

# Associate-Membership Examination

Friday 13 APRIL 2007

## Structural Engineering Design and Practice

9.30a.m. – 1p.m. and 1.30 – 5p.m. (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 books, 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 in the bottom right-hand corner. Only the answer book(s) 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 35 marks are allocated to Section 1 and 65 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 books 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.

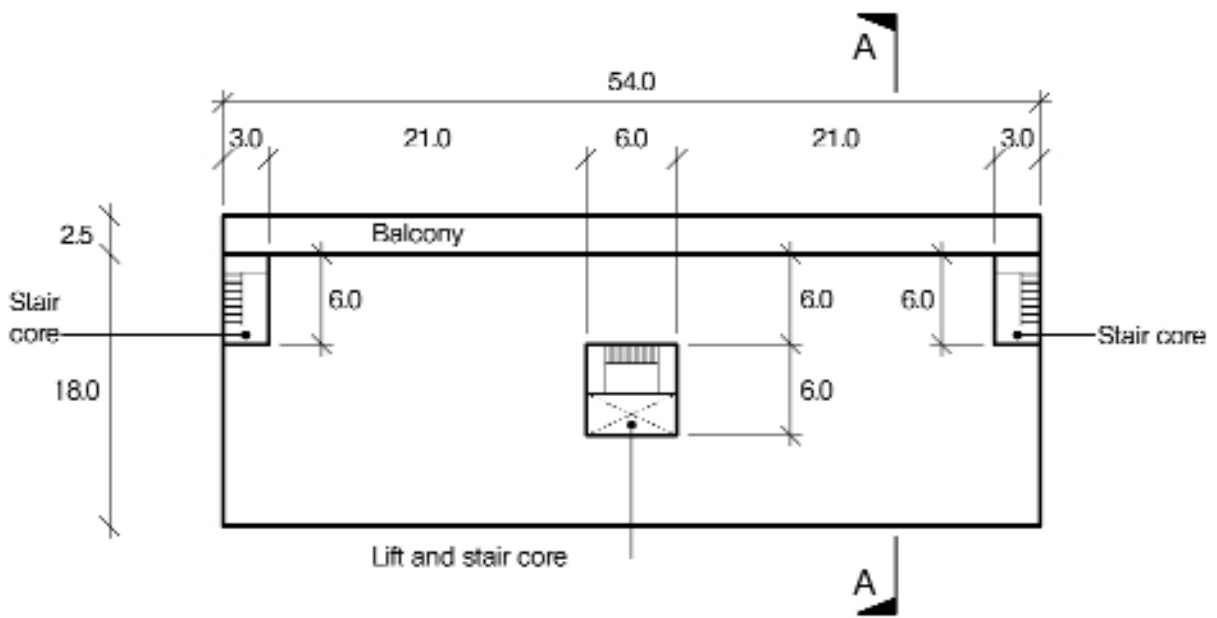
The unusual requirement of the examination is that you demonstrate the validity of the training and experience that you have acquired in recent years. The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural 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 your structural solution you must show by brief, clear, logical and systematic presentation that you understood the general structural engineering principles involved.

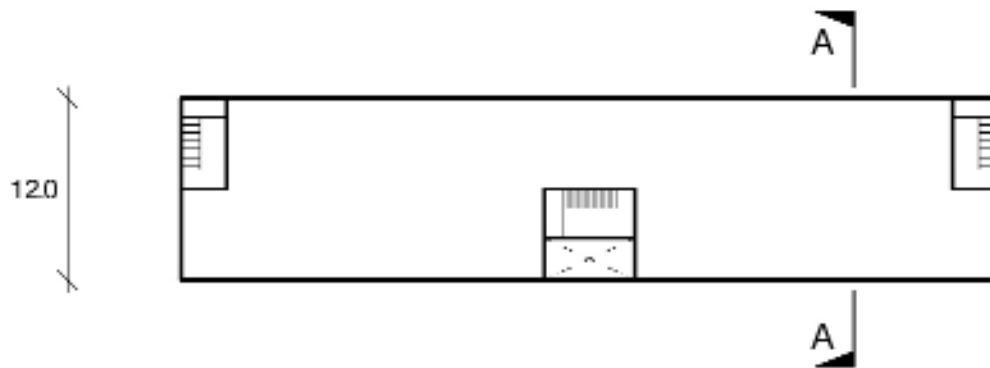
In selecting and developing your design you should also remember the guidance given in the Institution's report, Aims of Structural Design, and in particular:

- (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”.

