Role of measurements and experimental data in optimised bridge assessment

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Content

• Thoeretical modelling vs. measurements
• Bridge weigh-in-motion
• ARCHES implementations:
  ▪ Soft load testing
  ▪ Traffic loading
  ▪ Dynamic amplification factors
• Results
**Theoretical modelling vs. measurements**

**Modelling**
- Models "anything"
- Unlimited data
- Can forecast the future
- Based on assumptions

**Measurements**
- Measure "real life"
- Measurement inaccuracies
- Not always possible
- Can be costly

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*Should work together (model calibration)*
## Load modelling/ measurements on bridges

**Modelling**
- can model expected extreme loading that cannot be measured
- can simulate the future
  - bridge behaviour
  - change of traffic
  - change of pavement
- based on assumptions
- requires simplifications
- more conservative results

**Measurements**
- account for structural specifics
- do not care about:
  - bridge condition
  - pavement conditions
  - vehicle characteristics
- limited duration
- limited data
- can optimise results
- less conservative results
Measurements in ARCHES

- to simplify and optimise bridge assessment
- to update structural models based on bridge WIM measurements:
  - soft load testing (updating of the structural model)
  - traffic load modelling
  - dynamic amplification factor
BRIDGE WEIGHT-IN-MOTION
Axle detection
Strain measurements
Strain transducer
Bridge weigh-in-motion installation
Bridge weigh-in-motion installation
186 m long bridge over 5 spans
530m long orthotropic deck bridge
| No | Date      | Time   | Cal | Comment | J  | Cale | Spd  | GVVV | W1  | W2  | W3  | W4  | W5  | W6  | W7  | W8  | A1  | A2  | A3  | A4  | A5  | A6  | A7  | T  |
|----|-----------|--------|-----|---------|----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 1  | 2006.09.26| 02:10:23| H   |         | 1  | 113  | 72.3 | 5   | 24.58| 4.40 | 7.00 | 4.49 | 4.40 | 4.40 | 3.61 | 5.65 | 1.29 | 1.29 | 14.9 |
| 2  | 2006.09.26| 10:39:54| H   |         | 1  | 60   | 68.7 | 3   | 14.74| 3.50 | 6.46 | 4.78 |      |      | 4.56 | 6.24 | 14.9 |
| 3  | 2006.09.26| 10:40:43| H   |         | 1  | 83   | 83.8 | 5   | 39.39| 3.56 | 9.02 | 8.02 | 7.35 | 10.44|      |      |      | 14.8 |
| 4  | 2006.09.26| 10:41:14| H   |         | 1  | 40   | 97.0 | 2   | 9.74 | 1.63 | 8.11 |      |      |      |      |      | 4.16 |
| 5  | 2006.09.26| 10:41:21| H   |         | 1  | 62   | 88.7 | 4   | 14.24| 4.52 | 6.41 | 0.86 | 2.45 |      |      |      |      | 4.16 |
| 6  | 2006.09.26| 10:42:18| H   |         | 1  | 40   | 79.3 | 2   | 7.67 | 1.47 | 6.40 |      |      |      |      |      | 3.53 |
| 7  | 2006.09.26| 10:42:38| H   |         | 1  | 113  | 65.7 | 5   | 33.79| 5.49 | 6.70 | 7.20 | 7.20 | 7.20 |      |      |      |      | 4.14 |
| 8  | 2006.09.26| 10:42:49| H   |         | 1  | 40   | 84.7 | 2   | 11.53| 3.61 | 7.72 |      |      |      |      |      | 5.29 |
| 9  | 2006.09.26| 10:42:59| H   |         | 1  | 41   | 83.8 | 2   | 10.59| 5.14 | 5.45 |      |      |      |      |      | 5.45 |
| 10 | 2006.09.26| 10:43:12| H   |         | 1  | 40   | 92.2 | 2   | 7.48 | 2.08 | 5.40 |      |      |      |      |      | 4.60 |
| 11 | 2006.09.26| 10:43:23| H_MP|         | 2  | 40   | 92.2 | 2   | 6.50 | 3.28 | 5.44 |      |      |      |      |      | 4.95 |
| 12 | 2006.09.26| 10:43:23| H_MP|         | 2  | 113  | 75.2 | 5   | 38.25| 6.67 | 8.40 | 8.40 | 8.40 |      |      |      |      | 3.84 |
| 13 | 2006.09.26| 10:43:31| H   |         | 1  | 113  | 84.7 | 5   | 39.61| 5.04 | 9.03 | 8.48 | 8.48 | 8.48 |      |      |      |      | 3.88 |
| 14 | 2006.09.26| 10:43:48| H   |         | 1  | 113  | 85.7 | 5   | 20.20| 5.00 | 5.16 | 3.34 | 3.34 | 3.34 |      |      |      |      | 3.58 |
| 15 | 2006.09.26| 10:44:02| H   |         | 1  | 110  | 91.0 | 5   | 41.41| 5.27 | 9.27 | 9.06 | 8.96 | 8.96 |      |      |      |      | 3.60 |
| 16 | 2006.09.26| 10:44:12| H   |         | 1  | 123  | 64.7 | 4   | 13.99| 3.47 | 5.44 | 1.69 | 1.69 | 1.69 |      |      |      |      | 3.82 |
| 17 | 2006.09.26| 10:44:31| H   |         | 1  | 61   | 84.7 | 4   | 24.67| 4.45 | 13.98| 3.12 | 3.12 |      |      |      |      | 5.38 |

