56° Congresso Brasileiro do Concreto

Management of aging Infrastructure
Challenges for Owners and Operators

Jürgen Krieger, Federal Highway Research Institute (BASt), Bergisch Gladbach, Germany

Outline

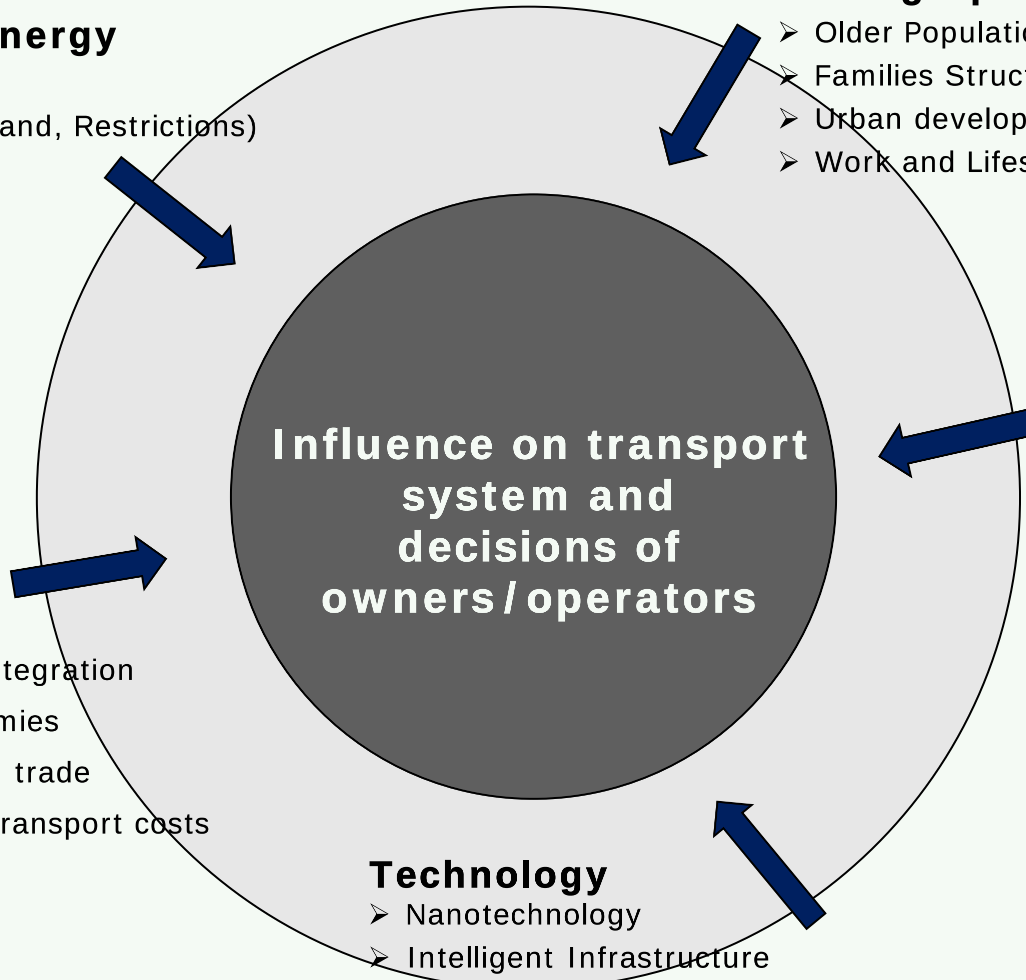
- Introduction
- Challenges
- Management
  - Inventory
  - Inspection
  - Load bearing capacity
  - Management System
- Extreme Weather
- Large Accidents and Explosions
- Innovation
- Summary and Conclusions

Reliable Road Infrastructure is a necessary Condition for **sustainable Mobility** and contributes to **economic Growth** and **Quality of Life**.

Transport System

Environment and Energy
- Sustainability
- Natural Resources (Demand, Restrictions)
- Climate Change
- Alternative fuels
- Loss of biodiversity

Demographics and social factors
- Older Population
- Families Structures
- Urban developments (Mega-Cities)
- Work and Lifestyle



Government/Politics
- Changes in Governance
- Financing Mechanisms
- Privatization
- Terrorism
- Regulations (national, EU)

Economics
- Increasing economic integration
- Emerging Asian economies
- Dependence on foreign trade
- Sustained increase in transport costs

Technology
- Nanotechnology
- Intelligent Infrastructure
- Advances in IT Technologies
- Medical Advances

Germany - Changes in Traffic Demand

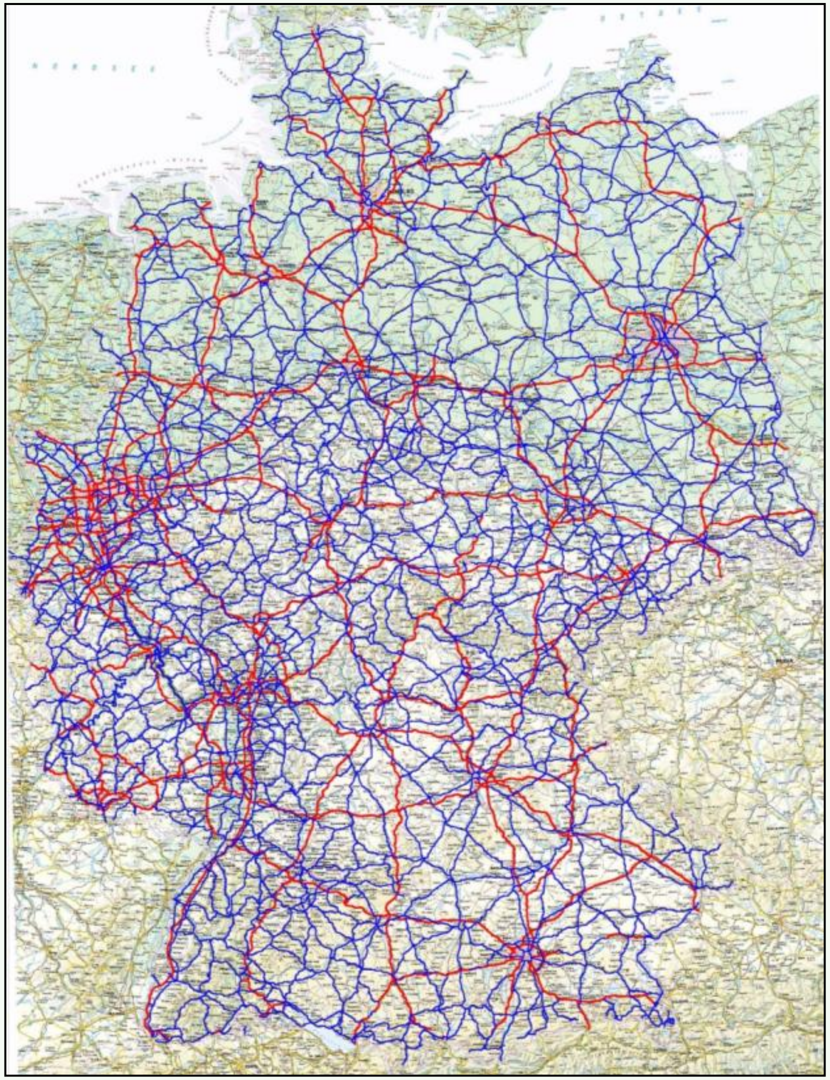
1950

1975

1985 until today

- Traffic increase
- Changing requirements for road infrastructure

Federal Roads in Germany



Roads:	**644.358 km**
Freeways:	**12.531 km**
Highways:	**40.711 km**

Federal Roads	
Bridges:	**40.000**
Tunnels:	**240**

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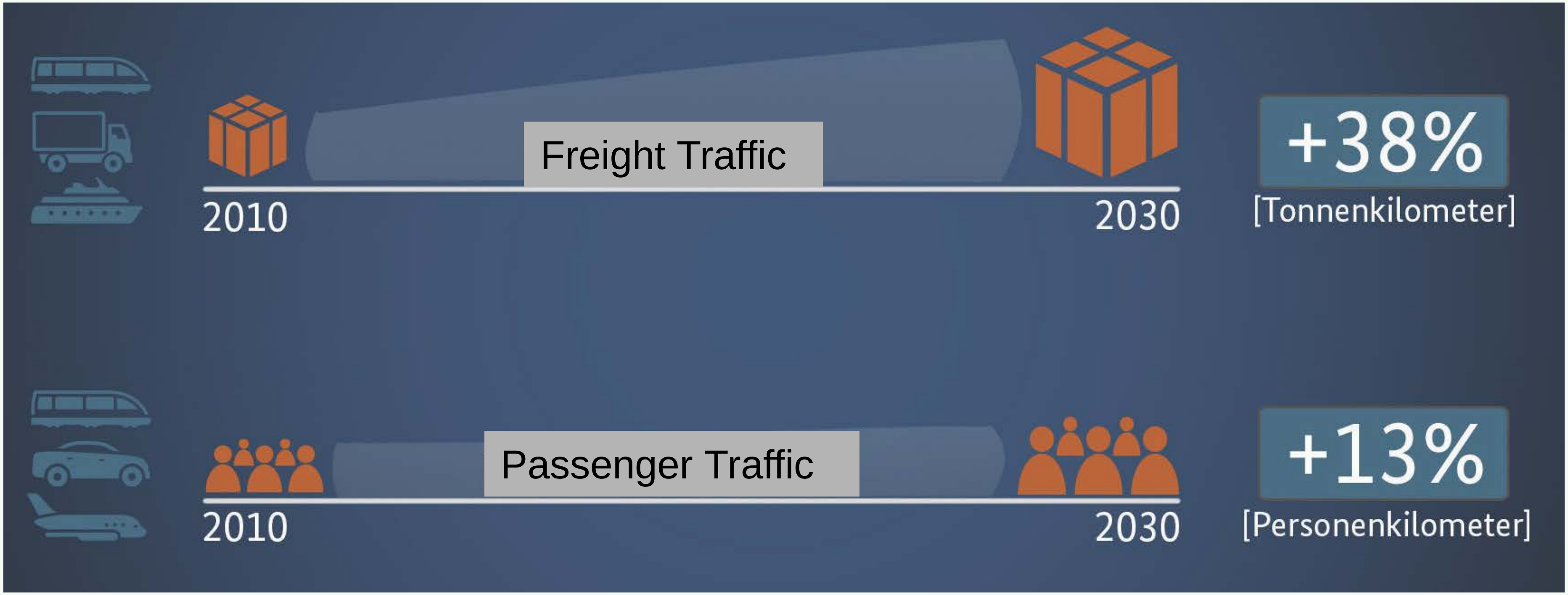
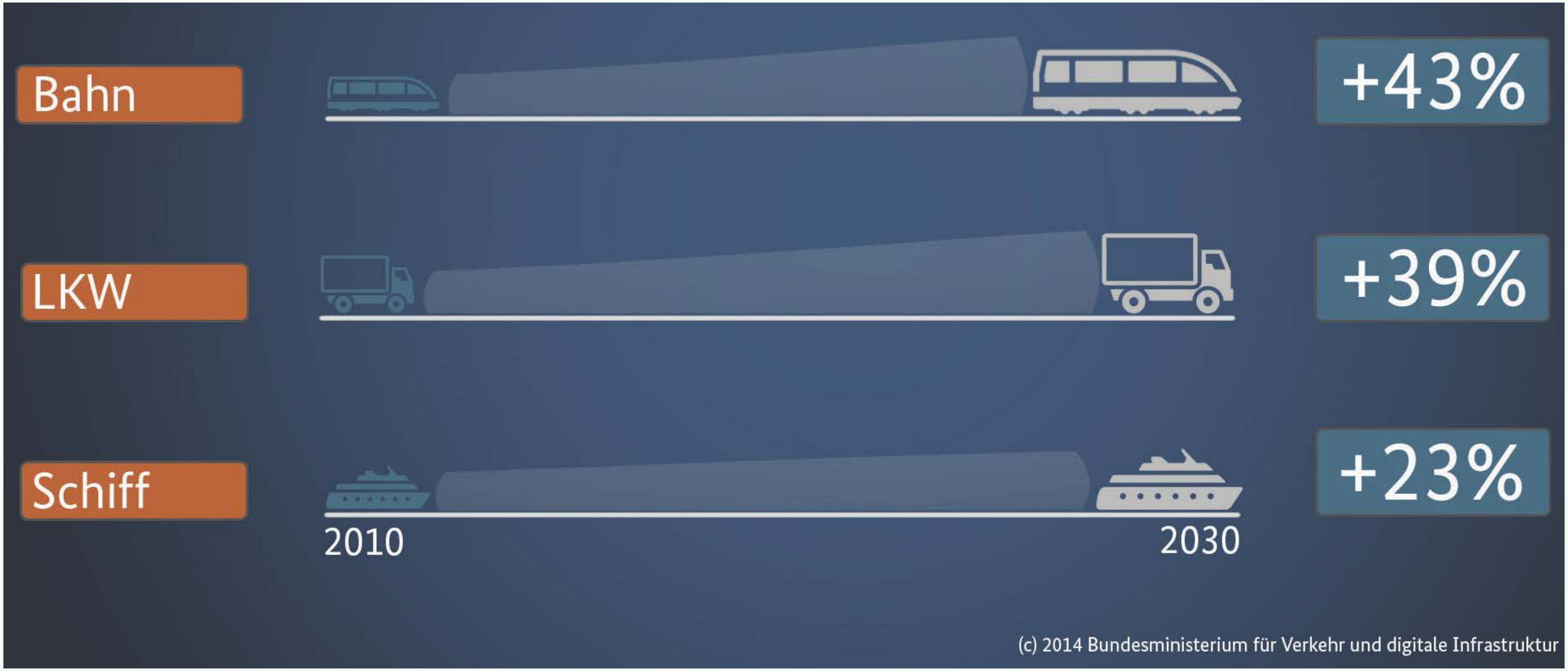
Traffic Prognosis for Germany



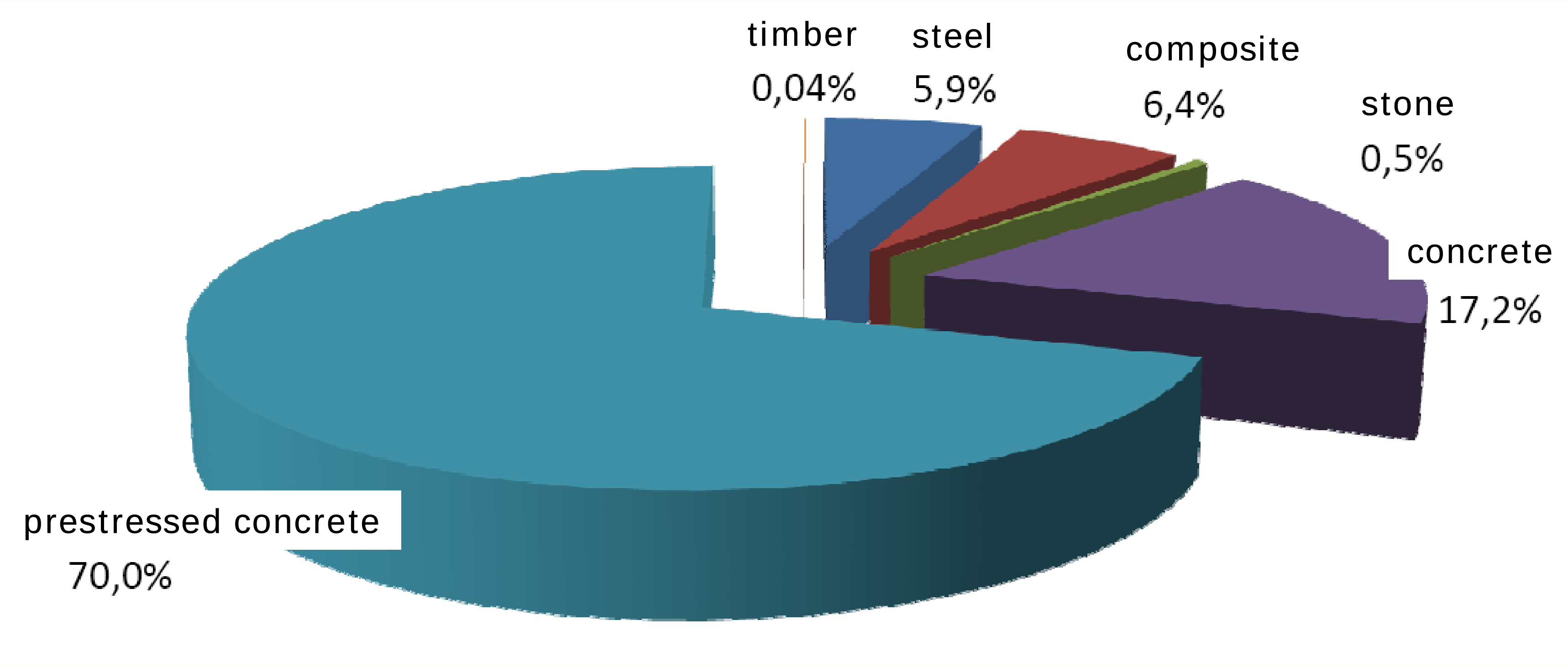
Quelle: www.bmvi.de

Germany - Traffic Prognosis 2030 (Freight Traffic)

