

AUTOSTRADA POLSKA 2015 / Kielce
21st Int. Fair of Road Construction Industry
Safety of Noise Barriers
 Lecture Notes on invitation by ENBF



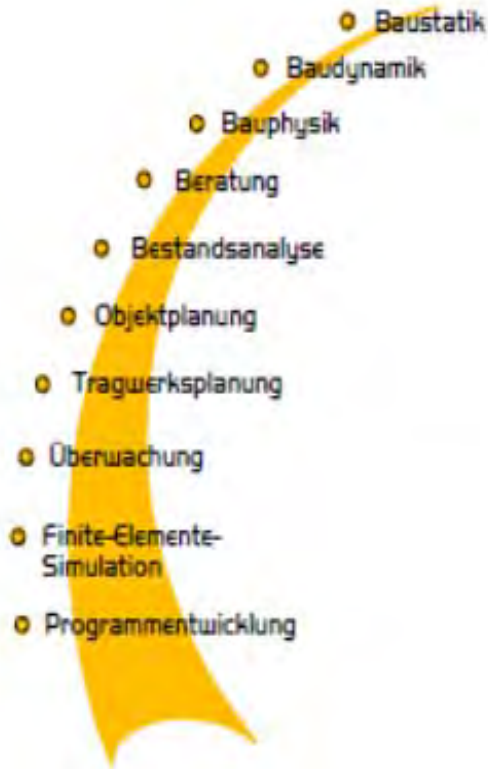
ingenieurbüro bau + fe
 dipl.-ing. volker claus falk
 + bauen ++ forschen ++ entwickeln +
 ingenieurkammer baden-württemberg
 freiwilliges mitglied nr. 4293



marienburger str. 16
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 fon: +49 - 015 22 - 195 75 09
 vcf@bauplusfe.de

Overview on person and profession

Name: Volker Claus Falk
 Profession: Civil Engineer, Diploma, Karlsruhe University
 1990, Germany
 Free Consultancy since 2000
 Cooperations: Various German Noise Barrier Producers
 DVLV, Germany
 ENBF, Belgium
 Working field: Structural Engineering / Structural Analysis
 Screens along roads and rails
 Material testing
 Transparent Materials
 Quality Control
 Interests: Structural Safety and Reliability
 Nonlinear Behaviour of Structures
 Beam and Truss Structures
 Behaviour of thin Plates (IIIrd Order)
 Structures with Changing Properties



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Structural Safety - A Matter of Files in a Web

Shown for Acoustic Screens

- Baustatik
- Baudynamik
- Bauphysik
- Beratung
- Bestandsanalyse
- Objektplanung
- Tragwerksplanung
- Überwachung
- Finite-Elemente-Simulation
- Programmentwicklung

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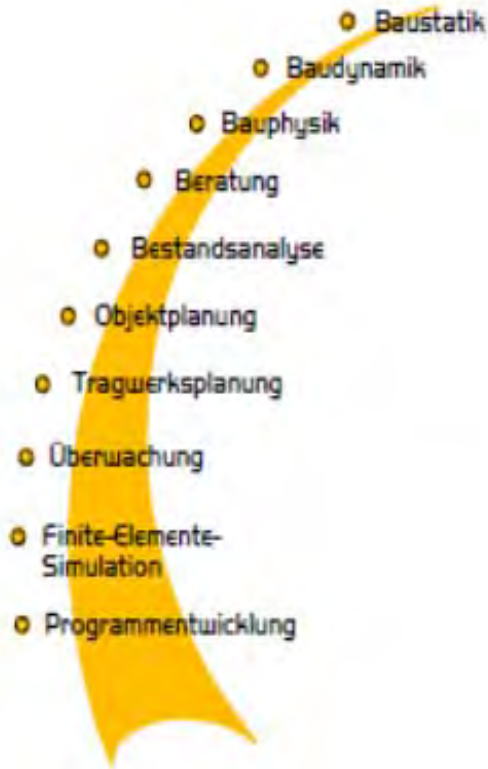


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CONTENT



- The Situation
- Materials
- Actions and Resistances
- Standards
- Design Concepts
- Economic Efficiency
- Procurement
- Production
- Workers
- The Quality-Web
- “What if ...”
- Conclusions
- Examples
- Summary

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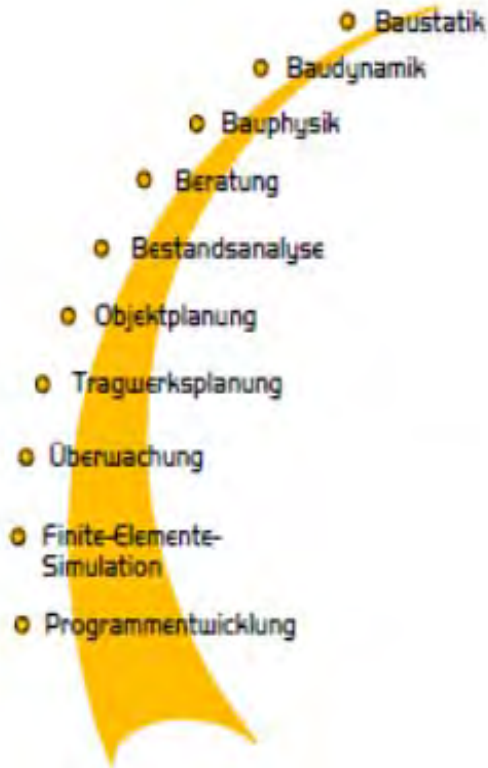
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THE SITUATION FOR SOUNDSCREEN BUILDING

- High Acoustic and Structural Requirements
- Different Materials (steel, aluminium, transparent sheets, ...)
- Different Actions (wind, ...) & Scattering Resistances (material)
- Various Design Standards (EC, 1990, 1991, 1993, 1999 etc.)
- New Design Concepts (semiprobabilistic safety)
- Hard Terms of Economic Efficiency
- Short and Complicate Procurement Situations
- Complex Assembling Processes
- Unskilled Workers with Little Motivation
- Complex Delivery and Mounting Situations
- Changing Usage Conditions



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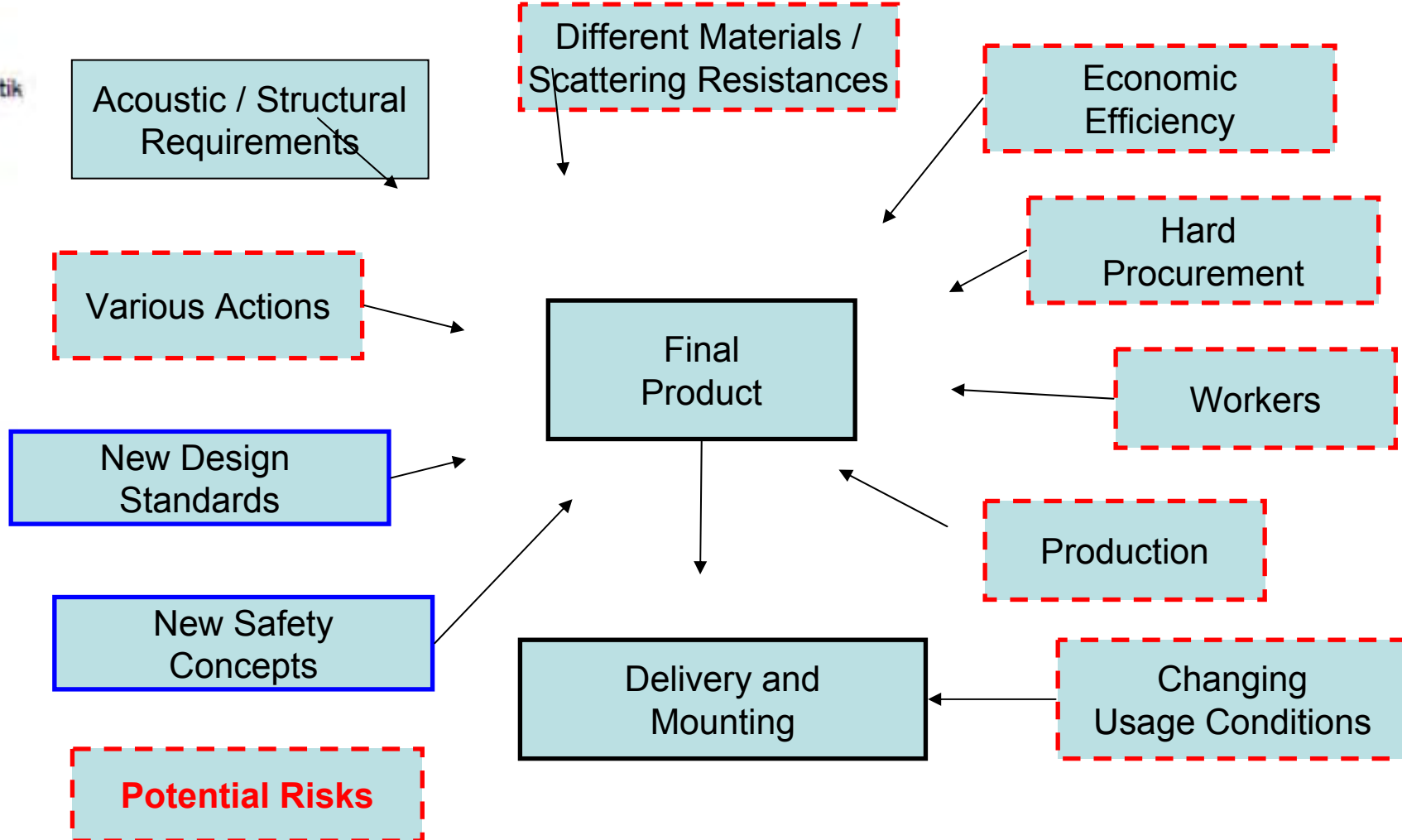
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THE SITUATION

