Acoustic Emission Monitoring of North East Trunnion Shaft on Oregon DOT Bridge 1377A I-5 over the Columbia River, Portland, Oregon

by

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Purpose: Apply acoustic emission (AE) monitoring to provide additional information on the nature of the ultrasonic indications in the north east trunnion shaft.

Background: Oregon DOT Bridge 1377A carries I-5 traffic over the Columbia River between Portland Oregon and Vancouver Washington. The structure consists of two separate bridges each carrying three lanes of traffic. The east bridge was built in 1917 with rehabilitation work done in 1960. This bridge carries the northbound traffic. The west bridge was built in 1958 and carries the southbound traffic. Each bridge has a span drive vertical lift span to permit large vessels to pass through. The lift span trusses are 272 feet long between the live load supports. Vertical clearance at low water is 39.86 feet and the maximum vertical lift is 139 feet. Oregon DOT records indicate that the bridge openings average 400 to 500 per year and the average daily vehicular traffic volume is 87,000.

1960 Rehabilitation

According to information furnished by Oregon DOT, the trunnion shafts on the east bridge were modified during the 1960 rehabilitation to allow application of tapered roller bearings in place of the plain sleeve bearings that were originally installed. The drawings indicate that prior to the taper machining operation on the shafts to accommodate the roller bearings, the longitudinal grease grooves were to be filled with weld metal. Laboratory testing performed on the shafts in 1987 under the supervision of Sverdrup Corp. determined that the forged steel had carbon content ranging from 0.50% to 0.87%. Carbon levels this high have a severe adverse effect on the weldability of the material. Charpy V-notch tests on samples taken from the bore area indicated low impact properties with a ductile to brittle transition temperature of 70° F or higher. Field Ultrasonic tests (UT) performed during the 1987 Sverdrup study and again in 1993 and 1996 by Oregon DOT indicated the presence of a crack indication in the vicinity of the shoulder at the outboard end of the north east trunnion shaft. The presence of the roller bearings makes access to the shaft surface impossible without major costly disassembly thus precluding direct examination of the area containing the UT indication. The high cyclic loads and questionable material properties in conjunction with the UT indications led Oregon DOT to consider the use of AE to aid in their understanding of the trunnion shaft condition. In October of 1994 BIRL engineers under the sponsorship of

Northwestern University's Infrastructure Technology Institute (ITI) conducted acoustic emission tests on all four of the east bridge trunnion shafts. These tests detected acoustic emission signals indicative of crack related activity in the vicinity of the outboard shoulder on the north east shaft (same area as UT indication). No similar activity was detected on any of the other shafts in the shoulder areas.

At Oregon DOT's request BIRL engineers re-tested the north east shaft in March of 1996. The purpose of the re-test was to gain additional confidence in the previous findings.

Procedure: The setup for the re-test used 5 AE sensors in a linear location and guard setup as was employed for the October 1994 tests. A sketch of the setup is shown in Figure 1. Linear source location was employed with a pair of sensors attached to opposite ends of the shaft in line with the ultrasonic indication. The remaining three sensors were positioned on the sheave drum to act as guard channels. The guard sensors intercept acoustic noise from the cable fretting and other sources located in the rim of the sheave. The equipment used for the re-test was the AMS3 manufactured by Vallen Systeme GmbH of Icking Germany. This equipment provides greatly improved AE data processing and display capabilities over the equipment used in the 1994 tests. All other testing conditions were the same as the 1994 tests. In the re-test only the north east shaft was tested. A total of four test runs were done. Each test run consisted of a complete lift and lower cycle of the bridge.