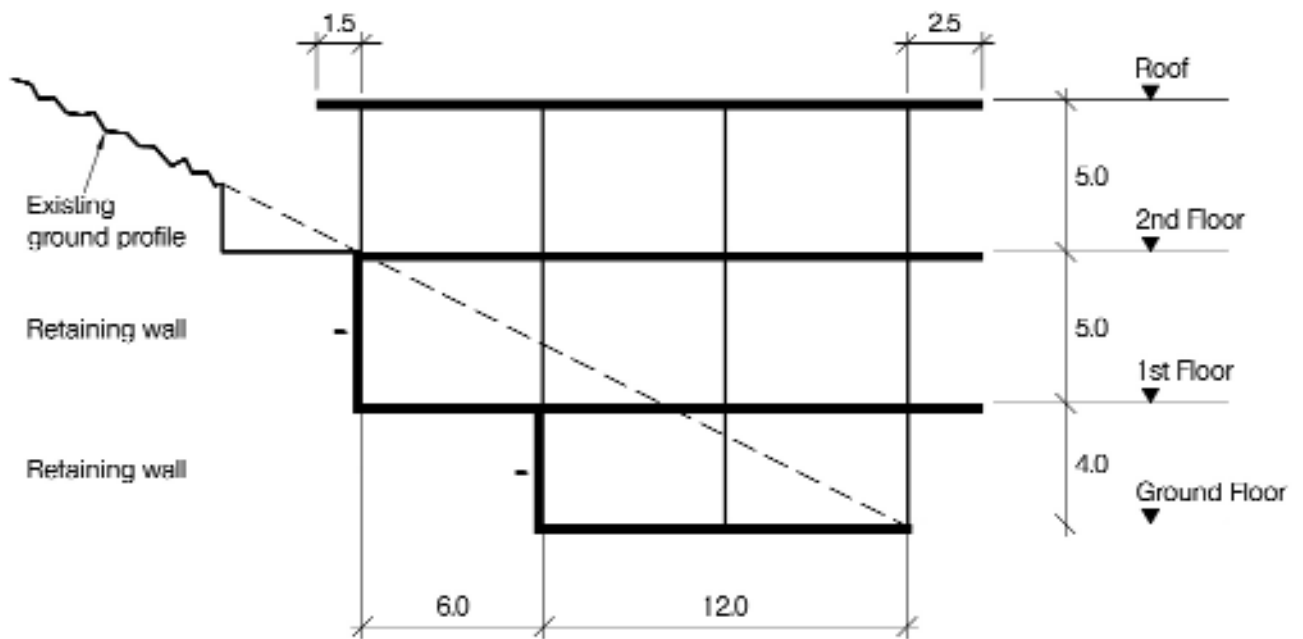
If you have difficulty in deciding the correct interpretation of a question, pay particular attention to point 6. notes to candidates, on the front cover. The examiners will take into account your interpretation – and the design you base on this – if this is clearly stated at the beginning of your answer.



FIRST AND SECOND FLOOR PLANS



GROUND FLOOR PLAN



SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q1

# Question 1. Exhibition / Art Gallery

## Client's requirements

1. A new private exhibition / art gallery built into sloping ground. See Figure Q1.
2. The first and second floor areas are to be column free spaces with a clear internal height of 3.5m.
3. The roof is to be clear span and exposed within the gallery for aesthetics. The roof is to be covered with composite steel cladding.
4. The exposed external walls are to be of glazed curtain walling.