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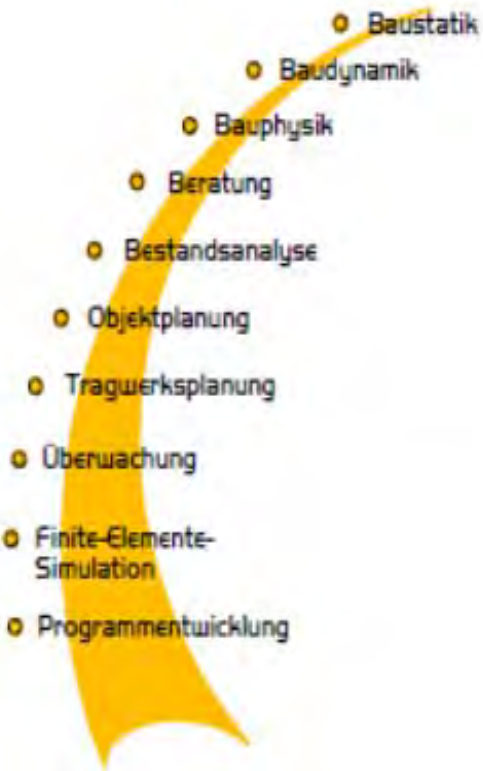


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SAFETY FOR SOUNDSCREENS IMPOSSIBLE ?!?

First Impression:

- Many Risks
- Little Chances
- Hard to achieve
- New Regulations in Standards
- New “European Requirements”



Let's have a more detailed look !



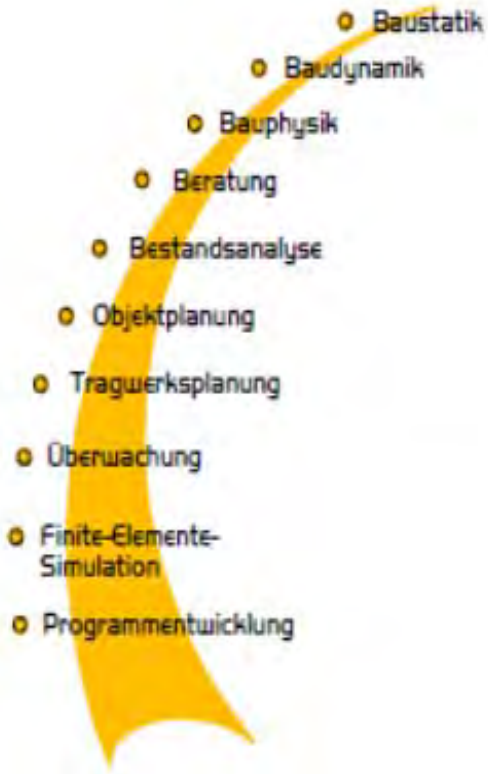
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MATERIALS

- Steel
- Aluminium
- Transparent Sheets (acrylics, polycarbonate, glass)
- Insulating Materials (mineral wool, hemp, ...)
- Cement Fibre Sheets
- Wood
- Various Others

Each of this materials has specific resistance values that scatter around a mean value

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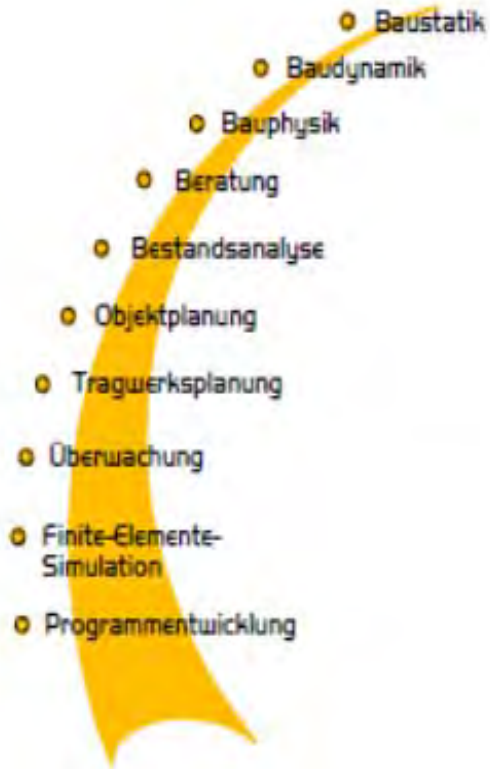
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ACTIONS

- **Wind Load**
- **Special Wind Load on Bridges**
- **Dynamical Impacts along rails**
- **Various Others**

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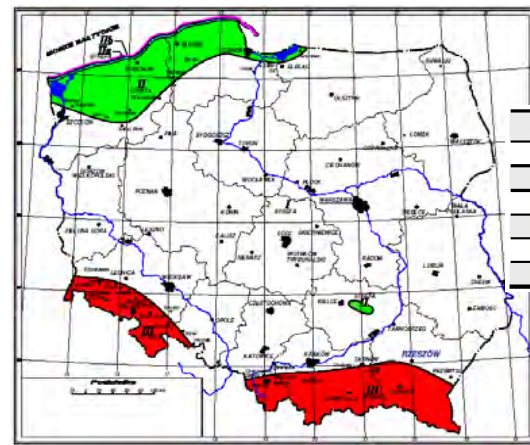


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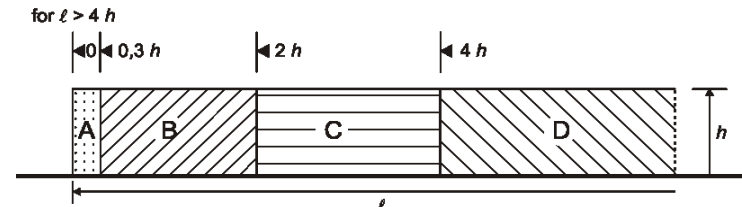
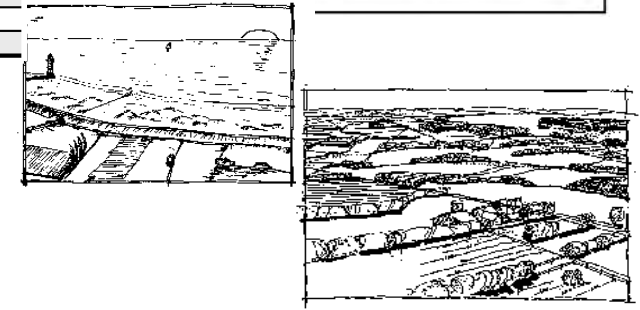
Wind loads

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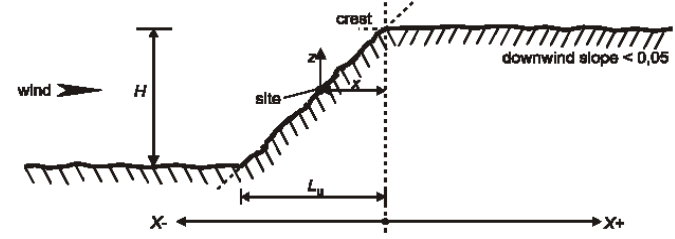
Strefa	V_k m/s	q_k Pa
I	20	250
II (III 200m.n.p.m.)	24	350
II a (III 400m.n.p.m.)	27	450
II b (III 600m.n.p.m.)	30	550
III	24-47*	**

Terrain category	z_0 m	z_{min} m
0 Sea or coastal area exposed to the open sea	0,003	1
I Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5
Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10



Solidity	Zone	Zone				
		A	B	C	D	
$\phi = 1$	Without return corners	$l/h \leq 3$	2,3	1,4	1,2	1,2
		$l/h = 5$	2,9	1,8	1,4	1,2
		$l/h \geq 10$	3,4	2,1	1,7	1,2
$\phi = 0,8$	with return corners of length $\geq h^a$		2,1	1,8	1,4	1,2
			1,2	1,2	1,2	1,2

