COST Action
TU 1402

Quantifying the Value of Structural Health Monitoring

Application of B-WIM measurements in assessment of existing bridges

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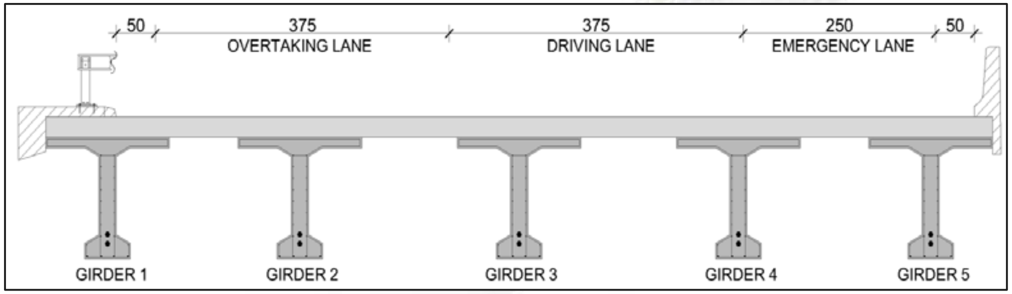
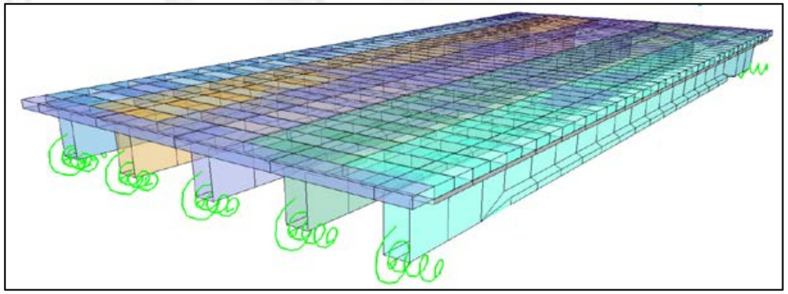
1. Decision scenario – assessment of existing road bridges

1.1 Introduction

- **Main objective – prove that initial investments in monitoring (SHM) will result in:**
  - Extended bridge service life
  - Reduction in bridge maintenance costs
  - Overall optimization of bridge management process
- **Case Study Bridge description**
  - Highway bridge, single span of 24,8 meters
  - Cross section – 5 prestressed I-type girders and monolithic deck
  - Original designs and drawings available from the records





1. Decision scenario – assessment of existing road bridges

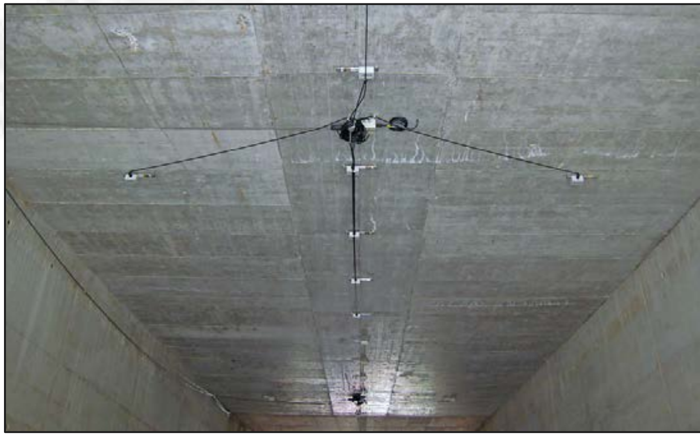
1.2 Selection of assessment strategy

- **Strategy B_0 – assessment without monitoring data**
  - Numerical model based on visual inspection and original design plans
  - Traffic loads based on design codes for new bridges
  - Bridge rating based on deterministic or probabilistic approach
- **Strategy B_1 – assessment with short-term monitoring data**
  - Calibration of numerical model with structural data obtained with monitoring
  - Traffic loads based on design codes for new bridges
  - Bridge rating based on probabilistic approach
- **Strategy B_2 – assessment with long-term monitoring data**
  - Calibration of numerical model with structural data obtained with monitoring
  - Site specific traffic load models based on monitoring data
  - Bridge rating based on probabilistic approach

2. Monitoring methods applied

2.1 Bridge Weigh-in-Motion (B-WIM)

- Method that measures vehicles as they drive over the bridge
- Uses instrumented bridges as weighing scales
- Sensors placed under the bridge
- **Advantages:**
    - Completely portable
    - High accuracy
    - No interruption of traffic
    - Provides structural information
- **Disadvantages:**
    - Requires knowledge about bridges
- **History:**
    - Since late 1970s, research in Europe in 1990s
    - SiWIM® in the last 18 years
    - 2500+ installations, 25+ countries



