Loughborough University

Engineering Materials for Construction
23CVA106

Semester 2 2024 | In-Person Exam Paper

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **2 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

<u>Help during the exam</u>

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

You may use a calculator for this exam. It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are **not** allowed).

This examination consists of two sections:
Answer **BOTH QUESTIONS** in Section A.
Answer **TWO QUESTIONS** in Section B.

Please use a separate answer book for each section. Print **SECTION A or SECTION B** on the front of the applicable answer books.

All questions carry equal marks.

Appendix A is provided for use with Question 2.

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SECTION A

(Answer **BOTH QUESTIONS** in Section A)

Q1. To accommodate the development of digital teaching and learning, a new DIGIHub building is to be constructed on Loughborough Campus.

At the proposed site, the simplified geology comprises 3 m of saturated, clayey glacial till (Anglian glaciation; saturated weight density = 20 kN/m^3) overlying the Mercia Mudstone Group (MMG; mainly containing clayey mudstone (saturated weight density = 21 kN/m^3). This mudstone also comprises thin layers of gypsum. Groundwater is typically at 1 m below the ground surface.

a) Describe the type of rock that forms the Mercia Mudstone and briefly discuss potential issues with this rock for the stability of foundations.

[7 marks]

b) Glacial tills are notoriously difficult to characterize. Explain why this is the case and briefly describe three potential construction issues relevant to the tills that you need to consider when developing the site.

[8 marks]

c) The till will be excavated to a depth of 2 m. The building will be constructed rapidly and will deliver a net uniform foundation stress of 150 kN/m^2 at the base of the excavation. Determine the total stress, pore water pressure and effective stress at 4 m below the original ground surface:

i) before excavation takes place

ii) immediately after excavation has taken place

iii) immediately when the net uniform foundation stress is applied, and

iv) a long time after the net uniform foundation stress has been applied.

[10 marks]

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Q2. The concrete mix defined for a floor slab in an office building is presented in the table below. The concrete requirements in the project specification are a characteristic compressive strength of 30 N/mm^2 at 28 days, with a 5% defective rate (k=1.64) and a standard deviation of 8 N/mm^2. The cement class is 52.5, and the slump required is 60-180 mm. The aggregates (uncrushed) will have a maximum size of 20 mm. Assume that single-sized 10- and 20-mm coarse aggregates are used. The relative density of the combined aggregate is 2.6 (SSD). 60% of the fine aggregate passes the 600 μm sieve.

Constituent materials	**Quantities (kg/m^3)**
Cement	350
Water	160
Fine aggregate (SSD)	473
Coarse aggregate (SSD) 10 mm 20 mm	 472 945

SSD: saturated surface-dry

The concrete delivered on-site had a slump of only 30 mm. As a mix design specialist, you have been tasked with redesigning the mix using the DoE method and determining if there was a mistake in the original design.

a) *Estimate* the water to cement ratio (w/c) and cement content (in Kg) you will have to weigh to satisfy the project requirements and produce 1.0 m^3 of concrete.
[10 marks]

b) *Estimate* the content (in Kg) of fine aggregate and coarse aggregate you will have to weigh to satisfy the project requirements and produce 1.0 m^3. Assume that the aggregates are in SSD condition.
[10 marks]

c) *Present* the final mix composition (quantities of the constituent materials in kg/m^3 of concrete) and *state* if there was a mistake in the original design.
[5 marks]

***Use* the DoE method of mix design (use the tables in the Appendix A).**

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SECTION B
(Answer **TWO QUESTIONS** in Section B)

Q3. a) Voids and pores of various sizes are present in hardened concrete. *Explain why* they occur and *why* it is important to keep the total volume of voids in concrete to a minimum. *Describe* how the w/c ratio effects permeability.

[9 marks]

b) *Explain* briefly, with an annotated hand-drawn sketch, how the UPV (ultra-sonic pulse velocity) NDT equipment for concrete works and the calculation required. What are its advantages and disadvantages?

[8 marks]

c) *Why* are cement replacement materials sometimes used in concrete?

Gbs and pfa are examples of commonly used cement replacement materials. *What* are they, and how do they work?

[8 marks]

Q4. a) *List* the five main constituents of paint, and state which two contribute to a paint's strength.