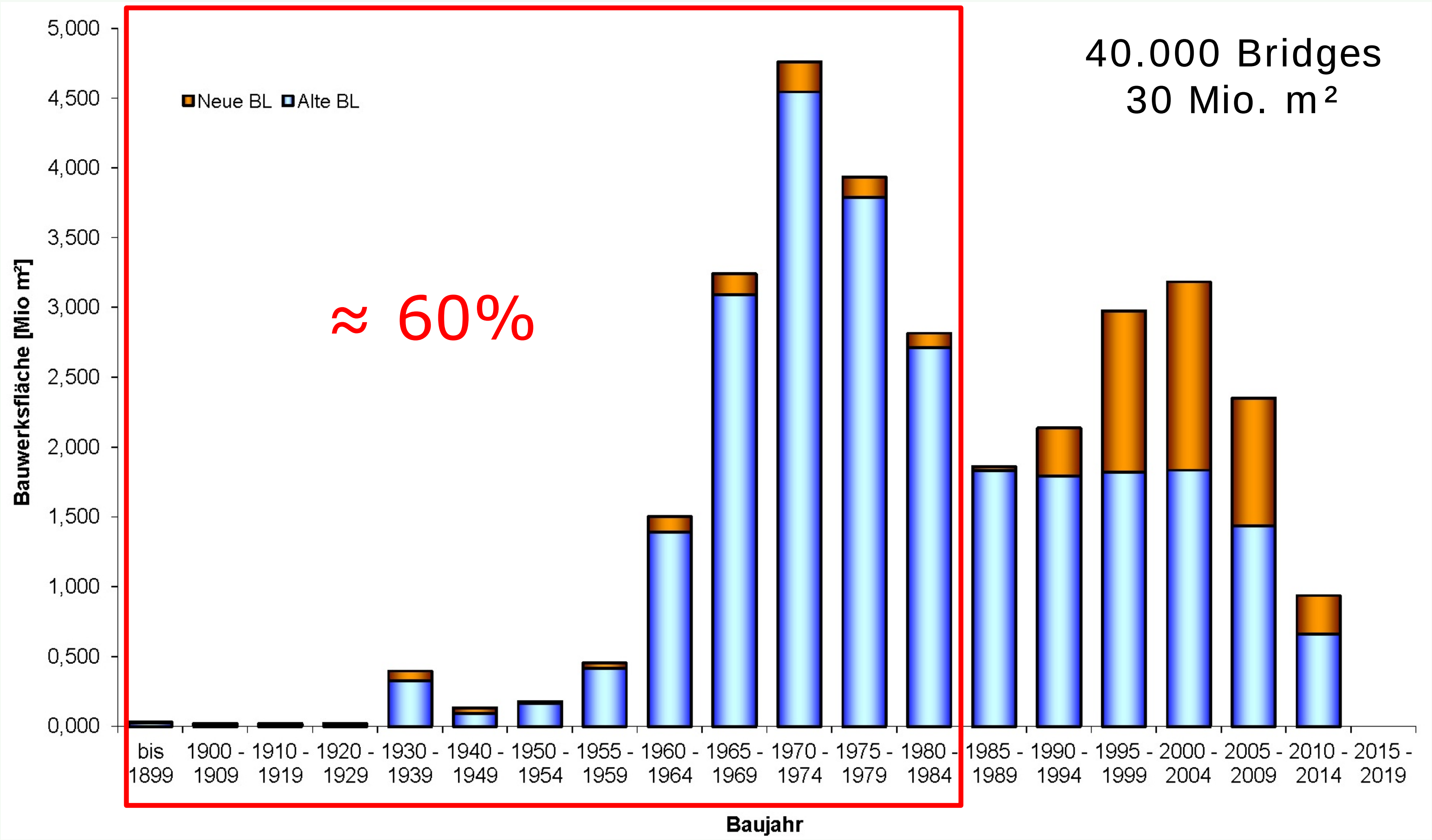


Quelle: www.bmvi.de

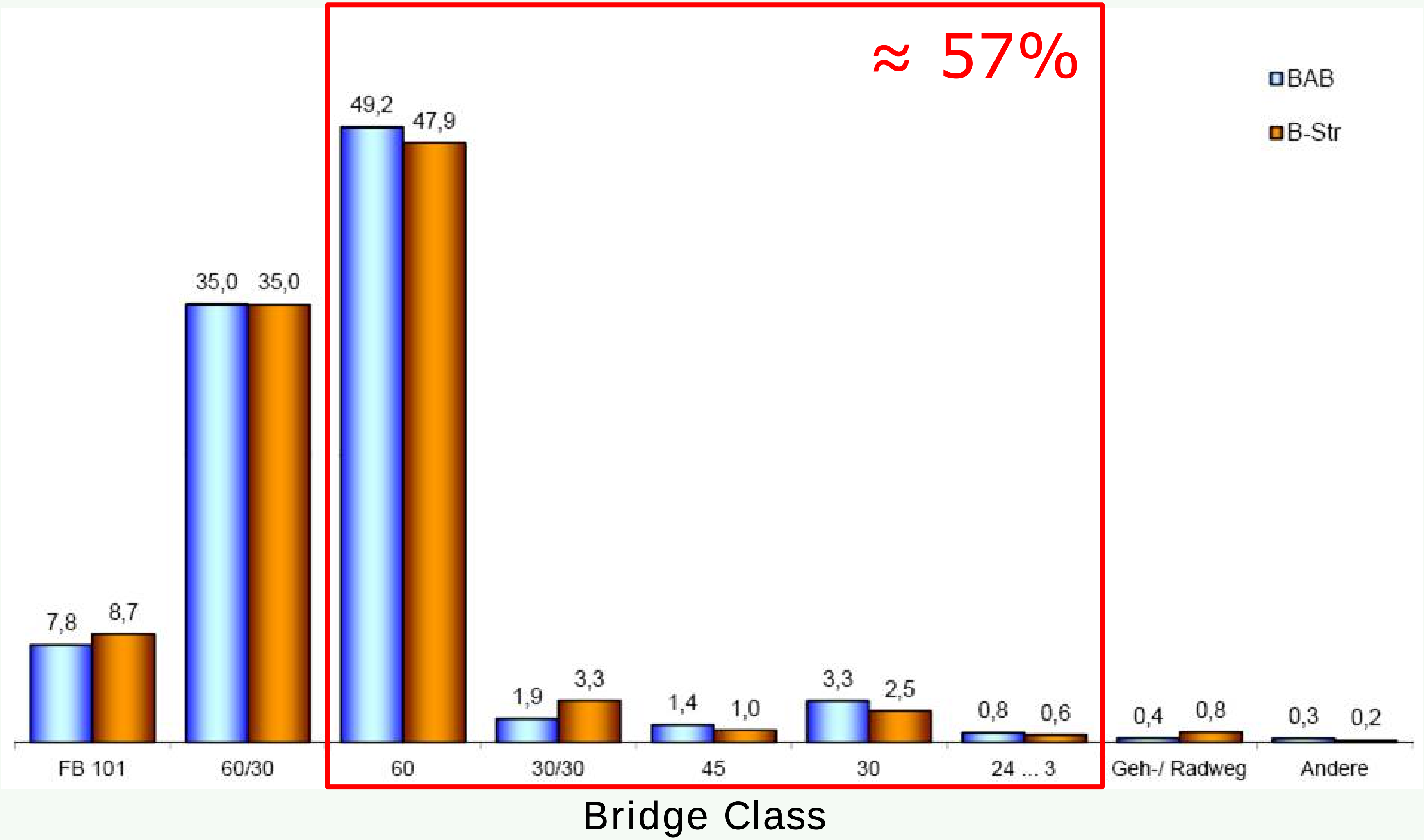
Bridges on Federal Roads



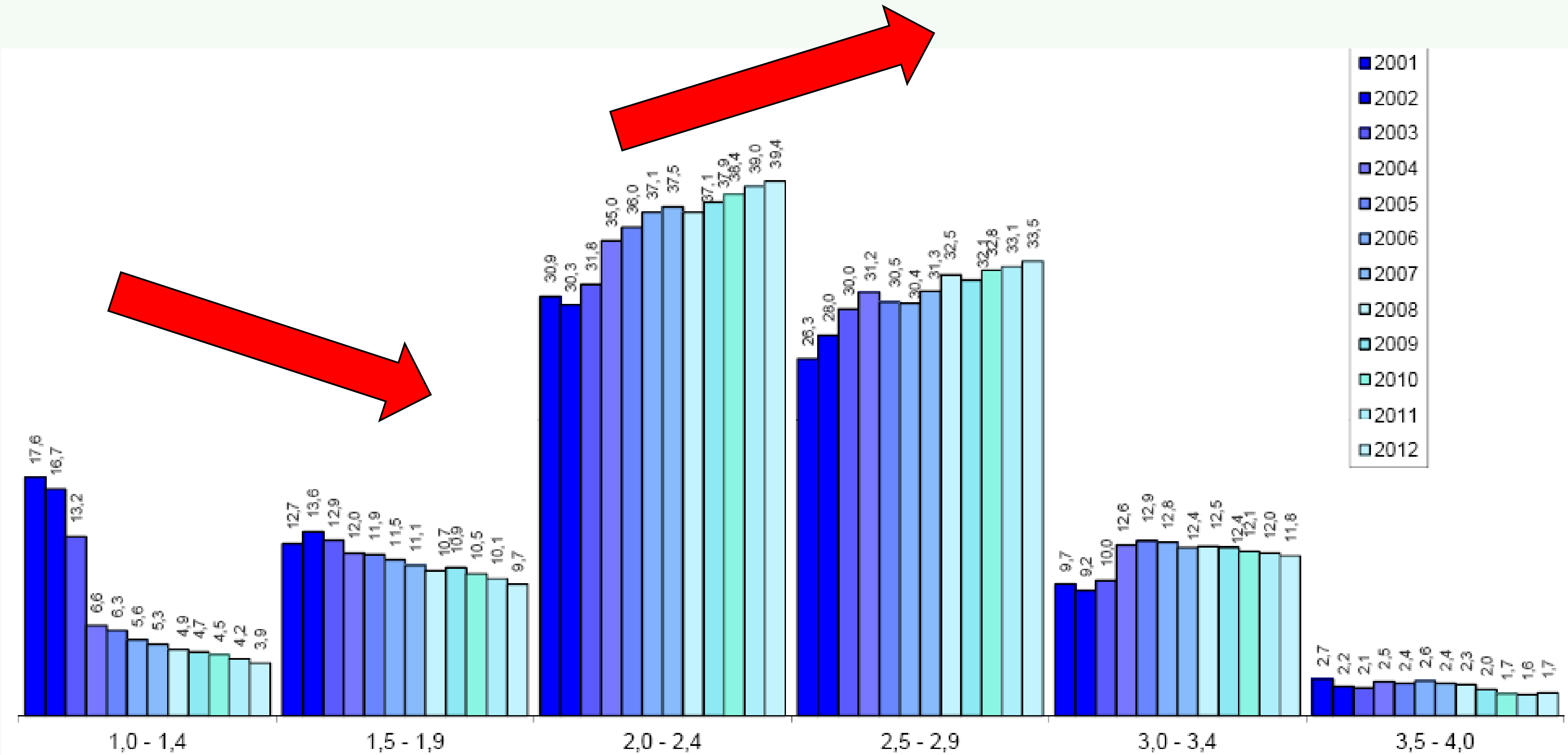
Bridges on Federal Roads – Age Distribution



Bridges on Federal Roads – Bridges Classes

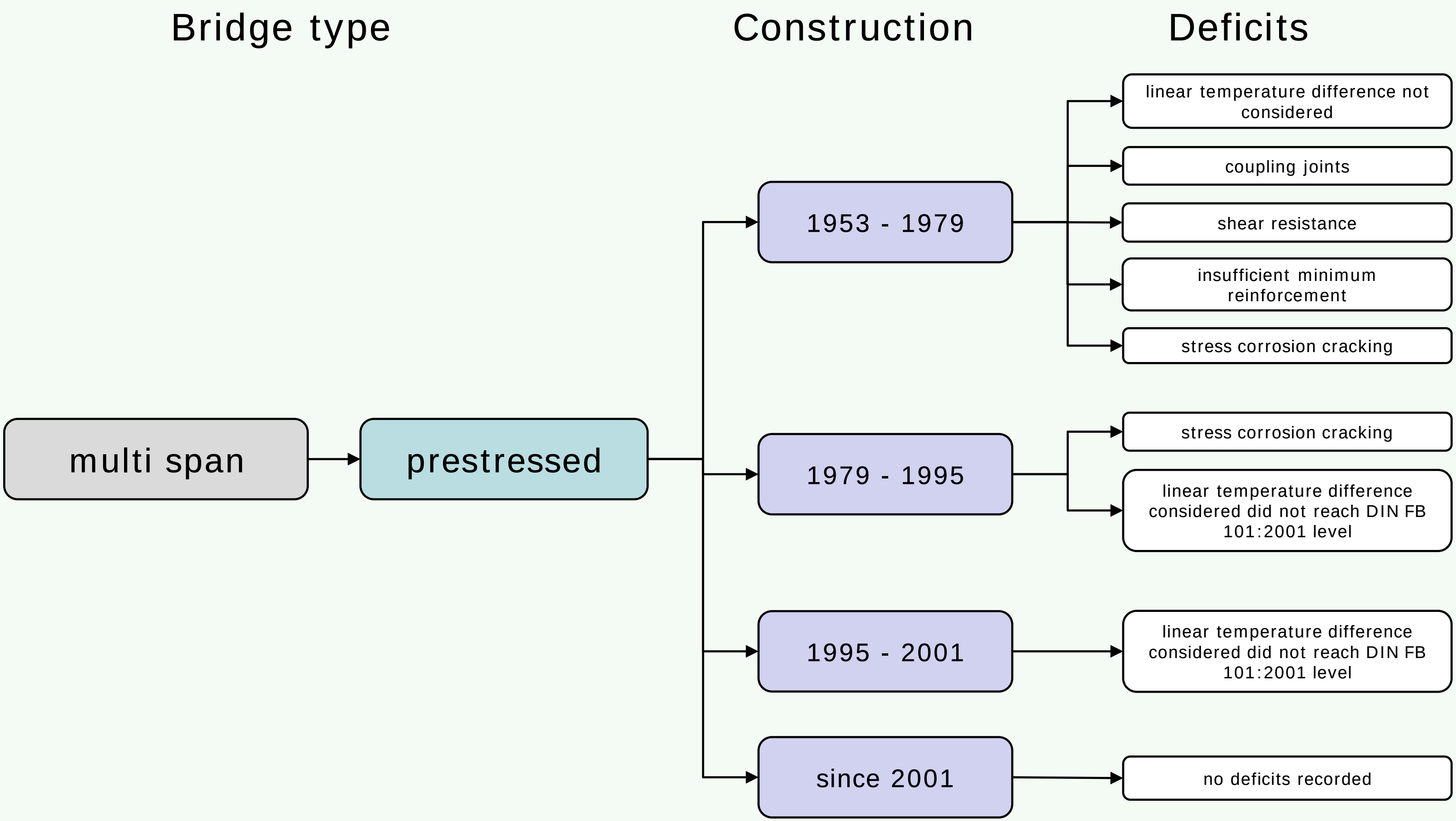


Bridges on Federal Roads – Condition Rating



Condition rating (Bridge inspection DIN 1076)

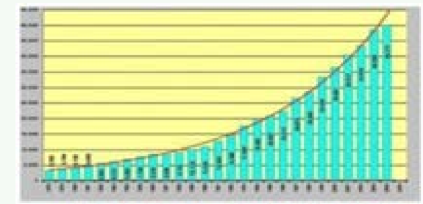
Possible Deficits of Bridges

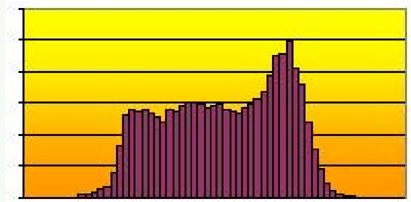


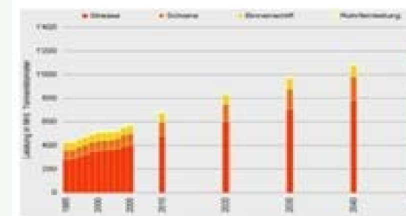
Sachstand Verstärkungsverfahren – Verstärken von Betonbrücken im Bestand, Bericht der Bundesanstalt für Straßenwesen, Heft B 75

Challenges for Owners and Operators

- Traffic demand – traffic prognosis
- Load bearing capacity and condition
- Maintenance under traffic
- Limited resources
- Extreme weather (Climate Change)
- Large accidents, criminal and/or terrorist activities







Owners and Operators have to make sure that their assets are available, durable, secure and safe!

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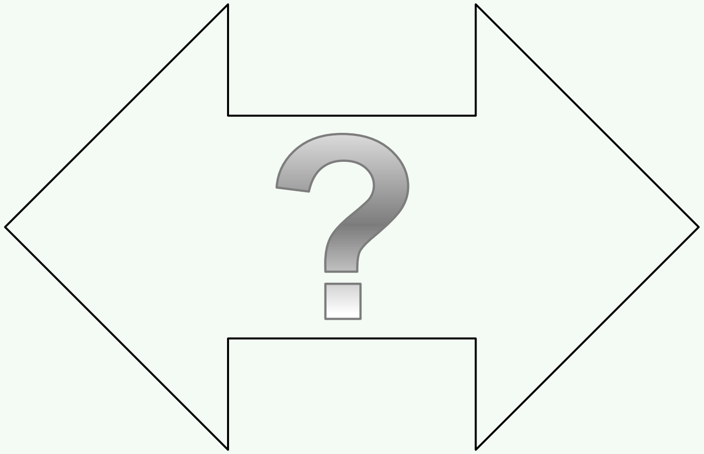
Management of (aging) Infrastructure

Budget



Infrastructure

Management of (aging) Infrastructure

Budget

Why?

How much?

When?

Where?

Infrastructure

Management of (aging) Infrastructure

Budget

Scenarios:

What if?

How much if?

Infrastructure

Management of (aging) Infrastructure

Budget

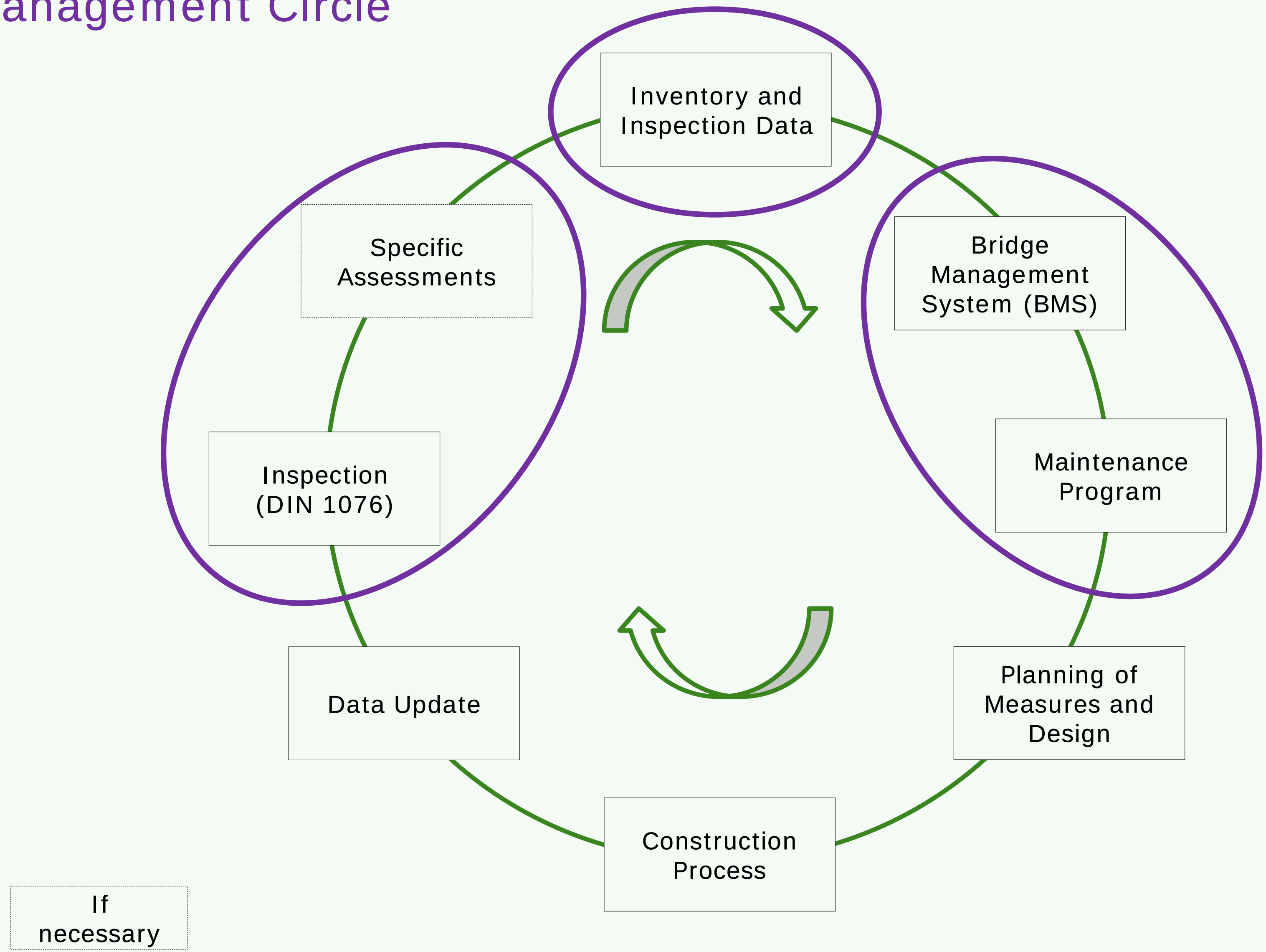
Decision Support

Scenarios:
What if?
How much if?

Why?
When?
Where?
How much?

Infrastructure

Management Circle



Bridge Management – Standards/Guidelines

Engineering structures in the course of roads (1999)

Inspection (2013)

Recording and assessment of damages, condition assessment

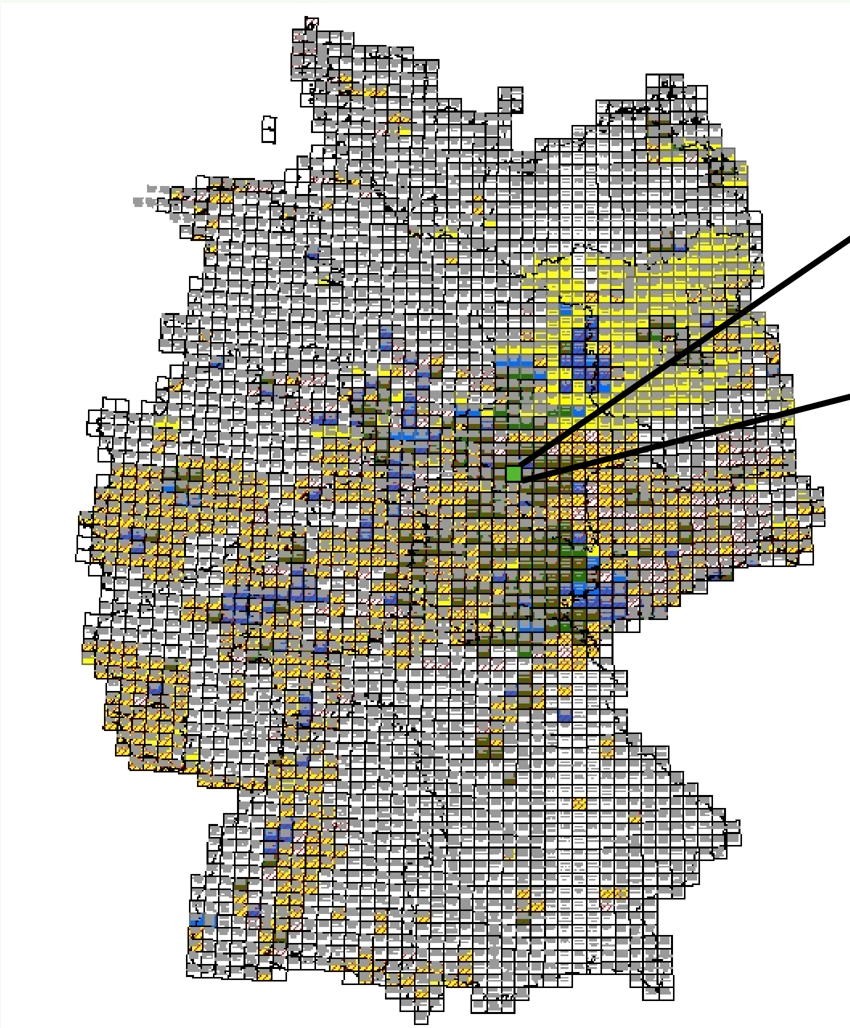
Inventory Guideline (2013)

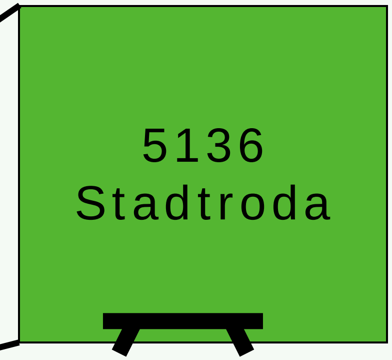
Software (2013)

