

# Dynamic characteristics of high-rise buildings: In-situ vs FEM

Davide Moretti | Okke Bronkhorst

Thomas van Dijk | Chris Geurts



August 27-31, 2023  
FLORENCE - ITALY

16th International  
Conference on  
Wind Engineering



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# Background



|                   | Montevideo tower | JuBi tower | NEMC tower | New Orleans tower |
|-------------------|------------------|------------|------------|-------------------|
| Measurement       | 0.41 Hz          | 0.46 Hz    | 0.53 Hz    | 0.28 Hz           |
| NEN 6702 (design) | 0.19 Hz          | 0.27 Hz    | 0.27 Hz    | 0.19 Hz           |

Bronkhorst, A. J., and C. P. W. Geurts. "Long-term vibration and wind load monitoring on a high-rise building." *Proceedings ISMA2020, Leuven, Belgium* (2020).

# Research questions

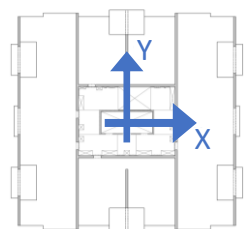
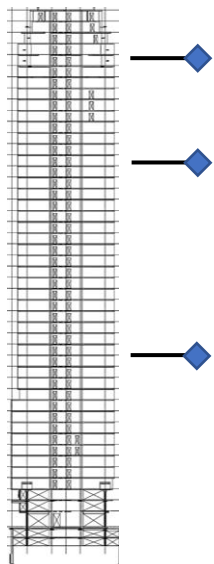
- What is the accuracy of FEM models in current design of Dutch high-rise building?
- What are causes for inaccuracies?

# Goals

- Current study
  - Compare FEM models and in-situ measurements
  - Identify modelling assumptions that cause mismatch
- HiViBe
  - Reliable prediction of wind-induced vibration in high-rise buildings

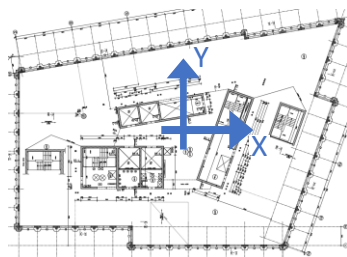
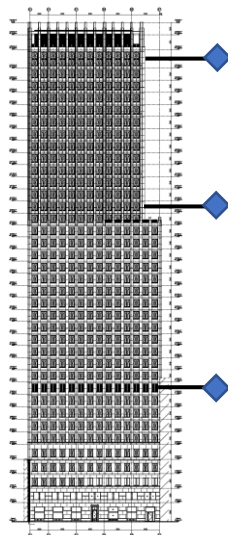
# Instrumented buildings

H=155m



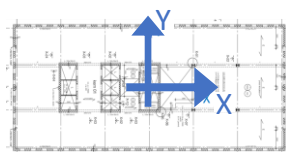
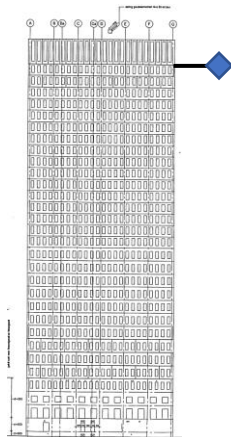
New Orleans  
Tower

H=148m



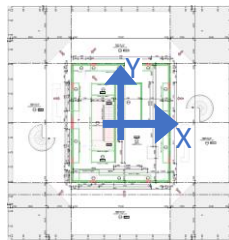
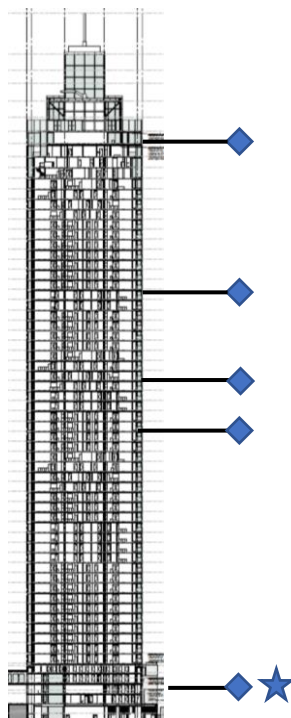
JuBI  
Tower

