

# Incorporated-Member Examination

Tuesday 15 July 2025

## 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.

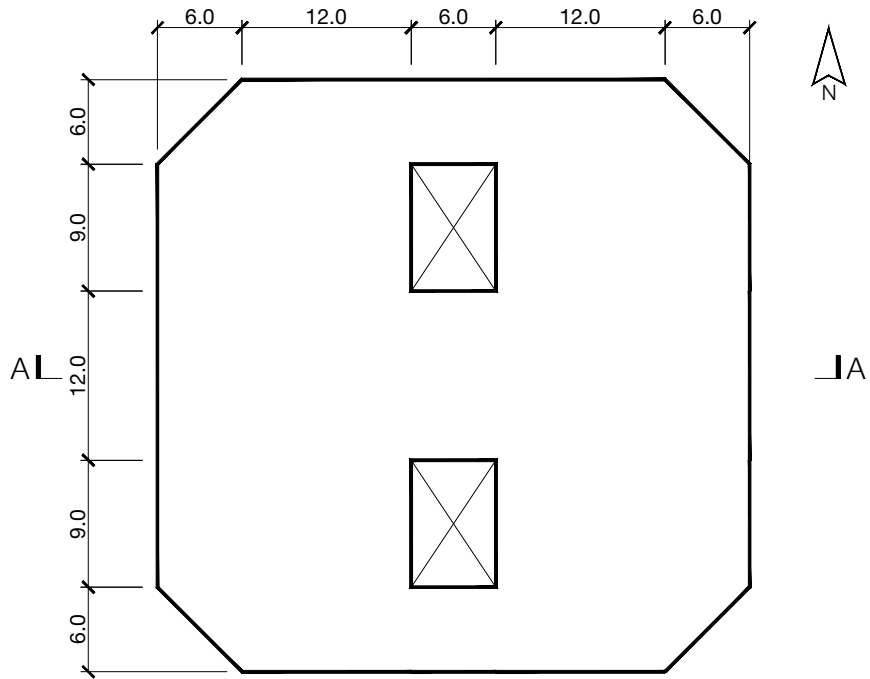
The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural design problems whether or not the problem is presented in terms that are within your actual experience.

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.

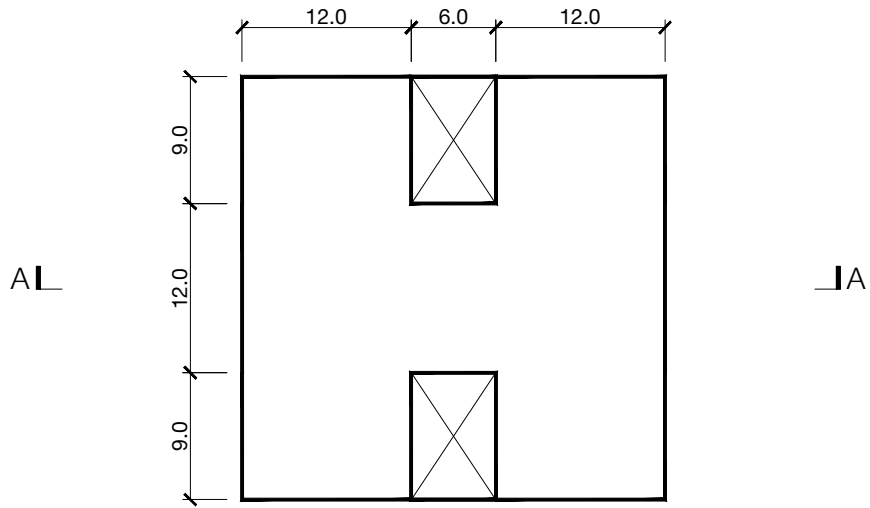
In selecting and developing your design you should also remember the guidance given in the Institution's report, Structural design - achieving excellence, and in particular:

- (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".

