Collapse of the Koror-Babeldaob Bridge

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Summary

In September 1996, six months after the post-tensioned concrete bridge was retrofitted to correct midspan sag, the main span suddenly collapsed into the Toagel Channel. The investigation led by Wiss, Janney, Elstner Associates (WJE) found that the collapse was due to compression failure of the top flange. The retrofit and restrained thermal expansion substantially increased the compressive stress in the top flange over the main piers. The top flange was vulnerable to delamination because transverse reinforcement was not provided and planar cracking between the closely spaced tendons was especially likely.

Keywords: Box girder; post-tensioning; collapse; delamination; bridge; segmental construction.

1. Introduction and Background

Figure 1. KB Bridge shortly after construction, circa 1980.

The Koror-Babeldaob (KB) Bridge connected the islands of Koror and Babeldaob (a.k.a. Airai) in the Republic of Palau. When completed in April 1977, the 241 meter main span of the KB Bridge was the longest concrete box girder span in the world. A photograph of the bridge taken shortly after construction is shown in Figure 1.

Until recently, findings of the investigation were confidential pending resolution of litigation related to the collapse. The litigation is now closed, and the bridge has been rebuilt.

The rectangular concrete box section was 7.3 meters wide and varied in depth from 14 meters at the main piers to just 4 meters at the midspan hinge. The box section was post-tensioned using up to 310 tendons laid out in four layers in the top slab above the main piers.

Shortly after construction, a noticeable deflection at the midspan hinge developed. Between January 1977 and January 1993, the hinge dropped almost 1.4 m. To correct the midspan deflection, the Republic engaged an engineering firm to design a retrofit. The retrofit design had four primary objectives: 1) provide a smooth riding surface, 2) stabilize rotation at the hinge, 3) keep the bridge open, and 4) stay within a $2 million budget.

The final solution devised to correct the excessive deflection included additional post-tensioning tendons inside the box and jacking the bridge apart at the center hinge. The eight post-tensioning tendons were anchored in each back span and deviated downward in the midspan region, creating an uplift force. After jacking the bridge apart, flat jacks were filled with cementitious grout.

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This change fundamentally altered the structure; instead of two independent cantilevers, the retrofitted bridge was continuous. The center hinge jacking force as well as restrained thermal expansion was resisted by the box section and pile foundations.

On September 26, 1996, at 5:30 pm, the bridge violently collapsed. Two motorists were killed and four more were injured.

2. Investigation

Figure 2. KB Bridge after collapse, March 1997.

The site investigation began six months after the collapse, in March 1997. Figure 2 shows a view of the bridge taken from the Koror side at that time. The investigation team inspected both the above and underwater portions of the structure in three primary areas: 1) the main pier and backspan on the Airai side, 2) the main pier and backspan on the Koror side, and 3) the underwater portion of the main span.

Concrete core samples and fragments retrieved from the site were tested for physical properties and chloride content as well as general characteristics and quality. Also, to better understand the influence of the closely spaced ducts on the compressive strength of the top slab, replicas of the top slab were fabricated and tested in compression.

3. Conclusion

The collapse of the KB Bridge was triggered by compression-induced delamination of the top flange. A retrofit completed six months before the collapse substantially increased the compressive stress in the top flange. Furthermore, the closure of the center hinge resulted in daily variations in this stress. While the estimated stresses due to the retrofit are within normally accepted limits, the top flange was particularly vulnerable to delamination, mainly due to the closely spaced tendons and relatively low tensile strength of the concrete. Carbonation induced corrosion may have contributed to the delaminations. The delamination of the top flange led to compressive failure of the Airai side box section, ultimately resulting in collapse of both cantilevers, which were connected by the retrofit tendons.