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Second-Generation Hybrid Composite Beam Span: Pre-Revenue Service Test Summary

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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 has tested 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), Pueblo, Colo. The span performed well during 244 million gross tons (MGT) of accumulated heavy axle load (HAL) traffic.

Observations include:

- Advancements in fabrication and design of this second-generation HCB span are evident by marked improvements in span performance compared to the previous prototype span.
- The new HCB span has not shown any significant deterioration after 244 MGT of HAL traffic.
- An innovative, lightweight, modular polymer concrete ballast curb has not shown any significant deterioration after 244 MGT.
- The 42-foot HCB span weighs about the same as a 30-foot prestressed concrete span, enabling it to be handled with many existing on-track cranes.
- The reduced span weight is expected to enable replacement of timber spans on a 3-for-1 basis, compared to the 2-for-1 basis common with prestressed concrete.
- Maximum deflection was 67 percent of the recommended maximum of American Railway Engineering and Maintenance of Way Association, *Manual for Railway Engineering* (Chapter 8), compared to 91 percent for the previous prototype HCB span.

The 42-foot HCB was removed from FAST in November of 2012. Plans call for it to be installed in revenue service on a nearby BNSF main 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 (25 feet to 30 feet approximate length) 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 HCB span is a new design using both conventional bridge materials (concrete and steel) and an alternative material (fiberglass).

Previously published *Technology Digests* (TD) describe the hybrid composite beam system.^{1,2,3} It consists of a concrete arch with steel tension ties and shear stirrups encased in a fiberglass beam shell.

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

TTCI previously tested a 30-foot 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}

This TD updates previously reported information on the 42-foot HCB span tested at FAST.³

SPAN CHARACTERISTICS

At FAST, TTCI has tested a 42-foot professionally 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. 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, used on the 30-foot HCB prototype, as well as the prestressed concrete spans in this bridge. Figure 1 shows the ballast curb panels bolted to the steel supports prior to span installation.

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 wants to handle the longer span with 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. 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.



Figure 1. View showing Polymer Concrete Ballast Curb Panels and Steel Supports

Figure 2 shows the 42-foot HCB span at FAST. Figure 3 shows the removal of the span. 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. In Figure 3, note that the ballast curb panels have been removed to accommodate lifting slings. There were no problems or issues with removal of the ballast curb panels.



Figure 2. 42-foot HCB Span installed at FAST



Figure 3. Removal of 42-foot Span at FAST

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.

Compared to the 42-foot prestressed concrete span that was originally in this location, the 42-foot 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, so a deeper section is often required. A 2-inch track raise was used to provide a minimum ballast depth of 8 inches beneath ties on this span. The track on this span uses timber ties with Safelok elastic fasteners.

PERFORMANCE TESTING

During normal train operations, the 42-foot HCB span is subjected to HAL traffic. The train consist at FAST has 110 cars and operates at approximately 40 mph. Most of the cars carry 315,000-pounds gross rail load. The test 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 42-foot 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.

INSTRUMENTATION

Strains and deflections were measured on the 42-foot HCB span under normal HAL traffic. Additionally, loading measurements were taken over the 42-foot HCB span using instrumented wheelsets (IWS).

DEFLECTIONS

Figure 4 shows vertical deflection measurements of the 42-foot HCB span under HAL traffic. Deflections are shown for the center girders on dates near installation and upon removal of the span.

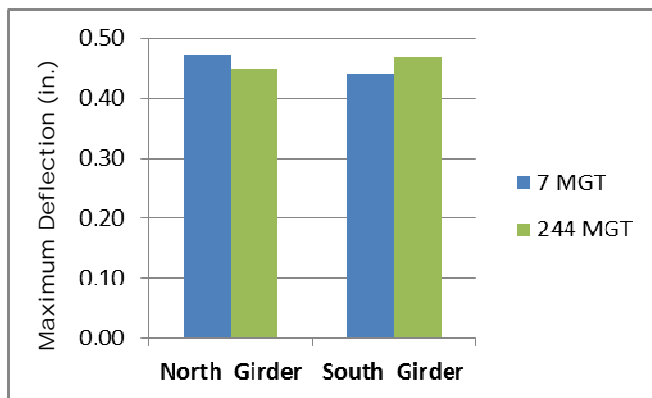


Figure 4. Maximum Deflections in Girders of the 42-foot HCB Span at FAST

The maximum vertical deflection shown in Figure 4 is about 0.47 inch. The maximum variation in vertical deflection between the beginning and end of testing is approximately 0.03 inch (6 percent increase). These small variations could

have been caused by a number of factors, including variation in train speed, lateral movement of track on span, change in track superelevation, and track degradation.

Figure 5 shows a comparison between the maximum deflections of the 42- and 30-foot HCB spans. AREMA recommended maximum deflection values are also shown. The measured deflection of the new 42-foot span is about 67 percent of the maximum recommended. The deflection of the 30-foot prototype span is 91 percent of the maximum recommended.

