Master Thesis

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1 Preface

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2 Introduction

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3 Theory

3.1 Bridge Weigh-in-Motion

A Bridge Weigh-in-Motion system is based on measurements of a bridge's deformation. The BWIM system uses these measurements to calculate passing vehicles axle loads. There are different approaches to assembling such a system, but they typically consists of a strain gauge measuring the strain induced by passing vehicles, a axle detector used to find the vehicle speed and spacing of axles and a computer or data storage device. An algorithm then is able to use the data gathered from the axle detector and strain gauge to calculate axle loads [2].

3.1.1 Moses' Algorithm

Moses' algorithm is based on the fact that a moving load along a bridge will set up stresses in proportion to the product of the value of the influence line and the axle load magnitude. The influence line being defined as the bending moment at the point of measurement due to a unit axle load crossing the bridge [2].

Moses' algorithm is built from the fact that a moving unit load on a bridge will induce stresses proportional to the product of the value of the influence line and the axle load magnitude.

Each individual girder's stress is related to moment:

$$\overbrace{\sigma_i}^{\text{stress in i'th girder}} = \frac{\overbrace{M_i}^{\text{bending moment i'th girder}}}{\underbrace{W_i}_{\text{section modulus}}} \tag{1}$$

Expressing the moment in terms of strain gives

$$M_i = W_i\sigma_i = \overbrace{E}^{\text{Modulus of elasticity}} \times W_i \times \underbrace{\varepsilon_i}_{\text{strain in i'th girder}} \tag{2}$$

The sum of the individual girder moments is therefore:

$$M = \sum_{i=1}^{N} M_i = \sum_{i=1}^{N} EW_i\varepsilon_i = EW\sum_{i=1}^{N}\varepsilon_i \tag{3}$$

The sum of the girder strains is proportional to the gross bending moment. The total bending moment and the measured strain is thus directly related by EW. These constants can be calculated through the bridge's dimensions and material properties. However through measuring the effects of a known vehicle passing the bridge these constants can be derived.

Weigh in motion is an inverse problem, the strain is measured and the cause of the strain is to be calculated. The theoretical bending moment corresponding to axle loads on the bridge at one strain sample, is given by:

$$M_k^T = \sum_{i=1}^{N} A_i I_{(k-C_i)} \tag{4}$$

$$C_i = (L_i \times f)/v \tag{5}$$

3.2 Influence lines

3.2.1 Matrix method

3.2.2 Optimization

testing [3].

3.3 Finding the train's speed

3.4 The axle distances

4 Method

4.1 Programming a BWIM system

Describe shortly how the BWIM system have been programmed. Keywords:

- Beam bridge model
- Producing a strain history through influence lines
- Finding the speed of the train
- Finding Axle distances
- Solving system for axle weights

This master project began by learning how the BWIM-system works, which means programming it. To not make this a too big project this meant building a simple beam model of a bridge in Matlab, and simulate moving loads crossing it. Through the theoretical influence lines of the beam a strain history was then produced for the given set of moving axle loads. This strain history could then be used as a base to build the code for a BWIM system.

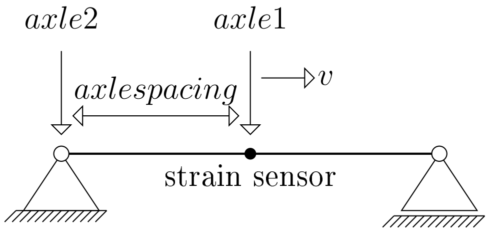

Figure 1: Beam model for initial BWIM

4.2 Finding influence lines

Describe how influence lines have been found from the given strain history from Lerelva Bridge. Keywords:

- Matrix method
- Optimization
- Speed

4.2.1 Matrix method

Describe the matrix method.

4.2.2 Optimization

Describe how optimization can be used to find optimal influence lines for the bridge.

4.3 System setup

To test the BWIM-program on actual data, we Gunnstein, Daniel set up a BWIM-system to gather strain data from actual train passings. The subject bridge were Lerelva-Bridge in Trondheim, a typical Norwegian steel railway bridge. Three strain gauges, 3 mm 120 ohms from HBM, were placed by the support towards Trondheim on the first section of the longitudinal stringer. The sensors were placed with 1 m spacing around the middle of the stringer section. These strain gauges were connected to a National Instruments compactDAQ with module NI 9235 which produced an continuous data flow to a standard laptop. A Kipor generator was brought for power.

4.4 Testing

Keywords:

- Comparing calculated strain with measured strain

5 Analysis

This chapter will describe how the BWIM system performs. What works? Why? How? etc.
Should include:

- Compare theoretical and calculated influence lines. Also include influence lines found through Abaqus.
- Check how influence lines found through matrix method and optimization reproduces the strain history
- Test obtained influence line by running the bwim routine on the hitherto unused freight train. (Depends on getting info about the train). Also Do this test on the other trains.

6 Conclusion and summary

A Dynamics

A train traversing a railway bridge creates actions in longitudinal, lateral, and vertical directions. Braking and traction from a passing train causes longitudinal forces Rocking, or rotations around an axis parallel to the longitudinal axis of the bridge, and vertical dynamic forces are created by structure-track-vehicle conditions and interactions.

A.1 Rocking and vertical dynamic forces

Lateral rocking of moving vehicles provide amplification of vertical wheel loads. This amplification increases the stresses in the members supporting the track.

Superstructure-vehicle interaction creates a vertical dynamic amplification of moving loads, which will result in vibrations causing additional stresses in members supporting the track.
The unloaded simply supported beam frequency $\omega_1 = \frac{\pi^2}{L^2}\sqrt{\frac{EI}{m}}$, provides a basic indicator of superstructure vertical dynamic response.

B Bibliography

[1] J. Doe, *The Book without Title.* Dummy Publisher, 2100.

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[3] A. Liljencrantz, R. Karoumi, and P. Olofsson, "Implementing bridge weigh-in-motion for railway traffic," *Computers and Structures*, vol. 85, no. 1-2, pp. 80–88, 2007.