^a Linear interpolation may be used for return corner lengths between 0,0 and h



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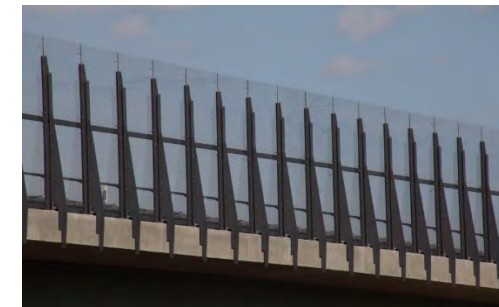
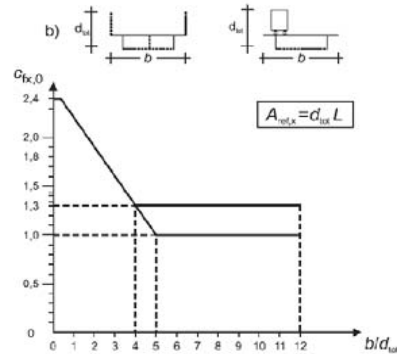
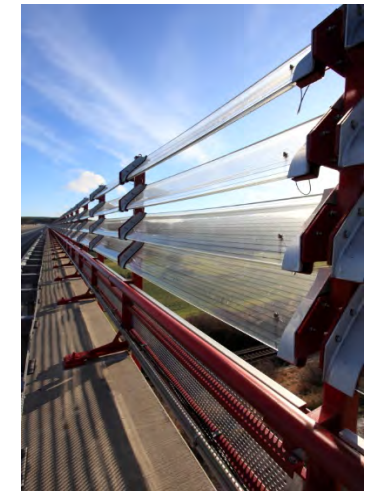
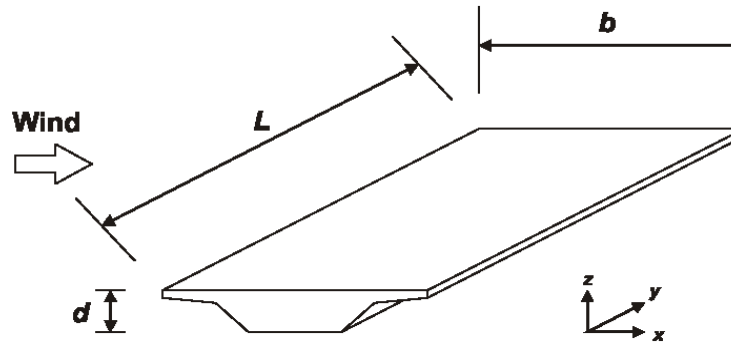
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Wind loads on bridges



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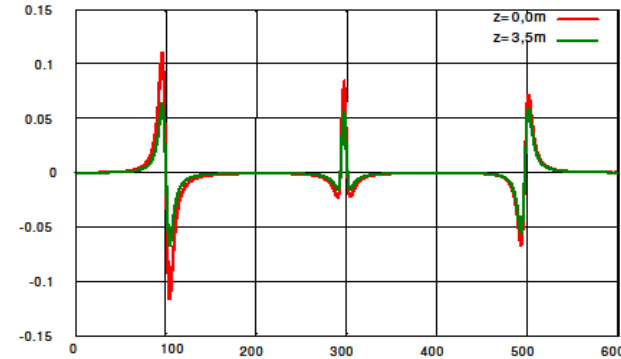
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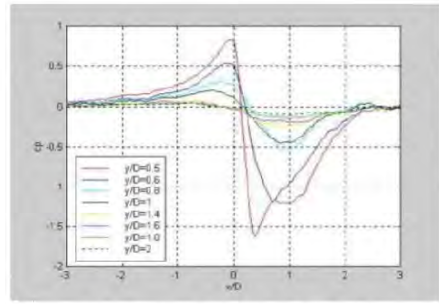
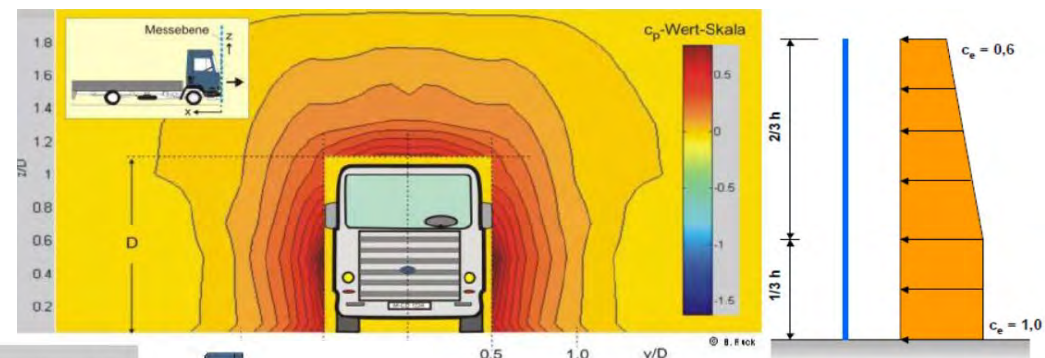
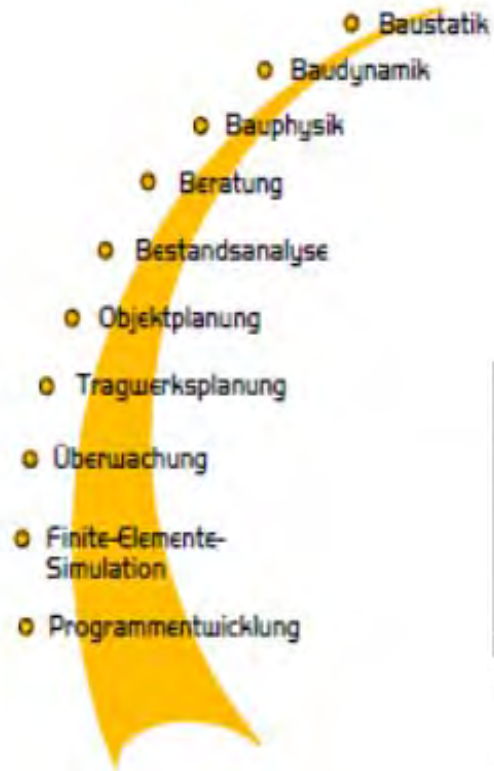
Dynamic loads along railways

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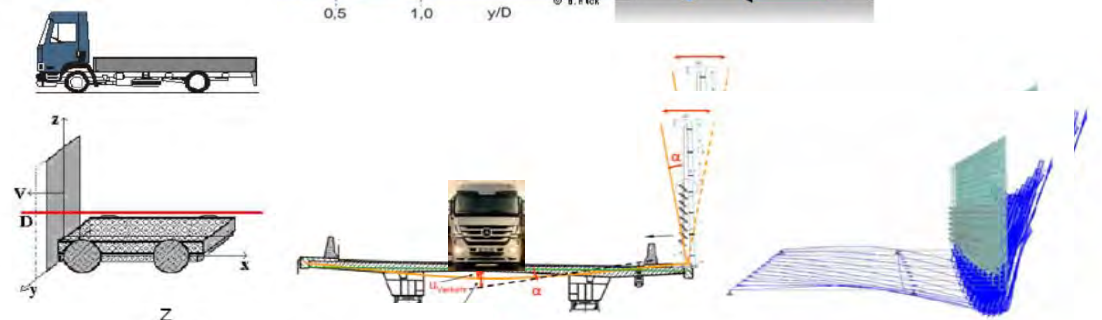




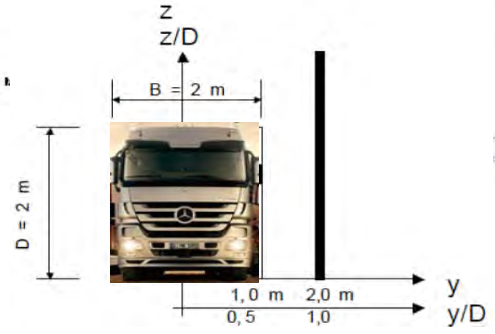
Dynamic loads along roads



Profiles of c_p along x direction for $z/D=0.5$



"Pressure Fluctuations Induced by Road Vehicles in Ambient Air - A I
 I. U. Macciachera¹ & B. Ruck²



