The Institution of Structural Engineers

Chartered Membership Examination

Friday 9 January 2015

Structural Engineering Design and Practice

09.30 – 13.00 and 13.30 – 17.00 (Discussion between individuals is not permitted during lunch period). A period of fifteen minutes is provided for reading the question paper, immediately before the commencement of the examination. Candidates are not permitted to write in answer sheets, or on drawing paper or to use a calculator during this time. Candidates must satisfy the Examiners in ONE question.

Important

The written answer to the question selected and any A3 drawings must bear the candidate's number and the question number at the bottom of the page. Only the answer sheets supplied by the Institution may be used. The candidate's name should not appear anywhere in the script.

Notes to Candidates

1. TO PASS THE EXAMINATION, CANDIDATES MUST SATISFY THE EXAMINERS IN BOTH PARTS OF THE QUESTION ATTEMPTED.
2. Examiners will only mark work written by hand during the examination.
3. A fair proportion of marks will be awarded for the demonstration of an understanding of fundamental engineering concepts, as distinct from calculation of member forces and sizes. NOTE: In the calculation part of all questions, establishing "form and size" is taken to mean compliance with all relevant design criteria, i.e. bending, shear, deflection, etc.
4. In all questions 50 marks are allocated to Section 1 and 50 marks to Section 2.
5. The Examiners are looking for sound structural designs. It should also be remembered that aesthetics, economy and function are important in any competent engineering scheme.
6. Any assumptions made and the design data and criteria adopted must be stated.
7. Good clear drawings and sketches are required; they should show all salient and structural features to suitable scales and should incorporate adequate details.
8. Candidates will not be allowed to include any previously prepared calculations, notes, sketches, diagrams, computer output or other similar material in their answer sheets or A3 drawings. Any previously prepared information submitted by candidates will be ignored by the examiners.
9. Candidates may not bring into the examination room any electronic devices capable of wireless communication, optical photography or scanning.

   The following devices are not permitted: Mobile phones, Laptops, notebooks or portable computers and similar devices, iPads, tablets and similar devices, E-readers (e.g. Kindle) and similar devices, Cameras, optical scanners and similar devices.

   Any candidates arriving at the examination room with such devices will be asked to switch them off and place them in a sealed bag kept by the Invigilator for the duration of the exam, which includes the lunch period.
10. This paper is set in SI Units.

Now read 'Reminder' on page 3.

Chartered Membership Examination, a reminder from your Examiners

The work you are about to start has many features in common with other examinations which you have tackled successfully but it also has some which are unusual.

As in every examination you must follow carefully the NOTES FOR CANDIDATES set out for your guidance on the front cover of this paper; allocate the available time sensibly and set out your work in a logical and clear way.

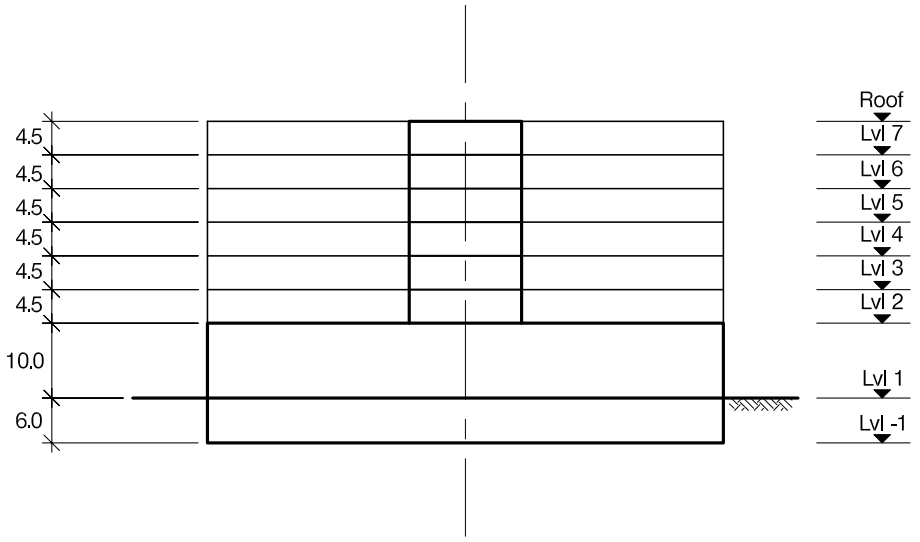
The unusual requirement of the examination is that you demonstrate the validity of the training and experience that you have acquired in recent years. The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural design problems – whether or not the problem is presented in terms that are within your actual experience.