## Imposed Loading

- |                         |                      |
|-------------------------|----------------------|
| 5. Roof                 | 1.0kN/m <sup>2</sup> |
| First and second floors | 6.0kN/m <sup>2</sup> |
| Ground floor            | 7.5kN/m <sup>2</sup> |
- Imposed loading includes allowances for finishes and services.

## Site Conditions

6. The site is on the side of a small hill on the outskirts of a large city.
7. Basic wind speed is 40m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20m/s.  
Note: The 3 second gust speed is used in the British Standard CP3 and the mean hourly wind speed is used in the British Standard 6399. Candidates using other codes and standards should choose an appropriate wind speed.
8. Ground conditions:

Ground level – 1.0m	Top soil and peat
1.0m – 2.0m	Soft weathered rock, allowable bearing pressure 150kN/m <sup>2</sup>
2.0m – 10.0m	Sandstone, allowable bearing pressure 1000kN/m <sup>2</sup>

## Omit from consideration

9. Detailed design of stair and lift cores although their contribution, if any, to the lateral stability of the building must be explained in Section 1a.

## SECTION 1

(35 marks)

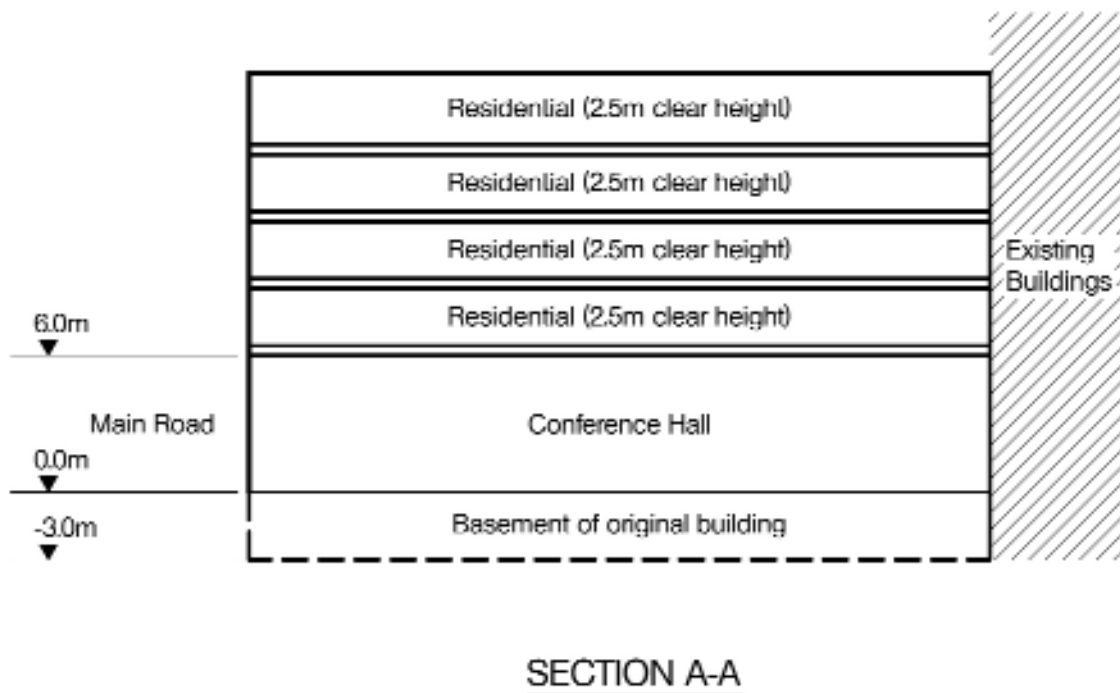
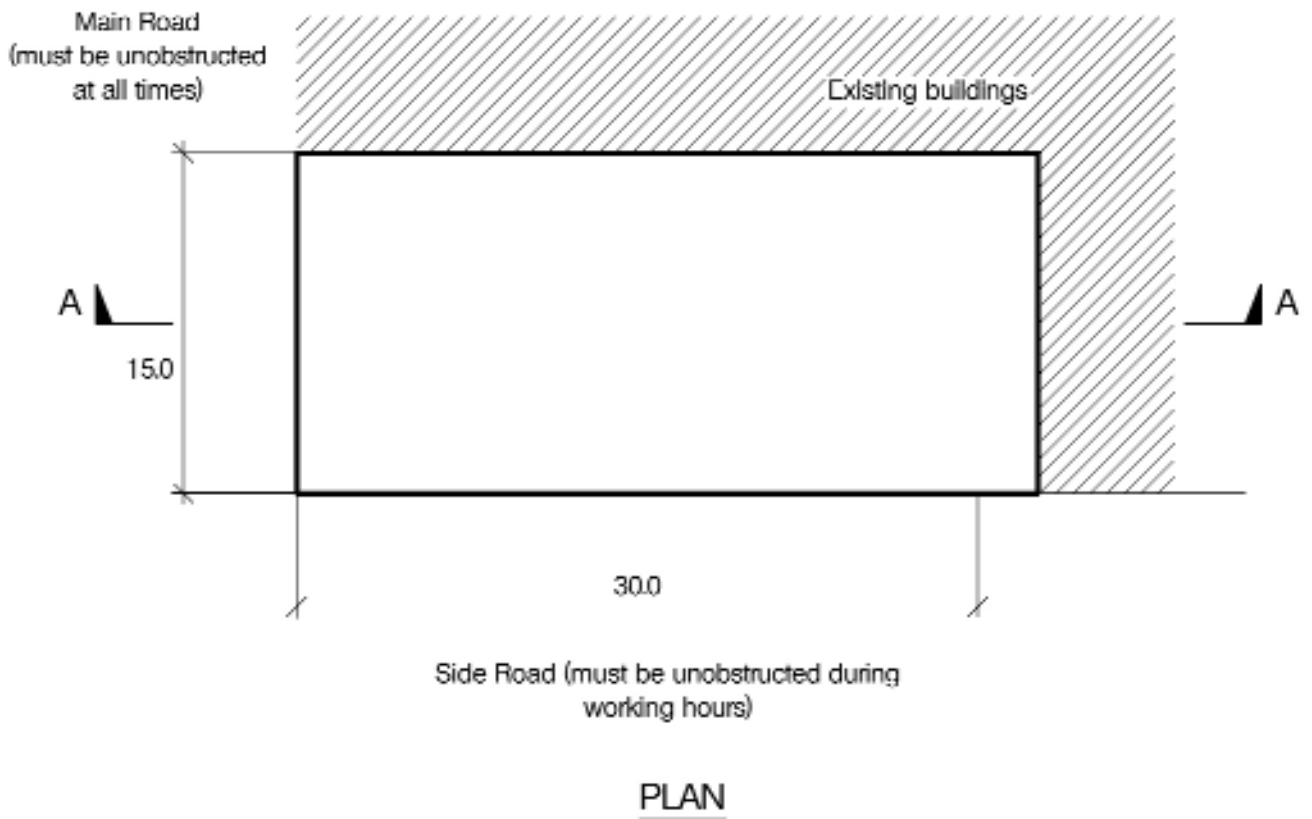
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (25 marks)
- b. After completion of construction the client finds he has insufficient storage space and asks if it is feasible to provide basement storage 15.0m long x 6.0m wide x 2.5m high. Describe the implications this will have on the original design and construction, using sketches as necessary to illustrate your ideas. (10 marks)

## SECTION 2

(65 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) A perimeter column floor and roof structural connection
  - (ii) A perimeter column and second floor beam connection to a retaining wall (25 marks)
- e. Prepare a detailed method statement for the safe construction of the building. (10 marks)



NOTE: All dimensions are in metres

FIGURE Q2

# Question 2. Conference Hall

## Client's requirements

1. A conference hall is to be constructed on the ground floor of a five storey residential development. See Figure Q2.
2. The conference hall is to have a 6m clear height. No internal columns or walls are permitted in the conference hall. There is to be no glazing to the elevations.
3. Four floors of apartments are required above the conference hall. Each floor is to have a 2.5m clear height between floor and ceiling. Each elevation is to be clad with brickwork but with 50 percent of the area glazed.
4. The site of the new building was originally the site of a building with a basement. This original building has now been demolished and the basement backfilled.
5. The new building abuts existing buildings on two sides. No loads are to be imposed on these adjacent existing buildings.
6. The roads adjacent to the site must remain open to traffic during normal working hours. The side road only may, however, be closed outside normal working hours.