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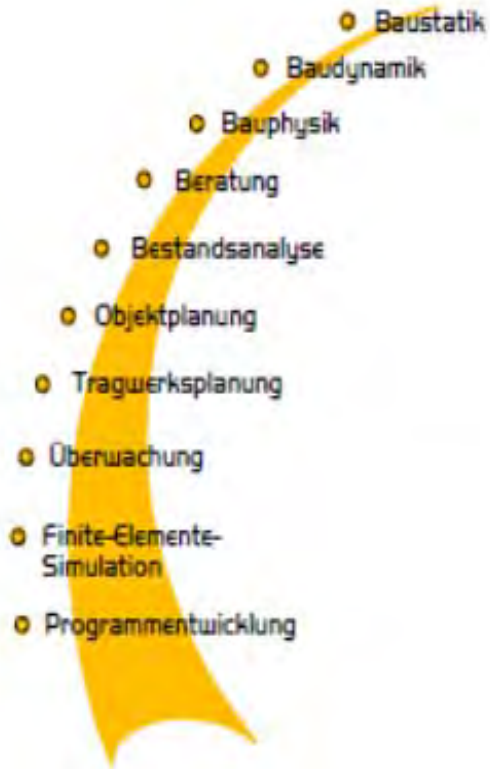
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Other actions

- Temperature
- UV Radiation
- Chemicals
- Stonechipping
- Brushfire
- Danger of Falling Debris
-

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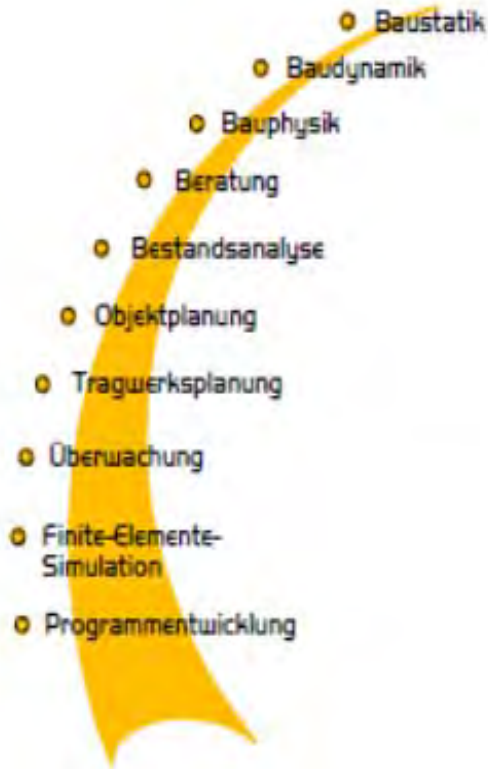
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THE STANDARDS

- **Delivery Standards (steel: EN 10025, aluminium: EN 573)**
- **Design Standards (EUROCODES, 1990, 1991, 1993, 1999)**
- **Process Standards (FPC acc. EN 14388 / [ISO 9001])**
- **CE Mark (EU directives: 89/106/EEC, 93/68/EEC
 EU regulation 305/2011)**
- **Quality Seals (e.g. RAL, TÜV, ...)**
- **Specific National Regulations**



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Material Standards

EN 10025

Steel

EN 573

Aluminium

ISO 7823

Acrylics

.....

.....

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Construction Design Standards

	EN 1990	
	EN 1991	
	EN 1993 (steel)	
	EN 1995 (wood)	
	EN 1999 (aluminium)	

Basic concepts

Actions

Materials

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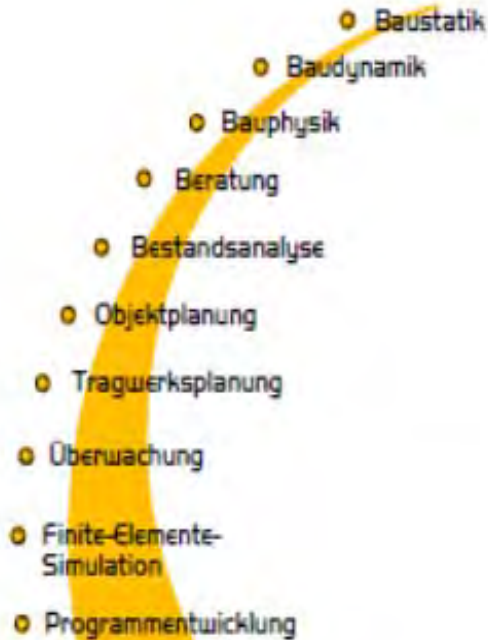
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QUALITY MANAGEMENT

- CE (EN 14388, 14389) – FPC
- EN 1090 (steel, aluminium)
- [ISO 9001]



PROFILIEN

De Lier, 4 april 2012

Werkbescheinigung für EN

Hiermit bestätigt BOAL B.V., dass alle an entsprechenden, welche in unseren Auftragsbe

Diese Spezifikationen umfassen sowohl die Materialie, als auch die mechanischen Eiger

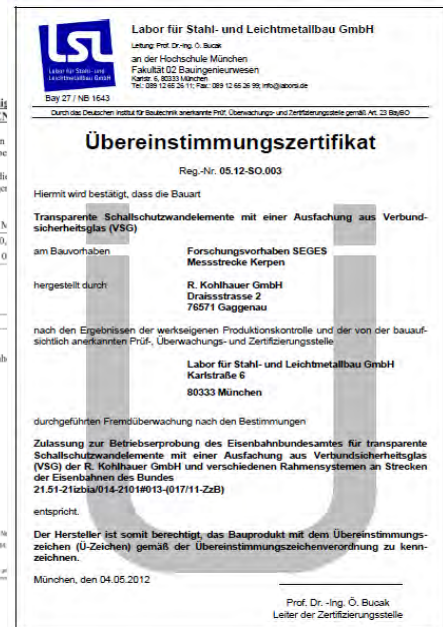
Chemische Zusammensetzung:

	Si	Fe	Cu	Mn	h
Min.	0,2				0,
Max.	0,6	0,35	0,1	0,1	0

Mechanisch Eigenschaften:

	Rp0,2	Rm
	N/mm ²	N/mm ²
Min.	200	245

Wir hoffen Sie hiermit zu Ihrer Zufrieden



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CE Marks

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<p>Notified body # 1350 M-Report 1360/05/04/17 24.01.2011</p>			
<p>Notified body # 0500 HM Type Test 5.2.11/0005-1 2012/01-19</p>			
<p>EN 14388:2005 Noise barrier for reduction of traffic and all other noise, acoustically transparent and insulating.</p>		<p>EN 14388:2005 Transparent noise barrier for reducing traffic and all other noise, acoustically reflective.</p>	
<p>Acoustic element type: KOHLHAUER[®] ALUPERA</p> <p>Standard size L x H x H (mm): 3.000/3.000 x 2.000/2.000 x 4.300/4.300</p> <p>Element thickness T (mm): 0,122</p> <p>Steel girth a₁ (mm) x a₂ (mm): 1,6/6,7/20/20/200 x 6/6/10/10/10/200</p> <p>Post type: HE-A-B-S-M (A₁) 100/100/200</p>		<p>Acoustic element type: KOHLHAUER[®] SICOBSA PRIME-B 01-10</p> <p>Standard size L x H x H (mm): 3.000/3.000 x 2.000/2.000 x 4.300/4.300</p> <p>Element thickness T (mm): 0,122</p> <p>Steel girth a₁ (mm) x a₂ (mm): 1,6/6,7/20/20/200 x 6/6/10/10/10/200</p> <p>Post type: HE-A-B-S-M (A₁) 100/100/200</p>	
<p>Dry weight (kN): 0,97 1,38 2,06</p> <p>Reduced wet weight (kN): 1,92 3,43 5,79</p>		<p>Dry weight: 1,7 kN</p> <p>Reduced wet weight: 1,71 kN</p>	
<p>Resistance to loads:</p> <p>Wind and dead load (kN/m²): 1,40 1,22 0,98</p> <p>Vertical load (kN/m): 4,67 4,51 4,43</p> <p>Snow clearance (dyn-load) (kN/2 x 5 m): 15,00 3,68 1,82</p>		<p>Resistance to loads:</p> <p>NBP: 25 dB</p> <p>Maximum vertical load: NPD</p> <p>Normal (NPD) load (due to wind): 1,31 kN/m²</p> <p>Normal (NPD) load (due to wind) (static external and self weight): NPD</p> <p>Bending moment at ground level (due to snow clearance): 2,22 kNm</p> <p>Normal (NPD) load (due to snow clearance): 0,22 kN/2x2 m</p>	
<p>Other resistances:</p> <p>Inward of stones: Filled</p> <p>Pre (anti-rust): Class 1</p>		<p>Inward of stones: Filled</p> <p>Pre (anti-rust): Class 1</p>	
<p>Acoustics:</p> <p>Sound Absorption: α_w(dB): 11 / Gruppe A2</p> <p>Sound Insulation: ΔL_w(dB): 28 / Gruppe B3</p>		<p>Acoustics:</p> <p>Sound Absorption: α_w(dB): 11 / Gruppe A2</p> <p>Sound Insulation: ΔL_w(dB): 28 / Gruppe B3</p>	
<p>Durability:</p> <p>Estimated service life, acoustical / structure (years): 15 / 30</p>		<p>Durability:</p> <p>Estimated service life, acoustical / structure (years): 30 / 30</p>	

