

UNIVERSITAT POLITÈCNICA DE CATALUNYA

MASTER OF SCIENCE IN COMPUTATIONAL MECHANICS

COMPUTATIONAL STRUCTURAL MECHANICS AND DYNAMICS

Practice 5

Dynamics

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1 Plane Frame

The plane frame depicted on Figure 1.1 is subject to a sinusoidal load. To evaluate the structural response of the frame, the dynamic model is used. The frequency of the load is a function of the first natural frequency of the structure, thus the vibration modes are firstly assessed without the consideration of the external force.

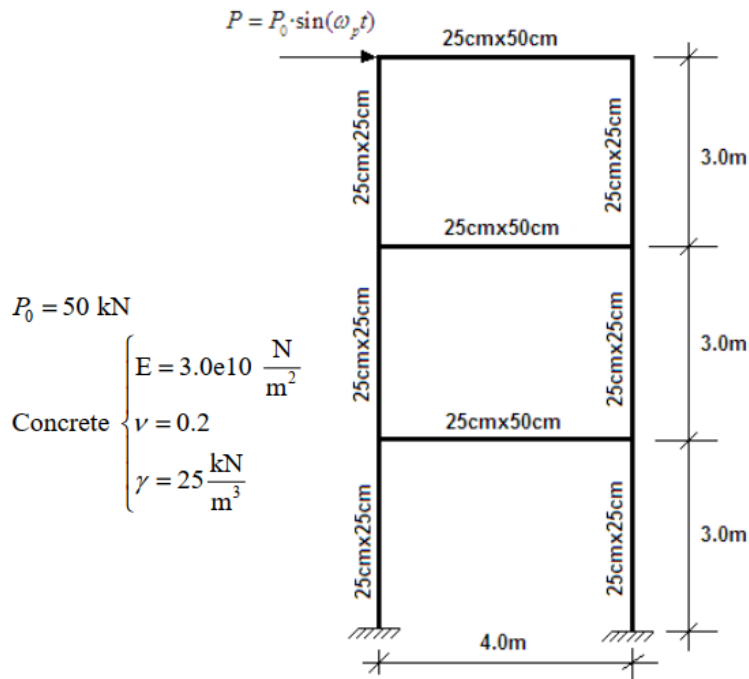


Figure 1.1: Problem description and material properties

The obtained natural frequencies are presented on Table 1.1, while the corresponding scheme of the vibration modes are shown on Figure 1.2.

Table 1.1: Natural frequencies

Mode	w (Hz)
1	3.472
2	10.99
3	18.73

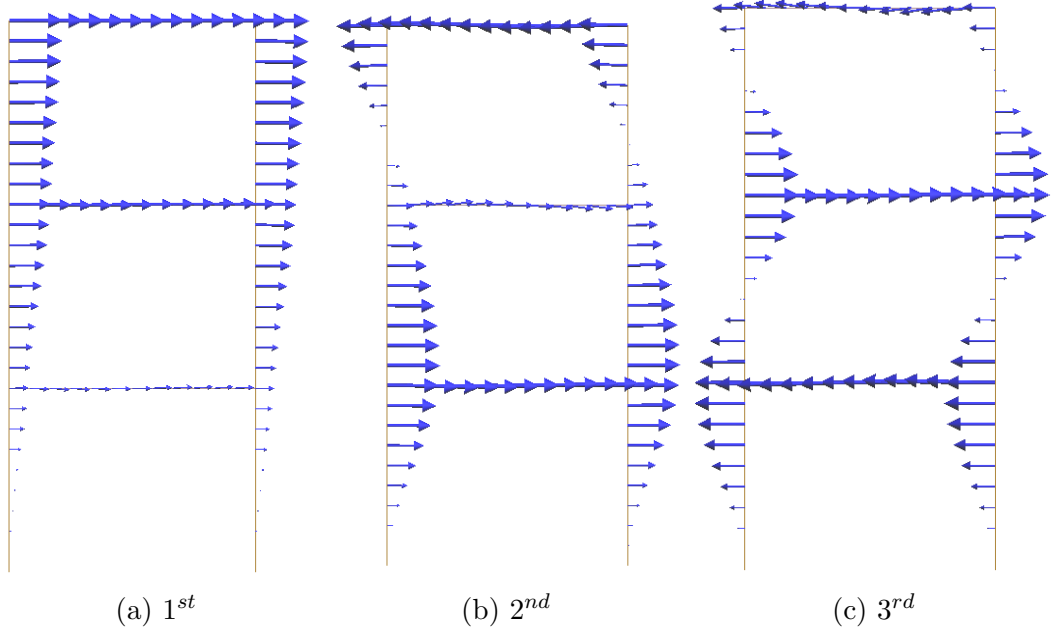


Figure 1.2: Natural vibration modes

With the natural frequencies calculated, the load frequencies can be readily computed, as shown on Table 1.2.

