

Associate-Membership Examination

Friday 13 April 2012

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 30 marks are allocated to Section 1 and 70 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. Portable computers or programmable calculators may be used but sufficient calculations must be submitted to substantiate the design, and these should be set out as in practice.
8. Good clear drawings and sketches are required; they should show all salient and structural features to suitable scales and should incorporate adequate details.
9. 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.
10. Strictly no external electronic contact is allowed between a candidate and anyone outside the examination venue. Mobile phones must be switched off throughout the duration of the examination.
11. This paper is set in SI Units.

Now read 'Reminder' on page 3.

Associate-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.

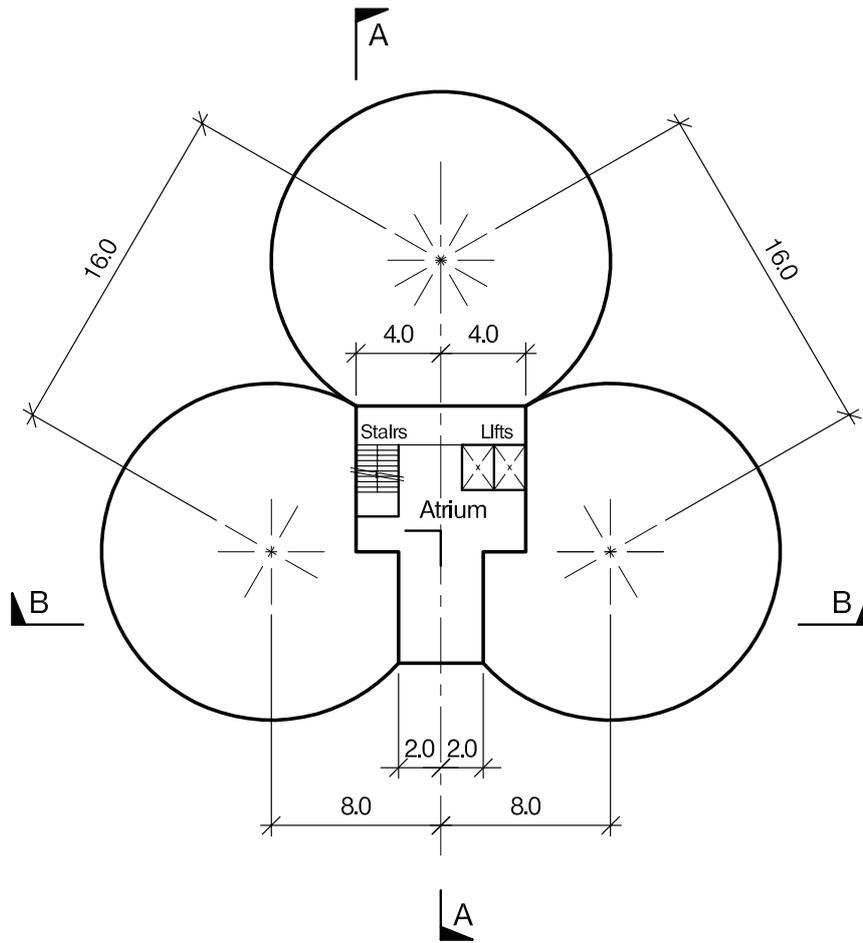
The unusual requirement of the examination is that you demonstrate the validity of the training and experience that you have acquired in recent years. The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural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

