ENGINEERING TRIPOS   PART IIB

Wednesday 9 May 2012   9 to 10.30

Module 4D7

CONCRETE AND MASONRY STRUCTURES

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: (i) Concrete and Masonry Structures: Formula and Data Sheet (4 pages).
(ii) The Cumulative Normal Distribution Function (1 page).

STATIONERY REQUIREMENTS	SPECIAL REQUIREMENTS
Single-sided script paper	Engineering Data Book
Graph Paper	CUED approved calculator allowed
	Extra copy of Fig.3 attached

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) Describe the manufacturing process for Ordinary Portland Cement (OPC), listing the primary ingredients and the main anhydrous products. Briefly describe the hydration process for OPC and comment on the beneficial and deleterious effects of the different anhydrous products. [30%]

(b) List the key factors which contribute to good quality, durable concrete and explain the significance of each. [20%]

(c) A simply-supported, precast, reinforced concrete beam spanning 8 m is loaded at mid-span by a point load P with mean value 5 kN. Self-weight of the beam can be ignored.

(i) The loading P applied to this beam during its design life is thought to be best represented by a probability density function which is uniform from 3 to 7 kN and zero elsewhere. Sketch the equivalent probability density function for the flexural **load effect** at mid-span and hence its characteristic value. [10%]

(ii) The beam is designed such that a population of identical beams would have a flexural strength with a probability density distribution which is uniform from R to $1.2R$ and zero elsewhere, where R is a measure of flexural strength. What is the probability of failure, under the loading given in part (i), for such a beam which is designed to have a characteristic strength equal to the characteristic load effect? [40%]

2 (a) Outline briefly the mechanical properties of ordinary concrete under uniaxial, biaxial and triaxial stress, and describe two situations in which the triaxial properties are exploited in design. Sketch a graph of uniaxial stress versus strain for a range of concrete strengths; include plots of volumetric strain and lateral strain for a uniaxial cylinder compression test at one of the chosen concrete strengths. Explain the effect of increasing the lateral stress on the shape of these stress versus strain plots. [50%]

(b) Discuss briefly the concept of whole-life costing of concrete structures to allow for the costs of possible repairs during the design life. Outline the effect on the calculations of the assumed discount rate, out-of-use costs, inflation, and any other important factors. [25%]

Two alternative strategies are available for providing reinforcement of a certain concrete structure in an aggressive environment;

(i) traditional reinforcement with initial cost £40,000 and repairs costing £10,000 every ten years; and

(ii) modified reinforcement with initial cost £50,000 and a cathodic protection system costing £500 per year to run. All cost estimates are in 2012 prices.

Using a discount rate of 3% per annum, and continuous discounting where appropriate, decide which strategy is the more economical for a design life of 40 years. [25%]

3 A 5 m long inverted U-shaped reinforced concrete cantilever beam is shown in Fig.1. An unfactored, uniformly distributed live load $w = 6\ \mathrm{kNm}^{-1}$ is to be supported by the beam over its full length. The concrete has characteristic cube strength $f_{ck} = 30$ MPa, effective Young's modulus $E_{ce} = 30$ GPa, modulus of rupture $f_{tk} = 4$ MPa and density 24 kNm^{-3}. The steel reinforcing bars are high yield deformed bars with Young's modulus $E_s = 210$ GPa and yield strength $f_{yk} = 460$ MPa.

(a) Given that before cracking the centroid is at the bottom surface of the top flange, and the second moment of area of the uncracked section $I_{un} = 0.006\ \mathrm{m}^4$, determine the magnitude of the live load at which you would first expect the beam to crack. The steel has been ignored when determining the gross section properties. [15%]

