

Incorporated-Member Examination

Thursday 16 July 2026

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 on the question paper, 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 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. 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.

Incorporated-Member 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.

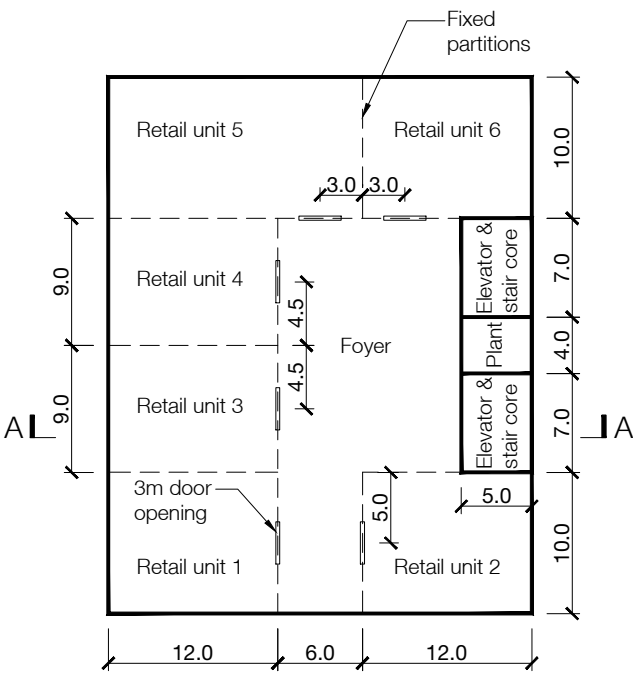
The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural design problems whether or not the problem is presented in terms that are within your actual experience.

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.

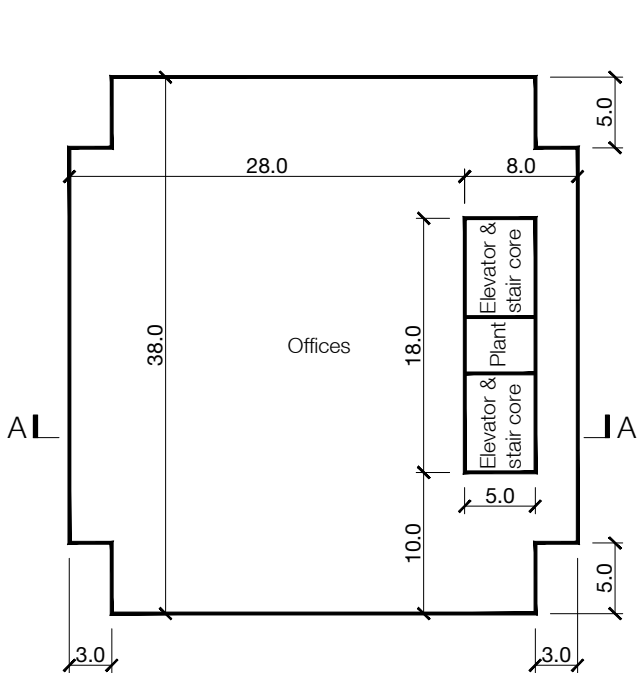
In selecting and developing your design you should also remember the guidance given in the Institution's report, Structural design - achieving excellence, and in particular:

- (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".

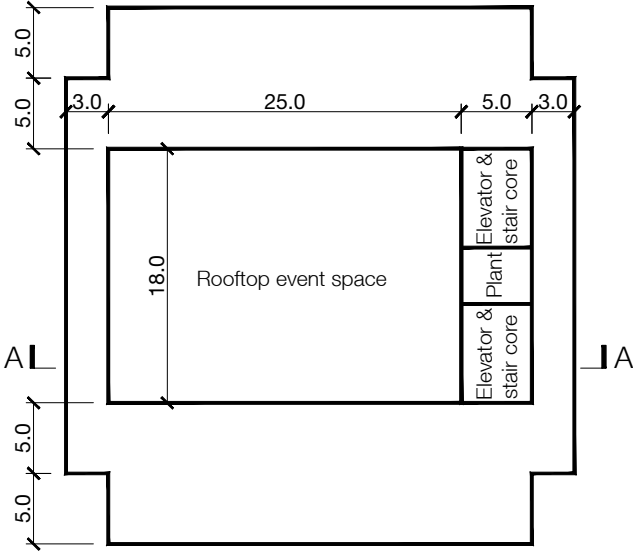
If you have difficulty in deciding the correct interpretation of a question, pay particular attention to point 6. notes to candidates, on the front cover. The examiners will take into account your interpretation – and the design you base on this – if this is clearly stated at the beginning of your answer.



