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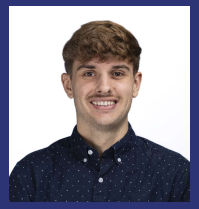
Amy Heilig, PE
Presenter

CEO – USA Office

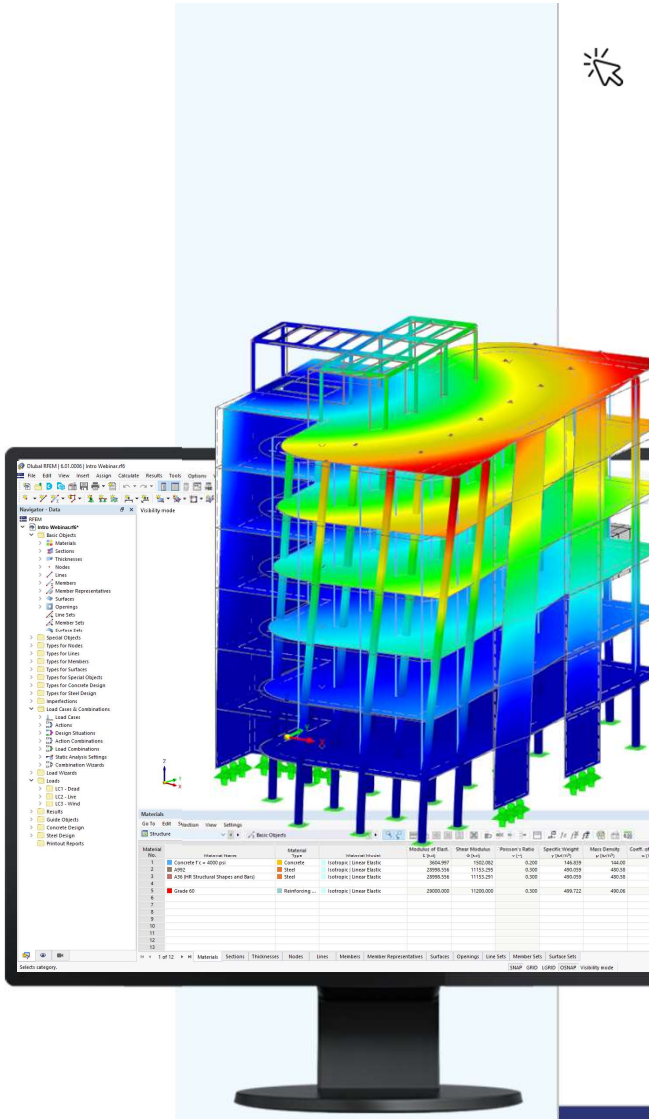


Alex Bacon, EIT
Moderator

Technical Support Engineer

Webinar

NBC 2020 Response Spectrum Analysis in RFEM 6



