TECHNOLOGY DIGEST
TD-16-044
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TIMELY TECHNOLOGY TRANSFER

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Hybrid Composite Beam Spans: Revenue Service Implementation

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Summary

Transportation Technology Center, Inc. (TTCI) is evaluating advanced materials and designs for use in railroad bridges. As part of the process, TTCI previously tested 30-foot and 42-foot hybrid-composite beam (HCB) spans at the Facility for Accelerated Service Testing (FAST) near Pueblo, Colorado.[1,2] To document the performance of the HCB span in revenue service, measurements were made on two spans: a 33-foot span on Canadian Pacific Railway (CPR) and a 42-foot span on BNSF Railway Company (BNSF). Preliminary observations from implementation to date include:

- The new HCB spans have not shown any change in structural performance to date in heavy haul service of about 85 MGT on CPR and 40 MGT on BNSF (after 244 MGT at FAST) with no maintenance required.
- An innovative, lightweight, modular polymer concrete ballast curb has not shown any change in structural performance.
- A typical HCB span weighs approximately 60 percent of a similar length prestressed concrete span.
- The reduced span weight has allowed for HCB use in a situation where crane capacity limitations precluded the use of prestressed concrete. The HCB is a viable alternative to steel for such spans.
- Maximum deflection was 50 percent and 70 percent of the recommended maximum by American Railway Engineering and Maintenance of Way Association.[3]
- The recorded strains indicate uniform load distribution and stresses near predicted levels in the steel prestressing tendons.
- No definitive impact load effects were measured on either span.

A 42-foot HCB span was previously tested at FAST, and then it was moved to a revenue service installation in Colorado on the BNSF. A 33-foot HCB span was the first revenue service installation in North America on the CPR in British Columbia. Both spans are being monitored for long-term performance and maintenance requirements.

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INTRODUCTION

TTCI continues to evaluate advanced materials and designs for bridge spans with a goal of finding cost-effective replacement components for aging bridges that can be installed efficiently. The hybrid-composite beam (HCB) uses concrete, steel, and fiberglass components, and offers a possible alternative for some bridges.

The HCB system consists of a concrete arch connected at its ends with steel prestressing tendons, all encased in a fiberglass beam shell. The concrete arch provides compression reinforcement, and the steel tendons provide the tension reinforcement. The HCB span offers the potential for savings in both material and installation costs.[4,5]

This *Technology Digest* presents test results from two revenue service installations and provides an update on the implementation of HCB spans. As this new bridge technology is introduced into revenue service TTCI, CPR, and BNSF intend to quantify the performance of the HCB spans periodically. Similar efforts are underway for implementation of HCB spans in highway service.[6]

PRE-REVENUE SERVICE TESTING

TTCI has tested a commercially produced 42-foot HCB span in the state-of-the-art concrete bridge at the Facility for Accelerated Service Testing (FAST) near Pueblo, Colorado. The span performed well during 244 million gross tons (MGT) of accumulated heavy axle load (HAL) traffic.[1,2]

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. The overall height of the span is 42 inches. Design of HCB spans for railroad loading, like steel spans, tends to be governed by deflection rather than strength, so deeper sections are often required. The ballast curb used on the 42-foot HCB is made of prefabricated modular polymer concrete panels bolted to steel supports. It is significantly lighter than a conventional reinforced concrete ballast curb used on the 30-foot HCB prototype.

BNSF bridge engineers challenged the HCB designers to keep the weight of the 42-foot span comparable to the weight of a conventional 30-foot prestressed concrete span. BNSF wanted to handle the longer span with existing on-track cranes. 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. The polymer concrete ballast curbs provided the majority of the desired weight reduction for this span. The modular ballast curb panels could also be used on prestressed concrete or steel spans.

The new 42-foot HCB span uses standard prestressing tendons for the tension reinforcement. Prestressing tendons are readily available and their properties are well known to structural engineers.

The maximum vertical deflection recorded was ~0.5 inch. According to AREMA Chapter 8,[3] the maximum allowable deflection for a 42-foot prestressed concrete bridge span is 0.8 inch. The tension strains measured on the bottom of the HCB cell at six transverse locations were in the range of 300-400 microstrains. The strains were fairly uniform, indicating good transverse load distribution. The strains translate to maximum tension stress of approximately 8.1 to 10.5 ksi in the steel prestressing tendons. Neither deflection nor strain data indicated degradation of the 42-foot HCB span during 244 MGT of HAL service at FAST.

