



Structural Analysis & Design Software



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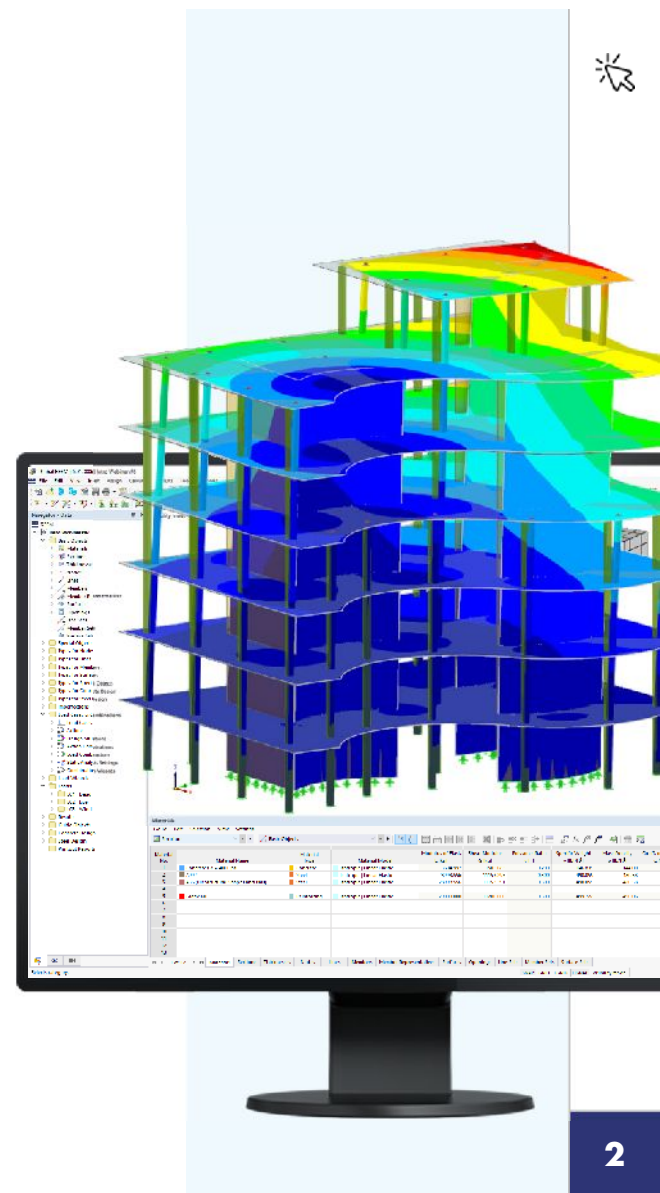
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Webinar