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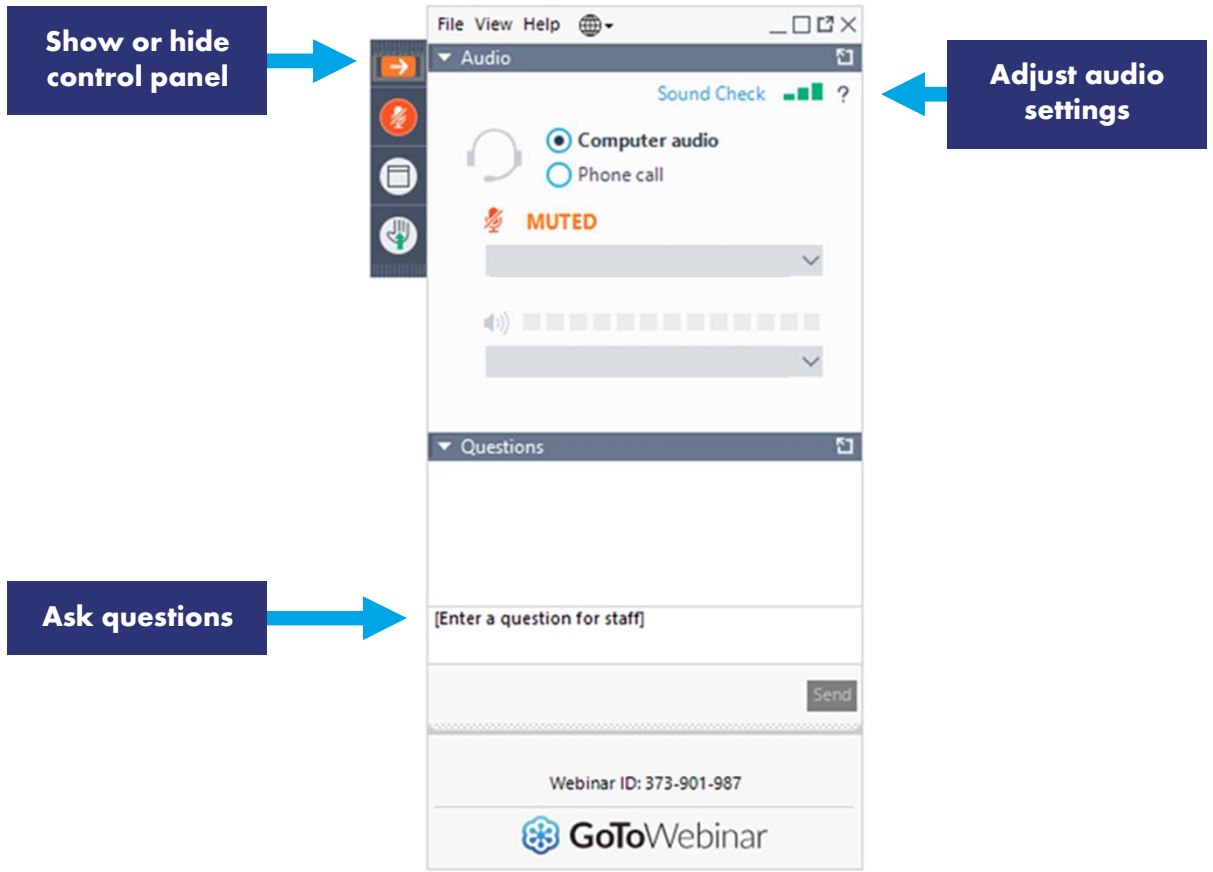

CONTENT

Webinar

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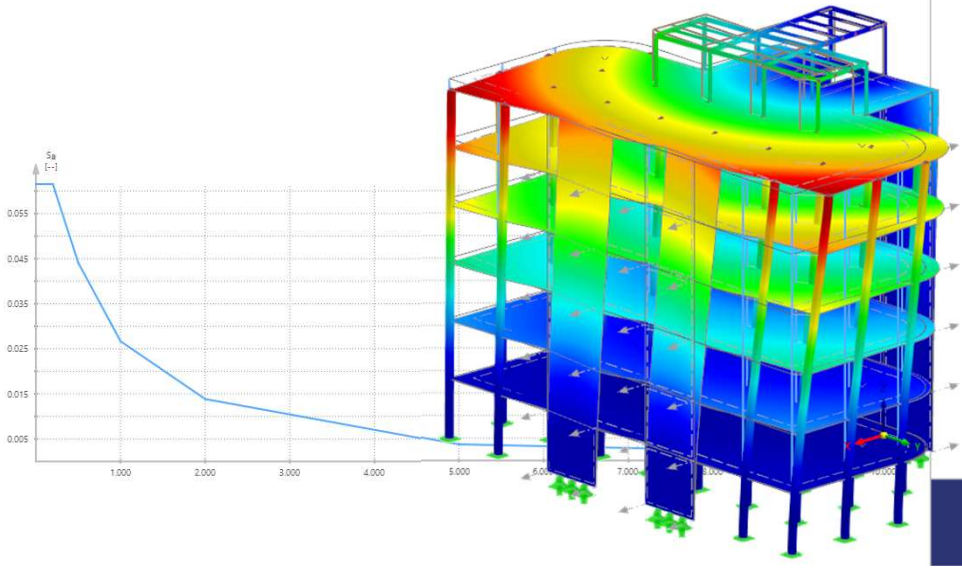
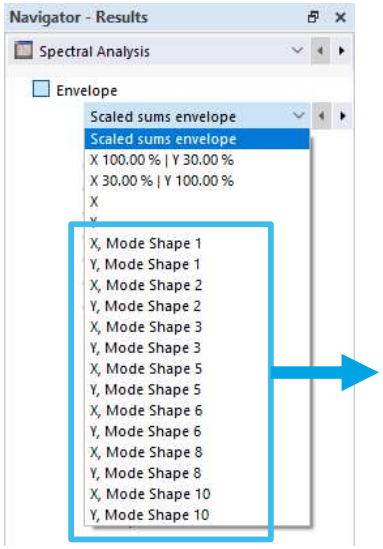
NBC 2020 Earthquake Method of Analysis