Table 1.2: Load frequencies

Case	w_p (Hz)	
1	$0.75 \cdot w_1$	2.604
2	$1.00 \cdot w_1$	3.472
3	$1.25 \cdot w_1$	4.34

The time step is calculated from the period (inverse of the frequency) and considering the 20 time steps within one period are sufficient:

$$T = \frac{1}{w_{p3}} = 0.23 \text{ s} \quad (1.1)$$

$$\Delta t = T/20 \approx 0.01$$

To verify the number of modes to be evaluated in the dynamic model, the condition $w_p > w/4$ is used. By using the largest $w_p = 4.34$ we obtain that the dynamic model should be used only for $w < 17.36$. Thus, according to Table 1.1, only the first two modes will be taken into account, whilst higher modes should be evaluated only by the static model.

The results for each load frequency are shown on Figures 1.3 and 1.4. Figure 1.3 plots the displacement of the point where the load is applied in respect to time. As expected the amplitude of movement caused by the load is practically the same on all test cases

except on case two, where the amplitude grows indefinitely with time. Given that, on case 2, the load frequency matches one of the natural frequencies of the structure, the load causes resonance, amplifying the load as it acts.

The same pattern is found on Figure 1.4, which plots the reaction force of the left junction of the structure with the ground. The reaction of both cases 1 and 3 are of similar magnitude as the one from the load, while case 2 again amplifies the force to values twice as high in as little as one second.

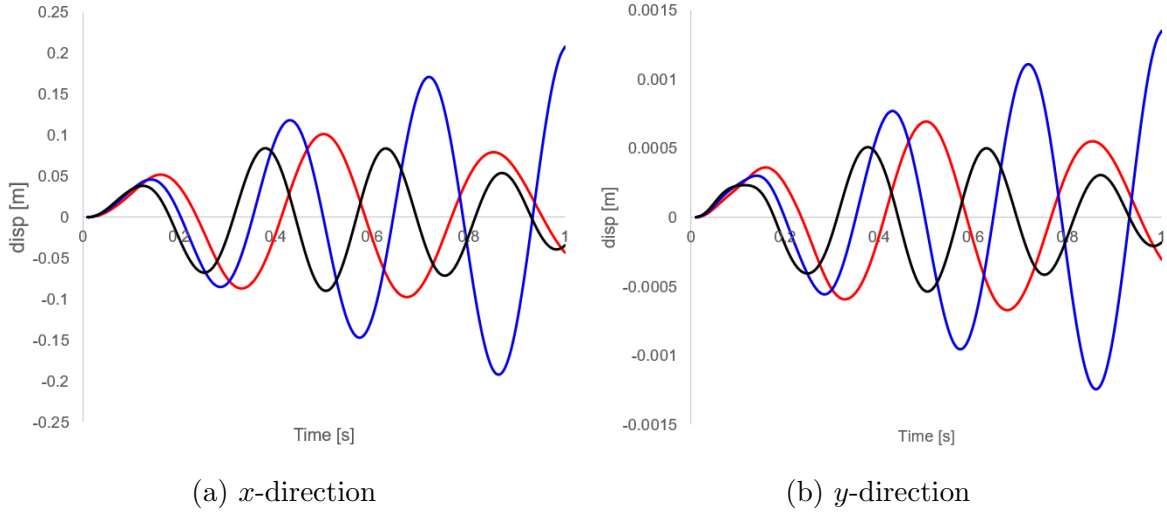


Figure 1.3: Displacement over time caused by the loads with w_p of $0.75w_1$ (—), $1w_1$ (—) and $1.25w_1$ (—)