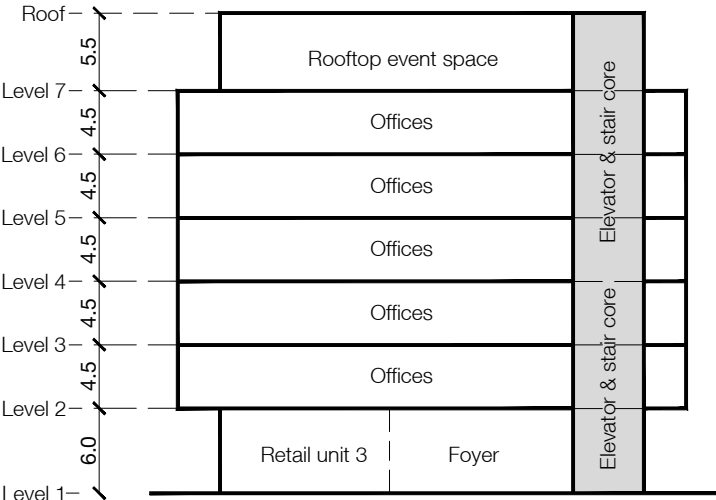
PLAN AT LEVEL 1



TYPICAL UPPER FLOOR



PLAN AT LEVEL 7



SECTION A-A

NOTE: All dimensions are in metres.

FIGURE Q1

Q1. Mixed-use city centre development

Client's requirements

1. A 7-storey mixed use development is to be constructed on a city centre site. See Figure Q1.
2. The building comprises an entrance foyer area and 6No. retail units on Level 1, open plan offices on Levels 2-6, and an event space on Level 7. The building is to have fully glazed elevations.
3. All upper floors are accessed via one of the two stair and lift/elevator cores, which extend to roof level and are accessed from the entrance foyer area on Level 1. The retail units at Level 1 are accessed from the foyer area, via a column free 3m wide doorway.
4. The roof of the event space at Level 7 is to be of lightweight framed construction while all other areas can be constructed using any appropriate structural material.
5. At Level 1 a floor to ceiling height of 3.8m is required, while within the offices (Level 2-6), the floor to ceiling height is to be 3.0m. A 0.15m raised access floor system is also required within the offices. At Level 7 the floor to ceiling height is to be 4.0m. A ceiling service zone of 0.6m is required at all levels.
6. On all levels column spacing should be kept to a minimum. At Level 1, in addition to columns being permitted within the foyer area and partition walls, a maximum of two columns are allowed within each retail unit. At Level 7 a maximum of two internal columns are permitted within the event space.
7. Apart from the cores, bracing members are only permitted in perimeter walls. As all bracing members will remain visible, they must be architecturally acceptable in appearance.

Imposed loading

- | | |
|--------------|------------------------|
| 8. Level 1-7 | 5.0 kN/m ² |
| Roof | 0.75 kN/m ² |

Site conditions

9. The building is located on a large city centre site. The basic wind speed is 40.0m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20.0m/s.

Ground conditions

Ground – 0.3m	Made Ground
0.3m – 2.0m	Firm clay (C=75kN/m ²)
2.0m - 5.0m	Stiff clay (C=175kN/m ²)
Below 5.0m	Rock, characteristic bearing strength = 4500 kN/m ²
Ground water was not encountered	

Omit from consideration

10. Design of stairs, lifts/elevators, and facade cladding/glazing.

SECTION 1

(30 marks)

