ENGINEERING TRIPOS PART IIB

Thursday 25 April 2013 9.30 to 11

Module 4D6

DYNAMICS IN CIVIL ENGINEERING

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

Attachments: 4D6 Data sheets (4 pages)

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

1 A beam that is clamped at both ends is shown in Fig. 1(a). The beam has a mass per unit length m and a bending stiffness EI.

(a) By using the lumped mass approach, estimate the fundamental natural frequency of the beam. [15%]

(b) Assume that the mode shape is approximated by a trigonometric function.

(i) Estimate the fundamental natural frequency of the beam. [40%]

$$\text{Note: } \int_0^{2\pi} \cos^2(x)dx = \int_0^{2\pi} \sin^2(x)dx = \pi$$

(ii) The beam is subjected to a vertical force F located at $x = L / 3$ as shown in Fig. 1(b). The force F varies with time as shown in Fig 1(c). Assume that m = 1 kg m^{-1}, EI = 1 N m^2, and L = 1 m. Estimate the maximum displacement of the beam caused by the first mode response. [30%]

(c) Explain using equations how you would estimate the natural frequency of the second mode of the beam. You are not required to solve for the frequency. Would the second mode response to the force F in Fig 1(b) be significant? [15%]

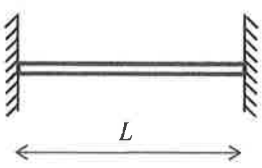

Fig. 1(a)

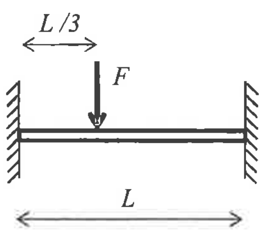

Fig. 1(b)

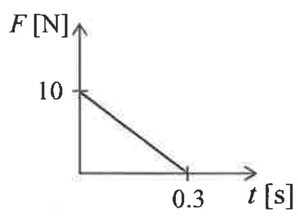

Fig. 1(c)

2 A three-storey structure can be idealised as the lumped mass model shown in Fig. 2a. The top floor (i.e. the roof) has a mass of 20,000 kg and the lower floors each have a mass of 10,000 kg. The floors are supported on columns that have a flexural rigidity EI = 12 MN m^2 and a height of 3 m. All columns are rigidly connected to the floors. You may also assume that the ground floor columns are fixed at the base.

(a) The building is anticipated to be shaken in the direction marked in Fig. 2a. Using the mode shape {0.4, 0.75, 1.0} for the vector of lateral displacements of the floors, show that the fundamental natural frequency of sway oscillations is around 1.85 Hz and that the corresponding modal participation factor is around 1.16. Explain what a modal participation factor is. [40%]

(b) The second mode shape of the structure is {-2.12, -1.55, 1.0}. Determine the second natural frequency of the structure. [20%]

(c) Using the Eurocode 8 design spectrum in Fig. 2b, estimate the peak shear force in the base of columns at ground floor level when a nearby earthquake causes a peak ground acceleration a_g of 0.2g at the site. In Fig. 2b, the ordinate is the ratio of spectral acceleration S_{da} to peak ground acceleration a_g. [40%]