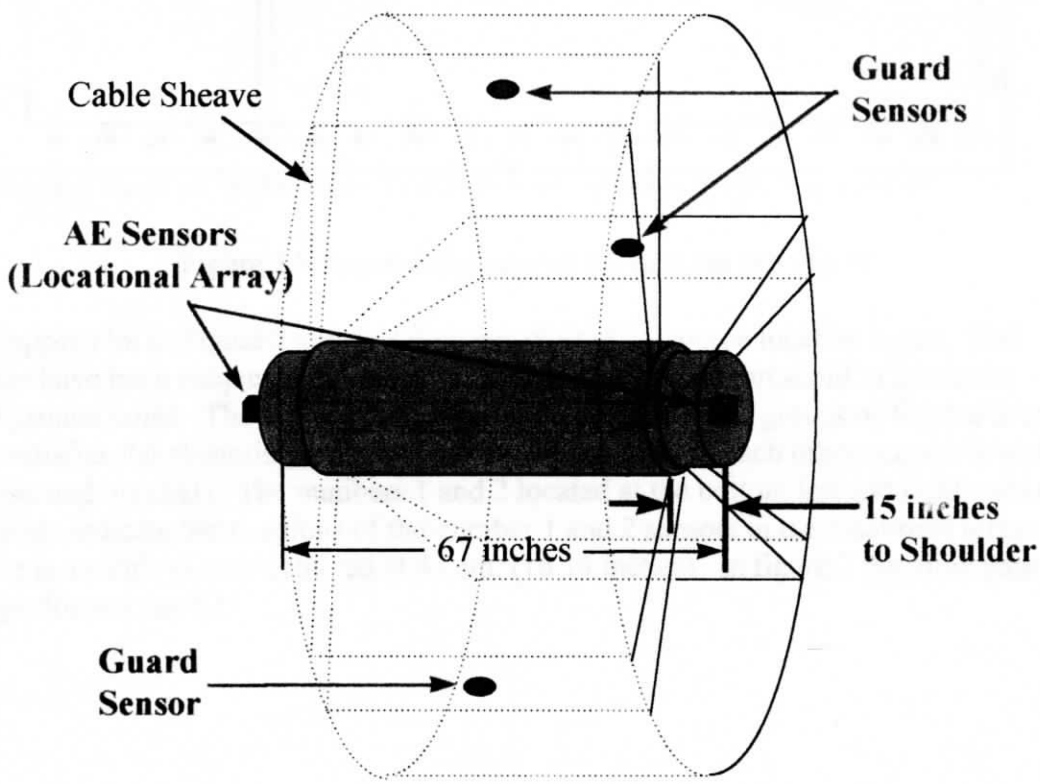

Figure 1 showing AE sensor layout for trunnion shaft tests

Results: Three of the four test runs produced useable data. The fourth run was marred by breakage of a sensor cable and produced no useable data. The data analysis used for the re-test was identical to that used in the 1994 tests. A combination of spatial and temporal clustering was employed that required a minimum of three AE events in a 2 cm location window to occur within a one second time interval as discussed in the November 1994 report[1]. Figures 2, 3, and 4 below show the AE results for the three useable data runs.

