EXPERIMENTAL DYNAMIC LOAD ALLOWANCE OF A PRESTRESSED CONCRETE BRIDGE

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SESSION: Innovative Techniques for Monitoring and Evaluating Concrete Bridges and Bridge Elements

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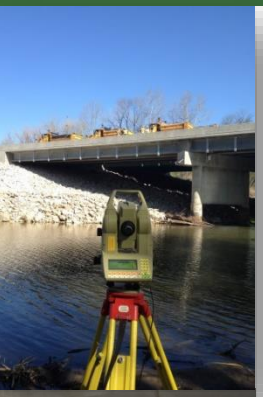


OUTLINE

- Introduction
- Determination of Impact Factor
- Bridge A7957
- Testing Equipment
- Field Test Procedure
- Load Test Results
- Concluding Remarks

➢ Introduction

- Load Rating

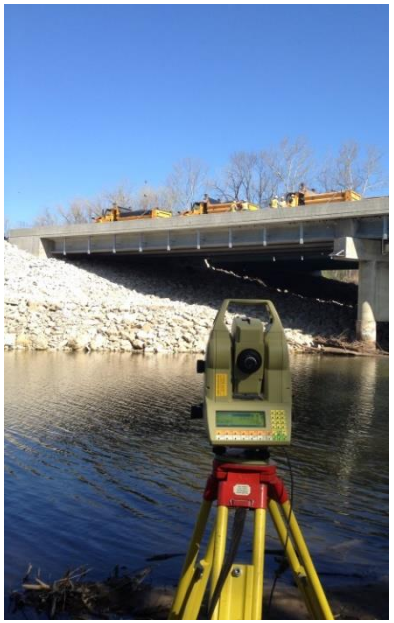
$$RF = \frac{Capacity - Dead}{(GDF)Live(1 + I)}$$

The strength evaluation procedure employed to obtain the live load carrying capacity that a bridge structure can withstand without suffering damage or undergoing collapse

Major basis in prioritizing maintenance operations
Traditional methods: analytical and experimental

➢ Introduction

- Field Tests



$$RF =$$

Introduction

- **Objective:** to obtain the **impact factor** of Bridge A7957 analytically and experimentally in an attempt to quantify differences between both approaches that are employed in bridge design and evaluation.

Laser Vibrometer

Accelerometers

Total Station

➢ Determination of Impact Factor (Analytically)

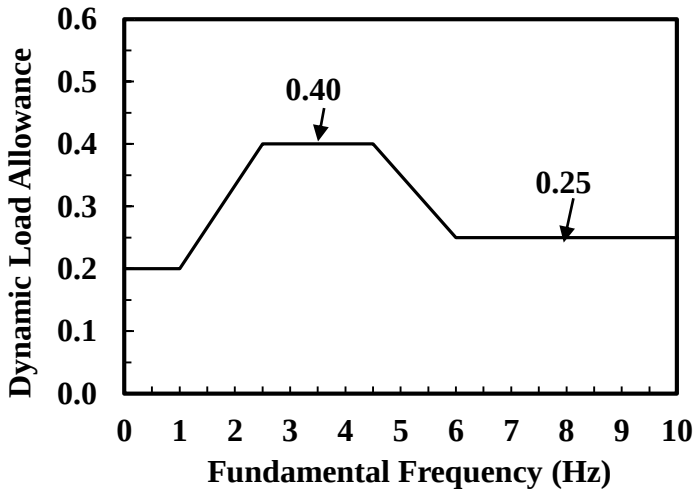
- AASHTO Standard (1992)

$$IM = \frac{15.24}{L + 38} \leq 0.30$$

- AASHTO LRFD (1994)

$$DLA = 0.33$$

- Ontario Highway Bridge Design Code (1983)



➢ Determination of Impact Factor (Experimentally)

$$IM = DLA = \frac{R_{dyn} - R_{sta}}{R_{sta}}$$

The value of IM is commonly defined as the ratio of the difference of the maximum dynamic and static responses to the maximum static response

➢ Missouri Bridge A7957

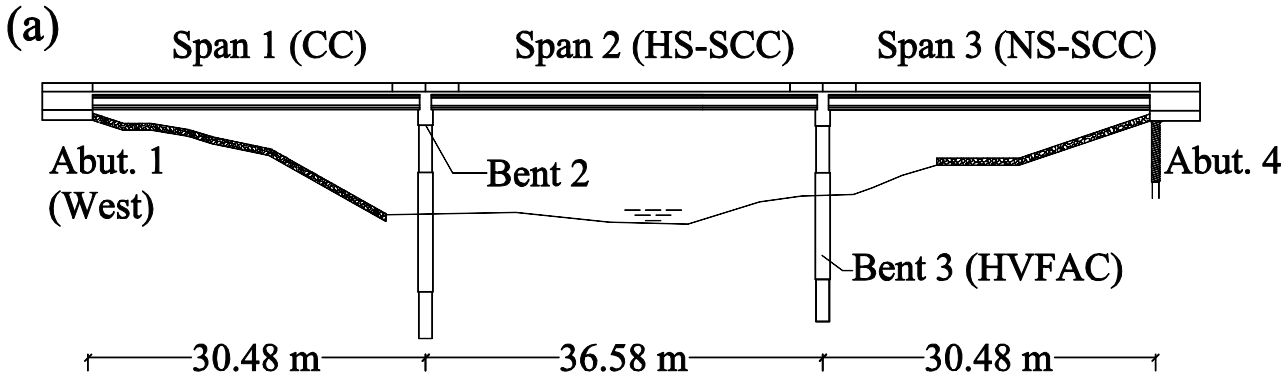
➢ PC/PS NU53 Girders:

Span 1: CC, f'c=8 ksi (55.2 MPa)

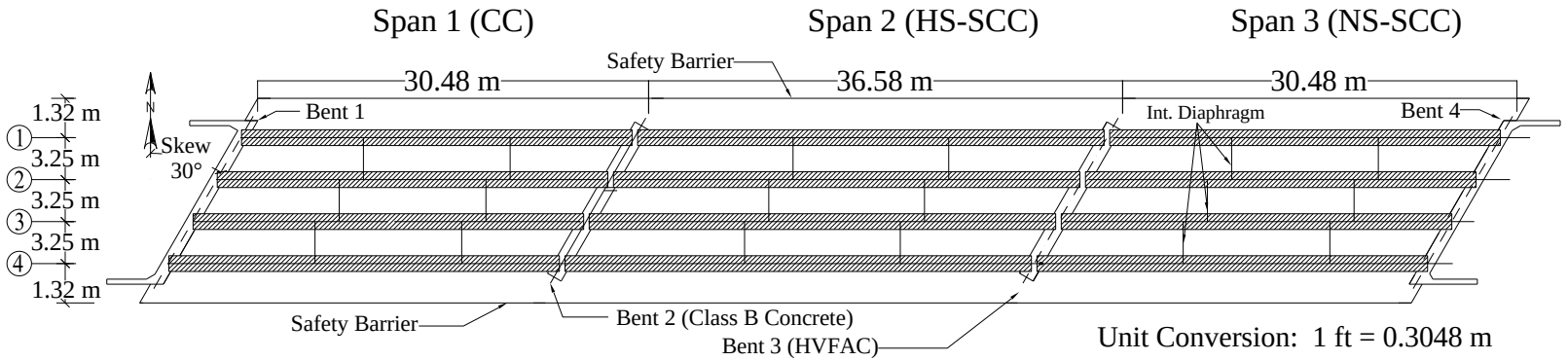
Span 2: HS-SCC, f'c=10 ksi (68.9 MPa)

Span 3: NS-SCC, f'c=8 ksi (55.2 MPa)

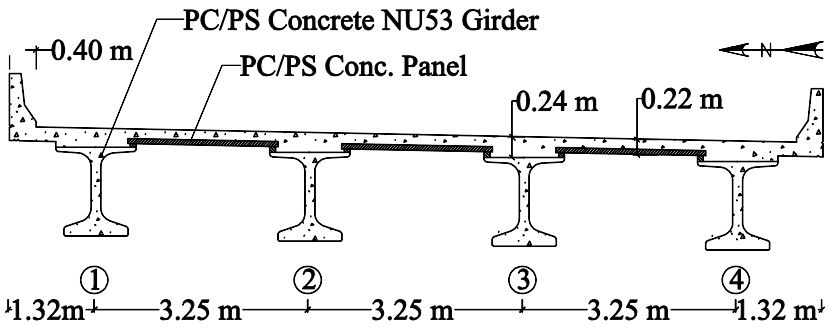
Bridge A7957
Hwy 50 Near Hwy US-63
West of Linn, MO