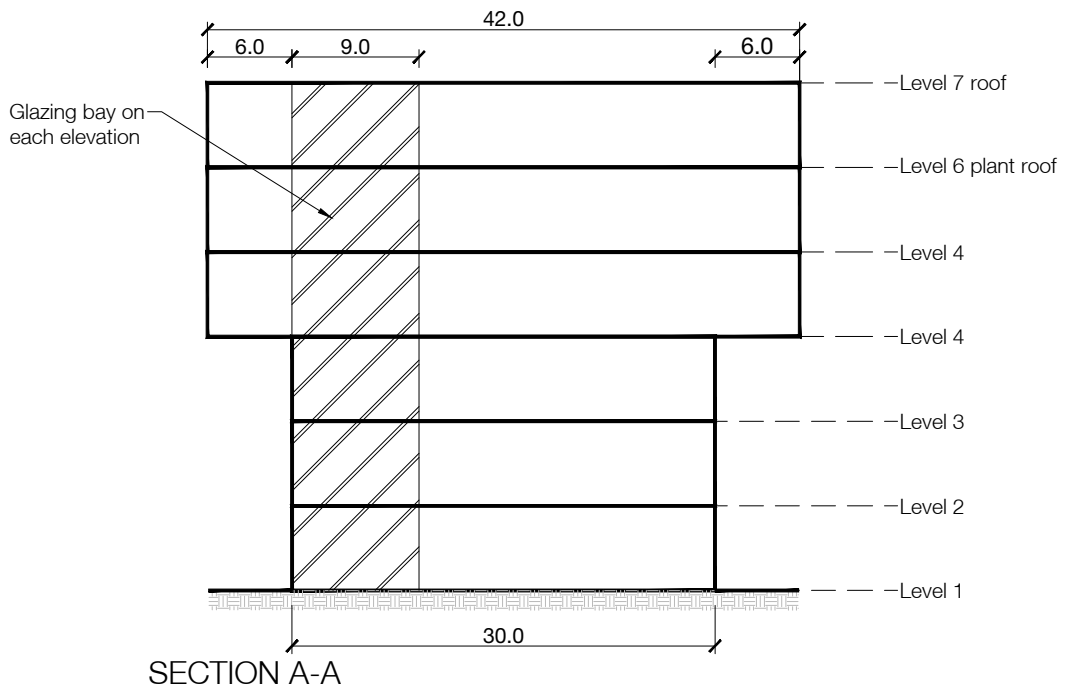
If you have difficulty in deciding the correct interpretation of a question, pay particular attention to point 6. notes to candidates, on the front cover. The examiners will take into account your interpretation – and the design you base on this – if this is clearly stated at the beginning of your answer.



UPPER FLOOR PLAN



LOWER FLOOR PLAN



SECTION A-A

NOTE: All dimensions are in metres.

FIGURE Q1

# Q1. City centre office

## Client's requirements

1. A 6-storey office block in a city centre. Levels 1, 2 and 3 are square in plan, Levels 4,5 and 6 are octagonal, and there are two stair/lift/elevator cores, each 9m x6m. The building is to be clad in 200mm thick non-structural precast concrete panels with vertical strip windows on each elevation. Level 1 is for retail use, Levels 2 to 5 are for office use, and Level 6 houses the plant room. See Figure Q1.
2. With the exception of columns around the cores, no internal columns are permitted in Levels 1 to 3, and a maximum of 6no. are permitted in each of Levels 4 and 5. There are no restrictions regarding bracing or number of columns at Level 6.
3. No bracing or shear walls are permitted around the cores except at Level 6. No bracing is permitted within the vertical strip windows.
4. Structure supporting Levels 4 and above may extend outside of the footprint of the lower floors as far down as Level 2.
5. At Levels 2 to 5 a floor to ceiling height of 3.0m is required with a services zone of 900mm. Levels 1 and 6 are to have a clear height of 6.0m from floor to underside of structure above.
6. The building is to have a 4 hour fire rating.

## Imposed loading

7. Roof general 1.50 KN/m<sup>2</sup>  
Office Floors 6.0 KN/m<sup>2</sup> which includes finishes services and partition allowance.  
Level 1 Retail 10.0 KN/m<sup>2</sup>  
Plant room 7.5 KN/m<sup>2</sup>

## Site conditions

8. The building is on a large site in the city centre. The basic wind speed is 42m/s on a 3-second gust; the equivalent mean hourly wind speed is 21m/s.

## Ground Conditions

9. Ground Conditions  
0.0m – 0.5m Made Ground  
0.5m – 3.0m Soft Sandy Clay (C=25 KN/m<sup>2</sup>)  
Below 3.0m Very dense sand and gravel SPT > 50  
Ground water level 10m below ground level.

## Omit from consideration

10. Design of the stairs, and external non-structural precast concrete cladding panels

## 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 same overall floor area. 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 perimeter foundation, ground slab, and vertical structure
  - b) the perimeter floor and vertical support connection at Level 4 (30 marks)
- e) Prepare a detailed method statement for the safe construction of the works. (10 marks)

