Bridge Management in Germany

Dipl.-Ing. Ralph Holst

Bundesanstalt für Straßenwesen
1 Organisation of Maintenance
2 Statistics
3 Data-(base)
4 Inspection
5 Management
6 Closure and Outlook
Development of a BMS

1. Organisation of Maintenance
2. Statistics
3. Data-(base)
4. Inspection
5. Management
6. Closure and Outlook

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State Administration
- structural data
- inspection
- maintenance program
- implementation
- documentation

BMVBS
- prognosis
- strategies
- political decision
- budget, restrictions
- actual/target comparison

BMS

BASt
- technical advisor of BMVBS
- analysis of data/programs
- research and development
- international cooperation

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1 Organisation of Maintenance
2 Statistics
3 Data-(base)
4 Inspection
5 Management
6 Closure and Outlook
Overall road network: 688.243 km
Federal Highways: 12.718 km
Federal Trunk Roads: 40.203 km
(01.01.2010)

Federal Roads: 39.039 bridges
Highways: 17.422 bridges
Trunk Roads: 21.617 bridges
(01.03.2012)
(01.03.2012)

39.039 Bridges
Bridge Deck Area = 29,95 Mio m²
[\%] of Bridge Deck Area
• insufficient durability of structures
• growing volumes of traffic / higher weights
• restricted resources
• no standardized maintenance planning procedures

BMS (planning, controlling, implementation)
Development of a BMS

1 Organisation of Maintenance
2 Statistics
3 Data-(base)
4 Inspection
5 Management
6 Closure and Outlook
BMS - Structure

- Network
- Structures
- Damages
- Maintenance
- Traffic
- Accidents
- Costs

Data base

- Costs (owner, user)
- Condition assessment
- Deterioration prediction

Analyses

- Restrictions
- Alternatives

Program requirements

(OECD 1992)
DIN 1076, Engineering structures in connection with roads; inspection and test, 1999

Guideline RI-EBW-PRÜF, 2007
Recording and assessment of damages, condition assessment

ASB Structures Inventory instructions, 2008
Extent and structure of data

Software SIB-Bauwerke, Version 1.8, 2008
Recording and evaluation of data; inspection software
**Construction-data**

**BAST, Brücken- u. Ingenieurbau**
Referat B4 "Bauwerkserhaltung"

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<table>
<thead>
<tr>
<th>Bauwerknummer</th>
<th>Name</th>
<th>Zustand</th>
<th>Art</th>
<th>Konstrukt.</th>
<th>Stadium</th>
</tr>
</thead>
<tbody>
<tr>
<td>4311687</td>
<td>A2 / K9 &quot;Bergkamener Str.&quot;/A2 / K9, FR Hannover</td>
<td>3,0</td>
<td>Plattenbalkenbrücke, Trägerrostbrücke</td>
<td>Stahl-Vollwandträger mit Ortbetonplatte (6-stegig)</td>
<td>Bauwerkverlauf</td>
</tr>
</tbody>
</table>

**Condition Index**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Plattenbalken / Trägerrost (mit Querverteilung)</td>
<td>ANL Hamm</td>
<td>AN Kamen</td>
<td>16.04.2007</td>
<td>18.11.2010</td>
<td>Stahlbetonfertigteile mit Ortbeton ohne Verbund</td>
</tr>
</tbody>
</table>

**Length, Width, Bridge Deck Area**

<table>
<thead>
<tr>
<th>Ges. Länge</th>
<th>Breite</th>
<th>Fläche</th>
</tr>
</thead>
<tbody>
<tr>
<td>17,60 m</td>
<td>19,65 m</td>
<td>346 m²</td>
</tr>
</tbody>
</table>

**Bridge Class (60)**

**MLC**

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**Damage description**

[5]: Superstructure; Corrosion; $S = 0; V = 0; D = 2$
Development of a BMS

1. Organisation of Maintenance
2. Statistics
3. Data-(base)
4. **Inspection**
5. Management
6. Closure and Outlook
Equipment

