ENGINEERING TRIPOS PART IIB
ELECTRICAL AND INFORMATION SCIENCES TRIPOS PART II

Saturday 3 May 2003 9 to 10.30

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.*

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

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1 (a) Briefly explain the SRSS method of modal superposition. Comment on possible alternative approaches. [30%]

(b) The simply supported beam AC shown in Fig. 1(a) has a mass of 300 kg/m and uniform bending stiffness $EI = 150$ kNm^2. The beam, at rest at $t = 0$, is subjected to a time-varying force $F(t)$ shown in Fig. 1(b) at point B.

(i) Show that the natural periods of the first two modes of oscillation are approximately 1.0 seconds and 0.26 seconds. [40%]

(ii) Estimate the maximum deflection at point B by superposing the maximum responses of the first two natural modes of the beam. [30%]

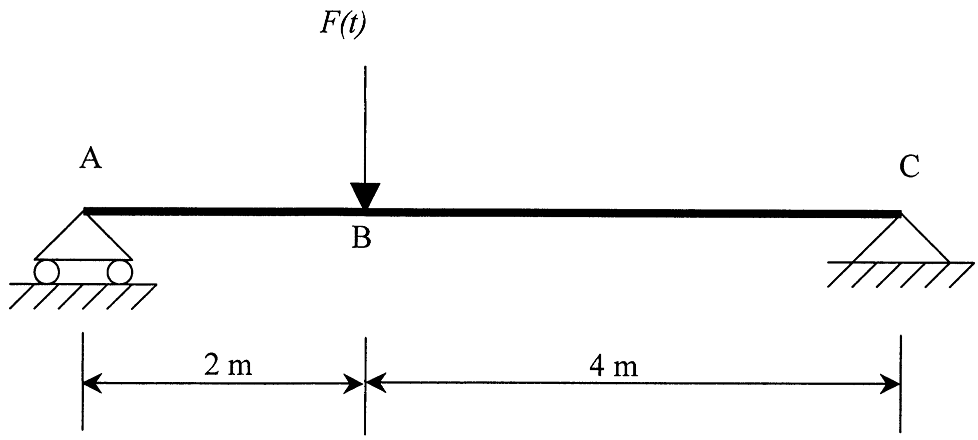

Fig. 1(a)

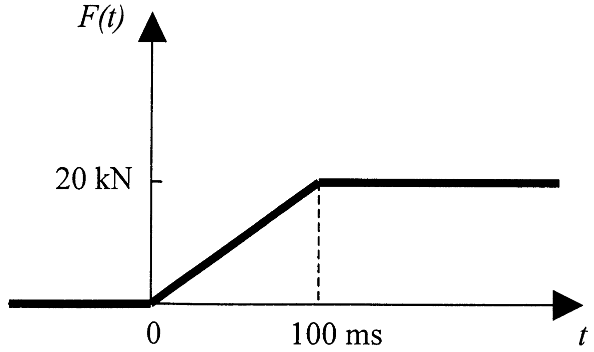

Fig. 1(b)

2 A two-storey building is to be built in an earthquake zone. The upper storey will be office space with frequent columns while the taller, lower storey will be used for retail and must have a large column-free area.

Figure 2(a) shows a two-dimensional, rigid-jointed, linear-elastic frame model of the building. The horizontal members are beams with a mass of 300 kg/m and may be treated as rigid. The columns may be treated as massless, inextensional and with uniform bending stiffness. The three top-storey columns each have bending stiffness $EI = 5000$ kNm^2, while the ground floor columns each have $EI = 10000$ kNm^2.

(a) If equal lateral loads are applied together to the first and second floors, show that the static deflection of the first floor is approximately 83% that of the second. [30%]

(b) The frame, initially at rest, is subject to the ground acceleration defined in Fig. 2(b). Assuming a vibration mode based on a static deflection of the frame, show that the frame has a natural period of approximately 0.3 seconds and estimate the maximum displacement of the top of the frame. [70%]

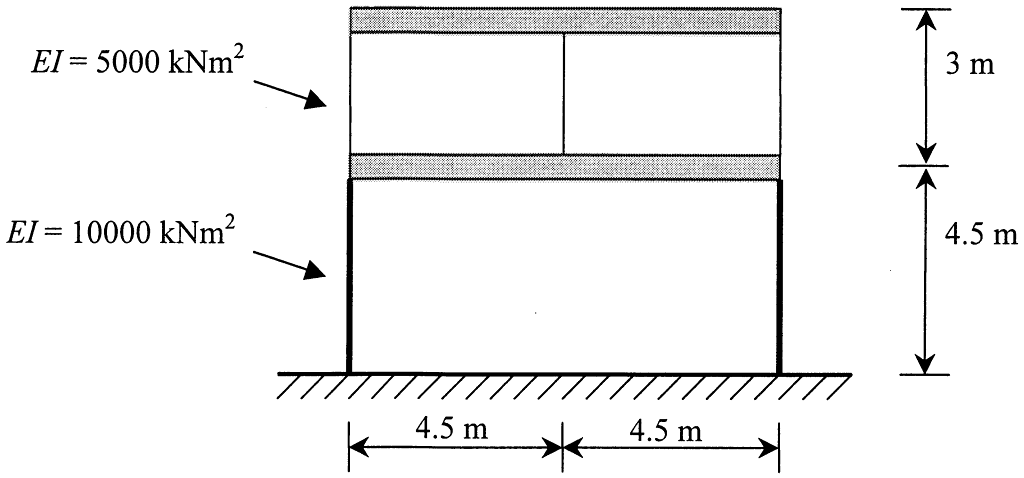

Fig. 2(a)

