ABSTRACT

Precast concrete construction is the preferred alternative for railroad bridges in coastal areas and river crossings. Often engineers face challenging demands by local agencies to improve the hydrology of a given river by employing fewer numbers of piers, resulting in design of longer than the standard precast concrete railroad bridges. This paper presents the challenging attributes of utilizing precast construction for a 95 feet long precast concrete box girder and offers several solutions.

Introduction

Precast construction offers attractive advantages and has been the preferred bridge type for short span bridges by railroad agencies. Advantages of precast concrete construction include:

- Quality control of precast concrete
- Low maintenance
- Durability
- Simple and fast erection
- Ease of replacement
- Cost effective

These advantages entwined with the fact that it is much easier to standardize a concrete section have led to the design and construction of a great number of simply supported precast concrete railroad bridges. Because of the heavy live load and ballasted bed, railroad bridges are heavier than the highway bridges thus must absorb larger seismic
loads. There are major differences between a highway bridge and a railroad bridge, which the designer must consider, in the design and detailing of a railroad bridge. A few important characteristics to be considered are:

- For simply supported railroad bridges, the bents act as a free head cantilever in the longitudinal direction and do not provide an effective bent action in concert with the other bents.
- The rail in a ballasted structure can contribute in resisting longitudinal seismic forces. The new proposed AREMA seismic design criteria acknowledges the contribution of the Continuous Welded Rail (CWR) in resisting longitudinal seismic forces. However quantifying the CWR contribution is subject to further research and development.

One of the shortcomings of precast box sections is span length limitation. The largest standard section can span up to 65 feet. The design and detailing of a 6'-0” deep precast box girder spanning 95 feet is presented in this paper.

![Project description](image)

The bridge provides a three-track crossing over concrete paved 300+ foot wide waterway. The bridge is 380 feet long consist of 4 equal spans of 95 feet.

The bridge replaced an existing single track steel truss structure across the waterway. The pier columns are five concrete CIDH extensions. The cap beam is 7 feet wide and 7 feet deep (see Figure 1, previous page).

The typical section of the pre cast beam is shown in Figure 2. The 6 feet beam is similar to the standard railroad precast section with the exception of the depth and the superstructure weight, which is about 1.5 k/ft for the 3-ft width. The box was designed for a total of 26 in of ballast.
Staged Construction

The bridge structure was constructed in three phases. During Phase 1, the 6 ft dia. CIDH piles in the river under the existing structure were placed. Next a portion of the abutment piles and the superstructure boxes to accommodate a new track were placed. The rail traffic was shifted to the new track. The existing steel truss bridge was demolished during Phase 2 to make room for the boxes for the second and third tracks in Phase 3 after the remaining CIDH piles at the abutments were placed.

Seismic Design

The bridge is located in an active seismic zone with an expected Maximum Credible Earthquake of up to magnitude 8 on Richter scale. The bridge is designed for two level seismic criteria; operational level earthquake (OLE) corresponding to an event with a return period of 72 years and a contingency level earthquake (CLE) for a seismic event with a return period of 1000 years. The goal of the seismic design criteria is to provide a high level of assurance that the overall system will be able to maintain operation following an OLE, and will survive without collapse and provide for public safety following a CLE.

Structure was designed to withstand the OLE without significant structural damage. The extent of damage should be such that repairs can take place while continuing operation and maintaining safety of trains at restricted speeds. Structure was designed to survive the CLE without collapse, but possibly with significant structural damage. The extent of damage should be such that passenger trains can be operated at reduced speed with minimum down time.

A three dimensional dynamic model was develop to perform a linear analysis utilizing a site-specific spectral density. The two sets of P-Y curves were used for transverse and longitudinal direction. The seismic analysis was performed for each stage of construction. The contribution of rail in resisting longitudinal seismic force was not considered for this study. 5% damping was used for the dynamic analysis.
In order to minimize the longitudinal deflection of the piers and preventing the formation of hinges under the lower level earthquake, the abutments were engaged in longitudinal direction. Passive soil pressure behind the abutments was mobilized in longitudinal direction. Proper restrainers or shear keys must be designed to provide a load path to transfer the forces from superstructure to substructure.

**Relative Stiffness**

Abutments are much stiffer than the bents. In addition to the passive soil pressure provided by the soil behind the back wall, the lateral resistance from embedded pile contributed a great deal in resisting seismic load. The amount of load resisted by the abutment must be designed and controlled by the retainer system. For the subject bridge, the abutment is resting on 4 CIDH piles. Through iterative processes the diameter of the piles, height of abutment stem and back wall was determined. In order to provide more flexibility to the abutment and engage the piers to a larger extent, an expandable polystyrene collar was provided around the CIDH piles. This technique will also enable the designer to control the amount of force absorbed by the abutment, which is critical in design of the shear keys and restrainers. The depth and thickness of the expandable collar was selected through a careful study of relative stiffness of the abutment with respect to the piers.

