Rehabilitation of a Viaduct Subjected to a Landslide Thrust

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Summary

The viaduct No. 1 located on the Caracas-La Guaira highway was affected by a landslide thrust detected in 1987. The structure consisted of three parallel double-hinged arch ribs built without longitudinal reinforcement, spanning over 152 m. and two approach viaducts located at either side of the arch rib span. This paper summarizes the rehabilitation measures conducted on the structure to extend its service life, which included the construction of redundant gravity and lateral load resisting systems, external post-tensioning of the arch ribs and the design of a plastic hinge at the crown of the ribs.

Keywords: Arch Bridges, Concrete Structures, External Post-Tensioning, Landslide, Plastic Hinge, Retrofitting, Structural Rehabilitation.

1. Introduction

The viaduct No.1 is shown in Figure 1. It consisted of three parallel concrete ribs, hinged at their bases, built without longitudinal reinforcement, and two approach viaducts located at both sides of the arch span. The structure was located on the Caracas-La Guaira highway, approximately 4 kilometers away from the city of Caracas, capital of Venezuela.

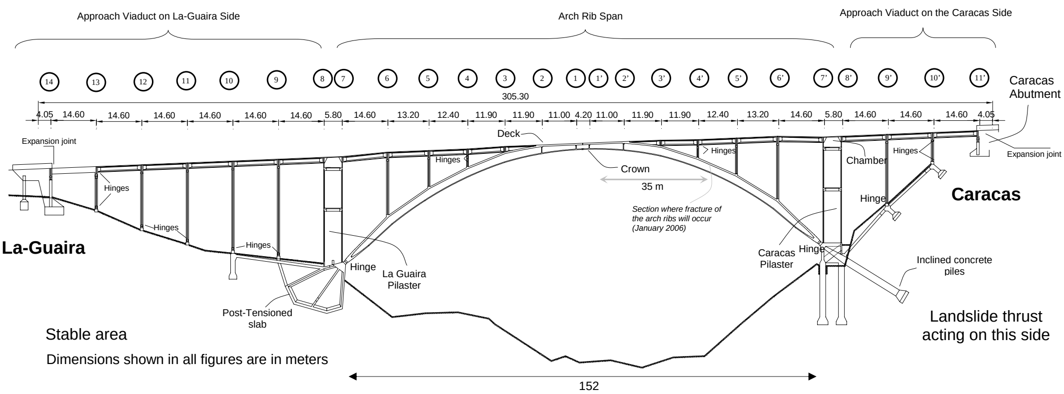

Fig. 1: The Viaduct Subjected to the Thrust

Cracking of the grade beams first observed in 1987 led to an extensive geotechnical investigation. Results from these investigations indicated the existence of an ancient landslide affecting the Caracas side of the viaduct. Surface monitoring showed that the landslide displacement vector intersects the viaduct at a 45 degree angle, thus inducing transverse and longitudinal displacements

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on the portion of the structure sitting on the Caracas side (Figure 2). A site inspection conducted in 1987 indicated that the expansion joints located at the abutments were closed. Because the arch ribs and the deck become a solid member at the crown, as shown in Figure 1, the arch ribs are restrained to advance longitudinally if the expansion joints between the deck and the abutments are closed. Thus, the first rehabilitation measure conducted on the viaduct (December of 1987) consisted of a concrete demolition of the deck to create a gap at the joints. It is worth mentioning that the expansion joints continuously closed, as a consequence of the landslide thrust and needed to be reopened in several opportunities, as it was done in December of 1987.

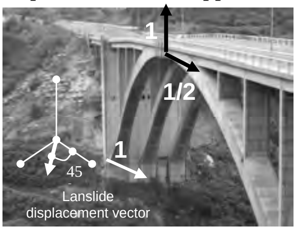
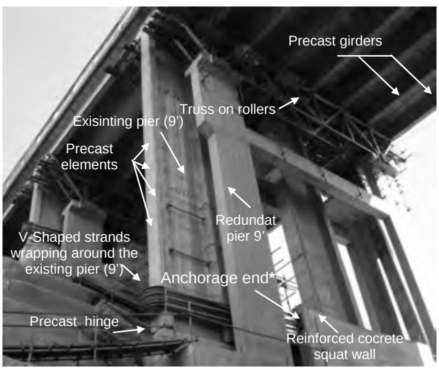


Fig. 2: Displacement Relatioships

In 1993 a redundant gravity load resisting system was built on the access viaduct located on the Caracas side, as shown in Figure 3. It consisted of a redundant steel truss at the Caracas abutment, a set of paired steel trusses supported on a redundant concrete piers located at either side of piers 9' (Figure 3) and 10', and a group of steel struts that supported the precast girders inside the chamber located on top of the Caracas pilaster. The entire redundant system was supported on rollers placed in the transverse direction of the Viaduct.

A redundant lateral load resisting system was built at the base of piers 9' and 10', as shown in Figure 3. Heavily reinforced concrete (RC) squat walls were built at both sides and parallel to each of the piers. The squat walls provided anchorage ends for a pair of prestressing strands each of which wrapped the existing piers in the transverse direction in a V-shape. Additionally, the ribs were post-tensioned (Figure 4) and a plastic hinge was designed at their crown. The idea was to convert a statically indeterminate arch rib, with two hinges, into a statically determinate one, with three hinges: two real hinges and one plastic hinge (PH) at the crown, and thus practically immune to the longitudinal thrust. Reinforcing details for the PH are shown in Figure 5. The statically determinate arch ribs the made it possible for the viaduct to accommodate net deformations up to 190 cm.



* This end provided anchorage for V-shaped strands that wrapped the column pier located further to the right in the picture.

Fig. 3: Lateral and Gravity Load Redundant Systems at Pier 9'

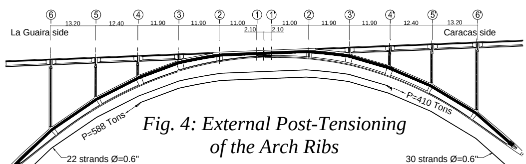


Fig. 4: External Post-Tensioning of the Arch Ribs

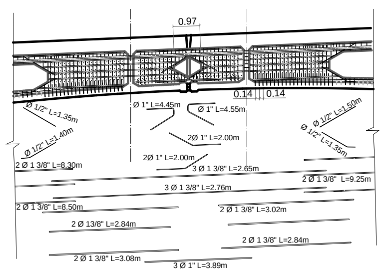


Fig. 5: Plastic Hinge Reinforcement

On January 5th 2006 after three days of intense raining, a sudden and significant landslide displacement of approximately 25 cm. affected the viaduct. Immediately all traffic over the viaduct was prohibited. The velocity of the landslide thrust reached values of approximately 0.8 cm./day in subsequent days. In March 18th 2006 the viaduct collapsed. Neither injuries nor casualties were associated with the collapse.