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Testing of a Prototype Hybrid Composite Beam Span at FAST

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Summary

Transportation Technology Center, Inc. (TTCI) is evaluating advanced materials and designs for use in railroad bridges. As part of this process, TTCI has tested a prototype hybrid composite beam (HCB) span at the Facility for Accelerated Service Testing (FAST). The experimental span performed well during 237 million gross tons (MGT) of accumulated heavy axle load traffic during its two years at FAST.

- The span required no maintenance during the test period.
- Deck thickness and reinforcement are critical in order to control deck cracking. The second deck, with similar thickness and reinforcing as a comparable prestressed concrete span, performed well. Some cracking, consistent with reinforced concrete, was noted in the deck after the span was removed from service.
- Mid-span deflections decreased after track surfacing, which most likely reduced vehicle dynamic effects. As track roughness increased with additional applied tonnage, the HCB mid-span deflections increased by about 10 percent.
- Mid-span deflections of the HCB span under train traffic are about twice those of a comparable prestressed concrete span.
- The HCB span is slightly deeper, but lighter than a typical prestressed concrete span of the same length.
- The design of HCB spans for railroad applications is likely to be governed by deflections. For this reason, HCB spans will tend to be deeper than prestressed concrete spans of the same length.

The primary potential benefit offered by this revolutionary bridge technology is reduced handling weight for construction equipment. The reduced weight may enable railroads to handle longer spans with their existing cranes as compared to typical prestressed concrete spans. For off-line construction, the HCB spans can be particularly advantageous, because the individual beams without the deck could be placed with a very small crane; the deck could be cast-in-place concrete. It might be possible to use HCB spans as 3-for-1 or 4-for-1 replacements of timber spans, rather than the 2-for-1 that is typical using concrete spans. HCB spans may also be more economical than some of the shorter steel spans that are currently used on railroad bridges.

The HCB span uses concrete, steel, and fiberglass components. The HCB system consists of a concrete arch connected at its ends with steel tendons, all encased in a fiberglass beam shell. The concrete arch resists compression, and the steel tendons resist tension. The span has a conventional reinforced concrete deck.

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INTRODUCTION

About 60 years ago, prestressed concrete was a new concept in bridge building. It has since become the material of choice for the majority of bridge construction on some railroads. More recently, the hybrid composite beam (HCB) has been introduced as a new concept in bridge building. In order to evaluate the potential applications and benefits of this technology for railroad bridges, TTCI has been testing a prototype HCB span at FAST.

Prices for bridge materials, particularly steel, have been volatile in recent years, making the potential benefits of alternative bridge materials and technologies more attractive. The HCB span offers the potential for savings in both material and installation costs.

This *Technology Digest* is an update to two previous reports on the HCB span tested at FAST.[1,2]

PERFORMANCE TESTING

The 30-foot prototype HCB span accumulated 237 MGT of traffic during two years of testing under the heavy axle load (HAL) train made up of about 110 315,000-pound cars. Typically, the test train at FAST runs at 40 mph and does not have wheels that generate significant impact loads.

The ballast deck test span was installed at FAST in a 5-degree curve with 4 inches of superelevation. The deck of the span had no superelevation. Ballast depth below ties on the low rail was 8 inches. Four inches of additional ballast was placed beneath the ties on the high rail side of the track, for a total of 12 inches ballast depth below the high rail.

SPAN MEASUREMENT

Measurements show that the HCB span deflects about twice as much as a comparable prestressed concrete span. Figure 1 shows the vertical deflections measured after various amounts of accumulated tonnage. Deflections were measured under each of the eight beam units that make up the HCB span. (Figure 8 shows the ends of four beam units.)

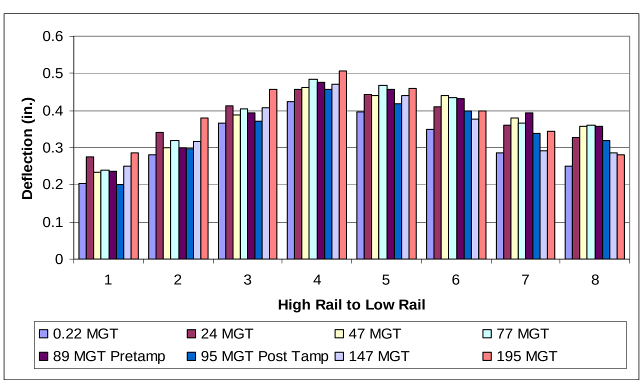

Figure 1. Vertical Deflections in the 8 HCB units at Various Tonnage Accumulations

Note that the deflections generally increased with accumulated tonnage, as track geometry became rougher. After tamping between 89 and 95 MGT, deflections decreased. With additional tonnage, the deflections again generally increased. The final deflection measurements were taken at 195 MGT. Variations in actual track superelevation and actual train speed also likely contributed to some of the variation in deflection measurements.

The maximum deflection measured was about 0.51 inch. The average deflection for all eight beams is less than 0.4 inch. The maximum recommended deflection for a 30-foot prestressed concrete span is 0.56 inch according to AREMA Chapter 8.[3] The same limit is recommended for steel spans in AREMA Chapter 15.[3] Theoretical average deflection was calculated to be about 0.3 inch,[1] not including any impact effects. The measured deflections for a 30-foot prestressed concrete span originally at this location, were less than 0.2 inch under the train at FAST. Field testing of timber trestles typically showed deflections of about 0.4 inch on spans of 14 to 15 feet, half the length of this HCB span.