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

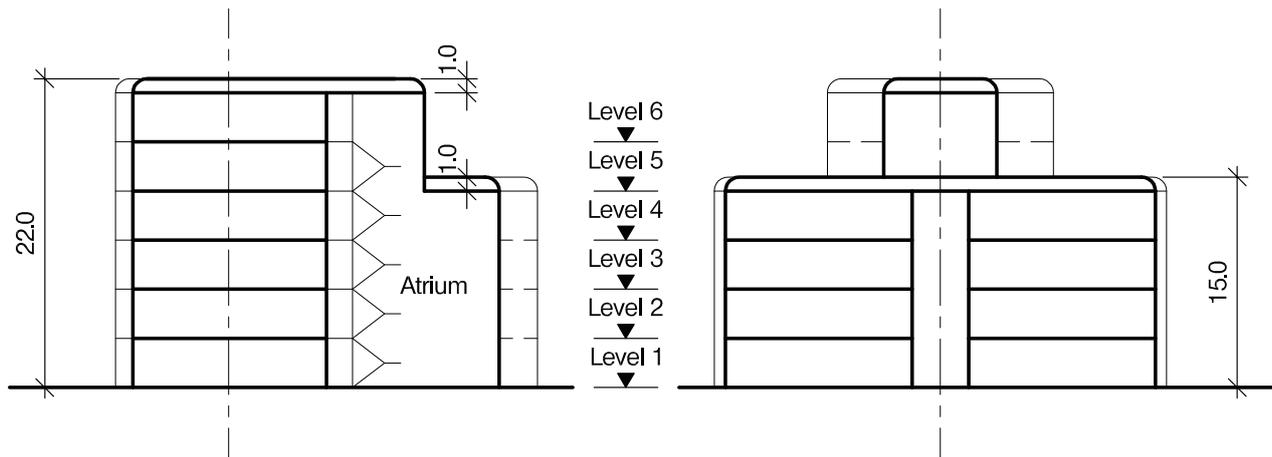
In selecting and developing your design you should also remember the guidance given in the Institution's report, Aims of Structural Design, and in particular:

- (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.



PLAN



SECTION A-A

SECTION B-B

NOTE: All dimensions are in metres

FIGURE Q1

Question 1. Office Development

Client's requirements

1. A new office development consisting of two four-storey circular buildings and one six-storey circular building connected by a central atrium area containing the access lifts and staircase. See Figure Q1.
2. The external cladding is to be glass curtain walling and roofs are to be flat. The roof is to have a semi-circular edge where it meets the glazing.
3. Only one internal column is permitted in each of the office areas and no columns are permitted in the atrium. Columns may be placed around the external perimeter: their centre-to-centre spacing must be not less than 6.0m.
4. The proposed vertical structure is to be exposed internally, and aesthetic consideration is to be given to the design and connection details.
5. The overall heights of the office buildings and the atrium are not to exceed the dimensions shown on Figure Q1. Each office area is to have a floor-to-ceiling clear height of 2.65m, together with a 150mm-deep raised floor and a 150mm-deep clear zone between the ceiling and the underside of the floor construction above.

Imposed loading

6. Roof 1.5kN/m²
Floors 5.0kN/m²
Imposed loading includes an allowance for finishes, services and partitions.

Site conditions

7. The site is level and located on the outskirts of a major city.
8. Basic wind speed is 40m/s based on a 3-second gust the equivalent mean hourly wind speed is 20m/s.
9. Ground conditions:

Ground level – 1.5m	Made ground
1.5m – 4.0m	Sand, N = 12
4.0m – 7.0m	Dense sand, N = 20
Below 7.0m	Firm to stiff clay, C = 200kN/m ²
Ground water was encountered 3.0m below ground level	

Omit from consideration

10. Detailed design of the staircase and lift shafts.

SECTION 1

(30 marks)