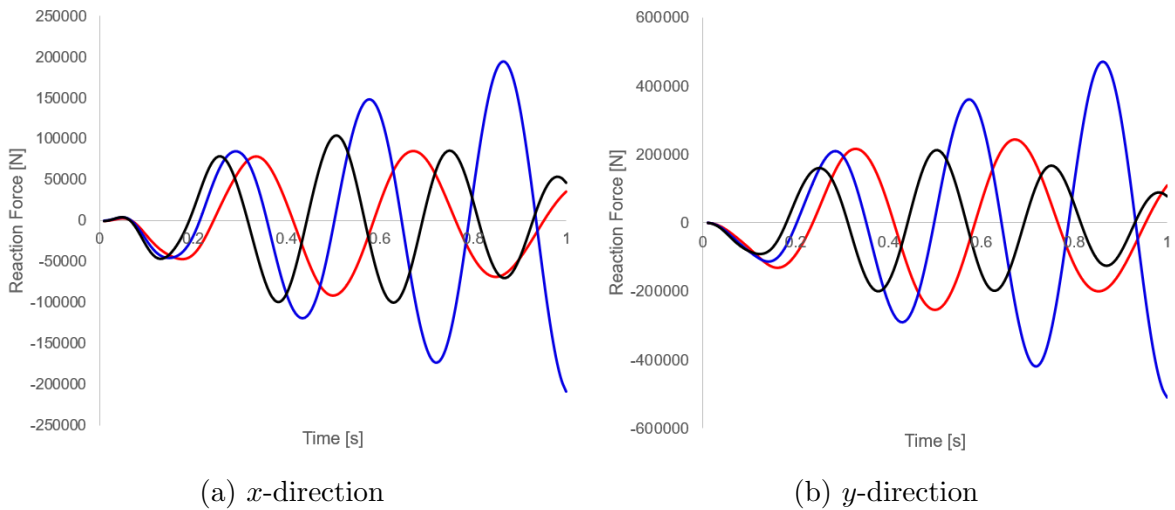


Figure 1.4: Reaction force on the base over time caused by the loads with w_p of $0.75w_1$ (—), $1w_1$ (—) and $1.25w_1$ (—)

2 Spatial shell

Calculate the natural frequencies and modes of the spatial shell in the figure. Perform a modal analysis and direct integration. Use a dynamic load frequency with the values $\omega_p = 0.75\omega_1$, ω_1 and, $1.25\omega_1$ where ω_1 is the principal natural frequency.

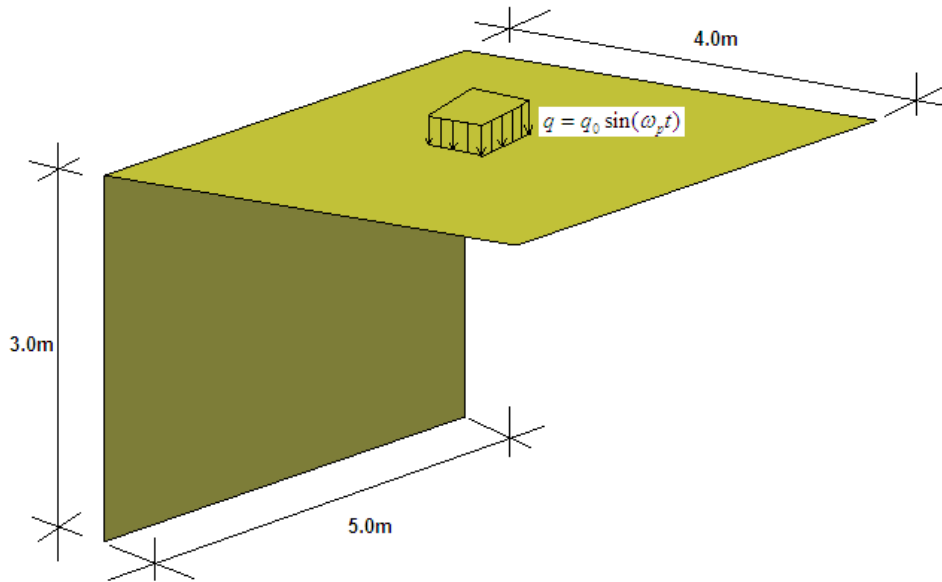


Figure 2.1: Spatial shell

Data:

$$q_0 = 50 \frac{kN}{m^2}$$

$$\text{Concrete: } \begin{cases} E = 3.0e10 \frac{N}{m^2} \\ \nu = 0.2 \\ \gamma = 25 \frac{kN}{m^3} \\ t = 0.30m \end{cases}$$

2.1 Geometry

The geometry was modeled in Ram-Series as shown in the figure 2.2 (a). As can also be seen in the figure 2.2 (a), the lower line of shell 1 is fixed.