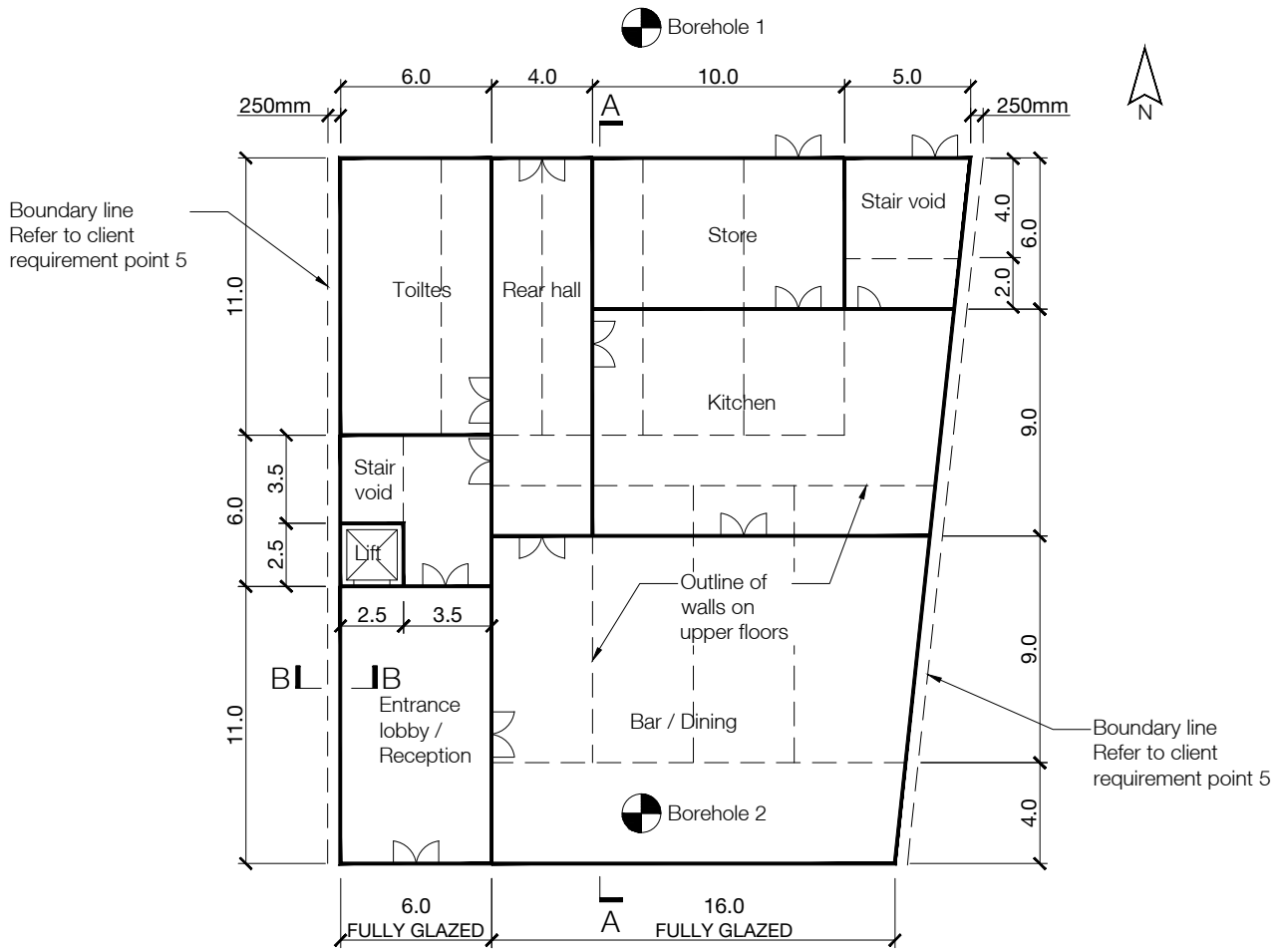


FIGURE 1 - LEVEL 1 LAYOUT

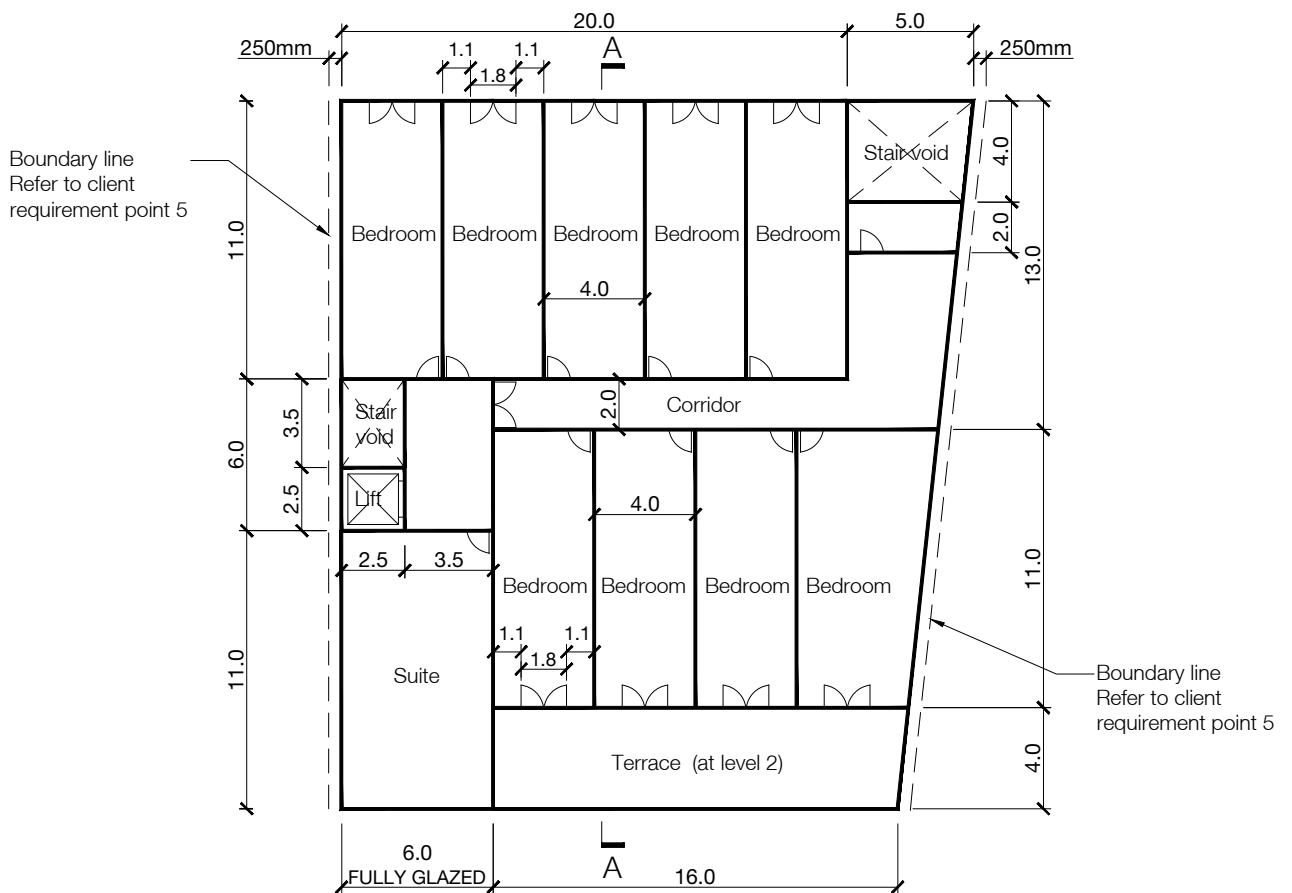


FIGURE 2 - TYPICAL UPPER LEVEL FLOOR LAYOUT

NOTE: Detail dimensions are in mm.