2. Monitoring methods applied

2.1 Bridge Weigh-in-Motion (B-WIM)

- **Traffic data collected for each vehicle**
  - Speed
  - Number of axles
  - Weight and spacing of each axle
  - Total weight of vehicle
- **Bridge structural data**
  - Bridge response to traffic loads
    - Influence lines
    - Load distribution
    - Dynamic characteristics

Time stamp	Lane	Speed [m/s]	Class	Number of axles	GSW [kN]	AW1 [kN]	AW2 [kN]	Axle spacing [m]
2007-03-22-00-39-28-955	1	17,5	41	2	123,8	37,07	86,69	6,07

- **Applications of B-WIM data**
  - Traffic analysis
  - Pavement and bridge design (or assessment)
  - Selection of overloaded vehicles etc.

2. Monitoring methods applied

2.1 Bridge Weigh-in-Motion (B-WIM)

- **Assessment strategies based on B-WIM data:**

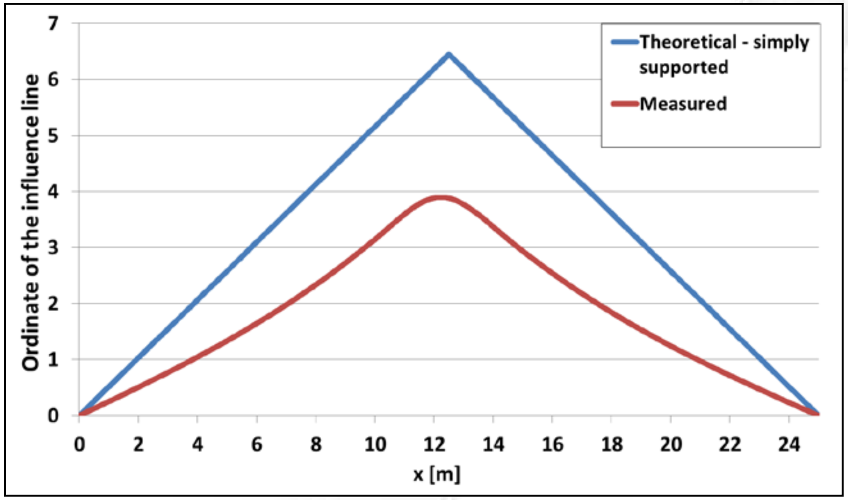
- **Strategy B_1 – short term measurement**
  - Calibration of numerical model:
    - Influence lines
    - Load distribution factors
  - Measurement time:
    - Few hours or few hundreds vehicles

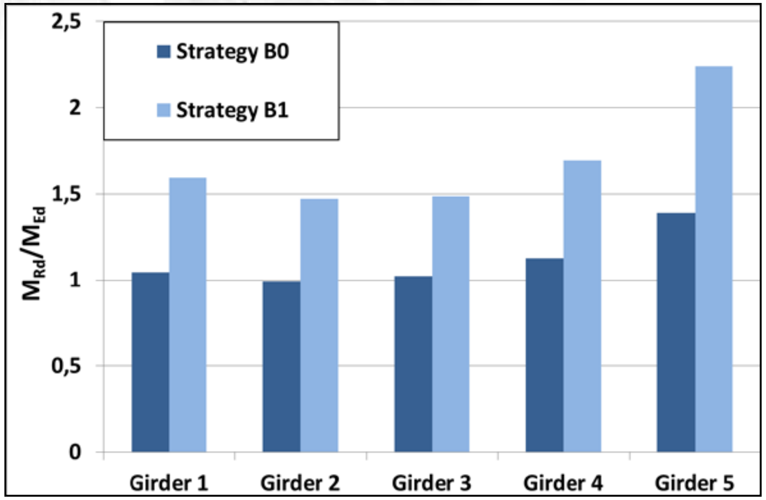
- **Strategy B_2 – long term measurement**
  - Calibration of numerical model:
    - Influence lines
    - Load distribution factors
  - Updating of traffic load:
    - Site specific traffic load model
    - Realistic dynamic factors
  - Measurement time:
    - Minimum of two months or at least 100 000 vehicles

3. Data and results obtained obtained

3.1 Structural data – bridge response to traffic loads (strategy B_1)

- Realistic influence line:
  - Reduction in total load effect (moments and shear forces)
  - Revealing the true bridge behavior (not simply supported)
- Distribution of total loads over girders
  - Indication of critical sections on the bridge
  - Revealing non visible cracks and changes in the stiffness