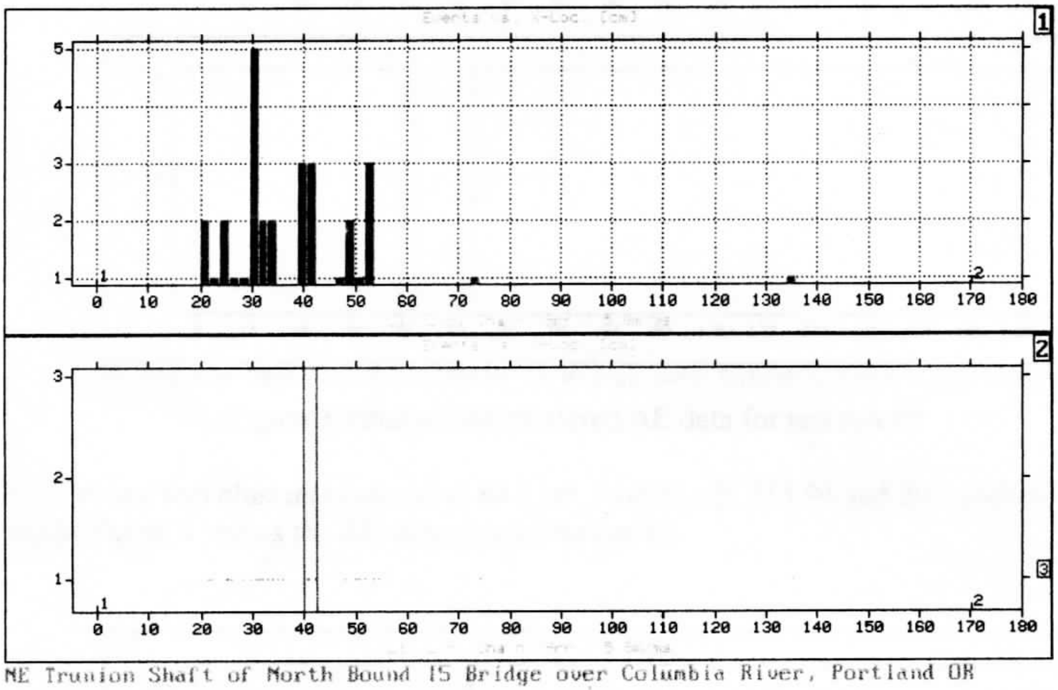

Figure 2 Filtered and clustered AE data for test run #1

The upper plot in Figure 2 shows AE events plotted vs. source location in cm. The events have been subjected to both an energy and amplitude threshold to minimize background noise. The bottom plot shows the locations of the groups of filtered events that satisfies the clustering criteria (3 events within 2 cm of each other occurring within a one second interval). The numbers 1 and 2 located at the bottom left and right ends of the plots indicate the positions of the number 1 and 2 sensors in the locational array. There is a single cluster centered at 41 cm. (16.14 inches). In figure 2 the same data is shown for test run #2.

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[1] "Acoustic Emission Monitoring of the Trunnion Shafts on Oregon DOT Bridge #1377A, the I-5 Columbia River Bridge East Lift Span, Portland, Oregon," David W. Prine, Report to Oregon DOT, November, 1994.

