Version FAM/4

EGT3
ENGINEERING TRIPOS PART IIB

Tuesday 6 May 2014 2 to 3.30

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.*

Write your candidate number ***not*** *your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Attachment: 4D6 Data Sheets (4 pages).
Engineering Data Book

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

1 A grandstand seating tier may be modelled as the cantilever beam shown in Fig. 1(a). The beam is a 6 m long, 305 × 165 × 54 Universal Beam, with its web lying in the vertical plane. The seating structure (not shown) provides additional mass loading of 20 kg m^{-1} measured along the beam.

(a) Estimate the natural frequencies of the first and second cantilever bending modes by assuming mode shapes of the form:

$$\bar{u}_j = 1 - \cos\frac{j\pi x}{12} \qquad j = 1, 2$$

[40%]

(b) The Structural Engineer is concerned about dynamic loading from enthusiastic football fans. By considering the idealised impact load shown in Fig. 1(b) applied vertically at the tip of the cantilever, estimate the peak displacement of the cantilever. Sketch each mode shape to illustrate your solution. [40%]

(c) Estimate the peak displacement if a 356 × 171 × 57 UB is used as an alternative section. What other options might be considered to reduce the displacement? [20%]

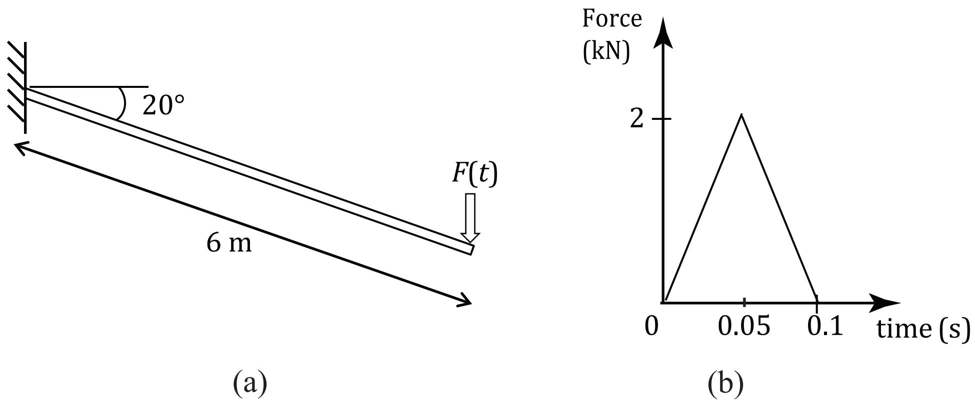

Fig. 1

2 Figure 2(a) shows a sway frame model of a building, consisting of rigid floor slabs supported on light flexible columns. Each floor slab has a mass of 1000 kg, and each column has a flexural rigidity $EI = 10$ MNm^2.

(a) Derive the mass and stiffness matrices associated with the model, taking the absolute lateral displacements at first and second floor level as the degrees of freedom. Hence calculate the mode shapes and corresponding natural frequencies of the frame. [40%]

(b) The building must sustain a short duration dynamic load that may be modelled as a point force $F(t)$ applied at the second floor level. The force $F(t)$ varies with time as shown in Fig. 2(b). Estimate the maximum lateral displacement in each mode and hence estimate the combined response using the SRSS method. [60%]