Ralph Holst
09./10.10.2012
<table>
<thead>
<tr>
<th>Assessment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>The defect/damage has <strong>no effect on the structural stability</strong> of the structural element/structure.</td>
</tr>
</tbody>
</table>
| 1          | The defect/damage **negatively affects the structural stability** of the structural element; however, it has **no effect on the structural stability** of the structure.  
  With respect to the as-planned utilization, **individually occurring, small deviations** in the condition of the structural element, the quality of the construction material or the element's dimensions are **still clearly within the scope of the admissible tolerances**.  
  Repairs to be carried out within the scope of **regular maintenance**. |
| 2          | The defect/damage **negatively affects the structural stability** of the structural element; however, it has **little effect on the structural stability** of the structure.  
  The **deviations** in the condition of the structural element, the quality of the construction material or regarding the dimensions or the as-planned stresses resulting from the utilization of the structure are **still within the scope of the permissible tolerances**. In individual cases, the admissible tolerances of the structural element may be exceeded.  
  Repairs must be undertaken within the medium term. |
| 3          | The defect/damage **does affect the structural stability** of the structural element negatively. the **deviations** with respect to the condition of the structural element, the quality of the construction material or regarding the dimensions or the as-planned stresses resulting from the utilization of the structure **exceed the permissible tolerances**.  
  The required restrictions on the use are not in place or are ineffective.  
  The **damage must be repaired at short notice. Restrictions regarding utilization must be put in place immediately.** |
| 4          | **The structural stability of the structural element and the structure no longer exists.**  
  Immediate measures must be taken during the inspection of the structure. Restrictions regarding the utilization must be put into place immediately. The repair or renovation must be initiated. |
Calculation of Condition Index

Example

2 (Stability)
2 (Traffic Safety)
3 (Durability)

1 = \diamond 0,1 (Extension of damage)
2 = \diamond 0,1 (Number of damage)
3 = \diamond 0,1 (Number of damaged structural components)
<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
</table>
| 1.0-1.4 | Very good structural condition  
The structural stability, traffic safety and durability of the structure are given. Continuous maintenance is required. |
| 1.5-1.9 | Good structural condition  
The structural stability and traffic safety and durability of the structure are given  
In the long term, the durability of the structure may be negatively affected to a small degree. Continuous maintenance is required. |
| 2.0-2.4 | Satisfactory structural condition  
It is possible that, in the long term, the durability of the structure may be negatively affected. An expansion of the damage or consequential damages which, in the long term, would lead to considerable deterioration of the structural stability and/or traffic safety and increased wear and tear.  
Continuous maintenance is required.  
Maintenance is required in the medium term.  
Measures to eliminate the damage or warning signs to maintain traffic safety might be necessary at the short notice. |
| 2.5-2.9 | Unsatisfactory structural condition  
The structural stability of the structure is given.  
Traffic safety might be negatively affected.  
The durability of the structure may be negatively affected quite a bit. An expansion of the damage or consequential damages which, in the medium term, would lead to considerable deterioration of the structural stability and/or traffic safety and increased wear and tear is to be expected.  
Continuous maintenance is required.  
Maintenance at short notice is required.  
Measures to eliminate the damage or warning signs to maintain traffic safety might be necessary at short notice. |
## Condition Index

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
</table>
| 1.0-1.4 | Very good structural condition  
The structural stability, traffic safety and durability of the structure are given. Continuous maintenance is required. |
| 1.5-1.9 | Good structural condition  
The structural stability and traffic safety and durability of the structure are given  
In the long term, the durability of the structure may be negatively affected to a small degree. Continuous maintenance is required. |
| 2.0-2.4 | Satisfactory structural condition  
It is possible that, in the long term, the durability of the structure may be negatively affected. An expansion of the damage or consequential damages which, in the long term, would lead to considerable deterioration of the structural condition is required.  
Continuous maintenance is required.  
Measure to eliminate the damage or warning signs to maintain traffic safety.
| 2.5-2.9 | Unsatisfactory structural condition  
The structural stability of the structure is considered to be inadequate.  
Traffic safety might be negatively affected.  
The durability of the structure may be negatively affected. Consequential damages which, in the short term, may lead to the fact that structural stability and traffic safety are no longer given.  
Continuous maintenance is required.  
Maintenance at short notice is required.  
Measure to eliminate the damage or warning signs to maintain traffic safety.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
</table>
| 3.0-3.4 | Critical structural condition  
The structural stability and/or traffic safety of the structure are negatively affected.  
Possibly, durability of the structure is no longer given. An expansion of the damage or consequential damages may, in the short term, lead to the fact that structural stability and traffic safety are no longer given.  
Continuous maintenance is required.  
Immediate repairs are required.  
Measures to eliminate the damage or warning signs to maintain traffic safety or restrictions in its use might be required as soon as possible. |
| 3.5-4.0 | Inadequate structural condition  
The structural stability and/or traffic safety are negatively affected quite a bit or is no longer given.  
Possibly, durability of the structure is no longer given. An expansion of the damage or consequential damages may, in the short term, lead to the fact that structural stability and traffic safety are no longer given and that it will result in an irreparable deterioration of the structure.  
Continuous maintenance is required.  
Immediate repairs or renovations are required.  
Measures to eliminate the damage or warning signs to maintain traffic safety or restrictions in its use might be required immediately. |
4 Recalculation Levels
- Level 1: German „Fachbericht“ or DIN EN 1992 – 1994, 1996,
- Level 2: supplementary regulations,
- Level 3: Results from measurements (e.g. Monitoring)
- Level 4: scientific methods (reliability based Methods)

