Vibration response of long cable-stayed timber footbridge – case study

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Outline

- Introduction and aim
- *Älvsbacka Bridge* in the city of Skellefteå
  - Timber footbridge
  - Pedestrian-induced vibrations
- Guidelines and codes
  - Comfort criteria
- Acceleration measurements at the bridge
  - Results
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- Conclusions

Introduction

Background

- **Cable-stayed pedestrian and bicycle bridge**
  - Design according to the old code (BRO2004)
  - Effects on dynamic design in the transition between two codes (BRO 2004 and Eurocodes)

- **Aim of this study**
  - Was the damping ratio from the Eurocode 5 more reasonable than that from BRO 2004?
  - Focus is on the vertical accelerations

Älvsbacka Bridge by “Martinsons träbroar”

Free span: 130 meters (426 ft.) and very slender with a width of only 4 meters

Cable-stayed pedestrian and bicycle bridge built summer 2011

The total amount of glulam is almost 400 m^3 or 200 tonnes. There are also 80 tonnes of steel in the form of castings and fixtures of different kinds

Pedestrian-induced vibrations

Dynamic forces

- Vertical
- Lateral
- Longitudinal

Force frequencies

- Walking 1.2-2.2 Hz
- Walking 0.6-1.1 Hz (lateral)
- Running 3 Hz

Guidelines and codes

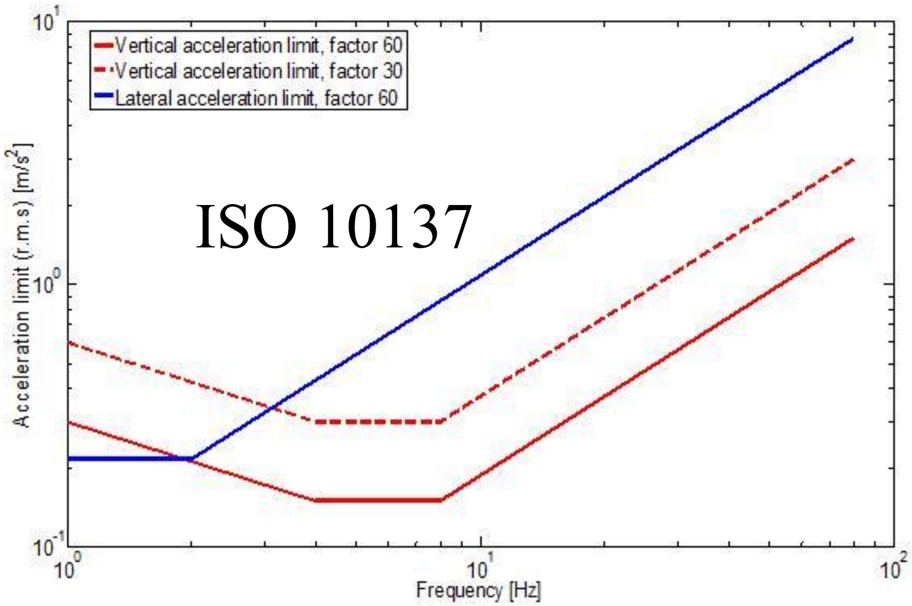
Comfort criteria: Recommended vertical acceleration limit

BRO2004: If natural frequency is below 3.5 Hz, peak value 0.5 m/s^2

Eurocode: Natural frequency is less than 5 Hz for the first vertical mode – perform verification of the comfort criteria

Vertical acceleration limit < 0.7 m/s^2

Design values of the damping factor
BRO 2004 0.6%
Eurocode 5 1.5%

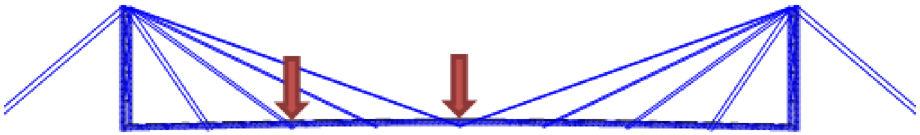


Acceleration measurements at the bridge

Three different tests conducted at the bridge:

