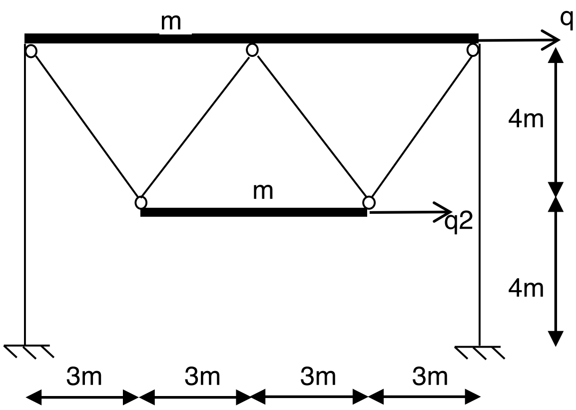
Switch off your mobile phone
Identify all paper sheets with name and number
Deliver each problem in separate sheets
Justify all answers
Duration: 2h 30m

Problem 1 (9,5/20)

Consider the structural model of a reinforced concrete building represented on figure 1, with the degrees of freedom referred to in the figure. The beams are undeformable in flexure and all elements are axially undeformable except the inclined struts. The mass is distributed along the length of the beams. The damping coefficient is 5%



$EI_{columns}$ = 500 000 kNm^2

EA_{struts} = 50 000 kN

m = 20 ton/m

Figure 1: Structural model of the building

a) Calculate the mass and stiffness matrices, referred to the degrees of freedom of figure 1. (2,0)
b) Calculate the periods and vibration modes of the structural model using the characteristic equation. (2,0)
c) Calculate the period and shape of the fundamental mode using the Rayleigh method. Compare the result with the one obtained in answer to the previous question and comment. (1,5)

In the framework of a linear dynamic analysis by response spectra according to EC 8 and the Portuguese National Annex, consider that the structure is of Class of Importance III, i is located in Faro in soil type C and is acted upon by an earthquake type 1 (zone 1.2). Considering a behavior factor q=3:

d) Calculate the base shear and the respective seismic coefficient (3,0)
e) Calculate the maximum axial force on the struts (1,0)

If you did not answered correctly to questions a) and b) consider T_1=0,9s, T_2=0,4s, $v_1 = \begin{Bmatrix} 0,6 \\ 1 \end{Bmatrix}$ e $v_2 = \begin{Bmatrix} -0,9 \\ 1 \end{Bmatrix}$

Problem 2 (5,0/20)

Consider the structural model of figure 1 with rigid struts.

a) Calculate the period of the structure. (1,5)
b) Calculate the maximum amplitude of vibration of the masses if the following forces are applied at the second level: F=100 cos 8t [kN] and F =200 cos 4t [kN]. (2,5)
c) Regarding the answer to the previous question, comment the ratios between the maximum values of the forces and the maximum displacements induced by those forces. (1,0)

Problem 3 (5,5/20)

a) Consider the structure of figure 2, in which both the beam and column are axially undeformable, under a horizontal seismic action. What are the relevant degrees of freedom in a plane dynamic analysis of the structure? Justify your answer. (1,5)

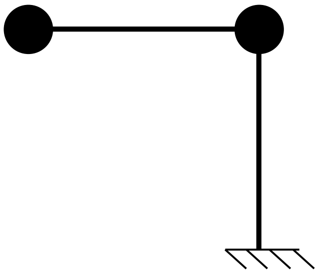


Figure 2

b) Is it possible to use modal analysis to perform a nonlinear dynamic analysis of a structure? Justify your answer.(1,0)

c) The Classes of Importance of structures, such as defined in EC 8, are associated with different rupture probabilities during the structures lifetime. Describe, in conceptual terms, how the calculation of the Importance Coefficients depends on the rupture probability. (1,0)

d) What is the minimum number of stations that is necessary to determine the epicentre of an earthquake? Justify your answer describing the procedure to calculate the location of the epicenter. (1,0)

e) From the point of view of seismic Conception of building structures, what is the best location in plan for structural walls, in the center or near the perimeter? Justify your answer. (1,0)

Quadro NA.I – Aceleração máxima de referência a_{gR} (m/s²) nas várias zonas sísmicas

Acção sísmica Tipo 1		Acção sísmica Tipo 2	
Zona Sísmica	a_{gR} (m/s²)	Zona Sísmica	a_{gR} (m/s²)
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 $a_g \le 1$ m/s² $\quad S = S_{max}$

para 1 m/s² $< a_g <$ 4 m/s² $\quad S = S_{max} - \frac{S_{max}-1}{3}(a_g - 1)$

para $a_g \ge 4$ m/s² $\quad S = 1,0$

em que:

a_g valor de cálculo da aceleração à superfície de um terreno do tipo A, em m/s²;

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:

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

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

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

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

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

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