Inventory and inspection

Outline

Location - unique Identifier

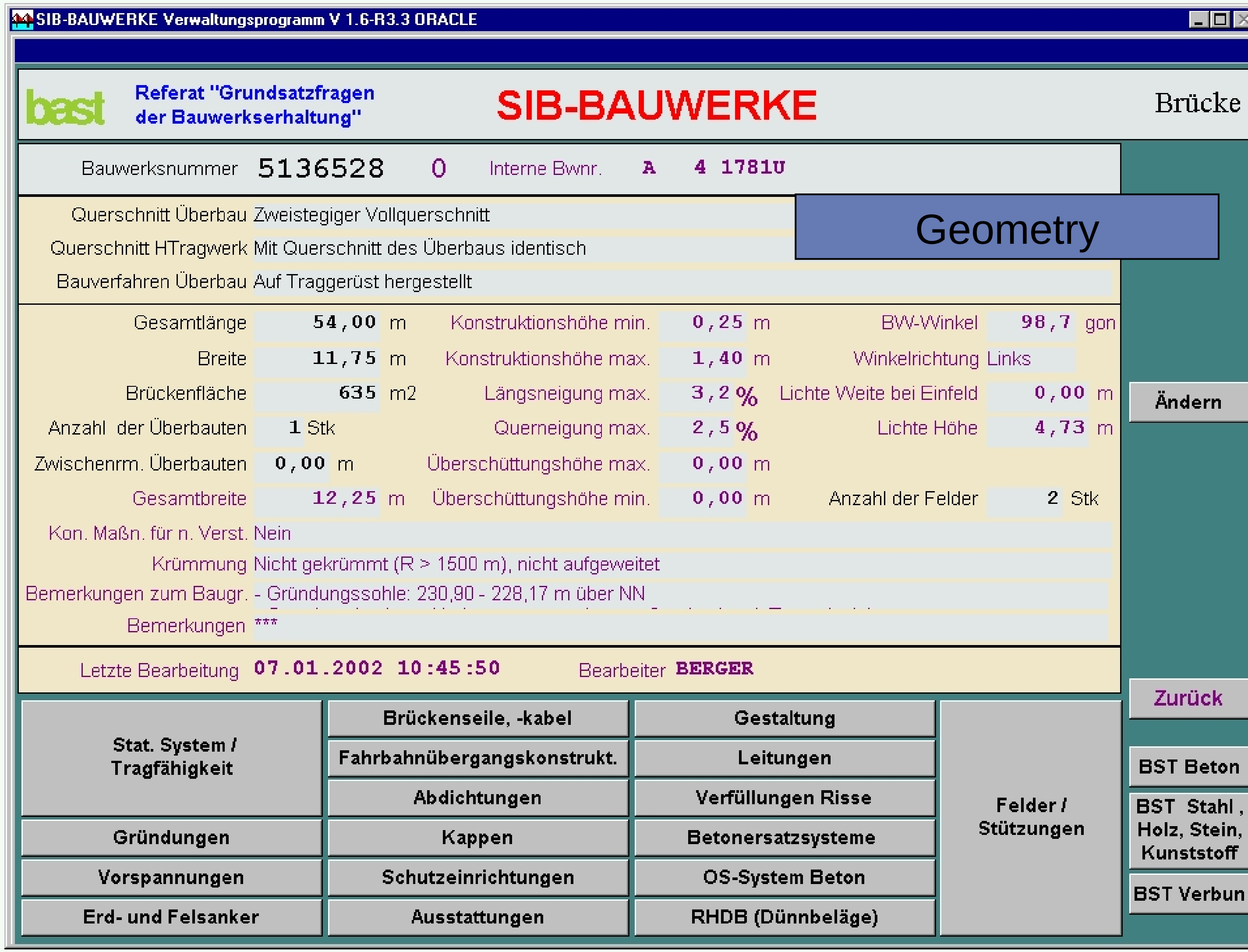




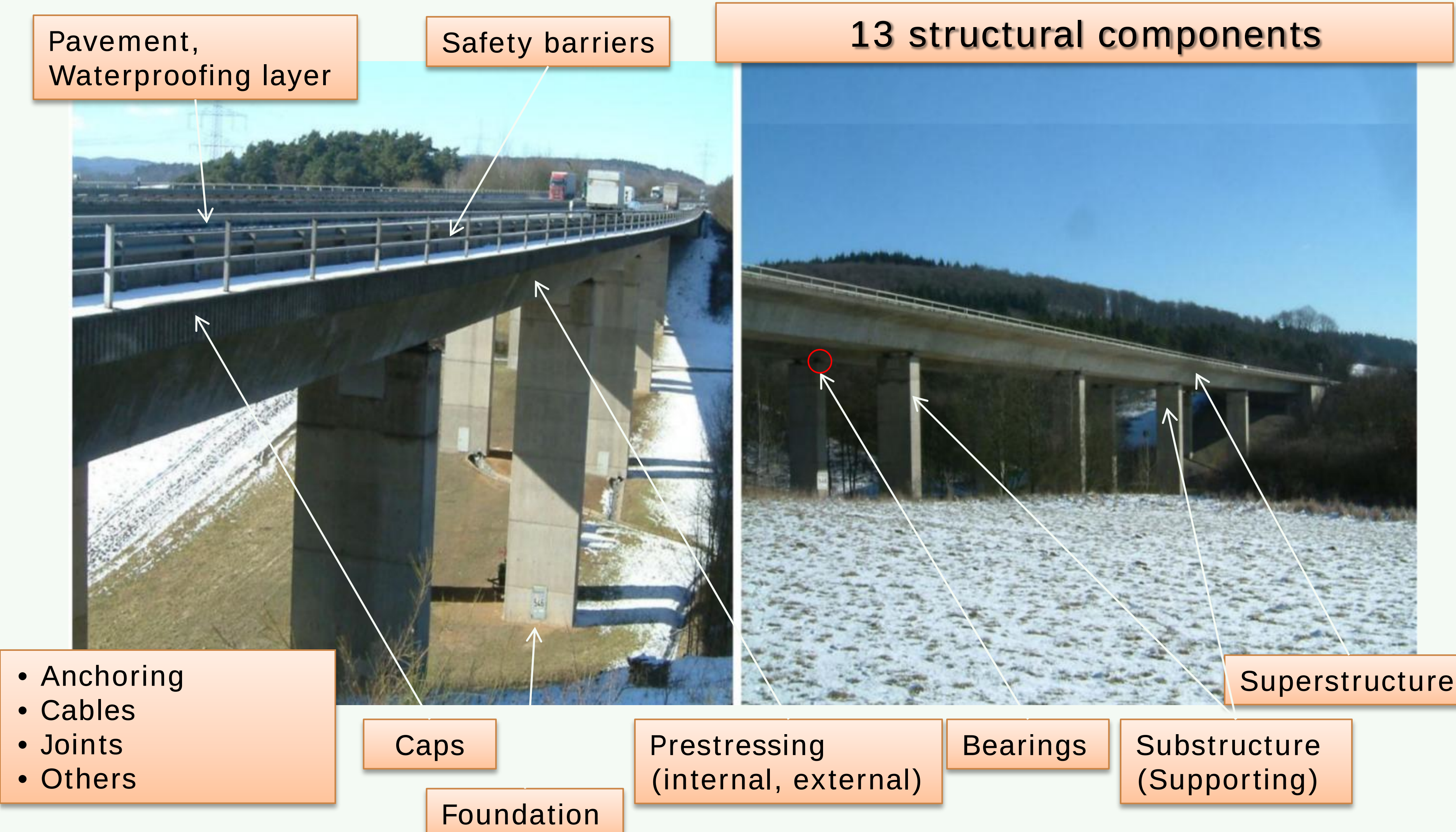
5136 528 _0

Location - unique Identifier

Bridge Inventory



Layout of Inventory Database

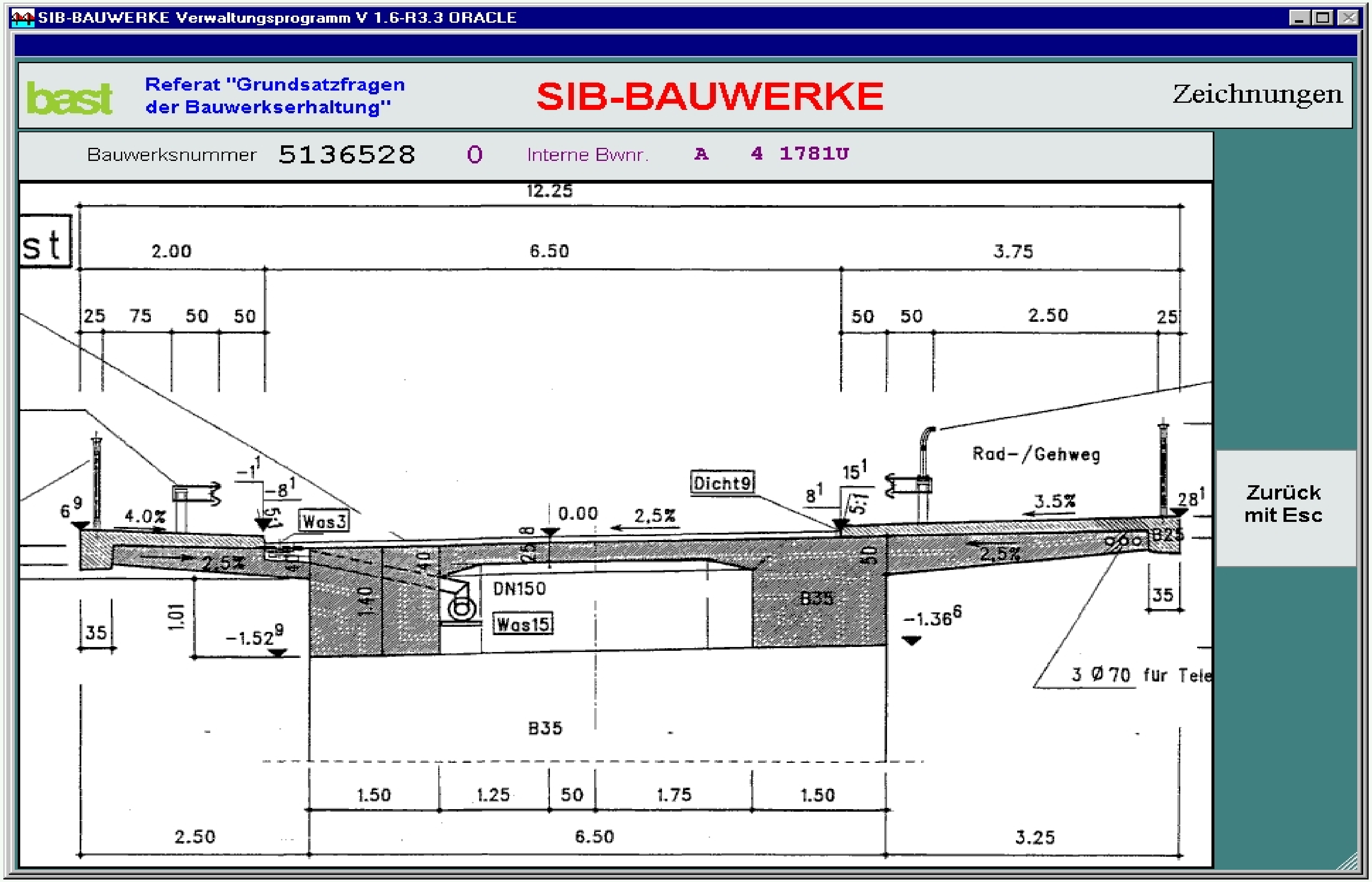


Keywords and Coding

Brücke	020071000000000
balkenartige und plattenartige Tragwerke	020071100000000
Plattenbrücke	020071110000000
Balkenbrücke / Mittelträger / Trapezplatte	020071120000000
Plattenbalken / Trägerrost	020071130000000
Hohlkastenbrücke	020071140000000
Balken/Platten-Mischsystem	020071150000000
rahmenartiges Tragwerk	020071200000000
offener Rahmen	020071210000000
geschlossener Rahmen	020071220000000
spezielle Rahmenkonstruktion	020071230000000
Trog-Haube-Konstruktion	020071231000000
Schrägstielrahmen	020071232000000
Rahmen-Mischsystem	020071240000000
bogenartiges Tragwerk / Gewölbe	020071300000000
Bogen mit aufgeständerter Fahrbahn	020071310000000
Bogen mit abgehängter Fahrbahn	020071320000000
Bogenscheiben	020071330000000
Gewölbe/Bogen	020071340000000
Gewölbe/Bogen ohne Aufbeton	020071341000000
Gewölbe/Bogen mit Aufbeton im Verbund	020071342000000
Gewölbe/Bogen mit Aufbeton ohne Verbund	020071343000000
Gewölbe/Bogen mit Lastverteilungsplatte	020071344000000
Rohr ohne Ummantelung	020071345000000
Rohr mit Ummantelung	020071346000000
Bogenmischsystem	020071350000000

Bridge
Beam- / Slab Structure
Slab bridge
Beam bridge
Rib slab bridge
Box girder bridge
Frame structure
open Frame
closed Frame
special Frame structure
...
...

Photos and Drawings



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Bridge Inspection – DIN 1076

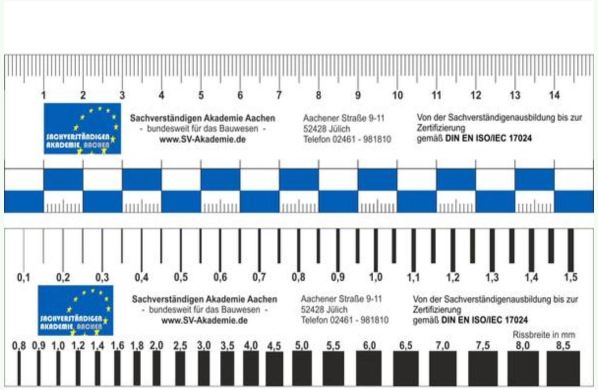
Visual Inspection

Bridge Inspection – DIN 1076

- **Major Inspection**
  Hands on visual inspection of all parts of a structure by engineers, every 6 years. Damage and condition assessment according to RI-EBW-PRÜF. First major inspection before the structure is opened to traffic, second major inspection before the end of the guarantee period
- **Minor Inspection**
  Hands on visual inspection by engineers every 3 years after major inspection, verification of major inspection results
- **Ad-hoc Inspection**
  Engineers obtain in-depth view of particular damages or deterioration process (accidents, flooding, ...)
- **Inspection in accordance with regulatory requirements**
  Machinery and electrical equipment forming part of highway structures, especially moveable viewing facilities and gantries, are inspected with other regulations and standards.
- **Superficial inspection**
  Maintenance personal, no special knowledge on highway structures, detection of major visible faults, checking the functionality quarterly basis (visual), annual inspection (all accessible parts)
- **Routine Monitoring**
  Ongoing observation of all highway structures with respect to their **safety** as part of the superficial inspection of the highway

Inspection Equipment

Optical Measurement



Crack width measurement

Tape measure

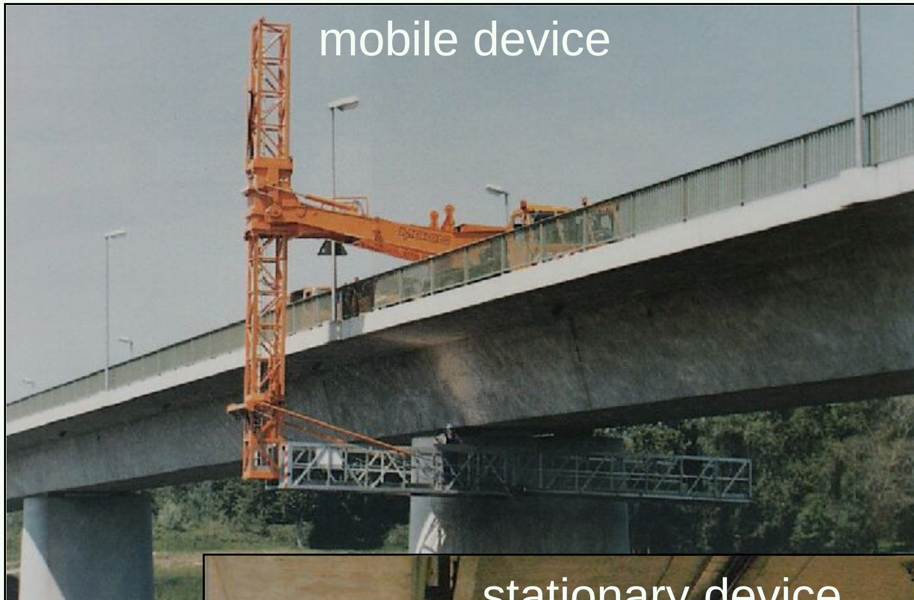
Crack width measurement

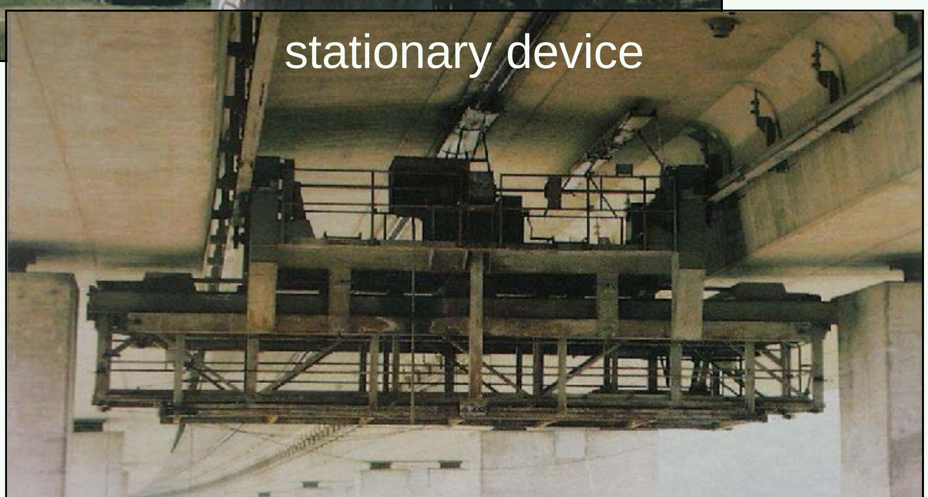
Concrete cover measurement

Schmidt-Hammer

Crayons

Inspection


mobile device


stationary device


inspection ship

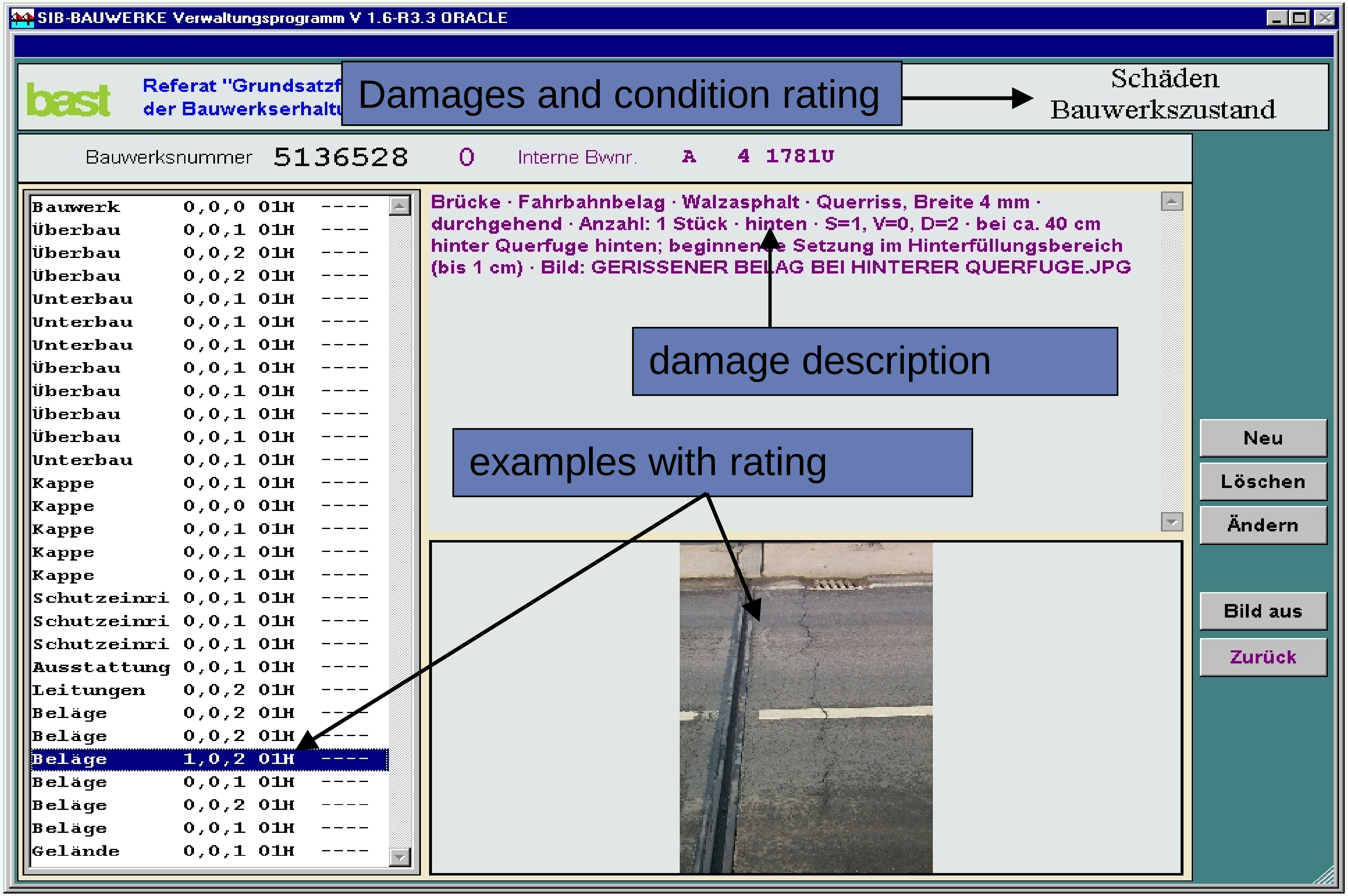

bridge cables

Inspection

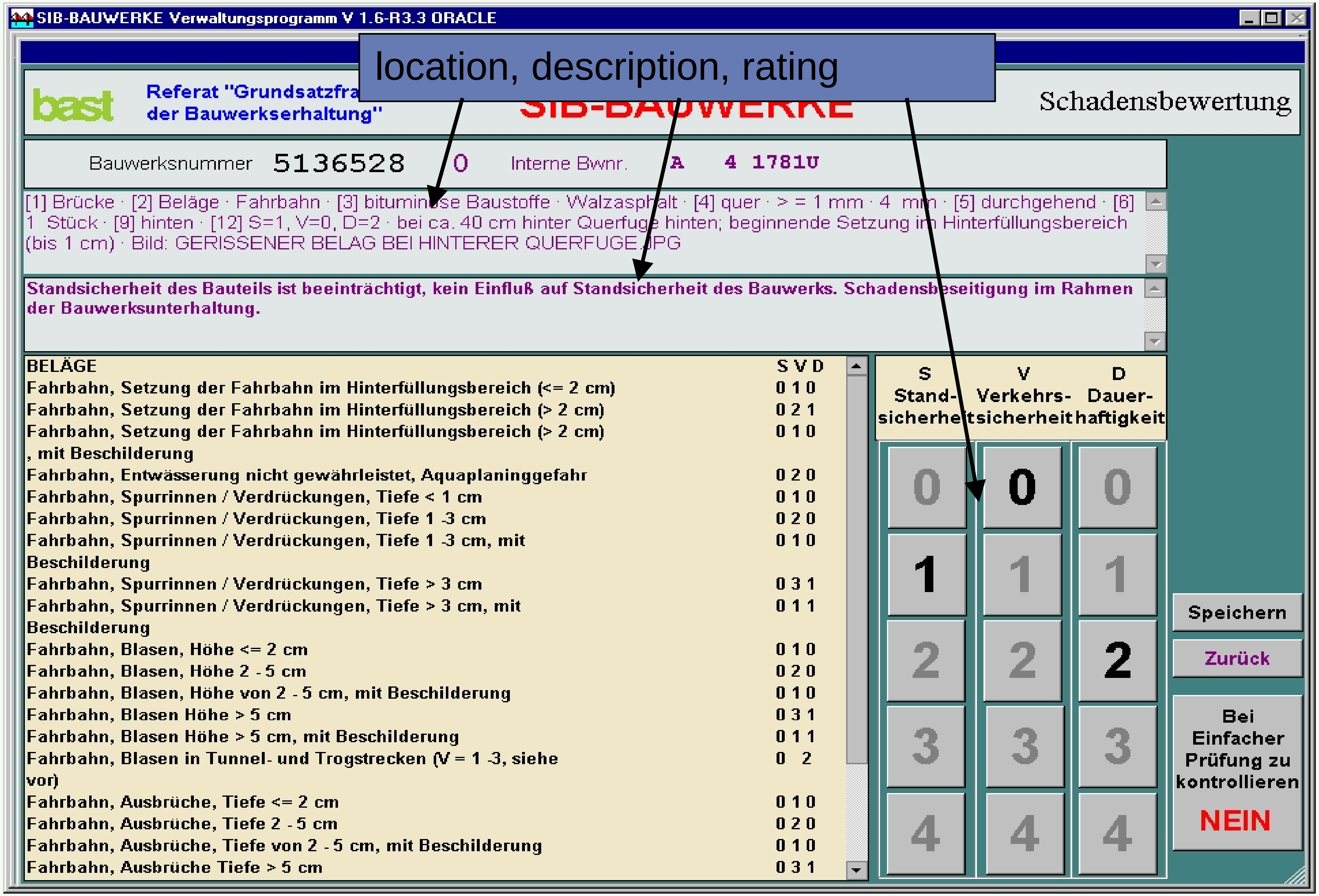
Inspection

Inspection

Rating of Damages



Rating of Damages



Damage Assessment – Stability

Damage Assessment "Structural Stability"	
Assessment	Description
0	The defect/damage has **no effect on the structural stability** of the structural element/structure.
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.**

