Computational Structural Mechanics and Dynamics

Practice 5

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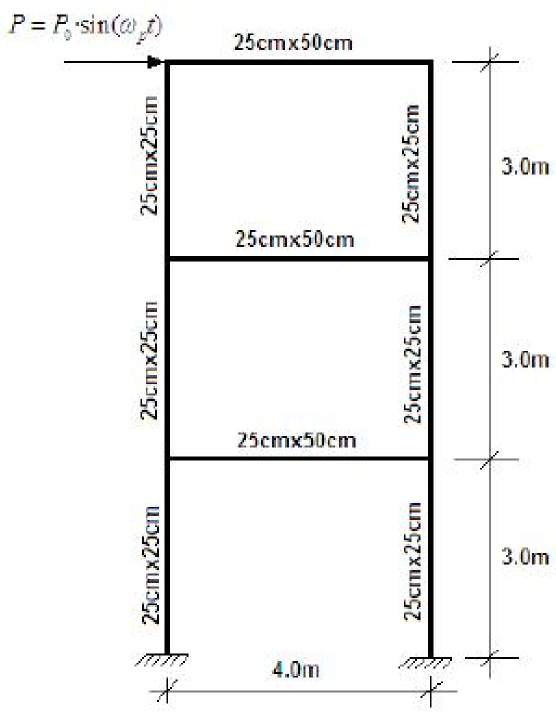
Exercise 1: Plane Frame

Calculate the natural frequencies and modes of the plane frame in the figure. Perform a modal analysis and direct integration. Use a dynamic load frequency with the values , $w_p = 0.75w_1, 1.0w_1$ and 1.25 w_1, where w_1 is the principal natural frequency.



Data

$P_0 = 50$ kN

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

Problem types in Compass FEM : beam and shell element type, 3D simulation dimension, dynamic modal analysis, linear elastic material model, linear geometry model.
We constrain movements in all direction for the bottom nodes. For the other nodes, we constrain movement only in Z direction, in addition to the rotations around X and Y directions.
We use rectangular HA-40 steel bars.

First, we choose the nodal to use, according to the limiting equation:
$w_p > 0.25w_0$

Where,

w_p : frequency of the load

w_0 : maximum natural frequency

Then we do the mesh and compute the natural frequency using dynamic analysis. We find that:

w_1=4.29 Hz and w_p varies in the between $+0.25w_1$-$0.25w_1$.

We use 1.25w1=5.365 to check the number of Eigen modes. Thus we can use all natural frequencies which are smaller than 21.46 Hz. We consider first three modes.

Now, we define self weight and dynamic load of first at the top left corner of the structure.

→Parameters of the load:

X force: 50kN; Sinusoidal load; Amplitude : 1; Frequency : 3.219Hz; Phase angle: 0 degree; Initial time: 0 s; end time:1 s

→Time step: T/20

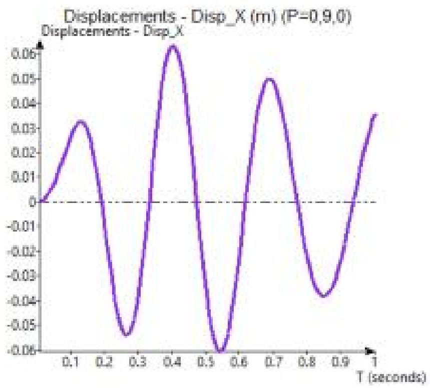
$\Delta t = (1/w_{max})/20 = 0.00932$

→The required number of time step:

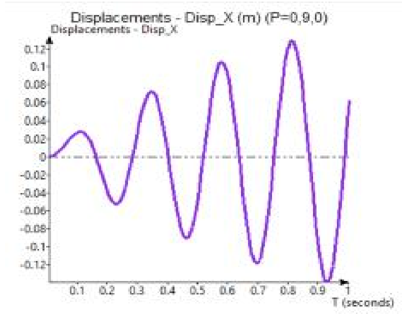
$1/\Delta t = 107.5 \approx 108$ time steps

