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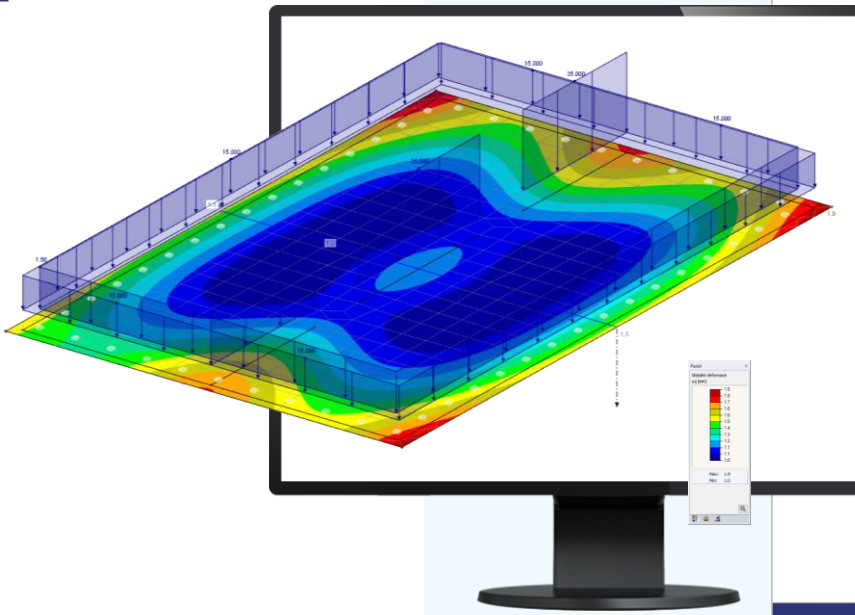
Webinar