Chartered Structural Engineers must have the ability to design and a facility to communicate their design intentions. Where you are required to list and discuss possible structural solutions you must show by brief, clear, logical and systematic presentation that you understood the general structural engineering principles involved.

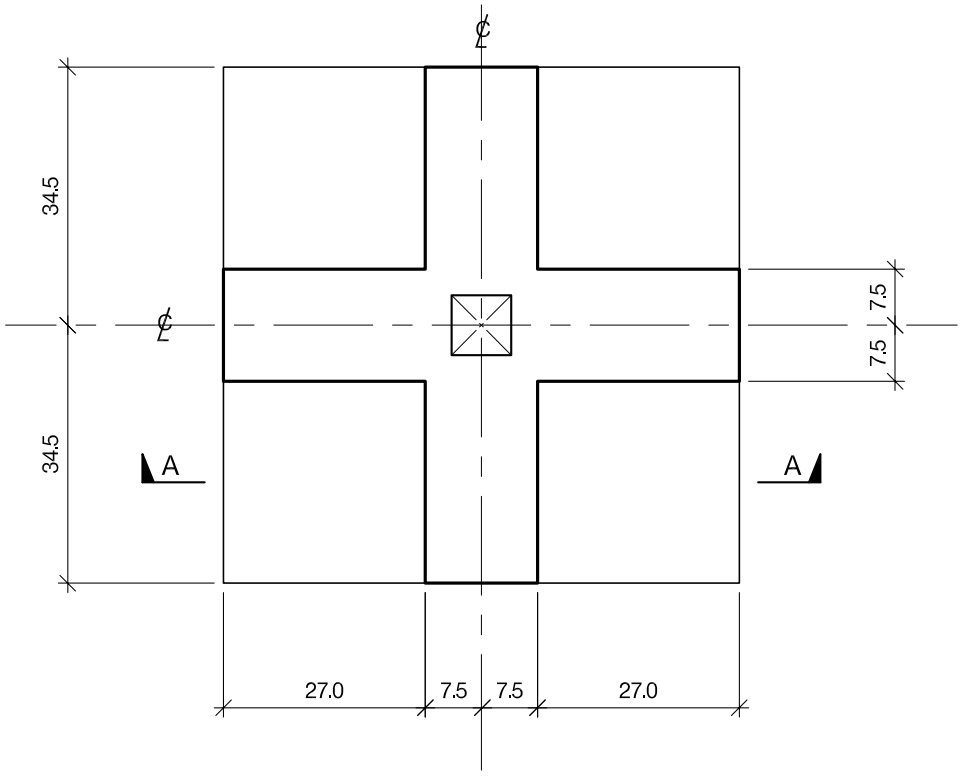
In selecting and developing your design you should also remember the guidance given in the Institution's report, Aims of Structural Design, and in particular:

(1) "the structure must be safe",
(2) "a good design has certain typical features – simplicity, unity and necessity",
(3) "the structure must fulfil its intended function".

If you have difficulty in deciding the correct interpretation of a question, pay particular attention to point 6. notes to candidates, on the front cover. The examiners will take into account your interpretation – and the design you base on this – if this is clearly stated at the beginning of your answer.



SECTION A - A



PLAN AT LEVEL 2

NOTE: All dimensions are in metres

FIGURE Q1

Question 1. New hotel and conference facility

Client's requirements

1. A new seven storey hotel with underground conference facilities. See Figure Q1.
2. The hotel is to have bedrooms on Levels 2 to 7. Each bedroom is to be 6.0m long x 4.0m wide. Four wings are required on Levels 2 to 7, with twelve bedrooms in each wing together with a 3.0m wide corridor: see Figure Q1.
3. At the end of each bedroom wing there is to be a storage room and staircase each measuring 6.0m long x 3.0m wide.
4. Restaurants, lounges, and the reception area are located on Level 1.
5. The following minimum clear internal heights are required: 3.5m for each bedroom, 7.5m for Level 1, and 4.0m for the underground conference facility. The maximum floor-to-floor heights are shown on Figure Q1.
6. One central core area measuring 8.0m x 8.0m is required for services.
7. Fully-glazed external elevations are required. Perimeter columns are to have a minimum spacing of 4.0m. Any internal columns on Level 2 and above are to be no closer than 3.5m to the core area.
8. A maximum of four internal columns is permitted at Level 1 and in the basement conference area. These columns must be located no further than 5.0m from the core area.

Imposed loading

9.