Vehicle info:

Subclass: 113
Category: 4
**Gross Weight: 39.51 t**
Lane: 1
Speed: 64.7 km/h
Total Axle Distance: 11.13 m
Warning flags: 0
### Vehicle Information

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**Category:** 4  
**Gross Weight:** 39,51 t  
**Lane:** 1  
**Speed:** 64.7 km/h  
**Total Axle Distance:** 11.13 m  
**Warning flags:** 0

### Vehicle Details

- **Vehicle photo:**  
- **Temperature:** 42.8°C  
- **Date:** 2006-09-26 10:43:31.774

### Data Table

| No  | Date       | Time       | Cal | Comment | JCl | Spd | GVV | W1  | W2  | W3  | W4  | W5  | W6  | W7  | W8  | A1  | A2  | A3  | A4  | A5  | A6  | A7  | T   |
|-----|------------|------------|-----|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1   | 2006-09-26 | 02:10:23   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.9|
| 2   | 2006-09-26 | 10:39:54   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.9|
| 3   | 2006-09-26 | 10:40:43   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.8|
| 4   | 2006-09-26 | 10:41:14   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.9|
| 5   | 2006-09-26 | 10:41:21   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.9|
| 6   | 2006-09-26 | 10:42:18   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.9|
| 7   | 2006-09-26 | 10:42:36   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.9|
| 8   | 2006-09-26 | 10:42:49   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.9|
| 9   | 2006-09-26 | 10:42:59   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.9|
| 10  | 2006-09-26 | 10:43:12   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.9|
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| 12  | 2006-09-26 | 10:43:23   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.9|
| 13  | 2006-09-26 | 10:43:31   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.8|
| 14  | 2006-09-26 | 10:43:48   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.8|
| 15  | 2006-09-26 | 10:44:02   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.8|
| 16  | 2006-09-26 | 10:44:12   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 14.9|
| 17  | 2006-09-26 | 10:44:31   |     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 15.0|

*Note: The image shows a vehicle on a highway with a scania truck.*
SiWIM - strain signals
SOFT LOAD TESTING
Soft load testing

- initiated in SAMARIS project
- efficient way of diagnostic load testing, based on B-WIM:
  - influence lines
  - distribution of loads
  - impact factors
  - under normal traffic, without pre-weighed vehicles and no road closures
- objective of ARCHES:
  To validate results of soft load testing with more traditional diagnostic and proof load tests
Experimental influence lines

- 9.2 m slab bridge
- built in 1980
- simply supported
Experimental influence lines

- 9.2 m slab bridge
- built in 1980
- not simply supported
Experimental influence lines

- 9.2 m slab bridge
- built in 1980
- **not** simply supported
Experimental influence lines

- 9.2 m slab bridge
- built in 1980
- not simply supported
- influence of thickness of the superstructure
Experimental influence lines

- 9.2 m slab bridge
- built in 1980
- not simply supported
- influence of thickness of the superstructure
- location of maximum moment
Load distribution factors

- distribution of traffic loading to different structural elements
- generally less dependent of wheel location at midspan than at support
- to update torsional characteristics of the bridge model
Soft load testing results

- 20 bridges on Slovene road network:
  - without SLT RF from 0.35 to 0.87
  - with SLT RF from 0.73 to 1.52
  - increase of RF from 1.30× to 2.84×

- many posted bridges rated as unsafe for normal traffic loads have been rated as safe

- biggest savings on smaller older bridges

- on continuous spans savings mainly due to better load distribution factors
DYNAMIC LOADING
Dynamic loading on bridges

• ratio between maximum (dynamic) and static loadings – DAF

• problem: combining the extremes of dead load and dynamic effects => very high DAF

• continuation of work from SAMARIS:
  - theoretical studies (UCD)
  - experiments (ZAG)
DAF and SiWIM

- updated SiWIM software calculates DAF by comparing measured with “static” signals
- from 6 tested algorithms the one using FFT low-pass filter was applied:
  - spectrum calculated from hundreds of vehicles
  - only static component left to compare with dynamic signal
Dynamic amplification
Dynamic amplification
Dynamic amplification
Dynamic amplification
Dynamic amplification
Dynamic amplification
Dynamic amplification

1 hour = 387 vehicles
Dynamic amplification

1 day = 4120 events
Calculation of DAF

Automatic DAF calculation for all vehicles (events) …
Calculation of DAF

... with visual inspection of all extreme loading events
DAF - 24.8 m beam/ deck bridge
DAF - 11.9 m slab
DAF - 11.65 m slab
DAF - 7.2 m slab
DAF – 7×25.0m beam/ deck bridge
Summary of DAF results

Site 1

Site 2

Site 4

Site 5
Pavement evenness - Site 1

Longitudinal pavement profile, driving lane, right wheel trail
Vransko (A1/0043)
Pavement evenness - Site 3

Longitudinal pavement profile, driving lane, right wheel trail
Trebnje (A2/0072)
Conclusions

• knowing real (measured) influence lines, load distribution factors and dynamic amplifications can significantly change the structural model

• Dynamic Amplification Factor:
  - design values too conservative for bridge assessments
  - ARCHES measurements show that DAF is below 1.06, with smooth pavement below 1.03

• measurements in safety assessment:
  - lead to big savings and optimised management
  - should be used for model updating where possible
Thank you for your attention!