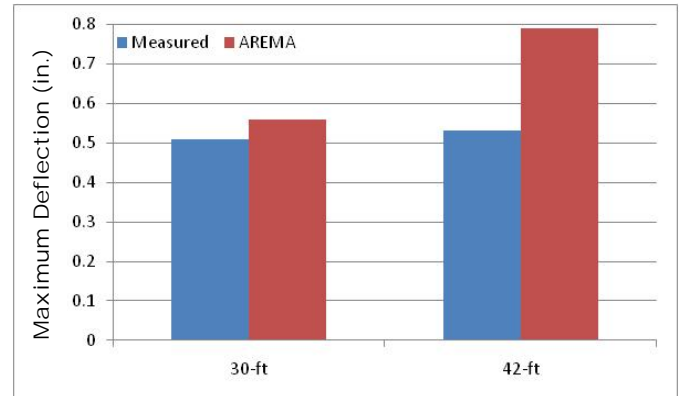


Figure 5. Comparison of Maximum Deflections for 30-foot HCB Span vs. 42-foot HCB Span

According to AREMA Chapter 8, the maximum allowable deflection for a 42-foot prestressed concrete bridge span is 0.79 inch.⁴ The maximum measured deflection was only 0.53 inch. 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; however, the maximum measured deflection was almost identical. The improved deflection performance provides validation of the advancements in fabrication and design of the professionally produced span as compared to the previous 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, 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 (steel, reinforced concrete) of similar length. The prestressing activates a very large cross sectional area to resist bending deflections.

STRAINS

Figure 6 shows tension strains measured on the bottoms of the HCB cell at six transverse locations, uniformly spaced across the girders at mid span. Measurements are shown for dates near installation and upon removal of the 42-foot HCB span. The strains are fairly uniform, indicating good transverse load distribution. Furthermore, the strains do not vary much between beginning and end dates. These strains translate to maximum tension stresses of about 8.1 to 10.5 ksi in the steel prestressing tendons. Neither deflection nor strain data indicate degradation of the 42-foot HCB span during its 244 MGT of HAL service at FAST.

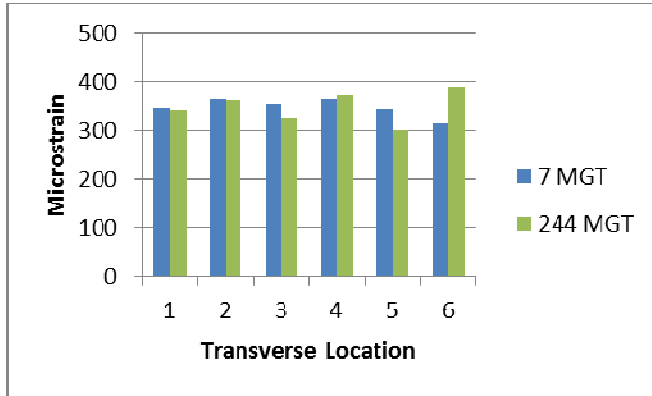


Figure 6. Tension Strains in Bottom of 42-foot HCB Span

DYNAMIC WHEEL LOAD ENVIRONMENT

Figure 7 shows the dynamic load environment as measured using IWS installed in a typical HAL car as it passed over the 42-foot HCB span. Data was gathered after 206 MGT of traffic accumulated on the span. The average loads on the high and low rail were 42.9 and 35.4 kips, respectively.

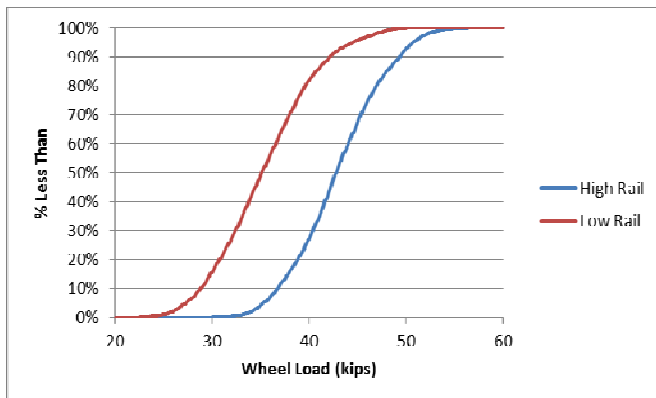


Figure 7. Dynamic Load Environment on 42-foot HCB Span from a Typical HAL Car

FUTURE TESTING

The 42-foot HCB span has been removed from FAST and returned to the BNSF. Plans call for it to be installed on a nearby BNSF line in southeastern Colorado, during an upcoming construction season. This location accrues approximately 60 MGT per year. Long-term performance will be monitored in revenue service. Figure 8 shows the HCB spans loaded on flatcars, ready to be moved to their future location.



Figure 8. 42-foot HCB Span Ready to be Moved

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