Roof	0.75kN/m^2
Bedrooms	2.50kN/m^2
All other areas	4.0kN/m^2

Site conditions

10. The site is located on the outskirts of a large city. Basic wind speed is 40m/s based on a 3-second gust; the equivalent mean hourly wind speed is 20m/s.
11. Ground conditions are constant across the site:

Ground level – 2.0m	Top-soil and fill
2.0m – 5.0m	Silty sand, N = 8
5.0m - 12.0m	Dense silty sand, N = 35
Below 12.0m	Rock, characteristic compressive strength 3500kN/m^2

Ground water was not encountered.

Omit from consideration

12. Detailed design of the lift and stairs.

SECTION 1 (50 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)

b. After the design has been completed the client advises you that he wishes to add a level of car parking below the conference facility. Write a letter to the client explaining the implications for your design. (10 marks)

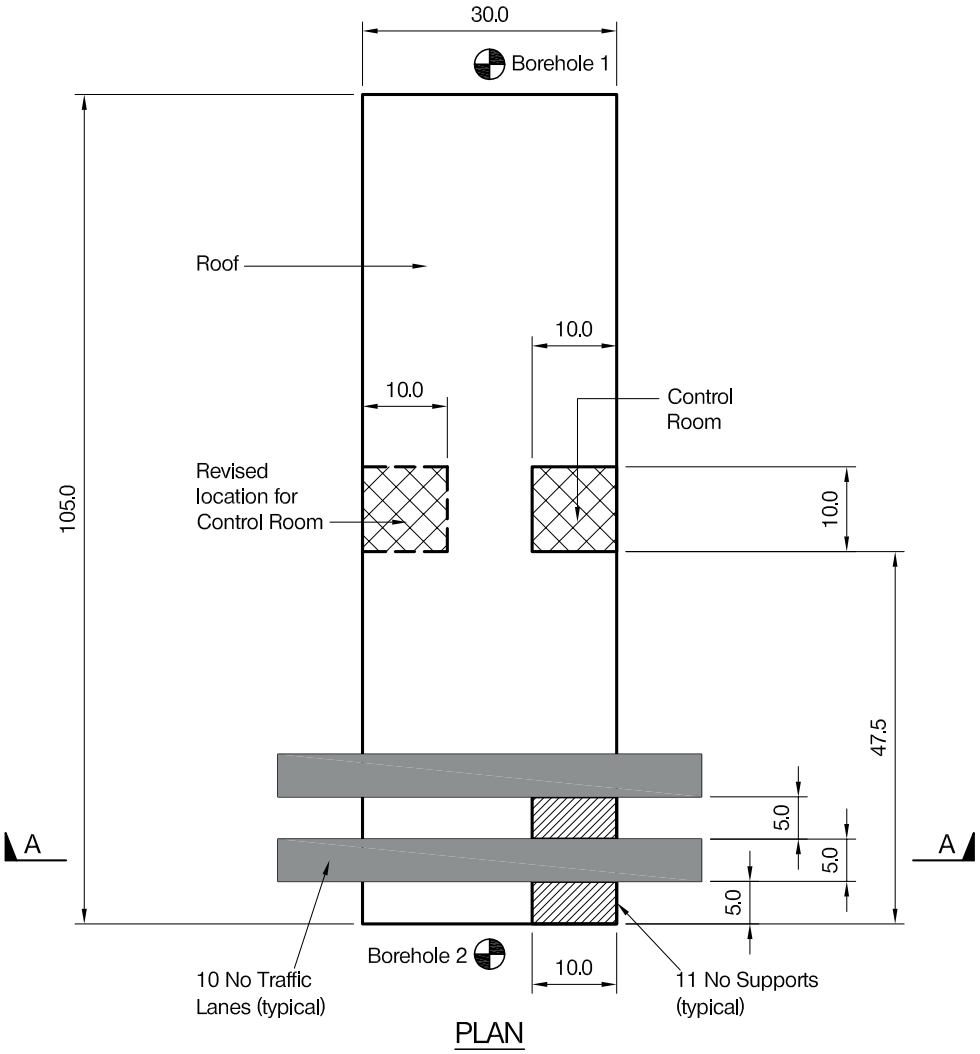
SECTION 2 (50 marks)

For the solution recommended in Section 1(a)