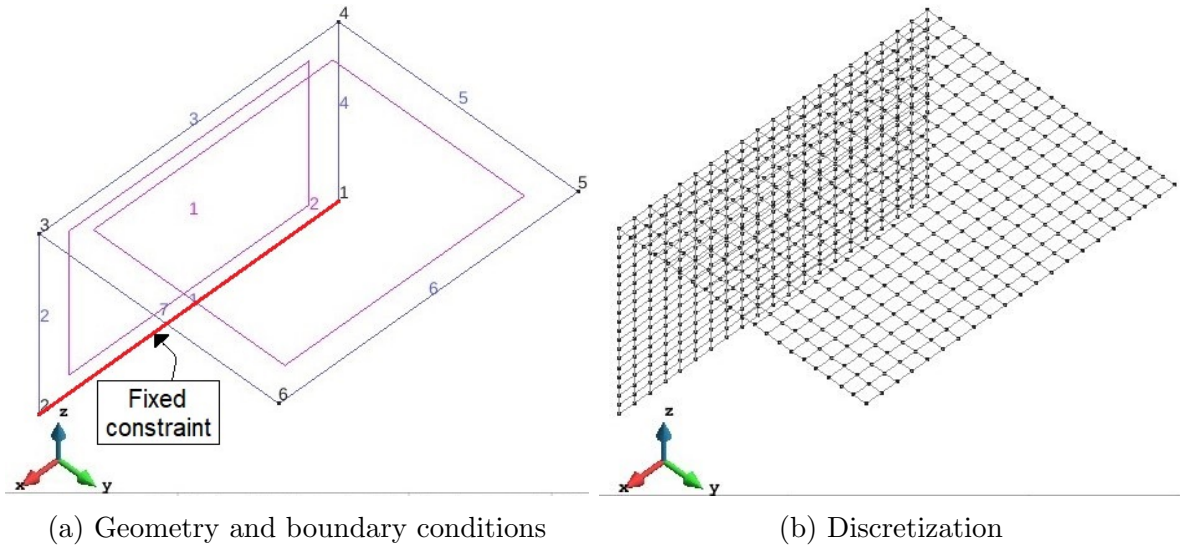


Figure 2.2

We consider a structured mesh with quadrilateral elements (figure 2.2 (b)).

2.2 Post-processing

Natural frequencies of the structure:

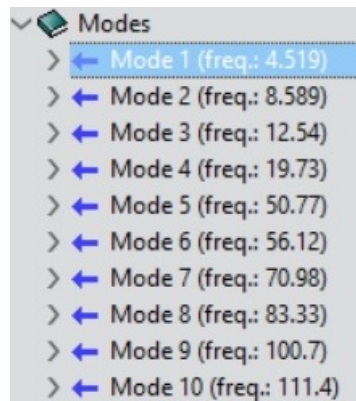


Figure 2.3: Natural frequencies

As shown in Table 2.1, with the natural frequencies we calculate the load frequencies and the number of necessary modes:

Table 2.1: Load frequencies

Tests	w1	wp	4*wp	No of modes
0.75	4.519	3.389	13.557	3
1	4.519	4.519	18.076	3
1.25	4.519	5.648	22.595	4

The time step is calculated from the period (inverse of the frequency) and considering the 20 time steps within one period are sufficient:

$$T = \frac{1}{w_{p3}} = 0.17 \text{ s} \quad (2.1)$$

$$\Delta t = T/20 \approx 0.01$$

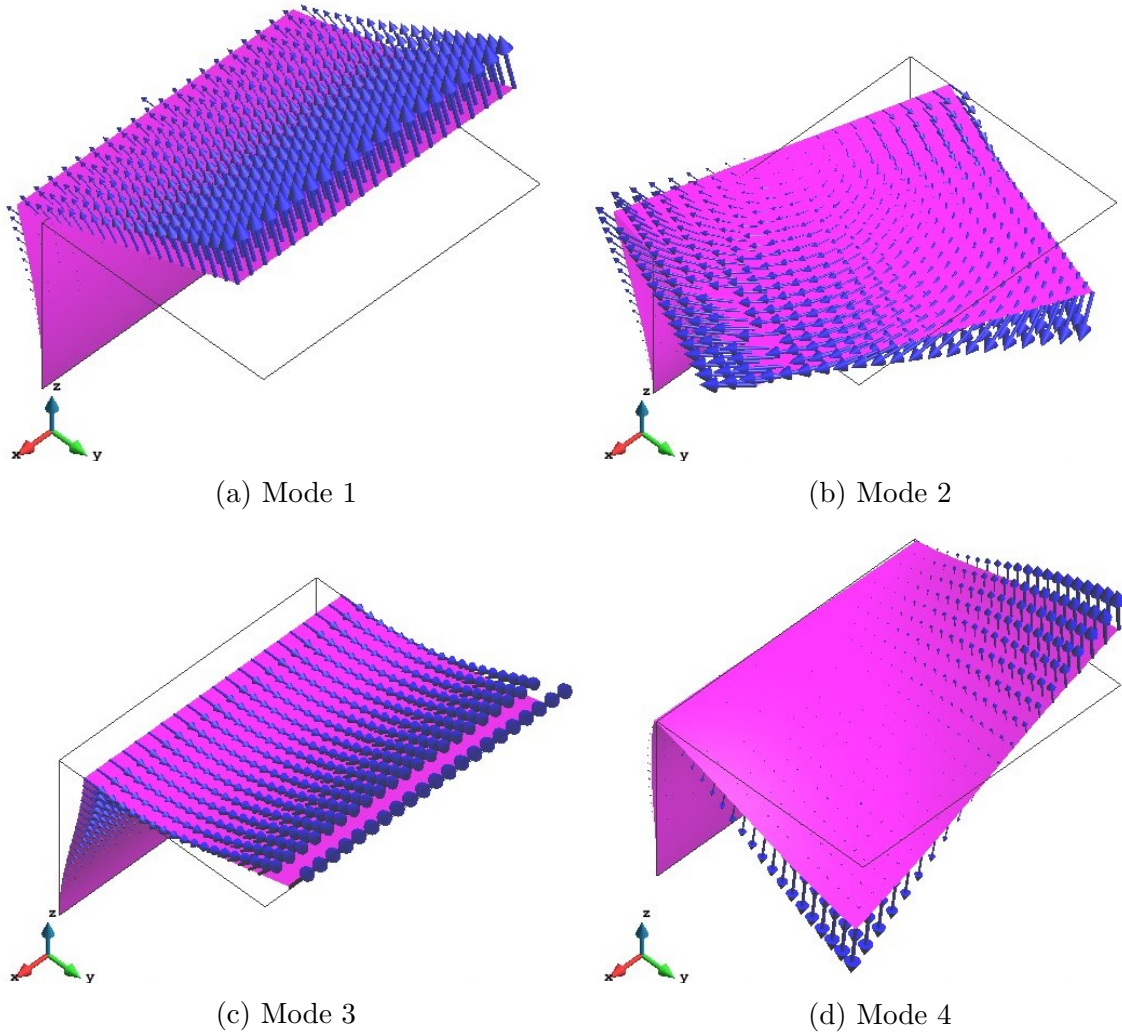
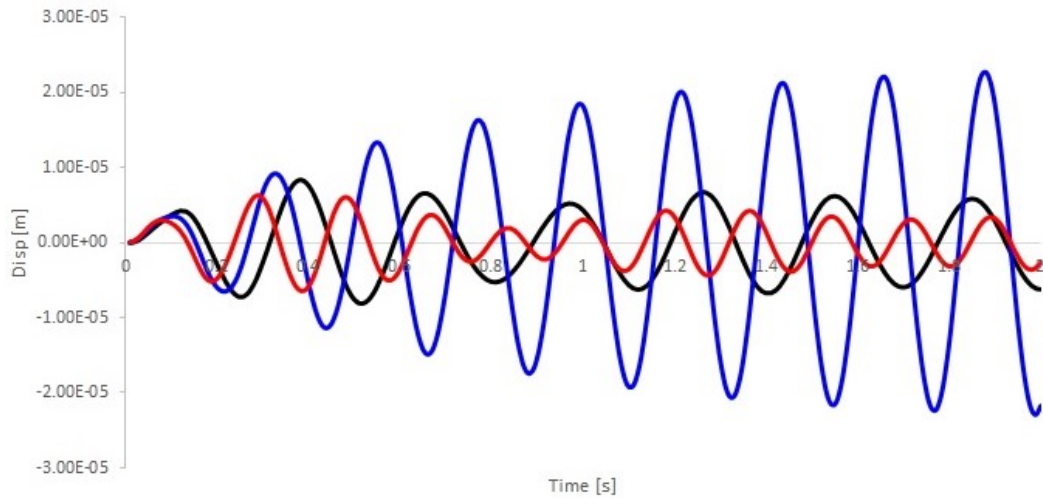
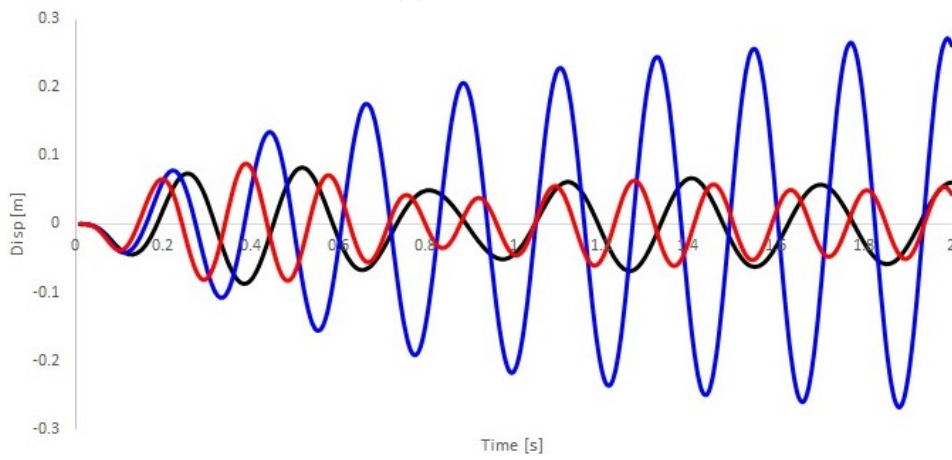


