Monitoring Trucks, Cars and Joggers on the Horsetail Falls Bridge Using Fiber Optic Grating Strain Sensors

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Abstract

Blue Road Research installed fiber optic grating sensors on the Horsetail Falls bridge in 1998 to monitor static strain in support of health monitoring of the bridge. In November 1999 Blue Road Research utilized high speed, high sensitivity fiber grating demodulation systems on this bridge to monitor the weight and speed of traffic. Sensitivity levels used were sufficiently high that joggers could be detected easily as well as people walking on the bridge. This paper provides an overview of these recent tests that show both health monitoring and traffic monitoring functions can be performed on a bridge using the same set of fiber grating strain sensors.

Introduction

The Horsetail Falls bridge in the Colombia River Gorge National scenic area, shown below, was instrumented by Blue Road Research in September 1998 with 28 fiber grating sensors[1,2] (Figure 1.) Two of the fiber grating sensors were lost during construction but the other 26 have been operational and used to support testing for over a year and a half with no measurable change in performance.

Figure 1. Horsetail Falls Bridge in the Colombia River Gorge National Scenic Area and 1.0 m fiber grating sensors used to support multipoint high speed dynamic strain measurements.

Initial testing performed on the Horsetail Falls bridge were made with a portable optical spectrometers with a resolution of about 5 micro-strain. This system was adequate for static strain measurements to support measurements necessary to establish that the composite wrap approach to strengthening the bridge was successful. Additional static testing was performed periodically over the course of a year. In order to perform more comprehensive testing, the Oregon Department of Transportation (ODOT) wanted sub micro-strain resolution and ideally response on the order of at least 100 Hz. Blue Road Research has been developing a fiber grating based spectral demodulation system for a the past five years and with improved light sources, fiber grating filters and receivers has been able to achieve less than 0.1 microstrain resolution at 2000 Hz[3,4]. To support multi-point, high resolution testing on the Horsetail Falls bridge, 5 systems were deployed by Blue Road Research in November 1999.

High Speed Testing on the Horsetail Falls Bridge

On November 3rd, 1999, the Horsetail Falls bridge was closed by the Oregon Department of Transportation and test positions for a test vehicle marked on the bridge. Figure 2 shows the dump truck used as a test vehicle. The truck was driven and placed at several positions on the bridge in order to allow static measurements of the deflection of the bridge to be made at 10 different beam positions supported by 0.7m and 1.0 m fiber grating sensors embedded in the concrete beams and in the composite over-wrap layer.

Figure 2. Test vehicle used to support static and dynamic testing of the Horsetail Falls bridge and five high speed, high sensitivity fiber grating demodulation systems deployed by Blue Road Research underneath the bridge for high speed measurements.

Underneath the bridge, as shown in Figure 2, five high speed fiber grating demodulators with a bandwidth of 10 kHz were positioned to support dynamic tests that consisted of running the test truck across the bridge at various speeds and looking at the deflection of the bridge at multiple locations simultaneously. A single 1.5 mW l300 nm light source was used to support all five channels. The fiber grating filters used were tunable and support a system dynamic range of approximately 1000 micro-strain. The data acquisition speed was set during the tests at 2 kHz.

The fully loaded truck was run over the bridge at various speeds to determine the dynamic characteristics of the bridge. Figure 3 shows the results of running the truck over the bridge at a speed of 24 km per hour. The sensitivity levels are approximately 0.2 micro-strain for the three fiber grating sensor responses shown. The slight bouncing of the truck as it passes over the bridge is clearly evident and it allows a comparison of the relative dynamic response of three widely separated beams on the bridge for structural analysis.

The tests described in association with Figure 3 were performed in support of health monitoring of the Horsetails Falls bridge. Another application that is very important to transportation officials is the ability to monitor vehicular traffic. Measurements of considerable value to the Oregon Department of Transportation include weighing vehicles passing over the bridge, classifying vehicles and being able to detect their presence on the bridge. A key question was the ability to detect very light vehicles such as motorcycles, which would be important for traffic monitoring applications. To check on the ability of the system to perform these tasks Blue Road Research in collaboration with the Oregon Department of Transportation selected one of the fiber grating sensors used to measure tension on a support beam and used a single high speed fiber grating demodulation system similar to that described above to monitor traffic. In this case the single demodulation system was supported by approximately 1 mW of optical power at 1300 nm instead approximately 250 μW used to support the earlier multi-point tests. The results are shown in Figure 4.