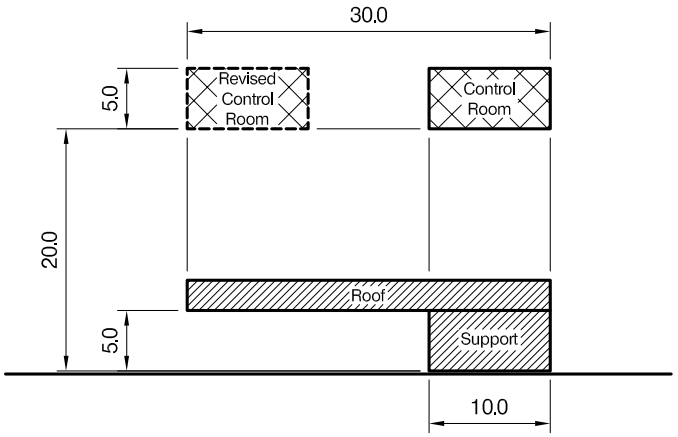
c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)

d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20 marks)

e. Prepare a detailed method statement for the safe construction of the building and an outline construction programme. (10 marks)



PLAN



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q2

Question 2. Facilities for road toll barrier

Client's requirements

1. A new roof is required for an existing road toll barrier with five lanes in each direction: see Figure Q2.
2. The roof is required to be 105.0m wide and 30.0m long in the direction of the road. Each lane is 5.0m wide and there is a 5.0m wide gap between adjacent lanes. A minimum of 5.0m clear height is required for vehicles.
3. A control room 10.0m long by 10.0m wide is required with a floor level 20.0m above the road surface. A clear floor to ceiling height of 5.0m is required inside the control room. See Figure Q2.
4. All supports for the roof and control room must be placed clear of all vehicle lanes and within a zone 10.0m wide running under one side of the roof: see Figure Q2. There are eleven positions, each 10.0m x 5.0m, where supports may be placed.
5. The roof, control room and supporting structures are protected from impact from road vehicles. The roof and control room must be able to withstand the removal of a single interior support without collapsing, while carrying the full dead load and one-third of the full imposed load.
6. The road is in continuous use. A maximum of three lanes may be closed at any one time for site access.

Imposed loading

7. Roof 1.0kN/m²
   Control room floor 4.0kN/m²

Site conditions

8. The site is located on the outskirts of a large city. Basic wind speed at sea level is 46.0m/s based on a 3-second gust; the equivalent mean hourly wind speed is 23.0m/s.

9. Borehole 1	0m – 0.4m	Asphalt
	0.4m – 5.0m	Silty clay C=50kN/m²
	Below 5.0m	Stiff clay C=100kN/m²
10. Borehole 2	0m – 0.4m	Asphalt
	0.4m – 3.0m	Gravel with traces of silt, N=15
	Below 3.0m	Rock – allowable safe bearing pressure 2,000 kN/m²

Water was encountered at 2.0m depth in both boreholes

Omit from consideration

11. Detailed design of stairs to control room.

SECTION 1 (50 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)

b. After the completion of the design the client asks that the control room be placed above the opposite side of the roof (see Figure Q2). Write a letter to your client advising him of the implications of this change. (10 marks)

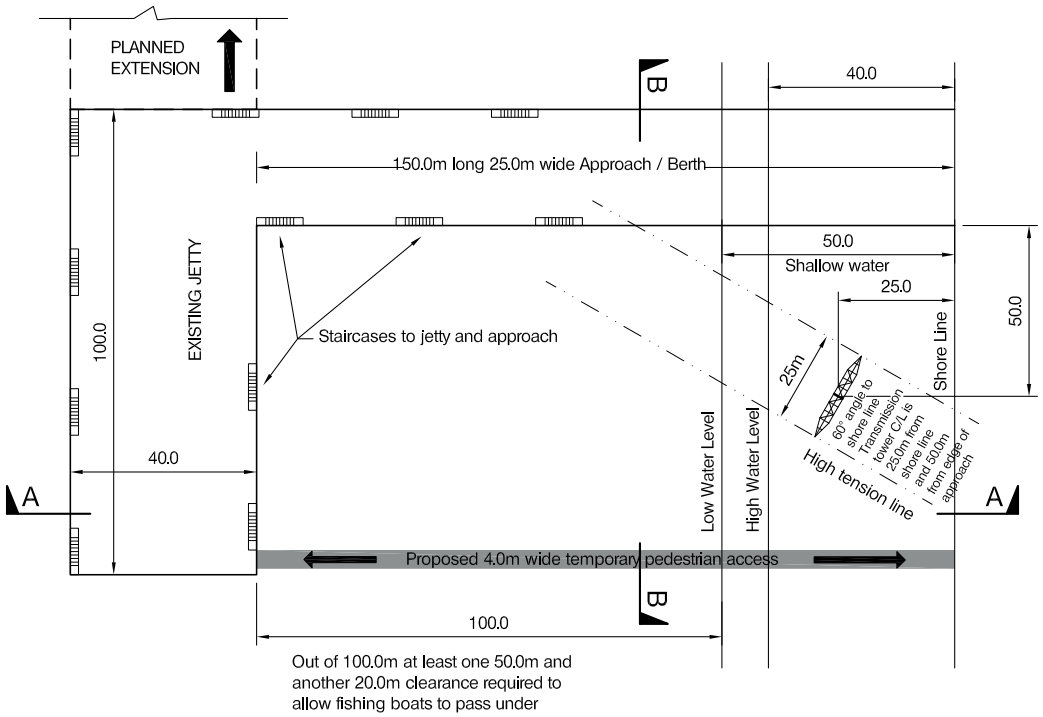
SECTION 2 (50 marks)

