Strain-based Damage Detection Algorithms on Bridge Structural Health-Monitoring System

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Abstract

Bridge SHM (Structural Health Monitoring) which typically includes specialized hardware and software algorithms has been widely investigated during the past two decades.
As the statistical damage detection tool, strain-based damage detection methodologies were further investigated and advanced. For the validation of damage detection approach, strain range data were obtained from a Sacrificial specimen attached to the utilized US 30 Bridge over the South Skunk river. Damage detection ability for methodologies was investigated and then analyzed in terms of false-indication.

Objective

The objective of the research is to finalize the development of the overall SHM system on the US 30 Bridge regarding;

1. Hardware – Sensor, data acquisition and communication architecture
2. Software – Bridge Engineering Center Assessment Software (BECAS)
3. Damage detection algorithms

Sensor Installation

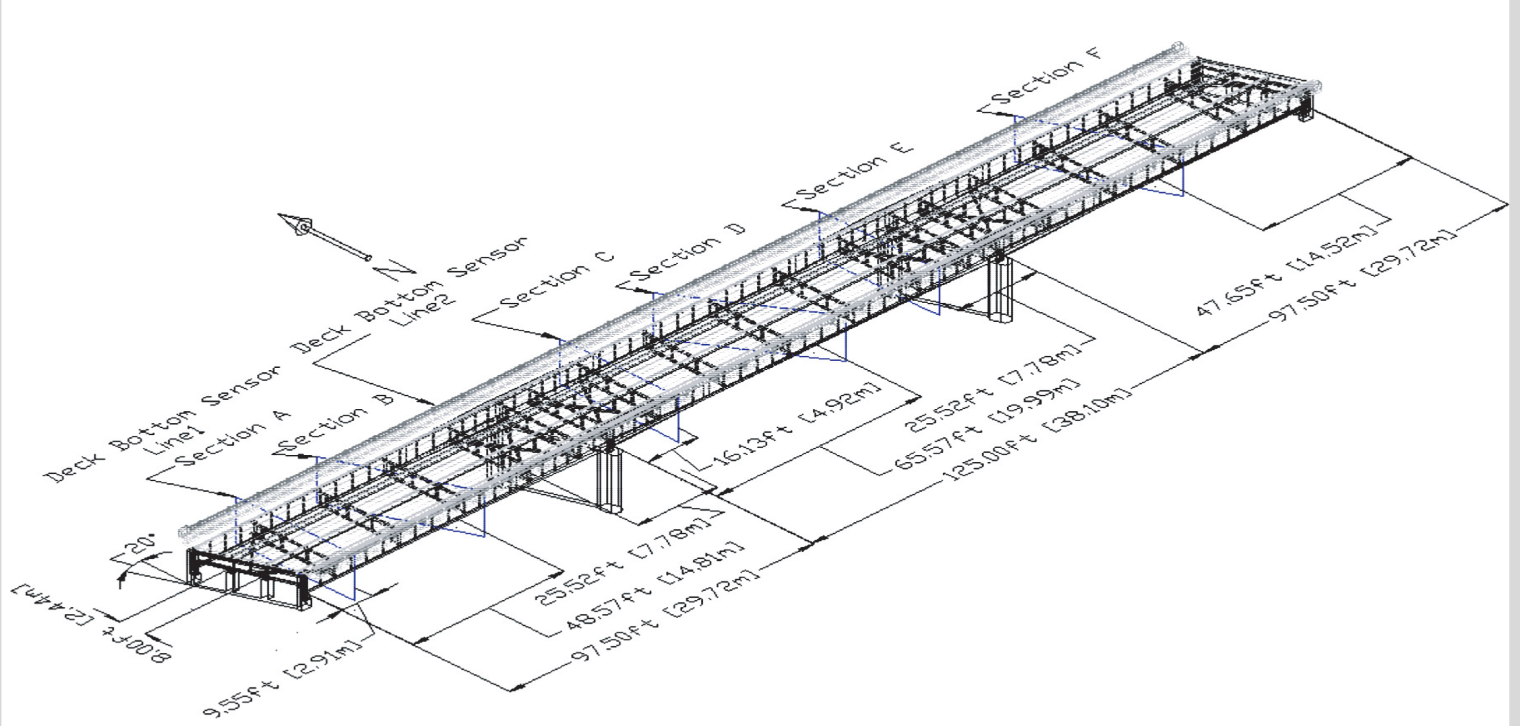

Fig. 1. Cross Section of US30 Bridge (Lu2008)

A total of 40 fiber-optic strain gauges were installed. A unique naming convention for each sensor indicates its location.

