Surgical Demolition of the Paseo Bridge

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ABSTRACT: Once the longest self-anchored suspension bridge in the world, the three-span Paseo suspension bridge, containing spans of 308, 616 and 308 feet, was demolished in 2011. Details of the original analysis and construction methods are presented along with an in-depth discussion of the step-by-step deconstruction modeling techniques used to analyze and safely remove the span are presented.

INTRODUCTION

Genesis Structures was appointed by the Paseo Corridor Constructors joint venture to carry out a detailed demolition analysis of the Paseo Bridge in Kansas City, Missouri. Figure 1 shows an aerial view of the bridge during demolition.

Figure 1 – Paseo Bridge during demolition

Using LUSAS Bridge analysis software, Genesis Structures built a model of the existing structure, incorporating all major renovations made to it during its lifetime. This was further developed to include all proposed demolition/removal steps.

An additional model was developed to assess the lowering of the main suspension cables, and another to investigate detailed stresses and effects on the pier tower base and anchor bolt system. All analyses proved that the intended demolition sequence could be undertaken safely.

STRUCTURE TYPE

The Paseo Bridge was designed by Howard, Needles, Tammen and Bergendoff in the early 1950's, and built by American Bridge Co. in 1954. It was a four-lane, self-anchored suspension bridge that carried I-29/35 and State Route 71 over the Missouri River in Kansas City, Missouri. Suspended spans of 308, 616 and 308 feet, south approach plate girder spans of 90 and 174 feet and north approach plate girder spans of 219 and 110 feet carried two 13-foot traffic lanes in both directions separated by a 4-foot median. When first opened to traffic, it was the longest self-anchored suspension bridge constructed in the world (Figure 2).

Courtesy American Bridge

Figure 2 – Paseo Bridge at completion of construction in 1954

The original construction of the bridge began with the erection of the 136-ft tall plate steel pier towers, braced with upper and lower struts. These towers supported the 10ft deep longitudinal plated stiffening girders, which were built in segments on falsework towers across the river, as shown in Figure 3. Hinged connections in these girders at mid-span and at each tower position used 13" diameter steel pins to accommodate rotational movement and longitudinal thrust during construction.

Courtesy American Bridge

Figure 3 – Stiffening Girder Erection

The suspension cables for the bridge passed through holes in the upper struts and sat on cable saddles (Figure 4) that were supported on a set of 12, 6" diameter by 30" long rollers that rested on a substantial steel plate support that allowed longitudinal movement throughout all stages of construction.

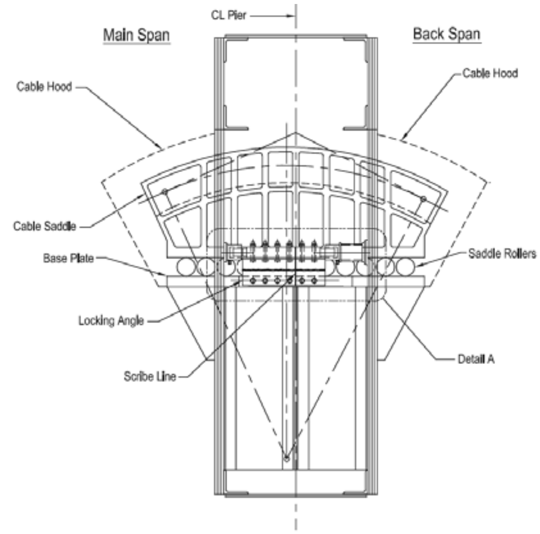

Figure 4 – Cable Saddles

Pairs of suspender cables connected the main cable to the stiffening girders, which were set approximately 60” high to allow for the connection, as shown in Figure 5. Once all suspenders were connected, the deck superstructure was lowered until it was fully supported by the main cable.

Courtesy American Bridge

Figure 5 – Suspender Cable Attachment

Bridge construction was completed with the placement of a 7” non-composite concrete slab. At this point, temporary bolted connections at the three hinge locations were removed and cover plates were riveted on to complete the connection and make the stiffening girder continuous. Permanent locking angles were also placed at the cable saddles (Figure 4) to restrict any further movement at the tops of the towers.