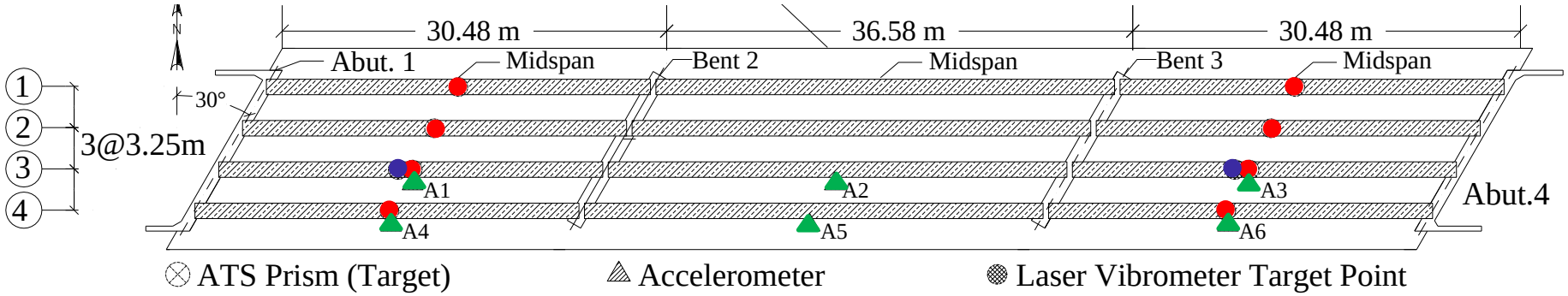
➢ Bridge A7957



Abutment 1 Bent 2 Bent 3 Abutment 4

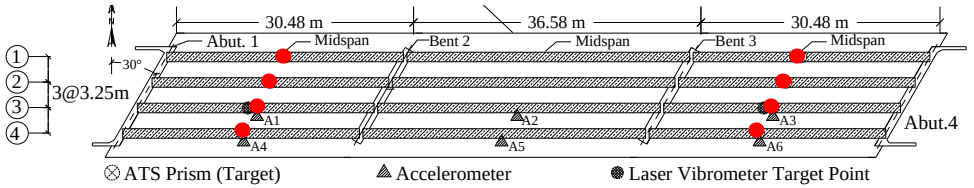


➢ Testing Equipment

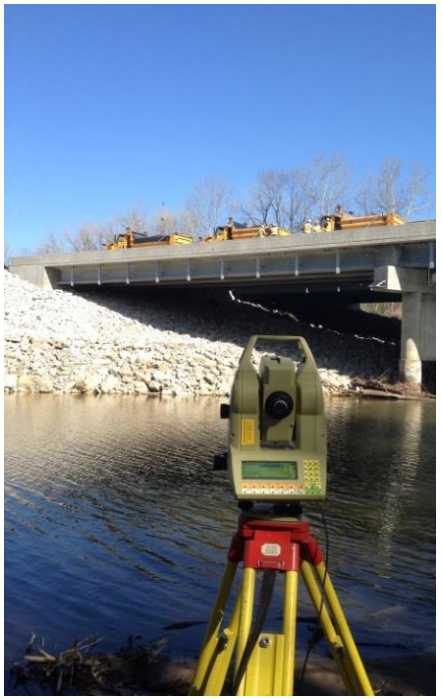


Bridge A7957 instrumentation layout

➢ Testing Equipment



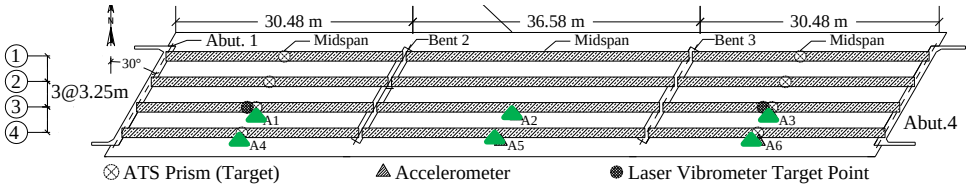
Automated Total Station (ATS)

