WIND TURBINES and EARTHQUAKES

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WIND TURBINES and EARTHQUAKES

- **Introduction**
- **Modal Approach**
- **Time-Domain Simulation of Earthquakes**
- **Results for Nordex N80 in Ryuyo-Cho (Japan)**
- **Conclusions**

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Introduction

- Wind loads : Wind turbines designed to withstand aerodynamic forces on rotor
- Wind farms in areas with strong earthquakes
- Earthquake: ground motion leads to structural vibrations and loads, earthquake loads should not exceed design loads
- Consequence: earthquake loads have to be calculated in order to assess whether a given wind turbine is suitable for a site or whether design modifications are necessary

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Introduction

U. Ritschel / WWEC 2003 Cape Town

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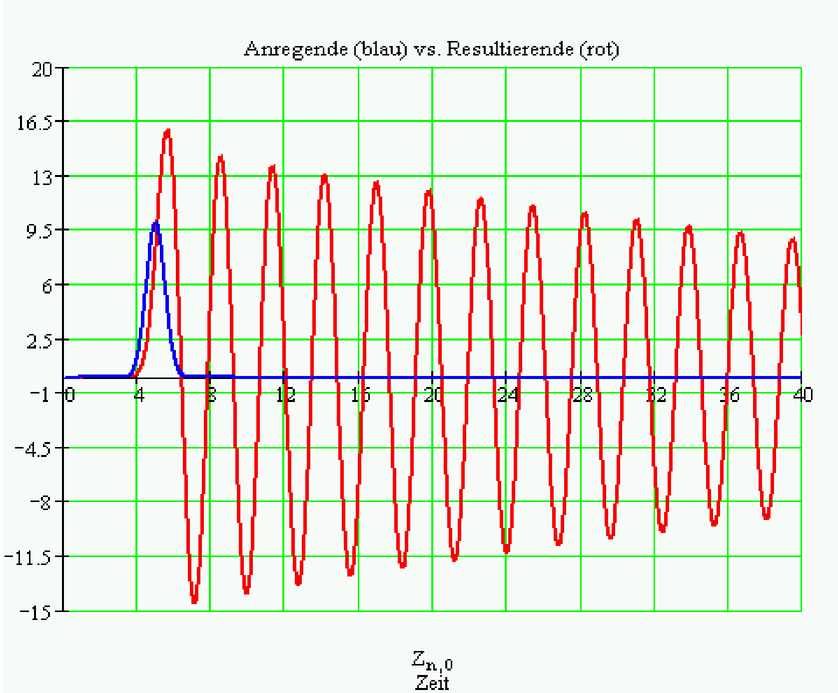
Introduction

- Wind turbines made from elastic materials like steel and fibre reenforced plastic
- Low structural damping



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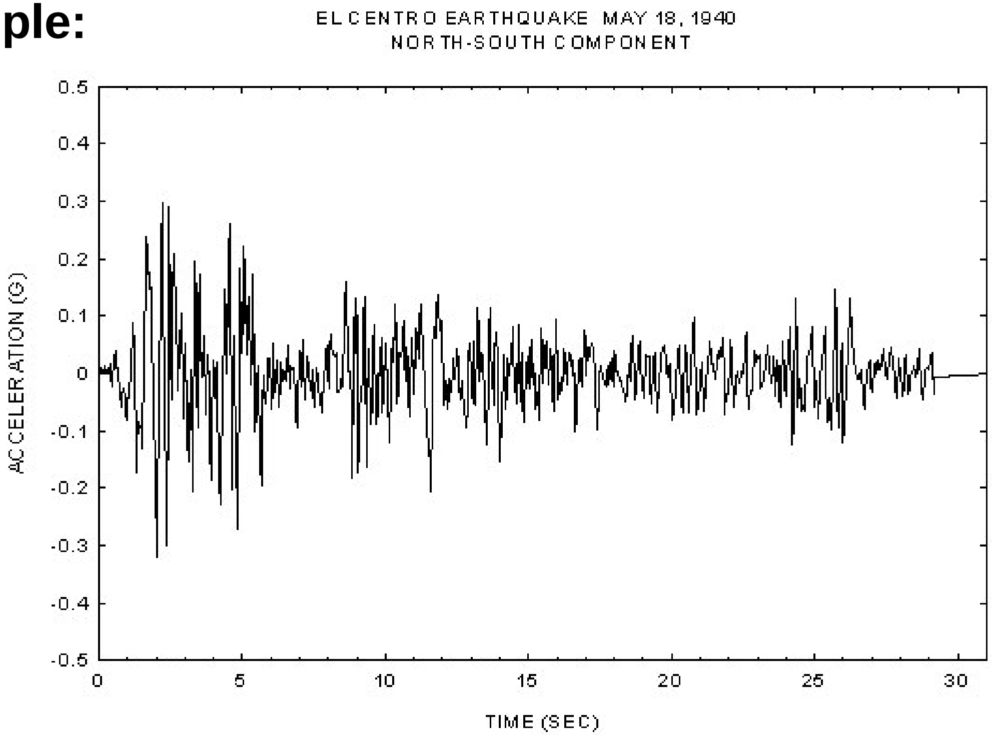
Introduction

