Austrian Experience using Eurocode 2, Concrete Bridge Design

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Current Situation in Austria

• For bridge design only the Eurocodes have been in use since Jan. 2009

• All national standards for structural engineering were withdrawn 2009

• From then on only the Eurocodes have been used for the design of all engineering structures in Austria

• So Austria is among the first country were only the Eurocodes are used because the national standards don`t exist anymore

• Big necessity for the further evolution of the Eurocodes because mistakes and non-conformity can only be discovered by practical use

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Concrete Bridge Design

Basis for the design of concrete bridges in Austria

Traffic Loads:

Material:

Geotechnic:
• ÖNORM EN 1997-1:2009 and national annex: B1997-1-1:2010

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Project 1: Composite Arch bridge

**Composite Arch bridge:**
- Span aprox. 35 m
- Arch: Steel tube dia. 559 x 59 mm
- Bridge deck: composite deck; thickness 50 cm
- Twin hanger: S460, dia 48 mm

**Special feature:** Computation of fatigue resistance (municipal road bridge)

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Project 2: Shallow Arch bridge for wildlife crossing and municipal road

Shallow Arch bridge for wildlife crossing
Span: aprox. 45 m
Arch: concrete slab, thickness 100 cm
Foundation: bore piles, dia. 90 cm, length: 18 m
Special features: Computation of soil-structure-interaction according to EC 7

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Description of the Bridge Projekt 1/2

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Description of the Bridge Projekt 2/2

Slab thickness (crown) 1.0 m

10 backfill layers

10 m

45 m

2.2 m

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Project 3: Post-tensioned street bridge

Post-tensioned street bridge
Overall length: 160 m
Superstructure: T-beams, web thickness 70 cm,
Hight webs: 1,6 m – 3,6 m

Special features: partial safety factors for the computation of bearing elongations and expansion joints

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Project 4: Single-span-frame

Integral concrete bridge
Overall length: 14,0 m
Superstructure: Concrete slab, thickness 1,10 m

Special features: Computation of fatigue, constraint stresses by temperature

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Improvement for practical use

- Improving the clarity
- Simplifying cross-references within the Eurocode 2
- Limiting the inclusion of alternative application rules
- Reducing the NDPs
- Avoiding or removing rules of low practical use in design
Example for simplification: Model for single span bridges (slabs, frames)
Example of LC and LG – combination ULS for single span beam – only traffic loads

### Eigengewichte:

<table>
<thead>
<tr>
<th>Stützweiten [m]</th>
<th>3,5</th>
<th>4,5</th>
<th>5,5</th>
<th>7,5</th>
<th>10,5</th>
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<tbody>
<tr>
<td>LC (kN·m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LG (kN·m)</td>
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### Querkrafte:

<table>
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<tr>
<th>Stützweiten [m]</th>
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<th>5,5</th>
<th>7,5</th>
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<tr>
<td>QUERKRAFTE (kN)</td>
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Investigated structures: Longitudinal section

Single-span beam

Frame

<table>
<thead>
<tr>
<th>Span L [m]</th>
<th>2,0</th>
<th>4,0</th>
<th>6,0</th>
<th>8,0</th>
<th>10,0</th>
<th>12,0</th>
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<tbody>
<tr>
<td>slab thickn. [m]</td>
<td>0,3</td>
<td>0,45</td>
<td>0,6</td>
<td>0,8</td>
<td>1,0</td>
<td>1,2</td>
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<table>
<thead>
<tr>
<th>withness Li [m]</th>
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<th>6,0</th>
<th>9,0</th>
<th>12,0</th>
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<td>0,60</td>
<td>0,80</td>
<td>1,00</td>
<td>1,25</td>
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<tr>
<td>wall thickn. [m]</td>
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<td>0,60</td>
<td>0,80</td>
<td>1,00</td>
<td>1,20</td>
</tr>
<tr>
<td>hight [m]</td>
<td>2,5</td>
<td>4,7</td>
<td>4,7</td>
<td>4,7</td>
<td>4,7</td>
</tr>
</tbody>
</table>

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Investigated structures: Cross Section

- Ballast: 55 cm
- Concrete layer: 5 cm
- Waterproofing: 1 cm

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Loads for FE-Calculation
LM 71

Centrifugal forces

Excentricity of vertical loads $e = r/18$

Traction and braking

$Q_{lak} = 33 \times L_{a,b} [m] \leq 1000 [kN]$

$Q_{lbk} = 20 \times L_{a,b} [m] \leq 6000 [kN]$

$Q_{lbk} = 35 \times L_{a,b} [m]$

Side impact

Qsk = 100kN

Track set

+0,10m

-0,10m

Excentricity of superelevation (cant)

Unloaded train

Load groups

gr11

gr12

gr13

gr14

...(cant)

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Finite-Element-Calculations
Loads for simplified calculation LM 71

LM 71

\[ Q_{vk} = 250 \text{kN} \quad 250 \text{kN} \quad 250 \text{kN} \quad 250 \text{kN} \]

\[ q_{vk} = 80 \text{kN/m} \]

unbegrenzt 0,8m 1,6m 1,6m 1,6m 0,8m unbegrenzt
Models for simplified calculation

Length of sleeper 2.60 m

Cross section of simplified model
- Ballast 55 cm
- Concrete cover 5 cm
- Waterproofing 1 cm
- Superstructure

Distribution of load on slab deck
- Single-span beam

Frame

2.80 m + d

Distribution of load in slab axis

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Comparison values of simplified calculation