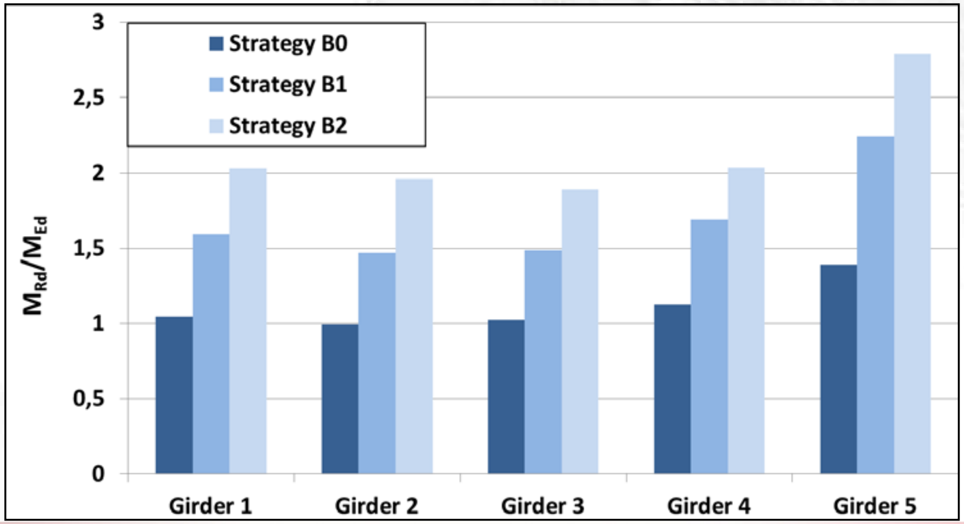




3. Data and results obtained obtained

3.2 Traffic data (strategy B_2)

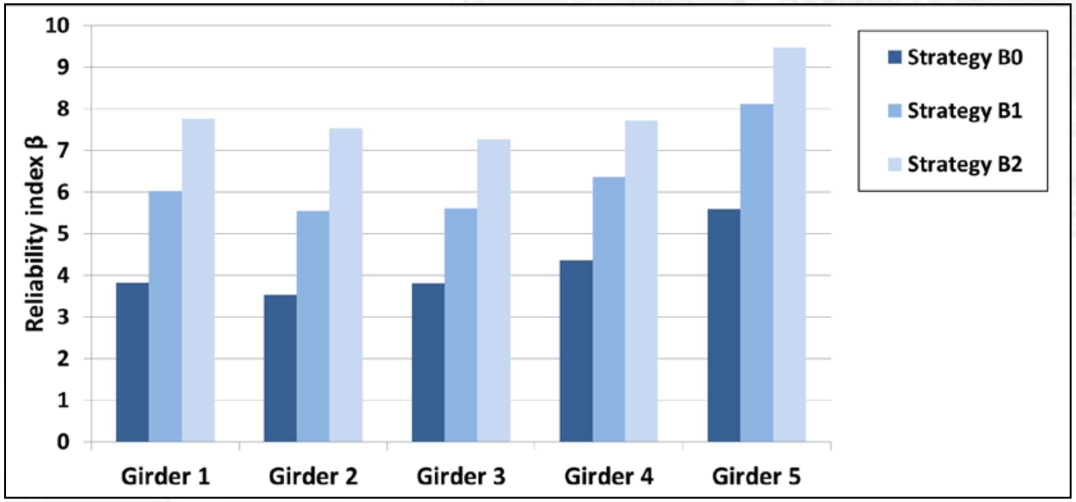
- Dynamic characteristics of the bridge:
  - Reduced dynamic amplification compared to the design codes recommendations
  - Revealing the state of the pavement
- Site specific traffic load model
  - Realistic traffic load on specific bridge, calculated for different time periods
  - Reduction of traffic load comparing to the codes