H=120m



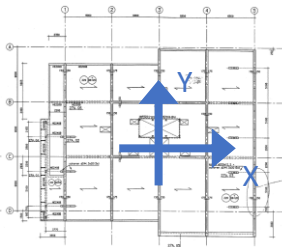
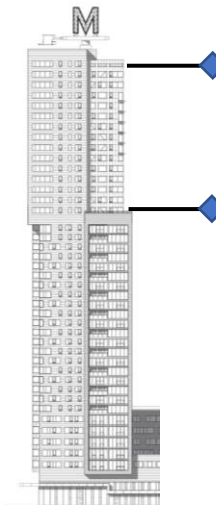
NEMC  
Tower

H=210m



Zalmhaven I  
Tower

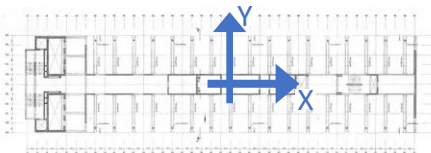
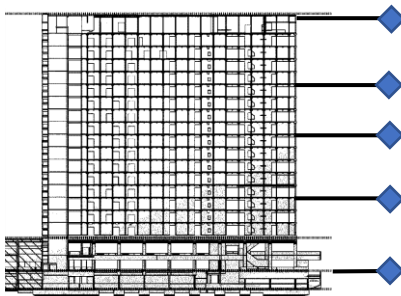
H=140m