Soil-Structure Interaction in RFEM



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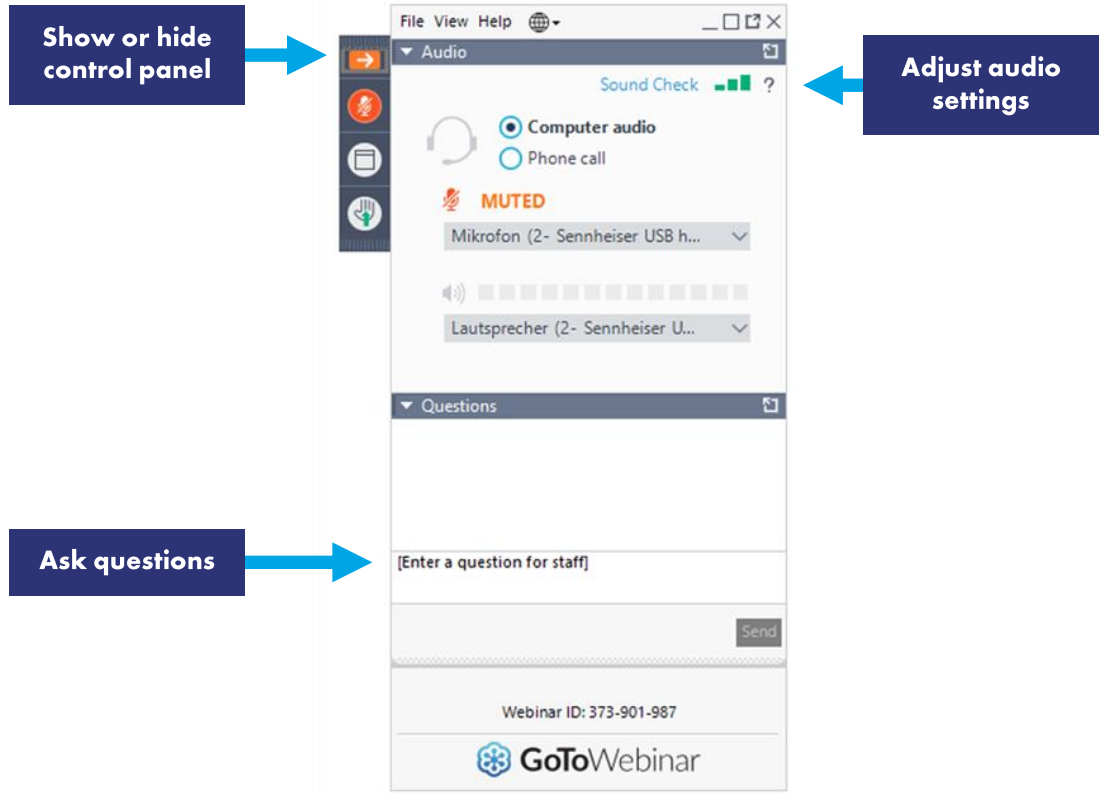
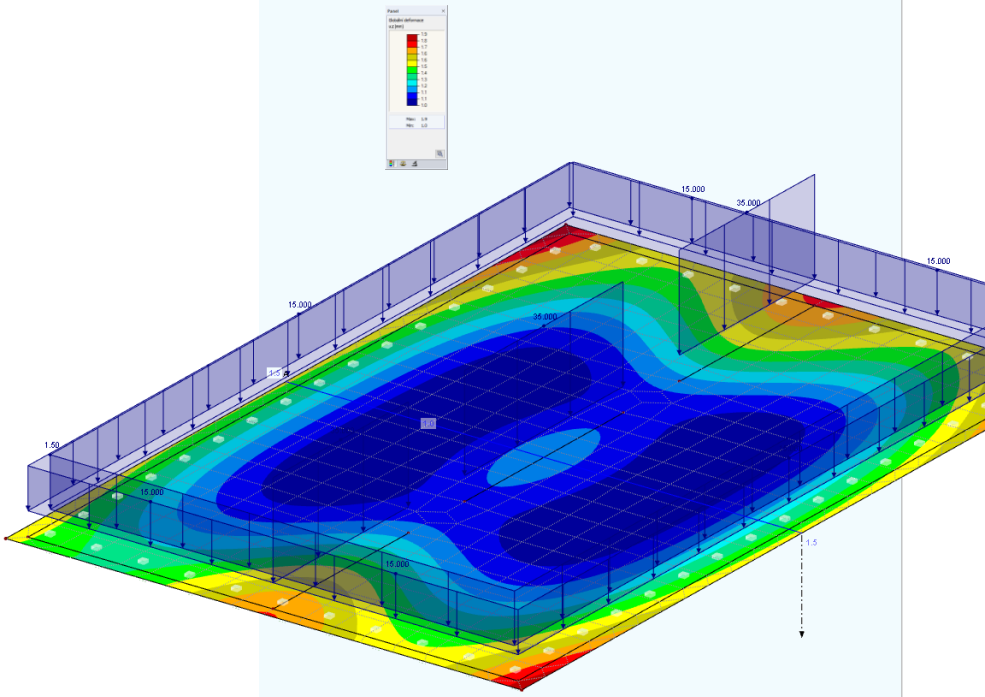


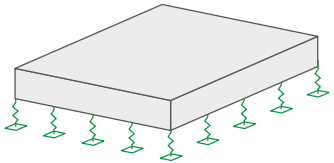
WEBINAR

CONTENT

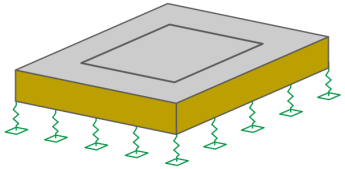


Soil Models

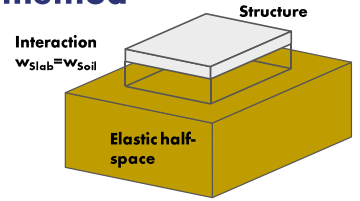
Subgrade reaction modulus method



Modified two-parametric soil model (with foundation overlaps)