Throughout the life of the bridge, there were minor modifications to the barrier system and only one major renovation in 2004. This involved the placement of an additional wearing surface and the replacement of the main stiffening girder bearings. The tops of the new bearings were set 3” lower than the originals to account for the weight of the additional wearing surface and reduce the negative bending in the stiffening girders at the pier towers.

All stages of the original bridge construction and subsequent renovation were modelled using LUSAS Bridge analysis software (Figure 6) to determine the displacements, girder stresses and cable forces for the final in-service condition prior to performing the demolition analysis.

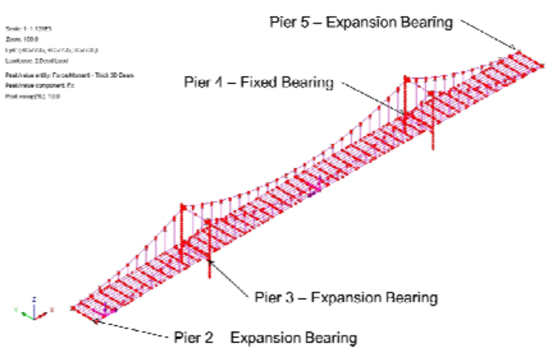

Figure 6 – LUSAS Model

DEMOLITION SEQUENCE

The basic plan for the demolition of the bridge was to reverse the steps taken during construction. As such, the first step in the demolition was the removal of the wearing surface from the entire bridge deck. Following wearing surface removal, the locking angles at the cable saddles were removed to allow for movement of the cables at the tops of the towers, thus eliminating the build-up of any bending stresses at the base of the pier towers.

Slab removal, shown in Figure 7, progressed from the center of the bridge outward. In conjunction with the slab removal, a detailed sequence of concrete block ballasting, as well as water ballasting within the stiffening girder, was implemented to minimize girder stresses during the removal. Once the slab removal was complete, stringers and selected floor beams were removed from the superstructure to leave a minimal structural configuration.

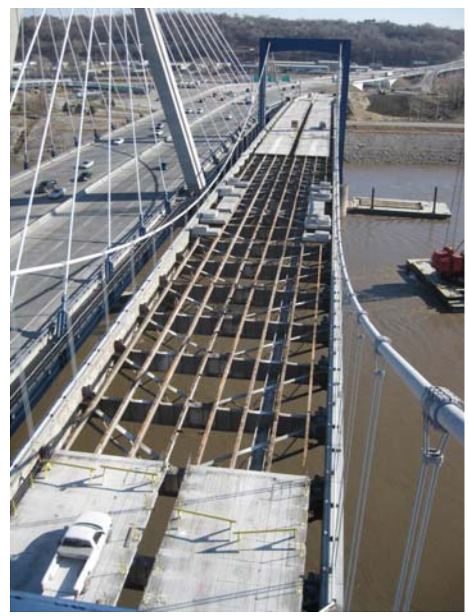

Figure 7 – Slab Removal

REMOVAL OF FORCE

To assist with the next stage of demolition, four falsework towers, each comprising 36” diameter pipes braced in a six-pile configuration, were installed under the center span (Figure 8). A jacking system consisting of four 246-ton hydraulic jacks at each falsework tower, along with sixteen 180-ton strand jacks (Figure 9) supported by the existing bridge pier towers was used to lift the longitudinal girders and remove the remaining superstructure load from the main suspension cables.

Figure 8 – Falsework Towers

Figure 9 – Strand Jack System

The total lifted load was approximately 5.2 million pounds, raising the girders 29” at the falsework towers and 24” at the bridge piers. As a result of the lift, the load in the suspender cables was reduced from approximately 70,000 pounds per cable to a nearly slack condition, which allowed the suspenders to be cut and removed (Figure 10).

Figure 10 – Suspender Cables after lifting

As the girders were lifted, it was important to ensure that the cable saddles were free to move to avoid inducing bending stresses at the bases of the pier towers due to the imbalance in tension in the main cable. Over the course of the lifting sequence, the saddles at each pier tower moved towards their respective back spans a total of 5.5”. During the entire deck removal and lifting operation, the force in each main cable was reduced from 4,000 kips to approximately 270 kips.