Goal:
- realistic Assessment of Bridge Condition (structural stability and usability)
1. Organisation of Maintenance
2. Statistics
3. Data-(base)
4. Inspection
5. Management
6. Closure and Outlook
Important Topics for a BMS (BRIME (BRIdge Management in Europe (1998-99))

- condition appraisal (DIN 1076),
- assessment of load carrying capacity (Guideline for Recalculation)
- rate of deterioration (RI-EBW-PRÜF),
- structural assessment of deteriorated structures
- deciding maintenance strategies and methods (Federal Ministry and State Administrations)
- prioritizing maintenance work (Federal Ministry and State Administrations)
regular Bridge Inspection

Guideline for Recalculation

BMS-MB; BMS-EP
Principles of maintenance planning

- Ensuring the safety and ease of traffic,
- Minimize traffic-interference,
- combination of actions (BMS, PMS, Asset Management)
- Results of Recalculation (structural weaknesses: securing off remaining service life)
- Prioritization:
  - Condition,
  - Importance of Highway/ of the structure in the network,
  - Reconstruction of Highways,
  - Requirements from PMS,
  - Political requirements,
Systematic Maintenance Planning

- Objectives
  - Long-term Prognosis, Budget

- Inventory
- Inscription
  - Condition Assessment

- Maintenance Strategies
- Damage Evaluation and -prognosis

- Prioritisation
  - Financial Requirements

- Documentation
- Program Creation

- Implementation of Projects

- Controlling
BMS – State Level

- inspection
  condition assessment

- maintenance alternatives
  costs, prognosis

- valuation on
  network level

- combination of BMS and PMS

- object related
  damage analysis

- effect on user and
  environment

- valuation on
  object level

- valuation of
  strategies

SIB-Bauwerke → BMS-MV

BMS-EP → BMS-MV

BMS-MV

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Generation of strategies

- Bridge-Data (construction, damages)
- catalogues (Measures, Costs, ...)
- Deterioration models
- Rules for Handling (e.g. combining of measures)
### Catalogue of Measures