After this initial proof testing, the 42-foot HCB span was removed from FAST and returned to BNSF for use in revenue service.

REVENUE SERVICE TESTING ON BNSF

In November 2015, BNSF installed the 42-foot HCB span on the main line of the Boise City Subdivision south of Las Animas, Colorado. Traffic is primarily coal, grain, and mixed freight, approximately 60 MGT per year. Traffic is virtually all southbound. Maximum train speed is 49 mph.

Measurements in 2016 were intended to quantify the initial revenue service behavior, and serve as a baseline for comparison for possible future measurements. These measurements also helped to determine and quantify whether or not there have been any changes in behavior since this span was tested at FAST.

Measurements on the BNSF 42-foot span included both mid-span performance and end shear. Mid-span measurements consisted of vertical deflections from each half section, and three strain gages oriented longitudinally on the bottom of each half section, centered beneath the HCB cells.

Figure 1 shows the strain gage measurement locations in a cross-section view. The gages are located near the center of each cell.

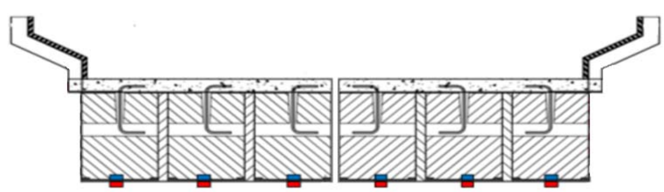

Figure 1. HCB Cross Section Showing Strain Gage Locations

Vertical deflections were measured using string potentiometers capable of measuring 1 to 2 inches of movement. These measurements were taken near the center of each half span (cells 2 and 5).

End shear measurements were made with strain gages at mid height of the exterior fiberglass panel, 8 feet from one end of the span. Modeling and analysis by the vendor indicated that maximum shear effect in the fiberglass panels is expected to be between 6 and 10 feet from the end of the span. Closer to the ends of the span (approximately the last 4 feet), the concrete fins and arches carry the majority of the shear load.

Data was collected under revenue service trains passing over the bridge. Data was collected for five loaded coal trains (#1-5) and one grain train (#6) during the collection period.

Figure 2. HCB Span on the BNSF Boise City Subdivision

Strains were reasonably uniform across all six cells of the HCB, indicating good load distribution (Figure 3). This indicates consistent fabrication of the HCBs and deck, as well as appropriate ballast depth and track structure. So far, the system is working well. Maximum strains recorded were typically around 300 microstrain under the loaded 286-kip cars. This is slightly less than what was recorded when the bridge was at FAST under the load of 315-kip cars. Maximum stress in the steel tendons is ~9 ksi at this strain level (compared to ~270 ksi ultimate strength). The shear strains were in the range of 150-200 microstrains (Figure 4).

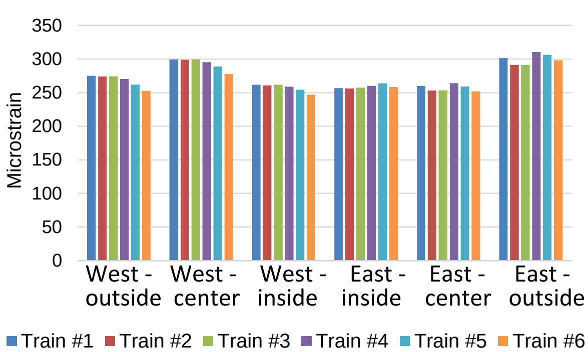

Figure 3. Average Bending Strain Peaks of BNSF HCB for Various Trains

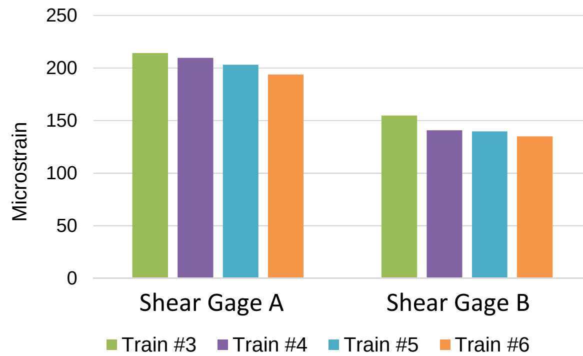

Figure 4. Average Shear Strain Peaks of BNSF HCB for Various Trains

Maximum deflection recorded was ~0.5 inch, or approximately two-thirds of the AREMA recommended maximum of 0.8 inch for this 42-foot span (Figure 5).