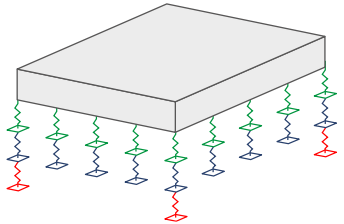


Stiffness modulus method

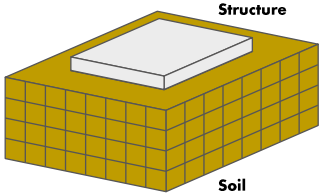


Modified subgrade reaction modulus method

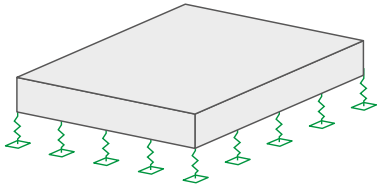
Modified two-parametric soil model (with additional springs)



3D half-space analysis



Subgrade Reaction Modulus Method

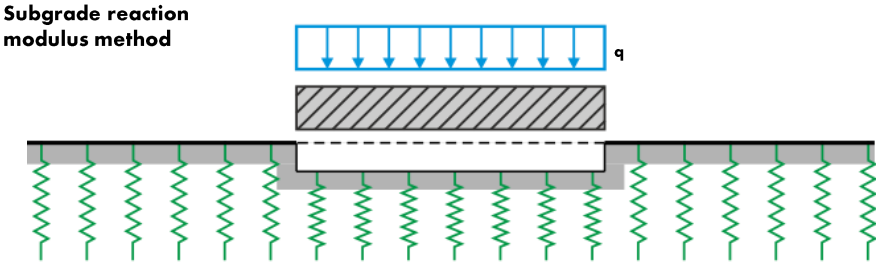


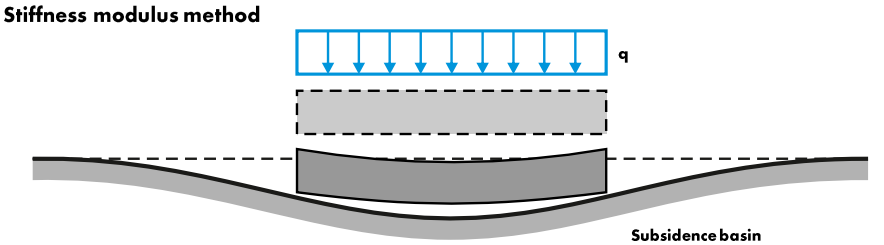
$$k_s = \frac{\sigma_0}{s}$$

k_s Winkler's foundation constant

σ_0 Soil contact stresses

s Settlement

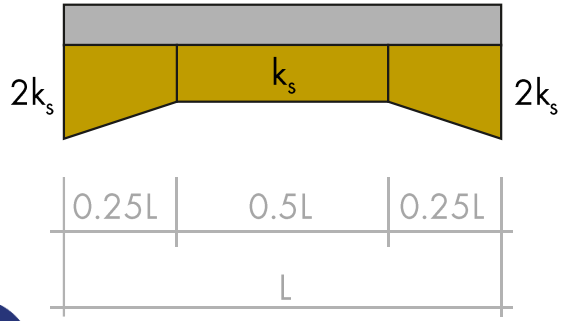




Modified Subgrade Reaction Modulus Method

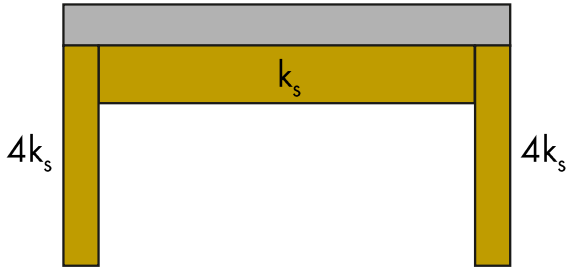
Acc. to Dörken and Dehne [2]

