5 MODELLING

5.1 GENERAL CONSIDERATIONS

Establishing a structural model for the simulation of the dynamic characteristics of an existing building it is postulated that the vibrational behaviour is reproduced as exact as possible. Not all details can be modelled in order to save computing time and storage needs. The number of degrees of freedom and the number of parameters may be reduced making use of simplifications. For example, the vibration modes within the stairs and the ramp are not further investigated, the building´s structure is modelled as a frame problem, and the model is strictly linear. Find a good compromise between the detail in modelling and the expense in realisation of the model is the skill of an engineer to achieve a good convergence between model and reality.

5.2 WAY OF PROCEEDING

As a first step the building and the ramp were inspected in order to verify dimensions, joints, restraints and loads. The obtained data was compared with project drawings, descriptions, construction protocols, etc. Then a three-dimensional AutoCAD drawing was created. This drawing was exported to the calculation programme SAP2000.

The cross-sections were chosen when purely metallic, or calculated and entered as general cross-sections in case of mixed elements.

From project drawings and inspections the restraints were defined and applied on the model. Actuating loads were estimated and applied as well.

5.3 ADAPTATION OF STRUCTURAL MEMBERS AND MASS DISTRIBUTION

With the results of dynamic testing the characteristics were adapted in order to simulate the measured vibrations. As to say, clamping ratios, material characteristics and loads were chosen within reasonable limits. Afterwards all element types (ramp, floors, frames, slabs) and materials (steel was considered as fix, concrete and asphalt were adopted) with their correspondent loads showed similar vibration characteristics in simulation and measurement.

5.4 PARAMETERIZATION

The next step was to compare global (building-) vibration. Therefore the Eigenfrequencies obtained from measurements are less helpful, as there are too many of them. It was considered a better solution to compare nodal displacements "in situ" with calculated values.

The original ramp was modelled with the following characteristics, in accordance with the measurement results:

- E_c = 35.000 N/mm² (concrete)

- Ea = 17.500 N/mm² (asphalt)
- γc = 22 kN/m^3

As the floor and roof frames showed many Eigenfrequencies, their variety of loads and stiffnesses has to be covered with simulations. Thus, the concrete´s specific weight was assumed from 22 to 25 kiloNewtons per cubic meter, with a Young´s modulus from 21.000 (n = 10) to 35.000 (n = 6) N/mm^2.

5.5 Moving Load as Time History

The dynamic load applied on the ramp is a bus. This bus is measured and weight in order to verify its characteristics, as to say axle distances and weights, see also chapter 4.1. The used calculation programme offers moving load algorithms to deliver influence lines. In order to calculate dynamic load cases, so called time history functions are to apply. These functions define a value for one load as a function of time steps.

Thus, with the aim to simulate a moving load, 34 point lines distributed over the ramp were defined. Each line crosses the longitudinal profiles which represent the ramp´s cross-section. To all those points in one line a load is assigned. So 34 load cases were defined, each with 7 point loads at equal ramp height:

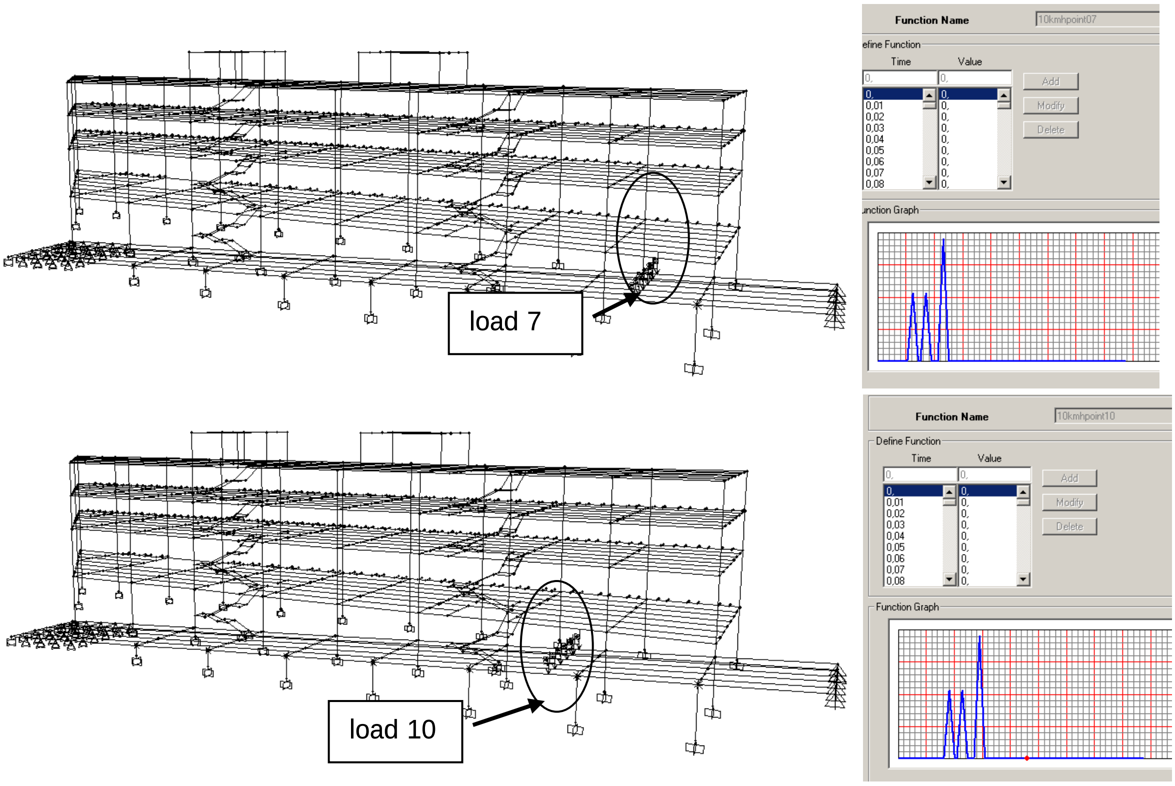

Figure 5–1: 34 lines of point loads with time history loads

For each load case a time history function was created. In this function, three peaks occur, representing the three bus axles. Now each load name (1 - 34) is applied with its correspondent time history function (1 - 34). This algorithm was created for 4 bus speeds: 10, 15, 20 and 25 kilometres per hour. One time step was set to 0,01 seconds.

5.6 RESULTS

5.6.1 NODAL DISPLACEMENTS

The measured nodes on roof and floor 3 of frame 1 and 2 showed the following theoretical nodal displacements:

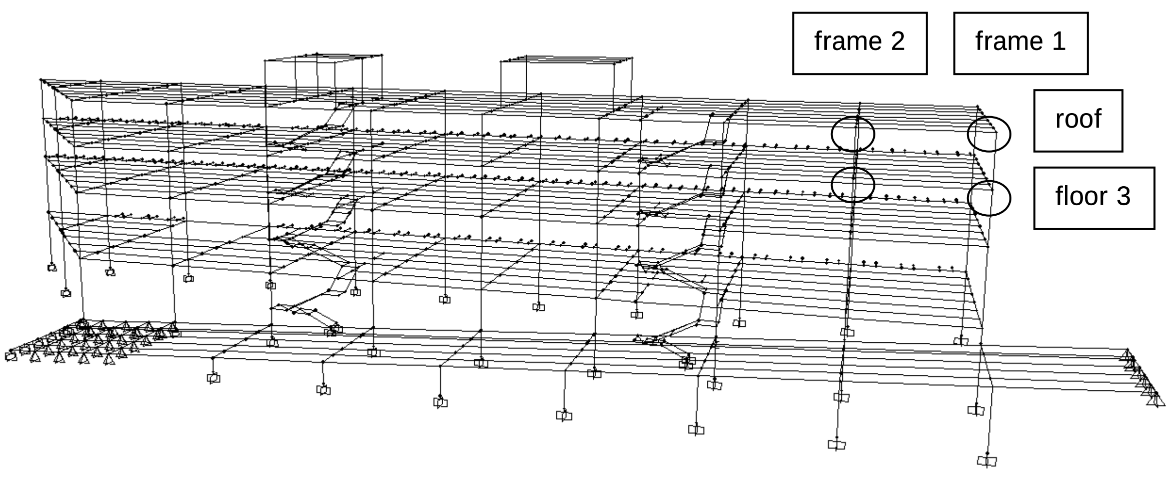

Figure 5–2: Model with indicated nodes to compare calculated and measured vibrations

These data can be seen in nodal displacement results:

- in frame 1 third floor and roof move most in Y-direction (=frame direction)
- during the load a vibration is shown
- movements in X- and Z-direction are directly related to the bus passing by
- frame 1 oscillates during load, frame 2 does not
- frame 1 is loaded before frame 2, as was to expect

Calc. displacements [mm]		X	Y	Z
Frame 1	roof	0,047	0,305	0,022
	floor 3	0,043	0,263	0,021
Frame 2	roof	0,047	0,170	0,019
	floor 3	0,043	0,176	0,019

Figure 5–3: Table calculated nodal displacements

Meas. displacements [mm]		X	Y	Z
Frame 1	roof	0,008	0,100	0,012
	floor 3	-	0,006	-
Frame 2	roof	0,009	0,017	0,012
	floor 3	-	0,002	-

Figure 5–4: Nodal displacements obtained from measurement

The relative errors between values obtained from measurement data analysis on one hand and calculation programme results on the other, are high, while the absolute errors are very low. This could be based in different time step lengths. While measurement data is logged with 205 Hz, the time history functions have 100 time steps per second.

5.6.2 EIGENMODES AND FREQUENCIES

Although displacements obtained from calculation programme and measured data analysis show relative errors, frequency-based conclusions indicate good match of model and reality. Modal shapes obtained from calculation (see chapter 3) and measurement (see chapter 4) are similar, the ramp´s Eigenfrequency in gravity direction was obtained and afterwards verified as excitation frequency on the building. Resonance-near behaviour was measured at frame 1, confirming the calculated frame´s Eigenfrequencies.