→**Results**

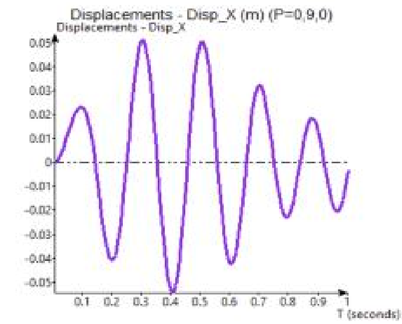
- Displacement, $w_p = 0.75w_1$



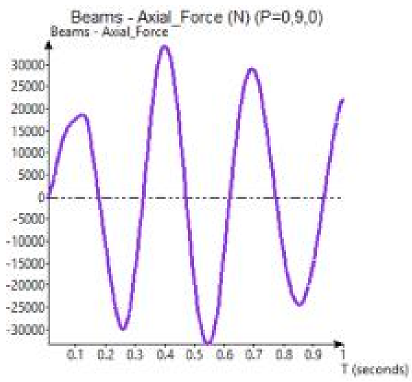
- Displacement, $w_p = w_1$



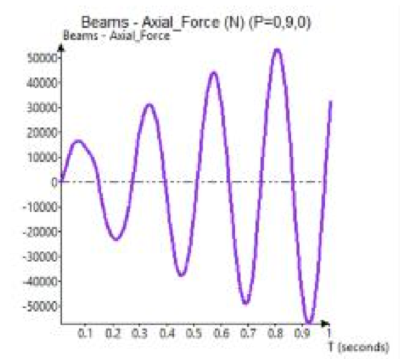
- Displacement, $w_p = 1.25w_1$



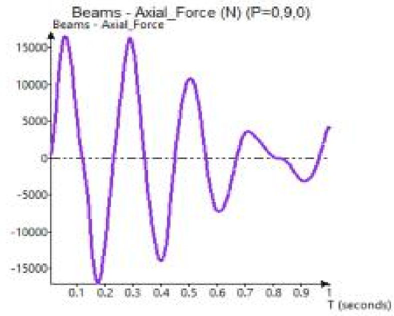
- Axial Force, $w_p = 0.75w_1$



- Axial Force, $w_p = w_1$



- Axial Force, $w_p=1.25w_1$



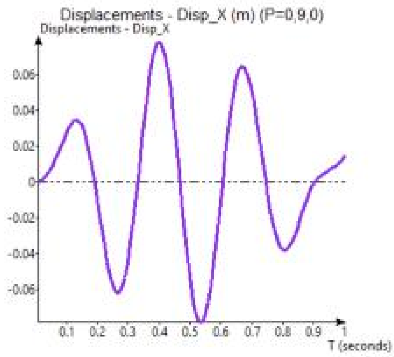
We see that the maximum displacement and axial force occur in the case of $w_p=w_1$.

When the frequency of the load is equal to the natural frequency of the structure, this case occurs. It leads to the maximum displacement and axial force.

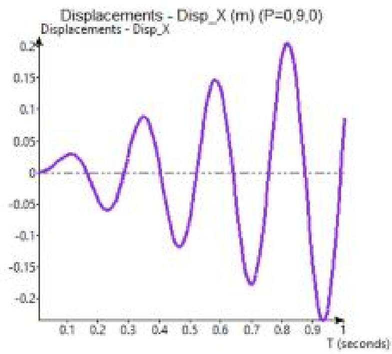
Hence, when we compare the other frequencies, we see that the higher frequency leads less damage than the lower frequency.

Now, we run the direct integration type using same parameters.

