Version JJO/8

EGT3
ENGINEERING TRIPOS PART IIB

Tuesday 27 April 2021   1.30 to 3.10

Module 4D7

CONCRETE AND PRESTRESSED CONCRETE

*Answer **all** 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 and at the top of each answer sheet.*

STATIONERY REQUIREMENTS
Write on single-sided paper.

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Attachment: 4D7 Concrete Structures data sheet (3 pages)
You are allowed access to the electronic version of the Engineering Data Books.

10 minutes reading time is allowed for this paper at the start of the exam.

The time taken for scanning/uploading answers is 15 minutes.

Your script is to be uploaded as a single consolidated pdf containing all answers.

1 (a) Adopting reinforced concrete as the primary structural material in construction can result in a considerable carbon footprint. Explain how the embodied carbon of reinforced concrete structures might be reduced and what effects, if any, such actions may have on the whole life performance of the built asset. [45%]

(b) A concrete bridge was constructed in 1960 and was assumed to be initially free of chloride contamination. The design specified the cover to the steel reinforcement to be 35 mm. Five years after construction, a core was taken into an exposed face of a bridge abutment and phenolphthalein indicator solution applied. The outer 12 mm region of concrete in the core was clear and the remaining region turned a deep pink colour.

In addition, concrete dust samples were taken from the same region of the abutment at a depth of 10 mm from the surface and tested in the lab at regular intervals after construction. Two years after construction these tests showed that the chloride concentration per unit weight of cement was 0.2%; after eight years it was 0.6%. The diffusion coefficient D for the concrete is assumed to be constant. Critical thresholds for depassivation of the steel (and hence initiation of corrosion) are assumed to be $Cl^{-} = 0.4\%$ by weight of cement or $pH = 12$.

(i) Estimate the age at which corrosion of the steel will first be initiated. [40%]

(ii) What factors might affect the time to initiation and the rate of corrosion? [15%]

2 (a) (i) Sketch a graph of stress versus axial strain for a range of strengths of concrete cylinders subjected to uniaxial compression identifying salient features. Include plots of volumetric strain and lateral strain for the cylinder at one of the chosen concrete strengths. Comment on the relationship between concrete strength f_c and the Young's Modulus, E_c. [20%]

(ii) How would the behaviour of a concrete specimen subjected to triaxial loading differ from one under uniaxial loading? Describe two situations in which the triaxial properties of reinforced concrete are exploited in design. [10%]

(b) A reinforced concrete beam has a web thickness 300 mm and the vertical distance between tension and compression chords is z = 500 mm. Concrete compressive cylinder strength is f_{ck} = 50 MPa. Longitudinal tension reinforcement totals 1257 mm^2.

(i) One section of the beam is to sustain a shear force V_{Ed} = 750 kN. Design a suitable arrangement of transverse reinforcement, assuming first that all the reinforcement is fully anchored, has design yield strength f_{yd} = 450 MPa, and is made up of diameter 12mm bars at 150 mm centres. [25%]

(ii) Iterate your design to reduce the volume of steel required for the beam, by making the design value of the shear force which can be sustained by the yielding shear reinforcement, $V_{Rd,s}$, equal to V_{Ed}. Comment on the efficiency of your design. [35%]

(iii) What other reinforcement is required according to the truss analogy? [10%]

(TURN OVER

3 (a) A uniform cross section simply supported elastic beam is subjected to three external loads, as shown in Fig. 1. Using data book cases for a cantilever beam subject to a point load, find a relationship between F_1 and F_2 such that the deflection at the midspan of the beam under these loads is zero. [30%]

(b) A continuous prestressed concrete beam has the cable profile shown in Fig. 2. The cable position d is measured positive downwards from the centroid of the beam section.

(i) Find equations for the forces exerted by the cable onto the beam at its two inflection points at D and B. [20%]

(ii) Derive a relationship between d_1 and d_2 such that the cable profile is concordant (causes no secondary moments). [20%]

(c) The beam shown in Fig. 2 has a constant prestressing force of 2,500 kN and a cable profile determined by $d_1 = -0.5$ m and $d_2 = 0.5$ m.

(i) Using the result of (b)(ii) and a suitable linear transformation, find the secondary moments induced over the internal support. [20%]

(ii) Explain briefly how the stress distribution in the beam may change over time due to creep if it is used to support a cast in-situ concrete slab. [10%]

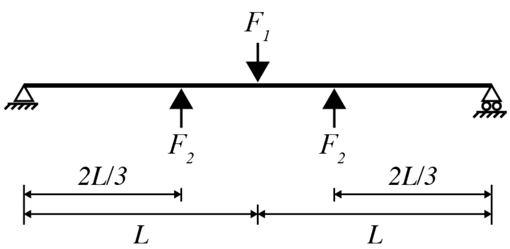

Fig. 1

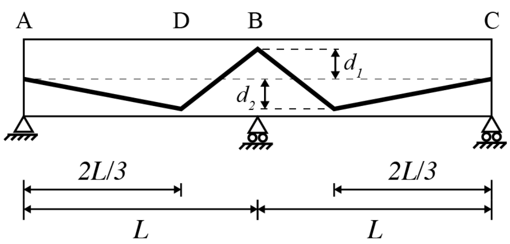

Fig. 2

END OF PAPER

ENGINEERING TRIPOS PART IIB

NUMERICAL ANSWERS 4D7 2021

1(b)(i) Carbonation t = 42.5 years; Chloride ingress t = 50 years
2(b)(i) $V_{Rd,s}$ = 848 kN
2(b)(iii) ΔF_{td} = 938 kN
3(c)(i) M = 486 kNm