- Linear increasement of the subgrade reaction modulus at the edges

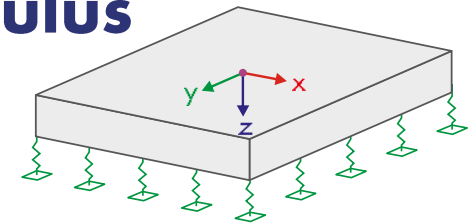


Acc. to Bellmann and Katz [3]

- Increasing the subgrade reaction modulus by the factor 4 at the edges (one finite element row)



Evaluating the Subgrade Reaction Modulus Method



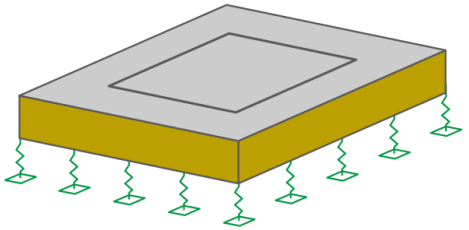
Advantages

- Easy input
- Short computation time (no iterative calculation)
- Extension to modified subgrade reaction modulus method possible

Disadvantages

- Inadequate soil modeling
- No consideration of adjacent soil areas
- No consideration of the soil's shear resistance
- No definition of soil layers
- No definition of structures' interaction
- Few realistic results

Modified Two-Parametric Soil Model (with Foundation Overlaps)



- Foundation overlap should be sufficiently large so that the settlements at the edge are close to zero
- Foundation overlap having only a small stiffness

Acc. to Pasternak [5]

Modulus of subgrade reaction

$$c_{1,z} = \frac{E_0}{H \cdot (1 - 2 \cdot \mu^2)}$$

Shear resistance

$$c_{2,v} = E_0 \cdot \frac{H}{6 \cdot (1 + \mu)}$$

Acc. to Barwaschow [5]

Modulus of subgrade reaction

$$c_{1,z} = \frac{E_0}{H \cdot (1 - \mu^2)}$$

Shear resistance

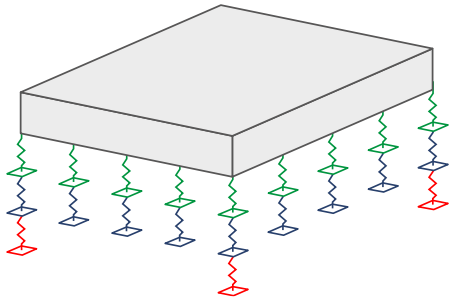
$$c_{2,v} = E_0 \cdot \frac{H}{20 \cdot (1 - \mu^2)}$$

E_0 Modulus of elasticity $= E_S \cdot \frac{1 - \mu - 2 \cdot \mu^2}{1 - \mu}$

H Elastic foundation depth

μ Poisson's ratio

Modified Two-Parametric Soil Model with Additional Springs



"Effective Soil Model" method according to Kolar and Nemec [4]

In general: $c_2 = c_{2,x} = c_{2,y}$

Shear resistance

$$c_{2,v} = c_{1,z} \cdot s^2$$

$$s = \frac{s_0}{4 \text{ bis } 5}$$

s_0 Range of subsidence basin (distance from the slab edge where settlements drop under 1 % of the foundation edge values)

Reference value for $c_{2,v}$

$$0.1 \cdot c_{1,z} < c_{2,v} < 1.0 \cdot c_{1,z}$$

Loose sand: $c_{2,v}$ towards 0

Solid rocks: $c_{2,v}$ towards 1

Average shear capacity: $c_{2,v} = 0.5 \cdot c_{1,z}$

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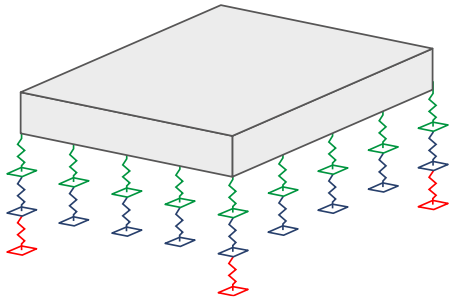
Modified Two-Parametric Soil Model with Additional Springs



"Effective Soil Model" method according to Kolar and Nemec [4]