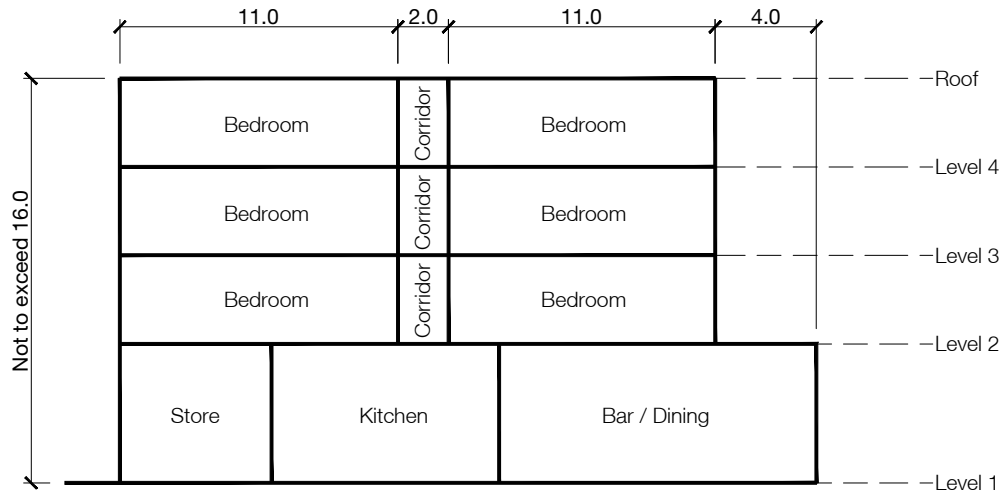


FIGURE 3 - SECTION A-A

## Q2. Seaside hotel

### Client's requirements

1. A 4-storey hotel in a coastal town, with the southern elevation immediately adjacent to a road which runs along the shoreline. Refer to Figure Q2.
2. The building is to have external masonry elevations with areas of glazing. The southern elevation is to be fully glazed at Level 1. At the upper levels, the southern elevation of the suites is to be fully glazed, while all other bedrooms are to have a 1.8m wide x 2.1m high window centred within each room. There are no windows on the east or west elevations.
3. There are 27no. standard bedrooms which are to have a minimum area of 40m<sup>2</sup> and 3no. suites with a minimum area of 60m<sup>2</sup>. Doors are typically 2.0m wide by 2.1m high except for bedroom doors which are 1.0m wide by 2.1m high.
4. All upper floors and roof are accessed via the stair and lift/elevator core, located beside the entrance lobby / reception area. A fire escape stair which serves all floors, exits to the northern elevation.
5. There is a 4-storey building adjacent to the western elevation and a vacant site adjacent to the eastern elevation. From a series of trial pits excavated along the western elevation, the existing foundations of the adjacent building extend out to the boundary line and are ground bearing at 1.5m below ground level.
6. At Level 1 the clear floor to ceiling height is to be 3.0m, while for other floors the ceiling height is to be 2.5m. A service zone of 0.6m is required at Level 1 and 0.3m at all other levels.
7. The overall height of the building from Level 1 to roof level shall not exceed 16.0m.
8. On all levels internal columns must have a minimum spacing of 4.0m centre to centre and must also be 4.0m from a perimeter wall or internal core wall. All columns must be located within partition walls at all levels. The only exception to this is in the bar/dining area at Level 1, where two internal columns are permitted within the open space.
9. No visible bracing is permitted on the southern elevation at Level 1 or the suites at all levels.

### Imposed loading

10. Level 1            5.0kN/m<sup>2</sup>
11. Levels 2-4       4.0kN/m<sup>2</sup>
12. Roof              1.0kN/m<sup>2</sup>

All loadings include finishes, services and partition allowance.

### Site conditions

The site is located adjacent to the coast. Basic wind speed is 40.0m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20.0m/s.

The ground conditions are as follows:

Borehole 1 & 2

Ground – 0.5m    Made ground

0.5m – 1.0m       Loose to medium dense sands (N=10)

1.0m – 6.0m       Dense sands (N=40)

Below 6.0m        Rock, characteristic bearing strength = 4500 kN/m<sup>2</sup>

Groundwater is present at 4.0m

### Omit from consideration

Design of the stairs and lift/elevator

## SECTION 1

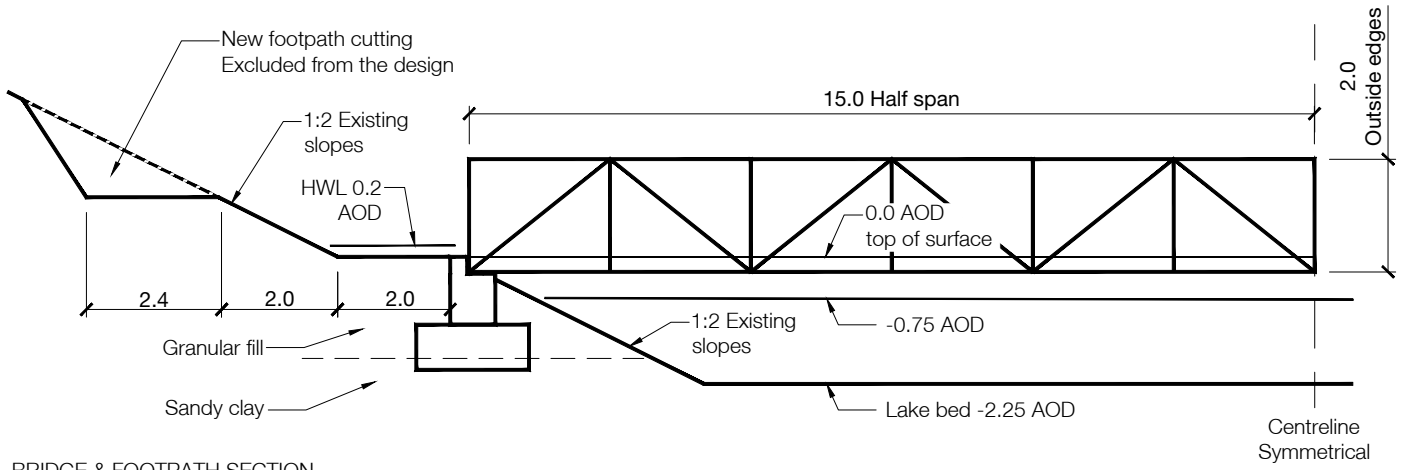
**(30 marks)**

- 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 number of bedrooms and their minimum areas. Write to your client proposing possible changes. As part of any proposals made, explain the effect these might have on your design. (10 marks)