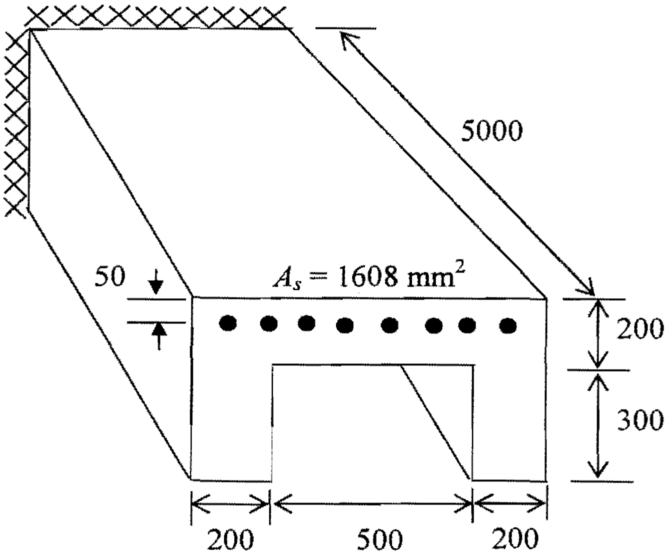
(b) Calculate the maximum stress in the concrete cantilever beam at the serviceability limit state using elastic no-tension theory. Hence estimate the strain in the reinforcing bars at SLS. [30%]

(c) Estimate the deflection of the tip of the cantilever under short term SLS loading assuming;

(i) the beam behaves as if *uncracked* over its full length, [15%]

(ii) the beam behaves as if *cracked* over its full length. [15%]

(d) Use the appropriate interpolation formula to allow for tension stiffening and hence give a better estimate of the tip deflection. Explain why this will still be an overestimate of the actual tip deflection. [25%]



All dimensions in mm unless shown otherwise

Fig. 1

4 (a) A vertical brick wall 3.5 m in height and 300 mm in thickness is constructed using English bond as shown in Fig. 2. It is subjected to a permanent vertical force n of 900 kN (per unit length of wall) where n is the characteristic dead load from above.

(i) By considering the "vertical arching" method, or otherwise, estimate the characteristic lateral load q_{lat} that can be carried safely by this wall. Suggest an appropriate factor of safety and how it might be applied in this example. [20%]

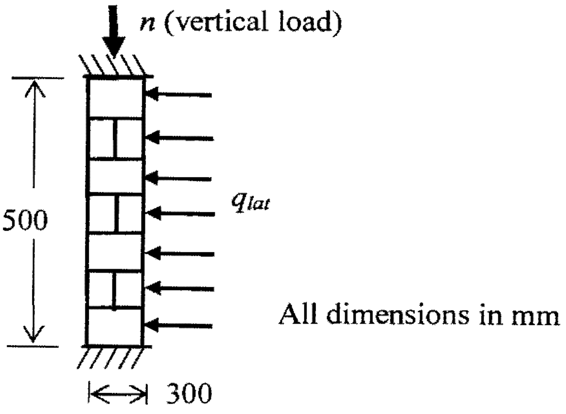


Fig. 2

(ii) What class of brick and mortar designation would be required if partial safety factors on material strength of 3.0 and on loading of 1.5 are assumed? [10%]

(b) Figure 3 (which is also available as a separate sheet) represents a simplified model of a masonry arch entrance to a church side chapel. The left hand wall abuts the main church structure and can be assumed immovable, as can the foundation supporting the arch. It is assumed that there is no slip between the stones. A new ornamental cross, which can be represented as a concentrated load P, is to be added at the pinnacle of the arch. What is the maximum weight of cross, in terms of the weight W of the right hand wall stone, that can be carried safely by the arch assuming an overall factor of safety against collapse of 2.0? Initially assume the density of all the stones is the same, γ_{stone} , and the thickness of the arch (into the page) is constant. [60%]

(c) If the wall stone on the right hand side of Fig. 3 is found to have a density half that assumed in part (b) above (i.e. $\gamma_{stone}/2$), what height H of triangular shaped pinnacle (of full density γ_{stone}) as shown dotted in Fig. 3, would be required to ensure the same weight of cross as determined in part (b) could be safely carried by the arch? The other stones remain unchanged. [10%]