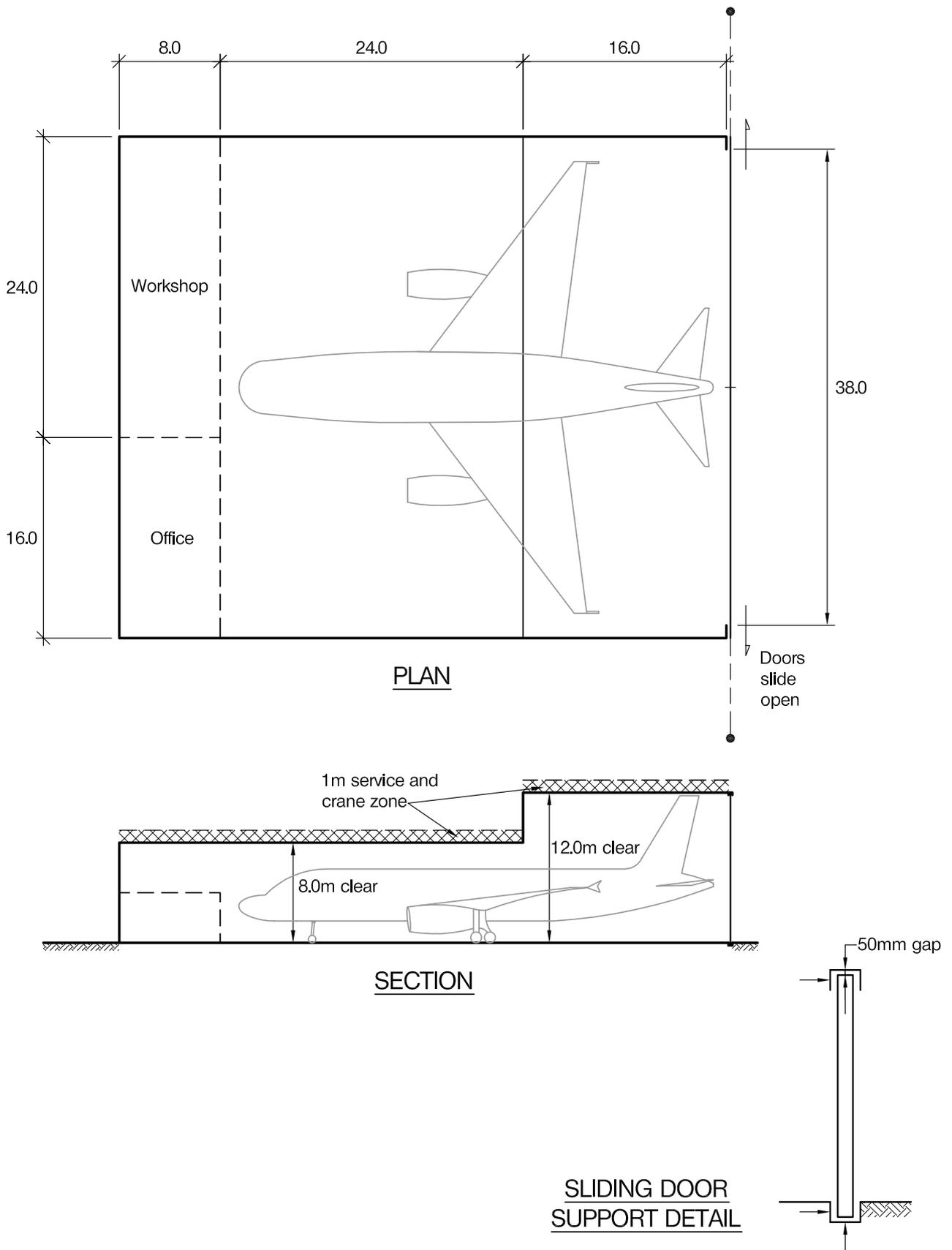
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (20 marks)
- b. On completion of the design the client asks if it is feasible for the offices to be column-free and for the floor-ceiling clear height on the ground floor to be increased to 5.0m. Explain the effect this will have on your design and outline any resulting changes which would need to be made to your original proposal. (10 marks)

SECTION 2

(70marks)

For the solution recommended in Section 1(a)

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
 - i) Typical detail at eaves level.
 - ii) Typical detail where an external column meets the foundation (30 marks)
- e. Prepare a detailed method statement for the safe construction of the building. (10 marks)