- Controlled walking test
- Jumping test
- Heel impact test

Four accelerometers were used in two positions:



Controlled walking test

Synchronized group

- Controlled walking frequency
- Entire bridge

Purpose of the test

- Excite both lateral and vertical modes
- Symbolize possible loading situations

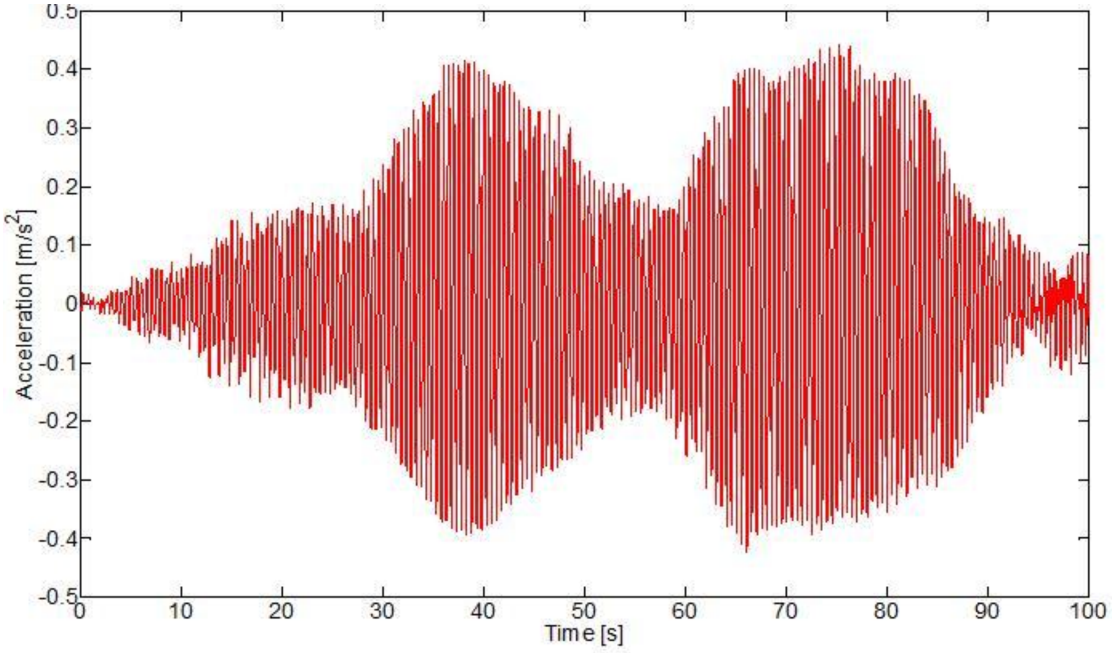
Results of controlled walking tests

Vertical results

- Walking frequency 1.9 Hz

Accelerations

- Measured in a quarter of the bridge span



- Maximum vertical acceleration: 0.44 m/s^2

Jumping test

Synchronized group

- Controlled jumping frequency
- Midspan and at quarter point of the span
- "Regular" jumps
- Ice skating jumps