## Imposed Loading

- |         |                      |
|---------|----------------------|
| 7. Roof | 1.0kN/m <sup>2</sup> |
| Floor   | 3.0kN/m <sup>2</sup> |
- Imposed loading includes allowances for finishes and services.

## Site Conditions

8. The site is level and located in a city centre close to a major river.
9. Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s.  
Note: The 3 second gust speed is used in the British Standard CP3 and the mean hourly wind speed is used in the British Standard 6399. Candidates using other codes and standards should choose an appropriate wind speed.
10. Ground conditions:

Ground level - 3m	Basement of original building filled with loose concrete rubble
3m – 20m	Sand and gravel, N = 20
Below 20.0 m	Stiff clay, C = 150kN/m <sup>2</sup>

Groundwater was encountered 4m below ground level.

## Omit from consideration

11. Detailed design of stair and lift cores although their contribution, if any, to the lateral stability of the building must be explained in Section 1a.

## SECTION 1

(35 marks)

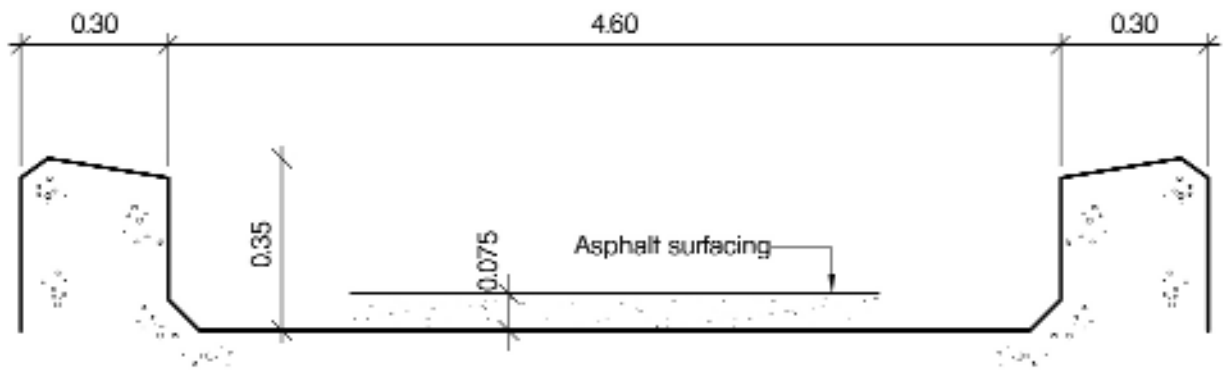
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (25 marks)
- b. The developer wants to include a single level underground car park below the conference hall. Explain the effect this will have on the design and outline any resulting changes to your original solution. (10 marks)