NOTE: All dimensions are in metres except as noted

FIGURE Q2

Question 2. Aircraft maintenance hangar

Client's requirements

1. A maintenance hangar is required by a regional airport to cater for large aircraft. See Figure Q2.
2. A clear column-free area of 40.0m by 40.0m is required, with additional space for a workshop and office. Clear headroom is required of 8.0m height over a 40.0m by 24.0m area, and 12.0m height over a 40.0m by 16.0m area next to the entrance doors in order to accommodate the aircraft tailfin. A services zone 1.0m high, including an allowance for overhead cranes, is also required above the clear headroom. See Figure Q2.
3. The hangar is to be clad in lightweight insulated metal panels and glazing.
4. The aircraft entrance to the hangar is to be 38.0m wide and 12.0m high, closed with two sliding doors. The weight of these doors is to be supported in a channel at ground level, and the doors are to be guided horizontally in an inverted channel at roof level.
5. Generous external space is available. The client would like an attractive and iconic structure within a reasonable budget.

Imposed loading

- | | |
|----------------------------------|---|
| 6. Roof | 2.5 kN/m ² |
| Overhead cranes attached to roof | Two point loads, each of 100kN, to be considered acting anywhere on the main roof elements. |
| Ground floor | 20.0 kN/m ² |
- The roof and floor loadings include allowances for finishes, services including the overhead crane beams, and partitions.

Site conditions

7. The site for the hangar is level and open. The airport is served by main roads and a canal.
8. Basic wind speed is 40 m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20 m/s.
9. Ground conditions:

Ground level – 1.0 m	Topsoil
1.0 m – 25.0 m	Sandy gravel with N increasing linearly with depth from 15 to 30.

 The highest recorded ground water level is 4.0 m below ground.

Omit from consideration

10. Design of the overhead crane beams, the stairs to the office and the hangar doors.

SECTION 1

(30 marks)

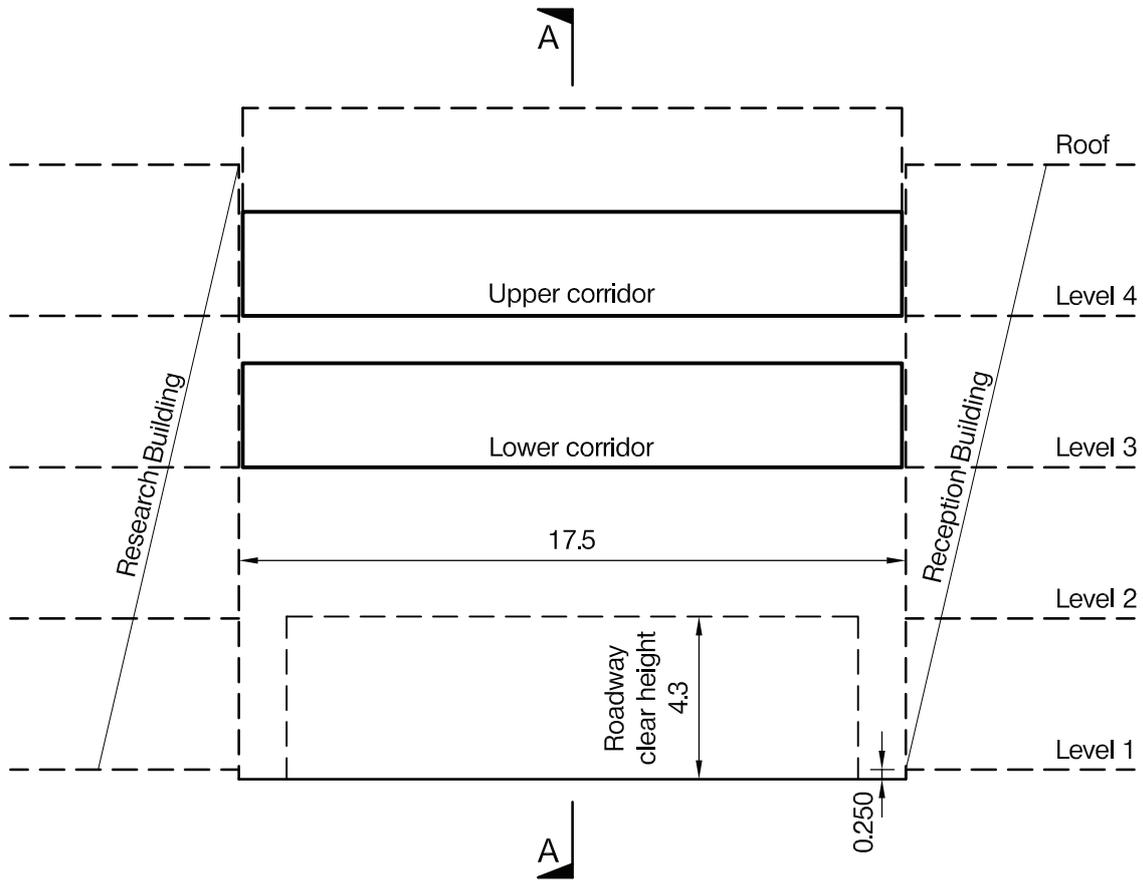
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (20 marks)
- b. After the roof has been made weather-tight and the doors have been installed there is a heavy snowstorm and the main doors jam because deflection of the roof causes the top channel to press on the doors. Explain to the client how this could be resolved, using sketches to illustrate your solution. (10 marks)