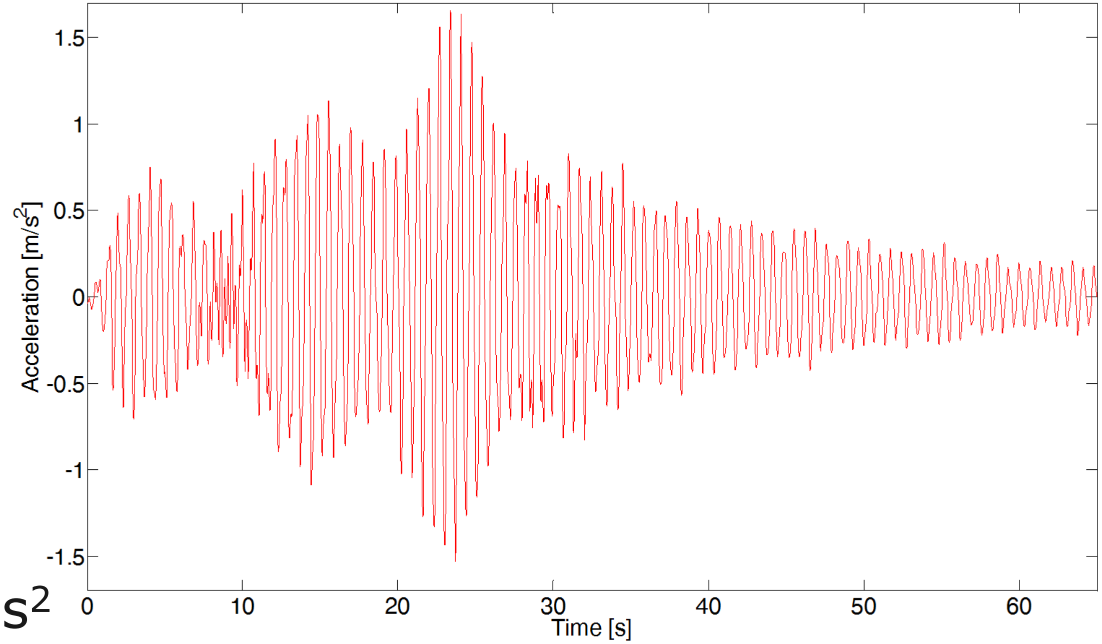
Purpose of the test

- Excite both vertical and lateral modes
- An extreme loading situation
- Damping factor

Results of the jumping tests

"Regular" jumps

- Jumping in midspan
- Frequency 1.4 Hz



Accelerations

- Measured in midspan
- Maximum vertical acceleration: 1.66 m/s^2

- Limit of 0.7 m/s^2

Heel impact test

Synchronized group

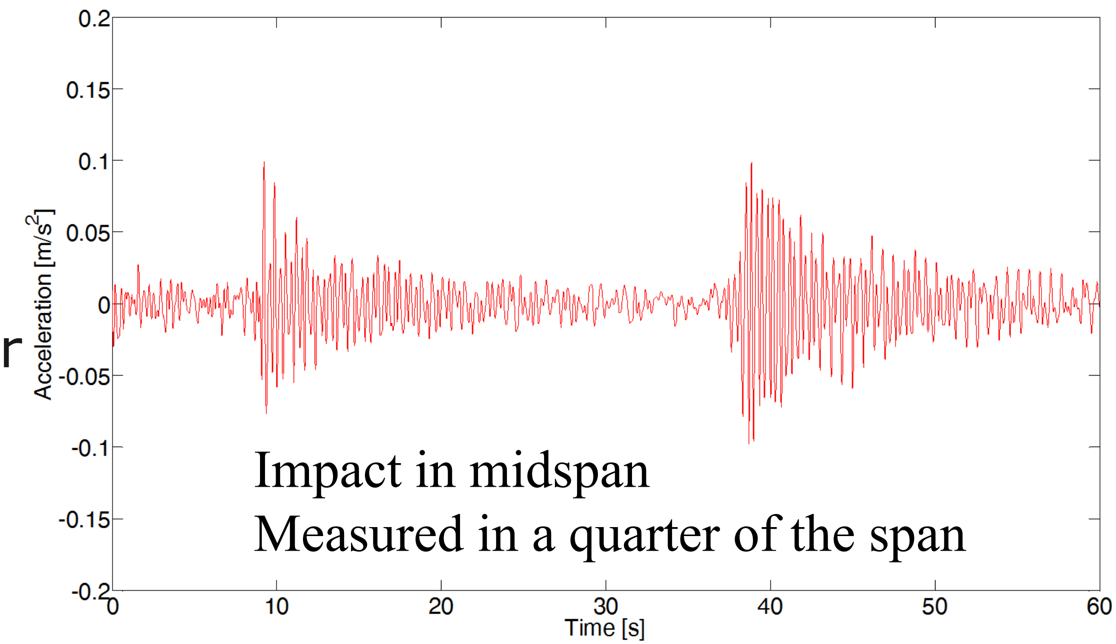
- Controlled impact
- Standing on toe, falling back on heel
- Midspan and a quarter of the span