- Classification of earthquake by peak ground acceleration
- Example: Ryuyo-Cho (Japan) with peak acceleration of 0.3 g

  (on average once during 475 years, MM scale IX, Richter scale ~ 7)
- Example:



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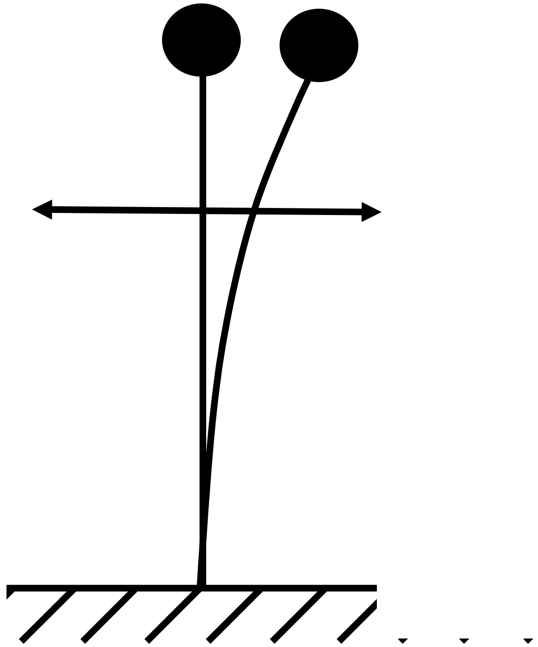
Introduction

Theoretical concept to describe effects on structures:

Single degree of freedom (SDOF) oscillator

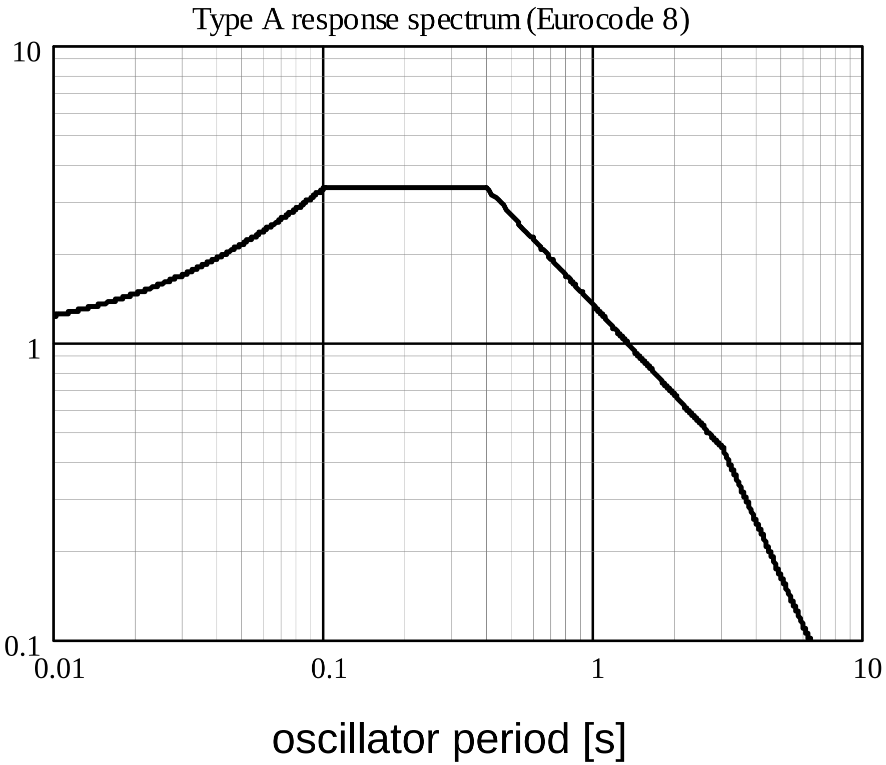
characterized by

- mass M
- stiffness K
- and resulting frequency Ω or period T



Introduction

- **Standards (Eurocode 8): SDOF Oscillator response spectrum**



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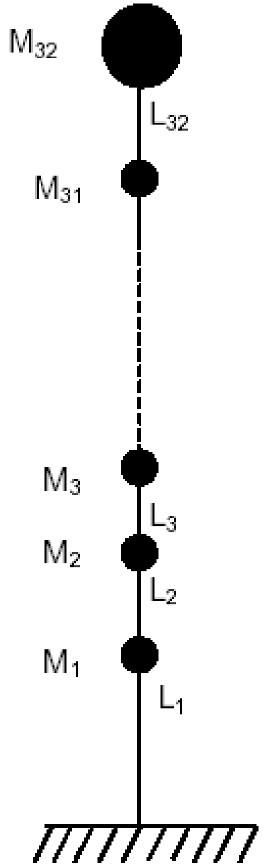
Modal Approach

- Tower approximated as system of lumped masses
- Nacelle and rotor as point mass at tower top
- Vibration modes can be calculated
- Tower modes can be regarded as SDOF oscillators



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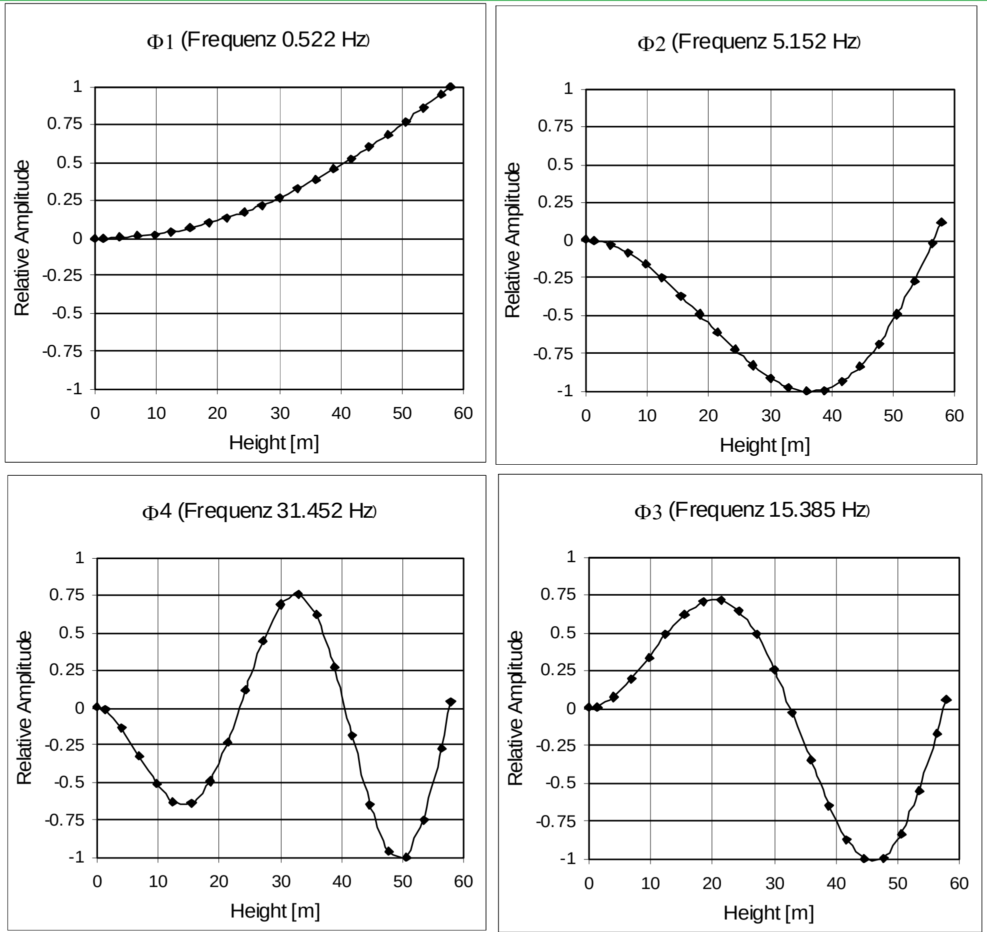
Modal Approach

