

Chartered Membership Examination

Wednesday 8 February 2023

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. Candidates should note that Figures are produced to illustrate the question and are not necessarily drawn to scale. Figured dimensions should be followed.
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.

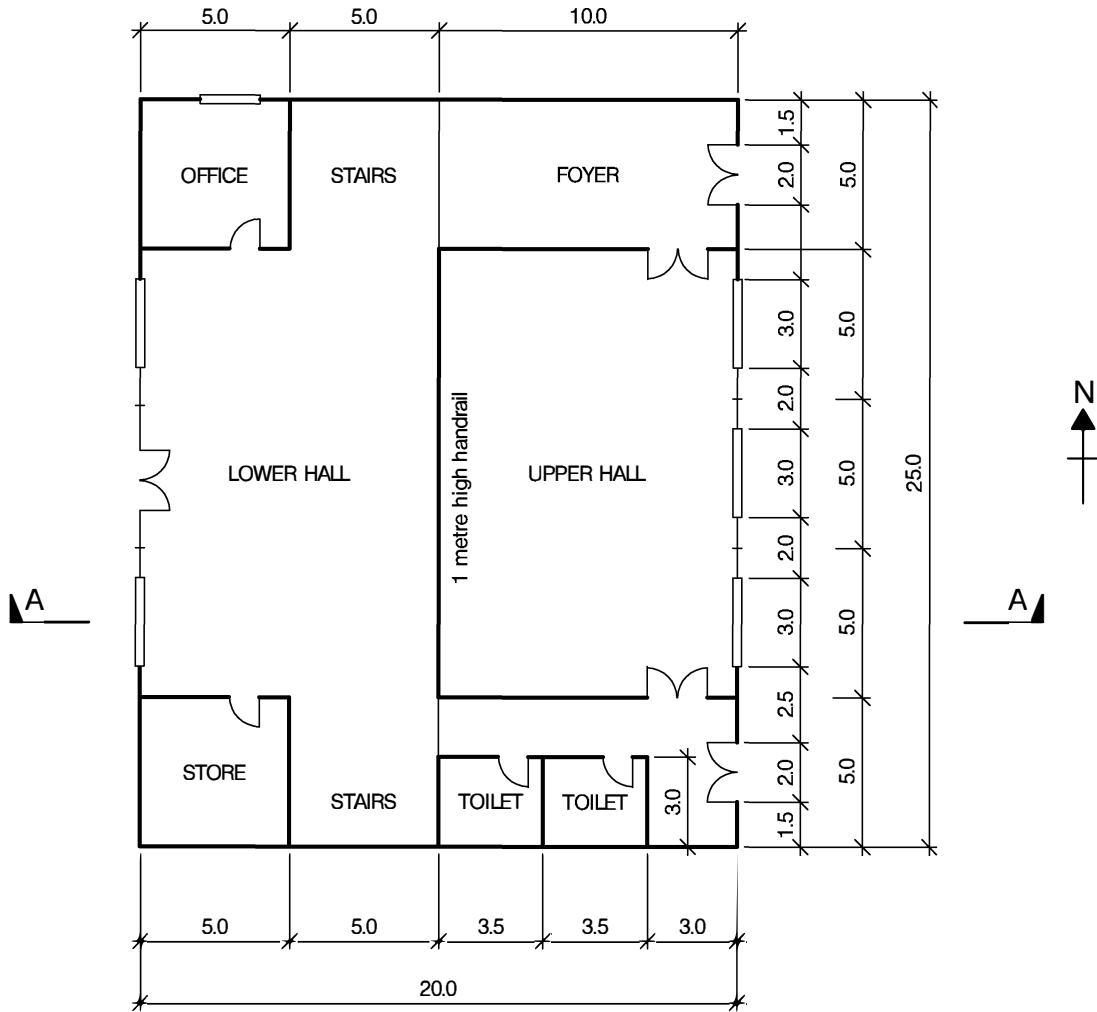
The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural design problems, whether or not the problem is presented in terms that are within your actual experience.

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.