<p>Notified body # 1350 M-Report 1360/05/04/17 24.01.2011</p>			
<p>Notified body # 0500 HM Type Test 5.2.11/0005-1 2012/01-19</p>			
<p>EN 14388:2005 Noise barrier for reduction of traffic and all other noise, acoustically transparent and insulating.</p>		<p>EN 14388:2005 Transparent noise barrier for reducing traffic and all other noise, acoustically reflective.</p>	
<p>Acoustic element type: KOHLHAUER[®] ALUPERA</p> <p>Standard size L x H x H (mm): 3.000/3.000 x 2.000/2.000 x 4.300/4.300</p> <p>Element thickness T (mm): 0,122</p> <p>Steel girth a₁ (mm) x a₂ (mm): 1,6/6,7/20/20/200 x 6/6/10/10/10/200</p> <p>Post type: HE-A-B-S-M (A₁) 100/100/200</p>		<p>Acoustic element type: KOHLHAUER[®] SICOBSA PRIME-B 01-10</p> <p>Standard size L x H x H (mm): 3.000/3.000 x 2.000/2.000 x 4.300/4.300</p> <p>Element thickness T (mm): 0,122</p> <p>Steel girth a₁ (mm) x a₂ (mm): 1,6/6,7/20/20/200 x 6/6/10/10/10/200</p> <p>Post type: HE-A-B-S-M (A₁) 100/100/200</p>	
<p>Dry weight (kN): 0,97 1,38 2,06</p> <p>Reduced wet weight (kN): 1,92 3,43 5,79</p>		<p>Dry weight: 1,7 kN</p> <p>Reduced wet weight: 1,71 kN</p>	
<p>Resistance to loads:</p> <p>Wind and dead load (kN/m²): 1,40 1,22 0,98</p> <p>Vertical load (kN/m): 4,67 4,51 4,43</p> <p>Snow clearance (dyn-load) (kN/2 x 5 m): 15,00 3,68 1,82</p>		<p>Resistance to loads:</p> <p>NBP: 25 dB</p> <p>Maximum vertical load: NPD</p> <p>Normal (NPD) load (due to wind): 1,31 kN/m²</p> <p>Normal (NPD) load (due to wind) (static external and self weight): NPD</p> <p>Bending moment at ground level (due to snow clearance): 2,22 kNm</p> <p>Normal (NPD) load (due to snow clearance): 0,22 kN/2x2 m</p>	
<p>Other resistances:</p> <p>Inward of stones: Filled</p> <p>Pre (anti-rust): Class 1</p>		<p>Inward of stones: Filled</p> <p>Pre (anti-rust): Class 1</p>	
<p>Acoustics:</p> <p>Sound Absorption: α_w(dB): 11 / Gruppe A2</p> <p>Sound Insulation: ΔL_w(dB): 28 / Gruppe B3</p>		<p>Acoustics:</p> <p>Sound Absorption: α_w(dB): 11 / Gruppe A2</p> <p>Sound Insulation: ΔL_w(dB): 28 / Gruppe B3</p>	
<p>Durability:</p> <p>Estimated service life, acoustical / structure (years): 15 / 30</p>		<p>Durability:</p> <p>Estimated service life, acoustical / structure (years): 30 / 30</p>	

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 + bauen ++ forschen ++ entwickeln +
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DESIGN CONCEPTS

- **Scattering Action and Resistance Values**
- **Partial Safety Factors**
- **Ultimate Limit States**

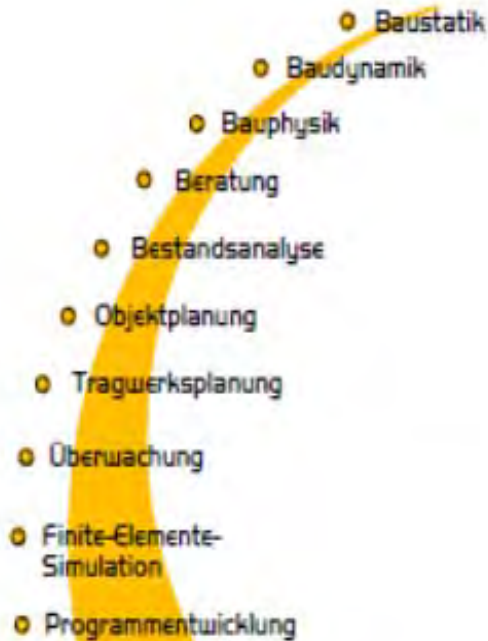
EQU **Loss of equilibrium**

STR **Internal Failure / Excessive Deformations**

GEO **Failure of the Ground**

FAT **Fatigue Failure**

- **Interaction Rules**
- **Safety Proofs**



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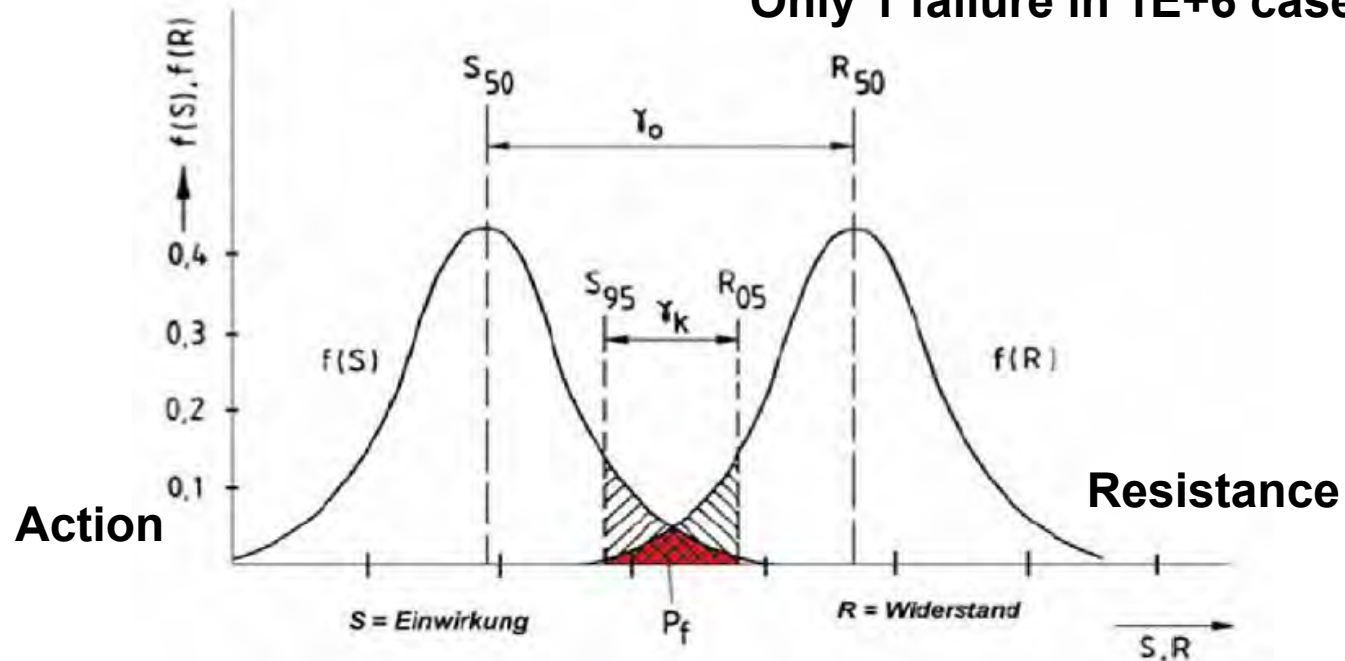
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Partial Safety Factors

Similar to “6-σ concept“ for car building:
 Only 1 failure in 1E+6 cases



- Baustatik
- Baudynamik
- Bauphysik
- Beratung
- Bestandsanalyse
- Objektplanung
- Tragwerksplanung
- Überwachung
- Finite-Elemente-Simulation
- Programmentwicklung



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Basic structural concepts

Table 2.9. ULS classification

Notation	Definition
EQU	Loss of static equilibrium of the structure or any part of it considered as a rigid body, where : - minor variations in the value or the spatial distribution of actions from a single source are significant (e.g. self-weight variations) - the strengths of construction materials or ground are generally not governing
STR	Internal failure or excessive deformation of the structure or structural members, including footings, piles, basement walls, etc., where the strength of construction materials of the structure governs
GEO	Failure or excessive deformation of the ground where the strengths of soil or rock are significant in providing resistance
FAT	Fatigue failure of the structure or structural members.