## SECTION 2

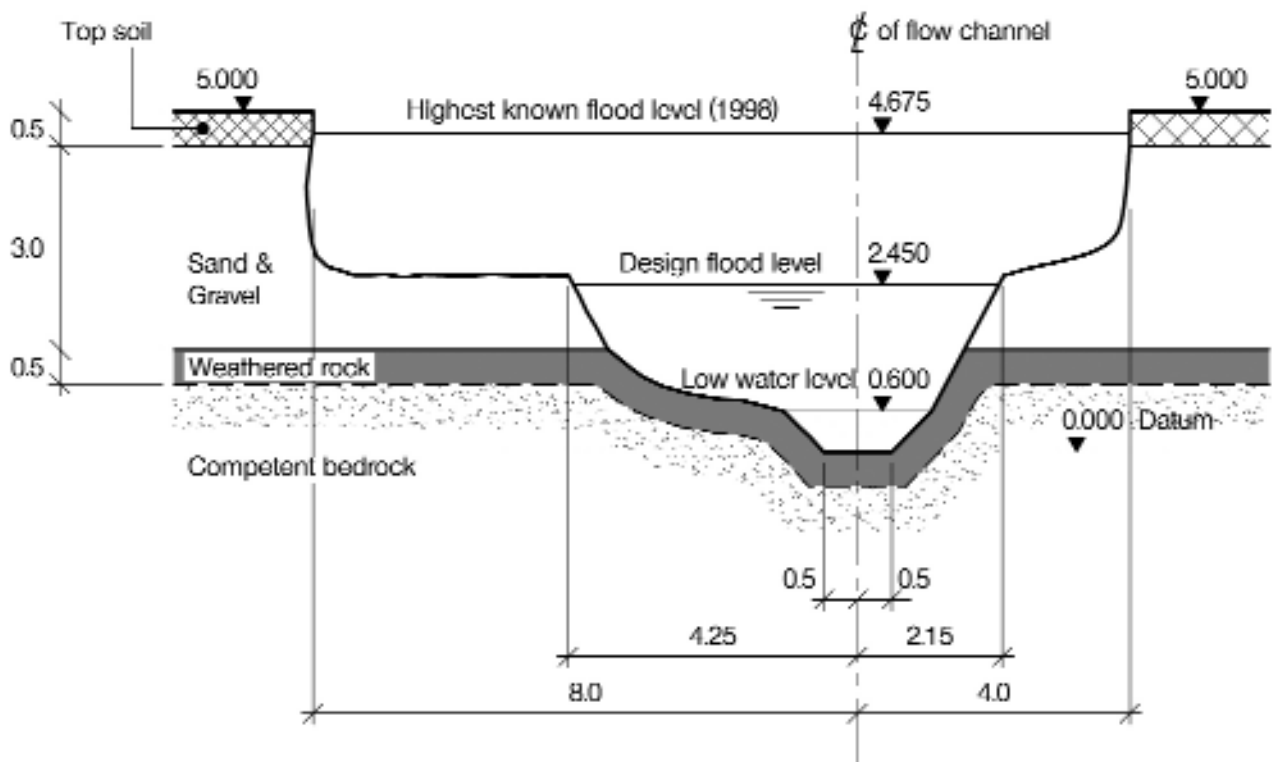
(65 marks)

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) Connection of a column adjacent to the road to a beam over the conference hall
  - (ii) Connection of a column adjacent to the existing buildings and its foundations (25 marks)
- e. Prepare a detailed method statement for the safe construction of the building. (10 marks)



SECTION THROUGH DECK



SECTION ON CENTRE LINE OF PROPOSED BRIDGE

NOTE: All dimensions are in metres

FIGURE Q3



# Question 3. Forestry Bridge

## Client's requirements

1. A permanent (service life of more than 40 years) 3-span vehicle access over a small river in a remote country area. See Figure Q3.
2. The abutments and intermediate supports are built clear of the design flood level so as to not restrict the river flow.
3. Aggregates for concrete are available locally. Portland cement (in bags) is readily available. Reinforcement must be transported from the nearest port 400km away. Structural steel and precast concrete are unobtainable. The local timber supplies are sufficient for formwork but not yet available for the structure.
4. A minimum vertical clearance of 0.9m is required above the design flood level to allow the passage of floating debris.

## Imposed Loading

5. Vehicle loading      Uniformly distributed load which varies with the length of the bridge that is loaded:
  - 28.2kN/m<sup>2</sup> for a loaded length of 3m
  - 21.6kN/m<sup>2</sup> for a loaded length of 4m
  - 10.5kN/m<sup>2</sup> for a loaded length between 6.5m and 23.0mCoexistent single transverse knife-edge load of 40kN/m, positioned, longitudinally, to have the most adverse effect on the bridge.