- **With modes and SDOF oscillator spectrum forces and moments in the tower are obtained**
- **Additional wind loads on turbine taken into account**



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Time Domain Simulation

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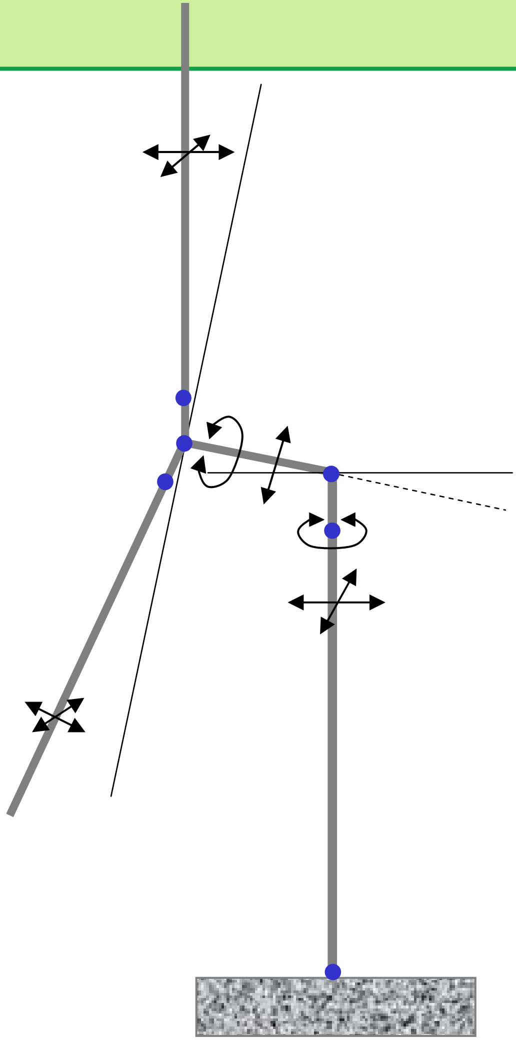
Time Domain Simulation



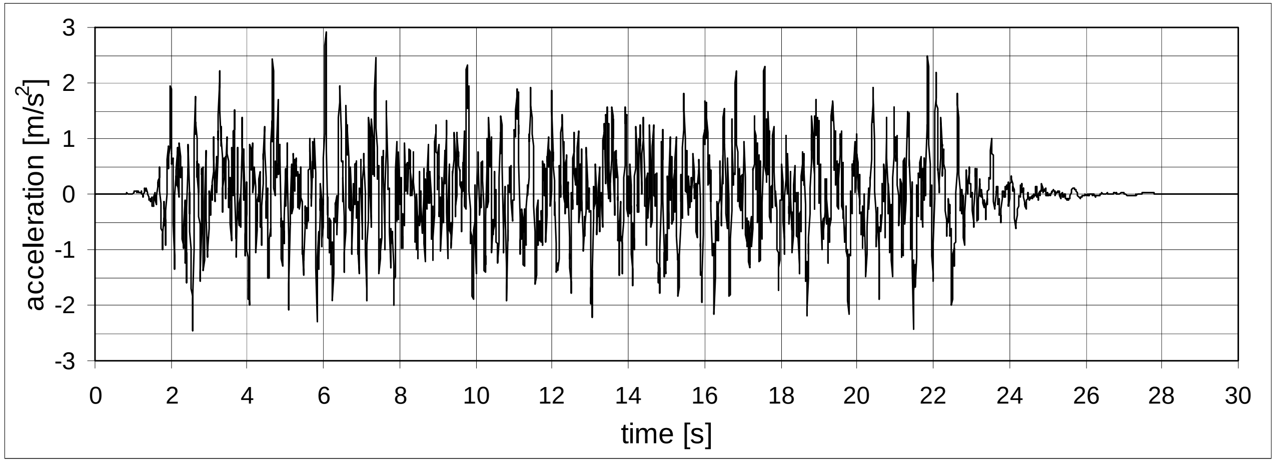
Flex5 - multi body and modal dynamics

(S. Øye, DTU)

