Preliminary assessment of a second-generation hybrid composite beam span at FAST

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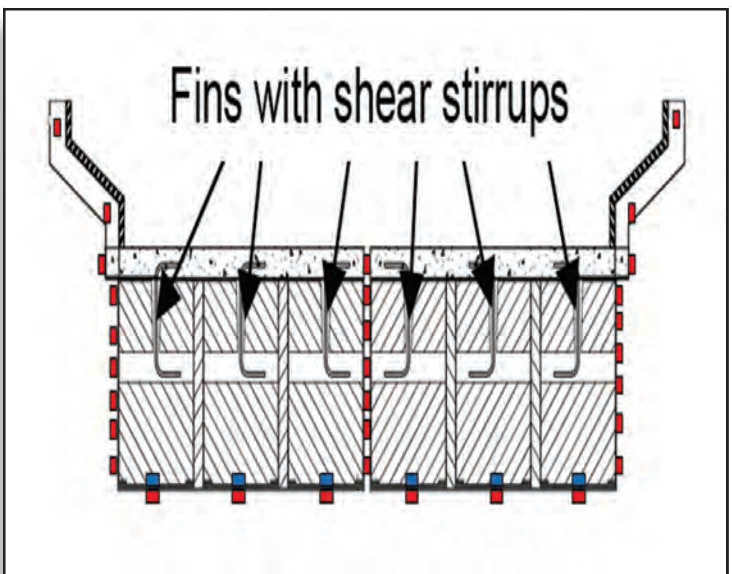
TTCI researchers test and evaluate a 42-foot hybrid composite beam span at FAST.

Transportation Technology Center, Inc., Pueblo, Colo., 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). This span was designed and built for BNSF. It is being tested at FAST prior to being installed on a revenue service line on SF. The new HCB span is performing well after more than 200 million gross tons (mgt) of heavy-axle-load (HAL) traffic.

Figure 1 illustrates the cross section of the BNSF span with six HCB cells.



In addition to the HCB technology, this span also features an innovative, lightweight, modular polymer concrete ballast curb design. To date, the ballast curbs are also performing well. These lightweight ballast curbs contribute significantly to weight reduction.

Observations to date include:

- Strains and deflections were measured on the HCB span under normal HAL traffic. The maximum vertical deflection measured was about 0.53 inch. The measured deflection of the new 42-foot span was about 67 percent of the maximum recommended by AREMA.
- Strains measured on the bottoms of each HCB section under train operation were fairly uniform and translate to maximum tension stresses of about 8.5 ksi to 10 ksi in the steel prestressing tendons.
- The hybrid span has not required any maintenance since its installation at FAST.
- Advancements in fabrication and design of the second-generation HCB span are evident by marked improvements in span performance compared to the previous laboratory produced 30-foot prototype HCB span.[1,2] 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 three-for-one basis, compared to the two-for-one basis common with prestressed concrete. These spans are also being considered as replacements for some steel spans.

Figure 2 shows the polymer concrete ballast curb panels and steel supports.

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. 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, as well.

The HCB span is designed to be used as a three-for-one or a four-for-one replacement of timber spans, rather than the two-for-one replacement that is typical when using concrete spans. This 42-foot HCB span is designed to replace three 14-foot timber spans.

Span characteristics

In the HCB system, each cell consists of a tied concrete arch encased in a fiberglass beam shell, previously described in *RT&S*.[3] Figure 1 shows a cross section of the BNSF span with six HCB cells. The concrete arch carries compression and the steel prestressing tendons carry tension. The fiberglass shell and diagonal reinforcing stirrups provide shear strength.

The 42-foot span is comprised of two half-span pieces with a five-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.

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.

Lifting weight of the half-span section with the deck and ballast curb (27 tons) is about 43 percent lighter than the prestressed concrete double cell box girder section (47 tons) that was removed. Figure 3 shows the completed installation.

The second-generation 42-foot HCB span differs from the previously tested 30-foot HCB span[1,2] in that it has an integral concrete fin above the arch, which was used to facilitate placement of the diagonal shear reinforcement during fabrication. 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 eight inches deeper than the shorter prototype 30-foot HCB span.

Compared to the 42-foot prestressed concrete span that was originally in this location, the HCB span is six 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 two-inch track raise was used to provide the minimum recommended ballast depth of eight 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 at FAST, 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. It operates at approximately 40 mph. The train normally does not have any wheels producing significant impacts from wheel tread defects. Wheels are

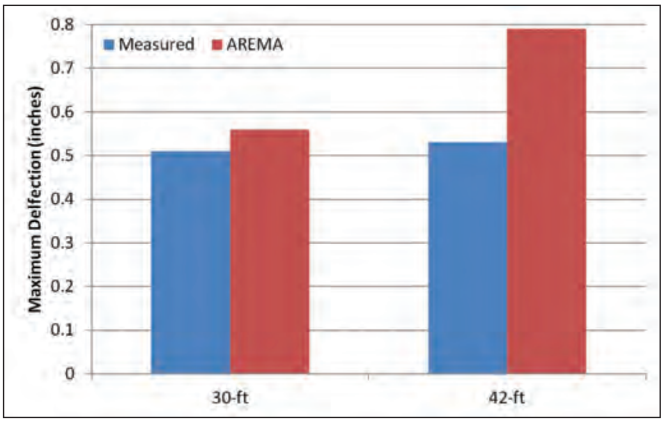


Figure 3, top, shows the completed installation of the 42-foot span at FAST.

Figure 4 illustrates the maximum deflections for a 30-foot HCB span versus 42-foot HCB span.

typically removed when impacts exceed 80,000 pounds.

The HCB span was installed at FAST on a five-degree curve with four inches of superelevation. Ballast depth below ties is eight inches at the low rail and 12 inches under high rail. The deck of the span is level.

Strains and deflections were measured on the HCB span under normal HAL traffic. The maximum vertical deflection measured was about 0.53 inch. Figure 4 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.

According to AREMA Chapter 8, the maximum allowable deflection for a 42-foot prestressed concrete bridge span is 0.79 inch.[4] This is 49 percent 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 measured on the bottoms of each HCB section under train operation were fairly uniform and translate to maximum tension stresses of about 8.5 ksi to 10 ksi in the steel prestressing tendons.[5]

Future testing

Future plans call for this new span to be tested at FAST for about 250 to 300 mgt and nearly two-million load cycles. 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.

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