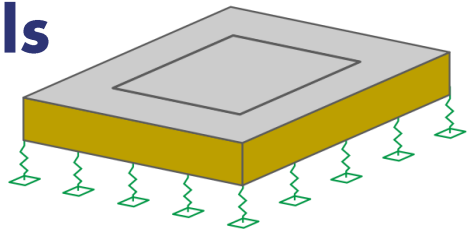
Line springs

$$k = \sqrt{c_{1,z} \cdot c_{2,v}}$$

Single springs at the outer edges

$$K = \frac{c_{2,v}}{2}$$

Evaluating Two-Parametric Soil Models



Advantages

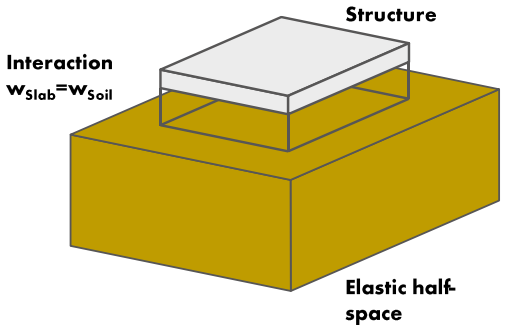
- Realistic results if used properly
- Consideration of adjacent soil areas
- Consideration of the soil's shear resistance
- Short computation time (no iterative calculation)
- Definition of structures' interaction possible when utilizing the soil model with foundation overlaps

Disadvantages

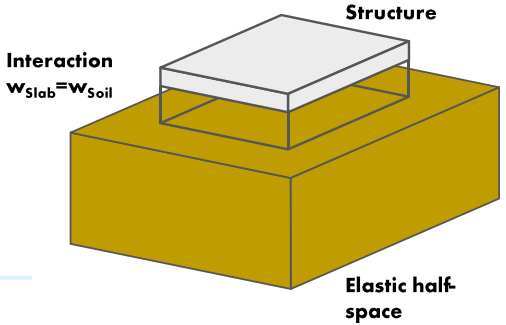
- Additional considerations and inputs necessary
- No definition of structures' interaction possible when utilizing the soil model with additional springs
- Definition of soil layers only approximately

Stiffness Modulus Approach

- When utilizing the FE option, a stiffness matrix of the soil surface related to the contact surface between structure and soil is created
- Discrete nodal points are reference points in this contact surface
- FE program determines the structure's stiffness related to the support settlement in these reference points
- Support settlements of the slab model and surface settlements of the soil are aligned by iterative calculation ($w_{Slab} = w_{Soil}$)
- Stiffness of the structural system and the soil modeled as elastic half-space are now one unit



Evaluating Stiffness Modulus Approach



Advantages

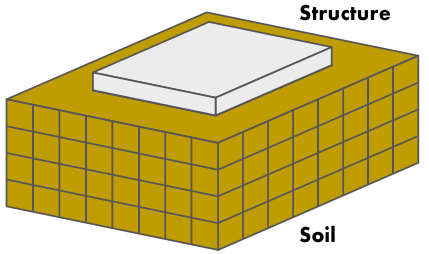
- Usually realistic results
- Realistic soil modeling
- Consideration of adjacent soil areas
- Definition of soil layers and interaction between structures

Disadvantages

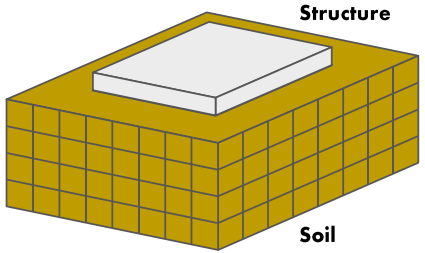
- Iterative calculation necessary and superposition principle no longer applies (nonlinear calculation)
- Increased computation time caused by iterative caluclation

3D Half-Space Analysis

- Elastic half-space of the soil is modeled with displaying the soil layers as 3D model with FE solid elements
- Leads to a good connection between soil and structure
- Soil modeling until the settlement decreases
- 3D half-space analysis shows the complex modeling of the soil-structure system most clearly