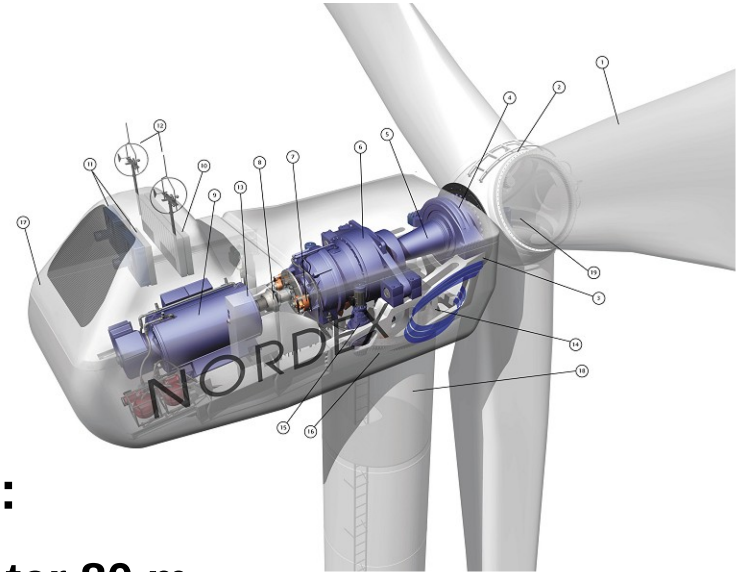
- **2 modes flapwise and 2 edgewise for blades**
- **drive train rotation and torsion ...**
- **more than 20 degrees of freedom**
- **time-domain dynamic equation integrated**
- **sectional loads are obtained**
- **takes into account wind and functional loads in realistic fashion**

Time Domain Simulation

- Generate 3-D synthetic accelerograms that are consistent with SDOF oscillator response spectrum
- Specified in Standards e.g. Eurocode 8
- Include accelerograms in simulation program



Results for Nordex N80



Nordex N80:

- **Rotor diameter 80 m**
- **Rated power 2500 kW, variable speed, pitch-regulated**
- **Hub height Ryuyo Cho 60 m**
- **Certified for IEC1A site**

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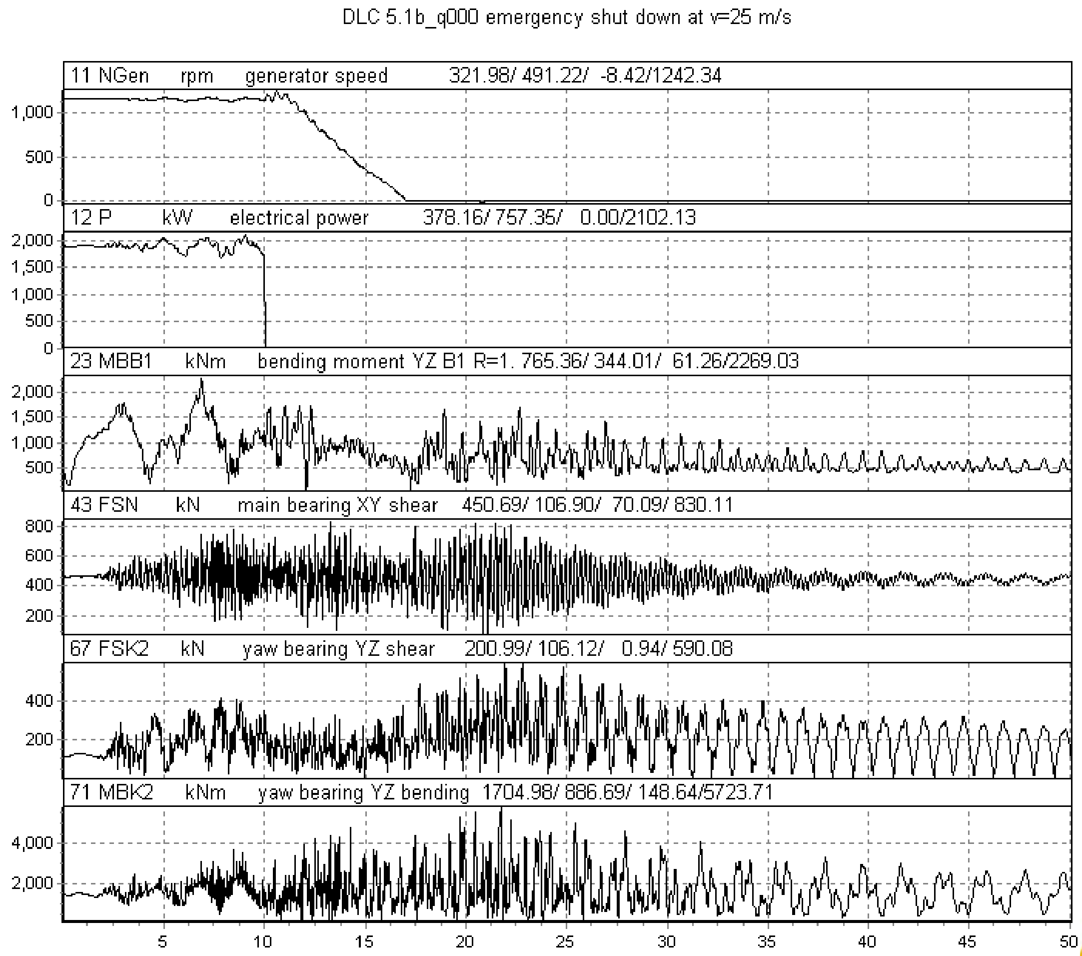
Results for Nordex N80