Strain Data Identification

Fig. 2. Side and Bottom View of the US30 South Skunk Bridge (Lu 2008)

The data collection process developed includes a novel approach for;

1. Data zeroing
(to remove temperature effects)
2. Data Filtering
(to obtain the quasi-static response)

Strain data was utilized from

1. Only right-lane
2. Five-axle
3. Heavy trucks.

Validation of Damage Detection

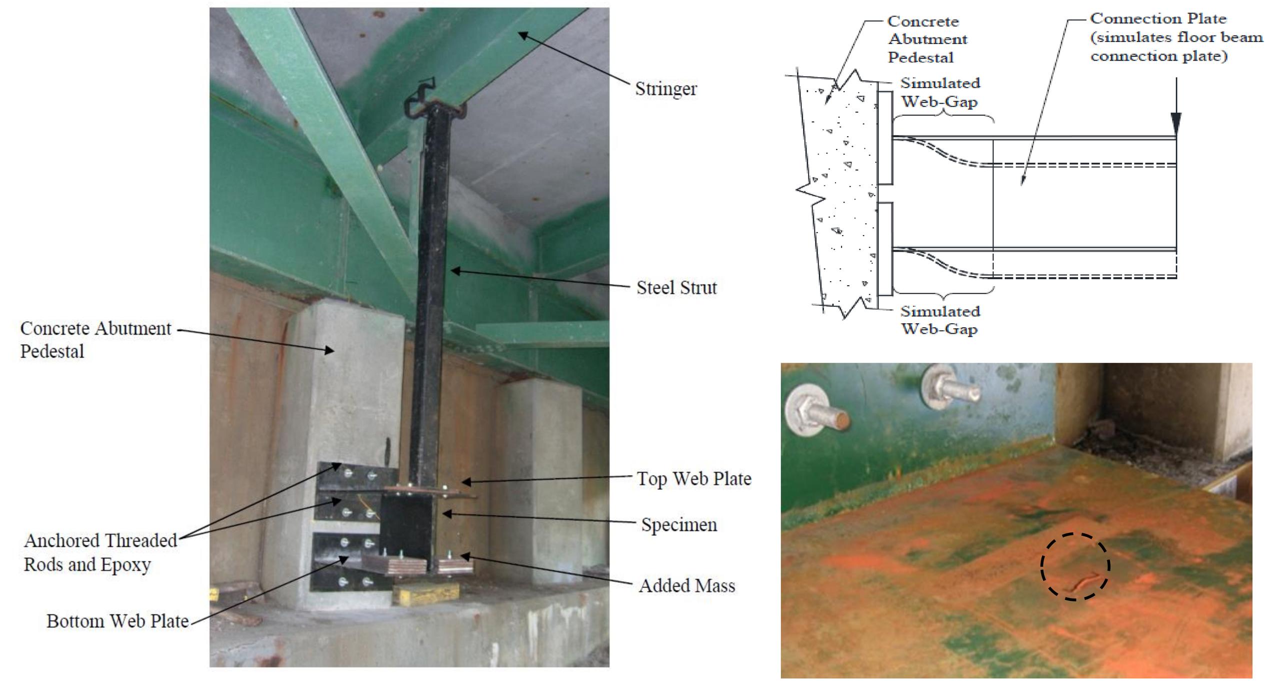

Fig. 3. Installed Sacrificial specimen and double curvature bending of Sacrificial specimen

To validate the damage-detection algorithm with actual damage data, Sacrificial specimen, simulating the floor-beam web gap region in the US 30 Bridge were fabricated. It was integrated in the bridge in such a way that it response to traffic loads but did not create a safety concern with the introduction of damage.

Results and Discussion

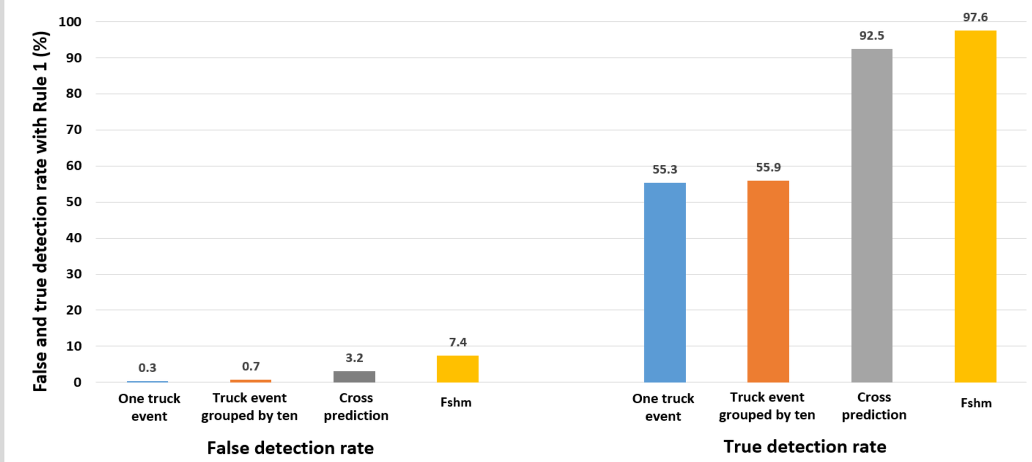

Fig. 7. False and true detection rate

By in large, the proposed and developed four methodologies detect damage quite well.

Reference

Lu, P., *A statistical based damage detection approach for highway bridge structural health monitoring*, Ph.D. dissertation, Iowa State University, 2008.
Phares, B., Wipf T., Lu, P, Greimann, L., Pohlkamp, M.. *An experimental validation of a statistical-based damage detection approach,* Center for Transportation Research and Education, Iowa State University, 2011.
Lu, P. Phares, B. M, Greimann L., Wipf, T. J., *Bridge structural health-monitoring system using statistical control chart analysis*, Journal of the Transportation Research Board, No. 2172, pp. 123-131, 2010.