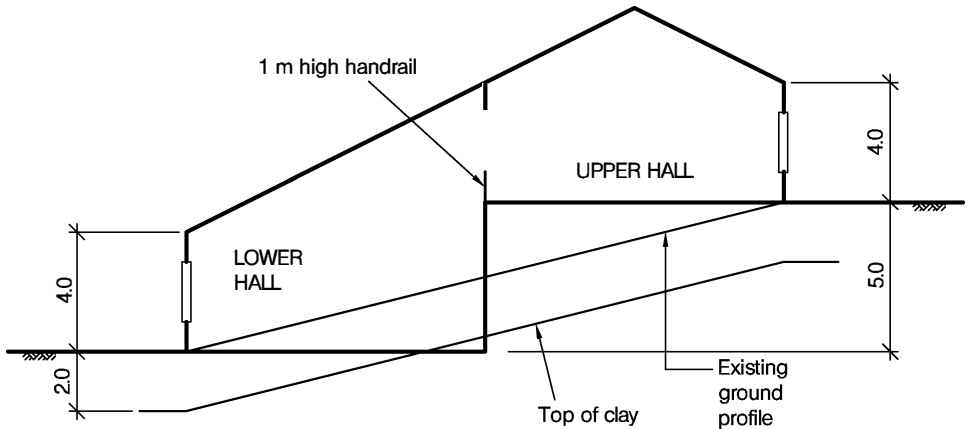
In selecting and developing your design you should also remember the guidance given in the Institution's report, Structural design - achieving excellence, and in particular:

- (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 AND GROUND / SOIL PROFILE

NOTE: All dimensions are in metres

FIGURE Q1

Q1. Hillside Building

Client's requirements

1. A new hilltop visitor centre is to be constructed on sloping ground. The building is to have two large halls linked by staircases at both ends of the building. The upper level is to include toilets, the lower level is to include an office and a storeroom; see Figure Q1.
2. Columns are not allowed internally in halls, circulation areas, office, storeroom, toilets and stairs, but are permitted within partitions and external walls.
3. The building is to have 3.0m long by 2.0m high windows on the east and west elevations to maximise the use of natural lighting. The office is to have a 2.0m long by 2.0m high window on the north elevation. All doors are to be 2m wide.
4. Handrailing 1m high is to be provided along the west edge of the upper hall overlooking the lower hall.
5. Cladding to the elevations and roof are to be selected to minimise energy consumption.
6. The building is to have a 1-hour fire rating.

Imposed loading

- | | |
|----------------------------|----------------------------|
| 7. Roof including services | 1.0kN/m ² |
| Level 1 and 2 floors | 5.0kN/m ² |
| Handrail loading | 1.5kN/m at handrail height |

Site conditions

8. The site is located outside a city.
Basic wind speed is 40.0m/s based on a 3-second gust; the equivalent mean hourly speed is 20.0m/s.
Ground conditions
Ground level – 0.3m Topsoil
0.3m – 2.0 m Medium SAND and GRAVEL, N = 10
Below 2.0 m Stiff Clay, C = 200 kN/m²

No groundwater was encountered.

Omit from consideration

9. Design of stairs and services.

SECTION 1

(50 marks)

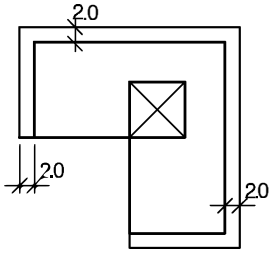
- a) Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes, and identify the solution you recommend, giving reasons for your choice.
(40 marks)
- b) After the scheme design has been approved, the client informs you that they wish to relocate the storeroom under the upper floor with access from the lower floor, and to add a second external door to the west elevation of the lower hall. Write a letter to the client explaining the changes needed to your design.
(10 marks)

SECTION 2

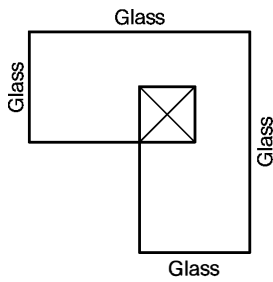
(50 marks)

For the solution recommended in Section 1(a):