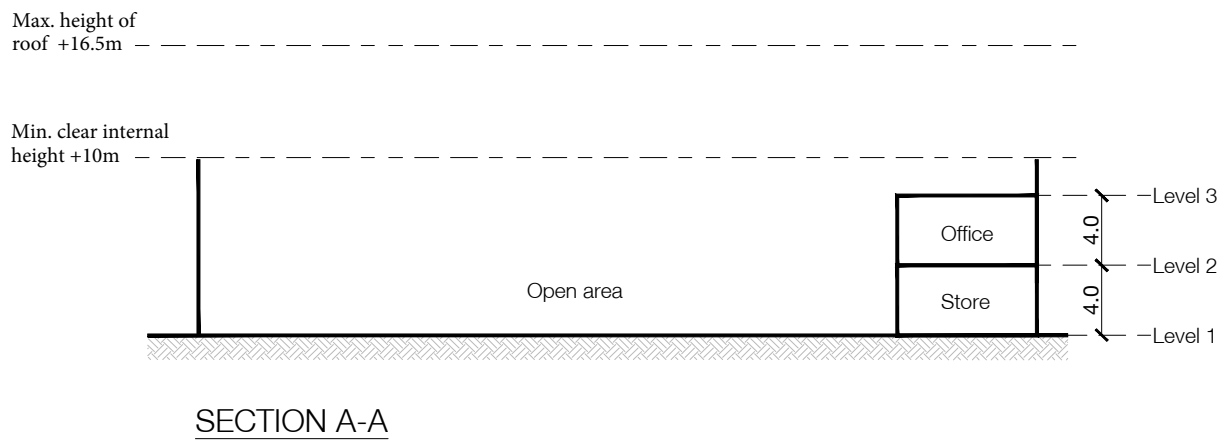
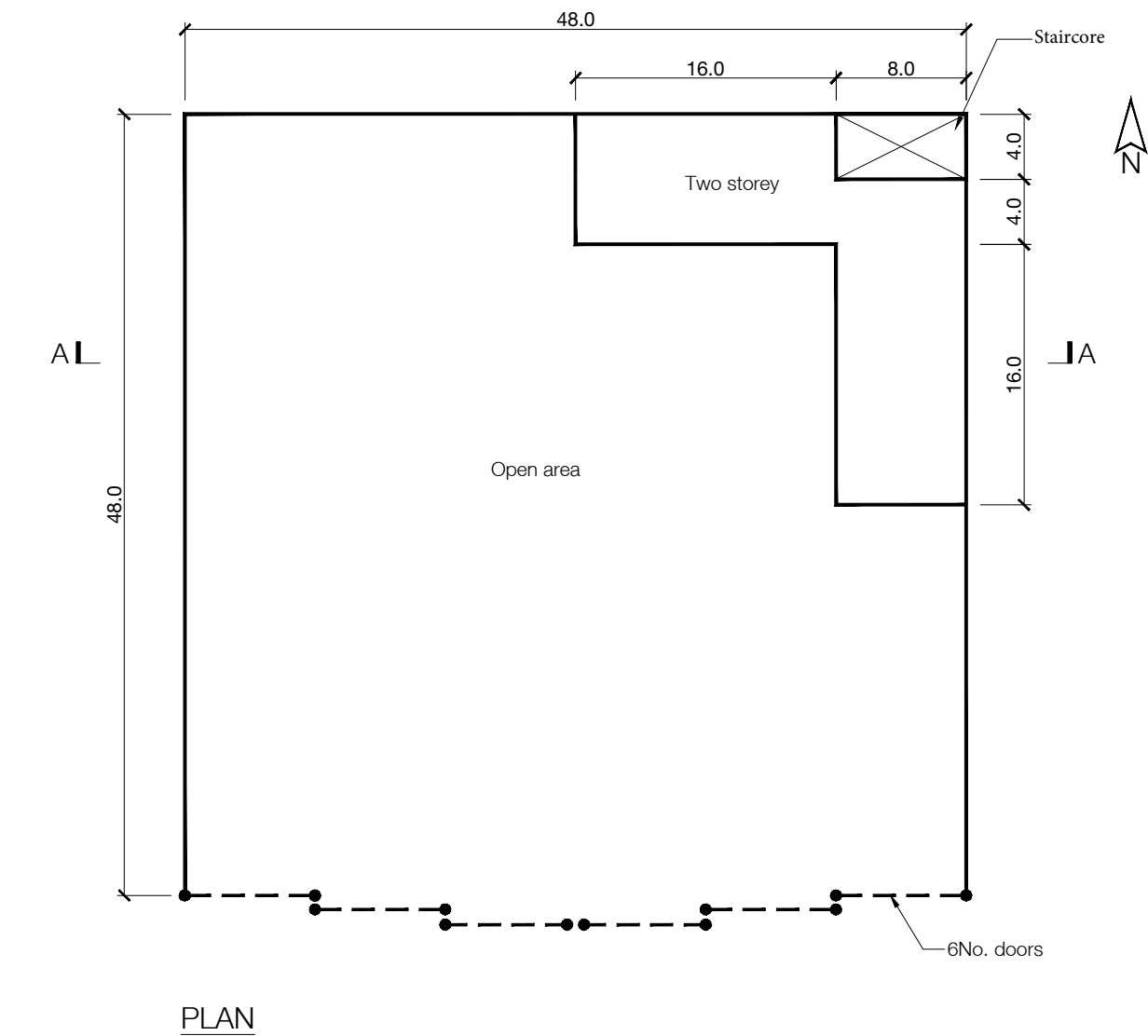
- a) Prepare a design appraisal with appropriate sketches indicating a viable and sustainable solution for the proposed structure including the foundations. Clearly indicate the functional framing, load transfer, serviceability, and stability aspects of the scheme. Using sustainability as a key criterion, justify the reasons for your solution. (20 marks)
- b) After the scheme design has been completed, the client asks whether changes could be made to the brief in order to reduce usage of materials, whilst maintaining the building footprint and number of floors. Write to your client proposing possible changes. As part of any proposals made, explain the effect this may have on the 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 the principal structural elements including the foundations. Include approximate A1-A3 carbon calculations for each of your principal elements. (30 marks)
- d) Prepare general arrangement drawings, which may include 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:
 - a) the cantilever details at Level 2
 - b) the foundations to a perimeter column (30 marks)
- e) Prepare a detailed method statement for the safe construction of the works. (10 marks)