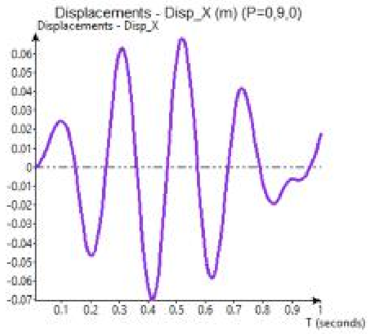
- Displacement, $w_p=0.75w_1$



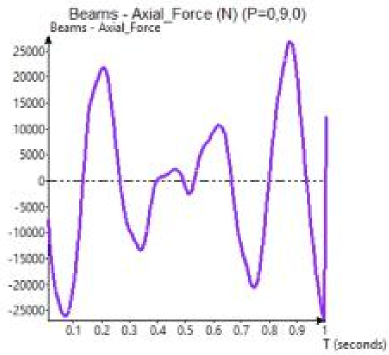
- Displacement, $w_p=w_1$



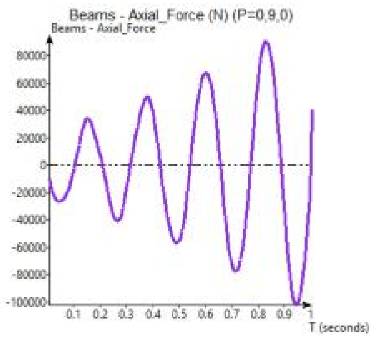
- Displacement, $w_p=1.25w_1$



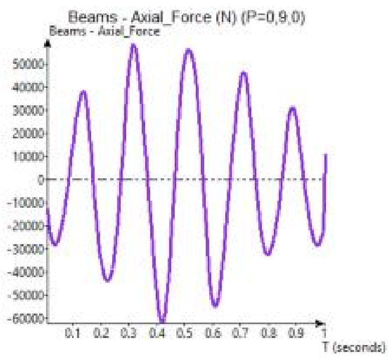
- Axial Force, $w_p=0.75w_1$



- Axial Force, $w_p=w_1$



- Axial Force, $w_p=1.25w_1$



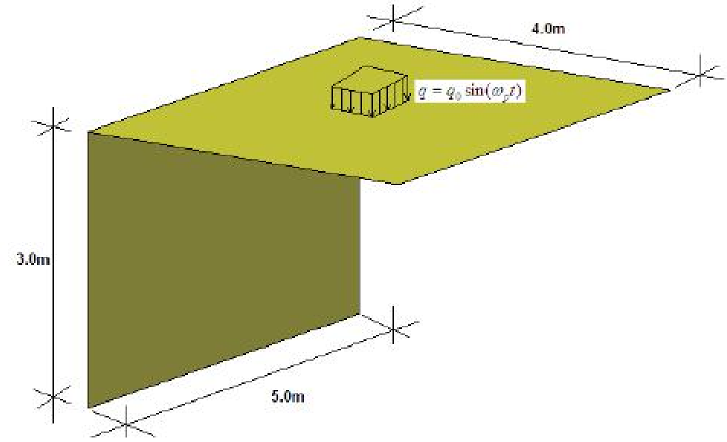
As a result, we see that we have the similar results after modal analysis and the direct integration.

In case of the resonance, we have the higher values for axial force and displacement.

We clearly see that we have higher values in the direct integration analysis. This method requires less time and lower precision than the modal analysis.

Exercise 2

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 , $w_p = 0.75w_1, 1.0w_1$ and 1.25 w_1, where w_1 is the principal natural frequency.



Data

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

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

Problem types in Compass FEM : beam and shell element type, 3D simulation dimension, dynamic modal analysis, linear elastic material model, linear geometry model.
We constrain movements at the base of the spatial sheel.
We use 50x50 cm quadrilateral elements are used for the mesh.

Now, we run the calculation of the natural frequencies of the spatial shell.

We find that:

The main natural frequency : w_1=4.522Hz

w_1=4.522 Hz and w_p varies in the between $+0.25w_1-0.25w_1$.

The first 10 natural frequencies and modal mass are:

Mode	Freq [Hz]	Mass_x [Kg]	Mass_x [%]	Mass_y [Kg]	Mass_y [%]	Mass_z [Kg]	Mass_z [%]
1	4.522	6.229e-023	0.0000	7942	29.6708	6035	22.5443
2	8.681	7742	28.9234	1.5e-022	0.0000	3.303e-023	0.0000
3	12.65	7.013e-023	0.0000	2479	9.2629	1.581e+004	59.0465
4	19.94	231.1	0.8633	1.404e-023	0.0000	1.305e-023	0.0000
5	51.89	1.855e-026	0.0000	2088	7.8000	473.9	1.7703
6	57.14	1.238e-026	0.0000	715.6	2.6734	150.6	0.5624
7	72.77	322.6	1.2054	2.99e-025	0.0000	1.298e-028	0.0000
8	84.27	1.268e+004	47.3585	1.478e-026	0.0000	2.475e-026	0.0000
9	106.8	4.176e-026	0.0000	91.6	0.3422	1869	6.9834
10	116.9	844.1	3.1536	2.537e-027	0.0000	1.74e-025	0.0000

Total Mass [Kg]= 26767.550591
Modal Participation X [%]= 81.50
Modal Participation Y [%]= 49.75
Modal Participation Z [%]= 90.91

We use 1.25w1=563 to check the number of Eigen modes. Thus we can use all natural frequencies which are smaller than 22.612 Hz. We consider first three modes.