- **Method of Analysis [4.1.8.7]**
- **Equivalent Static Force Procedure (ESFP) [4.1.8.11]**
  - Seismic Category is SC1 or SC2 [Table 4.1.8.5.-B]
  - Regular, H < 60 m, and T_a < 2 sec
  - Irregular structures [Table 4.1.8.6] w/ H < 20 m and T_a < 0.5 sec
- **Dynamic Analysis Procedure [4.1.8.12]**
  - Response Spectrum Method, Time History Method, or Non-linear Dynamic Analysis
  - All structures not satisfying Article 4.1.8.7



Modal Combination Method



1. Square Root Sum of the Squares (SRSS)

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

2. Complete Quadratic Combination (CQC)

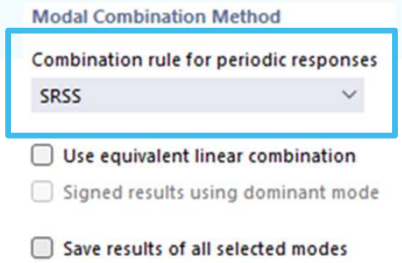
$$E_{CQC} = \sqrt{\sum_{i=1}^{p} \sum_{j=1}^{p} E_i \cdot \varepsilon_{ij} \cdot E_j}$$

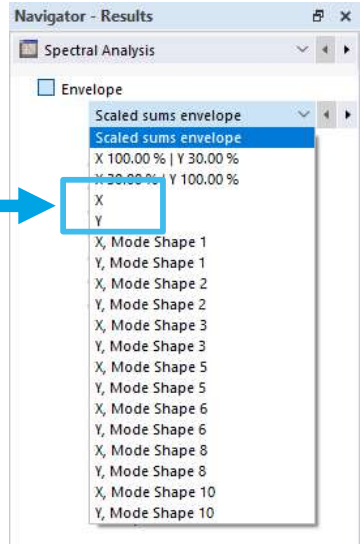
Where the correlation coefficient ε is:

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

3. Absolute Sum

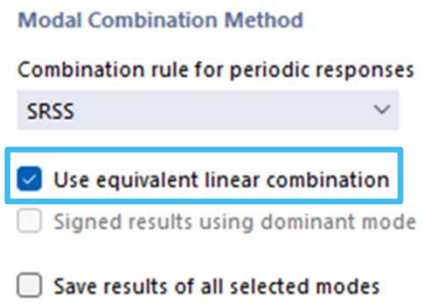
$$E_{AbsSum} = \sum_{i=1}^{p} |E_i|$$





Modal Combination Method (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



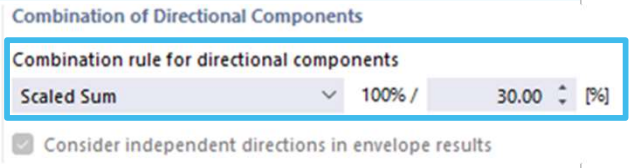
1. **Square Root Sum of the Squares (SRSS) linear combination**

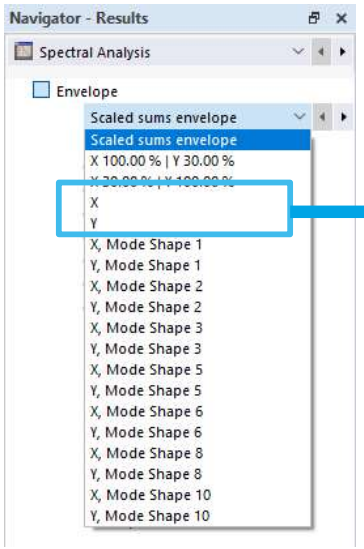
$$E_{SRSS} = \sum_{i=1}^{p} f_i \cdot E_i \quad \text{where} \quad f_i = \frac{E_i}{\sqrt{\sum_{j=1}^{p} E_j^2}}$$