Montevideo  
Tower

- ◆ Accelerometer
- ★ Strain gauges

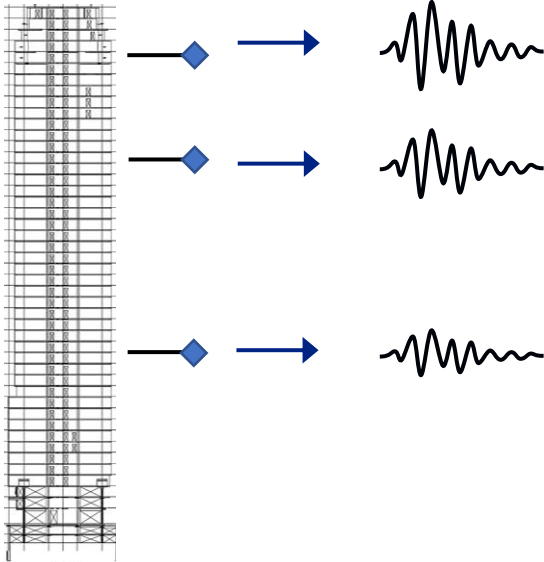
H=78m



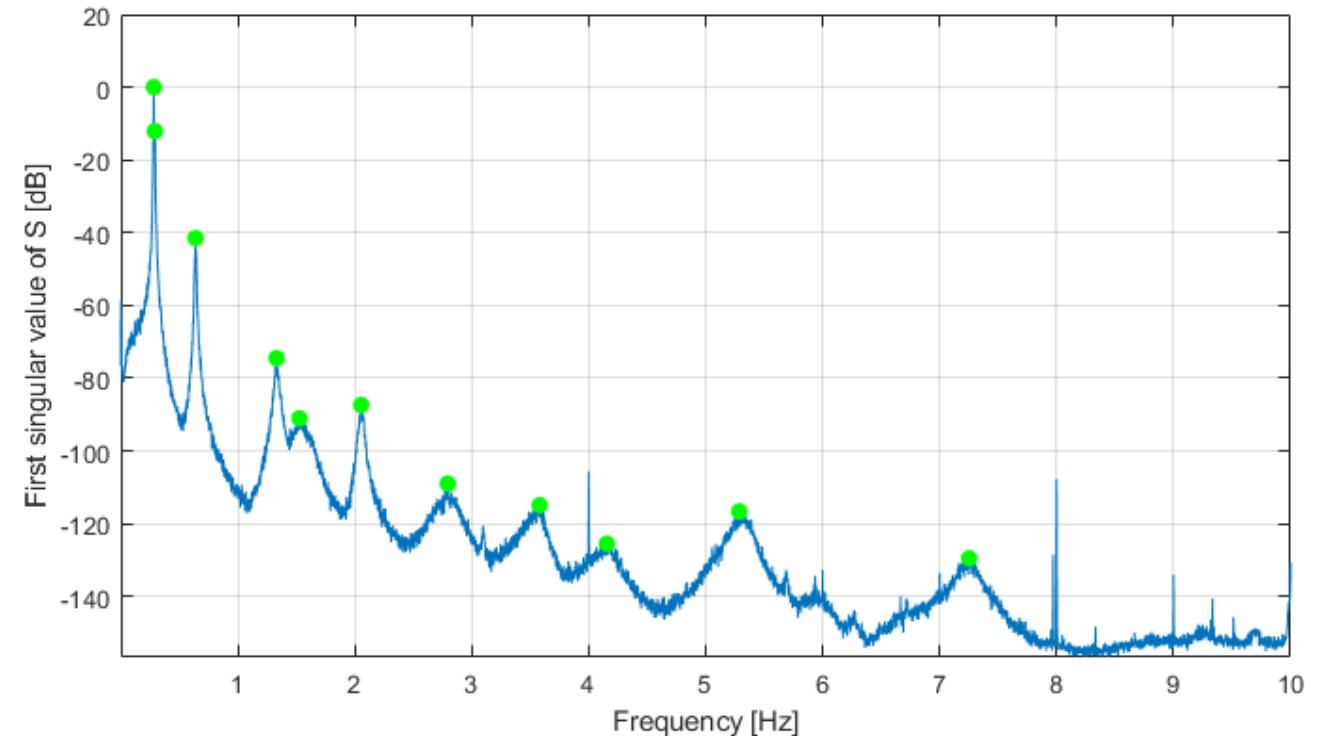
Tinbergen  
Tower

# Analysis

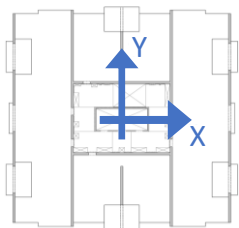
H=155m



## Frequency domain decomposition (Brincker & Zhang, 2000)



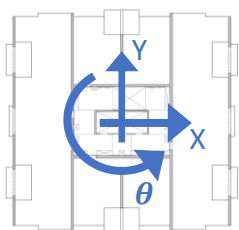
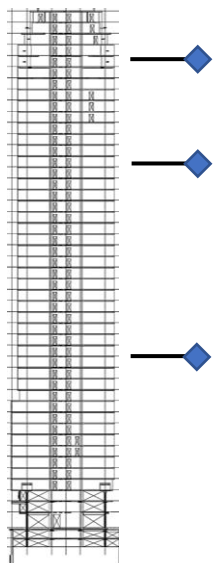
Bronkhorst, A. J., Moretti, D., & Geurts, C. P. W. (2022). Identification of the dynamic properties of the residential tower New Orleans. In *Experimental Vibration Analysis for Civil Engineering Structures: Select Proceedings of the EVACES 2021* (pp. 469-479). Cham: Springer International Publishing.