[7 marks]

i) *Explain* why it is important to adhere to the manufacturer's recommendations for the minimum and maximum times between the applications of paint coats.

[3 marks]

ii) *Describe* what potential *health risks* there could be with paints?

[3 marks]

b) *Explain* how and why ruts occur in bituminous roads under traffic loading.

[6 marks]

c) For effective asset management of roads, monitoring is carried out. *Describe* what type of measurements or observations can be conducted to help assess pavement deterioration?

[6 marks]

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Q5. a) *Name* and *sketch* three different brickwork bonding (laying) arrangements.

[9 marks]

b) *Sketch* the four different types of conversion defects which may occur when timber is cut from logs into long planks.

[6 marks]

c) Some types of timber have a better fire resistance than others. *Describe* and *discuss* and *draw* (a cross section of timber), why this is the case and *describe* how fire is taken into account in design.

[10 marks]

C I Goodier
A Blanco
T Dijkstra

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APPENDIX A (for use with Q2)

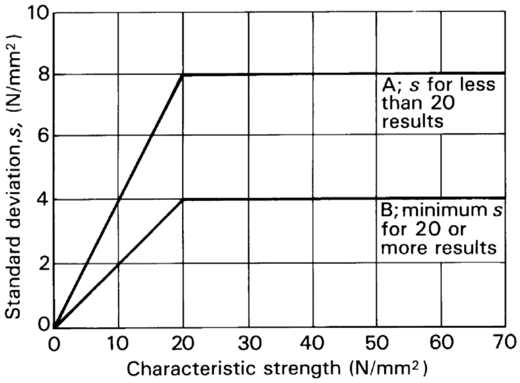

Table 2 Approximate compressive strengths (N/mm²) of concrete mixes made with a free-water/cement ratio of 0.5

Cement strength class	Type of coarse aggregate	Compressive strengths (N/mm²) Age (days) 3	7	28	91
42.5	Uncrushed	22	30	42	49
	Crushed	27	36	49	56
52.5	Uncrushed	29	37	48	54
	Crushed	34	43	55	61

Throughout this publication concrete strength is expressed in the units N/mm².
1 N/mm² = 1 MN/m² = 1 MPa. (N = newton; Pa = pascal.)

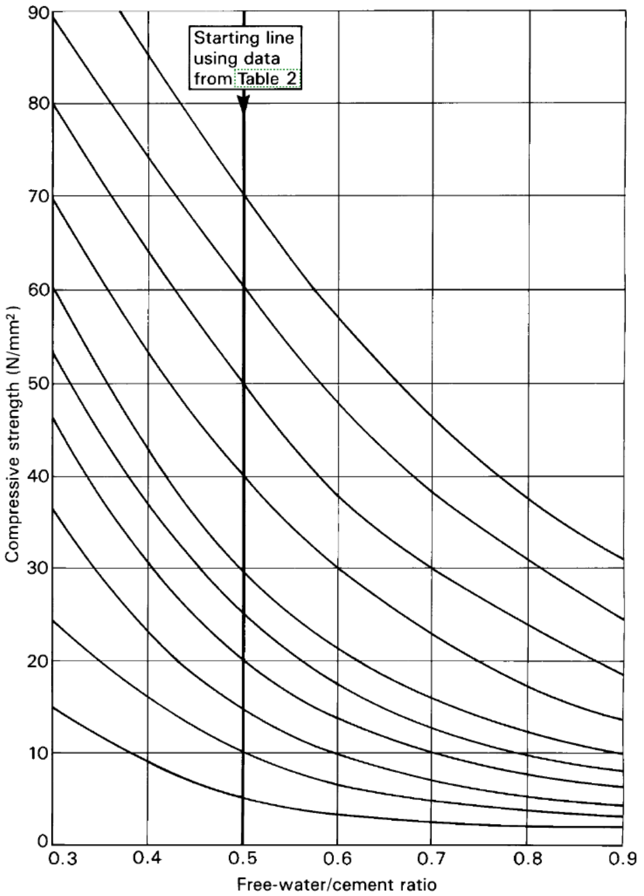

Figure 4
Relationship between compressive strength and free-water/cement ratio

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Table 3 Approximate free-water contents (kg/m^3) required to give various levels of workability

Slump (mm)		0–10	10–30	30–60	60–180
Vebe time (s)		>12	6–12	3–6	0–3
Maximum size of aggregate (mm)	Type of aggregate				
10	Uncrushed	150	180	205	225
	Crushed	180	205	230	250
20	Uncrushed	135	160	180	195
	Crushed	170	190	210	225
40	Uncrushed	115	140	160	175
	Crushed	155	175	190	205

Note: When coarse and fine aggregates of different types are used, the free-water content is estimated by the expression:

$\frac{2}{3} W_f + \frac{1}{3} W_c$

where W_f = free-water content appropriate to type of fine aggregate
and W_c = free-water content approporiate to type of coarse aggregate.