SECTION 2

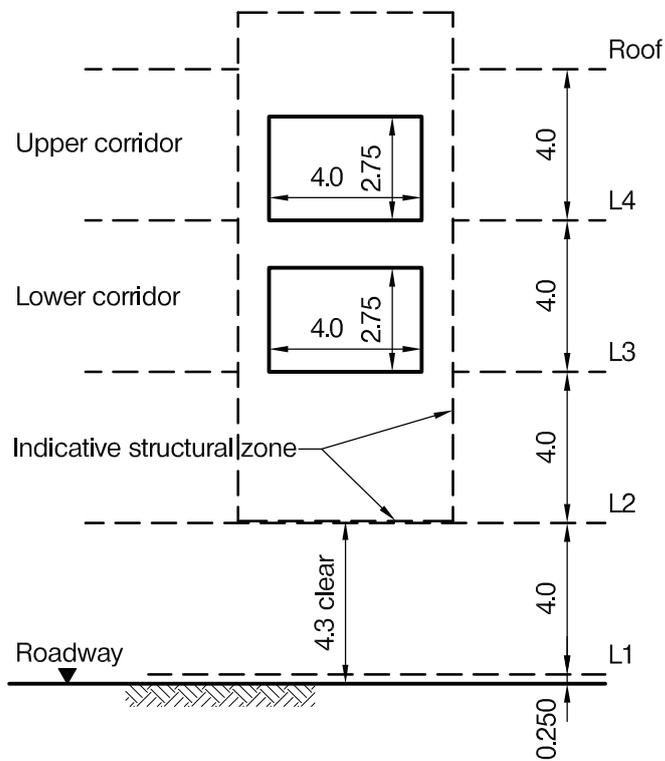
(70 marks)

For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the cladding support structure and foundations. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
 - (i) The connection between a main column and primary roof structural element.
 - (ii) A typical perimeter foundation, ground floor and main column connection at ground floor level. (30 marks)
- e. Prepare an outline programme and method statement to minimise construction time. (10 marks)



ELEVATION



SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q3

Question 3. Hospital Link Bridge

Client's requirements

1. A double-level bridge for pedestrians, hospital trolleys and other equipment, linking two existing buildings and spanning across a roadway. See Figure Q3.
2. The bridge is to link the buildings on Levels 3 and 4. The two bridge corridors are to be enclosed and weather-tight with a roof and glazed, full-height walls. Each corridor is to have minimum clear internal dimensions of 4.0m width and 2.75m height.
3. The clear distance between existing building façades is 17.5m. The roadway under the bridge is to have a minimum height clearance of 4.3m and is to be at least 15.0m wide. The road surface is 0.25m below Level 1. The floor-to-floor height for each of the existing Levels 1-2, 2-3, 3-4 and 4-roof is 4.0m. See Figure Q3.
4. Each bridge corridor floor must meet the building floors flush, with no step. The bridge structure is to be independent of the existing buildings and no loads may be transmitted from the bridge to the buildings.
5. The existing buildings have recently been completed and occupied. The client wants the bridge to create a light, open, linking effect between them without creating a visual barrier, reflecting the innovative research programmes being carried out within them.