<table>
<thead>
<tr>
<th>Bauwerksart, Hauptbauteil, Konstruktionssteil, Bauteilergänzung oder Hauptbaustoff, Schaden</th>
<th>Einheit des max Instandsetzungsumfangs</th>
<th>Verhaltensmodell (Fest maßgebende (Standard))</th>
<th>Maßnahme 1</th>
<th>Einheit der Maßnahme</th>
<th>Rücksetzung</th>
<th>Maßnahme 2</th>
<th>Einheit der Maßnahme</th>
<th>Rücksetzung</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRUCKEN, UBERBAU, ..., -- (weitere BSP durch Angabe des Baustoffs, Schadens) durchgehen (Bewertung abhängig vom Grad der Durchbiegung)</td>
<td>OSA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRUCKEN, UBERBAU, ..., BETON außer Betondeckung, --</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abplatzungen im oberflächennahen Bereich mit oder ohne frakt. Bewehrung, D = 1-2</td>
<td>m² (Instandsläche) Überbau unten</td>
<td>FTB, AKR, Ka, Cl</td>
<td>0</td>
<td>0</td>
<td>Zementmörtel mit Kunststoffzusatz (POC II)</td>
<td>m² Instandsläche</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Abplatzungen wie vor, aber über Verkehrsraum, V = 1-3, D = 1-2</td>
<td>m² (Instandsläche) Überbau unten</td>
<td>FTB, AKR, Ka, Cl</td>
<td>0</td>
<td>0</td>
<td>Zementmörtel mit Kunststoffzusatz (POC II)</td>
<td>m² Instandsläche</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>freiliegende Tragbewehrung mit korroderter Bewehrung (keine nennenswerte Querschnittsminderung)</td>
<td>m² (Instandsläche) Überbau unten</td>
<td>Ko, Cl</td>
<td>1</td>
<td>0</td>
<td>Spritzbeton BII</td>
<td>m² Instandsläche</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Tragbewehrung liegt im karbonatisierten Bereich und ist korrodiert (nicht Spannbewehrung)</td>
<td>m² (Instandsläche) Überbau unten</td>
<td>Ko, Cl</td>
<td>1</td>
<td>0</td>
<td>Spritzbeton mit Kunststoffzusatz (SPCC II)</td>
<td>m² Instandsläche</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>freiliegende Tragbewehrung mit korroderter Bewehrung (einsetzende Querschnittsminderung)</td>
<td>m² (Instandsläche) Überbau unten</td>
<td>Ko, Cl</td>
<td>2</td>
<td>0</td>
<td>Zementmörtel mit Kunststoffzusatz (POC II)</td>
<td>m² Instandsläche</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>stark korrodierte Tragbewehrung (fortgeschrittene Querschnittsminderung)</td>
<td>m² (Instandsläche) Überbau unten</td>
<td>Ko, FTB, AKR</td>
<td>3</td>
<td>0</td>
<td>Zusatzbewehrung OSA</td>
<td>OSA</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>stark korrodierte Tragbewehrung (teilweiser Ausfall von Tragbewehrung)</td>
<td>m² (Instandsläche) Überbau unten</td>
<td>Ko, FTB, AKR</td>
<td>4</td>
<td>0</td>
<td>Zusatzbewehrung OSA</td>
<td>OSA</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Großeinlage Durchfeuchtung, Austrocknung, D = 2.3</td>
<td>OSA, Ka, Cl, Ko</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRUCKEN, UBERBAU, ..., BETON, --</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Betondeckung der Tragbewehrung &gt; 30 mm, schlechte Betonqualität</td>
<td>m² (Instandsläche) überbau unten</td>
<td>Ka, Cl</td>
<td>0</td>
<td>0</td>
<td>Hydroprodukt OSA-A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Betondeckung der Tragbewehrung &gt; 15 mm, schlechte Betonqualität</td>
<td>m² (Instandsläche) überbau unten</td>
<td>Ka, Cl</td>
<td>0</td>
<td>0</td>
<td>Hydroprodukt OSA-A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Betondeckung der Tragbewehrung &gt; 15 mm, schlechte Betonqualität</td>
<td>m² (Instandsläche) überbau unten</td>
<td>Ka, Cl</td>
<td>0</td>
<td>0</td>
<td>Hydroprodukt OSA-A</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- maintenance alternatives
- object related strategies
- traffic safety measures
- owner costs
Future behaviour

- Lifetime models (structural elements, linear, deterministic approach)
- Deterioration models (chloride, carbonation, corrosion; deterministic approach)
- Consequence of maintenance
- Intervention interval (warning-/threshold v.)
Macroeconomic Evaluation on Object level

- (direct) Owner costs
- Costs because of hindrance (road works)
- Costs because of bottleneck effect
- Costs because of alternative routing
- Costs because of speed limit
Analysis on Object Level

Wanted:
Optimised maintenance program
(budget, other constraints)

• Rating of alternatives for every object (network-wide)
• Maintenance program without restrictions

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Goal for maintenance:
Optimal condition level
minimal User costs

Restriction:
Given Budget

Goal for maintenance:
minimal (direct) costs
minimal User costs

Restriction:
Given condition level

Financial scenario

Quality scenario
Condition Index of Bridge

Maintenance in Year 1

Condition Index of Bridge Parts

Condition Index Class
Development of a BMS

1. Organisation of Maintenance
2. Statistics
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4. Inspection
5. Management
6. Closure and Outlook

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39
- Need for systematic maintenance is rising steadily,
  - the information of the regular bridge inspection and additional investigations are the most important basis,
    - Data quality,
    - Data availability,
  - A management system for optimization of financial resources with consideration of intervention in the traffic and technical possibilities is necessary,
    - Direct costs,
    - User costs,
  - Selective use of sensors / sensor networks for better/earlier information about bridge condition,
  - Extension to probabilistic approaches for the future (bridge inspection an management),
Thank you very much for your attention!