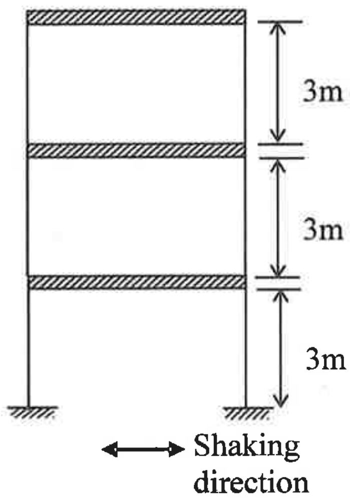

Fig. 2a

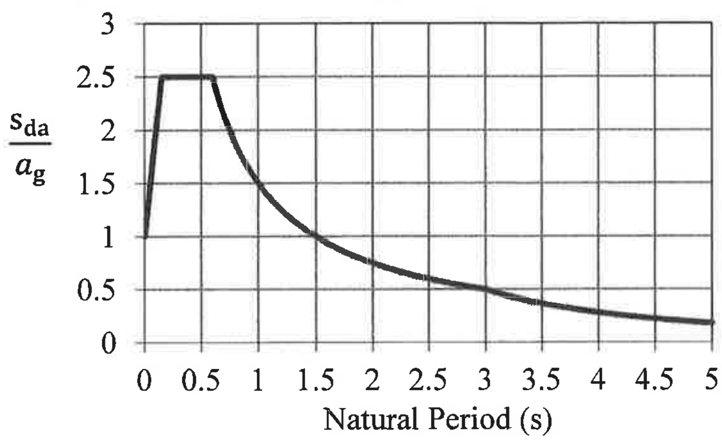

Fig. 2b

3 (a) Explain what is meant by dynamic soil-structure interaction. [10%]

(b) Explain why numerical integration is employed when considering dynamic soil-structure interaction problems. [10%]

(c) A sway-frame structure is to be constructed on a dry sandy deposit with a floor height of 4 m, as shown in Fig. 3. The mass of the structure is 5000 kg which can be assumed to be lumped at the top of the structure. The structure extends to 3 m into the plane of the paper. The flexural stiffness of the left hand column is 1×10^6 N m^2 and that of the right hand column is 2×10^6 N m^2. Assuming that the structure is fixed at the ground level, estimate the natural frequency of the structure. [15%]

(d) The columns of the structure are supported on a common raft foundation as shown in Fig. 3. Describe a simple discrete model that can account for horizontal vibrations of the structure and the foundation. [20%]

(e) The dry sand is found to have a unit weight of 16 kN m^{-3}, a Poisson's ratio of 0.3 and a shear wave velocity of 120 m s^{-1}. The concrete raft foundation has a width of 3 m and extends 3 m into the plane of the paper. It is embedded to a depth of 0.5 m below the ground surface, as shown in Fig. 3. The unit weight of concrete is 24 kN m^{-3}. Using the simple discrete model in part (d), calculate the natural frequencies of the soil-structure system for horizontal vibrations. Assume that a soil mass 10 times the mass of the foundation will participate in horizontal vibrations. [30%]

(f) Following heavy rain, the water table moves to the ground surface. Explain how this structure may suffer if the soil below the foundations liquefies during a strong earthquake. [15%]

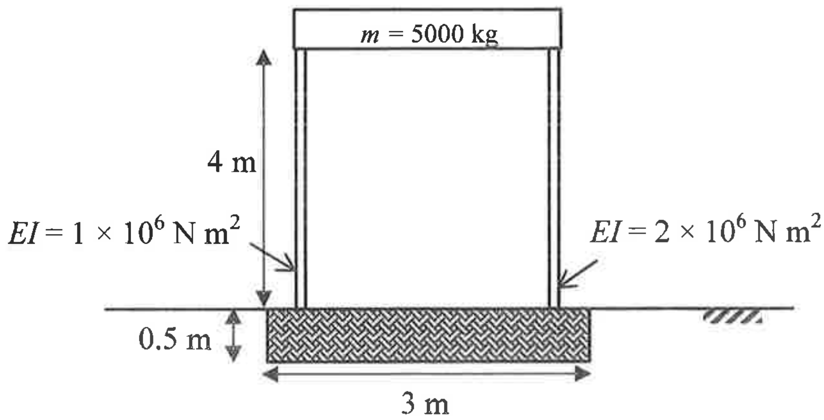

Fig. 3

4 Explain briefly:

(a) the differences between the wind flow patterns in thunderstorms and in hurricanes; [10%]

(b) the resolution to D'Alembert's paradox for the drag force on a body in a fluid; [10%]

(c) galloping (and give examples); [20%]

(d) the different characteristics of the pressure profiles generated by high explosives and by gas blasts; [20%]

(e) aerodynamic admittance; [20%]

(f) how naive finite element modelling of a suspension bridge can lead to erroneous estimates of mode shapes and modal frequencies, and describe a procedure for overcoming this difficulty. [20%]

END OF PAPER