Structural Design II

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Bending

- Bending and flection
  - Bending stiffness
  - Deformation of bending beams
  - Resistance of bending beams
  - Resistance of frames
  - Structures efficiency
Bending and flection

Bending beam with flection
Bending and flection

Distribution of the deformation along the girders height
Distortion of a bent beam segment

\[ x = \frac{1}{r} \]
Bending

Bending and flection
- Bending stiffness
  - Deformation of bending beams
  - Resistance of bending beams
  - Resistance of frames
  - Structures efficiency
Bending at different beams heights

\[ N_{c1} z_1 = N_{c1} z_1 = N_{c2} z_2 = N_{c2} z_2 = M \]
Bending stiffness

Force-deformation diagram
\( N_t^* z = N_c^* z = M [Nmm] \)

\[ \chi = \frac{1}{r} \]

Bending moment-deflection diagram
Internal forces in a bent beam with rectangular section at linear-elastic material behaviour
Influence of width and height of the cross-section to the bending strength
Rectangular section and I-section with same height and same amount of material
Internal forces in a bent beam with I-section at linear-elastic material behaviour
Internal forces in a 90° bent beam with I-section at linear-elastic material behaviour
Bending

Bending and flection
Bending stiffness

- Deformation of bending beams

Resistance of bending beams
Resistance of frames
Structures efficiency
Deflection of a beam with two single loads and the influence of the span $l$ on the bending.
Deformation of bending beams

Deflection of a beam with two single loads and the influence of the span l on the bending
Deformation of bending beams

Deflection of a cantilever with point load
Deformation of bending beams

Deflection of a beam and a cantilever with distributed load
Deformation of bending beams

Arch-cable structures and the deflection of a overhanging beam
Deformation of bending beams

Deflection of continuous beam
Bending

Bending and flection
Bending stiffness
Deformation of bending beams
• Resistance of bending beams
Resistance of frames
Structures efficiency
Resistance of bending beams

Bending-flection relation at plastic material behaviour

\( N_t \cdot z = N_c \cdot z = M \) [Nmm]

\( \chi = \frac{1}{r} \)

linear elastic material behaviour

plastic material behaviour

Bruch
Resistance of bending beams

Mechanical resistance of a beam at plastic material behaviour
Resistance of bending beams

Collapse load comparison between a beam with double height and two beams on top of the other
Resistance of bending beams

Collapse load comparison of a beam with I-section
Bending

Bending and flection
Bending stiffness
Deformation of bending beams
Resistance of bending beams
• Resistance of frames
Structures efficiency
Resistance of frames

Maximum capacity load (collapse load) analysis
Maximum capacity load (collapse load) analysis
Maximum capacity load (collapse load) analysis
Maximum capacity load (collapse load) analysis
Bending

Bending and flection
Bending stiffness
Deformation of bending beams
Resistance of bending beams
Resistance of frames

• Structures efficiency
Comparison of cross-sections (under vertical loads) with increasing efficiency under bending stress from left to right
Possible cross-sections for a beam loaded in the middle
Required amount of material as a function of the slenderness $l/h$
Deflections at the midspan as a result of a centered load as a function of the slenderness \( l/h \) \( (\varepsilon_{\text{max}} = 0.001) \)
### Useful slenderness rate of structures

<table>
<thead>
<tr>
<th>Material</th>
<th>Structure</th>
<th>Economic slenderness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Steel</strong></td>
<td>Vierendeel girder</td>
<td>7 – 10</td>
</tr>
<tr>
<td></td>
<td>Truss girder</td>
<td>10 - 15</td>
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<tr>
<td></td>
<td>Space truss</td>
<td>12 - 18</td>
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<tr>
<td></td>
<td>Beam</td>
<td>15 - 20</td>
</tr>
<tr>
<td><strong>Reinforced concrete</strong></td>
<td>Beam</td>
<td>12 – 18</td>
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<tr>
<td></td>
<td>Plate</td>
<td>20 – 25</td>
</tr>
<tr>
<td><strong>Prestressed concrete</strong></td>
<td>Beam</td>
<td>18 – 25</td>
</tr>
<tr>
<td></td>
<td>Plate</td>
<td>28 – 35</td>
</tr>
<tr>
<td><strong>Wood</strong></td>
<td>Beam</td>
<td>15 - 20</td>
</tr>
</tbody>
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