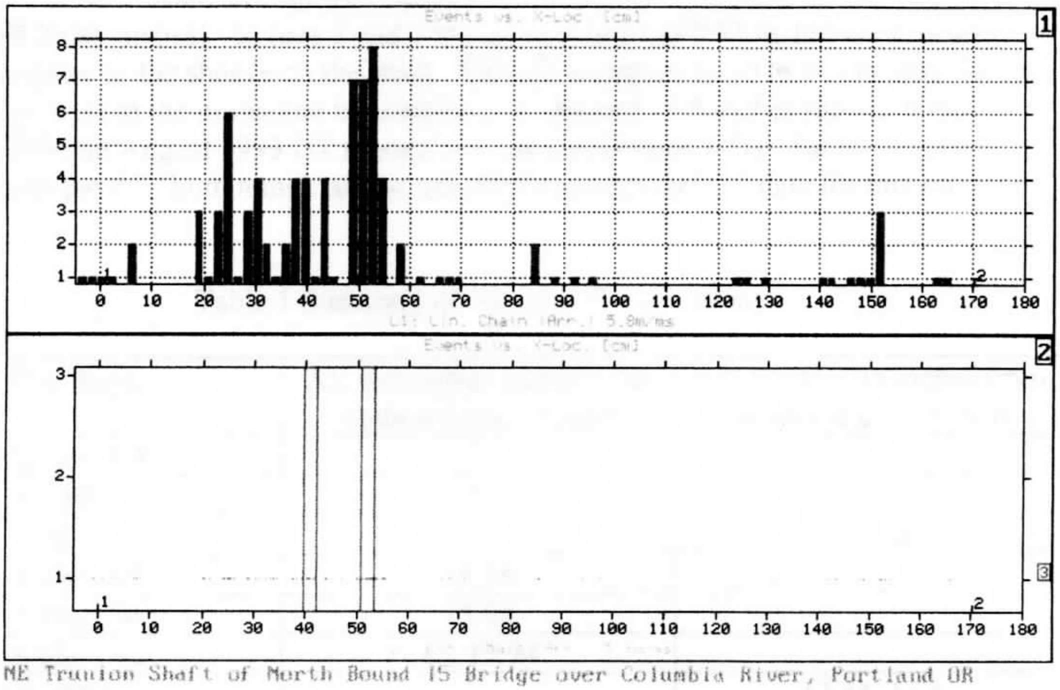

Figure 3 Filtered and clustered AE data for test run #2

Here we see two clusters centered at 40.5 cm. And 51 cm. (15.94 and 20.1 inches). Finally figure 4 shows the AE data plotted for run #3.

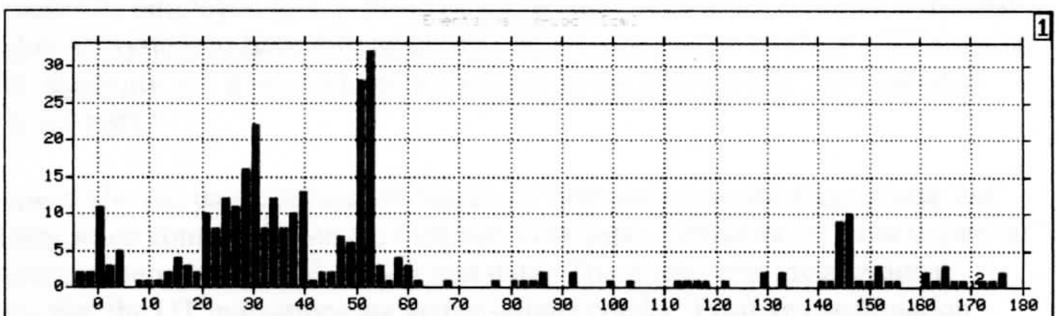

Figure 4 Filtered and clustered AE data for test run #3

In Figure 4 three clusters are shown centered at 33 cm., 40.5 cm., and 53 cm. (12.99, 15.94 and 20.86 inches). In runs 2 and 3 the clusters at 51 and 53 inches are probably due to slippage of the sheave on the shaft. The other clusters at 40 to 41 cm. and 33 cm. correspond well to the ultrasonic indications at 13.44 and 15.5 inches shown in the March 1996 and August 1993 UT reports provided by Oregon DOT. Table 1 below summarizes the AE (both temporal and spatial clustering) and UT data for this trunnion shaft.

Table 1 Summary of AE and UT indications

Test/Report	AE location in inches from outboard end of shaft	UT location in inches from outboard end of shaft
AE Run 3, Oct , 94	13	
AE Run 4, 1994	13	
UT Aug. 1993		13.53
AE Run 1 Mar., 96	16.14	
AE Run 2 Mar., 96	15.94	
AE Run 3 Mar., 96	13, 15.94	
UT March, 1996		13.44, 15.5

The temporal clustering technique that was applied to the data recorded in these tests was originally developed by David W. Prine for application to in-process weld monitoring. It has been well proven both in the laboratory and in the field to be a very effective filter criteria to allow reliable detection of crack growth in noisy environments. It has recently been successfully employed by Mr. Prine on bridge data. The Vallen AMS3 is the first commercial AE system to have this capability. When it is used with the AMS3's spatial clustering capability it is a very effective noise reduction technique as demonstrated during the I-5 tests.

Conclusions: The AE data collected in March of 1996 show excellent agreement and repeatability when compared with the October 1994 data. Furthermore, there is general good agreement between the AE and UT test data. These tests provide additional confidence that the UT indications are active fatigue cracks. Positive confirmation awaits the results of the metallographic examination that will be performed following removal of the shaft from the bridge.