→Parameters of the load:

Y pressure: 50kN/m3; Sinusoidal load; Amplitude : 1; Frequency : 3.392Hz; Phase angle: 0 degree; Initial time: 0 s; end time:1 s

→Time step: T/20

$\Delta t = (1/w_{max})/20 = 0.0088$

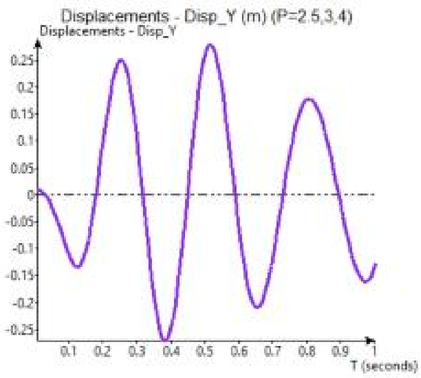
→The required number of time step:

$1/\Delta t = 113.6 \approx 114$ time steps

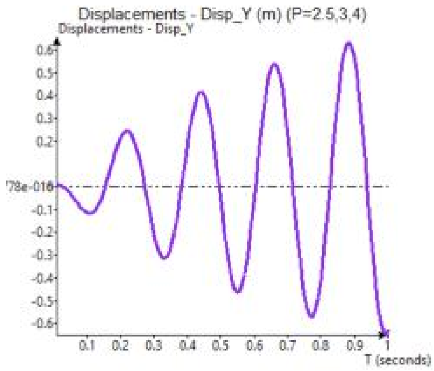
We apply the self-weight and the dynamical sinus pressure load on the top surface of the shell for the 3 different loads.

→**Results-Modal Analysis**

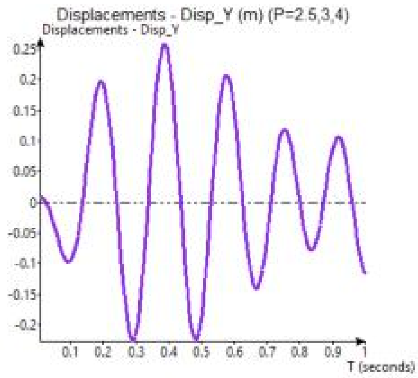
- Displacement, $w_p = 0.75 w_1$



- Displacement, $w_p=w_1$

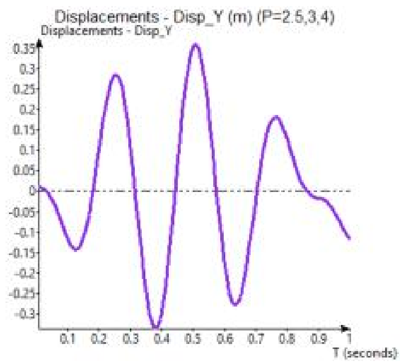


- Displacement, $w_p=1.25w_1$

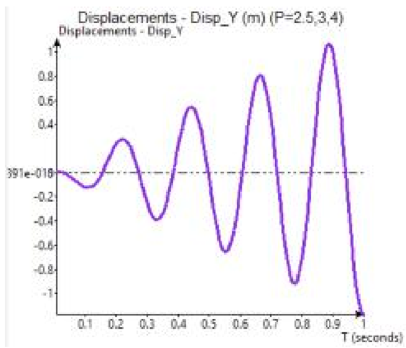


→**Results-Direct Integration**

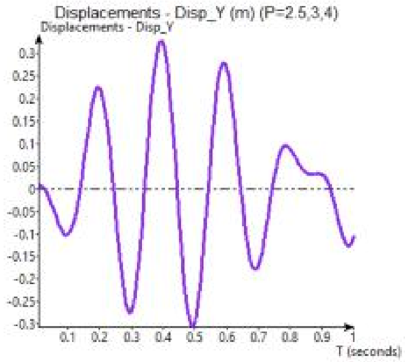
- Displacement, $w_p=0.75w_1$



- Displacement, $w_p=w_1$



- Displacement, $w_p=1.25w_1$



When the load frequency equals to the main frequenct of the shell, we get the highest displacement in case of direct integration and modal analysis. This means the resonance has the most impact on any structure.

Moreover, we see that when we have higher frequencies than the main natural frequencies, we get the smallest displacement in both analysis.

We can say that both methos are very similar; but the direct method presents higher values, saves computation time.