New Orleans

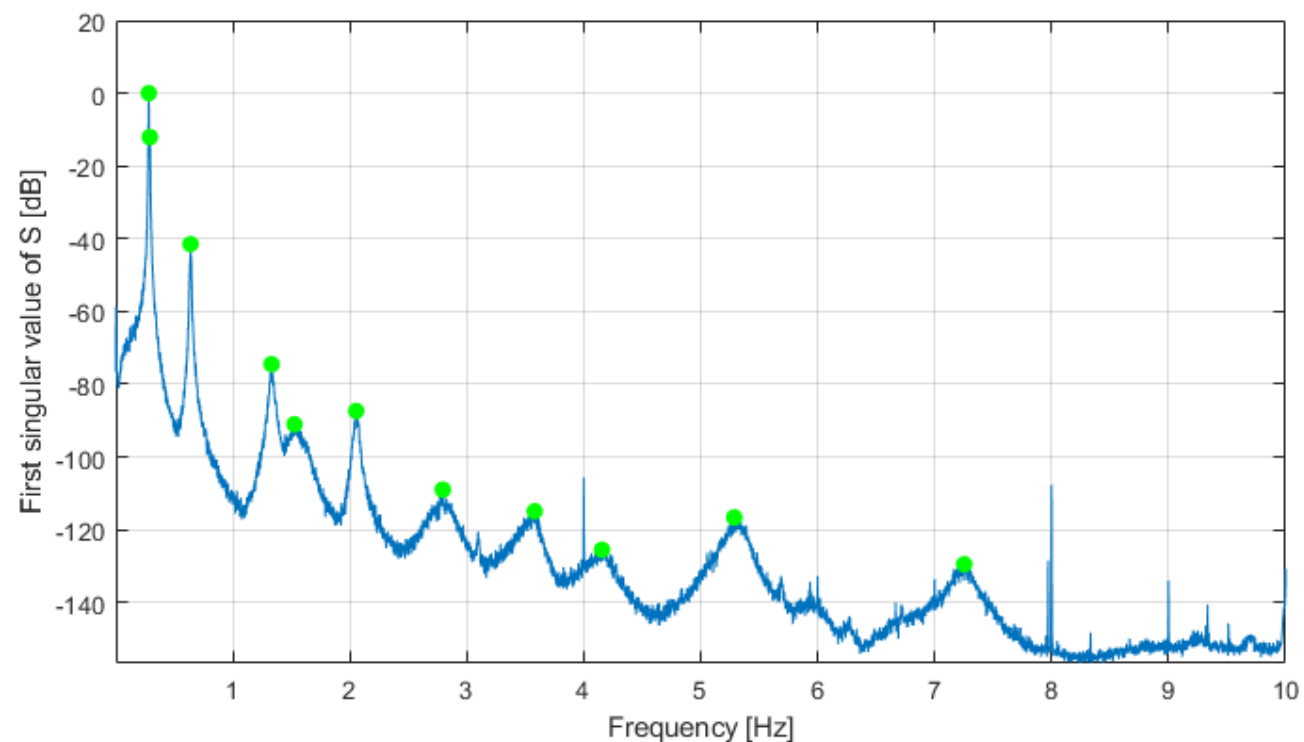
# Analysis

H=155m



| Mode        | Meas.<br>[Hz] |
|-------------|---------------|
| 1-Y         | 0.28          |
| 1-X         | 0.29          |
| 1- $\theta$ | 0.64          |
| 2-X         | 1.33          |
| 2-Y         | 1.53          |
| 2- $\theta$ | 2.01          |
| 3-X         | 2.77          |
| 3-Y         | 3.56          |

