Studies of Box Beams for Railway Bridges

by F. P. Drew*

It is no longer necessary to preface a paper on prestressed concrete by describing what it is or how it is used. This is now common knowledge among bridge engineers and certainly railroad bridge engineers are no exception. Now that this is accepted as a basic material the question is—How can it be used most effectively? This paper will describe the concepts behind the acceptance of box beams as a standard railway bridge element, research on single box beams and the use of double box beams in a concrete trestle.

Many concrete trestles that are built now are a replacement of an existing timber trestle. This does not imply that all timber trestles are being replaced with concrete. The timber trestle is still a convenient and economical method of construction on the railroads and I am sure will continue to be; however, the prestressed concrete trestle by virtue of the increasing number of installations may be more economical in certain locations.

The timber trestle is commonly built with pile bents 14 ft. on center. This varies on different railroads—some may be 12 ft. 6 in. and others may be 16 ft. The concrete trestle to replace this timber trestle must have a bent spacing in a multiple of the existing bent spacing and a 28 ft. spacing of concrete pile bents is being recommended for this. Concrete trestle construction for a railroad is distinctive not only because of the large live load which it will carry, but because it must be performed without interruption to regular train operations. In effect this means that pile driving and the replacement of span elements must be done between trains. The pile bents are located to clear existing bents, caps (if cast-in-place) must clear the underside of existing stringers (if precast must have erection clearance), and the slab spans must be readily lifted into position under the existing ties and rails. Prestressed box beams are ideally suited to this “keep-the-trains-moving” construction philosophy. Once the beams are in position they are ready for trains and ballast can be placed directly on the tops of the beams.

In 1962 the Masonry Committee of the American Railway Engineering Association began preparation of specifications for concrete trestles using box beams. However, before recommending these for publication a research program was initiated at the AAR Research Center to demon-

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strate the performance of full-size beams under static and repeated loading. Fig. 1 shows the testing arrangement for these beams.

The first beams in this program were of the conventional type with end blocks and a center diaphragm. They were 3 ft. wide, 2 ft.-9 in. deep and 24 ft. long. The AREA specifications recommended a 28-ft. length, but the deflection of beams of this length was greater than the loading jacks could accommodate. However, the position of the loads was such as to produce design shear and bending moment simultaneously.

Loaded statically a conventional type beam withstood an ultimate moment of 2.9 times the design moment (Fig. 2). This exceeded the specification requirement by 13 percent and the calculated ultimate moment by 6 percent. The cracking moment was 1.7 times design moment and the deflection at ultimate load was 3.1 inches. The mode of failure was by concrete compression associated with large tensile strains in the strands.

Repeated loads applied to a conventional type beam showed that it could withstand 2,000,000 cycles of load where the maximum was 1.7 times design load. When the maximum load was raised to 2.1 design loads, 520,000 load applications were necessary to produce a failure. This failure was by progressive strand breakage and was not a sudden rupture as was the case for static loading. It was associated with a noticeably widening tensile crack and bits of concrete falling from around the crack. Thus, there appeared to be ample warning of imminent failure. This is an important feature and could be very useful to the bridge inspector in judging service performance and is indeed an advantage that prestressed concrete offers.

Since the conventional type beam demonstrated a superior perform-

<table>
<thead>
<tr>
<th>Conventional Type</th>
<th>Static Loading</th>
<th>Through-Voided Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.7 × Design Load</td>
<td>Cracking Moment</td>
<td>1.5 × Design Load</td>
</tr>
<tr>
<td>2.9 × Design Load</td>
<td>Ultimate Moment</td>
<td>3.0 × Design Load</td>
</tr>
<tr>
<td>2,000,000 Cycles</td>
<td>Repeated Loading</td>
<td></td>
</tr>
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<td>520,000 Cycles</td>
<td>For 1.7 × Design Load</td>
<td>2,000,000 Cycles</td>
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<td>For 2.1 × Design Load</td>
<td>540,000 Cycles</td>
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June 1965
Fig. 2—Load Deflection Diagram—Conventional-Type Beam.

Fig. 3—Load Deflection Diagram—Through-Voided Beam.
ance, particularly under repeated loads, it was decided to cast a series of beams having identical dimensions but without end blocks or diaphragms. These are referred to as "through-voided" beams.

The performance of these through-voided beams was practically identical to the conventional type (Fig. 3). The ultimate static moment was 3.0 times the design moment, the cracking moment was 1.5 design loads. The deflection at ultimate was 3.0 inches.