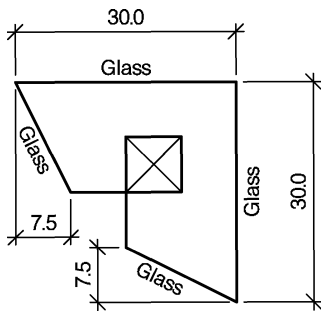
- c) Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations.
(20 marks)
- d) Prepare general arrangement drawings, which may include plans, sections and elevations to show the dimensions, layout and disposition of the structural 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 to include consideration of any temporary works that may be required.
(10 marks)



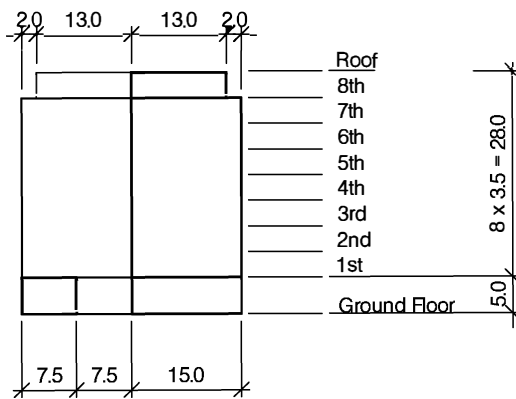
8th FLOOR TO ROOF



1st to 7th FLOOR



GROUND FLOOR



ELEVATION

NOTE: All dimensions are in metres

FIGURE Q2

Q2. Office Building

Client's requirements

1. An 8-storey office block is to be constructed. See Figure Q2.
2. All elevations are to be glazed. No bracing is permitted in glazed facades
3. Minimum column spacing is 6m. Only 2 internal columns are permitted at ground floor level. No columns are permitted outside the perimeter of the building
4. The first floor is to be 5m above the ground floor level. Other floors are to have a 3.5m floor to floor height.
5. On the 8th floor the façade is to be set back 2m from the lower floors. See Figure Q2.

Imposed loading

6. Roof 4 kN/m²
7. Floors 10 kN/m² on ground floor and 4kN/m² on other floors

Site conditions

8. The site is in the centre of a large city. Basic wind speed is 40.0m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20.0m/s.
9. The ground conditions are as follows:

Ground level – 5m	Heavily contaminated made ground N=2
-5m –to -10m	Firm clay C=50kN/m ²
Below -10m	Mudstone C= 150 kN/m ²

No water was discovered.

Omit from consideration

10. Design of the lifts/elevators and stairs.

SECTION 1

(50 marks)

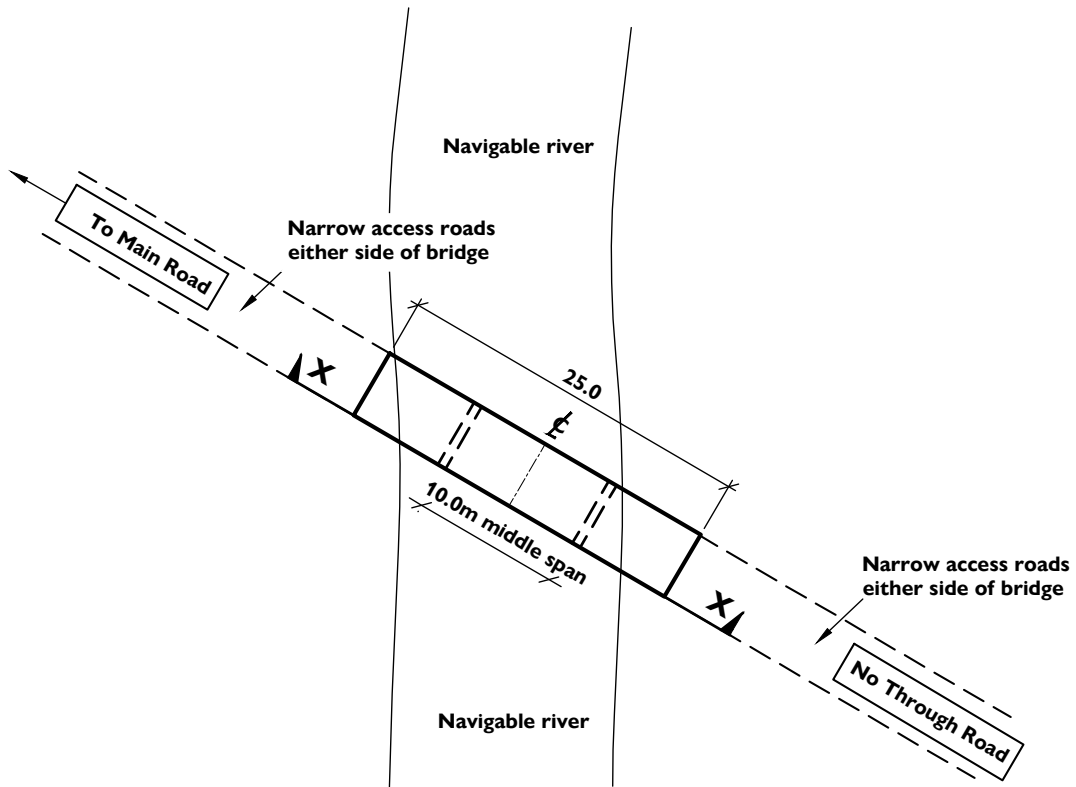
- a) Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes, and identify the solution you recommend, giving reasons for your choice.
(40 marks)
- b) After the scheme is complete, the client advises you that they wish to add an additional storey. Write a letter to the client explaining the implications on your design and the construction.
(10 marks)