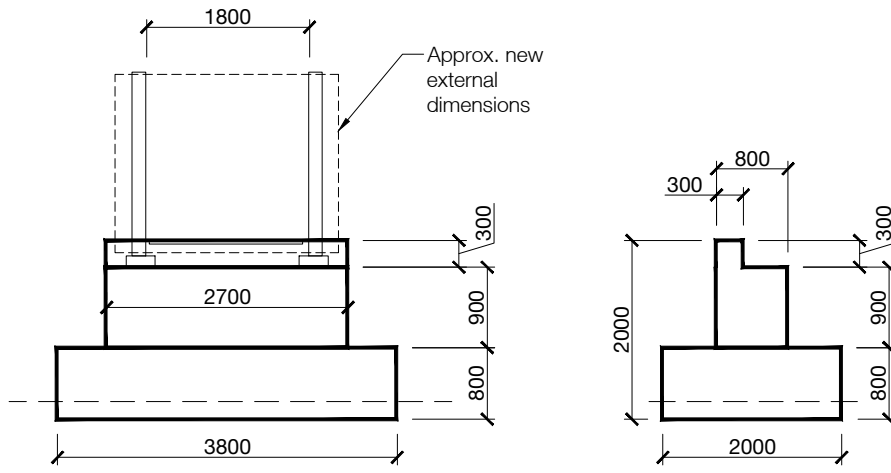
**SECTION 2****(70 marks)**

For the solution recommended in Section 1(a)

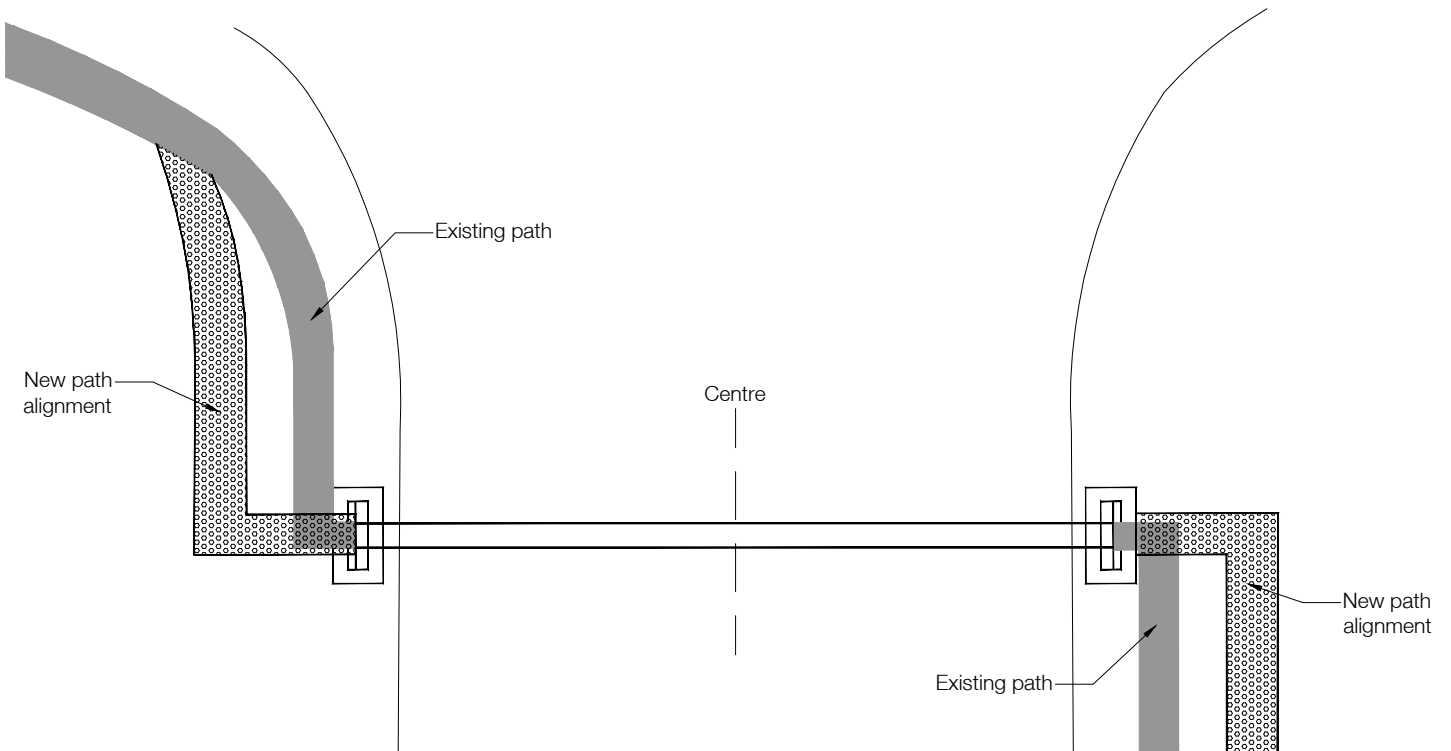
- c) Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. Include approximate A1-A3 carbon calculations for each of your principal elements. (30 marks)
- d) Prepare general arrangement drawings which may include plans, 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 perimeter foundation, ground slab, and vertical structure adjacent to the West boundary
  - b) the floor and vertical structure at Level 2 terrace over the bar/dining area
- (30 marks)
- e) Prepare a detailed method statement for the safe construction of the works. (10 marks)



**BRIDGE & FOOTPATH SECTION**  
Dimensions in meters



**FOUNDATION DETAILS**  
Dimensions in millimeters



NOTE: All dimensions on details are in millimetres. All other dimensions are in metres.