Purpose of the test

- Impact
- Damping factor

Accelerations

- Maximum vertical acceleration: 0.1 m/s²

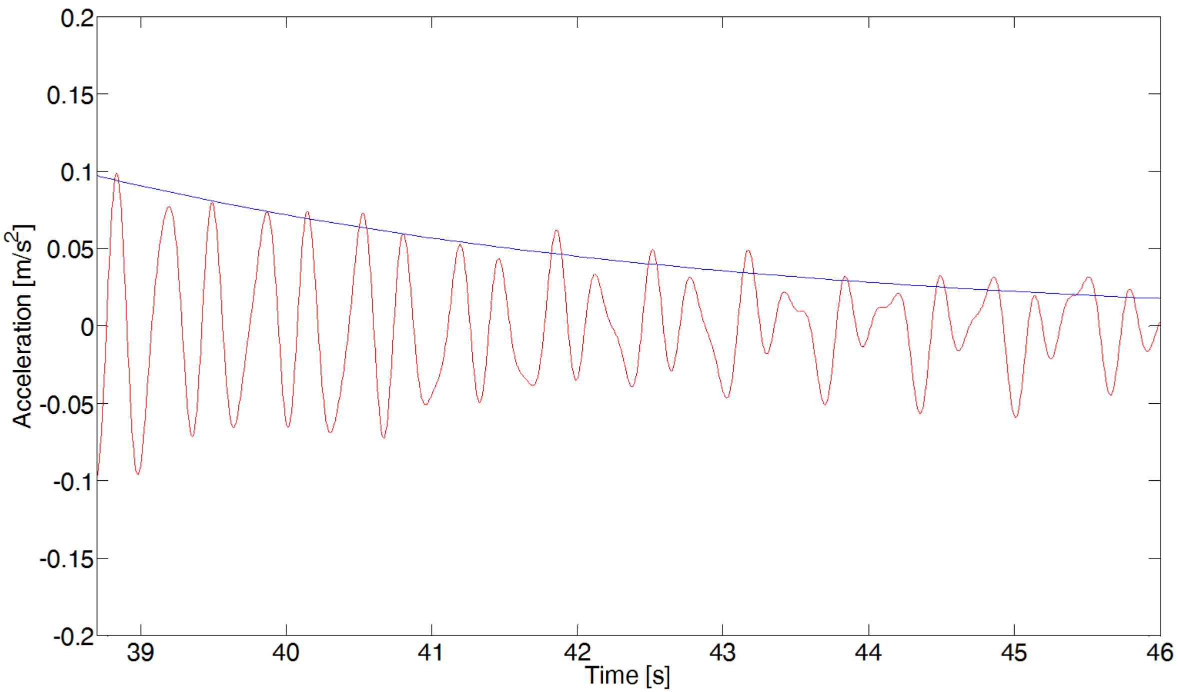


Damping factor from the heel impact tests

Damping

- Impact in midspan
