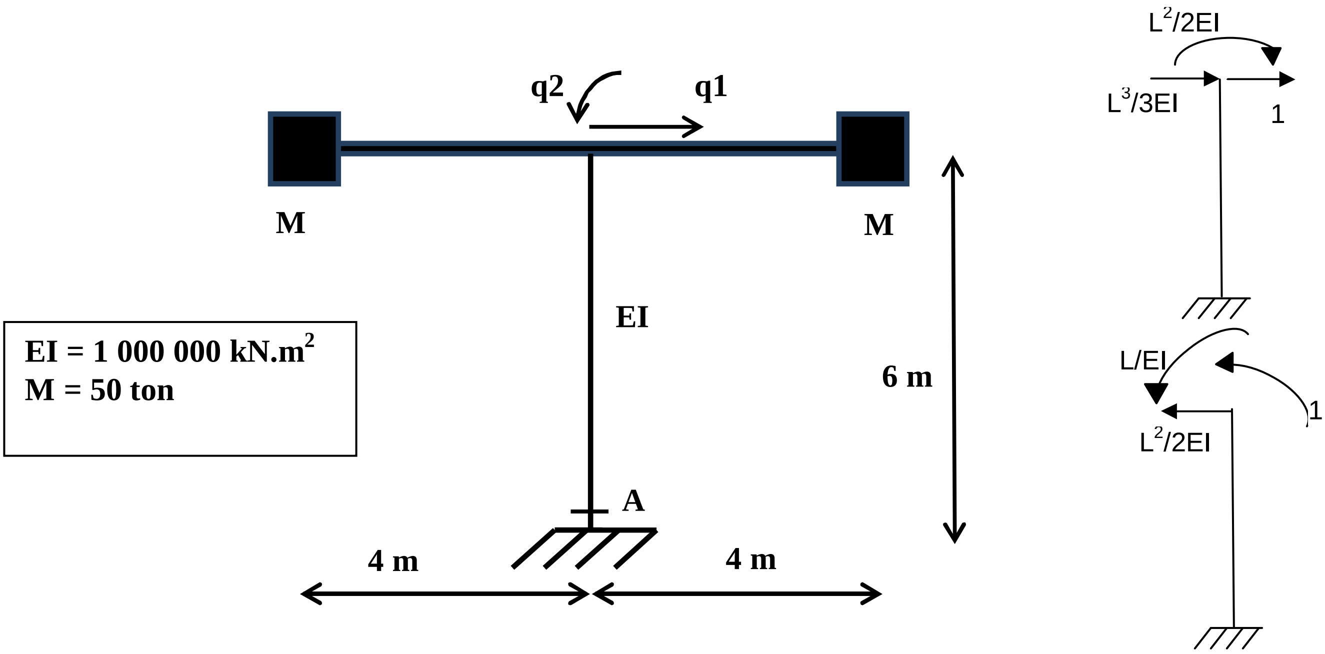
Earthquake engineering and structural dynamics
Integrated Master Course in Civil Engineering
5º year - 1º Semester – 9th January 2014 (1st period of Exams)

Switch off your mobile phone
Identify all paper sheets with name and number
Deliver each problem in separate sheets
Justify all answers
Duration: 2h30m

Problem 1 (10,5)

Consider the structural model represented in the figure. The beam is infinitely stiff and the columns are axially undeformable. The mass is concentrated at the extremities of the beam.



a) Calculate the mass and flexibility matrices considering the degrees of freedom indicated (2,5)

b) Calculate the vibration modes and respective periods using the method of Stodola for the configuration of the 1st mode and the orthogonality conditions for the 2nd mode. (2,5)

c) Normalize the modes by the mass matrix. If you did not solve a) and/or b) consider $v_1^T = \{1; -0{,}3\}$, $v_2^T = \{1; 0{,}2\}$ and $[M] = \begin{bmatrix} 90 & 0 \\ 0 & 1500 \end{bmatrix}$ (1,0)