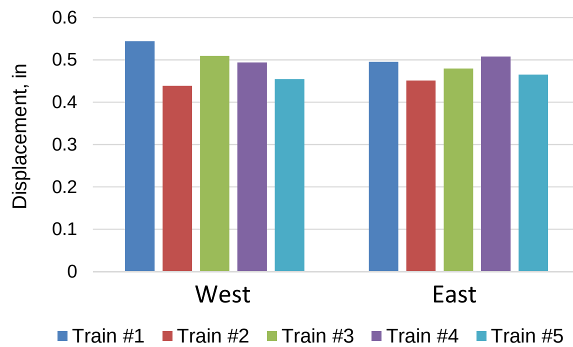

Figure 5. Average Displacement of BNSF HCB for Various Trains

REVENUE SERVICE TESTING ON CPR

In October 2014, CPR installed a 33-foot HCB span on the Cranbrook Subdivision near Fernie, BC. Traffic is primarily coal, grain, potash, and mixed freight, ~60 MGT per year.

In March 2015, the performance of the HCB span in revenue service was measured to quantify the initial behavior, and serve as a baseline for comparison for possible future measurements. In 2016, measurements were performed to determine whether or not there have been any changes in behavior, and if so, to quantify them. Measurements focused on mid-span performance. Mid-span measurements consisted of vertical deflections from each half section and three strain gages oriented longitudinally on the bottom of each half section, and centered beneath the HCB cells.

Vertical deflections were measured using string potentiometers capable of measuring 1 to 2 inches of movement. These measurements were taken near the center of each half span (near the center strain gage).

Data was collected under revenue service trains traversing the bridge. Maximum train speed is 30 mph.

The TTCI team recorded a total of 10 trains each year. Of most interest were loaded unit trains of coal and potash that can be seen in Figure 6.

Figure 6. HCB Span on the Main Line of the Cranbrook Subdivision near Fernie, BC

Maximum deflections recorded were typically just under 0.3 inch, or approximately half of the AREMA[3] recommended maximum of 0.6 inch for this 33-foot span (Figure 7).

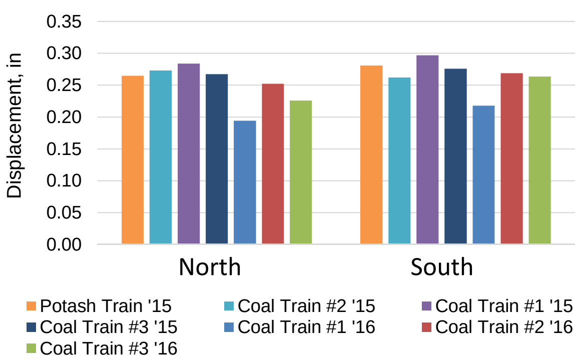

Figure 7. Average Displacement for Various Trains

Strains were fairly uniform across all six cells of the HCB, indicating reasonably good distribution of the load (Figure 8). The load distribution is a function of track structure and placement, ballast depth, superstructure deck, and fabrication of the HCBs. It appears the system is working well at this point. Maximum strains recorded were typically around 350 microstrains under the loaded 286-kip cars. This is similar to what was recorded at FAST on the BNSF 42-foot span. Maximum stress in the steel tendons is ~10 ksi at this strain level (compared to ~270 ksi ultimate strength).

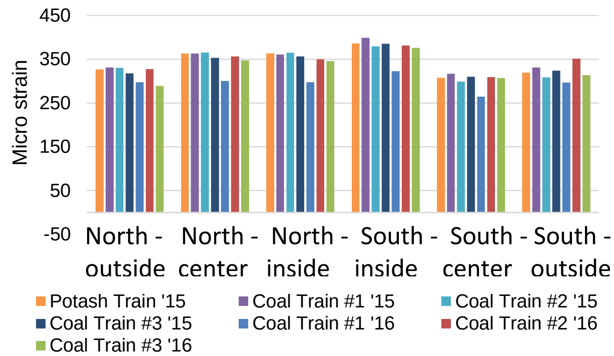

Figure 8. Average Stress Peaks for Various Trains

CONCLUSIONS

The revenue service tests on two HCB spans indicate that to date, the spans are performing structurally as intended. Maximum deflections are less than the AREMA recommended maximums. The recorded strains indicate uniform load distribution in the spans. The strains translate to maximum tension stress of approximately 9 to 10 ksi in the steel prestressing tendons. Future research will include continued monitoring for long-term behavior and implementation of design guidelines.

ACKNOWLEDGEMENT

TTCI thanks BNSF and CPR for their support.

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