Under repeated loads, the through-voided beam withstood 2,000,000 applications of load where the maximum was 1.7 design loads. When the maximum cyclic load was raised to 2.1 design loads, 540,000 applications were applied before strand failure occurred.

The mode of failure for both types of beams was the same.

Table 1 summarizes the laboratory results.

This laboratory investigation has shown that box beams with these proportions—either of the conventional design or of the through-voided type—are adequate for railroad service with an ample provision for many cycles of overload. The investigation was conducted jointly with the PCI who furnished the beam specimens, and the AAR who provided the laboratory equipment and personnel. These beams were made by the Martin-Marietta Co. As a continuing aspect of this study a series of through-voided box beams have been cast using lightweight aggregate. These beams have the same dimensions as those with the regular mineral aggregate. Static and repeated loads will be applied to these beams to afford a comparison between those cast with regular aggregate and lightweight aggregate. This phase of the investigation is also being shared by the PCI and the AAR; and in addition, by the Expanded Shale, Clay and Slate Institute and the Carter-Waters Corporation. Beams were made by the Nebraska Prestress Co. In all phases of these studies, the Portland Cement Association has taken an active and constructive interest.

The through-voided beams have some advantages over the conventional type. The obvious one is the accessibility to the interior of the beam. The interior concrete surface can be inspected and the slab and wall thicknesses can be measured. The type of void used in these beams is selected to withstand the pressure of the wet concrete and if adequately held in position will produce the desired wall and slab thicknesses. There is always the possibility, however, that the void will displace or lose its shape. A thin wall or slab may not be apparent until after it has been placed in service and it then becomes an expensive replacement.

If the through-voided beam comes into general usage, a collapsible steel slip form may be devised by which these beams could be fabricated more economically. Savings might be realized in the cost of the void material as well as the assembling of it and positioning it in the casting bed.

There is also a saving in concrete quantity by the elimination of the end blocks and diaphragms and, of course, a corresponding saving in weight.

The AREA Bulletin for January, 1964, includes "Specifications for Design and Construction of Prestressed Concrete Trestles for Railway Loading, using Box Beams".

June 1965
This specification, if not revised during the year, will appear in the AREA Manual next year. Included in this are 3 ft. wide box beams, (the same as were used for the laboratory investigation) and 4 ft. wide beams. Two standard widths are recommended as this makes possible by various beam combinations deck widths from 12 ft. to 16 ft. to comply with that used by individual railroads. All beams are 2 ft-9 in. deep and 28 ft. long. One-half inch strands are used.

Other features of the trestle include prestressed piles, pre-cast caps, elastomeric bearing pads, and an epoxy resin-sand mixture in the keyway for bonding the beams together (Fig. 4).

The AREA Masonry Committee is presently developing a companion specification for use of through-voided beams. These beams will have the same dimensions as the conventional box beams.

Also under study by the Committee is a specification for the use of double box beams. As presently conceived, these will have end blocks and diaphragms, but through-voided beams might also be used.

The Seaboard Railroad has installed a number of concrete trestles utilizing the double box design (Fig. 5). As used by the Seaboard, it facilitates erection since only two beams are required to form a complete span. The joint between the beams is at the track center line and no shear keys or bonding is used (Fig. 6).

The AAR conducted a field test of this Seaboard trestle. The beams are 28½ in. deep, 6 ft.-3 in. wide and 24 ft. long. Each has two rectangular voids. Stresses were recorded in the double box sections and in the prestressed piles under a diesel locomotive and loaded train operating at a full range of speeds from 5 mph to 65 mph. A series of tests was also conducted to study the longitudinal forces developed...
by starting and stopping the train on the bridge. This field test indicated that the live load stresses are well distributed throughout the section. Recorded static stresses are less than calculated and recorded impacts are less than that specified for the design.

Recently the AAR conducted a field test of a C&EI Railroad bridge. This bridge utilizes six box beams to form the roadway span of 43 ft. Each beam is 3 ft. wide, and 3 ft.-6 in. deep.

Research, both in the laboratory and in the field, is demonstrating that box beams of either conventional type with end blocks and diaphragms or the through-voided type are suitable for railway use. Further research and development will undoubtedly yield other techniques whereby prestressed concrete can effectively and economically serve the railroad bridge requirements.

*Presented at the Tenth Annual Convention of the Prestressed Concrete Institute, Washington, D.C., September 1964.*