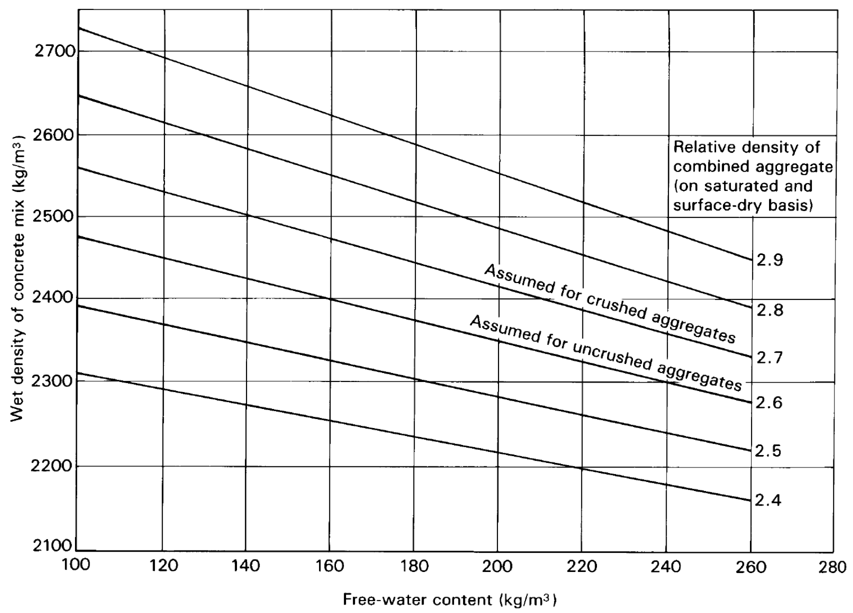

Figure 5 Estimated wet density of fully compacted concrete

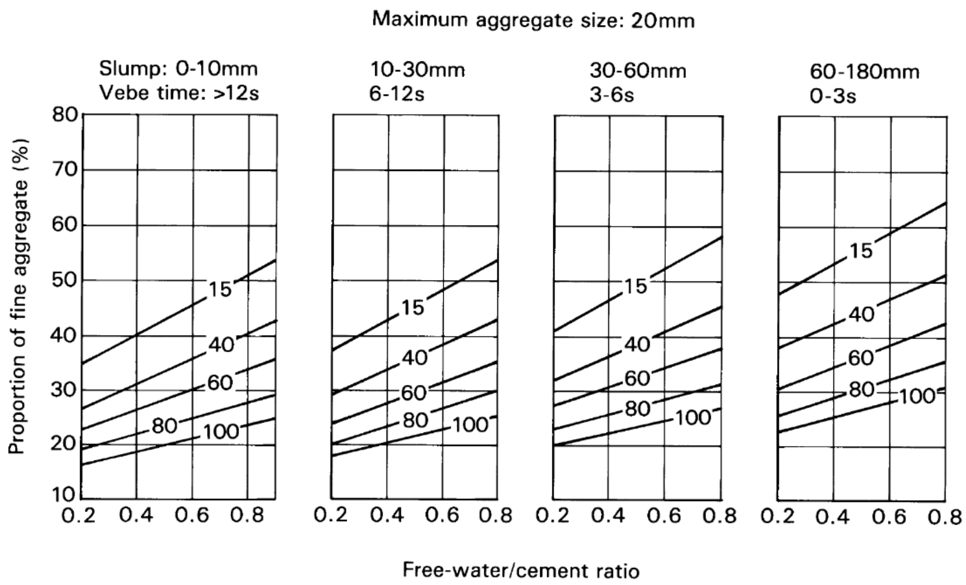

Figure 6 (continued)