## Frequency domain decomposition (Brincker & Zhang, 2000)

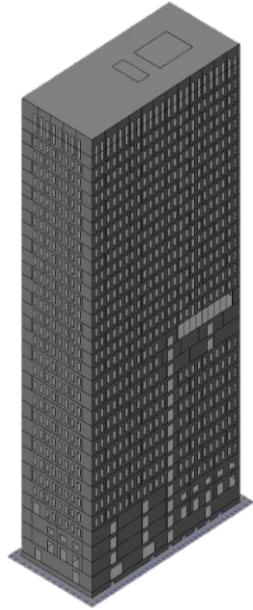


New Orleans

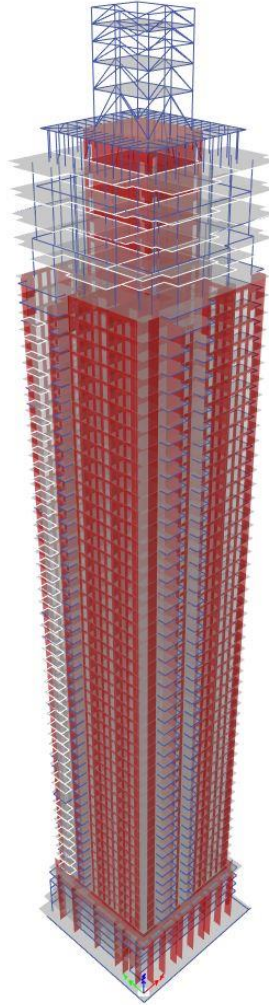
# Numerical models



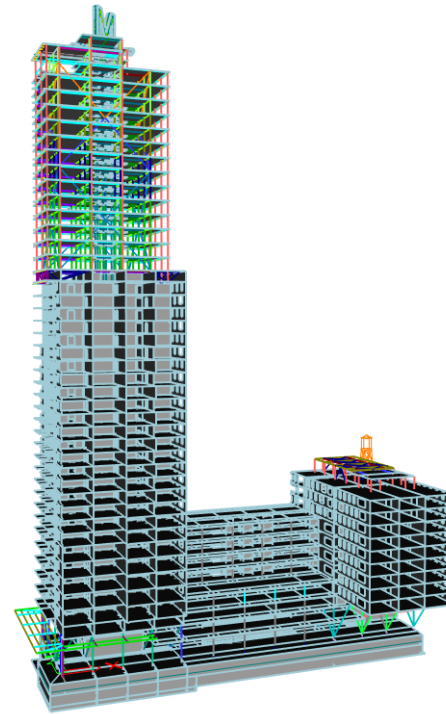
New Orleans



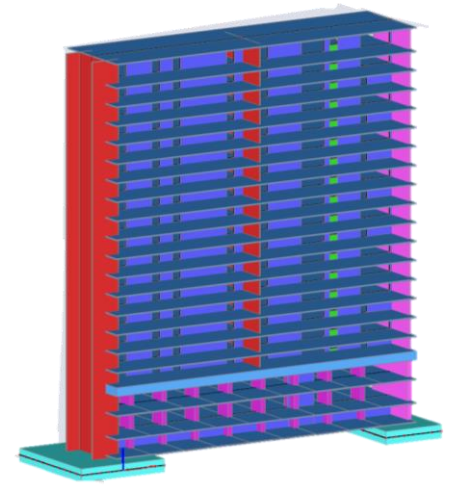
NEMC



Zalmhaven I



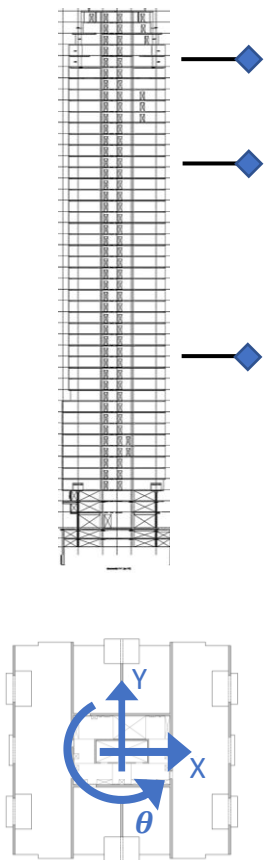
Montevideo



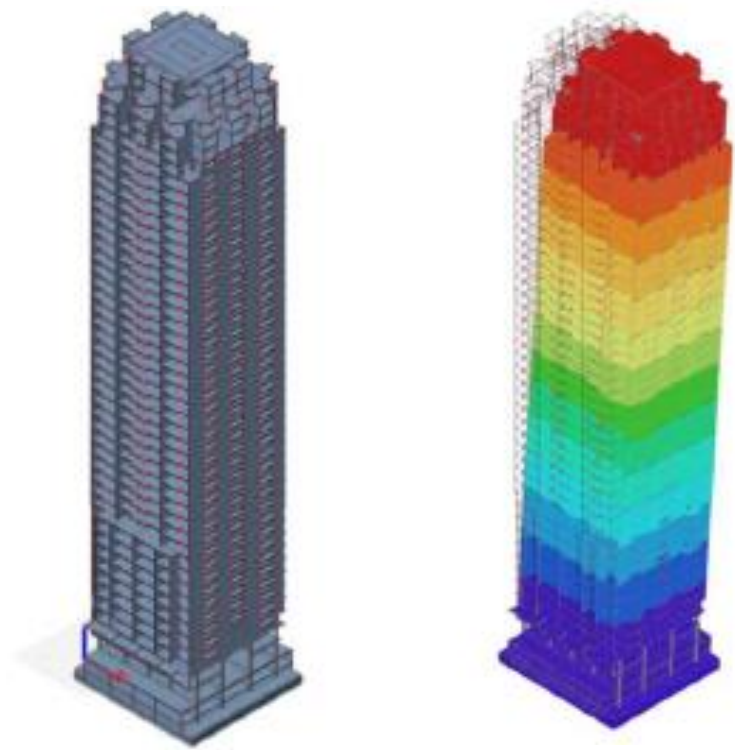
Tinbergen

# Results

H=155m



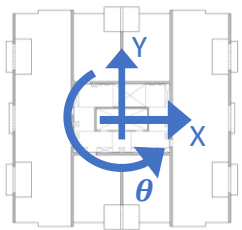
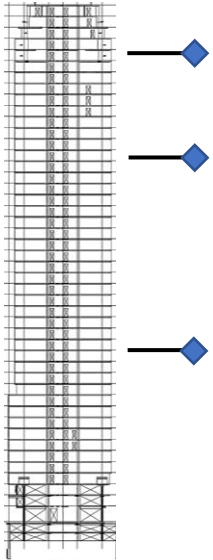
| Mode        | Meas.<br>[Hz] | FEM<br>[Hz] |