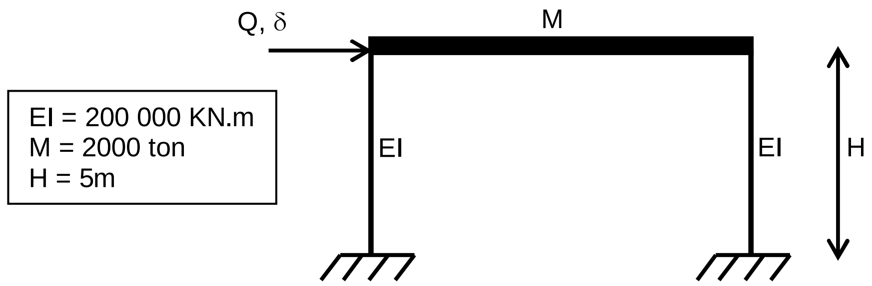
d) Assuming the structure is acted by earthquake type 1 (consider only the horizontal component in the structural plan), that the structure is located in zone 1.2 of the Portuguese National Annex, that the soil is type C, and the behaviour factor is q=3, calculate the bending moment and shear force on Section A.

(3,5)

e) What would be the bending moment in Section A if the structure was acted only by the vertical component of the earthquake? Justify your answer. (1,0)

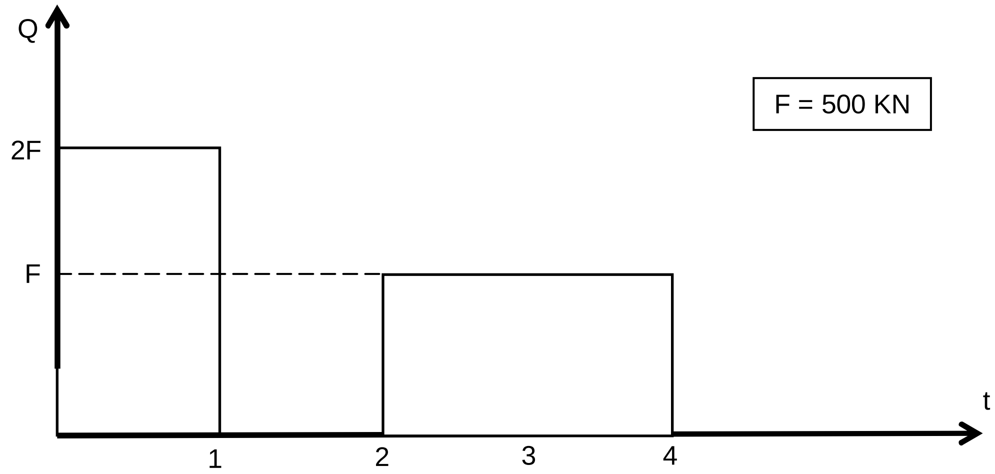
Problem 2 (4,0)

Consider the single degree of freedom system shown in the figure. The beam is infinitely stiff and the columns axially undeformable.



a) Calculate the frequency of vibration of the system. (1,0)

b) Assuming the structure is subjected to a force Q with the variation along time shown in the figure below, calculate the displacements δ at instants t = 1,5s and t = 3s. Assume that there is no damping.(1,5)



c) Assuming now that Q = F cos (4t) (KN, s) and ζ=5%, calculate the maximum displacement δ (consider only the permanent regime) (1,5)

Problem 3 (5,5)

a) Why does EC8 allow the formation of plastic hinges in columns of frames of wall equivalent mixed frame-wall systems of Ductility Classes Medium and High? Justify your answer. (1,0)

b) Why factor S (soil factor) of EC8 is larger for soft soil than for stiff soils? Justify your answer. (1,0)

c) A building with a rectangular plan and structure with double symmetry has a very stiff central core and frames on the periphery. What is the expectable configuration of the 1st mode in a tridimensional model?