Imposed loading

- | | |
|---------|--|
| 6. Roof | 1.0 kN/m ² |
| Floors | 5.0 kN/m ² including finishes and services. |

Site conditions

7. The site is level and located within a city.
8. Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s.
9. Ground conditions:

Ground level – 1.0m	Made ground
1.0m – 3.0m	Alluvial deposits, C = 10kN/m ²
3.0m – 8.0m	Sand and gravel, N = 15
Below 8.0m	Sandstone, allowable bearing capacity 2000kN/m ²

 Ground water was encountered 4.0m below ground level.

Omit from consideration

10. Formation of openings in the existing buildings for the bridge connection.

SECTION 1

(30 marks)

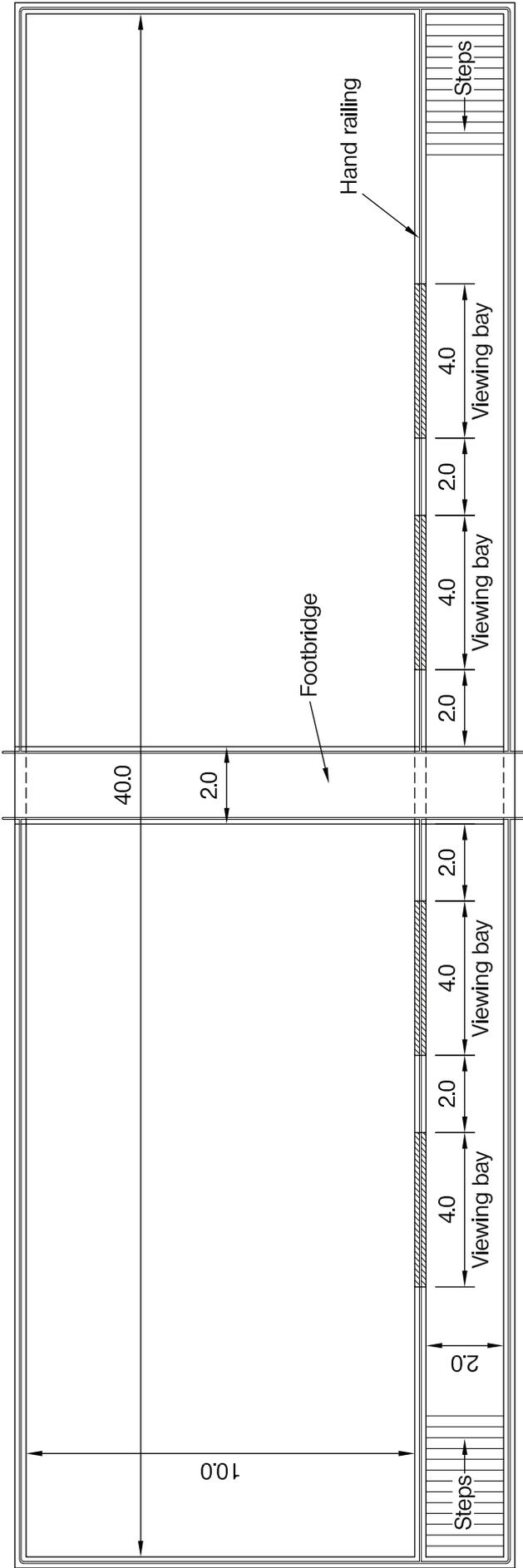
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (20 marks)
- b. The client is concerned that the bridge supports may be vulnerable to vehicle impact. Explain what measures can be taken to reduce the risk and effect of potential vehicle impact, while minimising constraints to the pedestrian and vehicle access under the bridge. (10 marks)