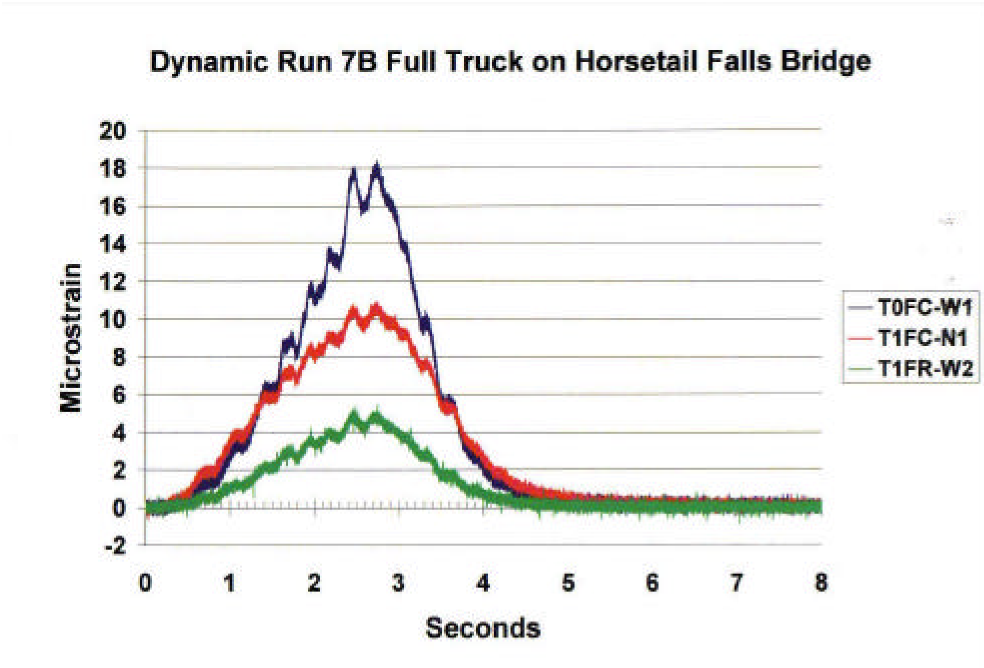

Figure 3. Output of three high speed fiber grating strain sensors monitor key locations on the Horsetail Falls bridge as a fully loaded test truck passes over it at 24 km/hr.

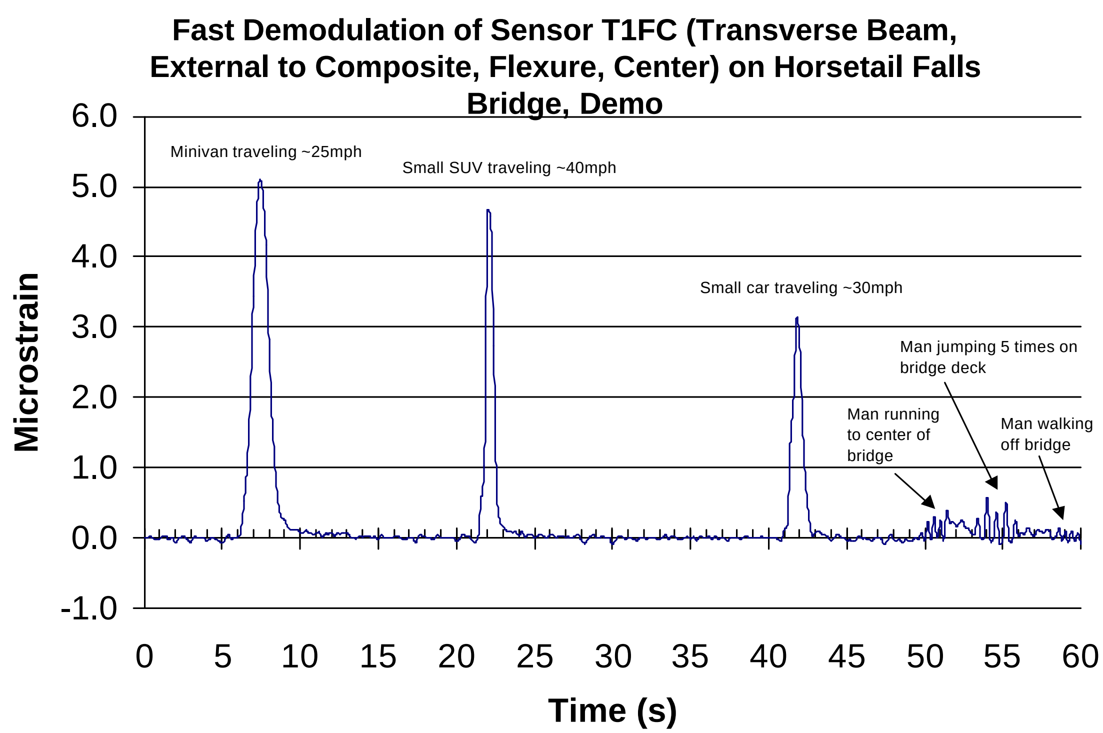

Figure 4. A single high speed, high sensitivity fiber grating sensor system used for monitoring traffic speed, weight and vehicle classification on the Horsetail Falls bridge.

From Figure 4 the speed of the vehicle traffic can be measured by the width of the signatures in time. In this Figure three vehicles are shown a minivan, a very small truck and a small car. The strain levels measured by the fiber grating sensors on the beam can be used to generate the weight of the vehicle.

Although no motorcycles are shown on this test run, the ability to measure small weights is shown by signals generated by a cooperative "jogger" who ran to the center of the bridge, jumped and then proceeded to walk off the bridge. Each of these signals is clearly distinguishable in Figure 4. While the intent of the tests was not to monitor pedestrian traffic on the bridge it would be reasonable to do so although the presence of a small child walking quietly on the bridge would require modest, albeit fairly readily achievable, improvements in sensitivity.

Summary

Dynamic high speed testing was conducted on the Horsetail Falls bridge that allowed multi-point sub-micro-strain measurements to be obtained to support health monitoring of this historic bridge. A single point fiber grating sensor was shown to be effective in monitoring vehicle traffic speed, weighing vehicles in motion and classifying traffic vehicles. The sensitivity of the single point fiber grating strain sensor system was shown to be sufficient to detect joggers on the Horsetail Falls bridge and adults walking.

References

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