   i) Translation in the direction of the largest plan dimension

   ii) Translation in the direction of the smallest plan dimension

   iii) Rotation around the center

   Justify your answer. (1,5)

d) Why is the historical seismicity important in seismicity studies aiming at defining the seismic action for engineering purposes? (1,0)

e) Explain the reasons why soft-storey buildings usually perform badly under seismic actions. (1,0)

Quadro NA.I – Aceleração máxima de referência a_{gR} (m/s^2) nas várias zonas sísmicas

Acção sísmica Tipo 1		Acção sísmica Tipo 2	
Zona Sísmica	a_{gR} (m/s^2)	Zona Sísmica	a_{gR} (m/s^2)
1.1	2,5	2.1	2,5
1.2	2,0	2.2	2,0
1.3	1,5	2.3	1,7
1.4	1,0	2.4	1,1
1.5	0,6	2.5	0,8
1.6	0,35	–	–

f) NA–3.2.2.2(2)P

Em Portugal, para a definição dos espectros de resposta elásticos o valor do parâmetro S deve ser determinado através de:

para $a_g \leq 1$ m/s^2 $\quad S = S_{max}$

para 1 m/s$^2 < a_g < 4$ m/s^2 $\quad S = S_{max} - \frac{S_{max} - 1}{3}(a_g - 1)$

para $a_g \geq 4$ m/s^2 $\quad S = 1{,}0$

em que:

a_g valor de cálculo da aceleração à superfície de um terreno do tipo A, em m/s^2;

S_{max} parâmetro cujo valor é indicado nos Quadros NA−3.2 e NA−3.3.

Em Portugal, para a definição dos espectros de resposta elásticos para a **Acção sísmica Tipo 1** devem adoptar-se os valores do Quadro NA−3.2 em vez do Quadro 3.2.

Quadro NA−3.2 – Valores dos parâmetros definidores do espectro de resposta elástico para a Acção sísmica Tipo 1

Tipo de Terreno	S_{max}	T_B (s)	T_C (s)	T_D (s)
A	1,0	0,1	0,6	2,0
B	1,35	0,1	0,6	2,0
C	1,6	0,1	0,6	2,0
D	2,0	0,1	0,8	2,0
E	1,8	0,1	0,6	2,0

h) NA–4.2.5(5)P

Em Portugal, os coeficientes de importância a adoptar são os indicados no Quadro NA.II.

Quadro NA.II – Coeficientes de importância γ_I

Classe de Importância	Acção sísmica Tipo 1	Acção sísmica Tipo 2	
		Continente	Açores
I	0,65	0,75	0,85
II	1,00	1,00	1,00
III	1,45	1,25	1,15
IV	1,95	1,50	1,35

(4)P Para as componentes horizontais da acção sísmica, o espectro de cálculo, $S_d(T)$, é definido pelas seguintes expressões:

$$0 \leq T \leq T_B : S_d(T) = a_g \cdot S \cdot \left[\frac{2}{3} + \frac{T}{T_B} \cdot \left(\frac{2{,}5}{q} - \frac{2}{3}\right)\right] \tag{3.13}$$

$$T_B \leq T \leq T_C : \ S_d(T) = a_g \cdot S \cdot \frac{2{,}5}{q} \tag{3.14}$$

$$T_C \leq T \leq T_D : S_d(T) \begin{cases} = a_g \cdot S \cdot \frac{2{,}5}{q} \cdot \left[\frac{T_C}{T}\right] \\ \geq \beta \cdot a_g \end{cases} \tag{3.15}$$

$$T_D \leq T : \quad S_d(T) \begin{cases} = a_g \cdot S \cdot \frac{2{,}5}{q} \cdot \left[\frac{T_C T_D}{T^2}\right] \\ \geq \beta \cdot a_g \end{cases} \tag{3.16}$$

Excertos da NP EN 1998-1 (Anexo Nacional NA, 2009)

$a_g = a_{gR}\ \gamma_I$ $\qquad\qquad$ $\beta = 0{,}2$