Finite element models

Initial FE-model (design phase)

Before any measurements are done, the vibration serviceability of the construction can be assessed by creating a finite element model, based on the architectural plans.

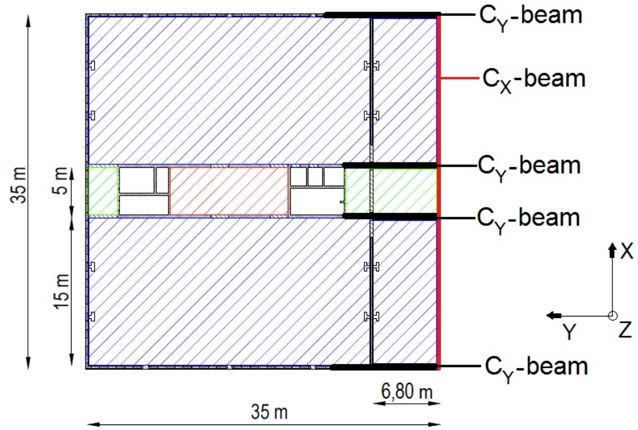

Figure 1: Global view on the first floor of the data centre.

An initial finite element model is developed based on the available technical drawings. At completion, the modal characteristics of the structure are identified experimentally and used to calibrate the numerical model. The two office areas of 35mx15m are constructed with pre-stressed hollow-core concrete slabs with spans of 15m, a thickness of 400mm and a compression layer of 60mm. The remaining area (patio and gangway) is comprised of a respectively 200mm and 250mm thick solid concrete slab. The system of concrete walls, columns and beams, enabled to realise a cantilever length of 6.8m.

The finite element model of the structure consists of a regular mesh of 4-node shell elements (Mindlin-Reissner theory) with six degrees of freedom at each node to model the floor areas and Timoshenko beam elements to represent the supporting beams at the borders of the cantilever area. The edges at the elevator shafts are considered perfectly clamped, all other support points are pinned with appropriate rotations restrained along the support lines corresponding to walls.

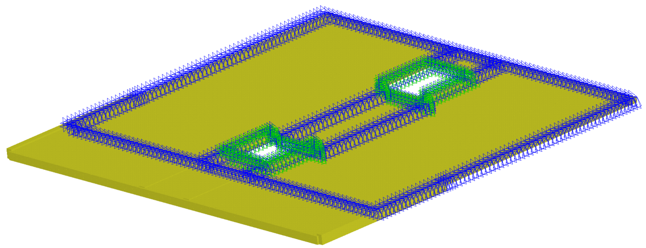

Figure 2: Initial FE-model of the concrete floor (ANSYS).

The floor in the office area, consisting of the hollow-core pre-stressed floor slabs and compression layer, is modelled as an equivalent solid slab with the same height as the actual floor but made of an orthotropic material. Table 1 summarizes the characteristic properties. The beams at the borders of the cantilever area (the cx-beam and cy-beams - see figure 1) are given an artificial high modulus of elasticity and density to simulate the behaviour of the concrete façades. Their stiffness will be tuned based on the experimentally identified modal characteristics.

Material properties		
Patio, gangway		
Isotropic	E=39.6 MPa	ρ=2500 kg/m^3
Office area	E$_x$=45.6 GPa	G$_{xy}$=14.7 GPa
Orthotropic derived	E$_y$=35.3 GPa	G$_{yz}$=14.7 GPa
according to [1]	E$_z$=45.6 GPa	G$_{xz}$=14.7 GPa
	$\rho = 1490$ kg/m^3	

Table 1: Material properties of the initial FE-model.

Calibrated FE-model (post-construction phase)

After the construction was built, the vibration serviceability can be reassessed based on a finite element model which is calibrated by adapting model parameters such that an optimal correspondence is found between the experimentally identified and calculated modal parameters. For the vibration serviceability after construction, the measured damping will be taken into account.

The FE-model was developed according to the as-built plans. The updating variables are those parameters for which poor prior knowledge is available. A total of 6 variables are considered in this analysis, the moduli of elasticity and shear (E$_x$, E$_y$ and G$_{xy}$, G$_{yz}$) of the orthotropic floor and the stiffness of the cx- and cy-beam elements used at the edges of the cantilever floor area (E$_{cx}$, E$_{cy}$). Calibrating the stiffness parameters of the left and right floor separately, will allow for a decoupling of the vertical bending modes between the left and right office area. Table 2 summarises the results of the updating procedure. It lists the values of the model parameters of the office floor before and after updating.

Material properties of the calibrated FE-model	
Left side	Right side
$E_{x,new} = 1.01 \times E_x$	$E_{x,new} = 0.95 \times E_x$
$E_{y,new} = 1.45 \times E_y$	$E_{y,new} = 1.45 \times E_y$
$G_{xy,new} = 0.4 \times G_{xy}$	$G_{xy,new} = 0.3 \times G_{xy}$
$G_{yz,new} = 1.8 \times G_{yz}$	$G_{yz,new} = 2 \times G_{yz}$

Table 2: Material properties of the calibrated FE-model.

Bibliography

[1] A.L. Smith, S.J. Hicks, and P.J. Devine, *Design of Floors for Vibration: A New Approach*, The Steel Construction Institute, 2007.