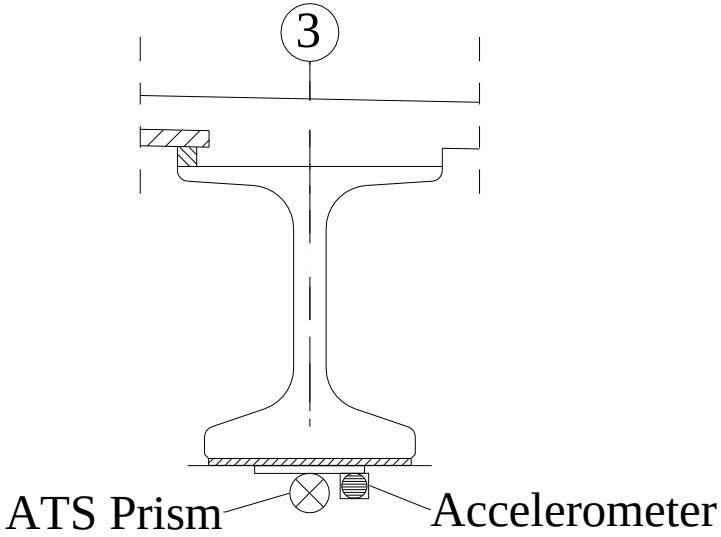


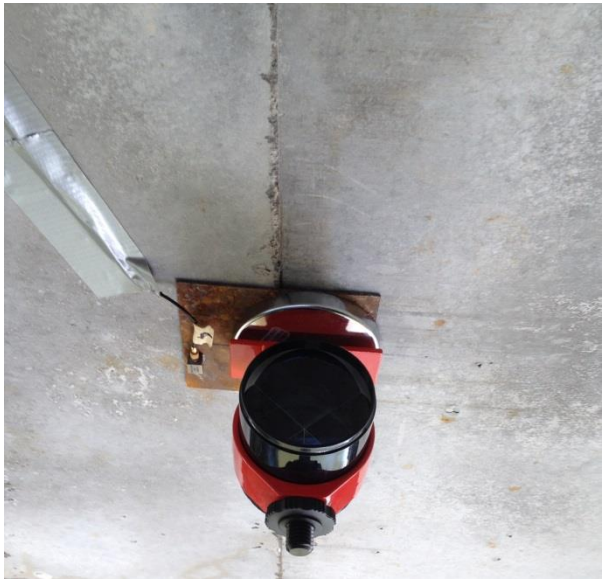
Leica TCA 2003
Accuracy: ±0.1 mm

Testing Equipment

Accelerometers



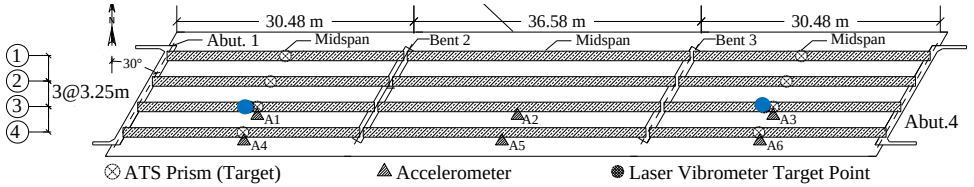




Sampling rate: 500 Hz

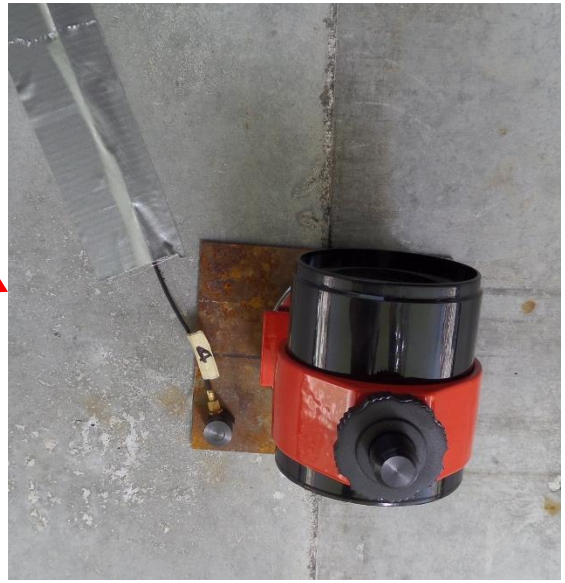
Varying speeds: 10 - 60 mi/h (16-96 km/h)

➢ Testing Equipment



Remote Sensing Vibrometer (RSV-150)

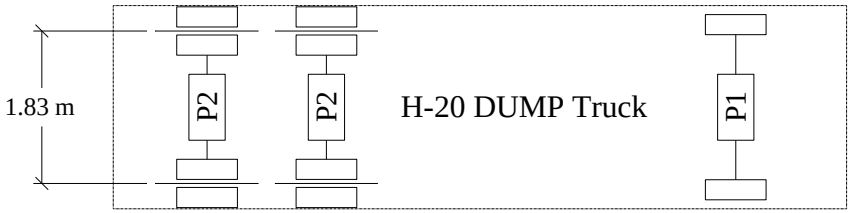
Sampling rate: 120 Hz

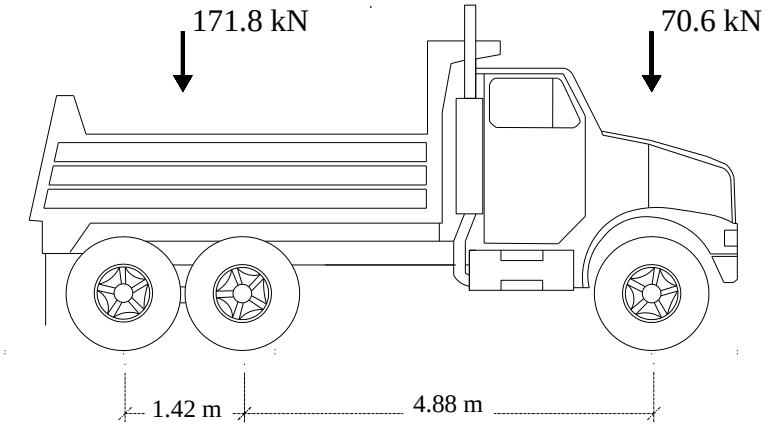


Varying speeds: 10 - 60 mph (16-96 km/h)
Accuracy: ±0.01 mm

➢ Field Load Test Description

Static Load Test

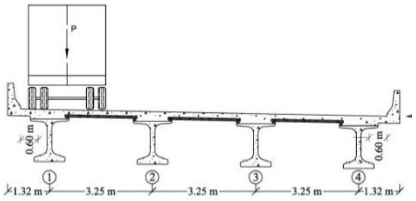


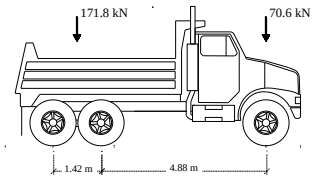


MoDOT H20 truck employed during static and dynamic tests.
Conversion factor: 1 m = 3.28 ft; 1 kN = 0.2248 kip
(171.8 kN = 38.4 kip, 70.6 kN = 15.9 kip)