Control Chart based Damage Detection Methodologies

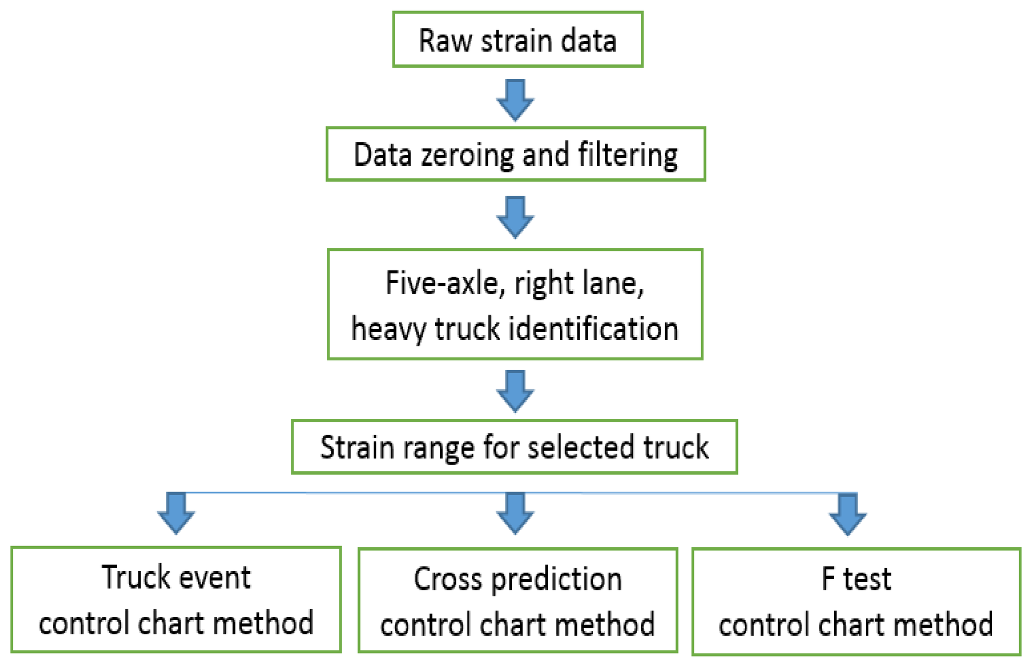

Fig. 4. Damage detection methodology

In this work, using orthogonal linear regression and the statistical F-test were proposed and developed to reduce relative high false-detection rate associated with cross prediction method.

Full model (Complex model)

$$y = (\alpha_1 + \alpha_3 x) + Z(\alpha_2 + \alpha_4 x)$$

Reduced model (Simple model)

$$y = \alpha_5 + \alpha_6 x$$

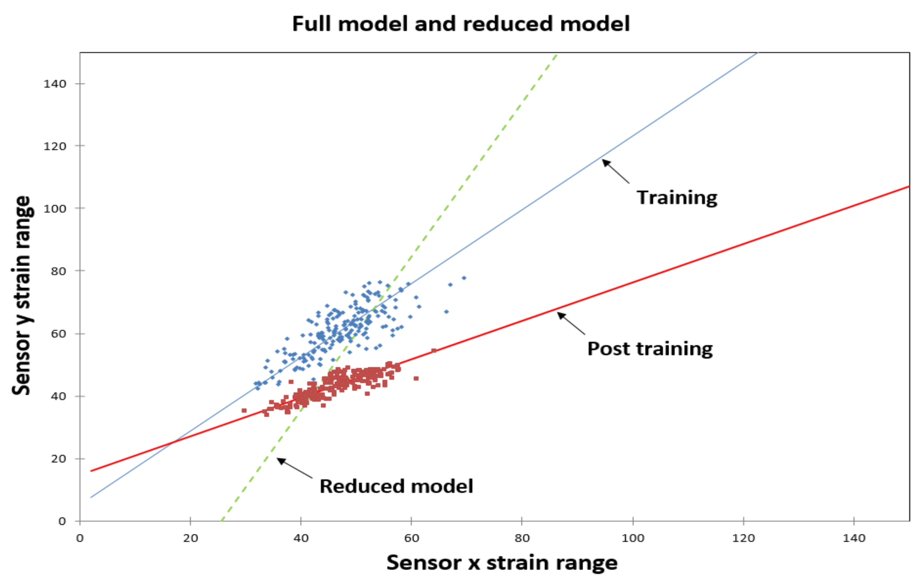

Fig. 5. Orthogonal fit line for the full and reduced model

H_0 (Null hypothesis): $\alpha 2 = \alpha 4 = 0$
H_A (Alternative hypothesis): $\alpha 2$ or $\alpha 4 \neq 0$

Fig. 6. Cross predication and Fshm control chart

1. Training period - to define the normal operation of the system.
2. Testing period - to evaluate the efficacy of the training period.
3. Evaluation period - for monitoring the bridge for change in structural performance