**FIGURE Q3**

## Q3. Replacement footbridge

### Client's requirements

1. An existing footbridge crosses a freshwater lake as shown in Figure Q3 in a national park which is always open to the public. The existing wooden deck is occasionally underwater after heavy rainfall and has deteriorated due to rot and needs to be replaced. The client wishes to replace and widen the deck and raise it by 1.0m. The client wishes to retain as much of the existing trusses and foundations as possible.
2. The internal width of the bridge is to be increased from 1.8m to 2.5m and is to remain close to or on the existing alignment. There is to be a 1.1m high handrail across the full length. A minimum headroom of 2.3m must be maintained above the deck.
3. The existing foundations are lightly reinforced concrete as shown on Figure Q3. Reinforcement has been determined by survey to be 16mm diameter bars at 200mm centres each way on each face at a cover of 70mm. The yield strength is 460 N/mm<sup>2</sup>. Concrete strength is 30 N/mm<sup>2</sup>
4. The existing truss is formed from 120x120x5 RHS sections of a yield of 355N/mm<sup>2</sup>. Connections are fully welded and may be assumed to have 75% of the capacity of the member. Access to the site is via a 2m wide gravel surface public paths which carry light maintenance vehicles only. There is a large car park and slipway into the lake 500m away for pleasure boats. This area can be used for a site compound.
5. The minimum water level is -0.75m AOD this is the normal water level. There is no navigation requirement under the bridge in service. High water level is 0.2m AOD. The catchment gives minimum 10 hours warning of a flood event.
6. The minimum depth of water in the main channel is 1.5m.

### Imposed loading

7. 7.5kN/m<sup>2</sup> footway  
2 x 10kN axle for a maintenance vehicle with axle spacing of 3 m and wheel spacing of 1.5 m.  
Wheel contact area 300mm x 300mm  
Horizontal load on handrail at 1.1m high – 1.5kN/m
8. Lateral flood loading on current bridge is estimated to be 3kN/m.

### Site conditions

9. Granular fill exists behind the full height of the abutments with  $\Phi = 30^\circ$   
Sandy clay at approximately -1.8m AOD has an allowable bearing capacity 150kN/m<sup>2</sup>. It has been determined that the friction coefficient under the foundation is 0.3.