For the solution recommended in Section 1(a):

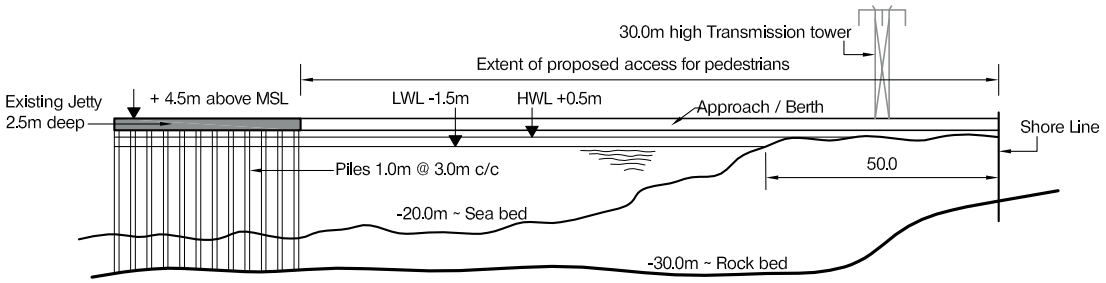
c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)

d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20 marks)

e. Prepare a detailed method statement for the safe construction of the roof and an outline construction programme. (10 marks)

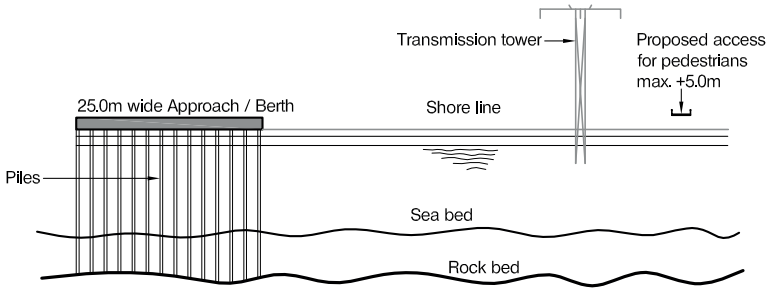


PLAN OF EXISTING JETTY AND APPROACH



SECTION A - A

(Piles under Approach not shown for clarity)



SECTION B - B

NOTE: All dimensions are in metres

FIGURE Q3

Question 3. Temporary pedestrian bridge

Client's requirements

1. A temporary pedestrian bridge is required to provide access from the shore to an existing jetty serving passenger ferries: see Figure Q3. The temporary bridge is needed while the jetty is extended, putting the permanent access bridge out of use. Access for fishermen's boats is required under the temporary bridge.
2. The tidal range is 2.0m, from +0.5m high water to –1.5m low water. Datum is Mean Sea Level (MSL). The bridge is to be 150m long and to provide a 4.0m clear width for pedestrians. The jetty is 100m away from the shore at low water. A minimum clearance of 3.5m is required under the bridge at all states of the tide, over an uninterrupted length of 50.0m and a second uninterrupted length of 20m within the 100m distance between the jetty and shore.
3. No temporary or permanent foundations may be installed closer than 75.0m to the jetty. The client advises that the existing jetty is capable of supporting unfactored loads of 500kN vertically and 250kN laterally in both horizontal directions from the temporary bridge. The existing jetty deck level is +4.5m above MSL.
4. In the 50.0m length of bridge over the tidal zone of the shore, no construction may leave any footprint after the bridge is removed.
5. All existing services should remain uninterrupted during the construction, use and removal of the bridge. There is a 30.0m-high electricity transmission tower and line close to the proposed bridge which will remain live throughout the construction, use and removal of the bridge.