ASCE 7-16 Response Spectrum Analysis in RFEM 6



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CONTENT

01

Modal analysis to determine natural frequencies and mode shapes

02

Response spectrum analysis acc. to ASCE 7-16

03

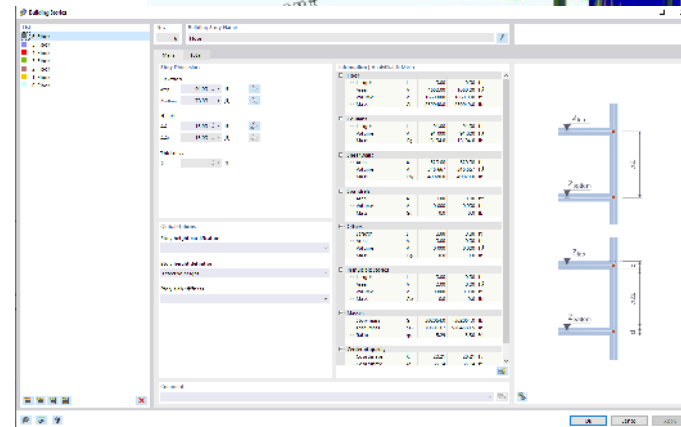
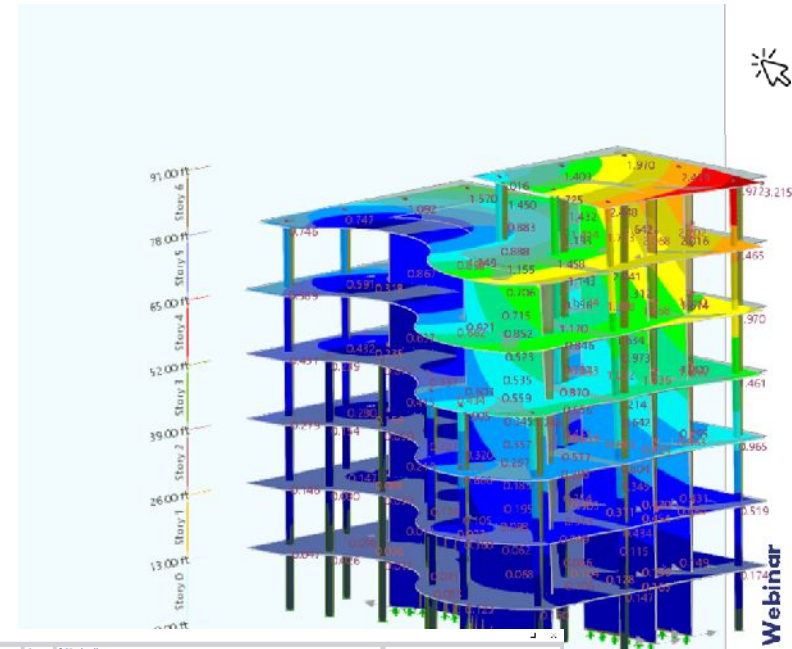
Review of tabular and graphical results

04

New Building Model add-on features for story results

05

Consideration of base shear, drift, and P-Delta effects



Webinar



Modal Analysis Results Combination

Main

Modal Combination Method

Combination rule for periodic responses

SRSS

Use equivalent linear combination

Signed results using dominant mode

Save results of all selected modes

Navigator - Results

Spectral Analysis

Envelope

Scaled sums envelope

Scaled sums envelope

X 100.00 % | Y 30.00 %

X 30.00 % | Y 100.00 %

X

Y

X, Mode Shape 1

Y, Mode Shape 1

X, Mode Shape 2

Y, Mode Shape 2

X, Mode Shape 3

Y, Mode Shape 3

X, Mode Shape 5

Y, Mode Shape 5

X, Mode Shape 6

Y, Mode Shape 6

X, Mode Shape 8

Y, Mode Shape 8

X, Mode Shape 10

Y, Mode Shape 10

1. Square Root Sum of the Squares (SRSS)

$$E_{SRSS} = \sqrt{E_1^2 + E_2^2 + \dots + E_p^2}$$

2. Complete Quadratic Combination (CQC)

$$E_{CQC} = \sqrt{\sum_{i=1}^p \sum_{j=1}^p E_i \cdot \varepsilon_{ij} \cdot E_j}$$

Where the correlation coefficient is:

$$\varepsilon_{ij} = \frac{8 \cdot \sqrt{D_i \cdot D_j} \cdot (D_i + r \cdot D_j) \cdot r^{\frac{3}{2}}}{(1-r^2)^2 + 4 \cdot D_i \cdot D_j \cdot r \cdot (1+r^2) + 4 \cdot (D_i^2 + D_j^2) \cdot r^2}$$

3. Absolute Sum

$$E_{AbsSum} = \sum_{i=1}^p |E_i|$$

Navigator - Results

Spectral Analysis

Envelope

Scaled sums envelope

Scaled sums envelope

X 100.00 % | Y 30.00 %

X 30.00 % | Y 100.00 %

X

Y

X, Mode Shape 1

Y, Mode Shape 1

X, Mode Shape 2

Y, Mode Shape 2

X, Mode Shape 3

Y, Mode Shape 3

X, Mode Shape 5

Y, Mode Shape 5

X, Mode Shape 6

Y, Mode Shape 6

X, Mode Shape 8

Y, Mode Shape 8

X, Mode Shape 10

Y, Mode Shape 10



Modal Analysis Results Combination (cont'd)