NOTE: Detail dimensions are in mm.

FIGURE Q2

Q2. Aircraft hangar

Client's requirements

1. An aircraft maintenance hangar is required for the routine checks and inspections on a single aircraft at a regional airport; see Figure Q2.
2. The building comprises an open area with no internal columns and minimum clear internal height of 10m to accommodate a single aircraft with the maximum dimensions, wingspan and length of 30m and height 8m. At the Northeast corner is a two-storey area with stores at Level 1 and Offices on Level 2. Only one staircase/lift/elevator core is required and there is no restriction on column spacing in the two-storey area.
3. The maximum height of the roof and the minimum clear internal height of the hangar are given on Figure Q2.
4. Materials for the external envelope of the building are to be selected to minimise energy consumption.
5. The south elevation is to have six panel doors 8m wide and 9m high and be capable of being stacked so that the full width of 48m can be provided. The hangar is to be available at all times and in all weather conditions.
6. A minimum floor to ceiling height of 3.0m is required for the two-storey area.
7. A minimum fire resistance period of 1 hour is required for structural elements.

Imposed loading

8. Roof including services allowance 1.5 kN/m²
 Stores 15 kN/m²
 Office floor 6 kN/m² includes allowance for internal partitions, finishes and services.
 Hangar floor 25 kN/m² or a patch load of 200 kN spread over an area of 1.2m x 0.9m.

Site conditions

9. The regional airport is located in an open flat area 16 kilometres from the nearest town. Basic wind speed is 42.0m/s based on a 3-second gust; the equivalent mean hourly speed is 21.0m/s.

Ground conditions

- | | |
|-------------|------------------------------------|
| 0.0m - 0.3m | Topsoil. |
| 0.3m – 2.0m | Loose Sand N value less than 10 |
| Below 2.0m | Stiff clay C=150 kN/m ² |
- Ground water was encountered at 1.5m below ground level.

Omit from consideration

10. Panel doors and staircase.

SECTION 1

(30 marks)