3. Data and results obtained obtained

3.3 Results – probabilistic approach

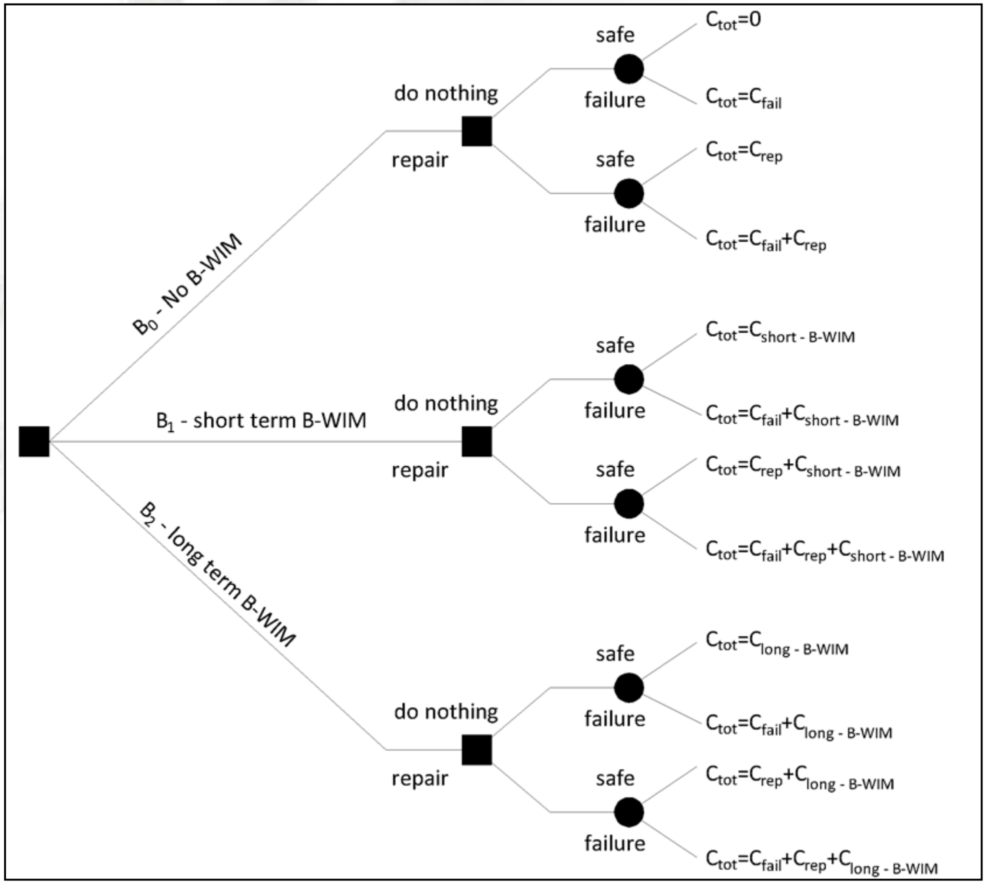
- Approach based on calculation of probability of failure p_f
- Probability of failure occurs when load effect **E** exceeds structural reliability **R**
- Reliability index **β** represents probability of failure
- Target values of **β**:
  - Eurocode – design of new structures
  - Probabilistic modal code – design and assessment of structures



4. Value of the SHM information for the owner/concessionaire

4.1 Reliability levels and associated costs

- Cost – benefit analysis
- Decision tree for calculation
- Definition of all related costs:
    - Cost of bridge failure – C_{fail}
    - Cost of bridge repair – C_{rep}
    - Cost of short term B-WIM – C_{B1}
    - Cost of long term B-WIM – C_{B2}
- Multi – level assessment method
- Time variant analysis – **prediction of future reliability and costs**
- **From previous experience:** Overall costs are minimal, due to the fact that the bridge does not have to be closed or restricted for next 10-20 years.



4. Value of the SHM information for the owner/concessionaire

4.1 Reliability levels and associated costs

- **Cost of bridge failure C_{fail} :**
  - Direct cost – bridge value due to its replacement
  - Indirect cost – approx. 2 – 3xbridge value (due to alternate routes, traffic jams etc.)
- **Cost of bridge repair C_{rep}:**
  - Direct cost – value of bridge repairs (bridge type, extent of damage etc.)
  - Indirect cost – approx. 1 – 2xbridge value if bridge is closed or restriction is imposed
- **Cost of short term B-WIM – C_{B1}:**
  - B-WIM installation – 0,075 – 0,1 mil. €
  - Data post processing – 0,005 – 0,010 mil. €
  - Bridge analysis - 0,005 – 0,020 mil. € (depending on the bridge size and type)
- **Cost of long term B-WIM – $C_{B2:}$**
  - B-WIM installation – 0,075 – 0,1 mil. €
  - Maintenance and data post processing – 0,020 – 0,025 mil. € (every year)
  - Bridge analysis – 0,015 – 0,030 mil. € (depending on the bridge size and type)

5. Open question addressed to decision makers

1. Do you perform any type of Weigh-in-Motion measurements on your roads/bridges?
2. If you do, what are you using results for?
3. Is this research enough for you to invest in WIM measurements for optimization of bridge management system?
4. Do you use any other measurement/monitoring technique to improve knowledge about your bridges and to optimise their structural assessment?
5. Are you interested in a pilot project on your bridges? Would you be prepared to finance it?

Thank you for your attention

http://www.cost-tu1402.eu/