Ultimate limit states
acc. EN 1990

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Interaction rules

$$E_d = \sum_{j \geq 1} \gamma_{G,j} \cdot G_{k,j} \oplus \gamma_{Q,1} \cdot Q_{k,1} \oplus \sum_{i > 1} \gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_{k,i}$$

Safety proofs

$$\gamma_F \cdot S \leq \frac{R}{\gamma_M}$$

Typical safety factors

$$\gamma_F = 1,5 / 1,35$$

$$\gamma_M = 1,1$$

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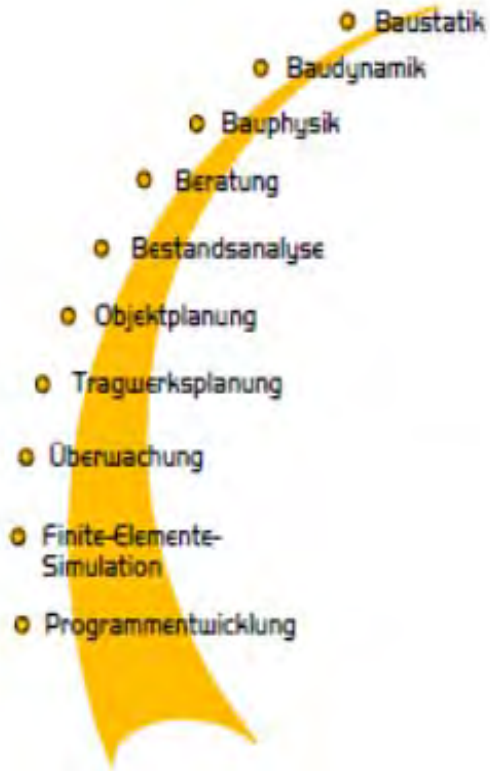
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ECONOMIC EFFICIENCY

- **European Economic Crisis**
- **Extreme Expenses**
- **Shift of Values**
- **Profit Maximization**

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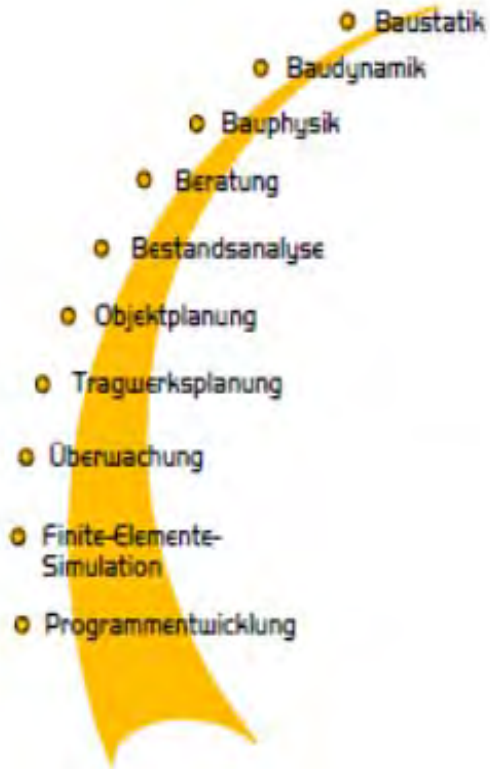
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SHORT PROCUREMENT CYCLES

- Slow Planning Decisions
- Hard Competition
- Long Contract Negotiations
- Little Stocking
- Factory Shutdowns
- Low Quality Products
- High Prices

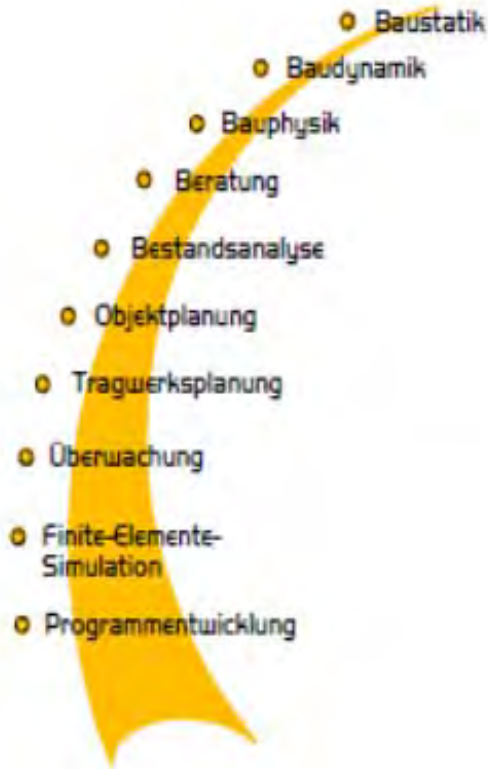
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PRODUCTION PROCESS

- Time Pressure
- Economic Pressure
- Problems with Material Availability
- Complex Processes
- “Optimized” Production Places

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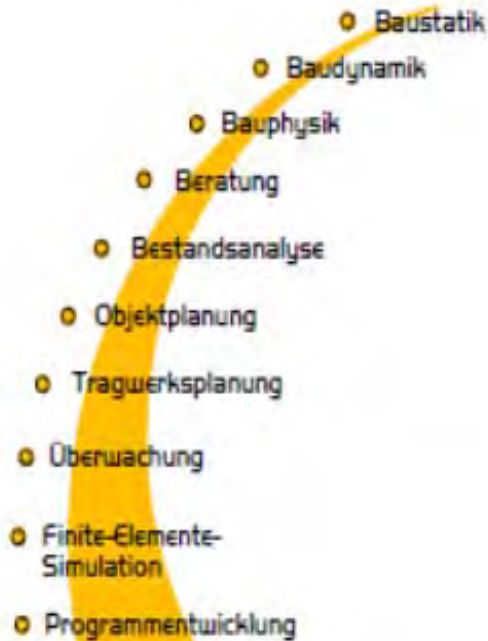
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WORKERS – “THE HUMAN FACTOR”

- Few Skilled Workers
- Bad Work Habits
- Stress
- Subcontracted Workers
- Little Stress Resistance
- Poor Concentrativeness



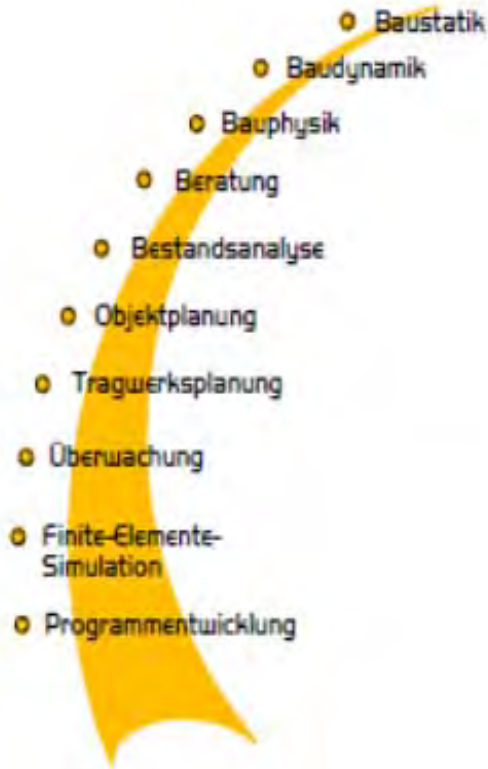
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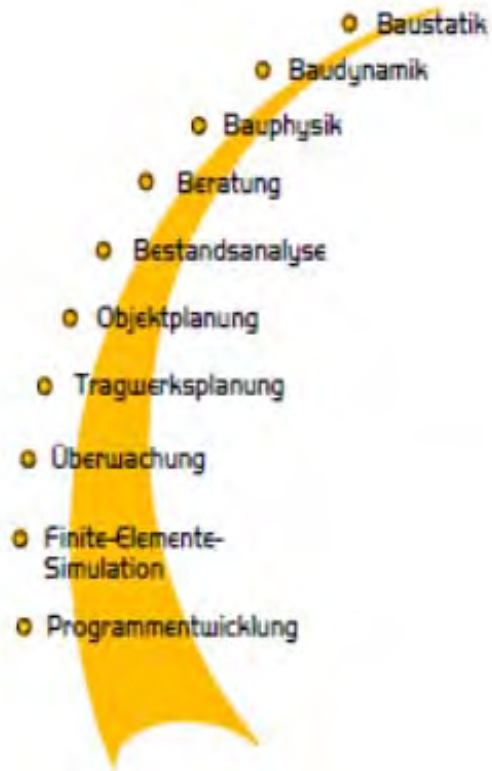