- Standard SRSS/CQC combinations, corresponding internal forces are lost (e.g., corresponding moment at max axial force)
- Equivalent linear combination gives more realistic results and correct signage

Modal Combination Method

Combination rule for periodic responses

SRSS ▼

Use equivalent linear combination

Signed results using dominant mode

Save results of all selected modes

1. Square Root Sum of the Squares (SRSS) linear combination

$$E_{SRSS} = \sum_{i=1}^p f_i \cdot E_i \quad \text{where} \quad f_i = \frac{E_i}{\sqrt{\sum_{j=1}^p E_j^2}}$$

2. Complete Quadratic Combination (CQC) linear combination

$$E_{CQC} = \sum_{i=1}^p f_i \cdot E_i \quad \text{where} \quad f_i = \frac{\sum_{j=1}^p \epsilon_{ij} \cdot E_j}{\sqrt{\sum_{i=1}^p \sum_{j=1}^p E_i \cdot \epsilon_{ij} \cdot E_j}}$$



Directional Component Combination

Combination of Directional Components

Combination rule for directional components

Scaled Sum 100% / 30.00 [%]

Consider independent directions in envelope results

Navigator - Results

Spectral Analysis

Envelope

Scaled sums envelope

X 100.00% | Y 30.00%

X 30.00% | Y 100.00%

X

Y

X, Mode Shape 1

Y, Mode Shape 1

X, Mode Shape 2

Y, Mode Shape 2

X, Mode Shape 3

Y, Mode Shape 3

X, Mode Shape 5

Y, Mode Shape 5

X, Mode Shape 6

Y, Mode Shape 6

X, Mode Shape 8

Y, Mode Shape 8

X, Mode Shape 10

Y, Mode Shape 10

1. Square Root Sum of the Squares (SRSS)