Examples for Damages

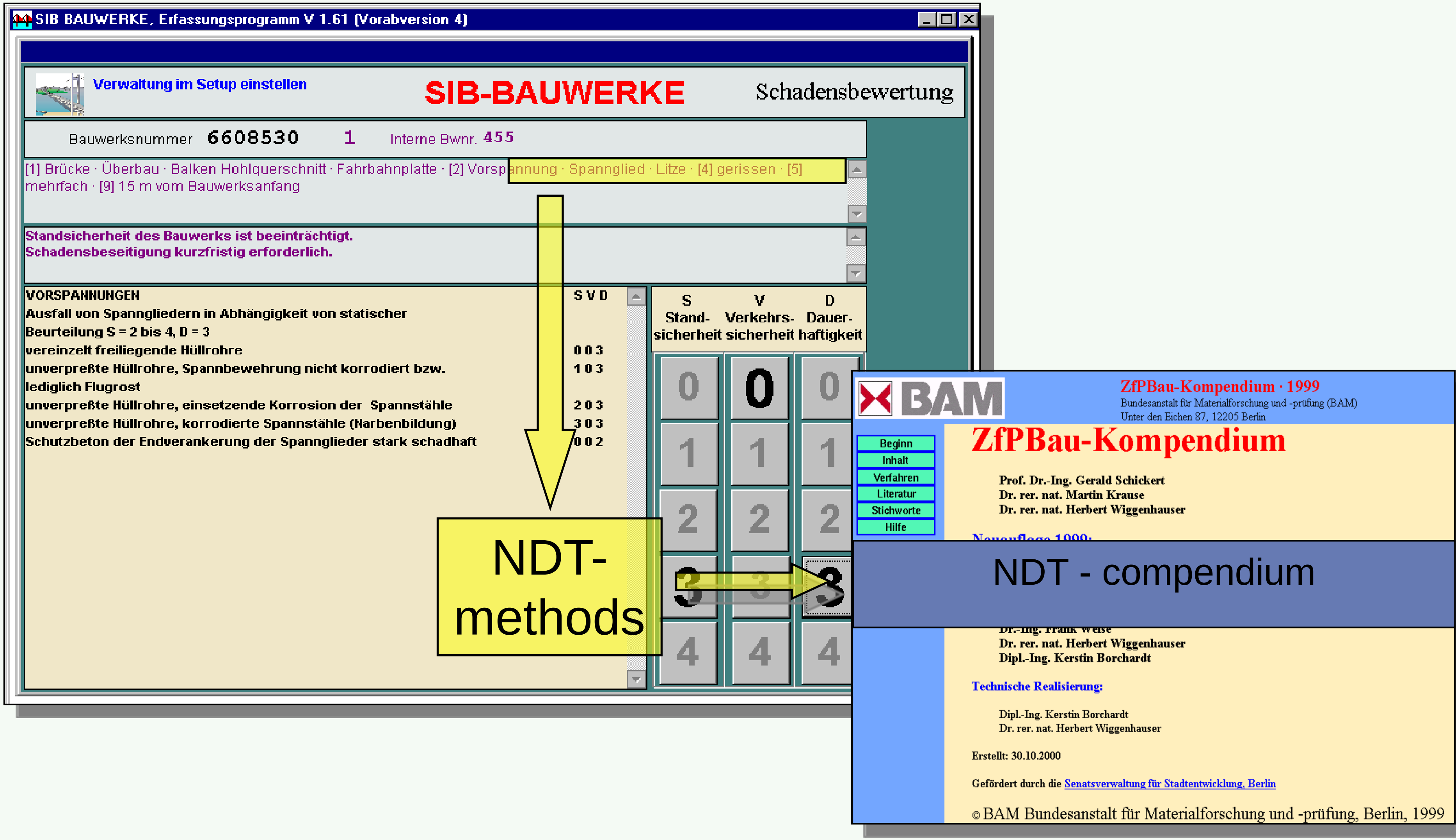
Steel corrosion of the bridge cap (deicing salt, sea water environment)

Corrosion due to less concrete cover

Determination of carbonization depth

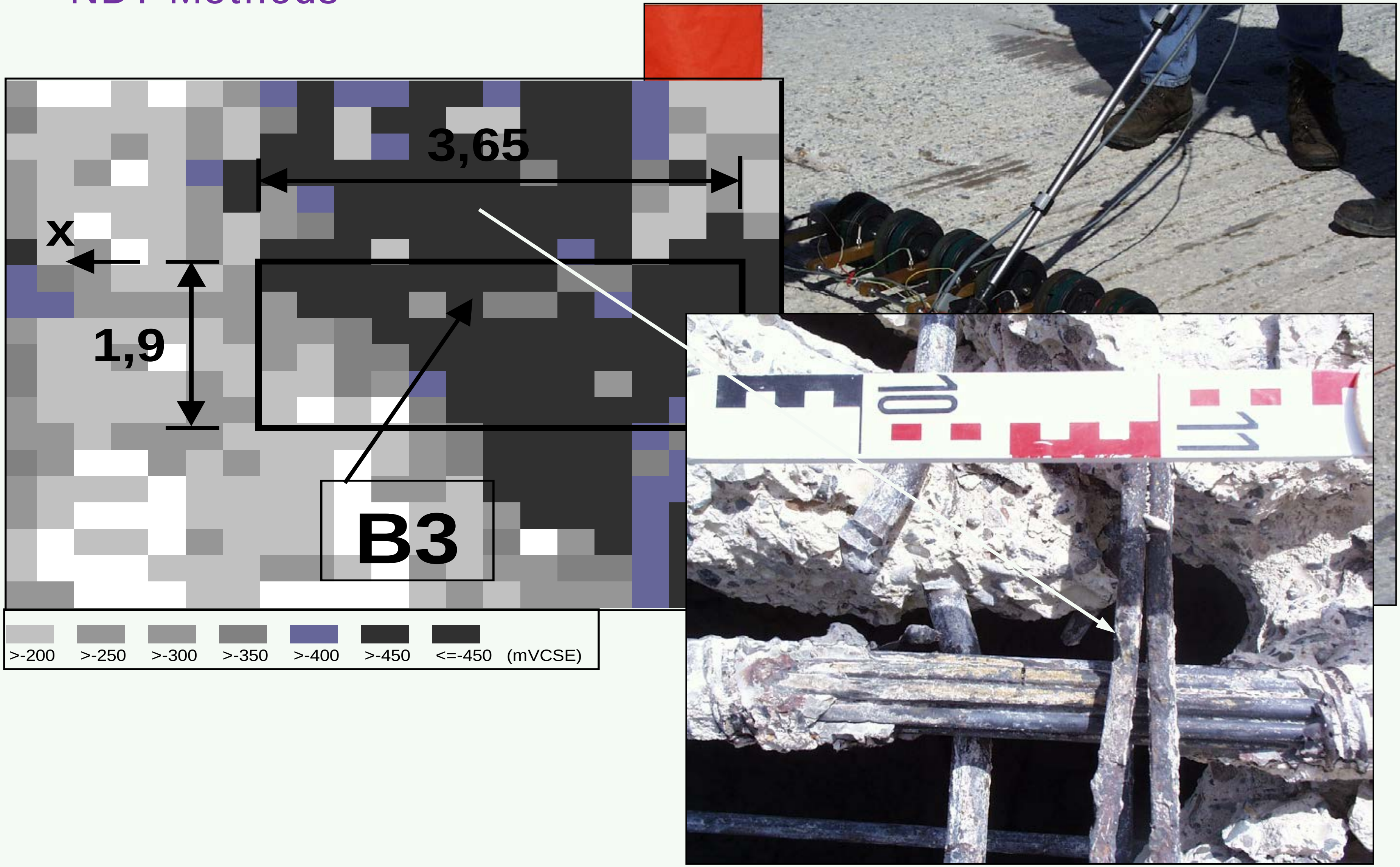
Concrete flaking

Link to NDT



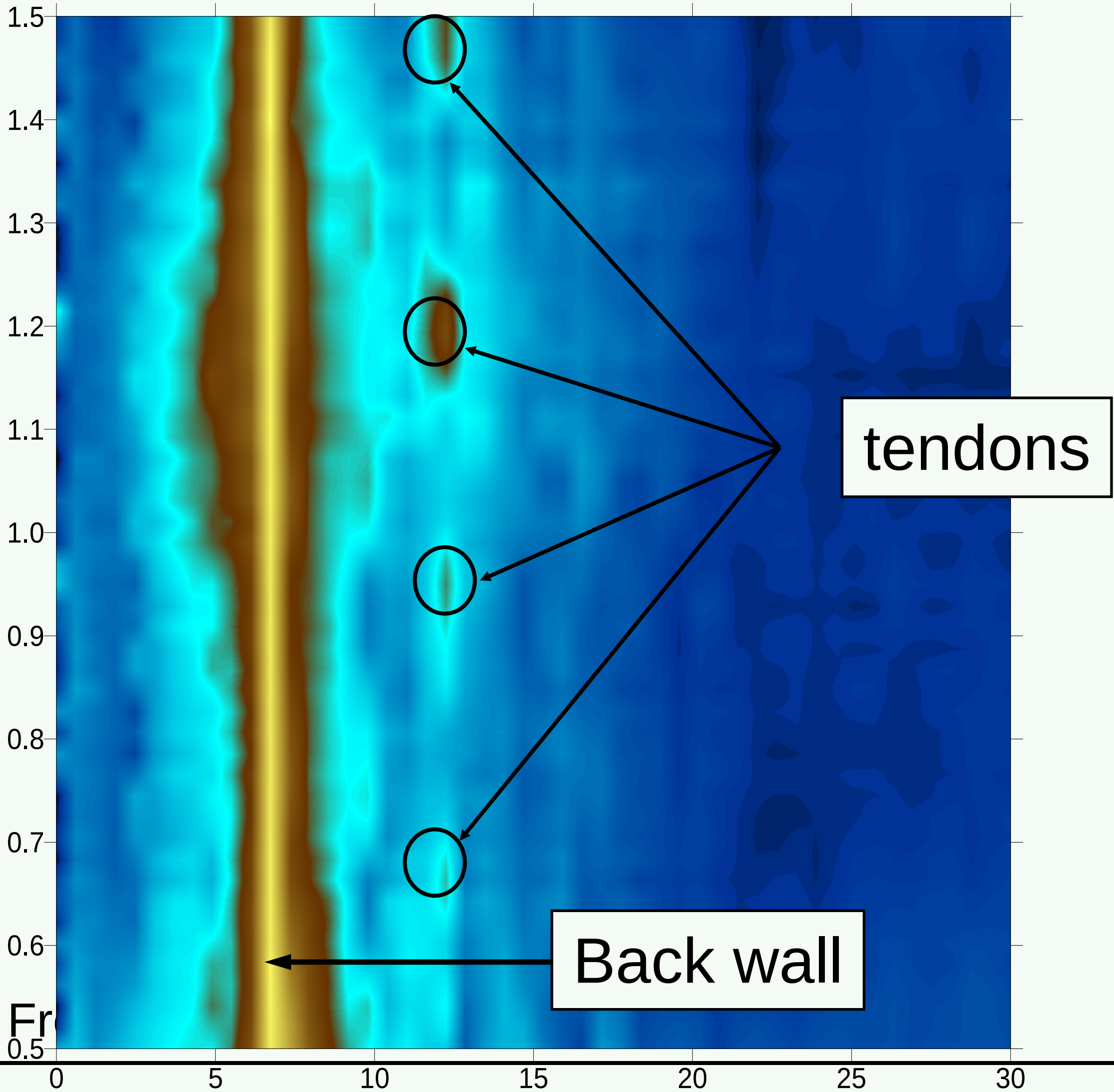
SIB BAUWERKE, Erfassungsprogramm V 1.61 (Vorabversion 4)
Verwaltung im Setup einstellen
SIB-BAUWERKE
Schadensbewertung
Bauwerksnummer 6608530 1 Interne Bwnr. 455
[1] Brücke · Überbau · Balken Hohlquerschnitt · Fahrbahnplatte · [2] Vorspannung · Spannglied · Litze · [4] gerissen · [5] mehrfach · [9] 15 m vom Bauwerksanfang
Standsicherheit des Bauwerks ist beeinträchtigt.
Schadensbeseitigung kurzfristig erforderlich.
VORSPANNUNGEN S V D
Ausfall von Spanngliedern in Abhängigkeit von statischer
Beurteilung S = 2 bis 4, D = 3
vereinzelt freiliegende Hüllrohre 0 0 3
unverpreßte Hüllrohre, Spannbewehrung nicht korrodiert bzw. 1 0 3
lediglich Flugrost
unverpreßte Hüllrohre, einsetzende Korrosion der Spannstähle 2 0 3
unverpreßte Hüllrohre, korrodierte Spannstähle (Narbenbildung) 3 0 3
Schutzbeton der Endverankerung der Spannglieder stark schadhaft 0 0 2
S Stand-sicherheit
V Verkehrs-sicherheit
D Dauer-haftigkeit
0 1 2 3 4
NDT-methods
BAM
ZfPBau-Kompendium · 1999
Bundesanstalt für Materialforschung und -prüfung (BAM)
Unter den Eichen 87, 12205 Berlin
Beginn
Inhalt
Verfahren
Literatur
Stichworte
Hilfe
ZfPBau-Kompendium
Prof. Dr.-Ing. Gerald Schickert
Dr. rer. nat. Martin Krause
Dr. rer. nat. Herbert Wiggenhauser
NDT - compendium
Dr. rer. nat. Herbert Wiggenhauser
Dipl.-Ing. Kerstin Borchardt
Technische Realisierung:
Dipl.-Ing. Kerstin Borchardt
Dr. rer. nat. Herbert Wiggenhauser
Erstellt: 30.10.2000
Gefördert durch die Senatsverwaltung für Stadtentwicklung, Berlin
© BAM Bundesanstalt für Materialforschung und -prüfung, Berlin, 1999

NDT Methods

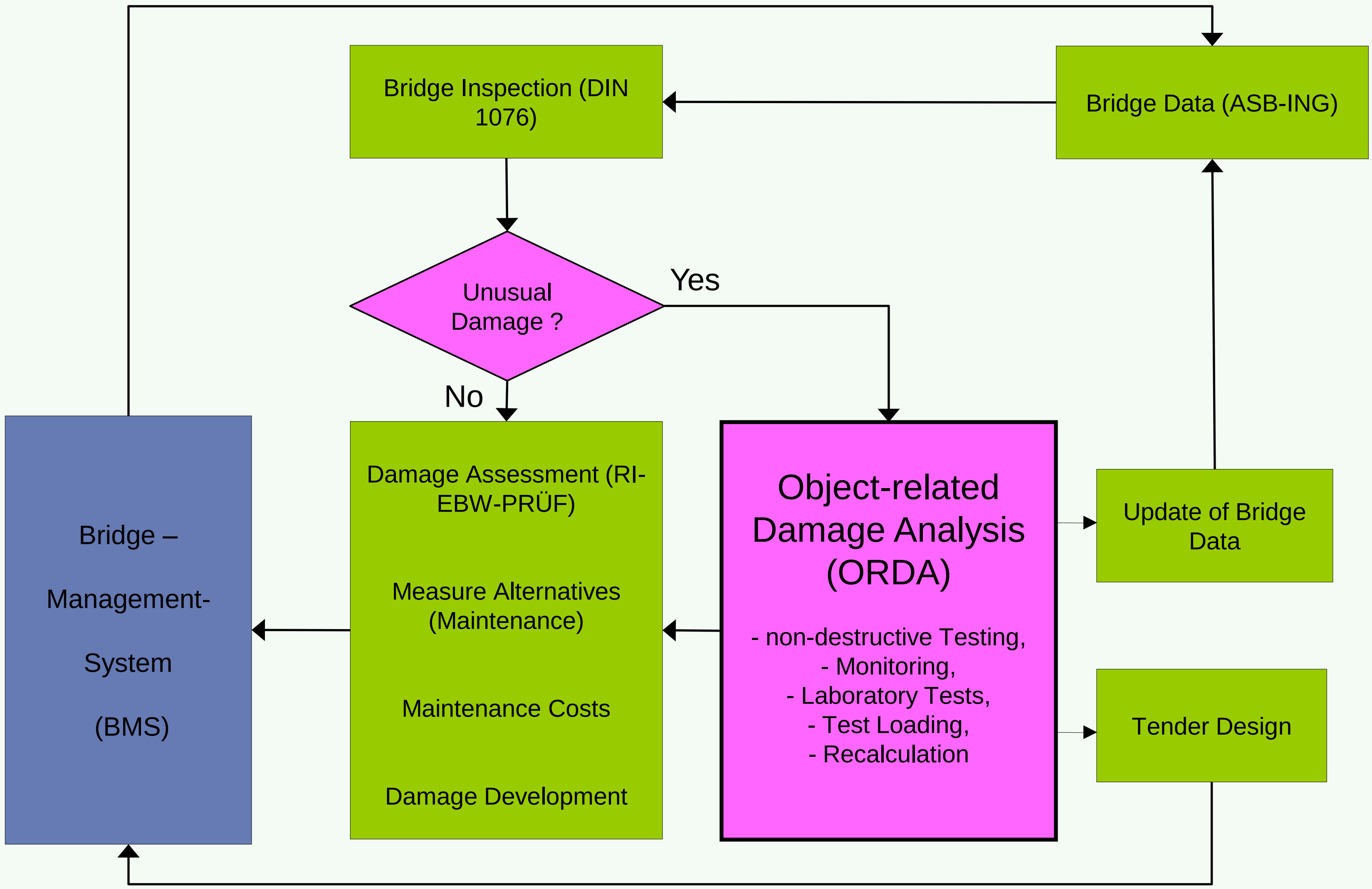


NDT Methods


Impact


1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0
5
10
15
20
25
30
tendons
Back wall

Additional Inspections



Bridge Condition according to DIN 1076

1,0 – 1,7	the structural element is in a very good / good condition. Intervention not necessary.
1,8 – 2,4	the structural element is in an acceptable condition. Intervention should be planned in time.
2,5 – 2,9	the structural element is in a bad condition. Measures should be planned in the near future.
3,0 – 3,4	the structural element is in a bad condition. Measures should be planned fast.
≥ 3,5	the structural element is in a very bad condition. Measures have to be planned immediately.

Inspection Report

Verwaltung im Setup einstellen

Sachgebiet Bauwerksprüfung

Teil-BW 6608530 1 (455)
Straße A 8
AM/SM Autobahnmeisterei [illegible]

Druck vom 30.01.2001, Deckblatt Seite 1

Prüfbericht 1999 H

nach DIN 1076

Bauwerksname	Talbrücke Friedrichsthal
Teilbauwerksname	Talbrücke Friedrichsthal
Kreis	Stadtverband Saarbruecken
Ort	FRIEDRICHSTHAL
Bauwerksart	Plattenbalkenbrücke, Trägerrostbrücke
Tragfähigkeit	60/30 nach DIN 1072
Baujahr	1969

Straßen im Bauwerksbereich

Straße	Von Netzknoten-punkt	Nach Netzknoten-punkt	[illegible]	Station Anfang	Station Mitte	Station Ende	[illegible]	Lage	[illegible]	Anz.	[illegible]	[illegible]	[illegible]
A 8	[illegible]	[illegible]		373	477	1181		oben	[illegible]	1	11	[illegible]	P
L [illegible]	[illegible]	[illegible]			2301			unten		1	11	[illegible]	

Prüfrichtung	Stationierungsrichtung
Prüfer	Baumann
Prüfung vom	10.04.1999 bis 04.06.1999

Zustandsnote: 3,0

Verwaltung im Setup einstellen

Sachgebiet Bauwerksprüfung

Prüfbericht 1999 H
Teilbauwerk: 6608530 1 (455)
Straße: A 8

Druck vom 30.01.2001, Schadensbeschreibung Seite 1

Schadensbeschreibung

Überbau

[1] Balken, Vollquerschnitt, ein Stück, Querriss, 1-tes Feld, 39,1 m vom Feldanfang, links,
S=0, V=0, D=1 EP

[2] Balken, Vollquerschnitt, Beton, ein Stück, abgeplatzt, 1-tes Feld, 24 m vom Feldanfang, Mitte, unten, Instandsetzung schadhaft,
S=0, V=0, D=2 EP

[3] Balken, Vollquerschnitt, Beton, ein Stück, abgeplatzt, 2-tes Feld, 11 m vom Feldanfang, links,
S=0, V=0, D=2 EP

[4] Balken, Vollquerschnitt, Beton, ein Stück, abgeplatzt, 2-tes Feld, hinten, links,
S=0, V=0, D=2 EP

[5] Balken, Vollquerschnitt, Beton, eine Stelle, abgeplatzt, 3-tes Feld, 18 m vom Feldanfang, links, unten,
S=0, V=0, D=2 EP

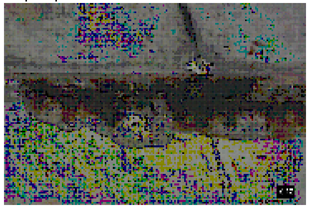
FLANSCH BETONABPLATZUNG

[6] Balken, Vollquerschnitt, Beton, eine Stelle, abgeplatzt, 4-tes Feld, 38 m vom Feldanfang, rechts,
S=0, V=0, D=2 EP

[7] Balken, Vollquerschnitt, eine Stelle, Querriss, Rissbreite 0,1 - < 0,2 mm, 5-tes Feld, 23 m vom Feldanfang,
S=0, V=0, D=1 EP

[8] Balken, Vollquerschnitt, eine Stelle, Querriss, Rissbreite 0,1 - < 0,2 mm, 5-tes Feld, 44 m vom Feldanfang,
S=0, V=0, D=1 EP

[9] Balken, Vollquerschnitt, Beton, eine Stelle, abgeplatzt, 5-tes Feld, 40 m vom Feldanfang, rechts,
S=0, V=0, D=2 EP



AUSKRAGUNG BETONABPLATZUNG 1

[10] Balken, Vollquerschnitt, Beton, eine Stelle, abgeplatzt, 5-tes Feld, 44 m vom Feldanfang, rechts,
S=0, V=0, D=2 EP

[11] Balken, Vollquerschnitt, eine Stelle, Schrägriss, Rissbreite 0,2 - < 0,4 mm, 3 m, 5-tes Feld, hinten,
S=0, V=0, D=1 EP

[12] Balken, Vollquerschnitt, Beton, vereinzelt, abgeplatzt, 6-tes Feld, hinten,
S=0, V=0, D=2 EP

[13] Balken, Vollquerschnitt, Beton, vereinzelt, abgeplatzt, 6-tes Feld, 28 m vom Feldanfang, links,
S=0, V=0, D=2 EP

[14] Balken, Vollquerschnitt, eine Stelle, Schrägriss, Rissbreite 0,2 - < 0,4 mm, 3 m, 7-tes Feld, vorne,
S=0, V=0, D=1 EP

[15] Balken, Vollquerschnitt, eine Stelle, Hohlstelle, 7-tes Feld, hinten,
S=0, V=0, D=1 EP

[16] Balken, Vollquerschnitt, Beton, eine Stelle, abgeplatzt, 8-tes Feld, vorne, rechts,
S=0, V=0, D=2 EP

[17] Balken, Vollquerschnitt, eine Stelle, Schrägriss, Rissbreite 0,1 - < 0,2 mm, 2 m, 8-tes Feld, vorne,
S=0, V=0, D=1 EP

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  - Inventory
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  - **Load bearing capacity**
  - Management System
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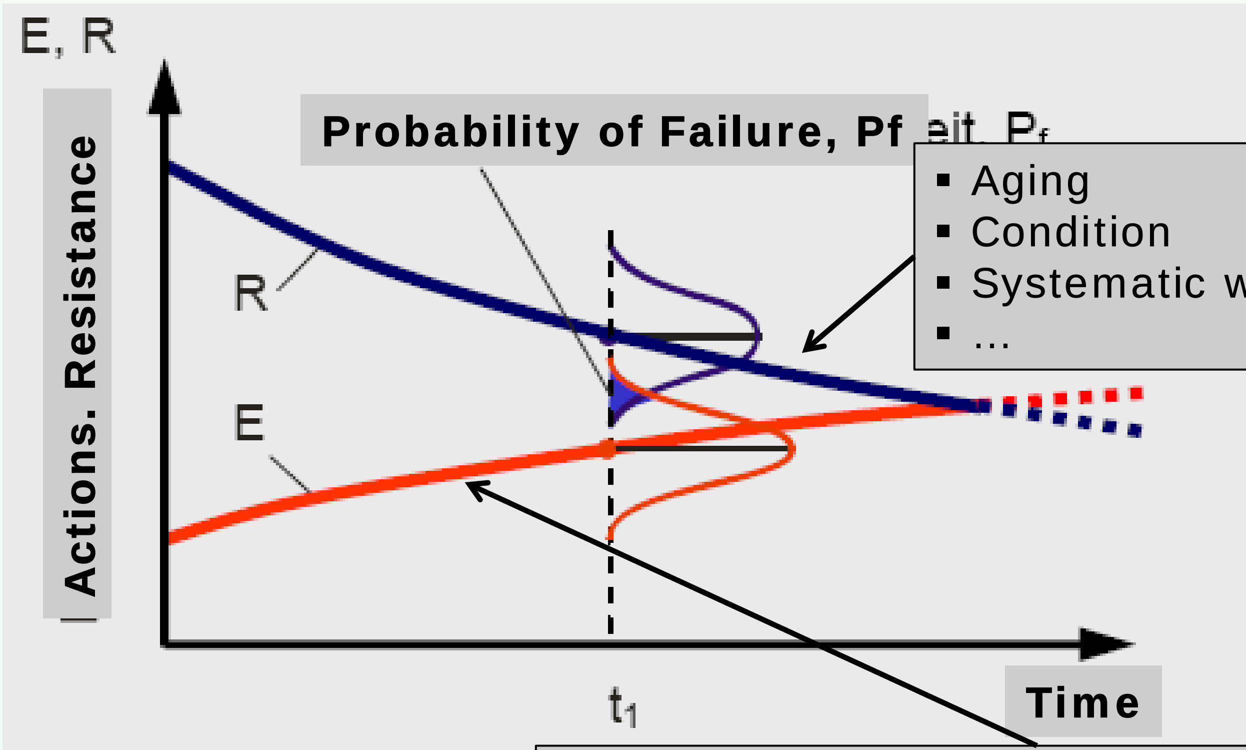
Load bearing Capacity of aging Bridges