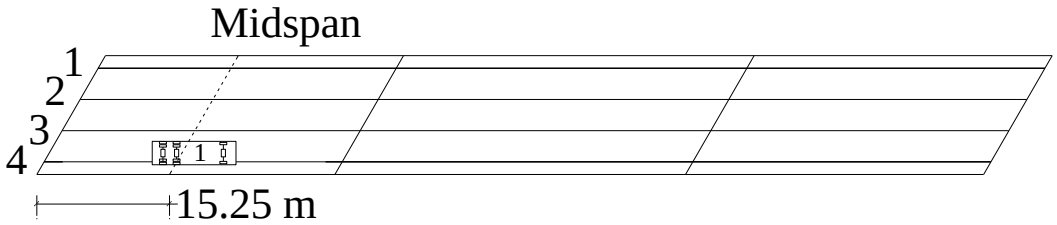
➢ Field Load Test Description

Static Load Test

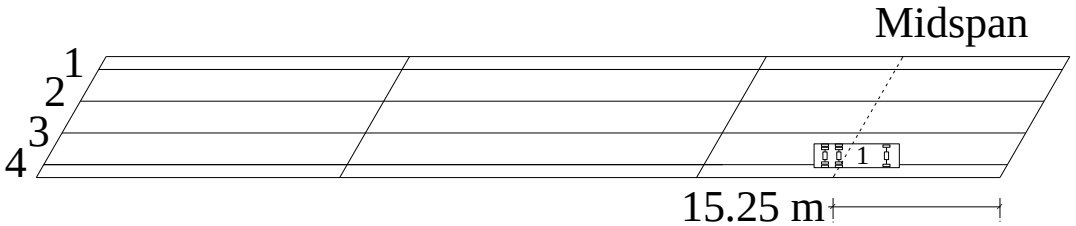


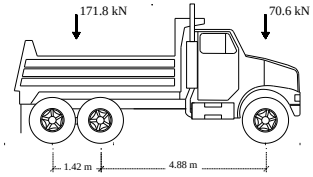


Test 1



(a) Static Test 1 (Span 1)





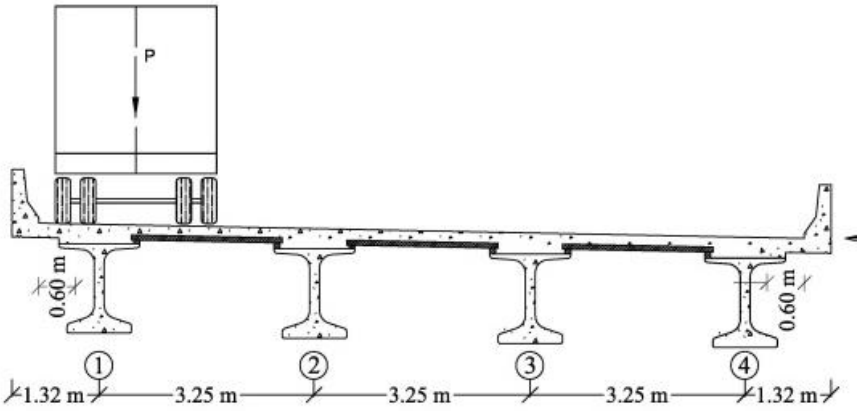
Test 2

(b) Static Test 2 (Span 3)

Static test configurations. Conversion factor: 1 m = 3.28 ft

➢ Field Load Test Description

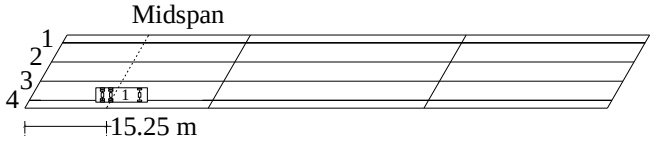
Dynamic Load Test



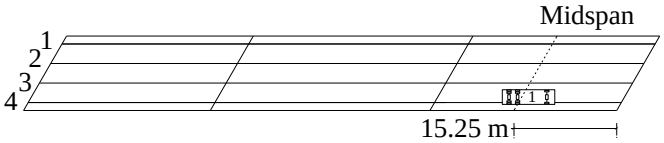
Load Test Results

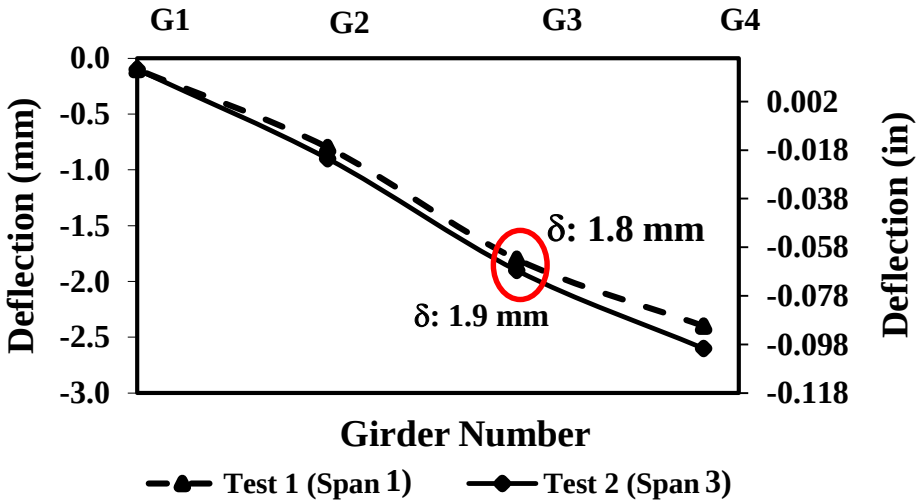
Static vertical deflection (ATS)

Test 1



Test 2





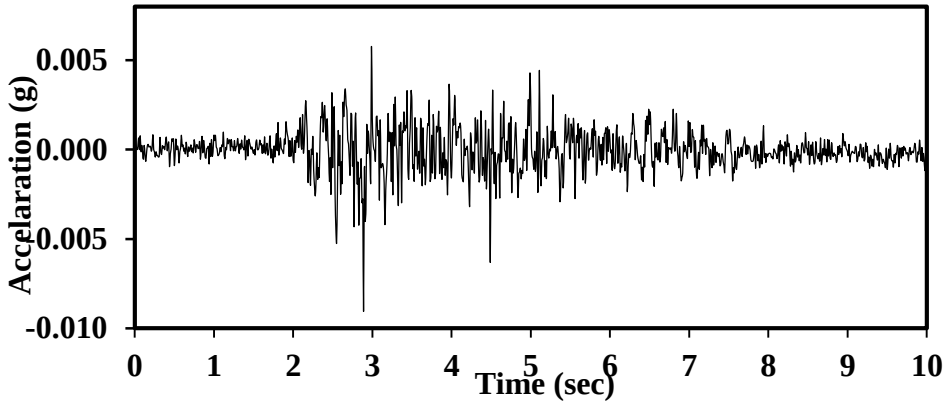
Static Test (Span 1)