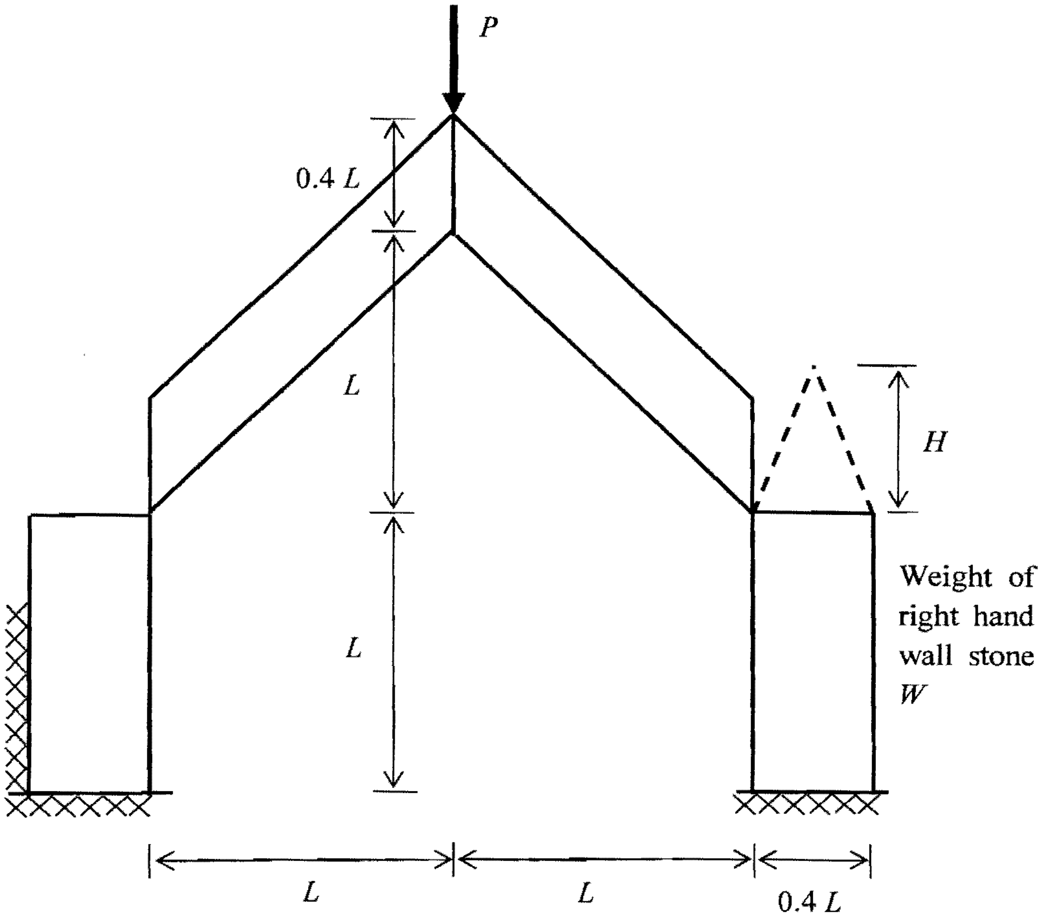


Fig. 3

END OF PAPER

ENGINEERING TRIPOS PART IIB 2011-12

NUMERICAL SOLUTIONS FOR 2012 EXAM

Module 4D7

CONCRETE AND MASONRY STRUCTURES

1 (c)
- (i) $S_k = 13.6$ kNm
- (ii) $P_f = 6.53 \times 10^{-3}$

2 (b)
- (i) $WLC_1 = £57.6$k assuming i-1; $WLC_1 = £57.1$k assuming i
- (ii) $WLC_2 = £60.9$k for t = 35 years; $WLC_2 = £61.7$k for t = 40 years

3

(a) $w_{LL} = 2.4$ kNm^{-1}
(b) $\sigma_c = 15.2$ MPa ; $\varepsilon_s = 0.0012$
(c)
- (i) $\delta = 5.7$ mm
- (ii) $\delta = 23.7$ mm

(d) $\delta = 14.2$ mm

4 (a)
- (i) $q_{lat} = 176.3$ kPa

(b) $P = 0.67W$
(c) $H = L$