- Measured in a quarter of the span
- Curve fitting

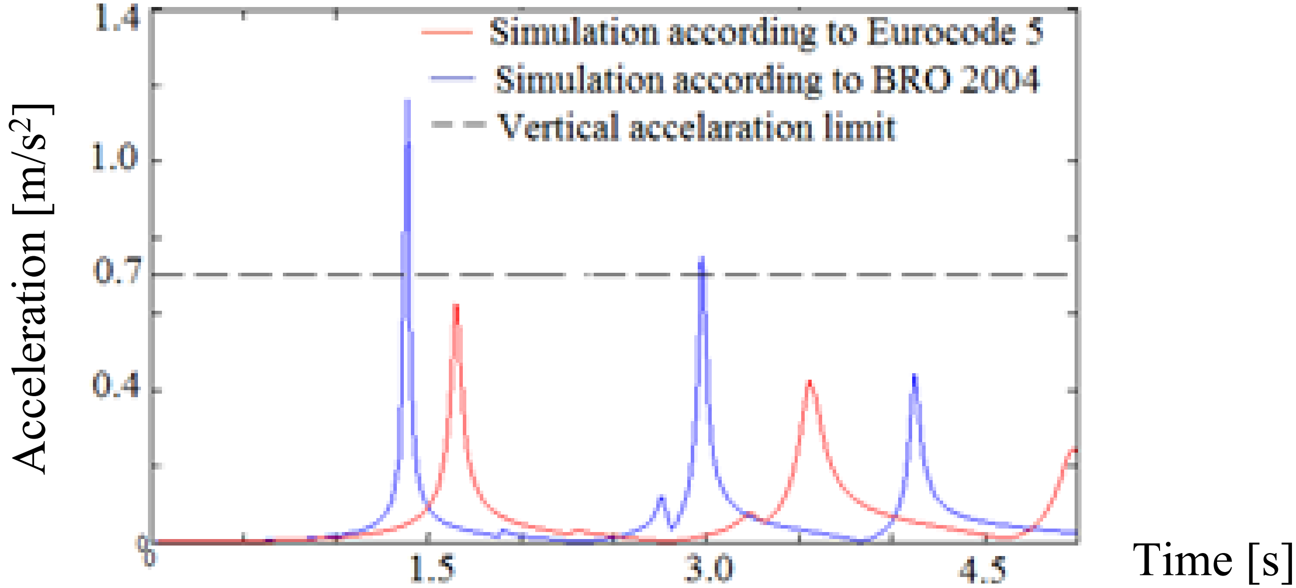
$$\zeta = \frac{1}{2\pi} \ln\left(\frac{a_i}{a_{i+1}}\right)$$



Results

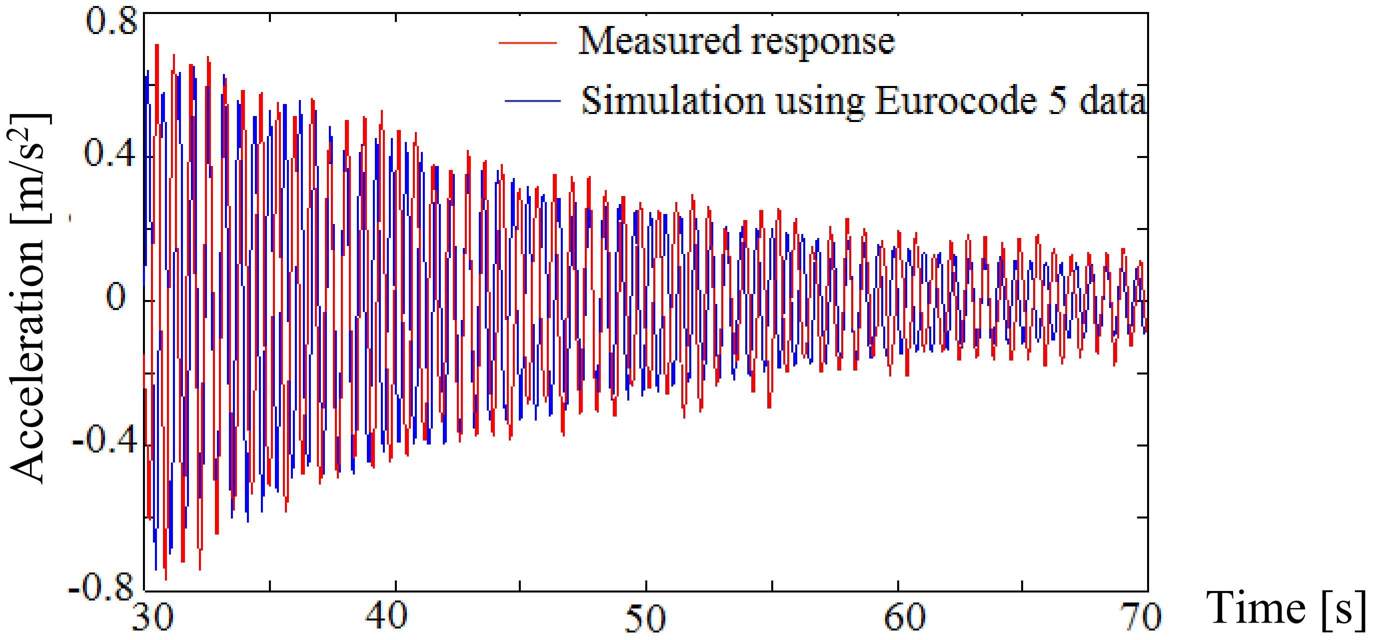
- 1.2% Twice the value presented in BRO 2004