SECTION 2

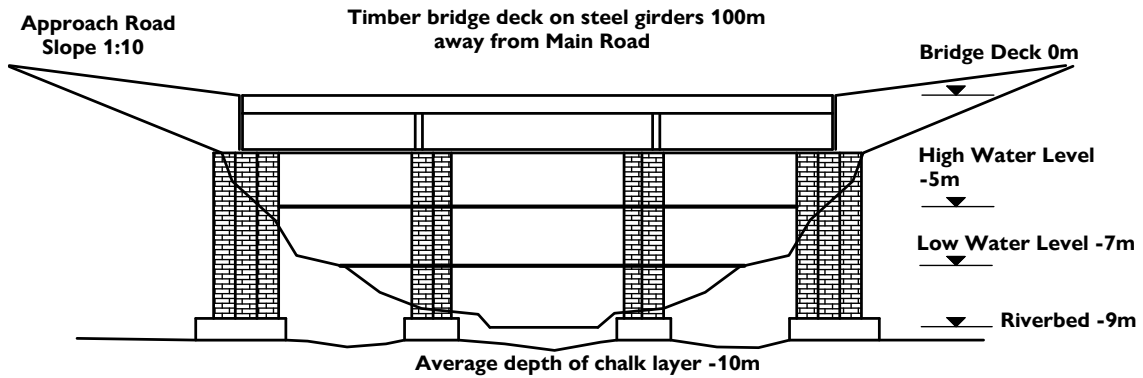
(50 marks)

For the solution recommended in Section 1(a):

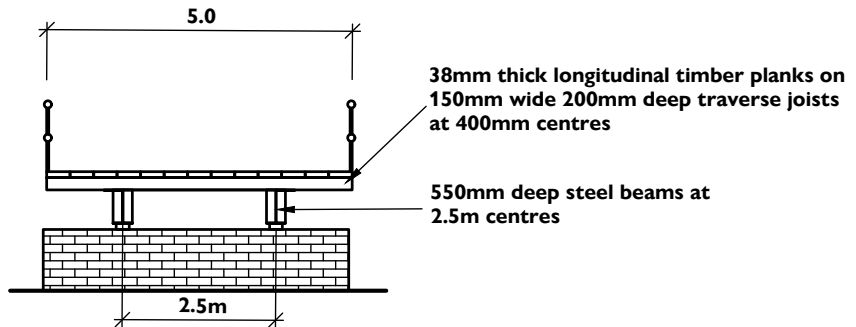
- c) Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations.
(20 marks)
- d) Prepare general arrangement drawings, which may include plans, sections and elevations to show the dimensions, layout and disposition of the structural 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 to include consideration of any temporary works that may be required
(10 marks)



PLAN VIEW OF EXISTING BRIDGE



ELEVATION X - X



TYPICAL CROSS SECTION OF BRIDGE SUPERSTRUCTURE

NOTE: All dimensions are in metres, do not scale

FIGURE Q3

Q3. Access bridge to private housing estate

Client's requirements

1. An existing bridge serves a small private housing estate. The bridge is in a poor state of repair and a recent bridge inspection report has confirmed that the bridge structure is not sufficient to carry the load of a fire engine. Strengthening or replacement of the bridge is required as soon as possible and the solution must be economical.
2. The approach road to the bridge cannot accommodate any heavy construction equipment including cranes.
3. Residents will need to be temporarily relocated during any periods when the bridge is not useable. Solutions should consider this and minimise the duration of any closure of the bridge.