Imposed loading

6. Live load on bridge deck. 5.0kN/m^2

Site conditions

7. The site is located in the open sea. Basic wind speed at sea level is 46.0m/s based on a 3-second gust; the equivalent mean hourly wind speed is 23.0m/s.
8. Ground Conditions

Sea bed – 30m below datum	Stiff clay, C = 200kN/m^2
30m - depth	Rock, characteristic compressive strength 1,000kN/m^2

Omit from consideration

9. Longitudinal imposed loading.

SECTION 1 (50 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)

b. After the completion of the design the client advises that a mistake was made in the calculation of the jetty load capacity, and the correct values are 50% of those previously advised in both the horizontal and vertical directions. Write a letter to your client advising of the implications this would have on your design and ways in which the design could be modified. (10 marks)

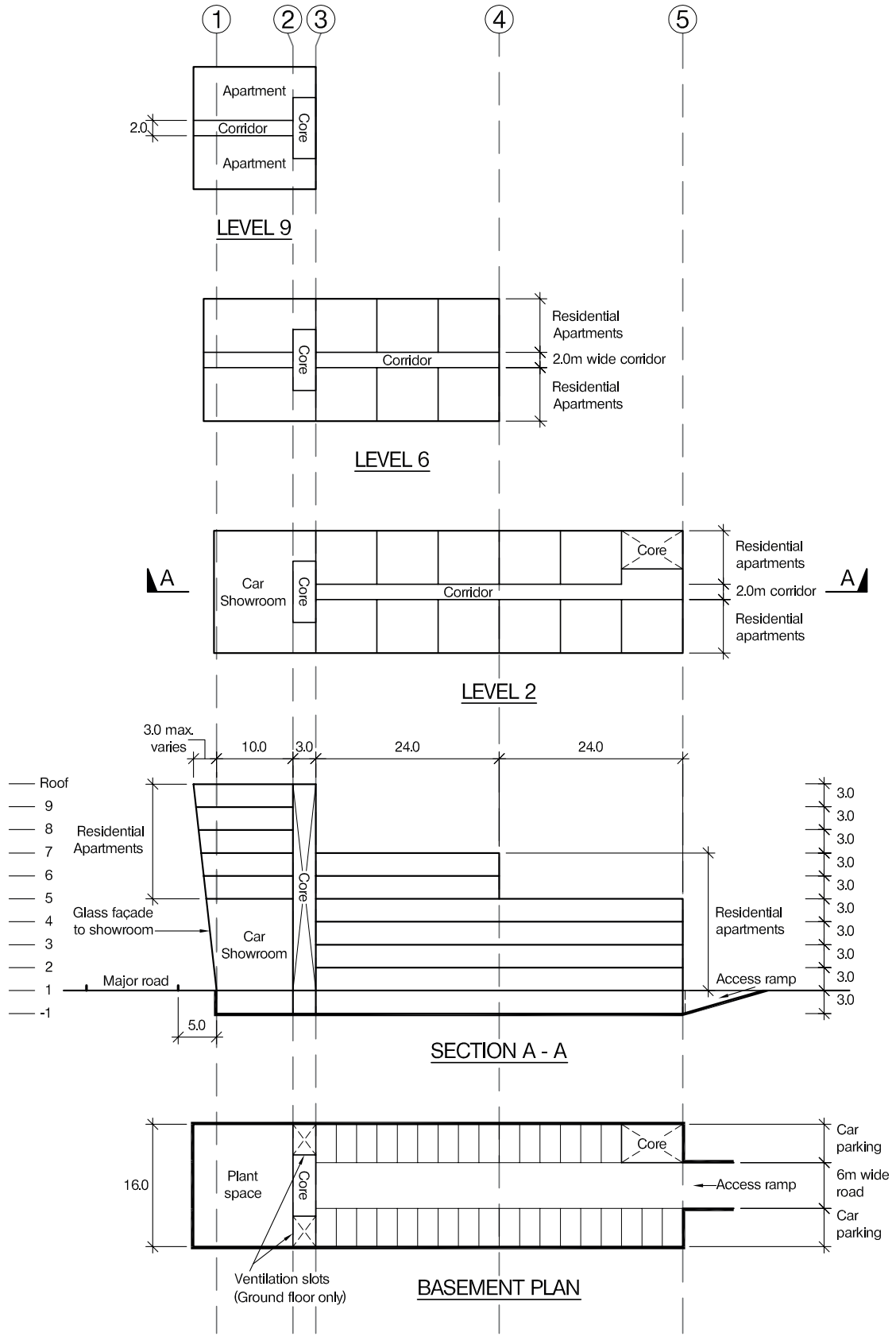
SECTION 2 (50 marks)