|-------------|---------------|-------------|
| 1-Y         | 0.28          | 0.23        |
| 1-X         | 0.29          | 0.20        |
| 1- $\theta$ | 0.64          | 0.50        |
| 2-X         | 1.33          | 1.02        |
| 2-Y         | 1.53          | 1.25        |
| 2- $\theta$ | 2.01          | 1.55        |
| 3-X         | 2.77          | 2.14        |
| 3-Y         | 3.56          | -           |



New Orleans

# Results

H=155m

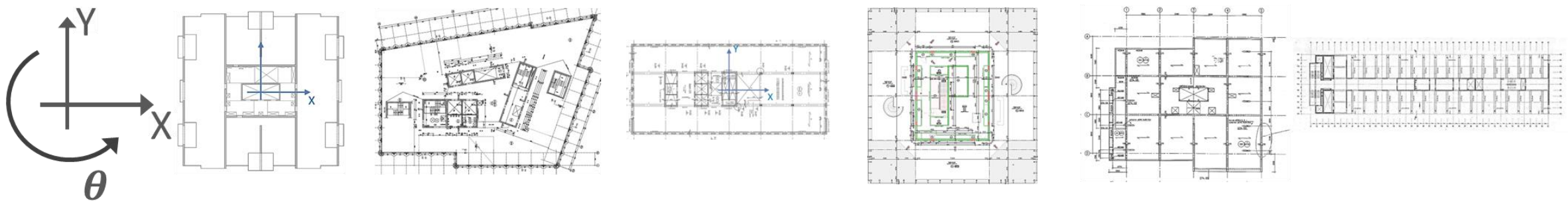
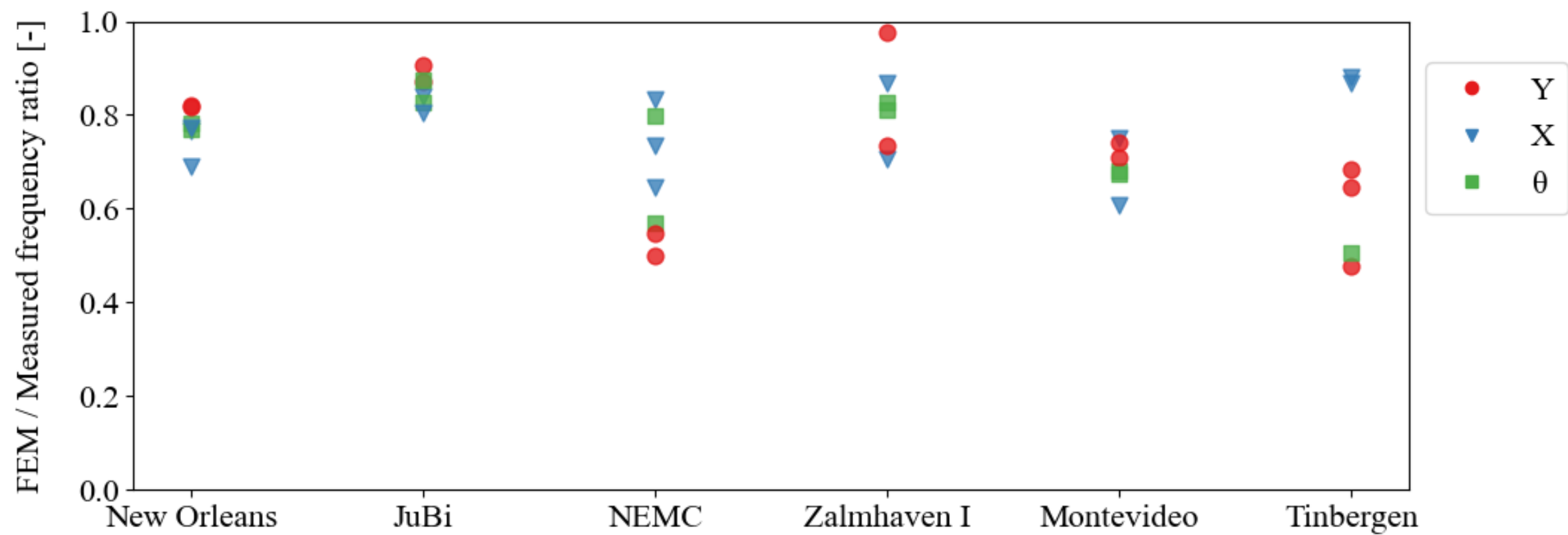


