Acoustic Emission and Strain Gage Monitoring

of

CALTRANS STRUCTURE B-22-26 R/L

I-80 Sacramento River (BRYTE BEND)

SACRAMENTO, CALIFORNIA

by

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Purpose

This report describes the results of a series of acoustic emission and strain gage tests performed on Caltrans structure B-22-26 R/L by Engineers from Northwestern University's Industrial Research Laboratory, BIRL. These tests were performed with the cooperation of Caltrans personnel under sponsorship of the Infrastructure Technology Institute of Northwestern University. The purpose of these tests was to provide Caltrans with additional information to better understand the nature of the cracks in the webs of this structure. Tests were performed in June of 1993 and again in June of 1994.

Background

The Bryte Bend Bridge carries I-80 traffic over the Sacramento River near Sacramento CA. The bridge consists of two 4,050 foot trapezoidal steel boxes, each thirty six feet in width. Its approaches are 146.5 foot simple spans 8.5 feet deep with main spans of 370 feet and 281.5 feet in length at a depth of 15.5 feet. Flanges on the sloped side and vertical center web support the composite concrete deck. The bridge was opened to traffic in 1971. In a Caltrans report dated January 1992[1], results of an in-depth visual inspection by Caltrans personnel indicates the presence of numerous cracks in the webs of the trapezoidal box at the lower attachment point for the stiffener cross frames. Caltrans and BIRL engineers have applied acoustic emission (AE) and strain gage monitoring to confirm that the cracks are active fatigue cracks.

Acoustic Emission Monitoring

BIRL engineers applied acoustic emission monitoring to three crack sites selected by Caltrans to determine the nature of the cracks. Since this bridge is an all welded structure, we were able to apply the acoustic emission using a simple guard channel approach (no extraneous noise sources were in the immediate vicinity of the crack). This approach also allowed us to circumvent AE source location problems caused by dispersive acoustic propagation that results from the combination of our operating frequency (175 KHz) and the thin plate (3/8") present in this bridge. The guard channel setup consisted of 4 sensors. A sensor was located at the visible crack tip and three others were placed in a triangular array surrounding the crack tip. A photograph of a typical AE test setup is shown in Figure 1. The AE data was recorded at a system gain of 80 dB and analyzed post test. Pencil lead breaks and simulated AE events generated by a pulser driven AE sensor were used to verify AE system integrity and to balance system gain for each of the AE channels. Any signal originating at the crack will reach the crack mounted sensor first. AE signals arriving from outside the array will be received at a guard sensor first. An additional sensor was mounted at the tip of the vertical stiffener to catch any AE generated by fretting from the end of the stiffener on the bottom flange. Post test analysis showed this precaution to be unnecessary for all but the third test. A large portion of the 12,233 events recorded in this test (SP29; Girder 1; XF5) came from the vertical stiffener fretting. A summary of the AE results is shown below in Table 1.

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[1] Caltrans Memo "Sacramento River Bridge and Overhead (Bryte Bend)", P. J. Stolarski, January 13, 1992

Figure 1 Acoustic Emission Test Setup

Figure 2 Strain Gage Layout

Location	Recording	Total	Crack Related	Crack
SP19;Girder 2;XF3	22 min.	2117	434	20
SP19;Girder 2;XF1	37 min.	1821	193	11
SP29;Girder1;XF5	25 min.	12233	335	13

Table 1 AE Summary for Bryte Bend Bridge

All three crack sites monitored show significant crack related activity. These amounts and rates of occurrence confirm that these cracks are being actively driven by the live stresses in this structure.

Strain Gage Monitoring

Strain gages were mounted on the web of the girder near the crack site. Two gages were mounted at each test site and data was recorded in the rainflow mode. Figure 2 shows a typical strain gage site. One gage is mounted parallel to the bridge's axis and the other is mounted perpendicular to the bridges axis. The gages used were quarter bridge Micro-Measurements Group type CEA-06-250UW-350 bonded gages. The strain gage data was recorded and analyzed using a Somat S2000 field computer. The first series of tests were performed in June, 1993. In the relatively short period of time taken for these tests (1 to 2 hours each) significant live strains were recorded with ranges of 200 microstrain and higher. Discussions with Caltrans engineers subsequently led us to apply strain gages over longer time periods to obtain more statistically significant live strain histograms. The long term testing was performed in June of 1994. The gages were mounted on or next to cross frame #4 in span 19. Analysis of the strain gage data further confirmed the fatigue findings. A summary of these tests is shown below in Table 2. The rainflow plot is shown in Figures 3 and 4. Channel 1 was connected to a gage previously mounted by Caltrans engineers on the horizontal stiffener transverse to the bridge axis. Channel 2 was connected to a Caltrans installed gage mounted on the vertical element of the cross frame. This gage failed to respond so no data was recorded from it. Channels 3 and 4 were connected to two of BIRL's original gages mounted on the vertical web with 3 horizontal and 4 vertical. The counts to date are based on the life of the bridge assuming uniform traffic volume and extrapolating the June 1994 data.

Total Counts	4831	577	1389
Counts/hour	39.72	4.74	11.42
Counts/day	953.27	113.86	274.08
Total Counts to-date	8,002,687	955,817	2,300,918
	Ch 1	Ch 3	Ch 4

Table 2 June 1994 Strain Gage Results (strain range > 100 micro-strain)

The rainflow data clearly shows significant live strain activity out to 200 μ_strain which corresponds to approximately 6 Ksi live stress. The rainflow data shows the range of the live strains but not their direction (i.e. tensile or compressive). To better understand the nature of these live strains, we recorded data from the three gages in time history mode and then compared signals from the three gages on a common time scale. The results of this analysis for a particular live load (probably a large truck) is shown in figure 5, a, b, and c. This data shows that in response to a given load, gage #1 (Fig. 5a) shows tensile strain as does gage #3 (5b), while gage #4 (5c) shows compressive strain for this load. This pattern is consistent for all of the recorded responses.

Summary

Acoustic emission and strain gage testing on three sites containing visible cracks confirm that the cracks are active and that high live strain cycles (greater than 100 μ_strain) frequently occur in both the web and the horizontal cross members. The AE activity detected on this structure is high in comparison to that typically experienced on other crack sites in other bridges that we have monitored. We have been made aware that Caltrans is developing retrofit strategies for this structure. We would like to suggest that further strain gage monitoring could be beneficial in gaining a better understanding of the complex effects of live loading on the cracked areas of the structure. An approach that could help greatly in understanding these forces would be to apply gages to the critical locations for an entire cross frame section and recording the simultaneous response of these gages to both traffic and known loads. Caltrans may wish to consider repeating these tests at multiple positions in a span or spans. BIRL has instrumentation suitable for these experiments and would be interested in assisting Caltrans in this study.