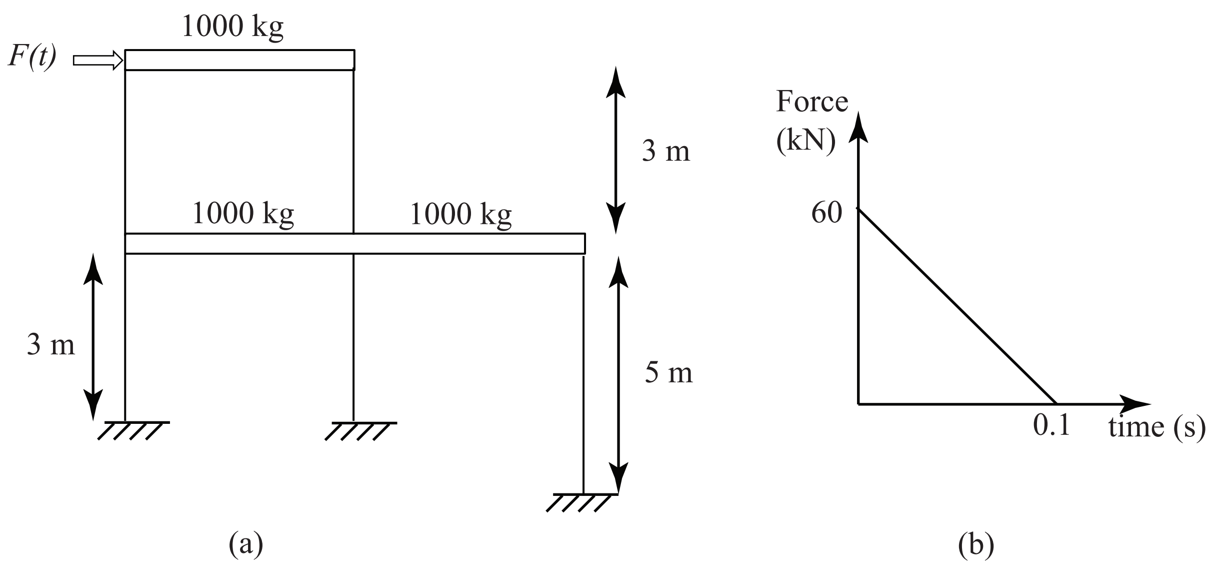

Fig. 2

3 (a) Explain briefly why some soils can liquefy and what soil characteristics are necessary for a soil to be classified as liquefiable. [10%]

(b) Describe two techniques by which potentially liquefiable soil could be remediated and discuss the relative advantages of the two techniques. [20%]

(c) A structure is to be constructed on a saturated sandy deposit, as shown in Fig. 3. The structure can be idealised as a lumped mass of 20,000 kg supported by two 5 m high columns, each with a flexural stiffness EI of 2×10^8 Nm^2 . Assuming the structure to be fixed at ground level, calculate the natural frequency of the structure in the horizontal sway mode. [10%]

(d) The foundation comprises a 3 m square, 0.5 m thick concrete raft embedded such that its surface is at ground level. The unit weight of concrete is 24 kN m^{-3}. If the saturated sand has a unit weight of 20 kN m^{-3}, a shear wave velocity of 100 m s^{-1} and a Poisson's ratio of 0.3, calculate the natural frequency of the soil-structure system in horizontal sway, assuming that a soil mass ten times the mass of the foundation will participate in the vibration. [30%]

(e) If liquefaction of the soil results in a drop of shear wave velocity to 15 m s^{-1}, how will this affect the performance of the system during earthquakes? [30%]

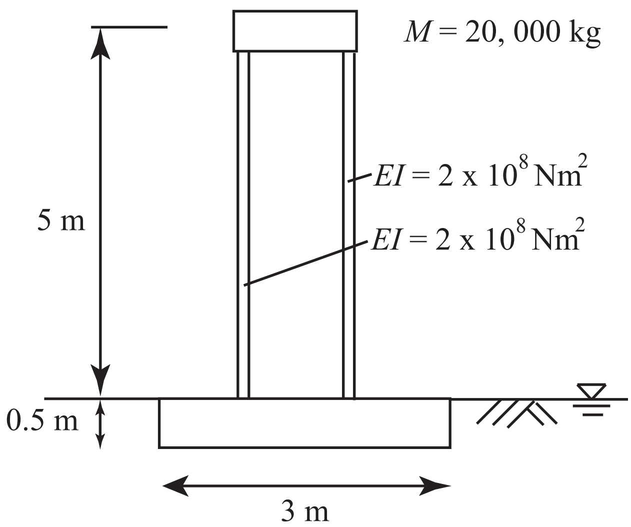

Fig. 3

4 (a) What are flutter derivatives and how may wind tunnel tests be used to determine them? [25%]

(b) Show that linear undamped structural modes are orthogonal with respect to both the mass and stiffness matrices provided that their modal frequencies differ. [25%]

(c) Explain what is meant by mechanical admittance and aerodynamic admittance. [25%]

(d) Outline the design principles for blast resistant buildings. [25%]

END OF PAPER

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1. a) 9.3 Hz, 14.5 Hz b) 8.3 mm c) 5.9 mm
2. a) 8.5 Hz, 19.8Hz b) 16mm, 3.3 mm, 16.3mm
3. c) 7 Hz, d) 5.7 Hz e) 1 Hz