| Mode        | Meas. | FEM  | Ratio      |
|-------------|-------|------|------------|
|             | [Hz]  | [Hz] | FEM / Meas |
| 1-Y         | 0.28  | 0.23 | 0.69       |
| 1-X         | 0.29  | 0.20 | 0.82       |
| 1- $\theta$ | 0.64  | 0.50 | 0.78       |
| 2-X         | 1.33  | 1.02 | 0.77       |
| 2-Y         | 1.53  | 1.25 | 0.82       |
| 2- $\theta$ | 2.01  | 1.55 | 0.77       |
| 3-X         | 2.77  | 2.14 | 0.77       |
| 3-Y         | 3.56  | -    |            |

- All ratios are  $< 1$
- Ratios are not uniform

New Orleans

# Results



# Summary of findings

*What is the accuracy of FEM models in current design of Dutch high-rise building?*

- FEM models underestimate measured natural frequencies
- Conservative design of the structure

# Ongoing work

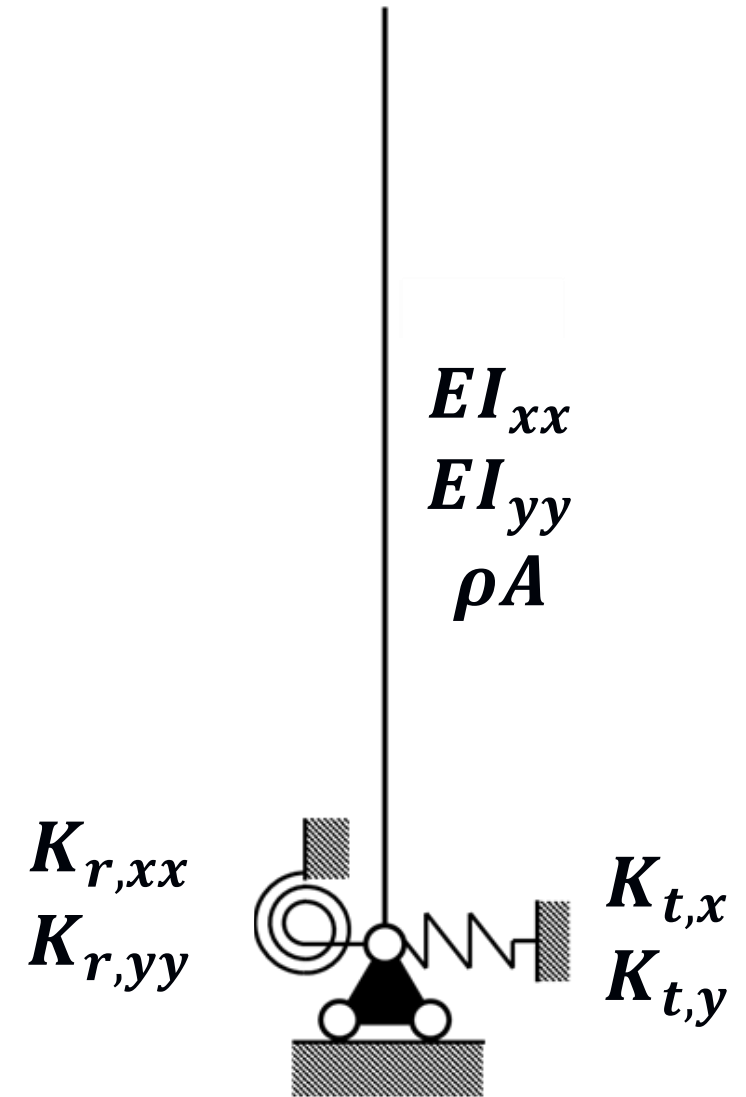
*What are causes for inaccuracies?*

- Model updating using a simplified Bernoulli-beam model
- Sensitivity study using the full FEM models