## Site Conditions

6. The ground conditions are shown in Figure Q3. The sand and gravel strata are highly variable with N values of 10 to 30 and are described as medium dense. The competent bedrock is intact granite with an unconfined compressive strength of 200MN/m<sup>2</sup>.
7. No groundwater was encountered during the summertime site investigation.

## Omit from consideration

8. Wind loading
9. Parapets, balustrades and hand railing

## SECTION 1

**(35 marks)**

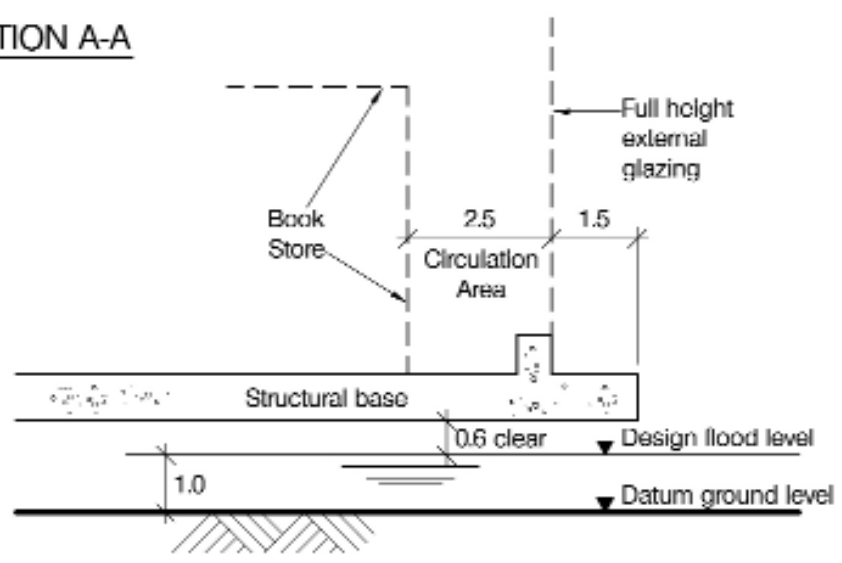
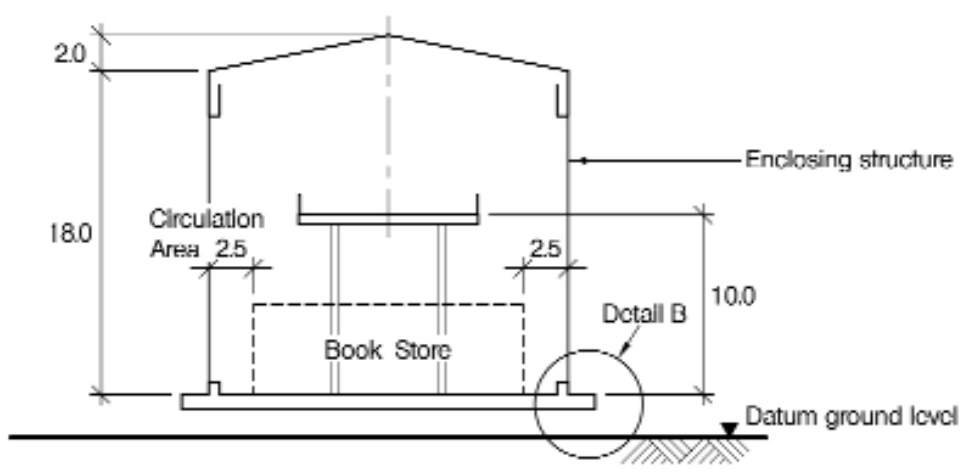
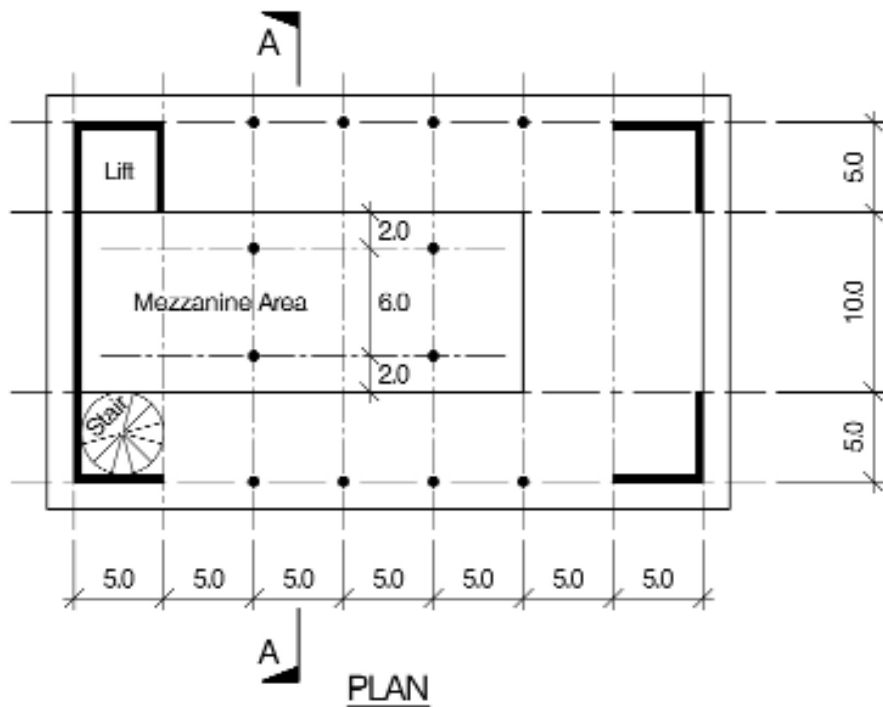
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (25 marks)
- b. The Client proposes a change to the brief. This requires a single-span vehicle access over the river with the abutments built clear of the highest known flood level of 4.675m above datum, again without restricting flow or trapping floating debris. Describe how this change could be achieved. (10 marks)