Frame

Single-span beam

max. bending moment (L/2)

max. shear force

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Comparison values of FEM calculation

max. value - comparison
Comparison of calculations
(shear and moment diagrams)

for FEM calculation (FE-Model)
\[
E_d = \sum_{j \geq 1} (\gamma_{G,j} \times G_{k,j}) + \gamma_{Q,1} \times Q_{k,1} + \sum_{i>1} (\gamma_{Q,i} \times \psi_{0,i} \times Q_{k,i})
\]

All Loadgroups (gr11 bis gr17) x \Phi 2x \alpha

Equal results

for simplified calculation (beam)
\[
E_d = \sum_{j \geq 1} (\gamma_{G,j} \times G_{k,j}) + \gamma_{Q,1} \times Q_{k,1} \times F_1 + \sum_{i>1} (\gamma_{Q,i} \times \psi_{0,i} \times Q_{k,i})
\]

Only LM 71 x \Phi 2x \alpha

Implementantion of Faktor F1

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# Results of slabs

## Results of bending moment L/2

<table>
<thead>
<tr>
<th>Span [m]</th>
<th>γ₀</th>
<th>α</th>
<th>Φ</th>
<th>Beam model</th>
<th>FE model</th>
<th>T1</th>
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</thead>
<tbody>
<tr>
<td>2.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.67</td>
<td>94.0</td>
<td>95.6</td>
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<tr>
<td>4.4</td>
<td>1.45</td>
<td>1.21</td>
<td>1.56</td>
<td>280.4</td>
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<tr>
<td>6.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.42</td>
<td>517.1</td>
<td>344.5</td>
<td>0.67</td>
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<tr>
<td>8.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.34</td>
<td>801.9</td>
<td>534.8</td>
<td>0.67</td>
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<tr>
<td>10.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.28</td>
<td>1054.4</td>
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<tr>
<td>12.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.24</td>
<td>1364.5</td>
<td>970.8</td>
<td>0.72</td>
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</table>

## Results of shear force

<table>
<thead>
<tr>
<th>Span [m]</th>
<th>γ₀</th>
<th>α</th>
<th>Φ</th>
<th>Beam model</th>
<th>FE model</th>
<th>ζ</th>
<th>F1</th>
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<tbody>
<tr>
<td>2.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.67</td>
<td>204.5</td>
<td>290.1</td>
<td>1.37</td>
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<tr>
<td>4.4</td>
<td>1.45</td>
<td>1.21</td>
<td>1.56</td>
<td>267.7</td>
<td>335.8</td>
<td>1.09</td>
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<tr>
<td>6.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.42</td>
<td>375.0</td>
<td>391.1</td>
<td>0.96</td>
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<tr>
<td>8.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.34</td>
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<td>453.7</td>
<td>360.9</td>
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</table>

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## Results of frames

### Results of bending moment corner

<table>
<thead>
<tr>
<th>Lichte Weite [m]</th>
<th>γ₀</th>
<th>α</th>
<th>φ</th>
<th>Beam model $m_{x,LM} \text{ [kNm/m]}$</th>
<th>FE model $m_{x} \text{ [kNm/m]}$</th>
<th>φ</th>
<th>F1</th>
</tr>
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<tbody>
<tr>
<td>3.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.53</td>
<td>-72.6</td>
<td>-87.3</td>
<td>1.20</td>
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<tr>
<td>6.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.35</td>
<td>-223.0</td>
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<tr>
<td>9.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.30</td>
<td>-490.1</td>
<td>-426.4</td>
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<tr>
<td>12.0</td>
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<td>1.21</td>
<td>1.28</td>
<td>-774.2</td>
<td>-873.5</td>
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<td>15.0</td>
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<td>1.24</td>
<td>-1141.1</td>
<td>-940.8</td>
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### Results of bending moment L/2

<table>
<thead>
<tr>
<th>Lichte Weite [m]</th>
<th>γ₀</th>
<th>α</th>
<th>φ</th>
<th>Beam model $m_{x,LM} \text{ [kNm/m]}$</th>
<th>FE model $m_{x} \text{ [kNm/m]}$</th>
<th>φ</th>
<th>F1</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.50</td>
<td>128.0</td>
<td>111.4</td>
<td>0.86</td>
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<td>6.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.35</td>
<td>377.4</td>
<td>259.7</td>
<td>0.69</td>
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<tr>
<td>9.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.30</td>
<td>633.8</td>
<td>128.8</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>12.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.28</td>
<td>912.2</td>
<td>639.2</td>
<td>0.69</td>
<td></td>
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<tr>
<td>15.0</td>
<td>1.45</td>
<td>1.21</td>
<td>1.24</td>
<td>1224.5</td>
<td>886.8</td>
<td>0.72</td>
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</table>

### Results of shear force

<table>
<thead>
<tr>
<th>Lichte Weite [m]</th>
<th>γ₀</th>
<th>α</th>
<th>φ</th>
<th>Beam model $v_{x,LM} \text{ [kN/m]}$</th>
<th>FE model $v_{x} \text{ [kN/m]}$</th>
<th>φ</th>
<th>F1</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>1.15</td>
<td>1.21</td>
<td>1.53</td>
<td>266.8</td>
<td>322.2</td>
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<tr>
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<td>561.2</td>
<td>521.7</td>
<td>0.93</td>
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**Span [m]**

- **bending moment L/2**
- **bending mom. corner**
- **shear force**
Conclusions

• Eurocodes are good bases for the design of any type of bridges

• However, the resulting effort for the calculation of simple structures is disproportional high

• Therefore: Proposal for simplification:
  – Simplification of load configurations (e.g., reduction of load-combinations, loadgroups)
  – Implementation of faktor F1 multiplied by LM71 for usual railway bridges

• Advantages:
  – Less effort of calculation process for same result and quality
  – Greater acceptance of Eurocodes by users
  – Increase of the practical suitability of EC`s

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Austrian Experience using Eurocode 2, Concrete Bridge Design

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