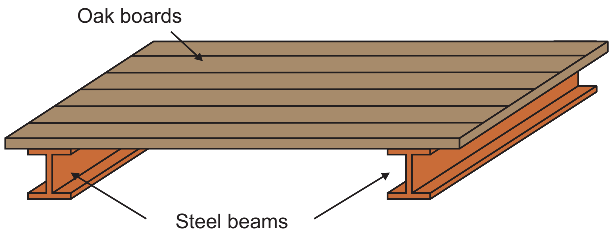
Arnaud Deraemaeker (aderaema@ulb.ac.be)

Session 5 : Remedial measures

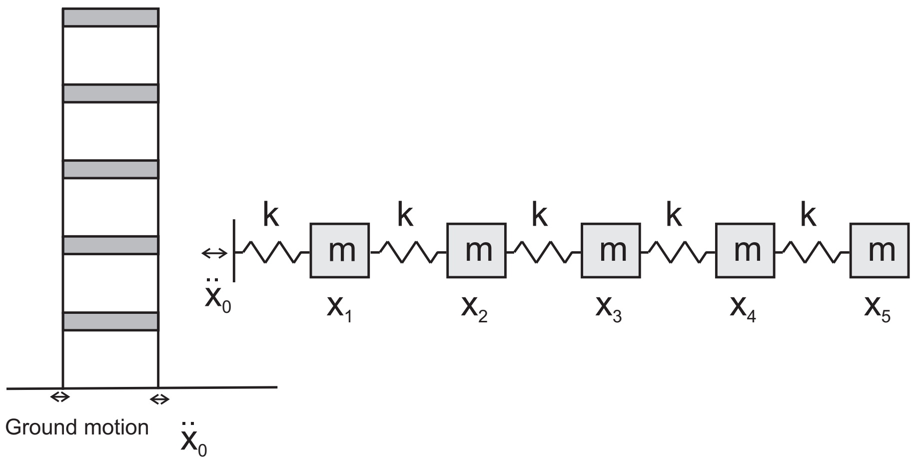
Exercise 1

Consider a footbridge of length $L = 30m$. The supporting structure is made of two steel $IPE600$ beams ($E = 210GPa$, $\rho = 7800kg/m^3$), which can be considered as simply supported at both ends. The bridge deck is made of oak tree boards ($\rho = 700kg/m^3$, thickness=$3cm$) which are fixed perpendicular to the IPE beams. The width of the bridge is $4m$. The weight of other non-structural elements (such as railings) is neglected in this calculation.



- Compute the equivalent mass and stiffness of this footbridge and the natural frequency for the first mode of vibration (use stiffness and mass factors). Is resonance likely to occur for this footbridge due to pedestrian dynamic loading ?
- Design a tuned mass damper (TMD) (find the mass, stiffness and damping of the TMD) aimed at reducing the vibration amplitude of the footbridge around the first natural frequency, to be located in the middle of the footbridge. Take a mass ratio of $\mu = 0.01$. Consider a modal damping of 0.5% for the first mode of the footbridge without the TMD.
- Plot the transfer function between a force acting at the location of the TMD in the vertical direction and the displacement of the footbridge at that same location and in the same direction, using the simplified equivalent 1DOF model for the footbridge. By what factor are you able to reduce the vibration at the first natural frequency of the footbridge ?
- What is the influence of an increase of 10% of the stiffness of the TMD on the efficiency of the device ?

Exercise 2



Consider a building with five storeys, which can be approximated by a 5 dofs model as shown in the figure. The values of the stiffness and mass of each storey are $m = 410\,10^3 kg$ and $k = 5.85\,10^9 N/m$.

- Compute the transfer function between the relative displacement of the top floor and the ground acceleration using the direct method in the frequency domain. Consider a global hysteretic damping with $\eta = 0.02$.
- Design an isolation system (spring and damper) in order to isolate the building as much as possible from ground vibration, taking into account the frequency content of the ground excitation of the Santa Cruz Earthquake ($quake.mat$ file). Compute the transfer function between the acceleration of the ground and the relative motion between the top floor of the building and the bottom of the building (above the isolation system). Compare with the previous transfer function (without isolation) and comment.

To load the time and signal vectors in Matlab for the Santa Cruz Earthquake

```
load quake
% Scaling factors
g = 0.0980; e = g*e/100;
dt = 1/200; t = dt*(1:length(e))';
```

The direct method for the computation of the transfer function consists in solving the system of equations

$$(K + i\omega B - \omega^2 M)X = F$$

in a range of frequencies. The matlab command to solve the equations is, for the ith frequency

```
X(:,i)= (K + 1i*w(i)*B - w(i)^2*M) \ F;
```

and the transfer function can be computed by building a frequency vector w and making a loop on i.