Figure 2.4: Vibration modes

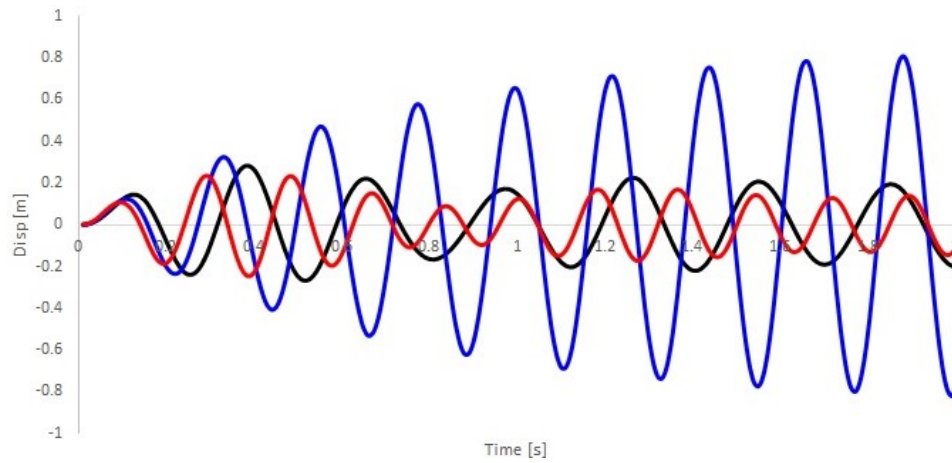
The results for each load frequency are shown on Figures 2.5 and 2.6. As expected the amplitude of movement caused by the load is practically the same on all test cases except on case two, where the amplitude grows indefinitely with time. Given that, on case 2, the load frequency matches one of the natural frequencies of the structure, the load causes resonance, amplifying the load as it acts.