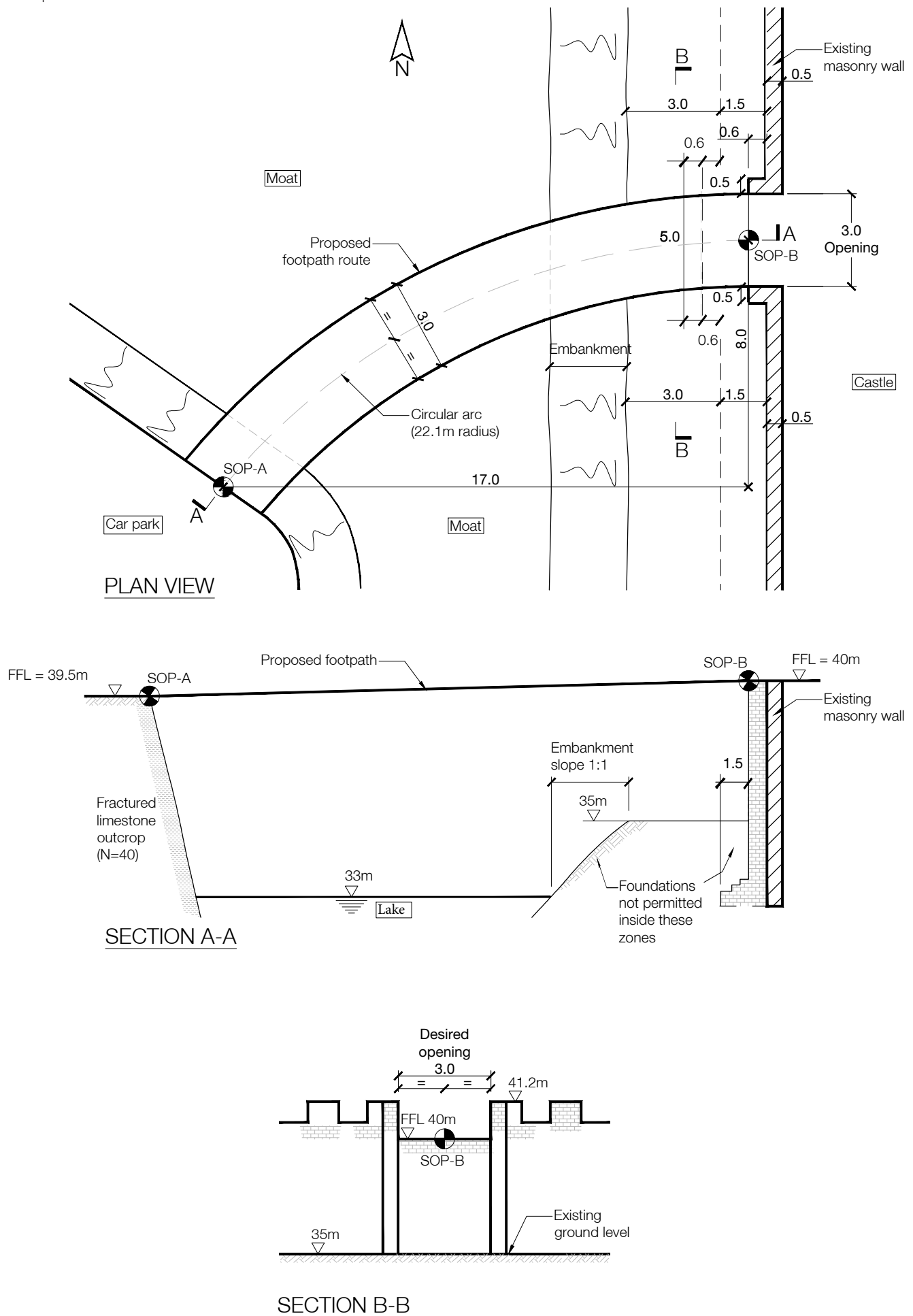
- a) Prepare a design appraisal with appropriate sketches indicating a viable and sustainable solution for the proposed structure including the foundations. Clearly indicate the functional framing, load transfer, serviceability, and stability aspects of the scheme. Using sustainability as a key criterion, justify the reasons for your solution. (20 marks)
- b) After the scheme design has been completed, the client asks whether changes could be made to the brief in order to reduce material usage while maintaining the requirement to accommodate the specified aircraft. Write to your client proposing possible changes. As part of any proposals made, explain the effect these might have on your 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 the principal structural elements including the foundations. Include approximate A1-A3 carbon calculations for each of your principal elements. (30 marks)
- d) Prepare general arrangement drawings which may include 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:
 - a) the proposed details at junction of the roof and vertical structure
 - b) the foundations to the main vertical structure
 (30 marks)
- e) Prepare a detailed method statement for the safe construction of the works. (10 marks)



NOTE: All dimensions are in metres.