# Model updating

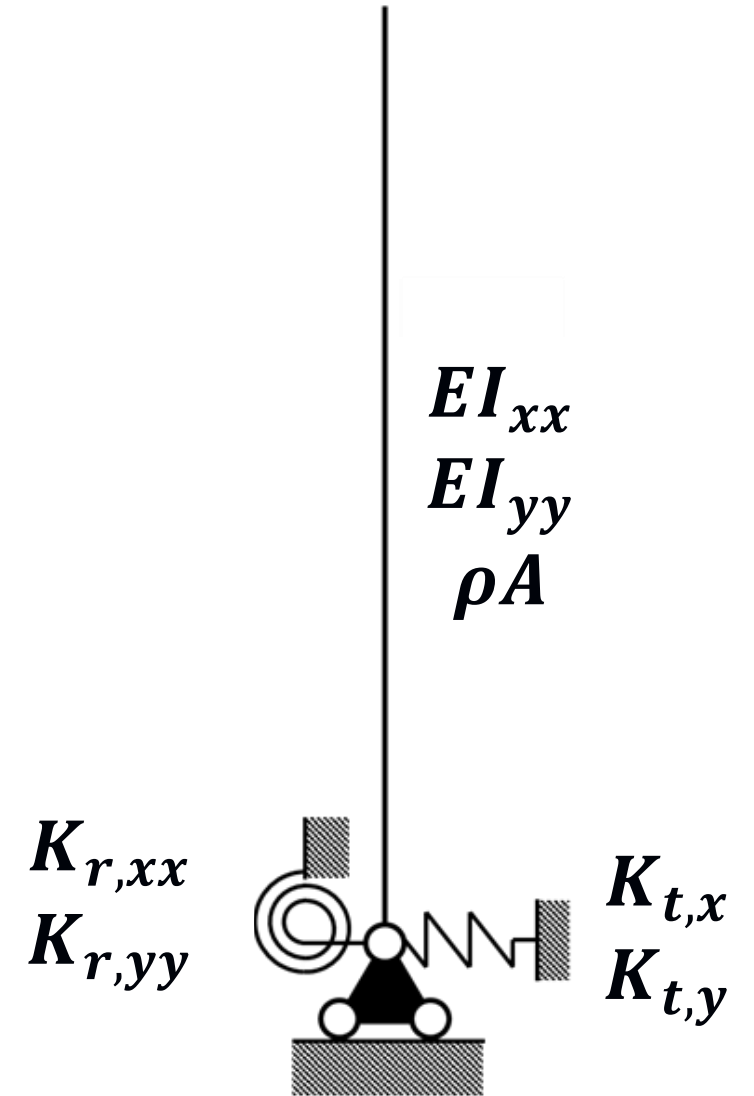
- Estimated the optimal beam properties
- Estimate equivalent beam properties from the full FEM models
- Compute the ratio between FEM and Optimised and equivalent beam properties

Moretti, D., A. J. Bronkhorst, and C. P. W. Geurts. "Identification of the structural properties of a high-rise building."



# Model updating

| Property   | Modal Updating / FEM ratio |             |
|------------|----------------------------|-------------|
|            | New Orleans                | Zalmhaven I |
| $EI_{xx}$  | 1.84                       | 1.74        |
| $EI_{yy}$  | 2.13                       | 1.60        |
| $K_{r,xx}$ | 1.15                       | 2.17        |
| $K_{r,yy}$ | 1.47                       | 2.63        |



# Sensitivity study

- Start from assumptions in design phase
- Vary properties within physical bounds (Young's moduli, pile stiffness, dynamic mass)
- Check against measured natural frequencies

# Thank you for the attention!



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