(a) x -direction

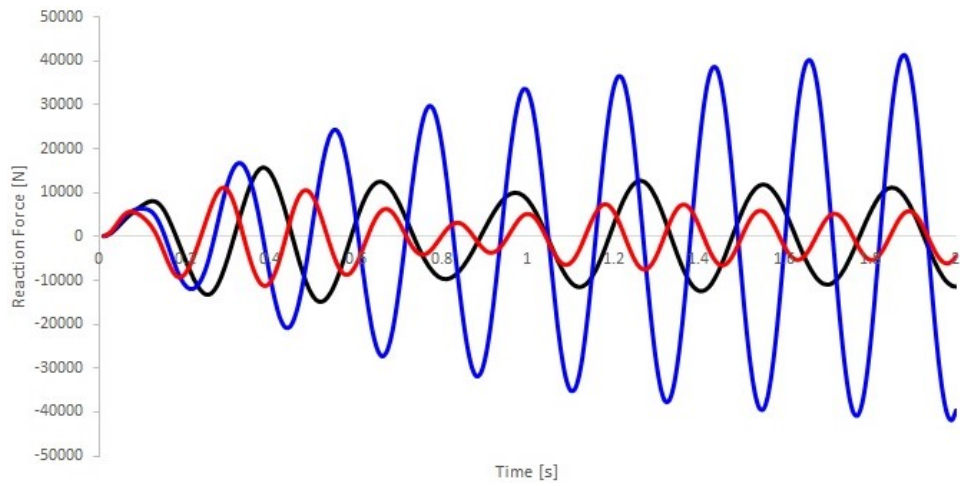


(b) y -direction

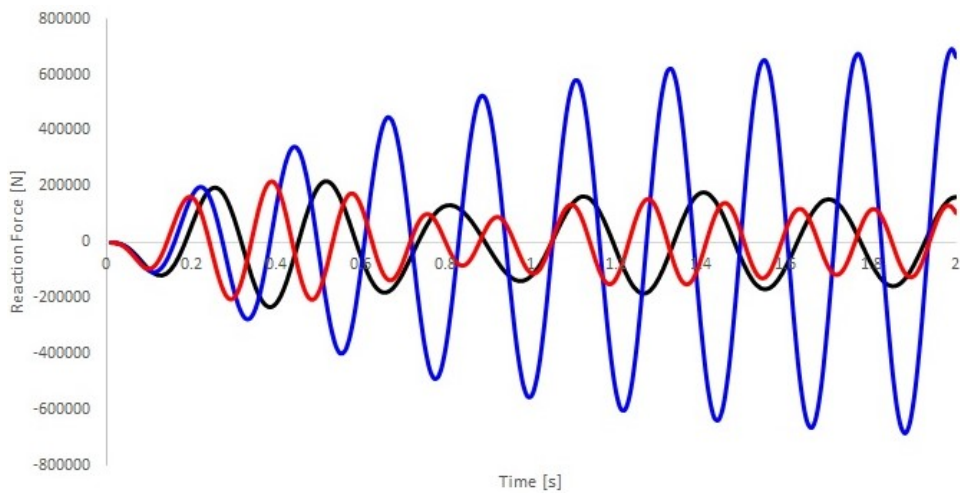


(c) z -direction

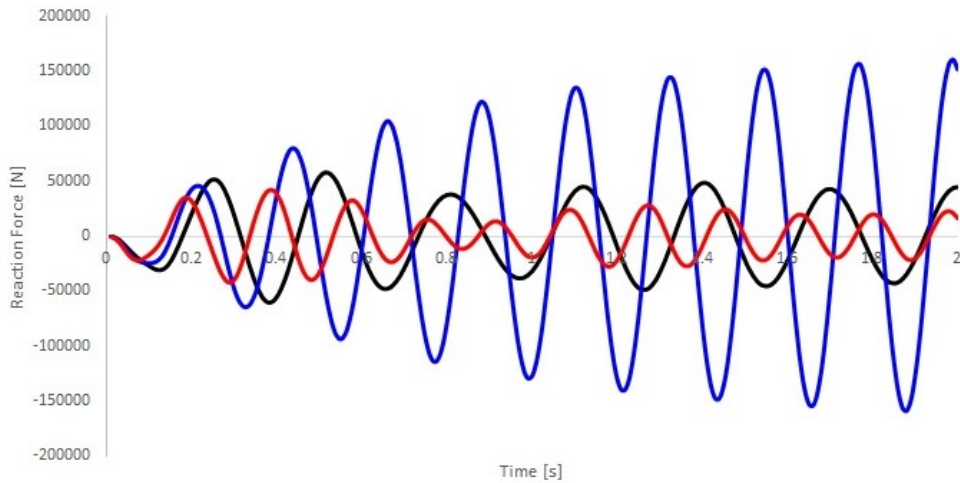
Figure 2.5: Displacement over time caused by the loads with w_p of $0.75w_1$ (—), $1w_1$ (—) and $1.25w_1$ (—)



(a) x -direction



(b) y -direction



(c) z -direction

Figure 2.6: Reaction force on the base over time caused by the loads with w_p of $0.75w_1$ (—), $1w_1$ (—) and $1.25w_1$ (—)

Finally, in Figure 2.7 it is possible to see the displacements for each of the forces applied. In case 2, (b) the displacements are greater due to resonance.