The beams toward the center of the span show higher deflections. This is likely due to a stiffening effect from the ballast curbs on the outsides. While the ballast curbs have gaps to reduce the amount of stress in the curb, they still add considerable stiffness. Perhaps a stiffer deck or transverse structural connections between beam elements would make the deflections more uniform and reduce the maximum deflection. The design of HCB spans for railroad applications is likely to be governed by deflections. For this reason, HCB spans will tend to be deeper than prestressed concrete spans of the same lengths.

In addition to deflection measurements, strain measurements were also taken. Strain gages were attached at mid span to the bottoms of the eight HCB sections. Strain gages were also applied near mid span to the side faces at various depths on the outside beams, as Figure 2 shows. The results from these strain gage measurements were presented previously.[2] (Inside beam faces were not accessible for installing strain gages.) Measurements after additional tonnage accumulation showed little change. They confirmed that the magnitudes of the strains continue to indicate low stresses in the various components of the HCB, as predicted.[1] Because deflection is the governing factor in the design of this particular HCB, there is plenty of reserve load-carrying capacity.

Figure 2. Gages for Measurement of Web Strains

SPAN CHARACTERISTICS

The span at FAST was comprised of eight HCB sections covered with a 6-inch deep reinforced-concrete deck. Each section was 28 inches deep by 20 inches wide. The eight sections were bolted together in two groups of four beams. The concrete deck was cast in two halves. The deck had both top and bottom bar reinforcement, in both the longitudinal and transverse directions. The span was installed in a similar fashion as is typically done with prestressed concrete spans, as Figure 3 shows. Note however, the use of slings as the original lifting loops were removed with the deck rehabilitation. Care was taken to avoid lifting too close to the center of the span.

Figure 3. Installation of HCB Span with New Deck at FAST

DECK CONCERNS

As stated before, the HCB performed satisfactorily. The concrete deck however, proved to be critical. In order to meet recommended deflection limits, the deck of this particular span was connected to the beam units with shear stirrups. The composite contribution from the deck helped reduce the span deflection to meet the recommended value. (Discussions with railroad bridge engineers indicate that some railroads design beams to meet deflection criteria without including contribution from the bridge deck.)

The initial 30-foot HCB prototype installed at FAST had a concrete deck only 4 inches thick, with minimal steel reinforcement (one layer of welded wire fabric). After a series of controlled tests and tonnage accumulation, the track was removed for deck inspection. The inspection revealed cracks in the concrete deck at both ends of the span.[1] The HCB sections themselves showed no signs of deterioration or damage.

In order to conduct endurance testing on the HCB span, the original deck was removed, except for the portion over the outermost beam, in order to retain the ballast curb. Figure 4 shows the removal of the 4-inch deck.

Figure 4. Removal of 4-inch Concrete Deck

A new 6-inch concrete deck was cast. Figure 5 shows the ballast curb and the remaining portion of the original deck, including the new reinforcement. The new reinforcement pattern followed the BNSF-Union Pacific joint common standard design for prestressed concrete double-cell box girders of the same length, with top and bottom layers of reinforcing bars longitudinally and transversely. Top bars were continued over the portion of the original deck to help provide continuity in the deck. Figure 6 shows the 6-inch concrete pour.

Figure 5. Reinforcement for New 6-inch Deck

Figure 6. Concrete Pour for New Thicker Deck

The new deck performed satisfactorily. After 20 MGT of traffic, and again after 95 MGT of traffic, the ballast was excavated at both ends and mid span to inspect the concrete deck. Only minor cracks and no other signs of deterioration were noted.

POST-TEST INSPECTION

The HCB span was removed from FAST after 237 MGT of accumulated tonnage. No significant damage to the beams was visible externally; however, the deck showed some cracks running parallel and perpendicular to the ballast curbs. Figure 7 shows a crack running longitudinally for about the middle 15 feet of the 30-foot span on the span piece, which was on the high-rail side (outside) of the curve. This crack coincides with the joint between the old and new deck concrete. Some transverse cracks are also highlighted. The cross section view in Figure 8 shows how the longitudinal crack coincides with the deck joint on the outside span piece. These cracks appeared to be narrow and controlled, consistent with reinforced concrete. There were no areas where the cracking was as significant as that noted with the original deck.[1]

Figure 7. Post-Test Cracks in High-Rail Span Piece

Figure 8. Cross Section Cracks in High Rail Span Piece

The low-rail (inside) span piece had fewer visible cracks and none as long or as wide as those in the outside span piece. The load on the high-rail side is higher under typical FAST train operations at 40 mph, which is faster than the balanced speed with an unbalance of almost 3 inches. The difference in loads between low and high rail is likely responsible for the differences in deck performance noted between the two pieces.

The only damage seen was the cracking in the concrete deck. No damage to the HCB sections was noted. As previously stated, the HCB relies partly on the deck to limit deflections. The HCB sections themselves have more than enough capacity to carry the train and track loads.

FUTURE TESTING AND PROMISING APPLICATIONS

From a preliminary economic analysis, HCB technology might be best suited for spans in the 40- to 60-foot range. In this length range, concrete spans become too heavy to handle with many conventional railroad cranes, and steel alternatives are more costly. In 2011, a 42-foot HCB span is scheduled for testing at FAST. Untested and unresolved concerns at this point are fire resistance and survivability in a lateral collision.

REFERENCES

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