Fatigue Evaluation and Retrofit of Pearl River Bridge

Jonathan McGORMLEY
Principal
Wiss, Janney, Elstner
Associates, Inc.
Northbrook, Illinois
jmcgormley@wje.com

Richard LINDENBERG
Senior Associate
Wiss, Janney, Elstner
Associates, Inc.
Northbrook, Illinois
rlindenberg@wje.com

Brian SANTOSUOSSO
Senior Associate
Wiss, Janney, Elstner
Associates, Inc.
Northbrook, Illinois
bsantosuosso@wje.com

Nick ALTOBELLI
State Bridge Engineer
Mississippi Department of
Transportation
Jackson, Mississippi
nalto@mdot.ms.gov

Summary

MDOT commissioned a comprehensive assessment of the I-20/55 Pearl River Bridge in respons
to cracking in the river crossing spans. Five diaphragm connections were instrumented to evaluate the connection performance under control truck loading before and after the installatior of trial retrofits. These retrofits included large cored holes to remove cracks and alter the stresses in the web gap as well as new fillet welds fixing the connection plate to the girder top flange. Test results show that the cracking is caused by out-of-plane distortion of diaphragm connection plates at the girder webs. Attaching the connection plates by welding to the girder top flange and down 305 mm (12 in.) on the web is the recommended retrofit to address both positive and negative moment region cracking and extend the service life of the bridge by more than 30 years

Keywords: Fatigue Cracking, Steel Bridge, Fatigue Retrofits, Instrumentation, Field Testing

1. Introduction

Figure 1 Pearl River Bridge

A comprehensive assessment of the I-20/55 Pear River Bridge was commissioned by the Mississippi Department of Transportation (MDOT). Work included an instrumentation program to measure live load responses at fatigue sensitive details. This work was in response to cracking in the river crossing spans of both the eastbound and westbound structures (Figure 1).

Cracking at diaphragm connection plates has been an on-going problem with this bridge since first identified in about 2006. Subsequent inspections carried out in 2008, late 2011, and early 2012 identified numerous cracks at tack welds attaching the vertical connection plates to the girder top flange, at the intermittent fillet welds attaching the vertical connection plates to the girder web, and along the longitudinal weld of the girder web to top flange. The cracks were most prevalent in positive moment regions of the interior girders.

This paper presents the results of the field testing program performed to measure live load responses at details identified as having fatigue cracks. As part of the field testing, trial fatigue retrofits (Figure 1) were installed and their behavior evaluated to determine appropriate retrofits to address the fatigue cracking. Retrofits included welded repairs to reduce out-of-plane distortion and large cored holes to capture existing crack tips.

https://doi.org/10.2749/222137813806520983

2. Conclusions and Suggested Retrofits

The strain and displacement measurements at selected connection details verified that out-of-plane displacement is occurring at the diaphragm connection plates at levels sufficient to cause the observed cracking. Various trial retrofits were installed and instrumented to determine which retrofitted detail would offer the most acceptable level of performance. The data collected during the testing provided information necessary to propose retrofits for each of the selected details.

2.1 Positive Moment Diaphragm Connections

The cracking observed at the diaphragm connections is a result of displacement-induced distortion under live loading due to the lack of positive attachment between the vertical connection plate and girder top flange. This condition is further exacerbated by the stitch welds used to attach the vertical connection plate to the girder web plate. The stitch welds are of generally poor quality with uneven profiles and terminations.

The instrumentation data shows an increase in flexibility and stress when the vertical connection plates are separated from the girder top flange on each side of the web. Depending on the traffic loading location relative to the connection, lesser increases in connection flexibility and stresses were also observed when only one connection plate was separated; this typically occurred when traffic loading was on the same side as the separated connection plate.

The displacements and stresses were significantly reduced when the connection plate was welde to the girder top flange in combination with the large hole retrofit. However, no reduction in stresses was measured when the two top stitch welds on both sides of the connection plate were separated from the girder web and the connection plate-to-girder top flange was welded.

To address the observed cracking at the positive moment diaphragm connections, the selected fatigue retrofit was recommended to include welding the diaphragm connection plate to the girder top flange, as well as providing a continuous fillet weld the full depth of the diaphragm top chord member for a total length of about 305 mm (12 in.). This requires incorporating the three existing stitch welds on each side of the connection plate into one continuous fillet weld.

2.2 Negative Moment Diaphragm Connections

As with the positive moment connections, the cracking observed at the negative moment diaphragm connections is attributed to out-of-plane displacement of the web gap. Installation of large hole retrofit, which has historically worked well for web gap displacements less than 0.05 mm (0.0020 in.) appears not to have reduced the web stresses. It is possible that crack re-initiation from the large hole retrofit may occur with time and that a loosening or fixed retrofit is more applicable to this connection.

Because of the diaphragm geometry, cutting back the vertical connection plate to increase the web gap as part of a loosening retrofit is not possible. Therefore, as with the positive moment connections, installation of fillet welds at the girder top tension flange and to the full depth of th diaphragm top chord member 305 mm (≈ 12 in.) were recommended. By employing proper welding procedures, the probability of creating a defect while field welding to the tension flange substantial enough to cause a future fatigue problem is less likely than crack re-initiation using only the large hole retrofit. Once the welds have been installed, all remaining crack tips should be removed using a properly-sized cored hole. The removal of all crack tips should be verified using non-destructive test methods.

Based on this study, fatigue retrofits will improve the performance of this structure and extend it fatigue life by more than 30 years as historically demonstrated by similarly retrofitted details. This retrofit work is expected to cost approximately US $1.5 million as compared to a replacement cost of approximately seven times the retrofit cost.