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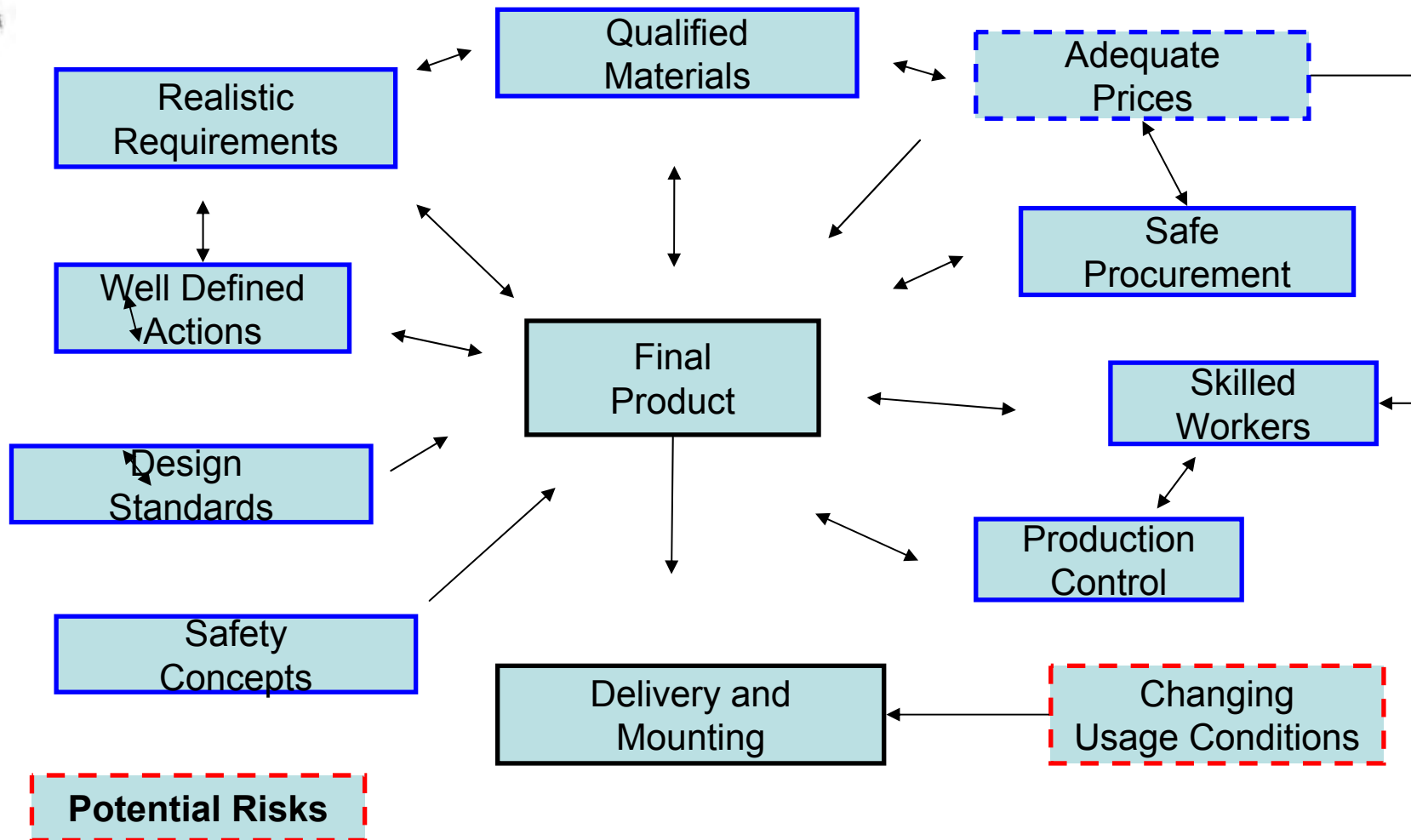


THE MEMBERS OF SAFETY

- Realistic Requirements
- Well Defined Actions
- Qualified Materials
- Design acc. Standards
- Safety Concepts
- Safe Procurement
- Skilled Workers
- Assembling Control
- Safe Transport
- Careful Mounting



IMPROVEMENTS



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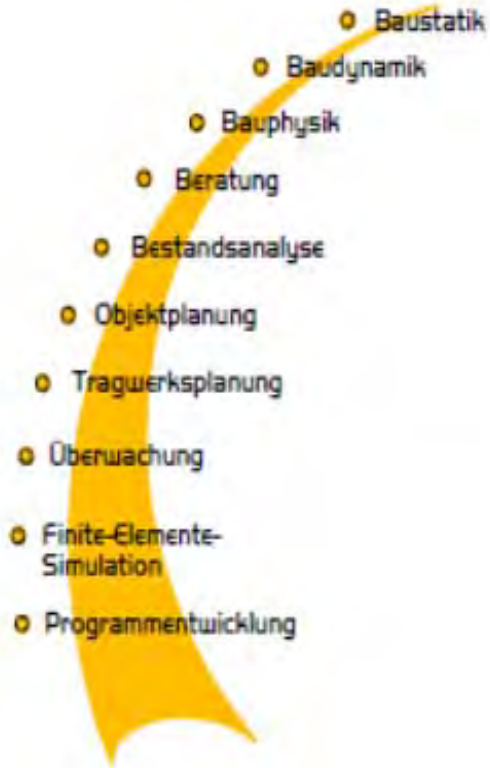
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WHAT IF ?

- Even single file failure can lead to severe problems

BUT:

- Multi-file failure reduces security level significantly
- Risk of damage will rise
- Risk of injuries and even deaths will occur
- In case of extreme actions danger of catastrophe



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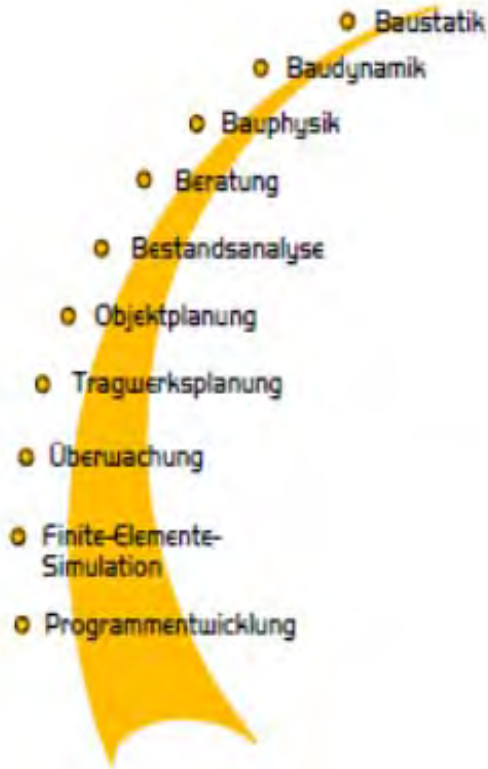
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CONCLUSIONS

- **Material, Design: In normal cases no problem**

BUT:

- **Needs for money saving: “Cheap materials”**
- **Procurement: Delivery times, wrong grades**
- **Production Process: Failure sensitive**
- **Workers: “The human factor” / Faults**



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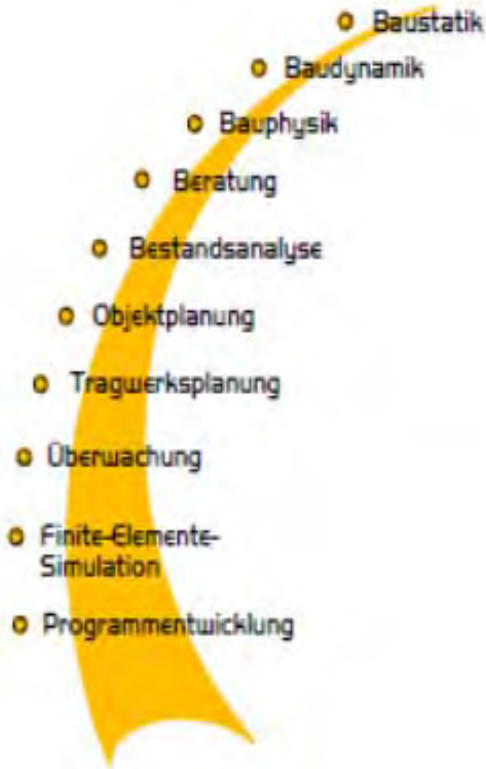
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HOW TO IMPROVE SAFETY

- Careful Design / Realistic Structural Models
- Quality Management in any Production Step
- Input / Output Control
- Factory Production Control (FPC)
- External Surveyance
- Customers Feedback

SOME DETAILS:

- Documentations
- Measurement Protocols
- Unique Product Identification
- Document Management



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FINAL RESULT

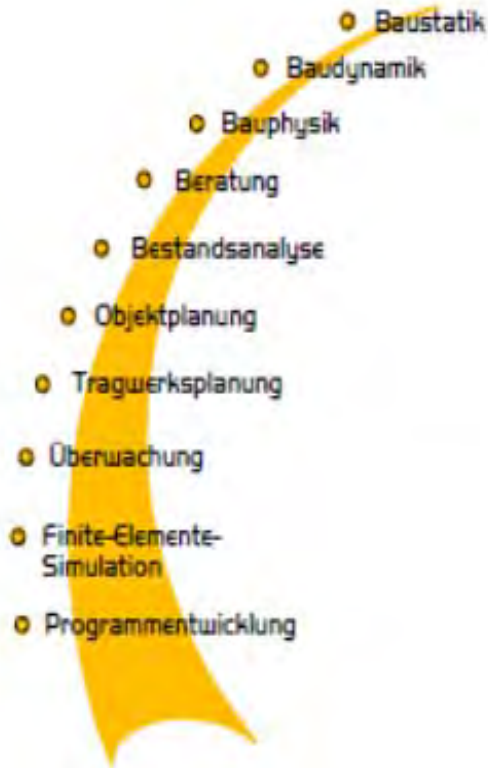
SAFETY FOR SOUNDSCREENS IS POSSIBLE !!!