$$E_{SRSS} = \sqrt{E_1^2 + E_2^2 + \dots + E_p^2}$$

2. Scaled Sum (100%/30%)

$$E_{Ed} = 1,0 \cdot E_{EdX} \oplus 0,3 \cdot E_{EdY} \oplus 0,3 \cdot E_{EdZ}$$

$$E_{Ed} = 0,3 \cdot E_{EdX} \oplus 1,0 \cdot E_{EdY} \oplus 0,3 \cdot E_{EdZ}$$

$$E_{Ed} = 0,3 \cdot E_{EdX} \oplus 0,3 \cdot E_{EdY} \oplus 1,0 \cdot E_{EdZ}$$

3. Absolute Sum

$$E_{Ed} = 1,0 \cdot E_{EdX} \oplus 1,0 \cdot E_{EdY} \oplus 1,0 \cdot E_{EdZ}$$

Navigator - Results

Spectral Analysis

Envelope

Scaled sums envelope

X 100.00% | Y 30.00%

X 30.00% | Y 100.00%

X

Y

X, Mode Shape 1

Y, Mode Shape 1

X, Mode Shape 2

Y, Mode Shape 2

X, Mode Shape 3

Y, Mode Shape 3

X, Mode Shape 5

Y, Mode Shape 5

X, Mode Shape 6

Y, Mode Shape 6

X, Mode Shape 8

Y, Mode Shape 8

X, Mode Shape 10

Y, Mode Shape 10





Base Shear and Drift Considerations

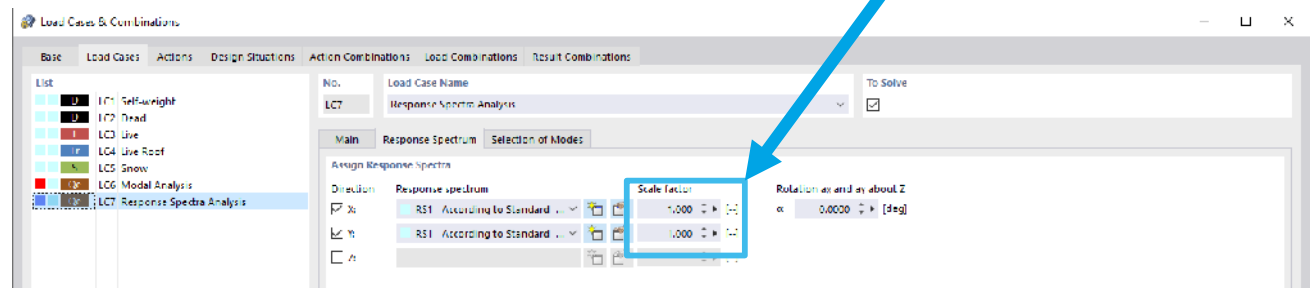
Scaling of forces [Sect. 12.9.1.4.1]

- Base shear in two orthogonal horiz. directions (X and Y)
- V_t = RFEM base shear from combined response [SRSS/CQC/Absolute Sum]
- V = base shear from ELFP [Sect. 12.8]
- When $V_t < 1.0V$, scale forces by factor V/V_t

Scaling of drifts [Sect. 12.9.1.4.2]

- When $V_t < C_s W$ with $V = C_s W$, scale drifts by factor V/V_t

Scaling applied in response spectrum scale factor

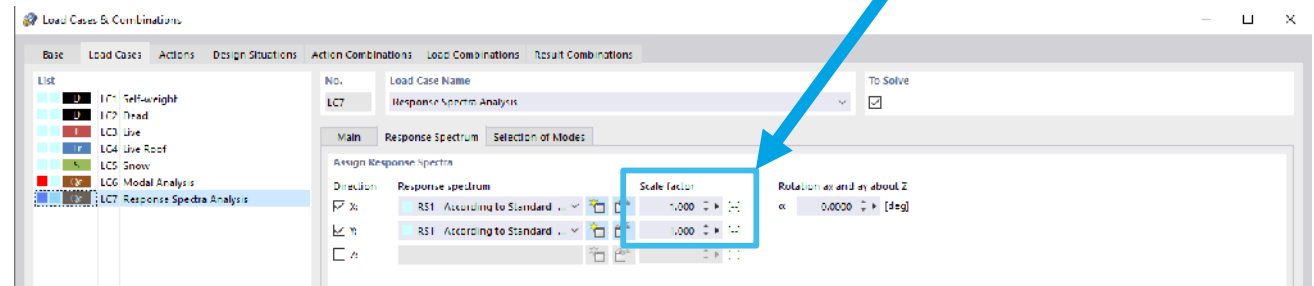


P-Delta Considerations

P-Delta Effects [Sect. 12.8.7]