Evaluating 3D Half-Space Analysis



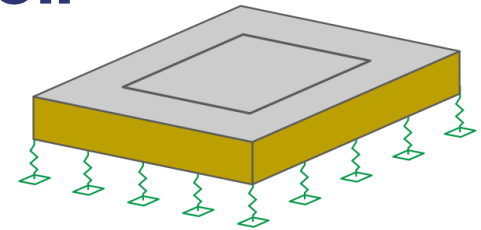
Advantages

- Very realistic soil modeling
- Consideration of adjacent soil areas
- Definition of soil layers and interaction between structures works very well
- No iterative calculation

Disadvantages

- High generation process and increased effort when evaluating results
- The software system must have 3D solid elements
- By utilizing the 3D modeling of the soil, very large system matrices might occur which leads to high memory requirements and long computation times (increased computer system requirements)

Example: Modified Two-Parametric Soil Model with Foundation Overlap



Input values

Modulus of elasticity $E_0 = 10000\ kN/m^2$

Elastic foundation depth $H = 5\ m$

Poisson's ratio $\mu = 0.2$

Soil parameters (acc. to Barwaschow [5])

Modulus of subgrade reaction

$$c_{1,z} = \frac{E_0}{H \cdot (1-\mu^2)}$$

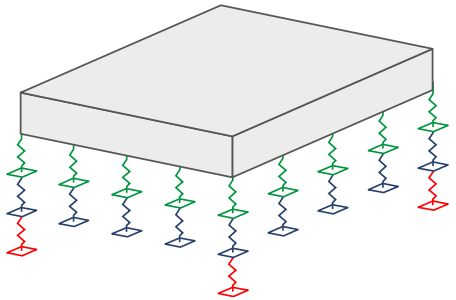
$$c_{1,z} = 2083.33\ kN/m^3$$

Shear resistance

$$c_{2,v} = E_0 \cdot \frac{H}{20 \cdot (1-\mu^2)}$$

$$c_{2,v} = 2604.17\ kN/m$$

Example: Modified Two-Parametric Soil Model with Additional Springs



Soil parameters

Modulus of subgrade reaction

$c_{1,z} = 2083.33\ \text{kN/m}^3$

Shear resistance

Assumption: average shear capacity

$c_{2,v} = 0.5 \cdot c_{1,z}$

$c_{2,v} = 1041.67\ \text{kN/m}$

Additional springs

Line springs

$$k = \sqrt{c_{1,z} \cdot c_{2,v}}$$

$$k = \sqrt{2083.33 \cdot 1041.67}$$

$$k = 1473.14\ \text{kN/m}^2$$

Single springs at the outer edges

$$K = \frac{c_{2,v}}{2}$$

$$K = \frac{1041.67\ \text{kN/m}}{2}$$

$$K = 520.84\ \text{kN/m}$$

Bibliography

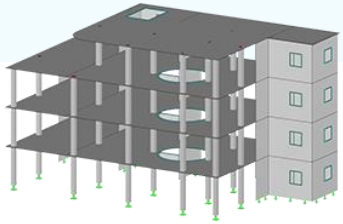
[1] Barth, C.; Rustler, W.: Finite Elemente in der Baustatik-Praxis, 2. Auflage. Berlin: Beuth, 2013

[2] Dörken, W.; Dehne, E.: Grundbau in Beispielen Teil 2. Nach neuer DIN 1054:2005, 4. Auflage. Köln: Werner, 2007

[3] Bellmann, J.; Katz, C.: Bauwerk-Boden Wechselwirkungen, 3. FEM-Tagung Darmstadt, TH Darmstadt, 1994

[4] Kolar, V.; Nemec, I.: Modelling of Soil-Structure Interaction. Amsterdam: Elsevier Science Publishers, 1989