Imposed loading

4. Vehicular traffic loading 10kN/m²

Site conditions

5. The site is in a rural area within five miles of the sea. Peak flow velocity of the river is 0.75m/s.
6. Basic wind speed is 46m/s based on 3-second gust; the equivalent mean hourly speed is 23m/s.
7. Ground conditions - silt deposit over chalk. Safe bearing capacity of the chalk 500kN/m².

Omit from consideration

8. Detailed scour depth calculation.
9. Wing walls to bank abutment.

SECTION 1

(50 marks)

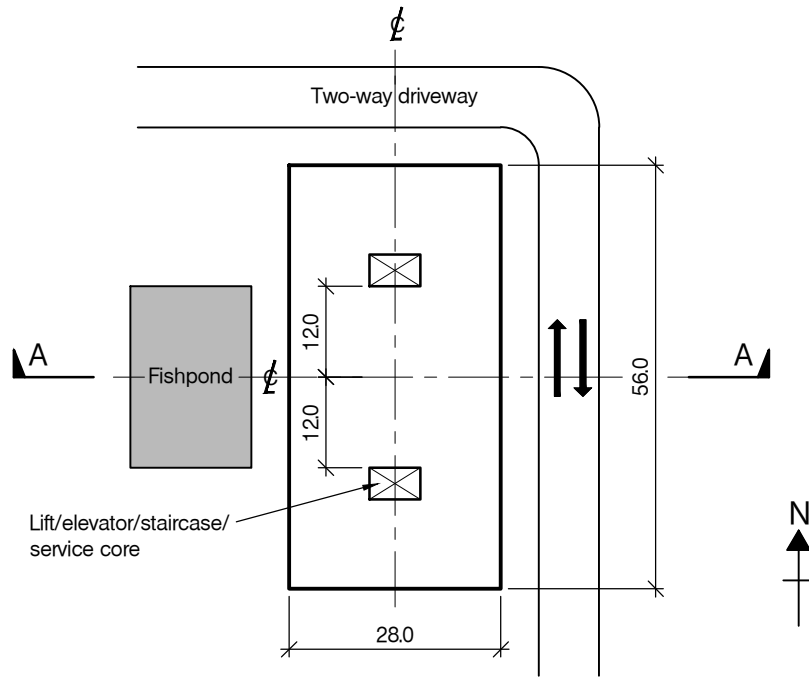
- a) Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes, and identify the solutions you recommend, giving reasons for your choice.
(40 marks)
- b) After completion of design the client states that there is no longer any programme constraint on the bridge replacement, and would like to know if this could result in a cheaper structure. Write a letter to your client on the implications to the design.
(10 marks)

SECTION 2

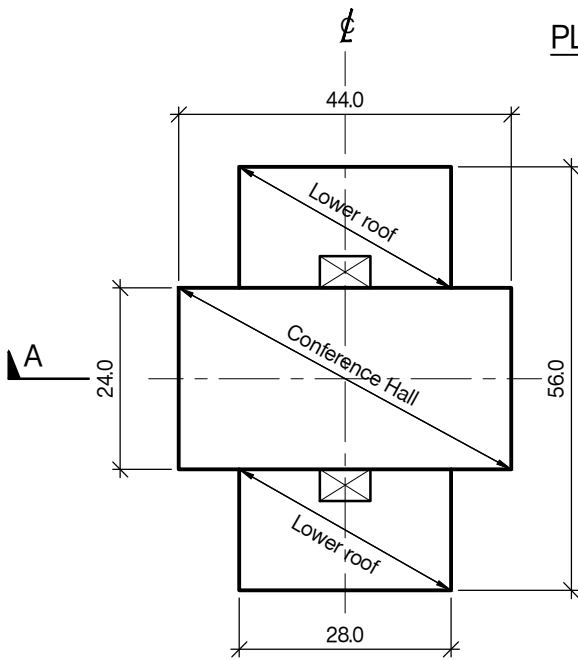
(50 marks)

