

Harbour crane analysis

Figure 2 shows the model of the harbour crane depicted in Figure 1.

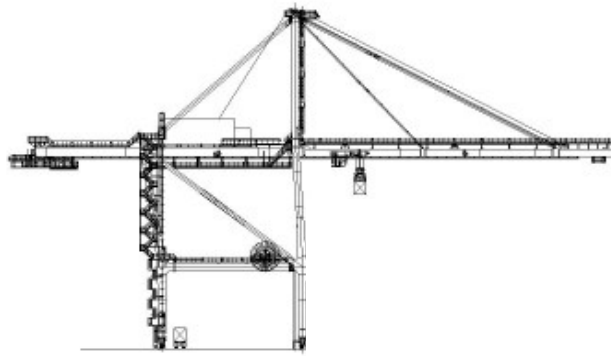


Figure 1: harbour crane

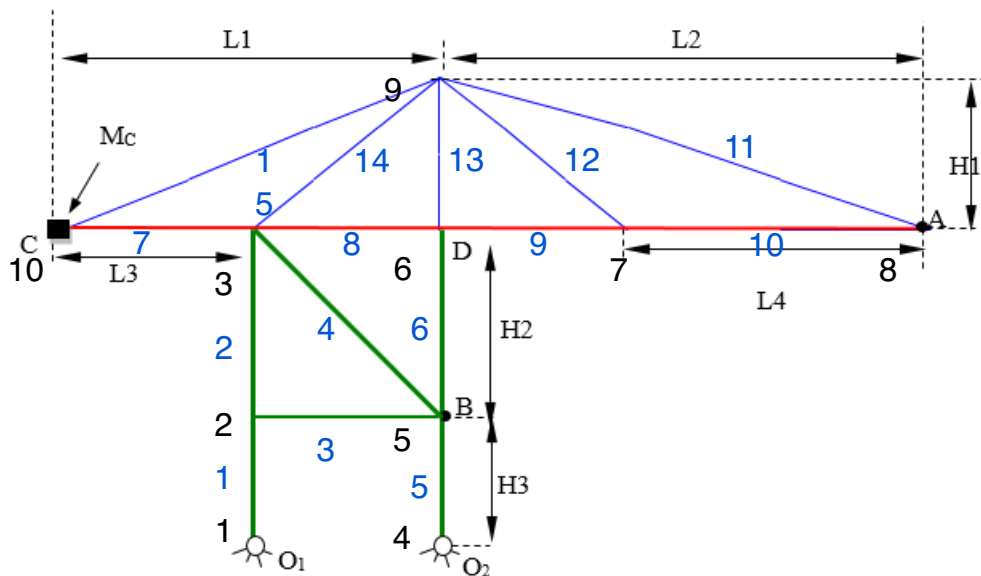


Figure 2: harbour crane model

Structural damping is to be accounted for according to the proportional damping assumption, $[C] = \alpha[M] + \beta[K]$, with values α and β assigned in the input data table.

The students are asked to:

- 1) Define a finite element model valid in the frequency range $0 \div 10$ Hz
- 2) Compute the system's natural frequencies and related modes of vibration in the frequency range $0 \div 10$ Hz
- 3) Compute the following frequency response functions (FRF) in the frequency range $0 \div 10$ Hz with step 0.01 Hz:
 - a. Input: vertical force at point A; output: vertical displacement of point A;
 - b. Input: vertical force at point A; output: horizontal displacement of point B;
 - c. Input: vertical force at point A; output: vertical component of the constraint force in the hinge O_2 ;
 - d. Input: vertical force at point C; output: vertical component of the constraint force in the hinge O_2 .

- 4) Compute the frequency response functions (FRF) in the frequency range $0 \div 10$ Hz, step 0.01 Hz for a horizontal distributed load (magnitude 1 N/m) applied on the right leg of the crane between points B and D. Outputs:
 - a. horizontal displacement of point A;
 - b. vertical displacement of point A;
 - c. vertical displacement of point C.
- 5) Assume a winch is placed at A and moves up and down a mass M_A according to a periodic time history $y_{rel}(t)$:

$$y_{rel}(t) = \sum_{i=1,3} A_i \cos\left(i \frac{2\pi}{T} t + \varphi_i\right)$$

which represents the periodic vertical relative displacement of the load with respect to point A (positive if upwards directed). Compute the corresponding time history of the absolute vertical displacement of point A.
- 6) Modify the structure in order to reduce at least by 50 % the maximum value of the constraint force computed at point 3, without increasing the total mass of the crane more than 5 % of its original value. Any change of the material and/or of the constraints (by adding or moving them) is not allowed. In case of change of one or more beams sections, both the inertial and the stiffness parameters m , EA , EJ have to be computed taking into account a real geometry of the new sections and the physical properties of steel material.

Input data:

Main horizontal red beam: linear mass (kg/m)	m_1	312
Main horizontal red beam: axial stiffness (N)	EA_1	8.2 E9
Main horizontal red beam: bending stiffness (Nm ²)	EJ_1	1.40 E9
Vertical, diagonal and secondary horizontal green beams: linear mass (kg/m)	m_2	200
Vertical, diagonal and secondary horizontal green beams: axial stiffness (N)	EA_2	5.4 E9
Vertical, diagonal and secondary horizontal green beams: bending stiffness (Nm ²)	EJ_2	4.5 E8
Blue beams: linear mass (kg/m)	m_3	90.0
Blue beams: axial stiffness (N)	EA_3	2.4E9
Blue beams: bending stiffness (Nm ²)	EJ_3	2.0 E8
Point mass in C (kg)	M_C	2000
Moment of inertia of the point mass in C (kgm ²)	J_C	320
L_1 length (m)	L_1	30
L_2 length (m)	L_2	39
L_3 length (m)	L_3	15
L_4 length (m)	L_4	24
H_1 height (m)	H_1	12
H_2 height (m)	H_2	15
H_3 height (m)	H_3	10
Moving load M_A (kg)	M_A	800
Point 5, amplitude of the first harmonic (m)	A_1	0.25
Point 5, amplitude of the second harmonic (m)	A_2	0.25
Point 5, amplitude of the third harmonic (m)	A_3	0.15
Point 5, phase of the first harmonic (rad)	φ_1	0
Point 5, phase of the second harmonic (rad)	φ_2	π
Point 5, phase of the third harmonic (rad)	φ_3	π
Point 5: period (s)	T	1.2
Coefficient for the structural damping evaluation	α	0.1
Coefficient for the structural damping evaluation	β	2.0e-4