shown for clockwise (CW) and counterclockwise (CCW) directions of train operation.

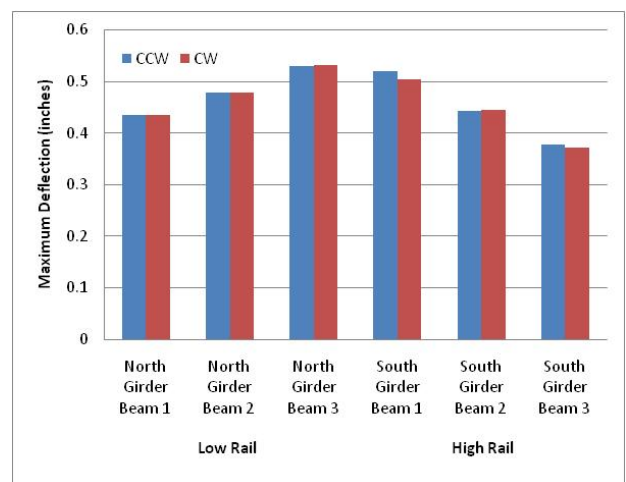


Figure 7. Maximum Deflections in the Six HCB Cells at FAST

The maximum vertical deflection measured was about 0.53 inch. The average deflection for all six beams was approximately 0.46 inch. The cells toward the center of the span showed higher deflections. Similar results were seen while testing the 30-foot HCB prototype,^{1,2} but the deflections were more uniform in the new 42-foot span. (For the new 42-foot HCB span, the minimum cell deflection was 70 percent of the maximum. For the 30-foot prototype span, the minimum was 55 percent of the maximum cell deflection.) The improved uniformity is likely due to the integral fabrication of the cells and improved fabrication quality processes, as well as more uniform bearing conditions made possible by the improved fabrication.

Figure 8 shows a comparison between the maximum deflections of the 42-foot and 30-foot spans. AREMA recommended maximum deflection values are also shown. The measured deflection of the new 42-foot span was about 67 percent of the maximum recommended. The deflection of the 30-foot prototype span was 91 percent of the maximum recommended.

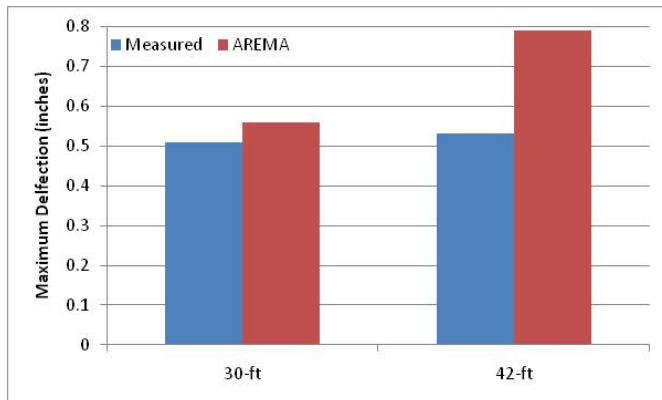


Figure 8. Comparison of Maximum Deflections for 30-foot HCB Span versus 42-foot HCB Span

According to AREMA Chapter 8, the maximum allowable deflection for a 42-foot prestressed concrete bridge span is 0.79 inch.³ This is well above the maximum measured deflection of 0.53 inch for the 42-foot span. In previous tests on the 30-foot prototype HCB span, the measured deflection was approximately 0.51 inch. The 42-foot span is 40 percent longer than the 30-foot span, but the maximum measured deflection was almost identical. The improved deflection performance provides validation of the advancements in fabrication and design of this commercially produced span as compared to the previous laboratory produced prototype span.

The 42-foot prestressed concrete span that was originally in this location had a maximum measured vertical deflection of only 0.29 inch, which is less than 60 percent of the maximum deflection in the 42-foot HCB span. Prestressed concrete box girders typically have very low deflections compared to other spans (i.e., steel, reinforced concrete) of similar length. The prestressing activates a very large cross-sectional area to resist bending deflections.

STRAINS

Figure 9 shows tension strains measured on the bottoms of each HCB cell for CW and CCW directions of train operation. The strains are fairly uniform, indicating good load distribution between the cells. These strains translate to maximum tension stresses of about 8.5 ksi to 10 ksi in the steel prestressing tendons.

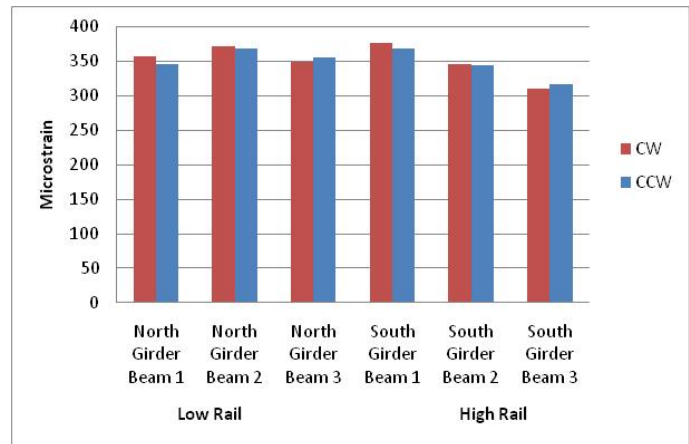


Figure 9. Tension Strains in bottom of HCB Span

FUTURE TESTING

Plans call for the 42-foot HCB span to remain under observation at FAST for up to two years, then be moved to a local BNSF line for revenue service installation. Long-term performance will be monitored in revenue service.

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