For the solution recommended in Section 1(a):

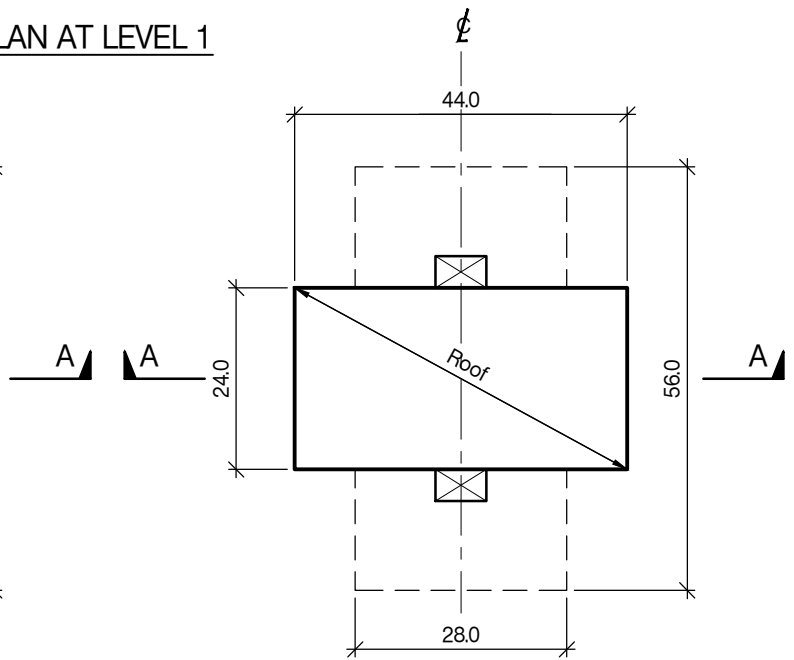
- c) Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations.
(20 marks)
- d) Prepare general arrangement drawings, which may include plans, sections and elevations, to show the dimensions, layout and disposition of the 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 to include consideration of any temporary works that may be required.
(10 marks)