BUT:

- Detailed Quality Control Needed

THUS:

**SAFE SOUNDSCREENS
CANNOT BE CHEAP
AND VICE VERSA**



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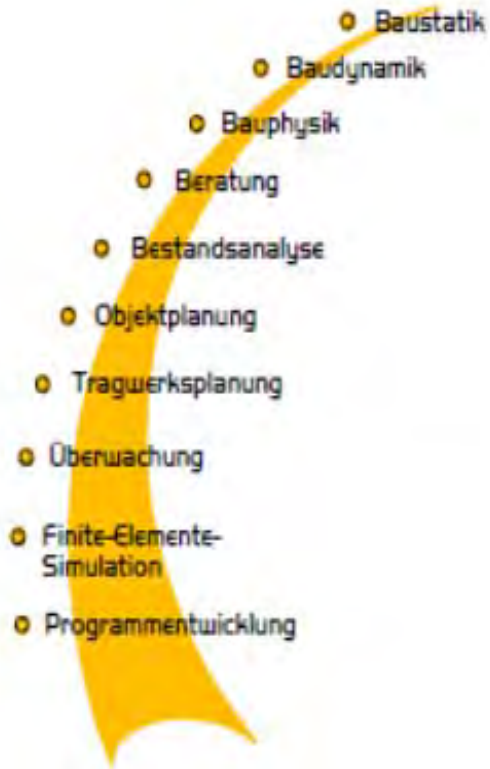
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Examples for Realized Quality in Europe

- GERMANY
- POLAND
- FRANCE
- LATVIA
- ITALY
- SOUTHERN EUROPE



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GERMANY

- Baustatik
- Baudynamik
- Bauphysik
- Beratung
- Bestandsanalyse
- Objektplanung
- Tragwerksplanung
- Überwachung
- Finite-Elemente-Simulation
- Programmentwicklung



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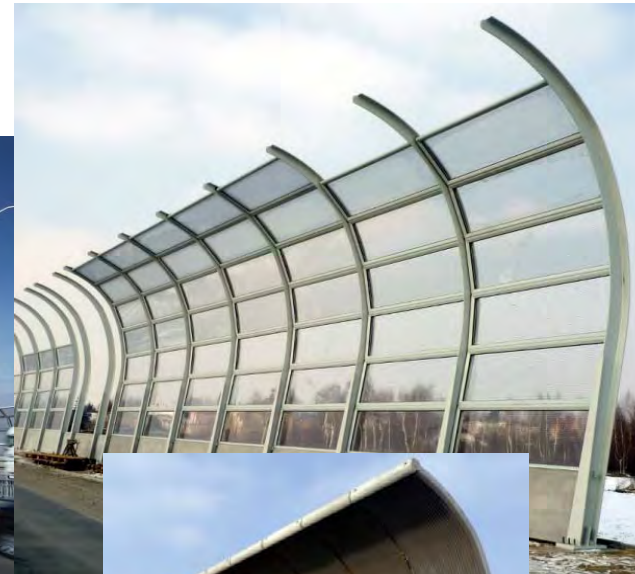
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POLAND

AOW – A8

- Baustatik
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POLAND - Various

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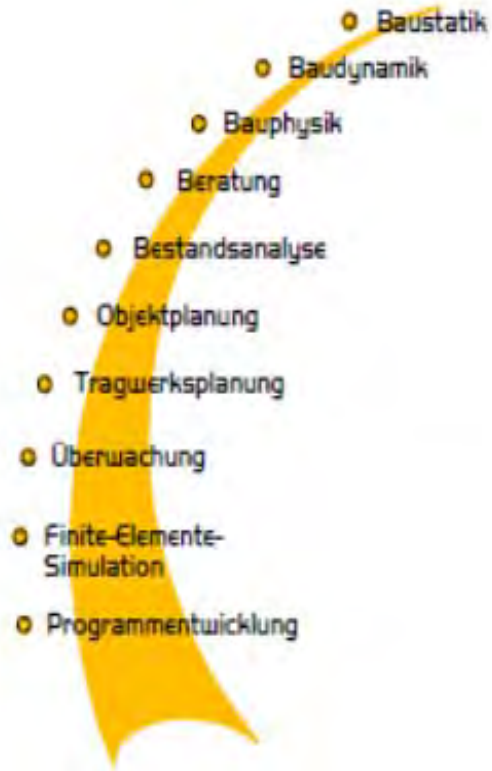


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POLAND - Warszawa – PKP



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FRANCE

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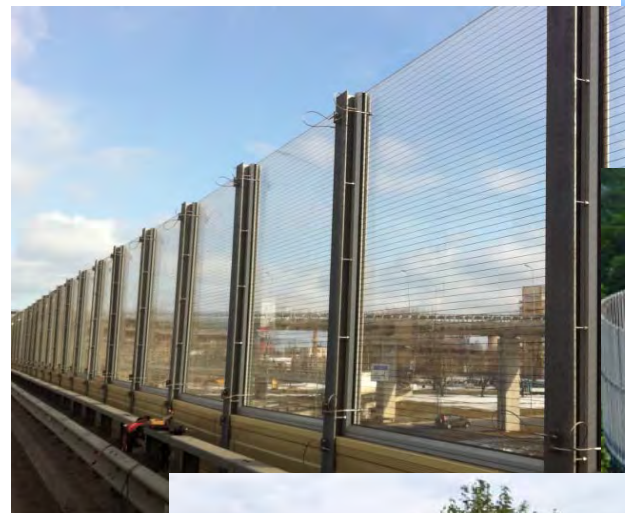


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LATVIA



- Baustatik
- Baudynamik
- Bauphysik
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ITALY

- Baustatik
- Baudynamik
- Bauphysik
- Beratung
- Bestandsanalyse
- Objektplanung
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Others in Southern Europe

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- Baudynamik
- Bauphysik
- Beratung
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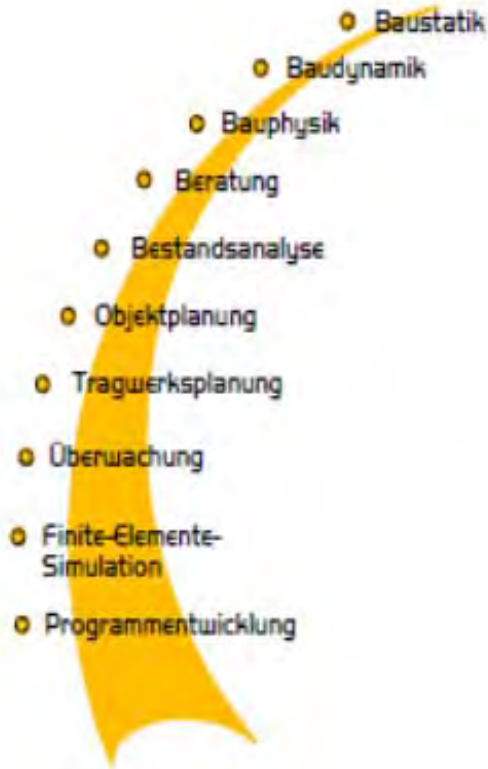


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SUMMARY



- The Situation
- Materials
- Actions and Resistances
- Standards
- Design Concepts
- Economic Efficiency
- Procurement
- Production
- Workers
- The Quality-Web
- “What if ...”
- Conclusions
- Examples

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QUALITY IS LIFE

THANK YOU FOR YOUR KIND ATTENTION

- Baustatik
- Baudynamik
- Bauphysik
- Beratung
- Bestandsanalyse
- Objektplanung
- Tragwerksplanung
- Überwachung
- Finite-Elemente-Simulation
- Programmentwicklung