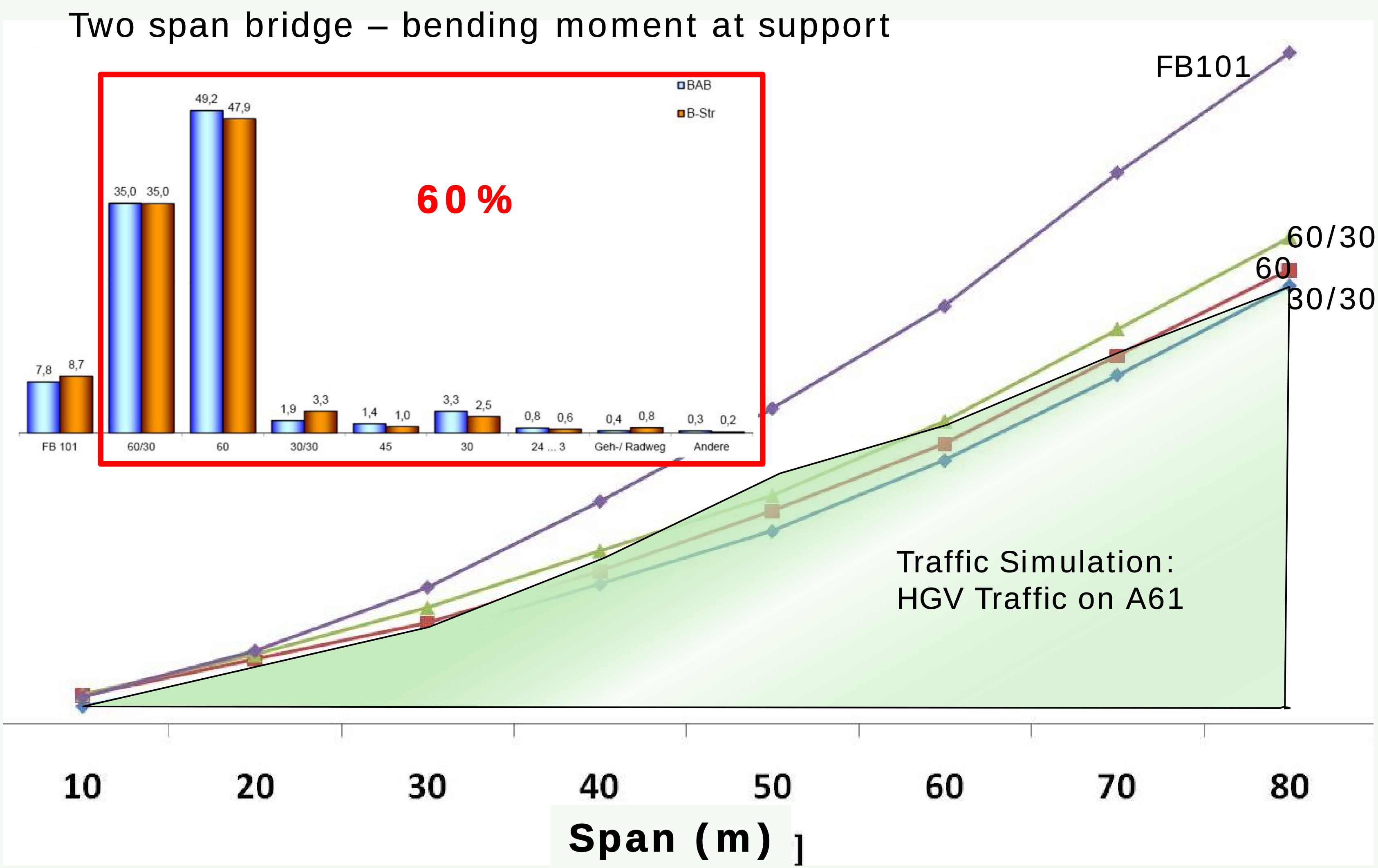


- Aging
- Condition
- Systematic weaknesses
- ...

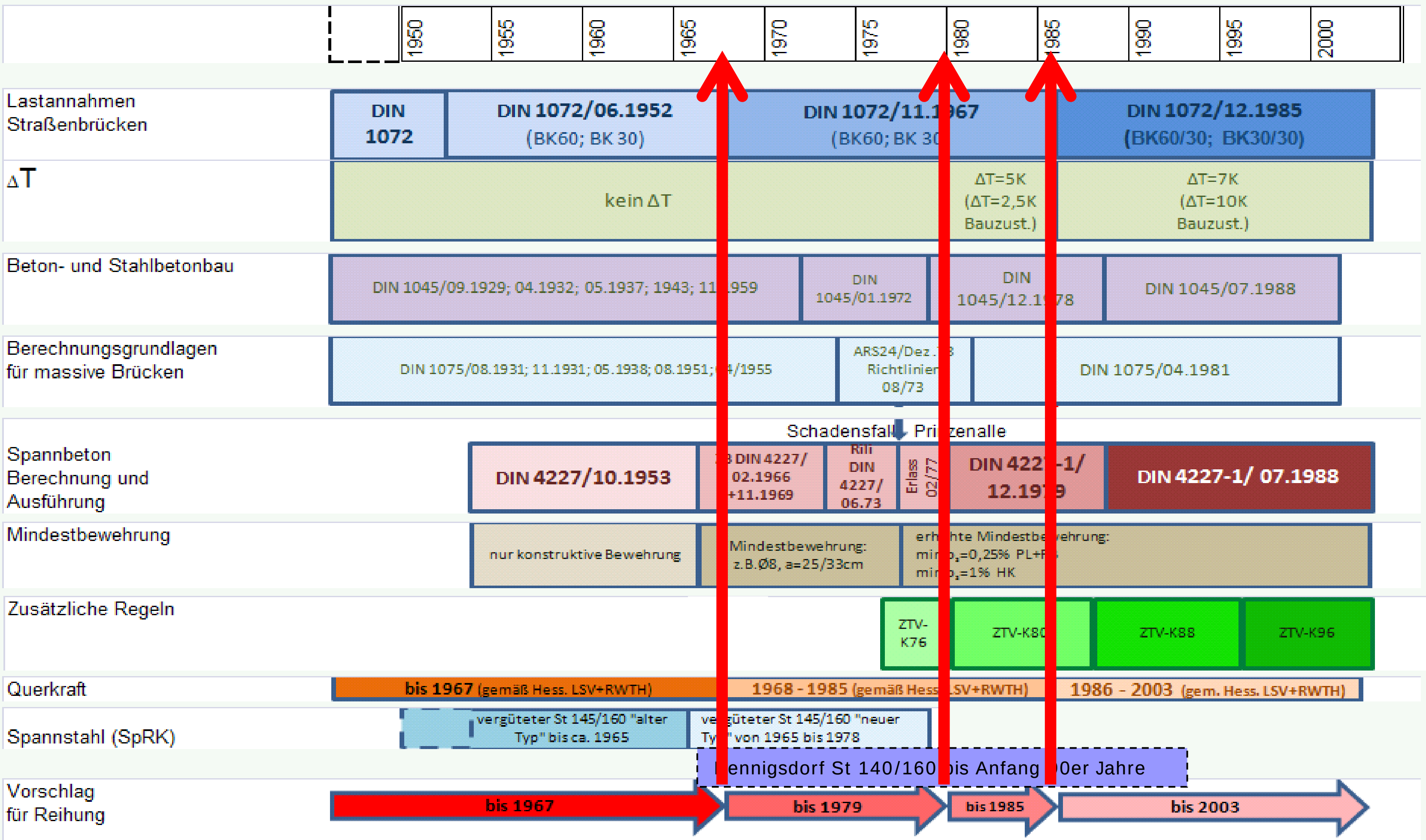
Quelle: Factas Universitatis; Ar

- Freight transport (with special permission)
- Overloaded trucks
- New vehicle concepts
- Extreme weather events (Climate Change)
- ...

Traffic Simulation



Risk Analysis – Standards and Guidelines



Risk Analysis

$$Z = (f_1 * Z_V + f_2 * Z_{ZN(ÜB)} + f_3 * Z_{DT} + f_4 * Z_{KF} + f_5 * Z_Q + f_6 * Z_{SpRK} + f_7 * Z_{ZN(TBw)}) * 7$$

Z_V	**Traffic** (f_1=0,45)
$Z_{ZN(ÜB)}$	**Condition** of superstructure (f_2=0,10)
Z_{DT}	„**DT“**-Consideration (f_3=0,10)
Z_{KF}	„**Coupling Joints**“ (f_4=0,10)
Z_Q	„**Shear Force**“ (f_5=0,10)
Z_{SpRK}	„**Stress Corrosion**“ (f_6=0,10)
$Z_{ZN(TBw)}$	**Condition** (f_7=0,05)
$f_1,\dots,f_7$	Weighting factors

Risk Analysis

Brücken im Zuge von Bundesautobahnen

Vordringlich zu untersuchende Brücken

Stand: Februar 2010

LFD. NR.	BL	STRECKE	ID_NR	BAUWERKSNAME	ORT	LÄNGE [m]	BAUJAHR	HAUPTBAUSTOFF
0001	BB	A 10	3443507 1	Brücke im Zuge der A 10 über DB und K 6303 Überbau 1, link	BREDOW	40,00	1978	Stahlverbund
0002	BB	A 10	3443507 2	Brücke im Zuge der A 10 über DB und K 6303 Überbau 2, recl	BREDOW	40,00	1978	Stahlverbund
0003	BB	A 10	3244500 2	Brücke im Zuge der A10 über die A24	Großziethen	65,20	1979	Spannbeton
0004	BB	A 10	3244500 1	Brücke im Zuge der A10 über die A24	Großziethen	65,20	1979	Spannbeton
0005	BB	A 111	3245502 0	Brücke im Zuge der A 111 über die A 10	VELTEN	64,20	1982	Spannbeton
0006	BB	A 114	3346514 1	Brücke im Zuge der A 114 über die A 10	SCHÖNERLINDE	80,00	1972	Stahl/Leichtmetall
0007	BB	A 114	3346514 2	Brücke im Zuge der A 114 über die A 10	SCHÖNERLINDE	80,00	1972	Stahl/Leichtmetall
0008	BB	A 117	3647516 1	Brücke im Zuge der A 117 über DB und Weg	WALTERSDORF	22,38	1962	Beton/Stahlbeton
0009	BB	A 117	3647516 2	Brücke im Zuge der A 117 über DB und Weg	WALTERSDORF	22,38	1962	Beton/Stahlbeton
0010	BB	A 13	4149513 2	[illegible]	[illegible]	36,24	1961	Beton/Stahlbeton
0011	BB	A 13	4149513 1	[illegible]	[illegible]	36,24	1961	Beton/Stahlbeton
0012	BE	A 100	3445051 2	Ringbahnbrücke und Rampenbrücke	Charlottenburg	108,60	1963	Spannbeton
0013	BE	A 100	3445105A2	Brücke über den Tegeler Weg	Charlottenburg	293,11	1972	Spannbeton
0014	BE	A 100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Spannbeton
0015	BE	A 100	[illegible]	Westendbrücke	Charlottenburg	243,46	1963	Spannbeton
0016	BE	A 100	3445105A1	Brücke über den Tegeler Weg	Charlottenburg	293,11	1972	Spannbeton
0017	BE	A 100	3445105B1	Brücke über den Tegeler Weg	Charlottenburg	273,21	1972	Spannbeton
0018	BE	A 100	3445105B2	Brücke über den Tegeler Weg	Charlottenburg	273,21	1972	Spannbeton
0019	BE	A 100	3445105C	Brücke über den Tegeler Weg	Charlottenburg	94,97	1972	Spannbeton
0020	BE	A 100	3545028A2	Brücke über die Mecklenburgische Straße	Wilmersdorf	363,63	1969	Spannbeton
0021	BE	A 100	3545028A1	Brücke über die Mecklenburgische Straße	Wilmersdorf	356,84	1969	Spannbeton
0022	BE	A 100	3545019 1	BAB A 100 Brücke über die Ausfahrt Detmolder Str.	Wilmersdorf	80,88	1969	Spannbeton
0023	BE	A 100	3545019 2	BAB A 100 Brücke über die Ausfahrt Detmolder Str.	Wilmersdorf	80,88	1969	Spannbeton
0024	BE	A 100 A(Ast)	3546508 1	Brücke AS Gradestr-/über Gottlieb-Dunkel-Str	Tempelhof	253,96	1981	Spannbeton
0025	BE	A 100 A(Ast)	3545037 0	Brücke Einfahrt zum AK Wilmersdorf	Wilmersdorf	79,11	1973	Spannbeton
0026	BE	A 100 A(Ast)	3545020 0	Rampenbrücke Ausfahrt BAB A 100 Detmolder Str.	Wilmersdorf	142,12	1969	Spannbeton
0027	BE	A 100 D(Ast)	3545031 1	Brücke über den Westring	Wilmersdorf	272,22	1974	Spannbeton
0028	BE	A 100 D(Ast)	3545034 1	Brücke über die Mecklenburgische Straße	Wilmersdorf	58,80	1973	Spannbeton
0029	BE	A 100 E(Ast)	3445084 0	Westliche Brücke über den Siemensdamm	Charlottenburg	177,01	1964	Spannbeton

Detailed Assessment
Strengthening and/or Replacement?

Quelle: http://www.bast.de/DE/FB-B/Fachthemen/b4-nachrechnung-bruecken

Reassessment

Bundesministerium für Verkehr, Bau und Stadtentwicklung

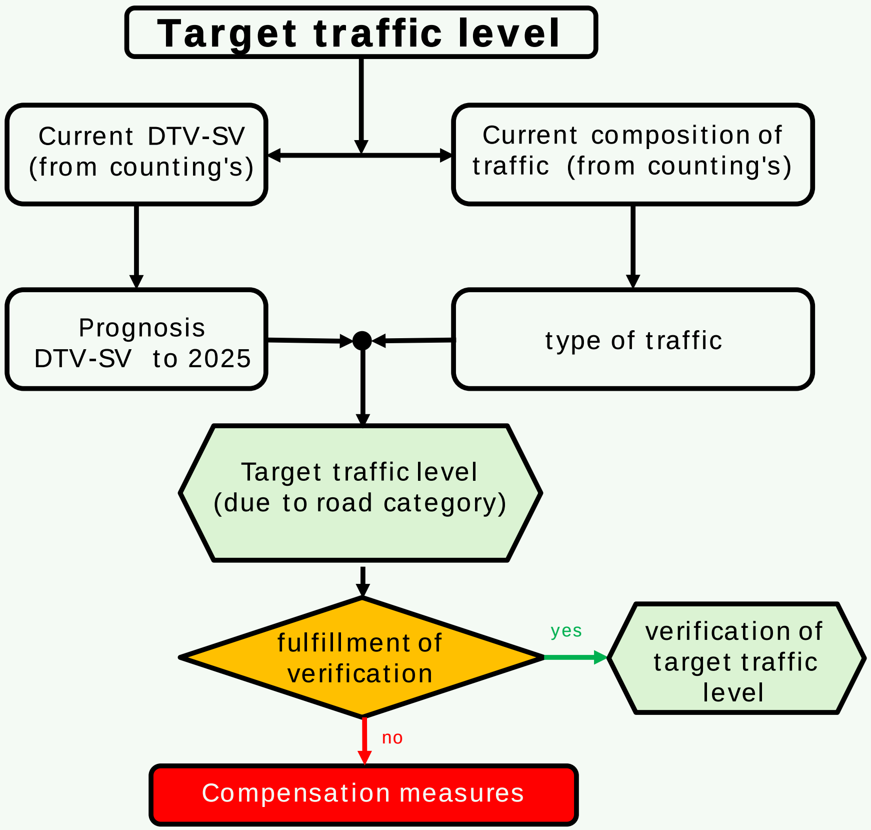
Abteilung Straßenbau

Guideline for the assessment of existing bridges

Ausgabe: 05/2011

Reassessment - vertical traffic loads

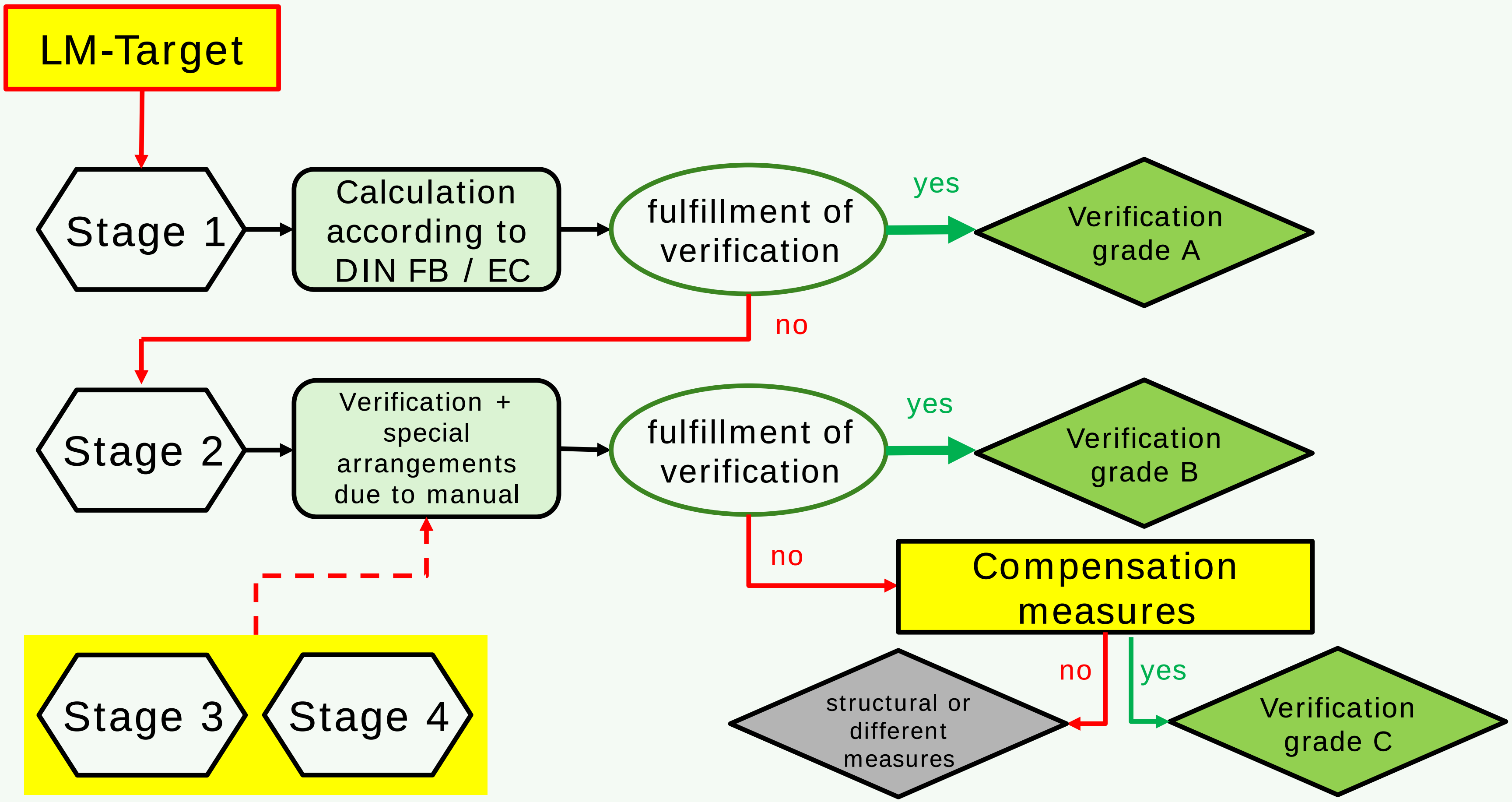
- Target traffic level
  - LMM: Load model 1
    (DIN EN 1991-2/NA)
  - LM1: Load model 1
    (DIN Fachbericht)
  - BK60/30: Load model 60/30
    (DIN 1072:1985)
  - BK60: Load model 60
    (DIN 1072:1967)
  - BK30/30: Load model 30/30
    (DIN 1072:1985)



- Type of traffic
  - long distance
  - medium distance
  - local traffic

Source: Bauingenieur, Ausgabe Januar 2012

Reassessment procedure



Source: Bauingenieur, Ausgabe Januar 2012

Compensation measures

- Limitations for traffic:
  - Load restriction
  - Ban of overtaking for trucks
  - Introducing a speed limit
  - Rearrangement of lanes
  - Closing and/or narrowing of lanes

- Compensating monitoring measures:
  - Installation of long-term monitoring
  - Additional inspections according DIN 1076

Retrofitting Methods for Concrete Bridges

- **Insufficient load-carrying capacity due to increased traffic loads**
  - external tendons
  - additional concrete in the compression zone
  - cross section expansion with shotcrete and additional reinforcement
  - near-surface-mounted steel reinforcement
  - near-surface-mounted FRP strips
  - external bonded FRP strips
  - external prestressed FRP strips
- **insufficient minimum reinforcement**
  - external tendons
  - additional reinforcement in grooves
  - near-surface-mounted FRP strips
- **shear resistance**
  - external tendons
  - additional concrete in the compression zone
  - cross section expansion with shotcrete and additional reinforcement
  - change of structural system
  - shear pin
- **coupling joints**
  - external tendons
  - additional reinforcement
  - external bonded FRP strips
  - external bonded steel plates
  - prestressed FRP strips

Source: Sachstand Verstärkungsverfahren – Verstärken von Betonbrücken im Bestand, Bericht der Bundesanstalt für Straßenwesen, Heft B 75

Outline

Management of (aging) Infrastructure

Budget

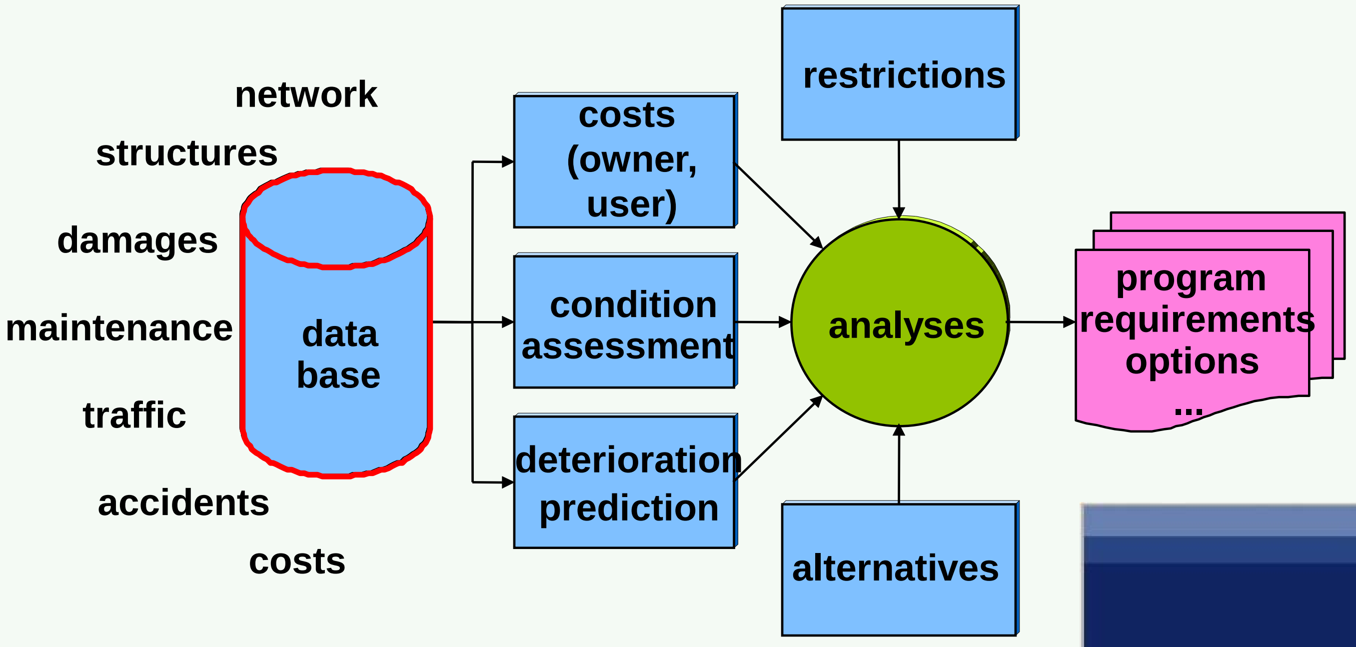
Decision Support

Scenarios:
What if?
How much if?