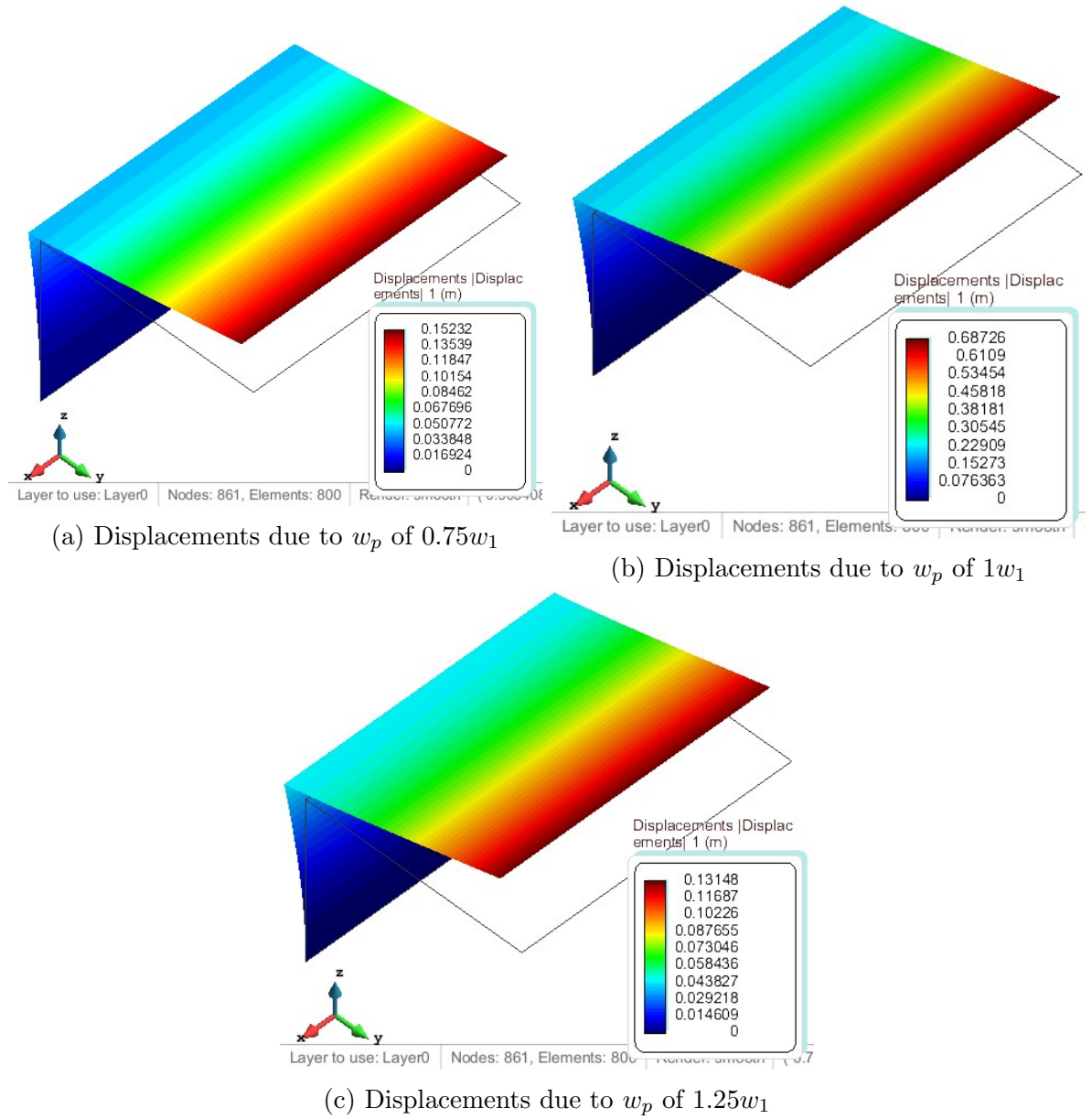


Figure 2.7: Displacements