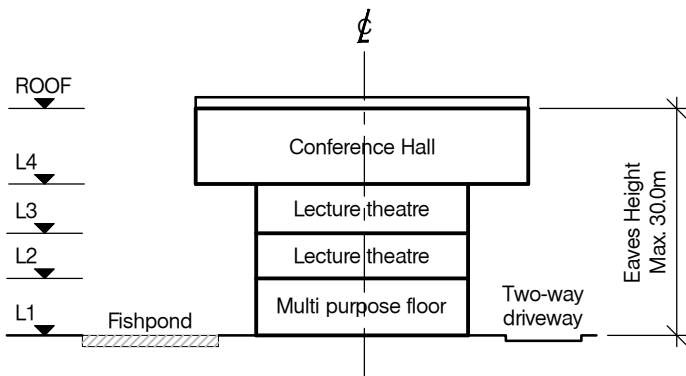
PLAN AT LEVEL 1



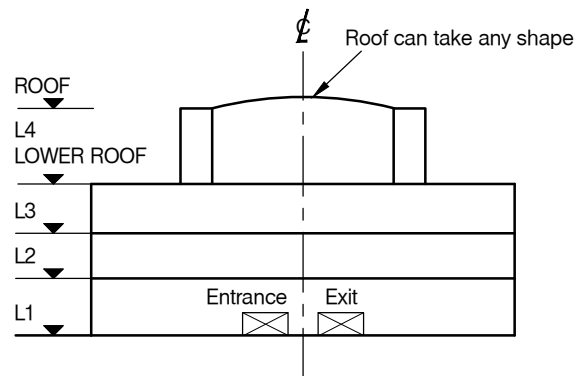
PLAN AT LEVEL4 / LOWER ROOF



PLAN AT ROOF



SECTION A - A



EAST ELEVATION

NOTE: All dimensions are in metres

FIGURE Q4

Q4. Faculty Building

Client's requirements

1. A new four-storey faculty building is to be constructed in an existing university situated on the outskirts of a city. The academic facility is 56.0m long and 28.0m wide at Level 1. See Figure Q4.
2. A conference hall is to be provided at Level 4. The cantilevered areas at the east and west ends of the conference hall must not be supported from below Level 4. See Figure Q4.
3. Two 8.0m x 4.0m lift/elevator/stair/service cores are to be provided to serve all the floors. Twelve external columns spaced at not less than 12.0m apart are permitted between Level 1 and Level 4 / Lower Roof. No internal columns are allowed at Level 1 and in the conference hall at Level 4. No more than two internal columns are permitted at Level 2 and Level 3.
4. Clear floor to ceiling height is to be 5.60m at Level 1, 4.60m at Level 2 and Level 3 and 6.20m in the conference hall at Level 4. A structure-free ceiling zone of 400mm is required at all the levels for services.
5. The maximum eaves height must not exceed 30.0m above Level 1. The roof of the conference hall can take any profile as long as it would not result in water ponding; however, highest roof cladding level must not exceed 32.0m above Level 1.
6. The entry and exit doors are to be at least 4.0m wide and 2.5m high on the east side of the building.
7. No internal vertical cross bracing is permitted in the functional space of the building at all levels.
8. Level 1 facades shall be 75% glazed, and the remaining facades are to have stone cladding.

Imposed loading

- | | |
|---------------------------|-------------------------|
| 9. Roof | = 0.6 kN/m ² |
| Level 4 (Conference hall) | = 5.0 kN/m ² |
| Level 4 (Lower roof) | = 1.5 kN/m ² |
| Level 2 and 3 | = 5.0 kN/m ² |
| Level 1 | = 7.5 kN/m ² |
- Loadings include allowances for finishes, ceiling and services.

Site conditions

10. Basic wind speed is 40m/s based on a 3-second gust; the equivalent mean hourly wind speed is 20m/s.

Ground conditions

- | | | |
|--------------------------|---|------|
| 11. Ground Level to 0.5m | Topsoil/Fill | |
| 0.5m to 1.0m | Loose sand and gravel | N=8 |
| 1.0m to 2.0m | Medium dense sand | N=12 |
| 2.0m to 7.0m | Dense sand | N=40 |
| Below 7.0m | Rock, allowable bearing strength = 1500 kN/m ² | |
- Ground water was observed at 5.0m below ground.

Omit from consideration

12. Detailed design of staircase, fishpond, glazed façade and cladding.

SECTION 1

(50 marks)