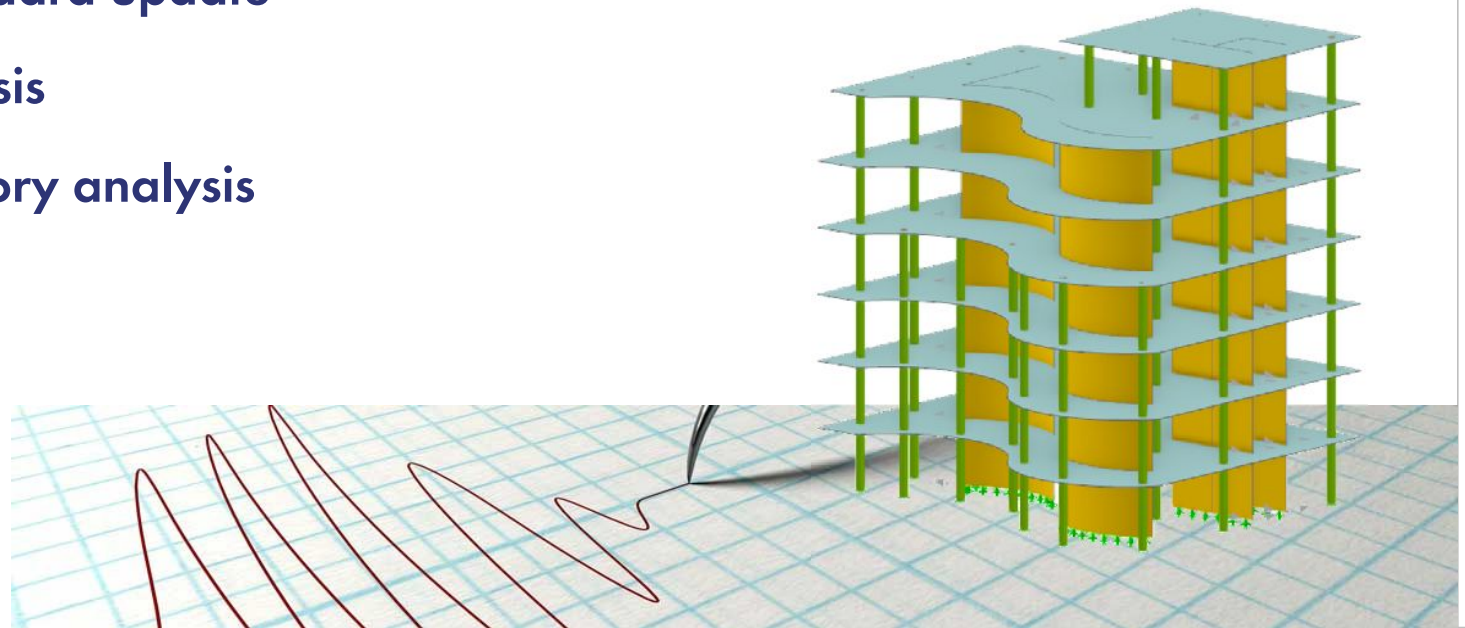
- Stability coefficient, θ [Eqn. 12.8-16]
- Neglected when $\theta \leq 0.10$
- When $0.1 < \theta < \theta_{\max}$, multiply displacements and forces by $1/(1 - \theta)$
- $\theta > \theta_{\max}$, redesign structure

Scaling applied in response spectrum scale factor

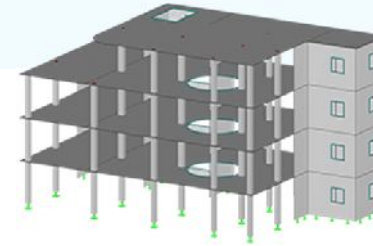


Future RFEM 6 Dynamic Developments

- ASCE 7-22 standard update
- NBC 2020 standard update
- Pushover analysis
- Linear time history analysis



Free Online Services



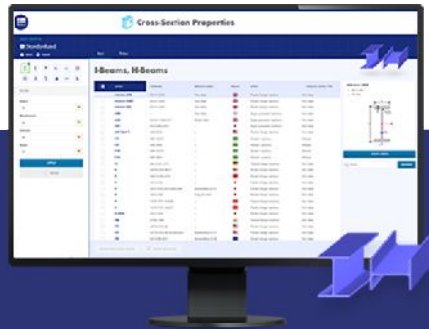
Geo-Zone Tool

Dlubal Software provides an online tool with snow, wind and seismic zone maps.



Cross-Section Properties

With this free online tool, you can select standardized sections from an extensive section library, define parametrized cross-sections and calculate its cross-section properties.