### Omit from consideration

10. Design of cut slope for footpath realignment.

## SECTION 1

**(30 marks)**

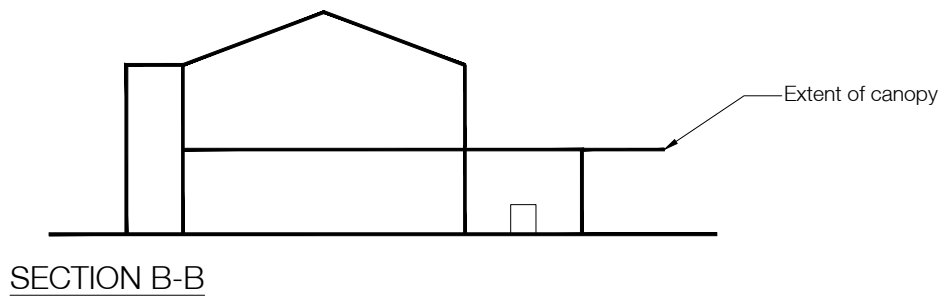
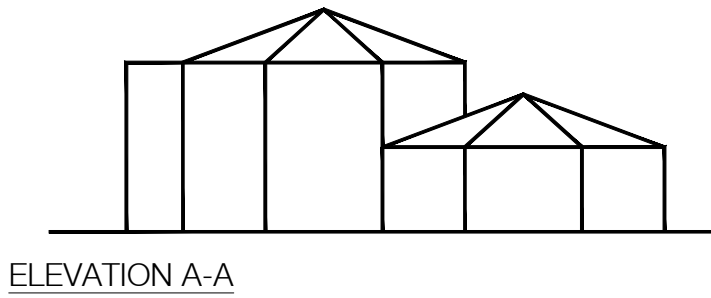
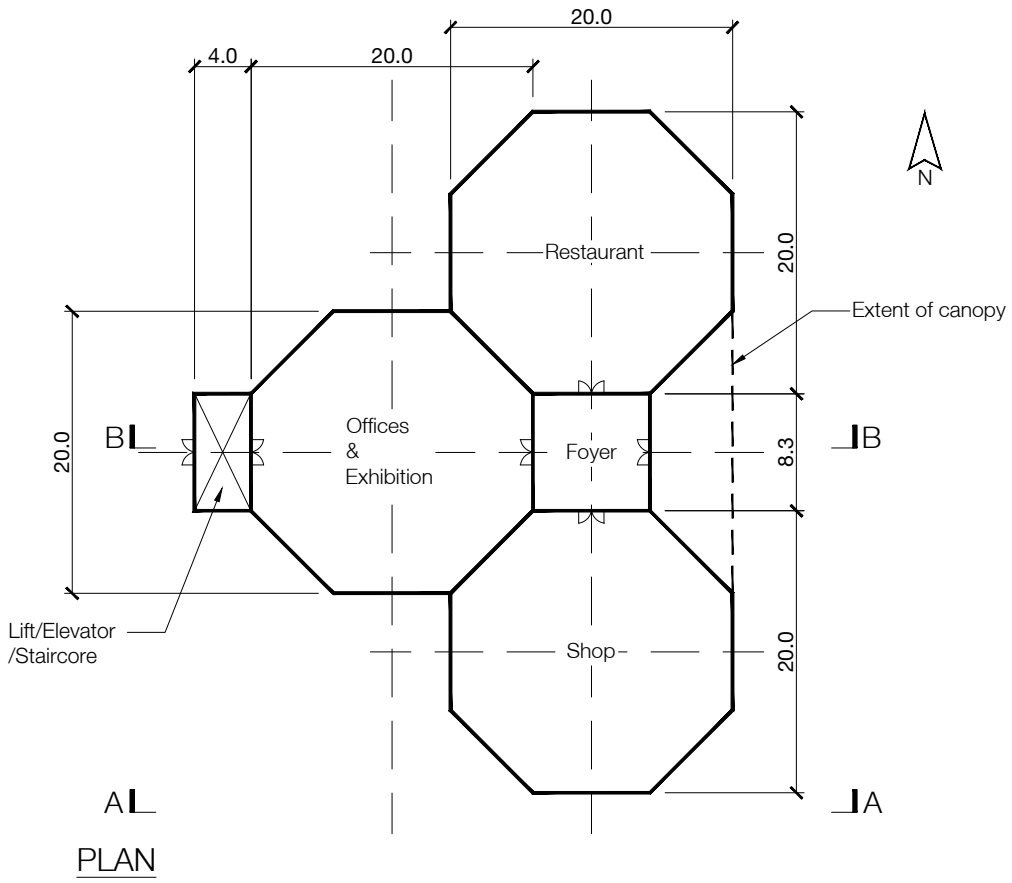
- a) Prepare a design appraisal with appropriate sketches indicating a viable and sustainable solution for the proposed bridge including the foundations. Clearly indicate the functional framing, load transfer, serviceability, and stability aspects of the scheme. Using sustainability as a key criterion, 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 increase in level. 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) vertical section through the new deck and its connection to the support structure
  - b) connection of the bridge to the supporting foundations (20 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. Country park visitors centre

### Client's requirements

1. A new visitors centre for a country park with panoramic views to the east across the park. See Figure Q4.
2. The building comprises a single-storey shop, a single-storey restaurant and a two-storey office and exhibition hall. Each area is a regular octagon in plan and has a pitched roof. The areas are connected by a single-storey entrance foyer with a flat roof and an external lift/elevator/staircase provides access to the first floor offices.
3. The external walls are to be of glass curtain walling. In order to maximise the views, no bracing is permitted on any eastern elevation except in the entrance foyer. The choice of cladding materials to the pitched roofs and staircase walls should consider maintenance and embedded energy.
4. All internal and external doors are to be 2.0m wide and 2.0m high. A minimum clear floor to ceiling height of 6.0m is required to all areas.

### Imposed loading

5. Roof 1.0 kN/m<sup>2</sup>
6. Floors 5.0 kN/m<sup>2</sup> which includes an allowance for partitions.

### Site conditions

The level site occupies a large area approximately one mile from the park entrance and is accessed by a single-track made road. There is a mature wooded area to the west of the proposed visitor centre under active woodland management for which there is a well-equipped maintenance workshop nearby.

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

### Ground Conditions

Ground level – 0.5m	Topsoil/ vegetation
0.5m – 1.0m	Medium Sand and Gravel N=10
1.0m – 3.0m	Clay Cu = 100
3.0m – 6.0m	Very Stiff Clay Cu = 200

No groundwater was encountered.

### Omit from consideration

Design of the lift/elevator 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 usage of materials, whilst maintaining the respective floor areas to the shop, restaurant, exhibition and office as the project cost estimate exceeds available finances thereby requiring a major rethink. 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 1(a):

- c) Prepare sufficient design calculations to establish the form and size of all the principal structural elements including any necessary checks on existing structural elements. Include approximate A1-A3 carbon calculations for each of your new 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 connection of the foyer roof to the restaurant and office & exhibition vertical structure
  - b) the perimeter foundation, ground slab and vertical support structure (30 marks)
- e) Prepare a detailed method statement for the safe construction of the works, including how temporary stability of the existing building will be maintained at all stages of construction. (10 marks)

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