Prisms

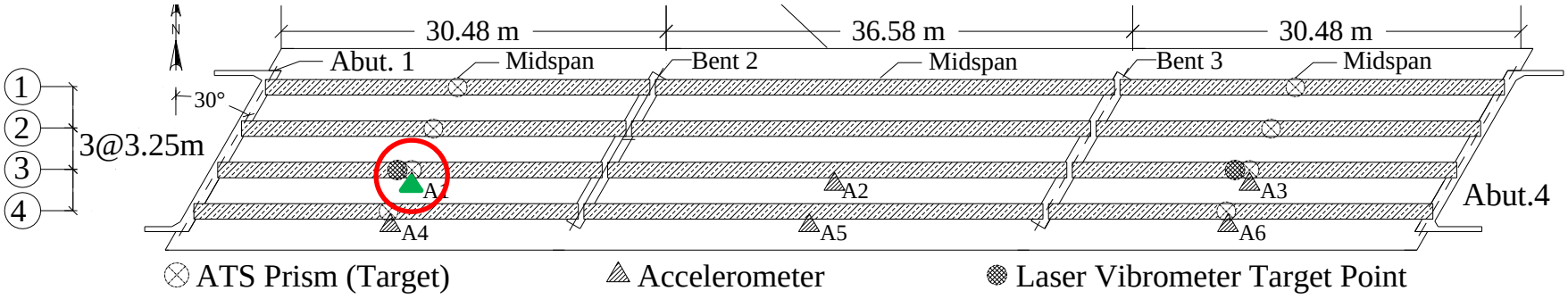
Automated Total Station

➢ Load Test Results

Acceleration response (accelerometers)

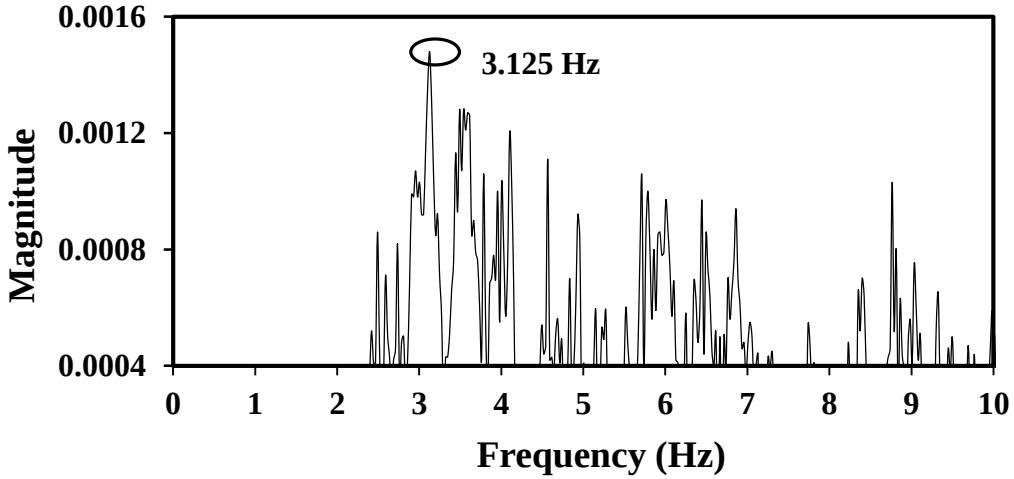


Measured acceleration response (96 km/h, west–east direction)

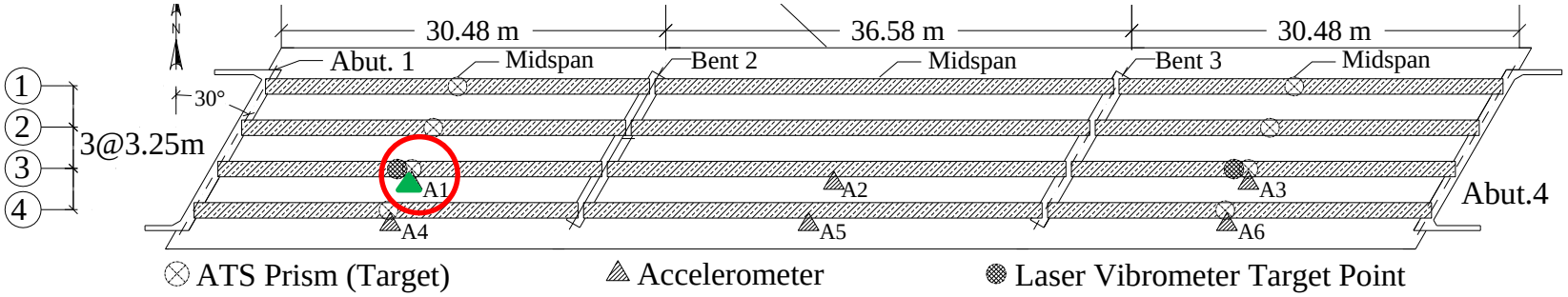


➢ Load Test Results

Fundamental Frequency – Fast Fourier Transforms (FFT)