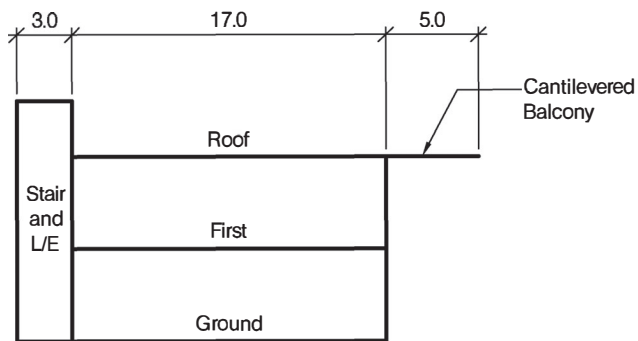
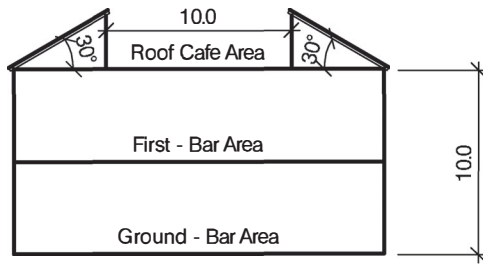
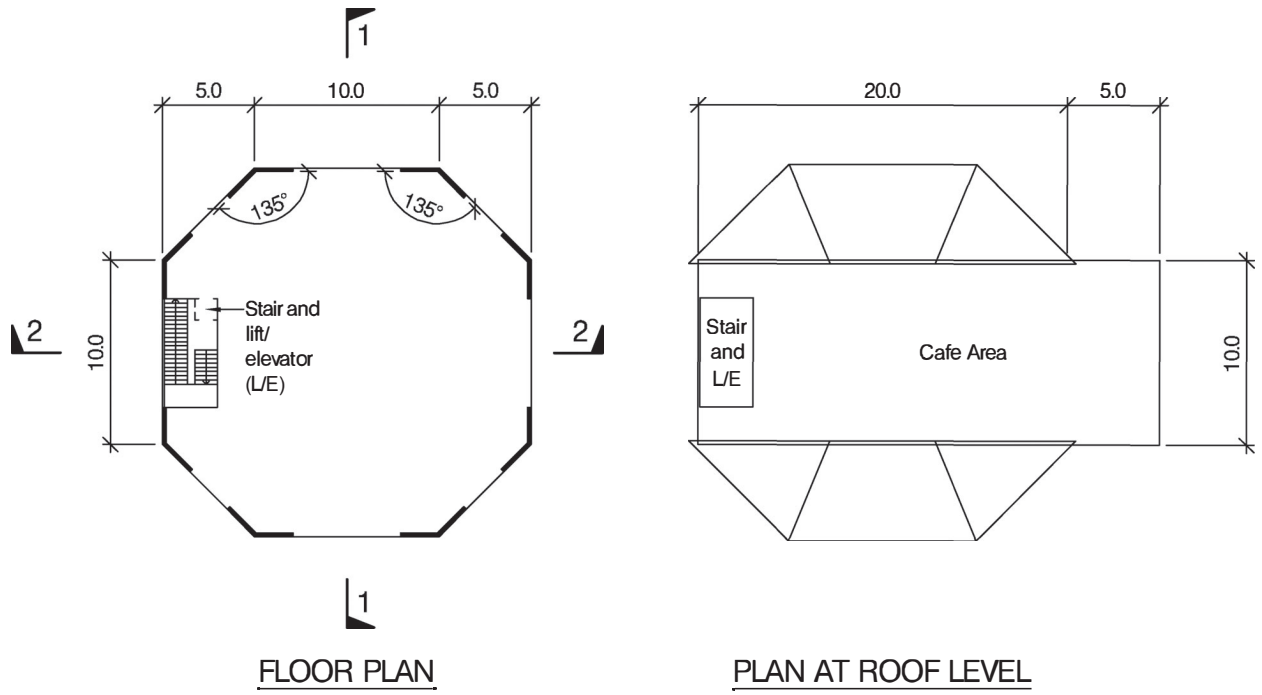
- a) Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes, and identify the solution you recommend, giving reasons for your choice. (40 marks)
- b) After you have completed your design, the client informs you that a clear column-free distance of 22m is required at Level 1 on the east side external face of the building to facilitate the movement and display of large objects during exhibitions. Write a letter to the client explaining the design and construction implications and advising how the design could be modified to suit the new requirement. (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 drawings, which may include 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 to include consideration of any temporary works that may be required. (10 marks)



NOTE: All dimensions are in metres

FIGURE Q5

Q5. Lakeside Café and Bar

Client's requirements

1. A two-storey octagonal building with a roof-top cafe is to be constructed adjacent to an existing lake. See Figure Q5.
2. Elevations are to be 50% glazed to take advantage of the surrounding views.
3. Structural support is to be placed within the external envelope with a maximum of one internal column.
4. Floor to floor height is limited to 5.0m with a minimum internal clear height of 3.5m between floors.

Imposed loading

5. Café roof Area 3.0 kN/m²
6. First and ground area 3.0 kN/m²

Site conditions

ž The site is on the outskirts of a city. Basic wind speed is 45m/s based on a 3 second gust; the equivalent mean, hourly speed is 24m/s.

*ž Ground conditions are the same across the site:

- | | |
|---------------------|---------------------------|
| Ground level – 1.0m | topsoil / unsuitable fill |
| -1.0m to – 6.0m | Gravel, N value 15 |
| Below - 6.0m | Rock with N > 30 |
- Groundwater was encountered at -1.5m below ground level.

Omit from consideration

9. Detail design of the lift/elevator 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, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes and identify the solution you recommend, giving reasons for choice. (40 marks)
- b) After construction was completed, the client decided to increase the seating capacity for the café area by a further 30%. Write a letter explaining how this can be achieved and provide options for the client to consider. (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 drawings which may include 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 to include any temporary works that may be required (10 marks)

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