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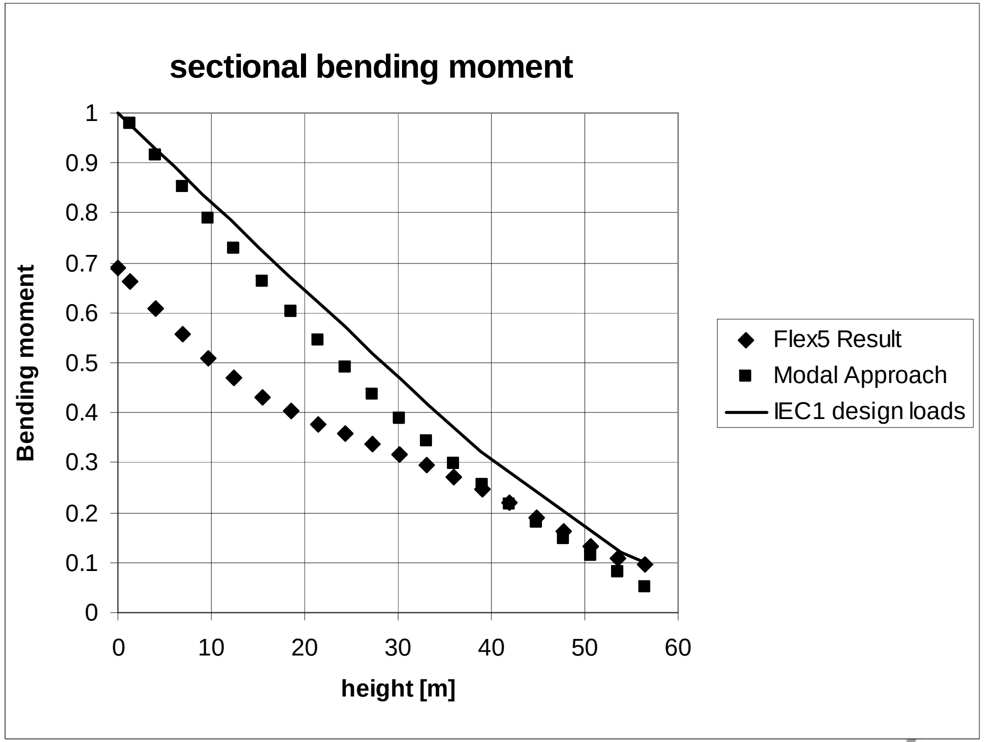
Results for Nordex N80

- Example: bending moments in the tower
- Detailed picture of blade and machine loads
- Earthquake loads are covered by design loads
- Vertical component taken into account, leads to extreme values
- 0.3 g is upper limit for peak ground acceleration



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Conclusions

- Modal approach and time-domain simulation (Flex5) compared
- Simulation leads to much more detailed information on loads on the structure near and above tower top
- Realistic combination of ground acceleration, wind forces and functional loads (shut down)
- Results show that especially loads near tower top are under-estimated by modal analysis
- Time-domain simulation recommended for sites with earthquakes of magnitude VII or more on the modified Mercalli scale

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