FIGURE Q3

Q3. Heritage castle access bridge

Client's requirements

1. A new footbridge is required to connect an existing heritage masonry castle to a new car-park over a moat. A circular plan profile is desired to best meet the geometric constraints of the site. See Figure Q3.
2. No new permanent foundations are allowed in either the moat or the embankment for archaeological and heritage reasons.
3. No new permanent foundations are allowed inside of the dotted line shown on the Plan View to avoid the risk of undermining or damaging the existing masonry foundations.
4. The new structure cannot exert any significant loading on to the existing masonry at any point.
5. Maximum height of pedestrian parapet is to be 1.15m above footbridge deck level.
6. The required finished footpath level (FFL) of the footbridge is to be as shown on Figure Q3.
7. The client would prefer an aesthetically pleasing design.

Imposed loading

8. Max gust wind speed for site = 40 m/s.
Pedestrian live load is 5kN/m²
The structure does not have to support maintenance vehicles

Site conditions

Car Park side of the moat:

6.5m - 5.5m	Topsoil / made ground
Below 5.5m	Fractured Limestone (N = 40)

Castle Side of moat:

2.0m to -3.0m	Weak Clay / Made ground – N=5
Below -3.0m	Fractured Limestone (N=40)

Omit from consideration

9. Detailed design of the parapet.

SECTION 1

(30 marks)

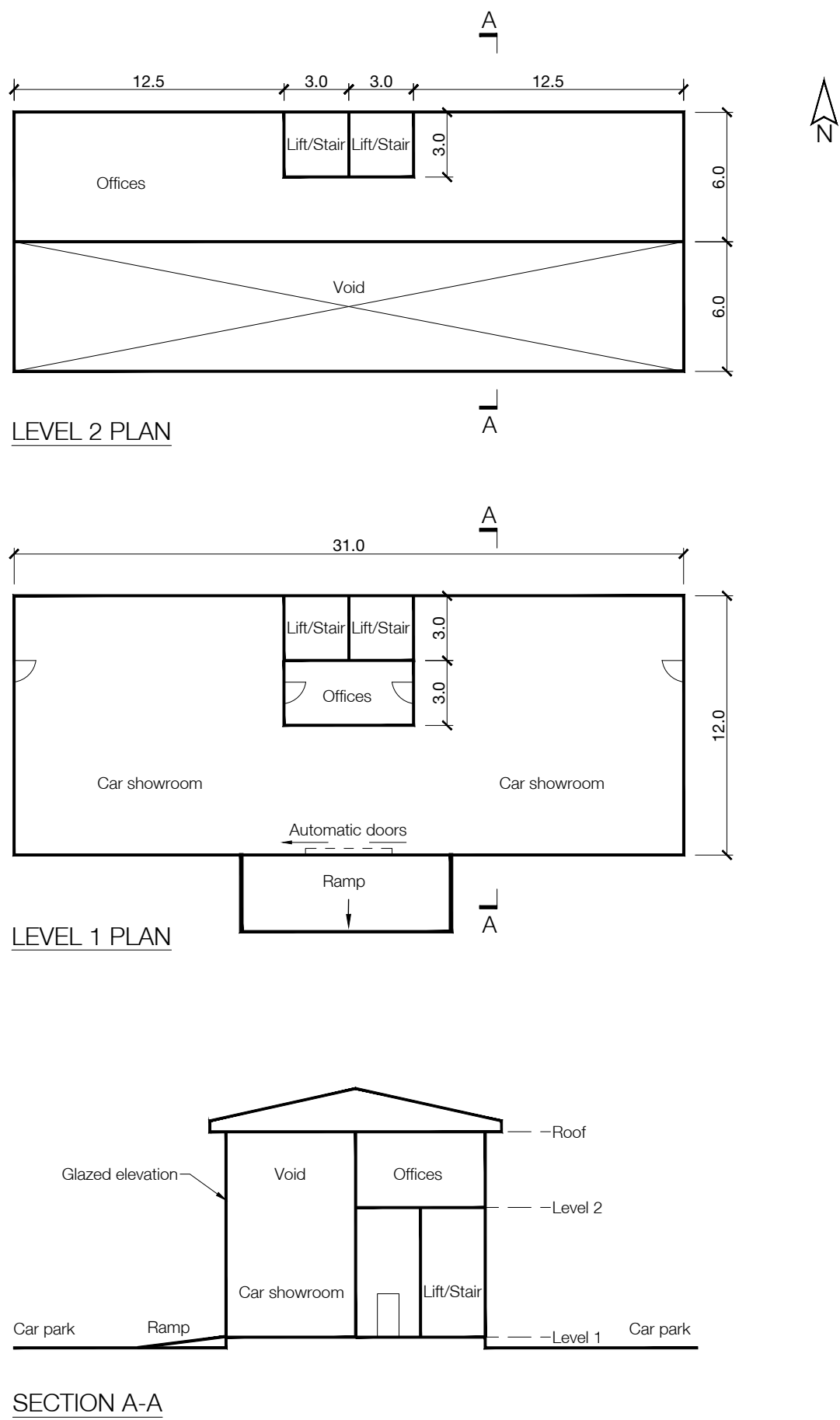
- a) Prepare a design appraisal with appropriate sketches indicating a viable and sustainable solution for the proposed bridge including the foundations. Clearly indicate the functional framing, load transfer, serviceability, and stability aspects of the scheme. Using sustainability as a key criterion, justify the reasons for your solution. (20 marks)
- b) After the scheme design has been completed, the client asks whether changes could be made to the brief in order to reduce material usage while maintaining the restriction on foundation positions driven by heritage, archaeological and existing masonry stability purposes. Write to your client proposing possible changes. As part of any proposals made, explain the effect these may have on the 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 the principal structural elements including the foundations. Include approximate A1-A3 carbon calculations for each of your principal elements. (30 marks)
- d) Prepare general arrangement drawings which may include 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:
 - a) the foundation of the bridge adjacent to the castle
 - b) a section through the parapet (30 marks)
- e) Prepare a detailed method statement for the safe construction of the works. (10 marks)