CABLE LOWERING

With the suspender cables unloaded and removed, the main suspension cable removal could begin. Despite the fact that it no longer supported any deck load, the suspension cable still carried 270 kips of tension under its own self weight, so simply cutting the cable at this point was not an option.

Another issue the design team had to work around during the cable removal phase was the limited crane access to each of the cable saddle locations. At this point in the demolition, the Christopher S. Bond Bridge, which was built to replace the Paseo Bridge, sat less than 10ft away. As a result, the bridge could only be accessed from the west side.

It was determined that the best way to remove the load in the main cable was to lower it, along with the upper strut of each pier tower, using the same strand jacks used for the girder lifting (Figures 11 and 12).

Figure 11 – Strand Jacks for Cable Lowering

Figure 12 – Cable Lowering

In order to accomplish this, the cable saddles had to be restrained once again to prevent movement during the lowering. Restraining the cable saddles, however, forced an imbalance in cable tension to develop between the main span and the back spans as the cable geometry changed and also touched down at the remaining floor beams. This became a point of concern, as the tension imbalance would induce bending stresses at the bases of the pier towers.

In order to fully understand the cable tension and pier tower base stresses throughout the lowering, two additional analysis models were created. The first model, shown in Figure 13, was developed using a geometric nonlinear cable with support displacements to investigate the forces in the cable as it was lowered. Inserting supports into the model as the cable touched down on the falsework towers, floor beams, or stiffening girders below gave an entire time history of reactions and forces.

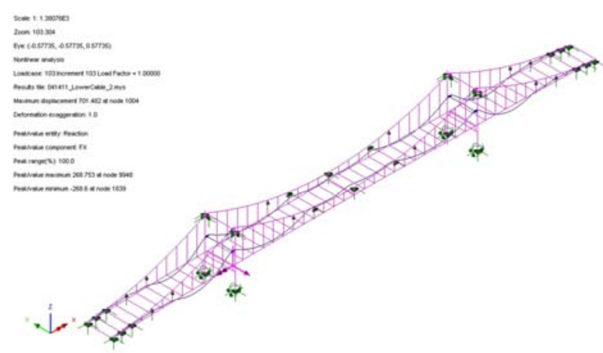

Figure 13 – Cable Lowering Model

Using the imbalance in the cable tension forces, a second model, shown in Figure 14, was created of the pier tower bases to ensure that the bending moments induced in the pier towers did not cause overstress or pullout of the pier tower anchor bolts.

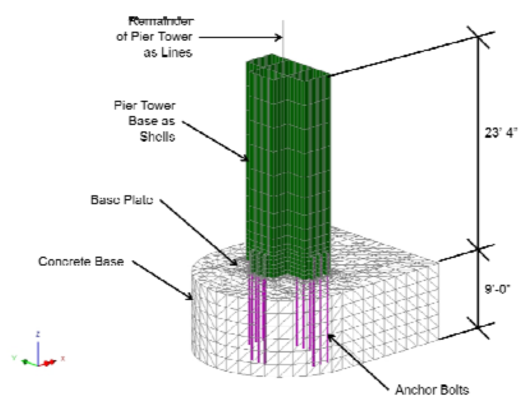

Figure 14 – Pier Base Model

GIRDER REMOVAL

The final major stage in the demolition process was the removal of the 10-ft deep stiffening girders and remaining floor beams. For this stage, four additional falsework towers were required. The falsework towers supporting the south back span of the bridge were comprised of 24” diameter pipes braced into a four-pile configuration, while the pair of falsework towers supporting the north back span of the bridge was able to be constructed on the bank out of HP12x84’s braced into a four-pile configuration with bracing between the two towers for stability. Once all falsework towers were erected, the stiffening girder could be cut into segments weighing approximately 200 kips each, and removed using a crane (Figure 15).

Figure 15 – Stiffening Girder Removal

CONCLUSION

Using LUSAS, Genesis Structures was able to accurately model construction techniques used in 1952 to determine the state of stress and geometry of this major self-anchored suspension bridge as the contractor prepared for the demolition. Knowing the exact state of stress in the structure allowed for a complete understanding of the demolition process during all stages including critical unbalanced lifting and lowering operations.

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