Version Paper_4D7_2015

EGT3
ENGINEERING TRIPOS PART IIB

Tuesday 28 April 2015 14.00 to 15.30

Module 4D7

CONCRETE 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.*

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: 4D7 Concrete Structures Formula and Data Sheet (4 pages)
Engineering Data Book

10 minutes reading time is allowed for this paper.

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

1 A square reinforced concrete column with sides of length 300 mm is shown in Fig. 1(a). The column is reinforced with four 32 mm diameter bars with a concrete cover of 30 mm. At the ultimate limit state, the concrete carries a uniform stress of 0.6 f_{cd} where f_{cd} = 25 MPa. The design yield stress of the steel in tension and compression is 460 MPa. Unless otherwise noted, the concrete strain at failure can be taken as ε_{cu} = 0.0035 and the steel yield strain as ε_y = 0.002. Axial force is applied through the centroid of the cross-section.

(a) Find the maximum axial compressive load that can be carried by the column. [10%]

(b) When the column is subjected to uni-axial bending about the X-X axis, find the applied moment and axial force associated with a balanced failure. [40%]

(c) Determine the applied loads that would be associated with a failure where the neutral axis passes through an axis defined by u = 100 mm and v = 200 mm, as shown schematically in Fig. 1(b). For this part of the question $\varepsilon_y / \varepsilon_{cu}$ can be taken to be small. [50%]

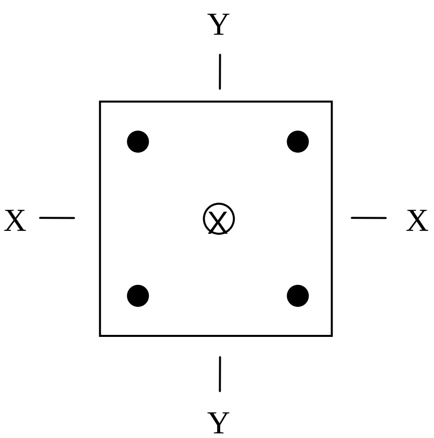

Fig. 1(a)

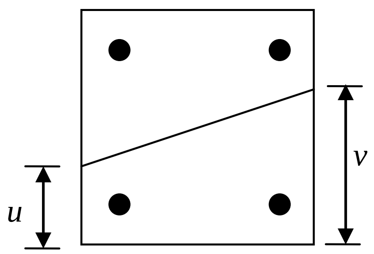

Fig. 1(b)

2 (a) A reinforced concrete half-joint supports a drop-in span that applies a force per unit length *P*. A designer is considering reinforcement options for the end region shown in Fig. 2. Assume that the distance from the nearest concrete surface to the centre of all reinforcement is 30 mm and that the reinforcement is well-anchored. The design yield strength of the steel is 460 MPa.

(i) One option is to provide steel along axes A and B. The steel provided along A consists of 10 mm diameter bars at 100 mm spacing. Estimate the maximum force *P* per unit length at the ultimate limit state and suggest a suitable bar size and spacing for the bars along axis B. [30%]

(ii) The designer wishes to increase *P* by adding an additional set of 10 mm bars at 100 mm spacing to the half-joint reinforcement layout. Sketch a proposed layout (differing from that shown in Fig. 2) and estimate the increase in *P* at the ultimate limit state. [30%]

(iii) Briefly comment on the assumptions implicit in your calculations. [10%]

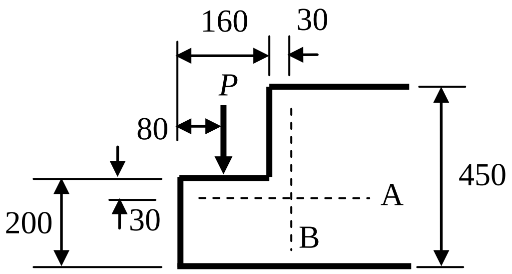

Fig. 2

(b) List four anhydrous compounds present in Ordinary Portland Cement (OPC). Describe the main reactions in the hydration process of OPC and comment on the unwanted materials that are formed and the rate of hydration, heat evolution and strength contribution of these anhydrous compounds in this process. [30%]

(TURN OVER

3 (a) A 3 m long reinforced concrete cantilever beam has a rectangular cross-section with width 250 mm and depth 450 mm. There is one layer of longitudinal steel with a total area of 2000 mm^2 and an effective depth of 400 mm. The Young's Moduli of Elasticity of the steel and concrete are 210 GPa and 30 GPa respectively. The concrete tensile strength is 3 MPa. The beam is loaded with a couple about the major axis at the end of the cantilever. The loading is applied over the short-term.

(i) Calculate the cracked second moment of area, I_{cr}, using elastic no-tension theory. [30%]

(ii) The uncracked second moment of area is $I_{un} = 1.94 I_{cr}$ and, when uncracked, the distance from the base of the section to the centroid is 208.1 mm. Accounting for cracked and uncracked regions, calculate the deflection of the tip of the cantilever under an applied couple of 50 kNm. [40%]

(b) There have been a number of advances in concrete material technology such as the introduction of (i) High Strength or High Performance Concretes, (ii) Reactive Powder Concrete (RPC) and (iii) Fibre Reinforced Concrete (FRC). Briefly outline two of these developments and explain their potential advantages over conventional reinforced concrete structures and where they might be used in practice. [30%]

4 (a) What major factors should be considered in the specification of a reinforced concrete structure if a designer wishes to ensure high quality, durable concrete? Explain why each of the factors listed is important for the performance of the final structure. [25%]

(b) The two primary mechanisms of deterioration which concern the owners of concrete infrastructure are chloride induced corrosion and carbonation.

(i) Explain briefly the deterioration process in each case. [15%]

(ii) Once corrosion has been initiated, describe the procedures you might employ to confirm its presence and then remedy the problem. [20%]

(c) Site investigations reveal extensive corrosion on the top surface of the deck slab of a concrete motorway bridge. It is estimated that repairs will take 10 working days at a capital cost of £150,000 for labour and materials. In addition, traffic disruption costs during these works are estimated at £10,000 per day. It is anticipated that the same amount of money and time will be needed for similar repairs every 20 years. The deck slab is also to be sprayed with silane to inhibit the ingress of chlorides. This costs £20,000 for materials and labour, involves two days of disruption to traffic, and needs to be reapplied every 15 years. Silane is not applied if the predicted residual life of the structure is less than 10 years.

The engineer wishes to consider an alternative repair option which would involve replacing the existing corroded steel reinforcement with stainless steel. The initial capital cost of using stainless steel would be £250,000 (including materials and labour), the duration of repair works would be 15 working days, the life expectancy of the stainless steel before similar major repairs is expected to be 50 years, and no silane treatment would be required.

Assuming a discount rate of 3.5% per annum for discounting in annual steps, should stainless steel be recommended on economic grounds if the required life of the structure is 65 years? All costs are in 2015 prices. [40%]

END OF PAPER

Engineering Tripos Part IIB **2014-15**

Module 4D7 Concrete Structures

List of numerical answers

Q1(a) N_u = 2782 kN

Q1(b) M_x = 204.2 kNm , N = 703 kN

Q1(c) N = 675 kN , M_x = 202.7 kN , M_y = 11.25 kN

Q2 (a)(i) P = 459.6 kN per metre length

Q3 (a)(i) $I_{cr} = 1.147 \times 10^9$ mm^4

Q3 (a)(ii) δ_{tip} = 5.22 mm

Q4 (c) NPV Option 1 = £557.1k , NPV Option 2 = £471.6k