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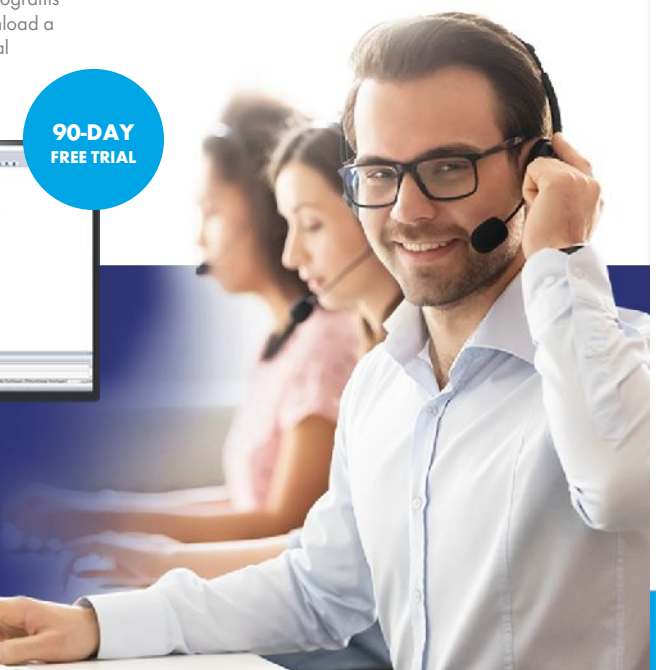
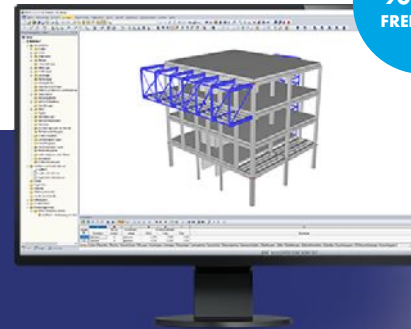
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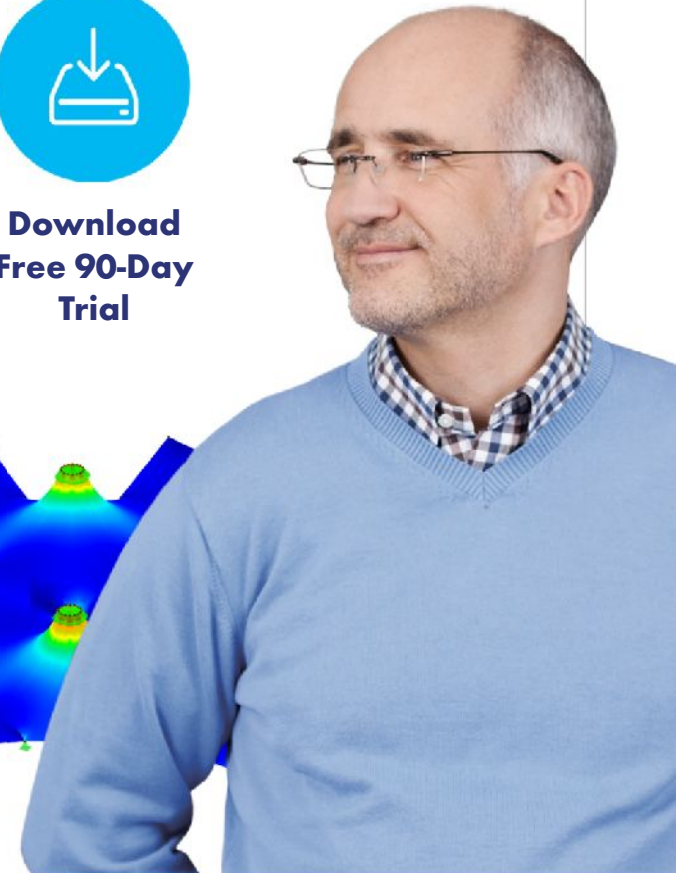
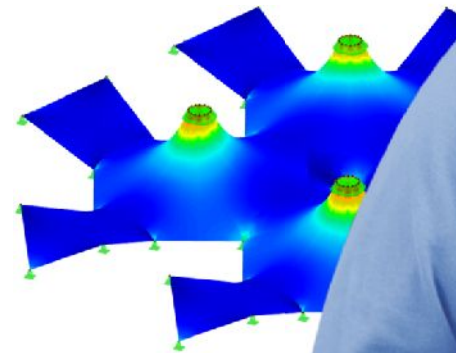
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