NOTE: All dimensions are in metres.

FIGURE Q4

Q4. Car showroom building

Client's requirements

1. A 2-storey car showroom building on the outskirts/edge of a city. Level 1 is for the car showroom floor, reception office, a lift/elevator and stairs to level 2. Level 2 is for flexible column-free open-plan offices with demountable partitions. See Figure Q4.
2. A minimum clear floor to ceiling height of 6.0m is required at Level 1 and 4.0m at Level 2.
3. At Level 1, ideally the car showroom floor area will be column-free, but no more than 4 internal columns are allowed. Columns are not permitted within the Level 1 reception office and lift/elevator and staircase areas.
4. The south elevation is to be glazed full height to provide natural light. No internal vertical bracing is allowed within the building other than within partitions and around the perimeter. Cladding to the roof is to be selected to minimise energy consumption and maintenance costs. All single doors are to be 2.1m high and 1.0m wide. Automatic sliding doors centrally located on the south elevation are required to provide a 4.0m wide by 3.0m high opening for vehicle access.
5. A minimum 1-hour fire resistance is required for structural elements.

Imposed loading

- | | |
|---------|---|
| 6. Roof | 1.5kN/m ² to allow for solar panels |
| Level 1 | 12.0kN/m ² |
| Level 2 | 8.0kN/m ² which includes allowance for partitions, finishes and services |

Site conditions

7. The site is a large flat open space.
Basic wind speed is 40m/s based on a 3-second gust, the equivalent mean hourly wind speed is 20m/s.

Ground conditions

Ground level - 0.3m	Topsoil
0.3m - 2.0m	Clay C = 100kN/m ²
2.0m - 6.0m	Sand and gravel, N = 40 increasing to 50
6.0m - 10.0m	Very stiff clay, C = 250kN/m ²

Although no standing water was encountered in trial excavations, a high moisture content was recorded in the sand and gravel deposits.

Omit from consideration

8. Detailed design of lift/elevator/staircases, automatic doors, ramp, and glazing system.

SECTION 1

(30 marks)

- a) Prepare a design appraisal with appropriate sketches indicating a viable and sustainable solution for the proposed bridge including the foundations. Clearly indicate the functional framing, load transfer, serviceability, and stability aspects of the scheme. Using sustainability as a key criterion, justify the reasons for your solution. (20 marks)
- b) After the scheme design has been completed, the client asks whether changes could be made to the brief in order to reduce material usage while maintaining the required car showroom floor area of Level 1. Write to your client proposing possible changes. As part of any proposals made, explain the effect these may have on the 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 the principal structural elements including the foundations. Include approximate A1-A3 carbon calculations for each of your principal elements. (30 marks)
- d) Prepare general arrangement drawings which may include 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:
 - a) the roof connection at eaves level
 - b) the perimeter foundation and ground slab details (30 marks)
- e) Prepare a detailed method statement for the safe construction of the works. (10 marks)

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