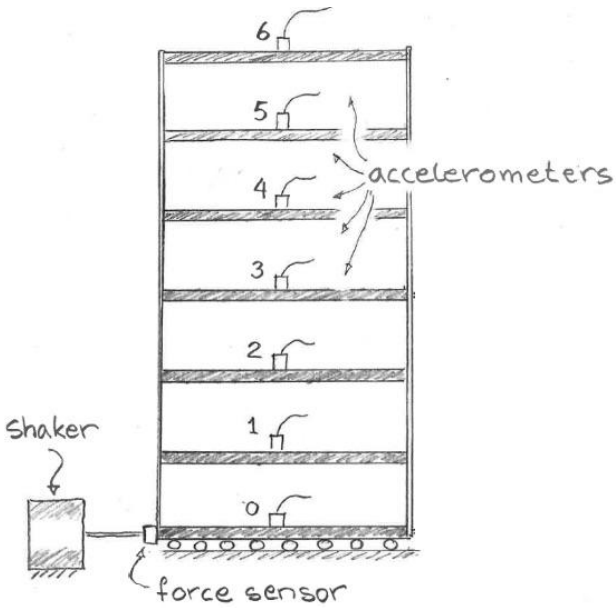
Project 1 - A six-storey frame

Structural Dynamic Computing 2018

The assignment concerns a six-storey frame (shown in the photo) and its low frequency structural vibrations. It is an idealized scaled model of a so called Shear-building. It consists of 7 wooden plates connected by four steel strips.

You are supposed to make measurements and establish models that can be compared to the experimental data.



The project concerns natural frequencies and mode shapes. The modal properties are investigated using harmonic base excitation.

The first model used is the idealized Shear-building model and the second is a finite element model using beam elements.

Each group will be able to book a one hour demo session for the measurements.

The experimental set up is according to the schematic figure above. A shaker puts the base into horizontal harmonic motion. Accelerometers are put on all seven wooden plates. The frequency of the base excitation can be varied and the amplitude can also be changed.

Laboratory tasks:

You need to store some data for comparison with the models. Bring your own USB-stick for this purpose. Data from all accelerometers and the force sensor can be logged as functions of time and stored in an ordinary text-file. See below.

- Determine mass and stiffness properties of the frame. Measure accurately the dimensions. The weight of the wooden pieces need not be determined. The mass of each plate is 2.24 kg.
- Let the frame be subjected to a transient. From a FFT-analysis of the time signals from the accelerometers it is possible to approximately locate the resonance frequencies. This is useful in the next task.
- Measure horizontal accelerations on the “floors” when the frame is subjected to harmonic ground excitation. Find and determine the resonance frequencies and the corresponding mode shapes. Plot the mode shapes from the experimental data. Determine as many resonances you can experimentally for steady state behavior of the frame.
- Make a rough estimate of the damping in the frame using the resonance peaks.

Data from the force sensor (f) and the accelerometers (a) are organized in columns with time values:

	f	a_0	a_1		a_6
t_1				….	
t_2				….	
etc				….	

The data from the force transducer are not needed directly for the comparison with models according to below.

Modeling tasks:

Two models should be established, as mentioned, and analyzed for natural frequencies and modes as well as for steady state harmonic loading. When handling experimental data in steady state, the relationships below are useful

$$v_0 = \omega u_0 \quad \text{and} \quad a_0 = -\omega^2 u_0$$

showing the connection between displacement, velocity, and acceleration amplitudes at a particular steady state frequency.

Shear building with 6 dofs (compare with Homework 2):

- Establish a shear-building model (with the wooden plates considered as rigid masses) without damping in terms of structural displacements and find the resonance frequencies and the mode shapes by an eigenvalue analysis.
- Compare with your experimental data and identify as many resonances and mode shapes you can.
- Find resonances in your model using steady state harmonic loading by a frequency sweep over all resonances in the model. Put equal harmonic forces in all dofs as $p_i = - m_i a_g$, with $i = 1, \ldots 6$, where m_i is the mass of floor i and a_g is the acceleration of the bottom plate. This is the earth-quake forcing concerning structural displacements. Compare with the experimental results near resonances. Note: no damping is present and your model will give results in structural displacements. Therefore it is difficult to get resemblance with absolute values from the experiments.

Finite element model with harmonic base displacements:

- Establish a FE-model in Calfem using beam elements (also for the wooden plates) by calculating mass and stiffness matrices. Find natural frequencies and modes from this model and compare with experiments.
- You also need to construct a reasonable damping matrix in order to make comparisons between simulations and measurements according to the next step.
- Shake the model frame numerically at the base with a sinusoidal time function acting in the horizontal direction as in the experiments.
- Compare the numerical solution with your experimental data near the resonances.

Report:

Document your findings in a written report that clearly shows your assumptions, measurements, model features and results. Try to keep it short and concise without leaving out essential information. Make sure that a qualified reader (i.e. with basic knowledge in structural dynamics) can understand. Don't spend too much text on basic theory. It is assumed to be known. Focus on your results and how you obtained them. The report should have

- Cover page with the names of the group members,
- Table of contents
- Introduction/problem description
- Measurements description
- Short about modeling and analysis
- Results discussion
- Appendix with code measured data etc

It should not exceed about 12 pages (Appendix excluded). Text references are (at least) the Lecture notes and the CALFEM manual (`beam2d`, `step2` & `exd2`).
To be handed in according to the course program.