**Foundation design**

It would be extremely difficult to design conventional abutments for the large forces associated with seismic loads. Abutments are normally designed with at least two rows of piles. Large lateral force would generate excessive tension and compression force on the abutment piles. To minimize the effect, the abutment must be designed with a short stem wall or simply extending the pile cap to provide the seat for the girders. Another solution is to utilize large size piles in a single row. For the subject project, four 5-foot CIDH piles in a single row were designed. The abutment in this case is very similar to the piers in shape and configuration.
Load Path

In compression mode, the forces the restrainer devices need to overcome are the passive soil pressure as well as the lateral pile resistance. The Backwall easily can be designed to act in the compression mode for transferring the seismic load. In order to lower the center of gravity of the applied load, a narrow strip of expanded joint filler will be glued to the bottom of the backwall (see figure 5, following page). In tension mode a restrainer will provide the path for transferring the load from superstructure to substructure. A steel rod embedded in the abutment seat and projected into the diaphragm can provide adequate load path. Note that the bar will also restrain the structure in transverse and vertical direction. An oversize pipe cast in the beam will provide construction tolerance and also provide flexibility of accommodating moderate relative movement, which is a characteristic of a standard railroad bridge.
Transverse Post-Tensioning

The stage construction of the bridge structure created an interesting problem of dealing with transverse post-tensioning in stages. To account for the stage construction, it was found prudent to post-tension the stage 1 boxes transversely with a 1 1/4 in. HS rod. The rod was not grouted in the duct to facilitate detensioning after stage 3 construction. Three – 0.5 in dia strands were used to post-tension transversely the entire structure. After grouting the strands in the ducts, the stage 1 post-tensioning was detensioned.

Discussion

Standard railroad bridges are heavier than highway bridges. They are mainly simply supported structures. The track provides a good longitudinal restraint. This fact is recognized by the proposed new seismic design criteria. However, the track contribution is difficult to quantify. For short railroad bridges track contribution can be significant. Many railroad engineers believe that the fact that most of standard railroad bridges performed better than highway bridges because of the track and the fact that they are mainly simply supported structure. However if the structure were relatively long, the track contribution would not be adequate to ensure the integrity of the structure during strong shaking. In such cases the designer would have several options. Either design supers bents or engages the abutments or both. Careful consideration must be given to the design and detailing of the abutment if it is to participate in resisting longitudinal seismic loads. The designer can achieve a good design through an iterative process. The stiffness compatibility is a critical issue, which deserves full attention. The designer needs to develop special details to ensure the integrity of all the elements as well as providing a functional load path.
**FIGURE 5 - RESTRAINER DETAIL AT ABUTMENT**

- 2" Ø ROD ASTM A709 (GR. 50) w/ HEX NUT, SWEDGED BOTTOM 2"-0" THREAD TOP 6", TYP
- 5" SCHEDULE 40 PIPE
- FILL VOID WITH RUBBERIZED ASPHALT IN THE GIRDER PORTION ONLY, (COLD APPLICATION TYP)
- 1" EXP POLYSTYRENE
- 5" SCHEDULE 40 PIPIC (2"-0" LONG WITH 3/8" PLATE WELDED ON ONE END)
- FILL VOID WITH EPOXY GROUT TO TOP OF ABUT SEAT BEFORE GIRDER ERECTION

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**FIGURE 6: VERTICAL RESTRAINER**

- 1/8" CAP
- (EXTRA BRG ONLY-TORQUE NUT SNUG TIGHT FOR FIX BRG)
- 5" SCHEDULE 40 PIPE
- FILL VOID WITH RUBBERIZED ASPHALT (COLD APPLICATION TYP), TYP
- 2" VERICAL RESTRAINER ROD
- WITH HEX NUT, SWEDGED BOTTOM 2"-0" AND THREAD TOP 6", TYP
Conclusion

Long span precast deep box sections can be designed and detailed for heavy railroad bridges. The contribution of Continuously Welded Rail in resisting the longitudinal seismic force is recognized by AREMA. For short rail bridges the CWR can provide adequate lateral resistance in case of a moderate seismic event. For relatively long rail bridges however, the abutments can be designed to participate in resisting the longitudinal seismic forces. Special attention must be given in design of the transverse post tensioning for deep precast box sections. Further research and development is required for the post tensioning force and to quantify the CWR contribution in resisting longitudinal seismic forces.