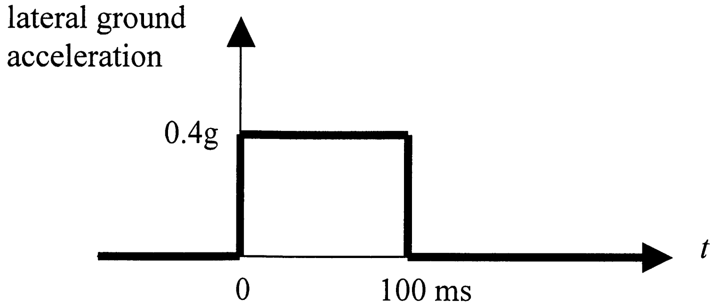

Fig. 2(b)

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3 A spherical propane tank of 5 m diameter, illustrated in Fig. 3, is to be built in an area prone to both cyclones and earthquakes. The mass of the tank when empty is 16 tonnes and when full is 80 tonnes. In both cases it may be assumed that the centre of mass of the tank is 12 m above the base of a supporting raft foundation. It is braced against horizontal deflection by a light but rigid system of columns and braces, such that the raft, support and tank may be considered to act as a single rigid block. The raft is 5m × 5m × 0.5m and is made of concrete of density 2400 kg m^{-3}. It is embedded to a depth of 0.5 m in loose saturated sandy soil of density 1800 kg m^{-3} and of Poisson's ratio 0.3.

(a) Assuming a drag coefficient of 0.8 for the spherical tank, estimate the lowest wind speed at which the tank would be expected to overturn. (You may assume that the density of air is 1.2 kg m^{-3} and may ignore drag on the support frame and restoring moments from horizontal forces exerted by the embedding soil). [30%]

(b) The shear wave velocity through the loose sand was determined using the cross-hole technique to be 120 m/s.

(i) Assuming the inertia of soil participating in the motion is negligible, estimate the natural frequency of small-amplitude rocking vibrations when the tank is full. [50%]

(ii) Give two reasons why the actual natural frequency of this mode may fall from this value during a strong earthquake. [20%]

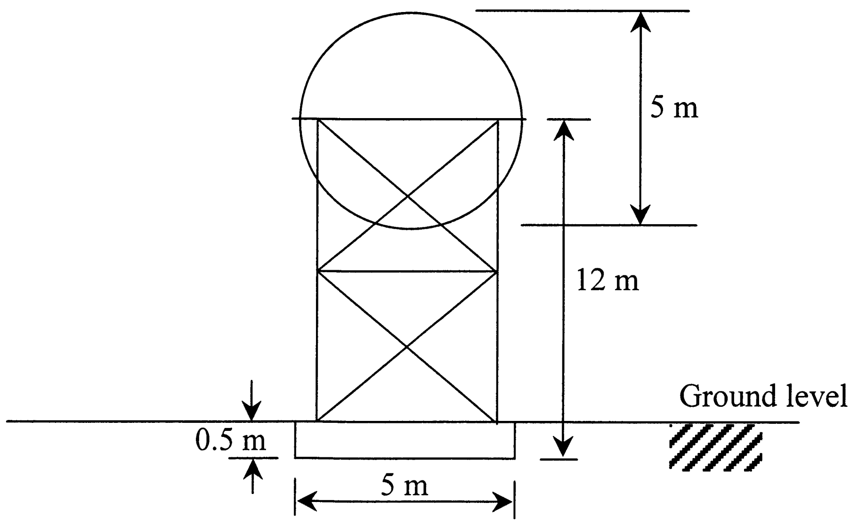

Fig.3

4 (a) Explain briefly what is meant by a pseudo-velocity response spectrum. [10%]

(b) Explain briefly how full liquefaction and partial liquefaction can occur in saturated sandy soils. [10%]

(c) Explain briefly the concept of aerodynamic admittance in the statistical theory of wind buffeting, and explain any limitations of the concept and of the statistical approach in general. Also explain briefly why wind engineers do not employ the concept of a response spectrum that is popular in earthquake engineering. [20%]

(d) Give two reasons why the classical theory of the flutter of a flat plate using quasi-static aerodynamic derivatives may not be appropriate for assessing the aeroelastic stability of a suspension bridge deck. [10%]

(e) Explain why a finite element analysis intended to estimate the natural frequencies of a suspension bridge needs to employ a geometrically-nonlinear formulation, and describe how a simple single-degree-of-freedom model may be constructed which estimates the natural frequency of the first lateral mode of vibration. [20%]

(f) Describe measures that can reduce the vulnerability of buildings and their occupants to the effects of bomb blasts. [20%]

(g) Explain why, during a hurricane, small high-velocity airborne debris (such as roof-tiles from buildings upwind) can lead to whole roofs downwind being lifted from their buildings. [10%]

END OF PAPER