For the solution recommended in Section 1(a):

c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)

d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20 marks)

e. Prepare a detailed method statement for the safe construction of the works and an outline construction programme. (10 marks)



NOTE: All dimensions are in metres

FIGURE Q4

Question 4. Mixed-use apartment block

Client's requirements

1. A new nine-storey building with basement parking: see Figure Q4. A four-storey-high car showroom is to occupy the front part of the building at Level 1. The remainder of the building at Levels 1 and above is to contain residential apartments. The building is to step in height as shown in Figure Q4.
2. Internal floor-to-floor heights are to be 3.0m. A 0.2m zone is required for ceilings and services under each floor. The client would like ceiling heights to be as high as possible in the apartments.
3. The building will be clad in brickwork throughout, with the exception of the car showroom which will be fully-glazed on three sides.
4. Two stair/lift cores extend the full height of the building and may contribute to lateral stability.
5. For the residential apartment levels, no columns are allowed within the apartment footprints but are permitted in corridor walls and partition walls between apartments.
6. In order to maximise views into the car showroom, no more than three columns are permitted on Grid Line 1 between Levels 1 and 5. No other internal columns are permitted in the showroom, and perimeter columns to the side façades should be kept to a minimum.
7. Minimum headroom is required of 2.1m in the car park and 2.5m in the plant room. No columns are permitted in the road, but there are no restrictions on columns in the plant room and columns may be placed between parking spaces.
8. A minimum fire rating of two hours is required throughout, with the exception of the plant room which requires four hours.

Imposed loading

9.

Roof	1.5kN/m^2
Residential floors	2.5kN/m^2
Car showroom floor	20kN/m^2
Car park	2.5kN/m^2
	Loadings include allowances for floor finishes, ceilings and services.

Site conditions

10. The site is located on the edge of a city. Basic wind speed is 40.0m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20.0m/s.
11. Ground Conditions

Ground level – 0.3m	Top soil/made ground
0.3m – 6.0m	Sands and Gravels, N = 20 to 30
Below 6.0m	Clay, C = 45 + 7z kN/m^2, where z = depth below top of clay

Groundwater was encountered at 1.0m below ground level.

Omit from consideration

12. Detailed design for staircases and lifts within cores, but the cores themselves are to be designed; detailed design of access ramp to car park; glazed façade and associated support system to car showroom.

SECTION 1 (50 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)

b. After completion of the design and before construction has started, the client advised that Level 1 is to be used as a supermarket between Grids 3 and 5. A single line of internal columns will be permitted within the supermarket, and minimum clear floor-ceiling heights on Levels - 1 and 1 are to be 3.5m. Write a letter to the client advising him of the implications on the design. (10 marks)

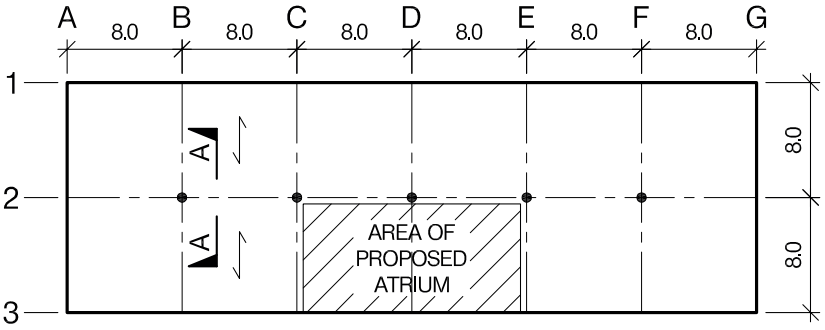
SECTION 2 (50 marks)

For the solution recommended in Section 1(a):