SECTION 2

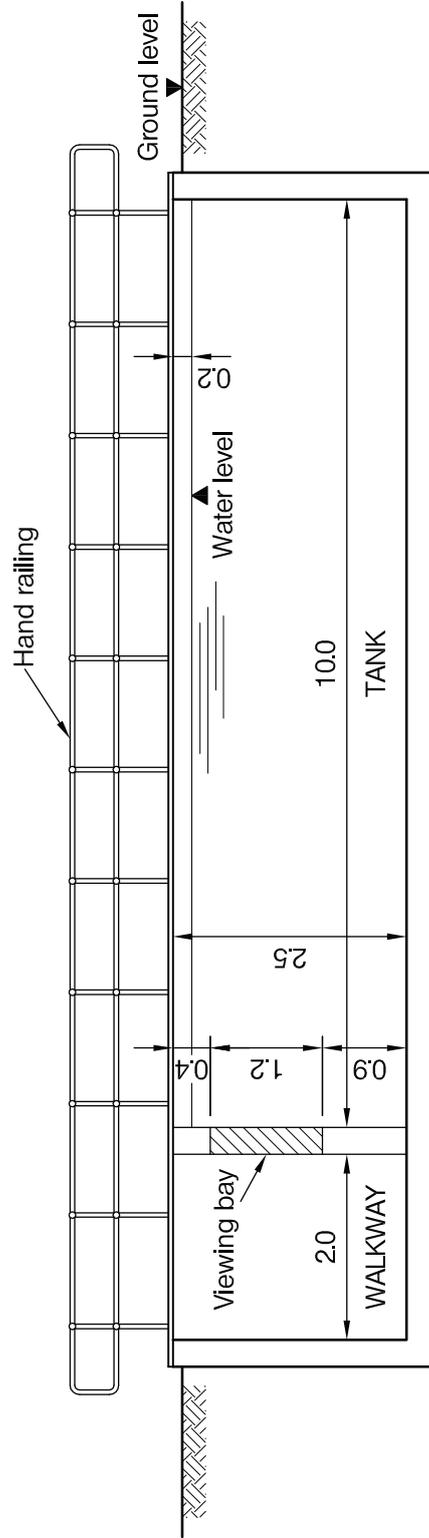
(70 marks)

For the solution recommended in Section 1 (a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
 - (i) The bridge roof and curtain wall,
 - (ii) A floor junction between an existing building and the new bridge corridor. (30 marks)
- e. Prepare a detailed method statement for the safe construction of the bridge. (10 marks)



PLAN



CROSS SECTION

NOTE: All dimensions are in metres

FIGURE Q4

Question 4. Viewing tank

Client's requirements

1. A large water retaining tank structure is required to display a live marine exhibit. See Figure Q4
2. A walkway is required along one side of the structure to allow viewing through glazed vision panels.
3. A pedestrian bridge is required to pass over the structure spanning the narrower dimension.
4. Handrailing is required to the perimeter of the entire tank and walkway to safeguard the viewing public.

Imposed loading

5. General ground loading in vicinity of structure 10.0kN/m²
Loading to bridge 5.0kN/m²

Site Conditions

6. The site is level and is on the outskirts of a large city.
Basic wind speed is 44 m/s based on a 3 second gust; the equivalent mean hourly wind speed is 22 m/s.
7. Ground conditions:
Ground Level 10.0m very weak alluvium, N = 0 to 5.
Below 10.0m. Weak rock, safe bearing pressure 100kN/m².
Ground water was encountered at 1.0m below ground level.

Omit from consideration

8. Design of glazed vision panels.

SECTION 1

(30 marks)

- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify reasons for your solution. (20 marks)
- b. Upon completion of the design the client asks whether the structure can be increased in depth to 3.5m from top of wall level. Describe the implications this will have on the original design. (10 marks)

SECTION 2

(70 marks)

For the solution recommended in section 1(a)

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
 - (i) The junction of the tank base and walls.
 - (ii) The junction of the bridge and the supporting walls. (30 marks)
- e. Prepare a detailed method statement for the safe construction of the structure. (10 marks)

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