2. **Complete Quadratic Combination (CQC) linear combination**

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

Directional Component Combination





1. Square Root Sum of the Squares (SRSS)

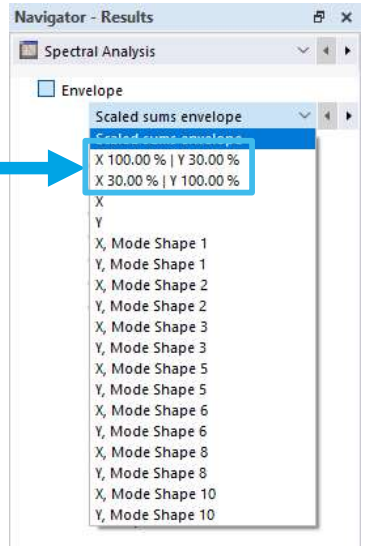
$$E_{SRSS} = \sqrt{E_1^2 + E_2^2 + \ldots + E_p^2}$$

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

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



NBC 2020 Base Shear Considerations

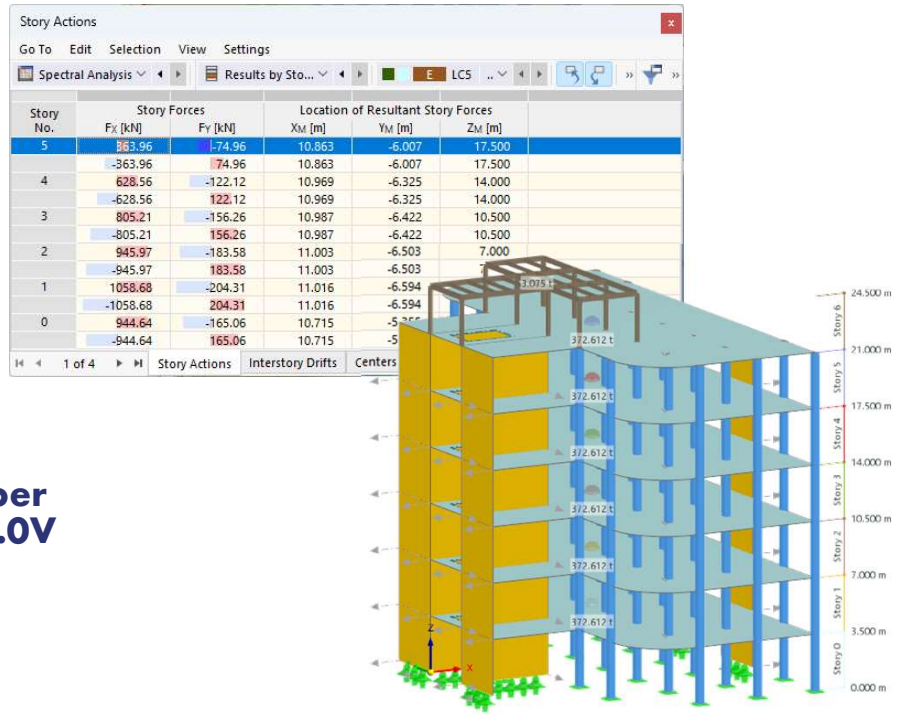
- **V_e = elastic base shear from dynamic analysis [4.1.8.12(5)]**
- **V_{ed} = adjusted elastic base shear [4.1.8.12(6)]**

$$V_{ed} = \text{Max}\left[\left(\frac{2}{3}\right)\frac{S(0.2)}{S(T_a)} \leq 1, \frac{S(0.5)}{S(T_a)} \leq 1\right] \times V_e$$

- **V_d = specified lateral earthquake force [4.1.8.12(7)]**

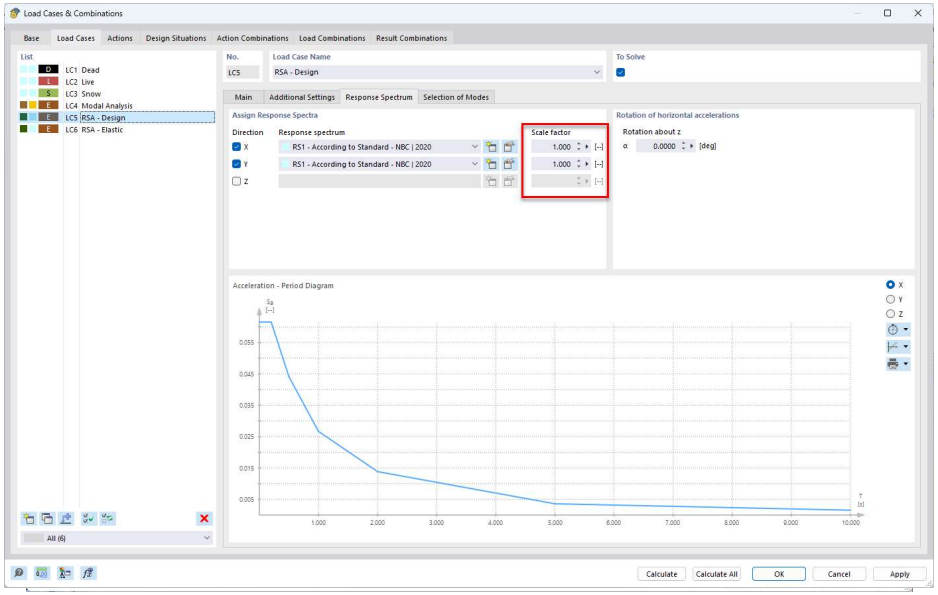
$$V_d = V_{ed}\left(\frac{I_e}{R_d R_o}\right)$$