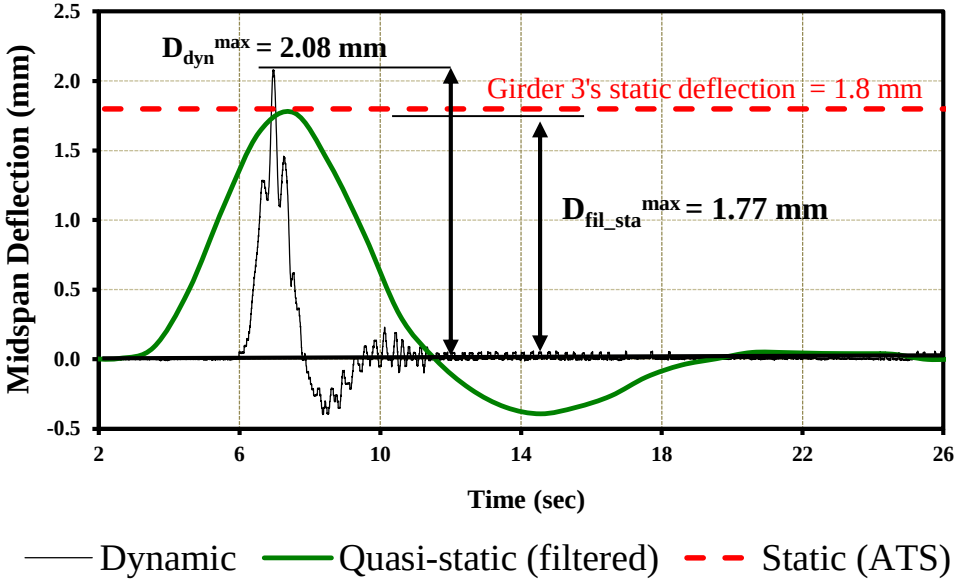


Natural frequency extracted through FFT



➢ Load Test Results

Dynamic and Static Vertical Deflection – RSV-150



Maximum static and dynamic deflections

$$IM^{exp} = DLA^{exp} = \frac{D_{dyn}{}^{max} - D_{sta}{}^{max}}{D_{sta}{}^{max}}$$

➢ Load Test Results

Dynamic and Static Vertical Deflection – RSV-150

$$\mathrm{RF} = \frac{\text{Capacity} - \text{Dead}}{(\mathrm{GDF})\text{Live}(1 + \mathrm{I})}$$

$$IM^{exp} = DLA^{exp} = \frac{D_{dyn}{}^{max} - D_{sta}{}^{max}}{D_{sta}{}^{max}} \qquad DAF^{exp} = (1 + IMexp)$$

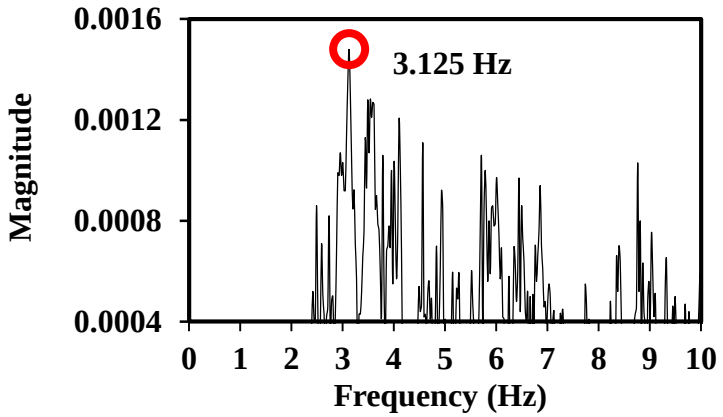
$$IM = \frac{15.24}{L + 38} \leq 0.30$$

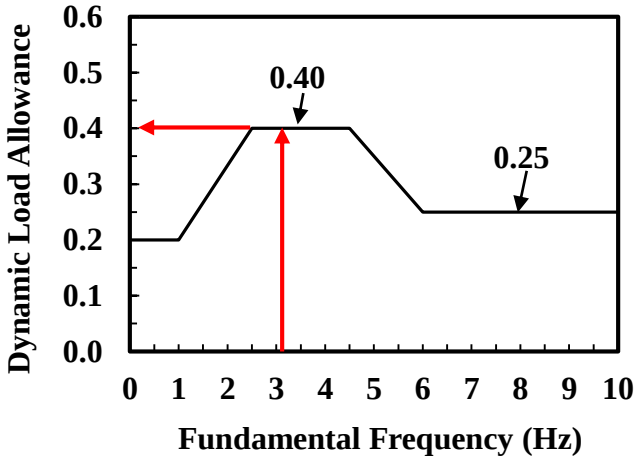
Experimental and analytical impact factor. Conversion factor: 10 mi/h = 16 km/h