Comparison between the force models and simulation of the response



Response due to the force models in ISO 10137 for a group of twenty pedestrians and comparison with the acceleration limit

Simulations of the tests in Brigade/Plus

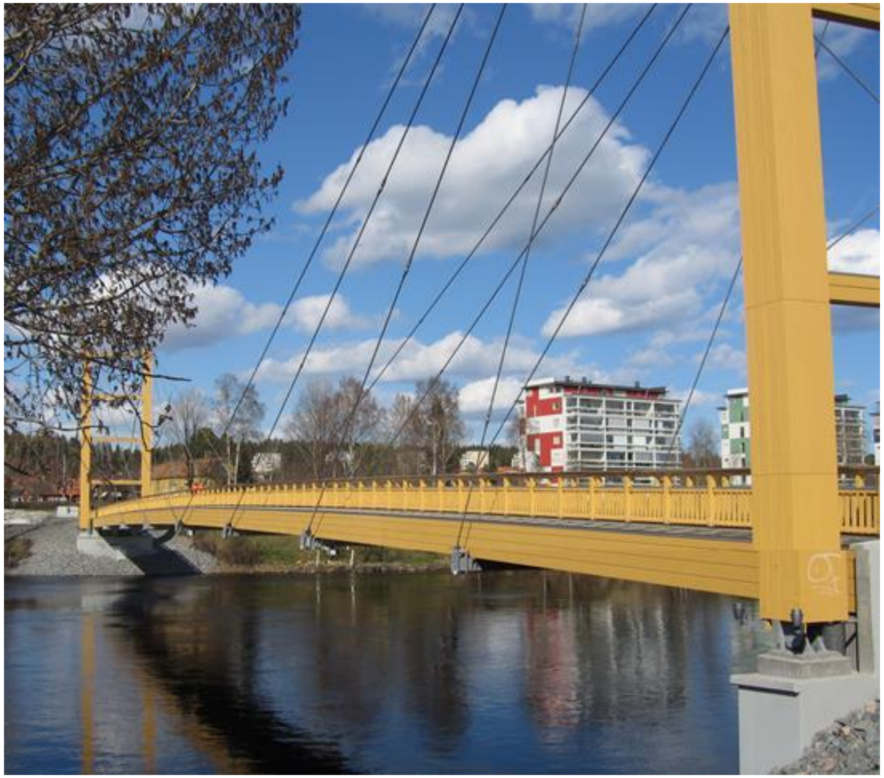


Comparison of measured response and simulations using the simple model according to Eurocode after the group has stopped jumping

Conclusion

Controlled walking test
symbolizes a possible loading situation: < 0.5 m/s^2
measured vertical accelerations < 0.2 m/s^2

Jumping tests
damping factor of 0.6% and
Heel impact tests
damping factor of 1.2%



Eurocode 5: damping factor 1.5%

Acknowledgement

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Thank you for listening!