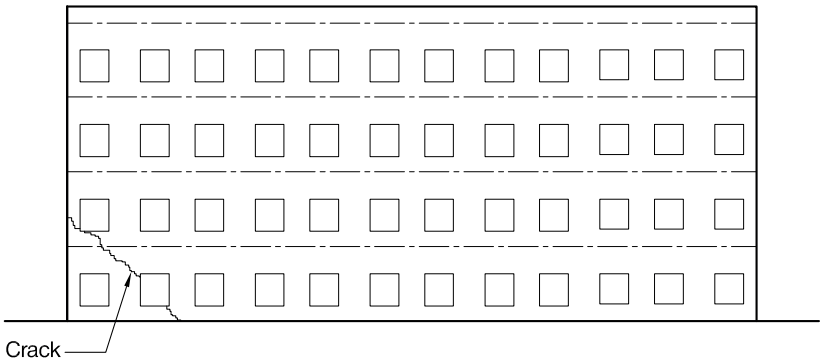
c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)

d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20 marks)

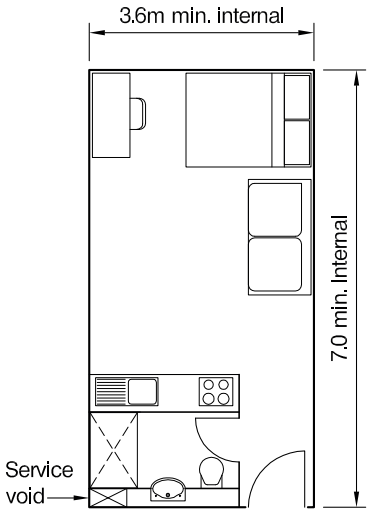
e. Prepare a detailed method statement for the safe construction of the building and an outline construction programme. (10 marks)



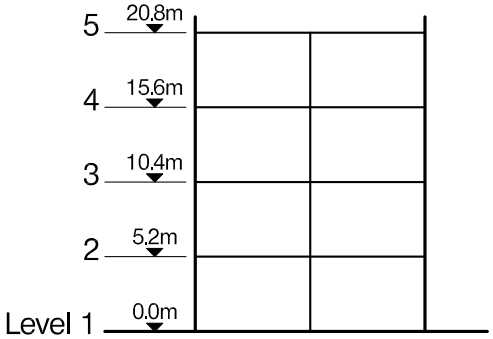
TYPICAL FLOOR PLAN



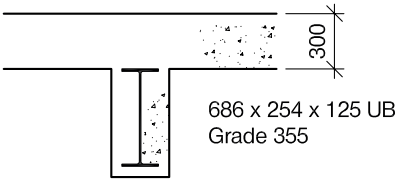
EXISTING ELEVATION GRID 3



TYPICAL APARTMENT



TYPICAL SECTION



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q5

Question 5. Conversion of industrial building to apartments

Client's requirements

1. An existing disused four-storey industrial building is to be converted into residential apartments: see Figure Q5. Two levels of 20 apartments are to be constructed on each existing floor, providing a total of 160 apartments over eight storeys. A typical apartment layout is shown in Figure Q5.
2. The existing building has solid brick external walls 0.45m thick. Floors are of reinforced concrete spanning on to steel beams encased in concrete. The floors are supported internally with steel columns. The perimeter walls have spread foundations 0.9m wide constructed of solid masonry. The size of foundations to the columns is unknown.
3. A minimum clear floor-to-ceiling height of 2.3m is required in each apartment. A full-height atrium clear of any transverse structural elements, with a glazed roof, is required as shown in Figure Q5. A 2.0m wide corridor is required on each apartment floor. Each apartment is to be provided with a balcony at least 2.0m wide and 3.0m long.
4. At corner A3 there is a diagonal crack approximately 25.0mm wide: see Figure Q5.

Imposed loading

5. Apartment floors 1.5kN/m^2
   Corridor floors 2.5kN/m^2
   Roof 0.8kN/m^2
   The unfactored imposed load capacity of the existing floors is 6.0kN/m^2.

Site conditions

6. The site is located in open countryside. Basic wind speed is 46.0m/s based on a 3-second gust; the equivalent mean hourly wind speed is 23.0m/s.
7. Ground Conditions

Ground level – 0.3m	Granular fill
0.3m – 6.0m	Stiff clay with organic peat lenses, C = 100kN/m^2
Below 6.0m	Weathered rock

   Groundwater was not present.

Omit from consideration

8. Stairs and lifts, which will be installed in new external shafts which may not be used to assist lateral stability.

SECTION 1 (50 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)

b. Shortly after commencement of the design, the client asks you to specify any investigative work which should be undertaken with regard to the existing building. Write a letter to your client explaining what investigations should be carried out, with reasons for their inclusion. (10 marks)

SECTION 2 (50 marks)

For the solution recommended in Section 1(a):

c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)

d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20 marks)

e. Prepare a detailed method statement for the safe construction of the works and an outline construction programme. (10 marks)

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