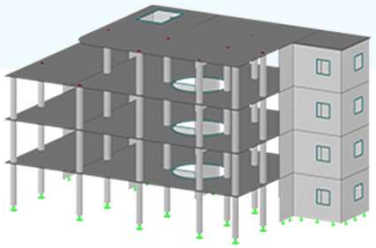
- **V = ESFP lateral earthquake force [4.1.8.11]**
- **$V_d/V < 0.8$ [4.1.8.12(8)] or $V_d/V < 1.0$ (irregular or timber structures) [4.1.8.12(9)/(12)], scale V_d to min 0.8V or 1.0V**



RFEM 6 Base Shear Considerations

- **Type "Design Spectrum"**
  - Specified lateral earthquake force, V_d [4.1.8.12(7)]
  - Does <u>not</u> include $\left[\left(\frac{2}{3}\right)\frac{S(0.2)}{S(T_a)} \leq 1, \frac{S(0.5)}{S(T_a)} \leq 1\right]$ factor [4.1.8.12(6)]
  - <u>Does</u> include $I_e/(R_dR_o)$ [4.1.8.12(7)]
- **Type "Elastic Spectrum"**
  - Elastic base shear, V_e [4.1.8.12(5)]
  - Does <u>not</u> include $I_e/(R_dR_o)$
  - Lateral deflections [4.1.8.13(2)]
- **Additional factors or scaling V_d/V**





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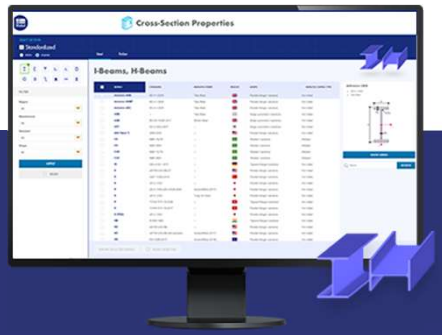

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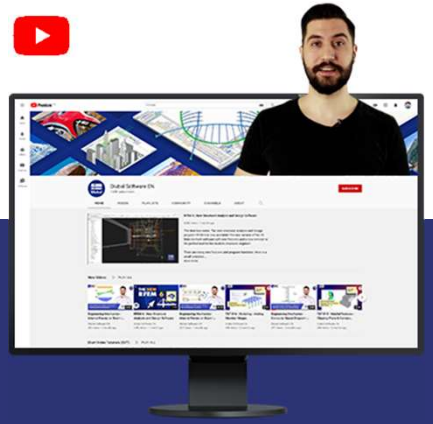

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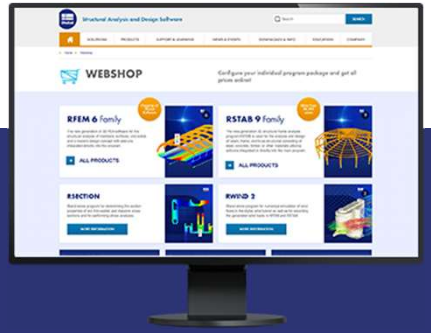

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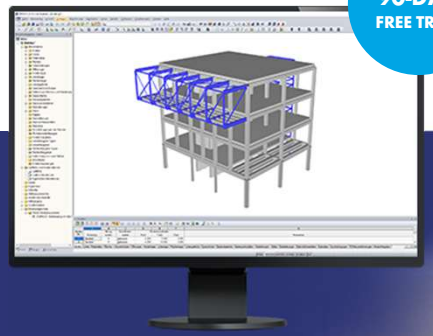

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