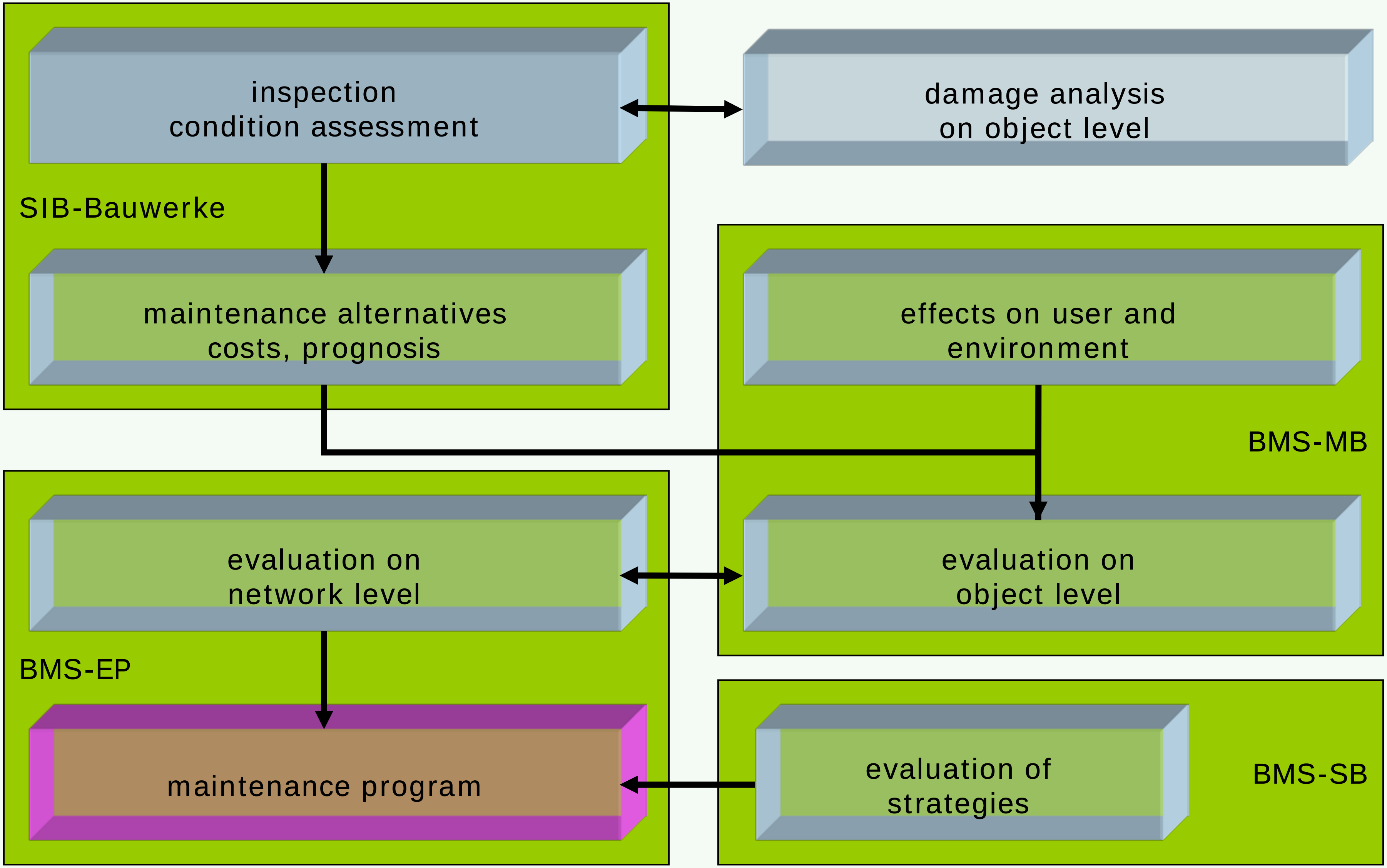
Why?
When?
Where?
How much?

Infrastructure

Bridge Management System

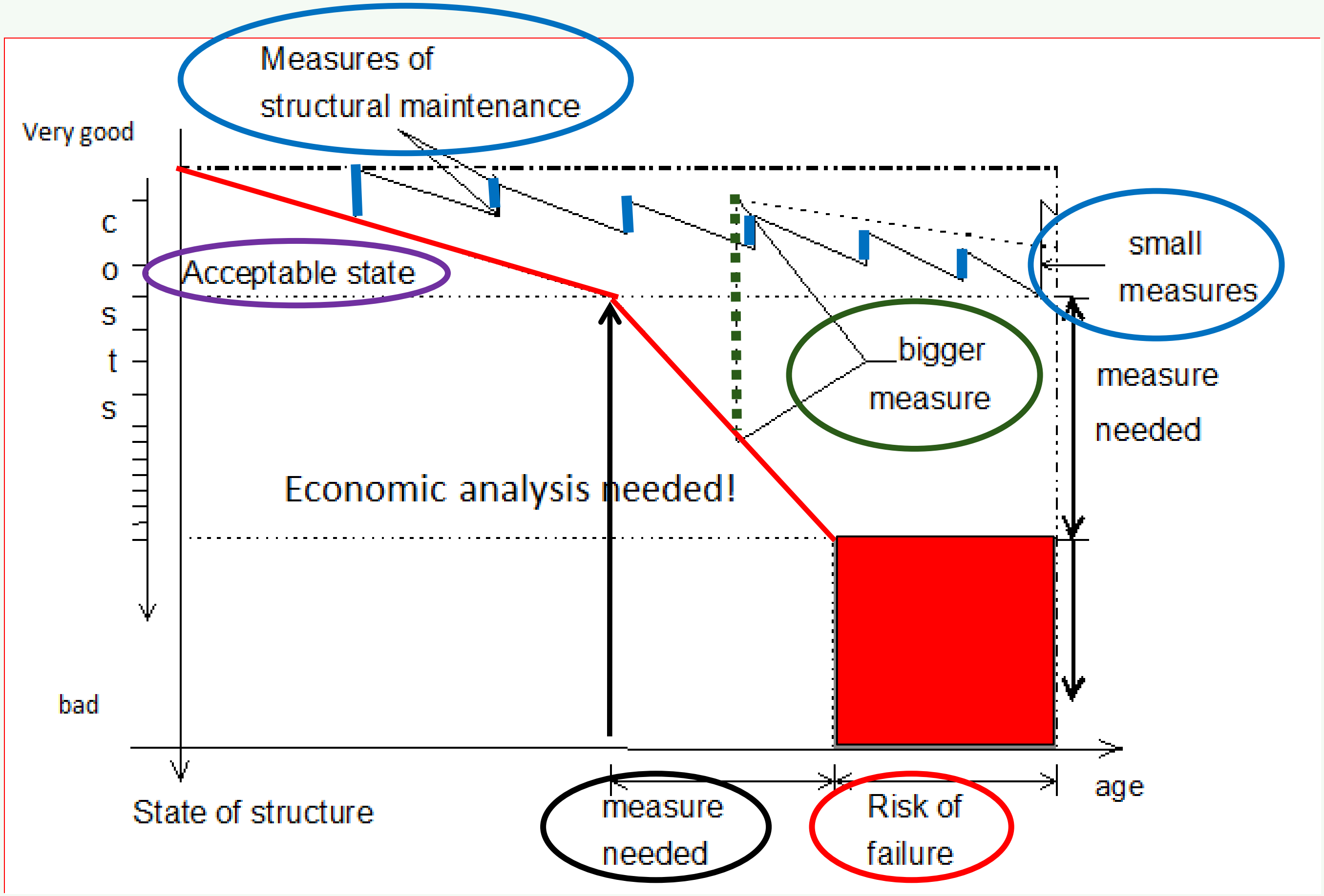


Bridge Management System



Maintenance Strategies

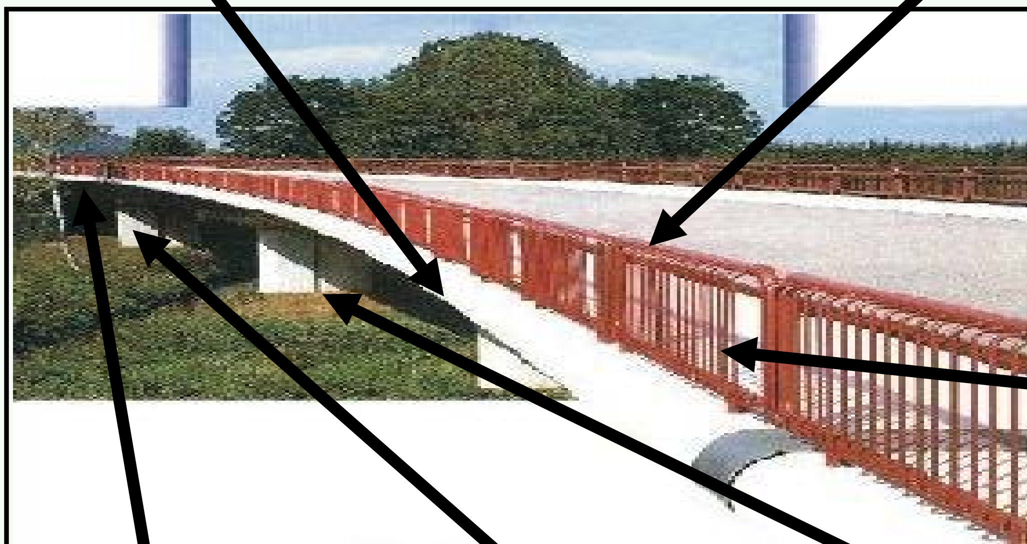
- Actual condition of the structure
- Prediction of further deterioration
- Effect of different maintenance measures



Bridge Management System - Example

Superstructure:
corrosion of reinforcement

Bituminous Layer:
cracks and delamination



Retainng System:
corrosion

Bearing:
excessive deformation

Substructure:
cracks

Embankment:
damaged

Bridge Management System - Example

Concrete repair 1.000 m²

costs	490.500 €	duration	3 months
intervention	2014 or 2015		

Asphalt replacement (without waterproofing)

costs	64.200 €	duration	3 months
intervention	2014 or 2015		

Crack injection

costs	129.100 €	duration	3 months
intervention	2014 to 2018		

Embankment repair (30 m³)

costs	11.700 €	duration	3 months
intervention	2014 or 2015		

Retaining System repair (33 m) / replacement (100 m)

costs	19.700 € / 34.100 €	duration	1 week
intervention	2014 to 2019		

Bearing repair / replacement

costs	24.700 € / 25.300 €	duration	1 week
intervention	2014 to 2019		

Bridge Management System - Example

Alternative	Measure					
	Concrete repair	Layer repair	Crack injection	Embank-ment repair	Railing repair/replace-ment	Bearing repair/re-placement
A	2014	2014		2014	2014 I	2014 I
B	2014	2014		2014	2014 A	2014 A
C	2015	2015		2015	2015 I	2015 I
D	2015	2015		2015	2015 A	2015 A
E	2014	2014		2014	2018 I	2016 I
F	2014	2014		2014	2018 A	2017 A
G	2015	2015		2015	2018 I	2016 I
H	2015	2015		2015	2018 A	2018 A
I	2015	2015		2015	2015 A	2018 A
J	2015	2015	2015	2015	2015 A	2015 A
K	2015	2017	2015	2015	2017 A	2016 A

I = repair A = replacement

Bridge Management System - Example

Alternative	costs [€] owner	user	environment
A	949.482	5.685.822	158.345
B	953.284	5.685.822	158.345
C	926.708	5.520.215	153.733
D	929.832	5.520.215	153.733
E	1.090.105	8.685.822	222.087
F	1.081.757	8.685.822	222.087
G	1.059.736	8.520.215	217.475
H	1.060.303	8.520.215	217.475
I	975.235	5.520.215	153.733
J	985.743	5.685.822	158.345
K	1.589.152	11.827.591	329.388

Owner:
maintenance
traffic safety
residual value

User:
time
operation
accidents

Environment:
climate
pollution
noise

Bridge Management System - Example

Alternative	benefit [€] user	benefit [€] environment
A	544.672.79	20.438.750
B	1.141.349.526	44.152.697
C	639.504.025	24.123.846
D	1.236.291.331	47.905.083
E	734.740.830	27.842.248
F	1.112.565.378	42.944.799
G	991.349.709	37.598.408
H	1.207.507.183	46.697.184
I	1.207.507.183	46.697.184
J	1.207.507.183	46.697.184
K	1.424.570.426	5.494.698

Benefit :

$\text{Costs}_{\text{do nothing}} - \text{Costs}_{\text{measure}}$

(user + environment)

Bridge Management System - Example

Prioriti-sation	Cost/Benefit-Ratio	
	without discount rate	with discount rate 3%
best	D	D
	I	I
	J	J
	B	B
	H	H
	F	F
	K	G
	G	K
	C	C
	E	E
worst	A	A

Cost / Benefit - Ratio:

Owner - Costs /

User + Environment - Benefit

Bridge Management System - Example

Nr.	Strategie	Jahr der Maßnahme	Gesamt-Maßnahme-Kosten*	Nutzen	Summe aus Nutzen und Kosten der Maßnahme	Rangfolge am Objekt
1	FBÜK	6	-30.000	123.200	93.200	37
2	FBÜK	7	-29.100	125.400	96.300	36
3	FBÜK	8	-28.227	127.600	99.373	34
4	FBÜK	9	-27.380	129.800	102.420	32
5	FBÜK	10	-26.559	132.000	105.441	30
6	FBÜK	11	-25.762	134.200	108.438	28
7	FBÜK	12	-24.989	136.400	111.411	27
8	FBÜK	13	-24.239	138.600	114.361	26
9	FBÜK	14	-23.512	140.800	117.288	25
10	FBÜK	15	-22.807	143.000	120.193	24
11	FBÜK	16	-22.123	145.200	123.077	23
12	Kappe	19	-60.000	144.900	84.900	40
13	Kappe	20	-58.200	147.000	88.800	39
14	Kappe	21	-56.454	149.100	92.646	38
15	Kappe	22	-54.760	151.200	96.440	35
16	Kappe	23	-53.118	153.300	100.182	33
17	Kappe	24	-51.524	155.400	103.876	31
18	Kappe	25	-49.978	157.500	107.522	29
19	Belag	17	-40.000	234.500	194.500	21
20	Belag	18	-38.800	238.000	199.200	19
21	Belag	19	-37.636	241.500	203.864	18
22	Belag	20	-36.507	245.000	208.493	16
23	Belag	21	-35.412	248.500	213.088	14
24	Belag	22	-34.349	252.000	217.651	12
25	Lager	22	-90.000	280.800	190.800	22
26	Lager	23	-87.300	284.700	197.400	20
27	Lager	24	-84.681	288.600	203.919	17
28	Lager	25	-82.141	292.500	210.359	15
29	Lager	26	-79.676	296.400	216.724	13
30	K+B	19	-87.636	579.600	491.964	7
31	K+B	20	-85.007	588.000	502.993	5
32	K+B	21	-82.457	596.400	513.943	4
33	K+B	22	-79.983	604.800	524.817	3
34	K+B+F	22	-159.110	1.261.400	1.102.290	2
35	K+L	23	-130.418	512.460	382.042	10
36	K+L	24	-126.505	519.480	392.975	9
37	K+L	25	-122.710	526.500	403.790	8
38	F+K	16	-82.123	320.100	237.977	11
39	F+K+B	16	-122.123	624.800	502.677	6
40	F+K+B+L	16	-212.123	1.467.200	1.255.077	1

- Analysis of alternatives for all objects
- Network-wide ranking
- Maintenance program without any restrictions

<u>Wanted:</u>

Optimised maintenance program (budget, other constraints)

Bridge Management System - Example

Scenarios:

Optimal network-wide condition level for a given budget (Financial Scenario)

Minimum budget for a given network-wide condition level (Quality Scenario)

Possible boundary Conditions:

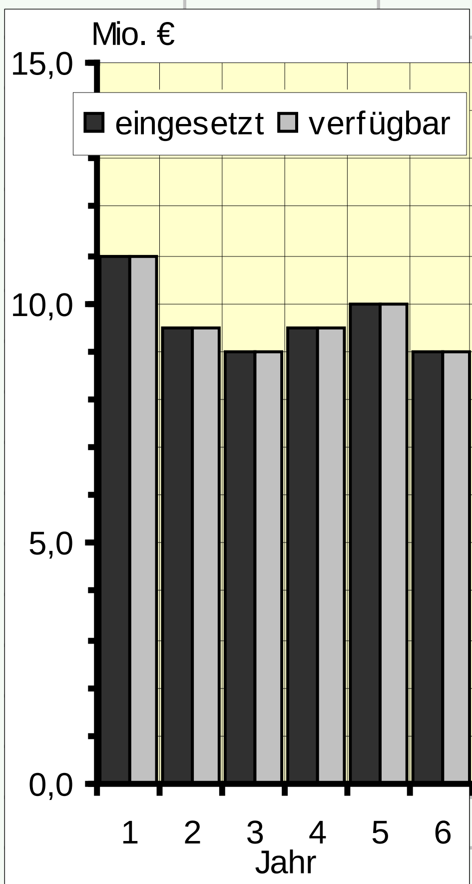
- yearly budget restrictions
- minimum condition standard
- favour structures with large traffic
- favour combination of measures within a line
- exceptional measures can be added manual