Speed (mi/h)	**10**	**20**	**30**	**40**	**50**	**60**
$D_{dyn}{}^{max}$ (mm)	1.77	1.79	1.79	1.77	2.03	2.08
$D_{fil\_sta}{}^{max}$ (mm)	1.77	1.77	1.77	1.77	1.77	1.77
IM^{exp}	0.000	0.010	0.010	0.000	0.150	0.175
DAF^{exp}	1.000	1.010	1.010	1.000	1.150	**1.175**
~~DLA (AASHTO LRFD[5])~~	~~0.33~~	~~0.33~~	~~0.33~~	~~0.33~~	~~0.33~~	~~0.33~~
IM (AASHTO Standard[4]) *	0.222	0.222	0.222	0.222	0.222	0.222
IM (AASHTO Standard[4]) †	0.204	0.204	0.204	0.204	0.204	0.204
DLA (OHBDC[6])	0.40	0.40	0.40	0.40	0.40	0.40

Load Test Results

Dynamic Load Allowance – OHBDC

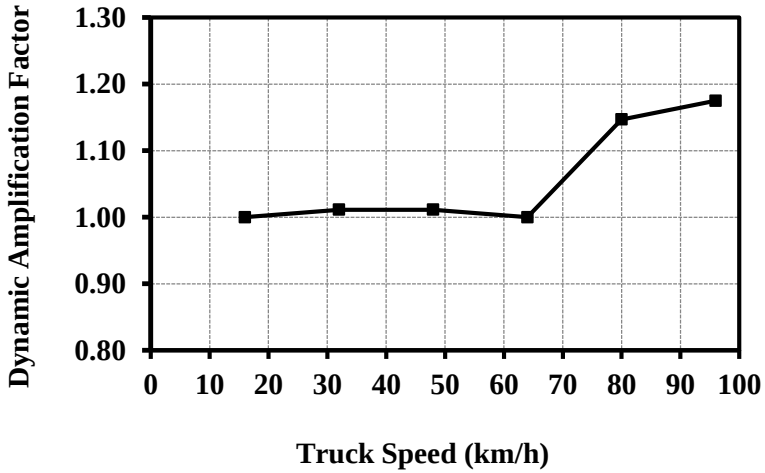




Speed (mi/h)	10	20	30	40	50	60
D_{dyn}^{max} (mm)	1.77	1.79	1.79	1.77	2.03	2.08
$D_{fil\_sta}^{max}$ (mm)	1.77	1.77	1.77	1.77	1.77	1.77
IM^{exp}	0.000	0.010	0.010	0.000	0.150	0.175
DAF^{exp}	1.000	1.010	1.010	1.000	1.150	**1.175**
DLA (AASHTO LRFD[5])	0.33	0.33	0.33	0.33	0.33	0.33
IM (AASHTO Standard[4]) *	0.222	0.222	0.222	0.222	0.222	0.222
IM (AASHTO Standard[4]) †	0.204	0.204	0.204	0.204	0.204	0.204
DLA (OHBDC[6])	0.40	0.40	0.40	0.40	0.40	0.40

Load Test Results

Dynamic and Static Vertical Deflection – RSV-150



$$RF = \frac{\text{Capacity} - \text{Dead}}{(GDF)\text{Live}(1 + I)}$$

Represents 13% difference between DAFs

Speed (mi/h)	10	20	30	40	50	60
D_{dyn}^{max} (mm)	1.77	1.79	1.79	1.77	2.03	2.08
$D_{fil\_sta}^{max}$ (mm)	1.77	1.77	1.77	1.77	1.77	1.77
IM^{exp}	0.000	0.010	0.010	0.000	0.150	0.175
DAF^{exp}	1.000	1.010	1.010	1.000	1.150	**1.175**
DLA (AASHTO LRFD[5])	0.33	0.33	0.33	0.33	0.33	0.33
IM (AASHTO Standard[4]) *	0.222	0.222	0.222	0.222	0.222	0.222
IM (AASHTO Standard[4]) †	0.204	0.204	0.204	0.204	0.204	0.204
DLA (OHBDC[6])	0.40	0.40	0.40	0.40	0.40	0.40

DAF=1.33

➢ Concluding Remarks

- The first series of static and dynamic load tests was conducted on Bridge A7957 to monitor its initial in-service dynamic response.

- The impact factor (IM) or dynamic load allowance (DLA) of Bridge A7957 was obtained from field measurements and using three design specifications. The impact factors obtained with the design specifications resulted in larger values compared to the experimental values.

- The impact factors obtained from field load tests implicitly take into account in-situ parameters such as **unintended support restraints, unintended continuity**, **skew angle**, **contribution of secondary members** and **soil-structure interaction** which improve the bridge's dynamic response.

- These factors are not considered by the analytical methods proposed in the current design and evaluation codes. Consequently, further research needs to be conducted to quantify the influence of these in-situ parameters on the dynamic response of a bridge structure.

➢ Acknowledgements

- The financial support from the Missouri Department of Transportation and the National University Transportation Center at Missouri University of Science and Technology is gratefully acknowledged.

- Special thanks are given to the Missouri S&T's staff members of the CArE Engineering Department: Brian Swift, Gary Abbott, John Bullock and Jason Cox, as well as the graduate students: Alexander Griffin, Hayder Alghazali, and Kaylea Smith.

Thank you

Questions ?

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