Version PD/4

EGT3
ENGINEERING TRIPOS PART IIB

Tuesday 25 April 2023 14:00 to 15:40

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.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Attachment: 4D7 Concrete Structures data sheet (5 pages)
Engineering Data Book

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

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

You may not remove any stationery from the Examination Room.

1 An owner would like to investigate whether the service life of their 37-year old concrete multi-storey car park can be extended. They have ordered a concrete assessment study which revealed a carbonation depth of 30 mm. The chloride tests showed a surface concentration of 1.6% by weight of cement and a chloride concentration of 0.3% by weight of cement at a depth of 30 mm. The homogeneous concrete initially contained negligible chlorides.

(a) Determine the carbonation coefficient and the chloride diffusion coefficient of the concrete. [30%]

(b) The client would like to extend the life of the structure by 15 years and has set the assessment team the following failure criterion: the structure has failed its durability requirements if 10% of the reinforcement is depassivated due to carbonation or the critical chloride content reaches 0.4% by weight of cement.

(i) If the concrete cover is normally distributed with an average of 39 mm and a standard deviation of 4 mm, calculate the carbonation depth and the chloride content at the critical depth in 15 years time (the total age of the structure is then 52 years). [40%]

(ii) Show whether it is possible to extend the service life of the structure without any interventions and still satisfy the durability requirements. Name three measures to protect against carbonation and chloride ingress that could be taken now to help ensure a longer service life. [20%]

(c) Name three other deterioration mechanisms that could affect the concrete structure. [10%]

2 A short concrete column of 350 mm square cross-section is reinforced by four steel bars of 20 mm diameter, placed one near each corner with cover 30 mm. The concrete has design cube strength f_{cd} = 30 MPa, and the design yield stress of the steel is 435 MPa. The column carries a compressive axial force of 200 kN together with bending moments M_x and M_y about axes through the column centre parallel to the sides of the cross-section, and $M_y = 0.85\ M_x$.

(a) Assuming that all the steel has yielded at failure, and that the concrete compression zone then carries a uniform stress 0.6 f_{cd}, determine the position of the neutral axis of this section under the combination of axial load and bending moments. [65%]

(b) Determine the value of M_x and M_y at failure. [10%]

(c) Using a sketch of a typical interaction diagram for biaxial bending, explain how varying the compressive axial force can influence the maximum bending moments M_x and M_y that can be applied on the column (no additional calculations are required). [25%]

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3 A rectangular post-tensioned concrete beam has a width of 1.5 m and a depth of 2.5 m. It is prestressed by three 30 m long tendons. Each tendon has a cross-sectional area of 8000 mm^2 and is stressed to 1000 MPa. The modulus of elasticity of this concrete is 20 GPa and that of the steel is 200 GPa.

(a) On release, the anchorage wedge for each tendon is pulled in by 3 mm. Determine the prestress loss due to wedge pull-in. [25%]

(b) The order of stressing and the eccentricities relative to the horizontal and vertical principal axes for each tendon are shown in Table 1. Determine the loss of stress in each cable due to elastic shortening of the concrete as the phased prestressing of each tendon occurs. [50%]

(c) What is the loss in total prestressing force for the beam after wedge pull-in and elastic shortening? [25%]

Table 1: Order of prestressing and eccentricities of each cable

Order of prestressing	Eccentricity from the horizontal principal axis (mm)	Eccentricity from the vertical principal axis (mm)
1	800	0
2	-800	-500
3	-800	500

END OF PAPER