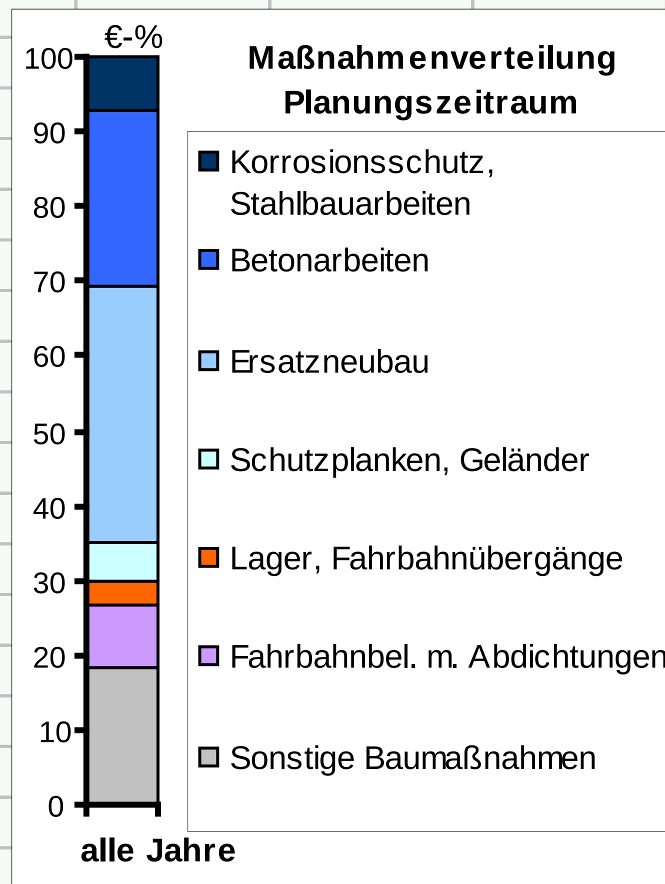
Bridge Management System - Example

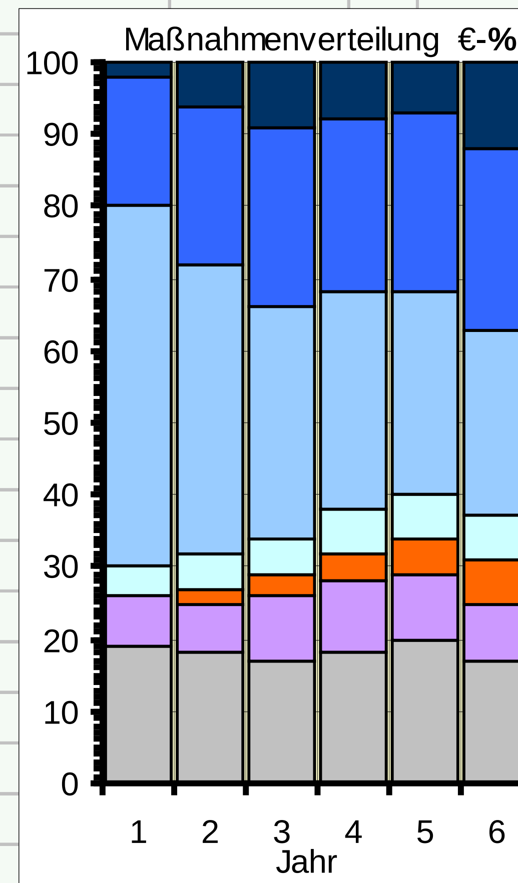
Zusammenfassung der BMS-Ergebnisse

Analysegruppe: **Bundesautobahn** Szenario: **Q-2004-023**

Optimierungsverfahren: **Qualitätsszenario**

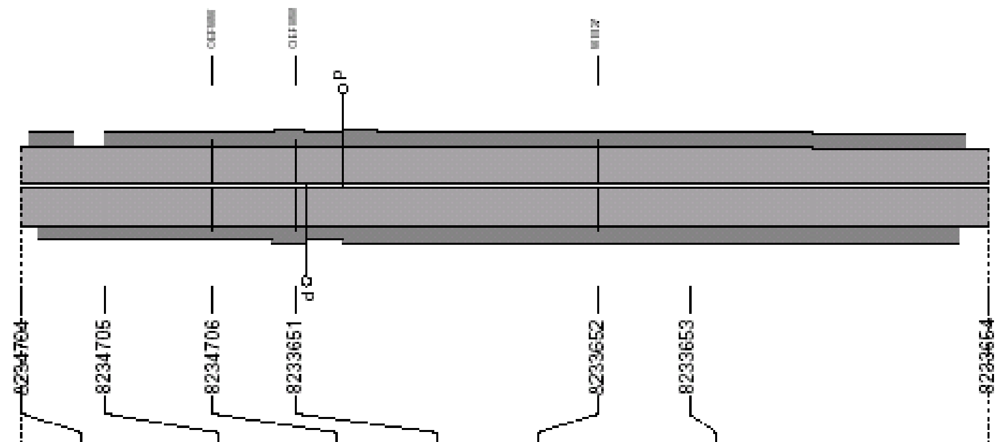






Bridge Management System - Example

Kreuzung
Parkplätze
Fahrbahnquerschnitt
Bauwerksnummer

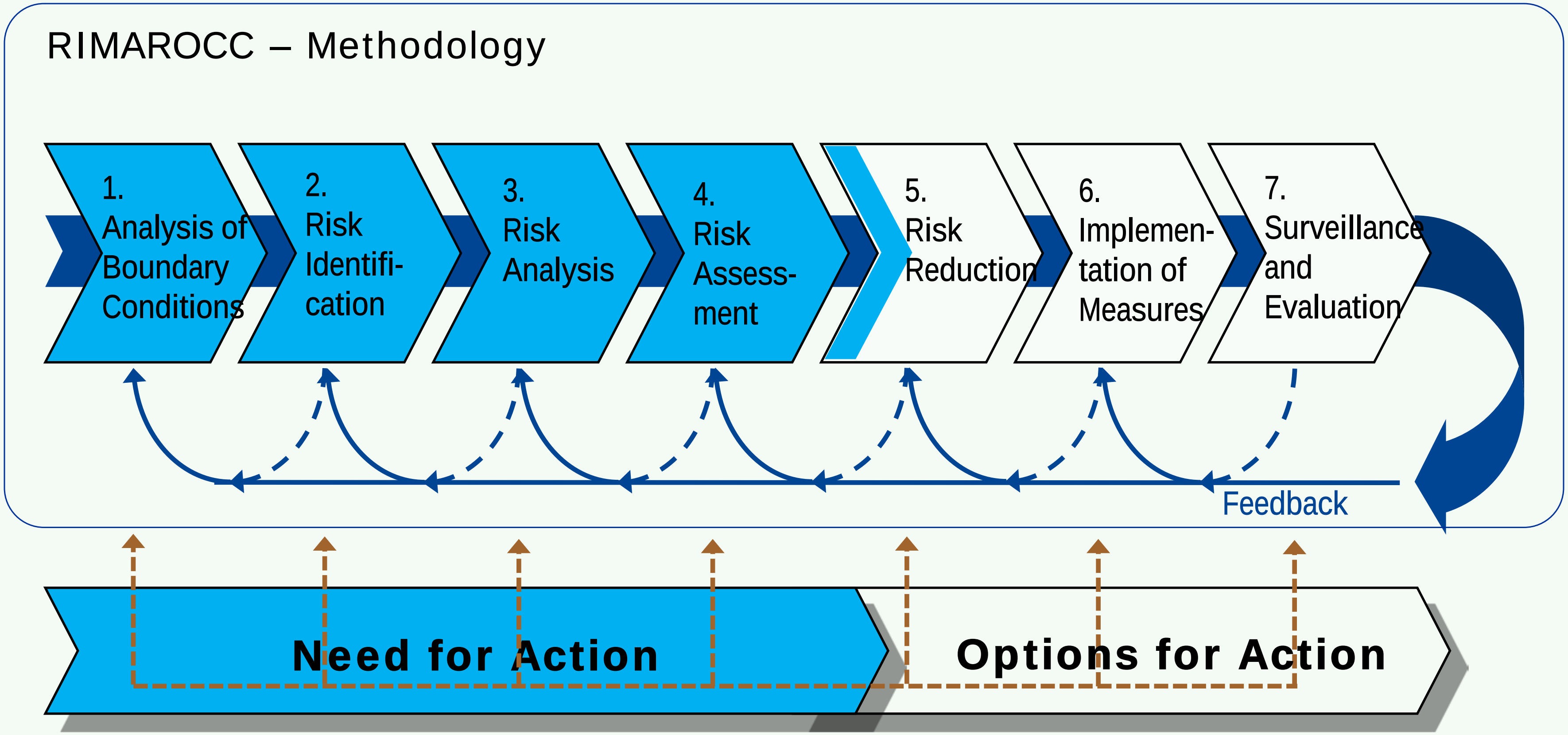


		8234704		8234705		8234706	8233651	8233652	8233653			
Bauwerk	ASB-Nummer	8234704		8234705		8234706	8233651	8233652	8233653			
	Interne BauwNr.	BW 51		BW 52		BW 53	BW 54	BW 55	BW 56			
	Betriebskilometer	42,568		43,020		43,612	44,068	45,725	46,231			
	Brückenfläche [m²]	482		678		336	520	465	3646			
	Lichte Höhe [m]	4,99		8,10		4,70	4,70	4,50	4,70			
Teilbauwerk	Teilbauwerksnummer	1	2	1	2	0	0	0	1	2	3	4
	Bauwerksart	▭	▭	▭	▭	▭	▭	▭	▭	▭	▭	▭
	Baujahr	1968	1968	1969	1969	1971	1971	1969	1972	1972	1972	1972
	Länge	14,4	14,4	21,8	21,8	44,8	65,3	10,5	68,8	68,8	68,8	68,8
	Brückenfläche [m²]	241	241	339	339	336	520	465	774	1049	1049	774
	Brückenklasse	60	60	60	60	30	30	60	60	60	60	60
	Hauptbaustoff Überbau	StB	StB	SpB	SpB	SpB	SpB	StB	SpB	SpB	SpB	SpB
	Bordbreite [m]											
	Bauwerkszustand	1,9	1,9	2,3	2,3	2,3	0	2,2	2,5	2,5	2,5	2,5
	Maßgebender Schaden	Ka 1,9	Ka 1,9	Se 2,3	Se 2,3	Fa 2,3		So 2,2	Ka 2,4	Ka 2,4	Ka 2,4	Ka 2,4
	Max S	Be 1,1	Be 1,1	Se 2,3	Se 2,3	Fa 2,3		So 2,2	Fa 2,1	Fa 2,1	Fu 2,1	Fa 2,1
	Max V	Be 1,1	Be 1,1	Be 2,1	Be 2,1	Fa 2,3		Ka 1,8	Se 2,0	Se 2,0	Se 2,0	Se 2,0
	Max D	Ka 1,9	Ka 1,9	Ka 1,8	Ka 1,8	Fa 2,3		Ka 1,8	Fa 2,1	Fa 2,1	Fu 2,1	Fa 2,1
MASSNAHMEN EMPFEHLUNGEN	obenliegend	A	A	ABGGG	ABGGG			G	ABG	ABG	ABG	ABG
	untenliegend	DDDD	DDDD	D	D			DD	DHDD	DHDD	DHDD	DHDD

Outline

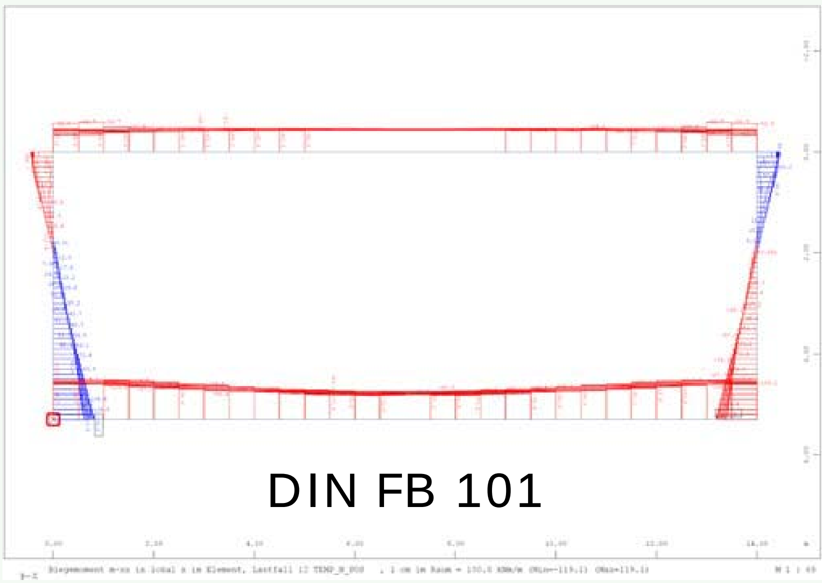
- Introduction
- Challenges
- Management
  - Inventory
  - Inspection
  - Load bearing capacity
  - Management System
- **Extreme Weather**
- Large Accidents and Explosions
- Innovation
- Summary and Conclusions

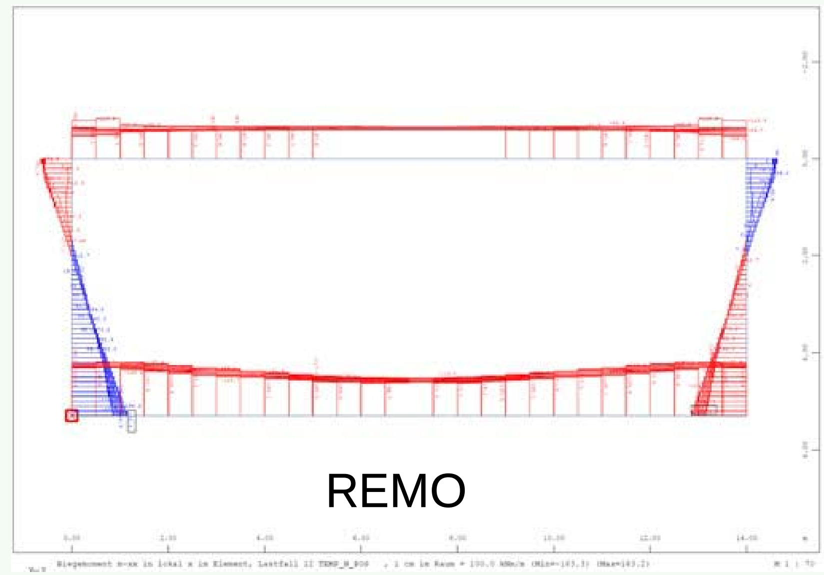
Extreme Weather



Extreme Weather – Example Concrete Frame

Load case: positive temperature gradient (DIN FB 101-2009) and relevant characteristic values from regional climate projection (REMO)





Temperature (constant and linear)

- Increase of the max. bending moment and the edge stresses by 7.5% compared to DIN FB 101
- Increase of max. bending moment and edge stress by 24% compared to DIN 1072:1967 (durability)

Extreme Weather - Conclusions

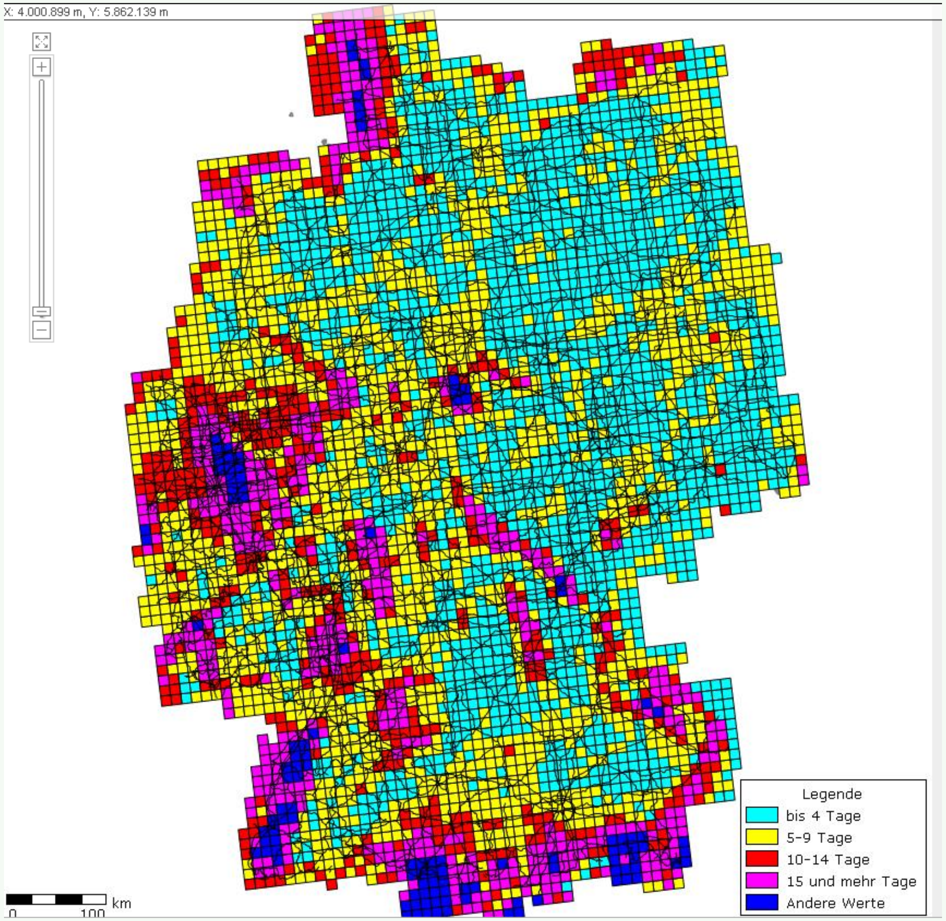
Temperature

- Design of bridge bearings
- Design of integral bridges and groups of fixed bridge piers
- Fatigue considerations

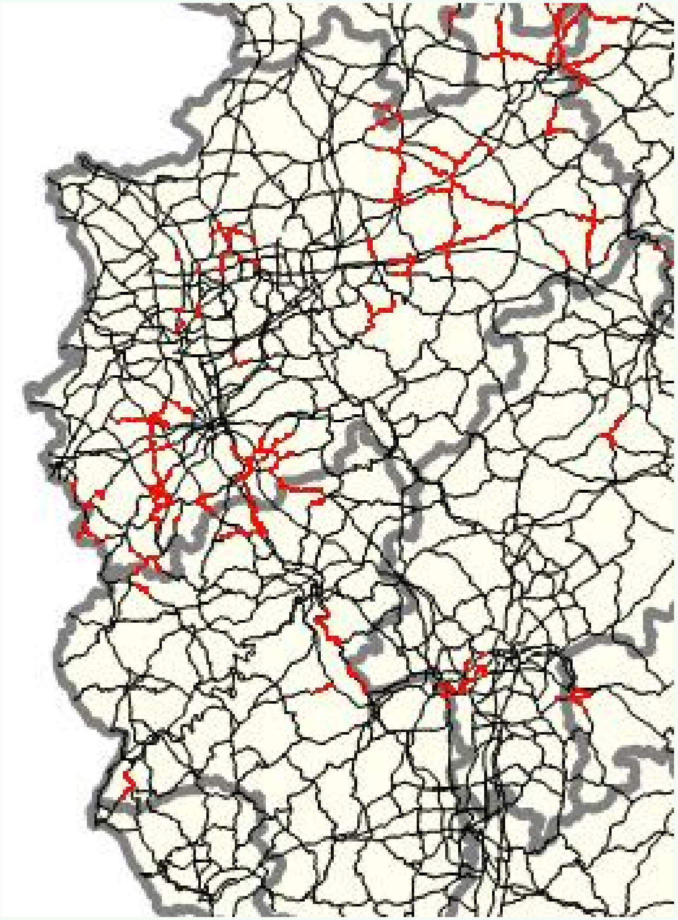
Wind

- Effects of second order for high bridges
- Reductions according to DIN FB as well as National Annexes have to be reassessed
- Bridges designed according to DIN 1072, 1967 have significant deficits in all respects

Extreme Weather – IT-System

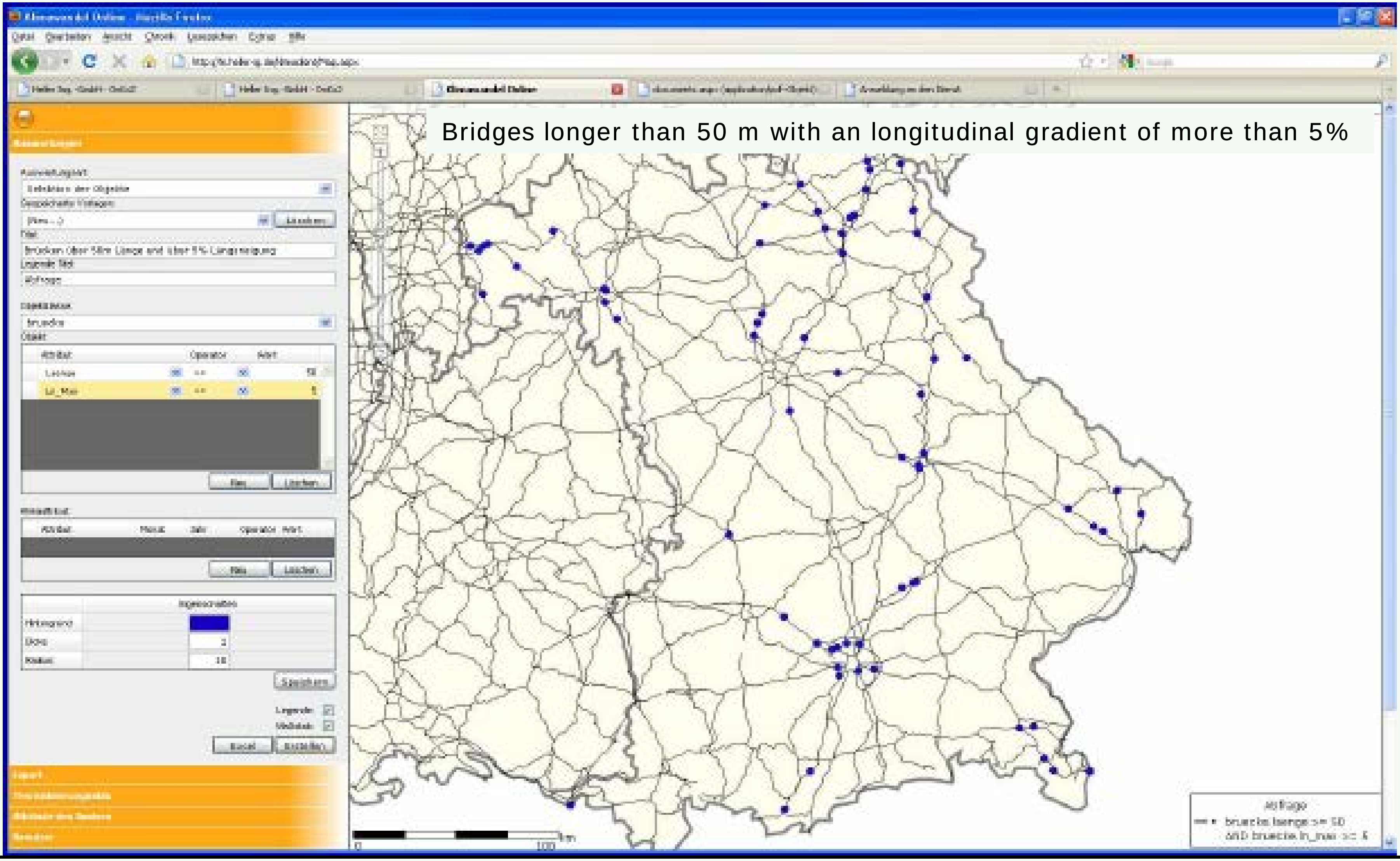


2040: Number of days with more than 20 mm/h



Road sections with qn <= 0,1 >20mm/h

Extreme Weather – IT-System



Outline

Simulation of large Fires on and under Bridges

Fire on Bridges

- Suspension Bridge, suspended deck arch bridge

Fire under Bridges

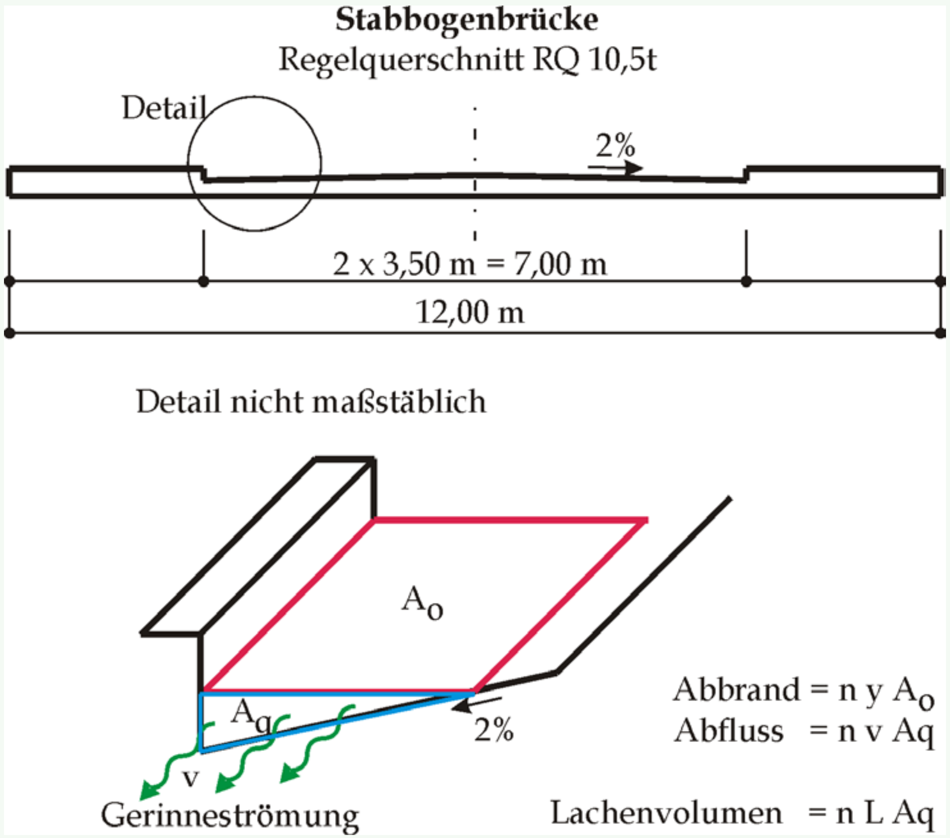
- Concrete, prestressed concrete, steel and composite bridges with slab, beam or box girder cross sections

Fire Scenarios:

- Tank truck with petrol: 20 kg/s release rate
- Tank truck with petrol: 300 kg/s release rate

Tank Truck (28t Petrol)

Fires on Bridges (suspended deck arch bridge)



Bezeichnung	Burning liquid [kg] an [%]	Drained liquid [kg] an [%]
Kuppe300G1	1.400 / 5%	26.600/ 95%
Kuppe 300G2	1.700 / 6%	26.300 / 94%
Kuppe20,6G1	5.000 / 18%	23.000 / 82%
Kuppe20,6G2	6.500 / 23%	21.500 / 77%
Neigung300G1	2.000 / 7%	26.000 / 93%
Neigung300G2	2.500 / 9%	25.500 / 91%
Neigung20,6G1	6.500 / 23%	21.500 / 77%
Neigung20,6G2	7.800 / 28%	20.200 / 72%