[5] Barwaschow, W. A.: Setzungsberechnungen von unterschiedlichen Modellen, Osnowania, fundamenti i mechanika gruntow, Heft 4/77, Moskau 1977 (russisch)



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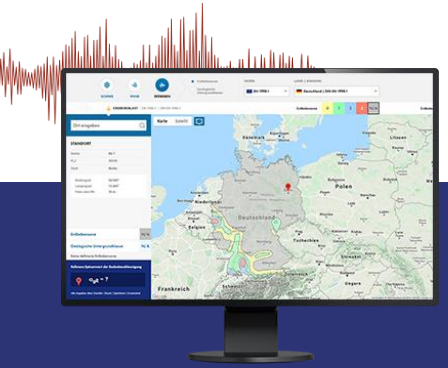

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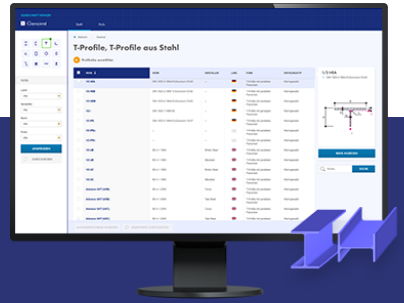

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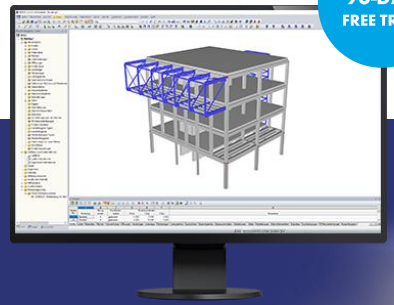

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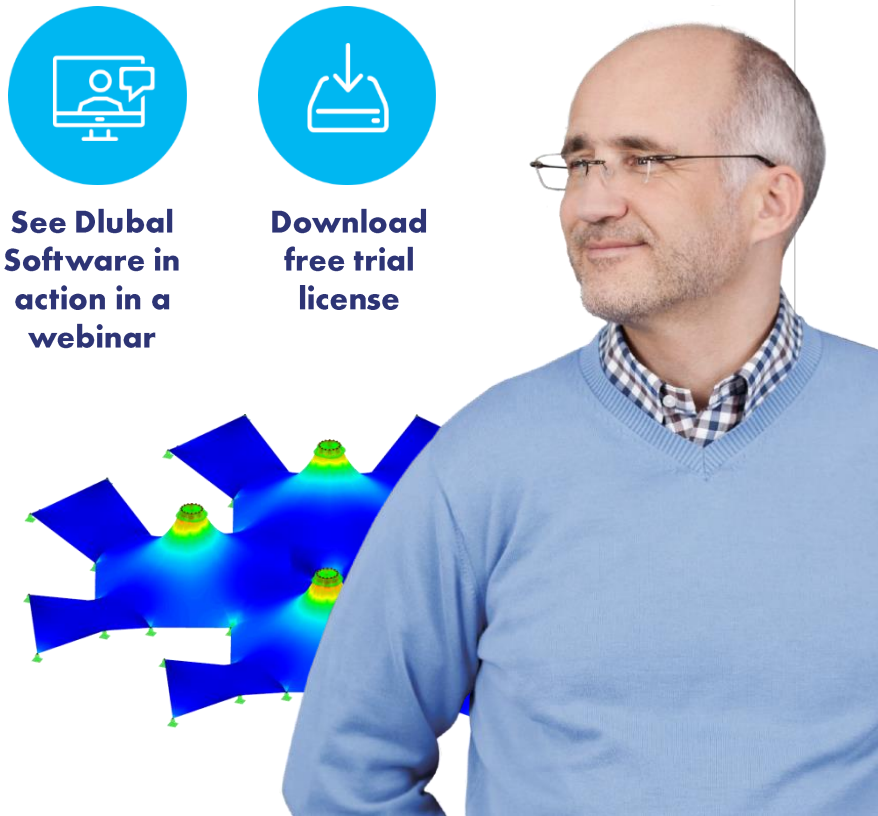

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