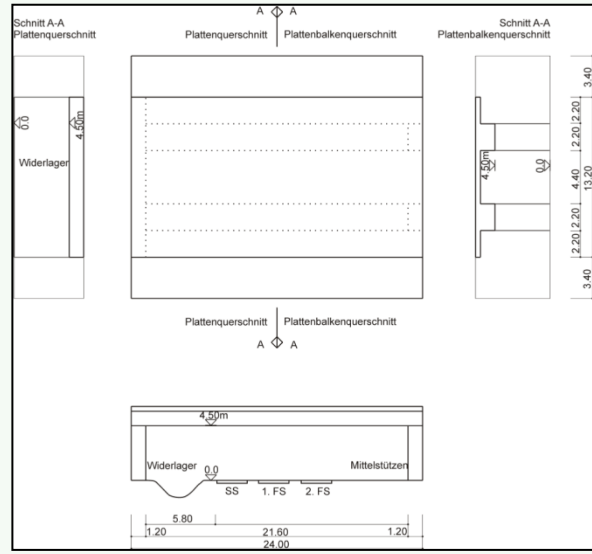
Aq Drainage Cross Section
Ao Surface
v Streaming
L Length of the Bridge
n Number of Draines

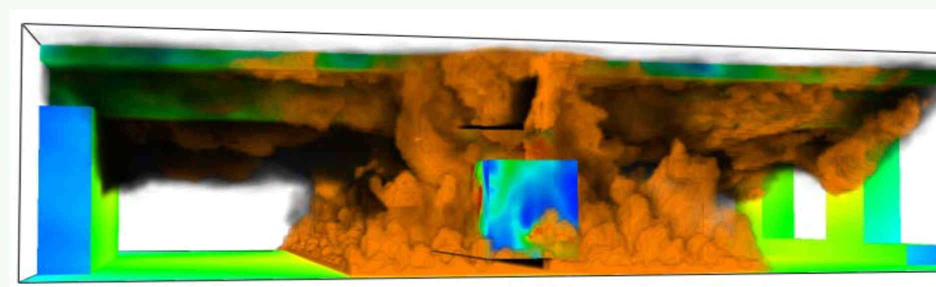
Tank Truck (28t Petrol)

Fires under Bridges

Pool fire geometry and size depend on:

- Terrain topology
- Design of Embankment
- Roadway slope
- Location of release





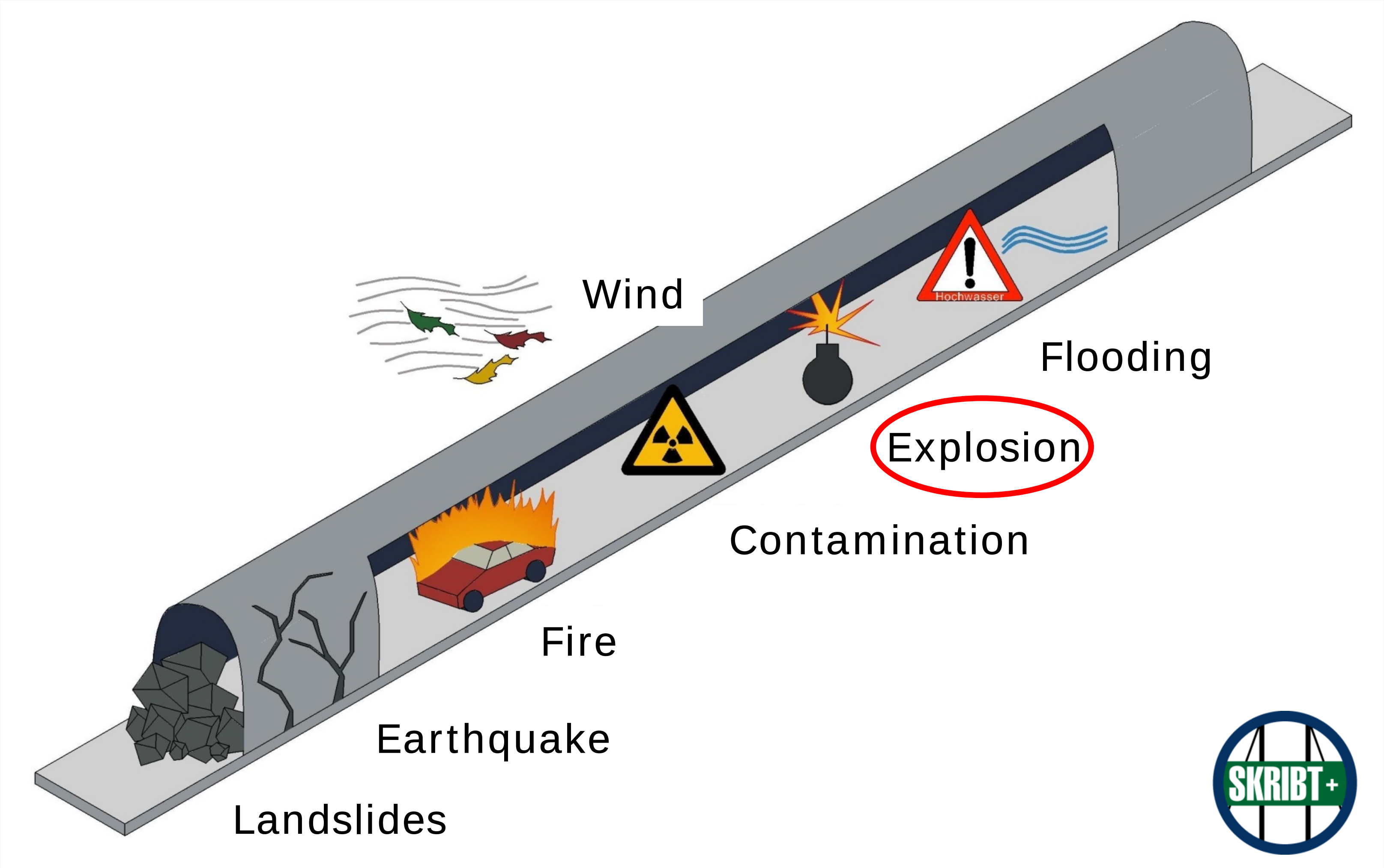
Released petrol may continue to burn in open drainages outside the bridge area
-> no effect on bridge structure

Conclusions

- Major Fires under bridges have similar characteristics as tunnel fires
  - Very high temperatures/steep temperature increases
  - Comparable to ZTV-ING-temperature-time-curve
  - Even relatively “small” fires result in temperatures >1.000 ºC (large scale test) and large areas with concrete spalling

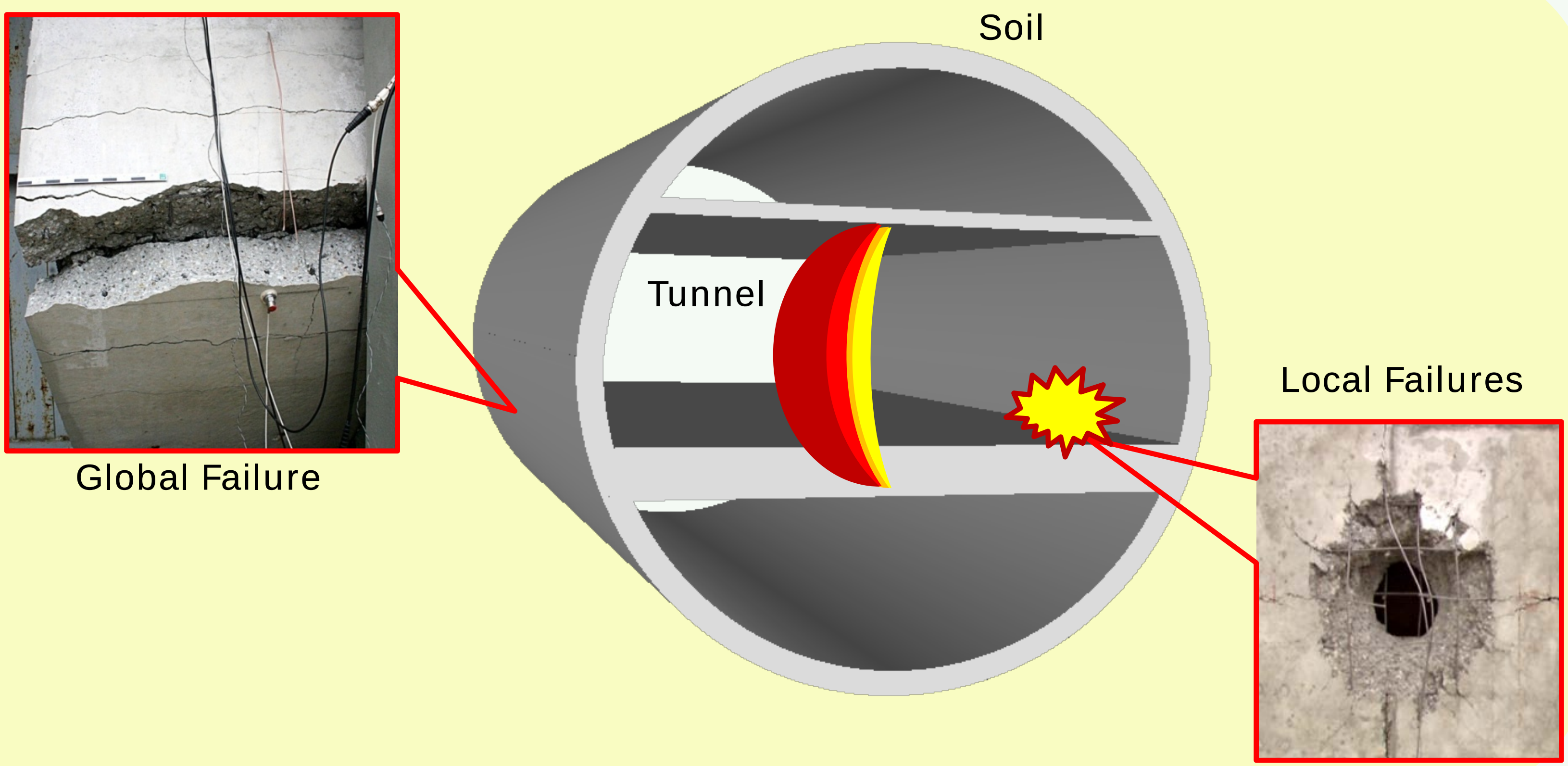
- Major Fires on Bridges lead to lower temperature loads
  - factorized ZTV-ING-temperature-time-curves
  - Load carrying members mostly thin walled steel. Therefore, possibly endangered

Threads for Road Tunnels



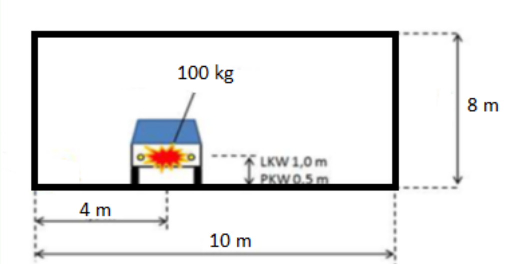
Explosions

High Speed dynamic Effects - Shield Tunnel under Blast Exposure

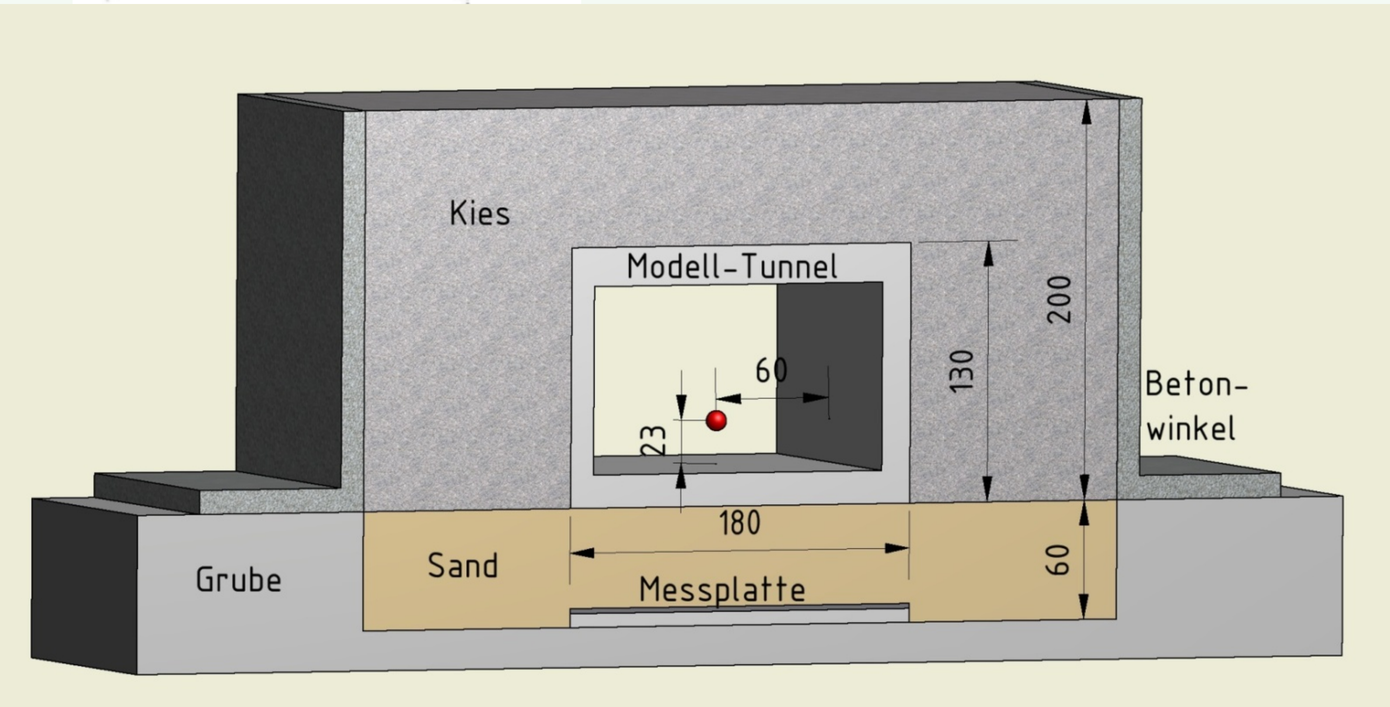


Explosions

Tunnel model tests



	Charge W (kg)	Distance R_1 (m)	Distance R_2 (m)
Original	100	0,5	4,0
Model	0,34	0,075*	0,6



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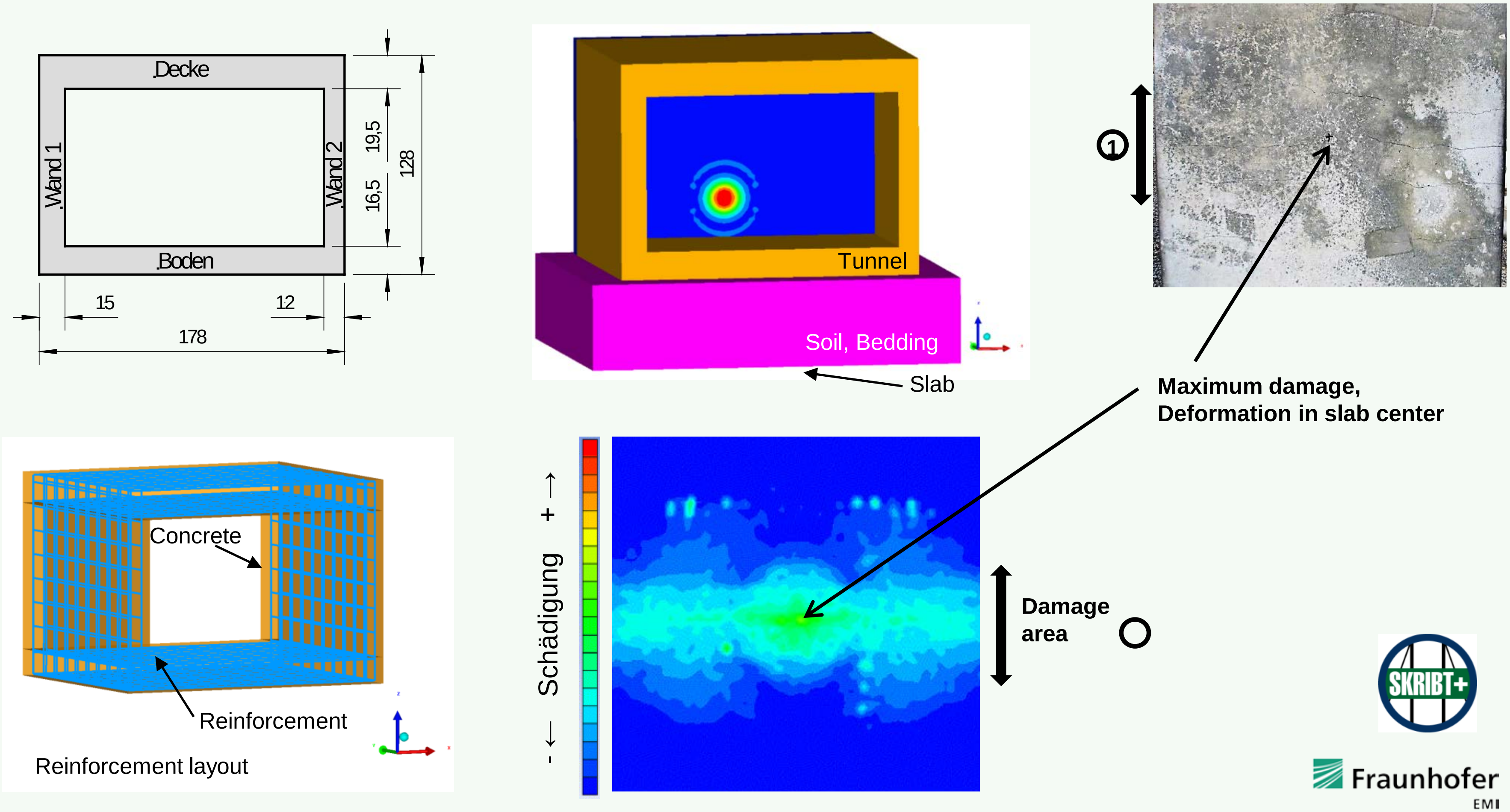
Explosions

Tunnel model tests – Numerical simulations



Conclusions for Bridges and Tunnels

- No protection measures for large explosive charges
- Small explosive charges are in general not critical for bridges and tunnels
- Where these charges are critical, protection measures are possible
  - Access prevention for box girders
  - Distance, linings for bridge cables
  - Protection layers with energy absorbing and ductile materials
  - Assessment of soil bedding

Outline

Road in the 21st Century

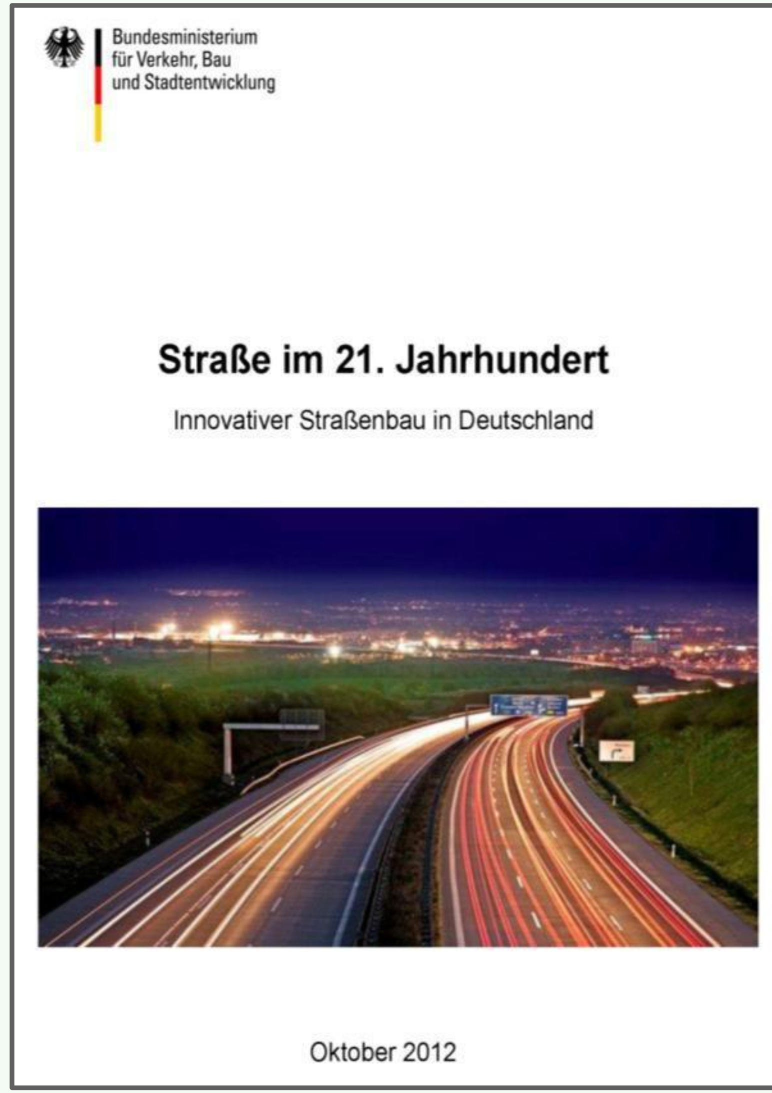
Federal Secretary of Transport:

“**Efficient, safe and reliable transport infrastructure** is a basis for growth and employment.

Road is more than concrete or asphalt. With **innovative techniques and materials** congestion and accidents can be reduced, noise and emissions lowered, and even energy could be produced. With our research program, we give the road a push of **innovation**.

This leads to a benefit for everybody: Road users, residents, economy and environment.„

www.bmvbs.de



Programmatic Key Aspects "Road in the 21st Century"

Safe and reliable

- Service Levels
- Climate Change
- Safety/Security

Intelligent

- Materials/Construction
- Alignment/Design
- IT Systems

Energy saving and delivering

- Kinetic Energy/Energy harvesting
- Photovoltaics, Thermovoltaics
- Geothermal energy
- Network Road

Low emission

- Low Noise
- Retention and reduction of emissions
- Emissions Vehicles/Road

Programmatic Key Aspects “Road in the 21st Century”

Part of the habitat

- Roads and Landscape
- Road and urban Environment
- Road and aging Society

Sustainable

- Closed loop recycling
- Lifecycle Management
- Maintenance-/Asset-Management

Carrier for innovation

- Boundary conditions
- Funding instruments
- From innovation into practice (pilot applications)

Outline

- Introduction
- Challenges
- Bridge Management
  - Bridge Inventory
  - Bridge Inspection
  - Load bearing capacity of existing bridges
  - Bridge Management System
- Extreme Weather
- Large Accidents and Incidents (security)
- Innovation
- **Summary and Conclusions**

Summary and Conclusions

- Aging Infrastructure contributes to reduced availability
- Aging infrastructure can lead to additional risks
- Regular inspections and assessments together with a risk management approach are indispensable
- Effects from extreme weather (Climate Change) are to be taken into account in long term infrastructure management
- Upgrading and/or replacement are to be planned with regard to the criticality of infrastructure objects (network level)

Holistic Management of Road Infrastructure
(lifecycle and risk based)

Thank You very much for your kind attention!

Additional information:
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