## SECTION 2

**(65 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 upstands along the edges of the deck
  - (ii) The top of the intermediate supports (25 marks)
- e. Prepare a detailed method statement for the safe construction of the three span bridge. (10 marks)



**NOTE:** All dimensions are in metres

**FIGURE Q4**

# Question 4. Library Mezzanine and Ground Floor

## Client's requirements

1. An elevated structural base and mezzanine floor for a library building. See Figure Q4. Note that the enclosing structure is to be provided under a separate design-and-build contract.
2. The design flood level is 1.0m above ground level and a 0.6m vertical clearance is required between the design flood level and the underside of the structural base.
3. The superstructure base must support the loads from the bookstore, the circulation area, the office-and-reading mezzanine area and the loads from the enclosing structure.

## Imposed Loading

4. 

Book store area	15.0kN/m <sup>2</sup>
Circulation areas	4.0kN/m <sup>2</sup>
Mezzanine area	2.5kN/m <sup>2</sup>

Imposed loading includes allowances for finishes and services.
5. The design and build contractor for the enclosing structure has supplied the following self weight loading:

End-bay walls	400kN/m
Intermediate columns	750kN per column

## Site Conditions

6. The site is flat and is located at the edge of a small town.
7. Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s.  
Note: The 3 second gust speed is used in the British Standard CP3 and the mean hourly wind speed is used in the British Standard 6399. Candidates using other codes and standards should choose an appropriate wind speed.
8. The site is beside the local river that has a history of flooding. The design flood level has been determined at 1.0m above local ground level.
9. Ground conditions:

Ground Level - 0.3m	Loose fill
0.3m - 2.3m	Silt and peat
2.3m- 5.0m	Clay, C = 150kN/m <sup>2</sup>
5.0m - 15.0m	Stiff clay, C = 200kN/m <sup>2</sup>
15.0m - 25.0m	Stiff clay, C = 300kN/m <sup>2</sup>

Variable groundwater levels were found in the silt and peat strata.

## Omit from consideration

10. Detail design of the enclosing structure. However, wind forces should be considered, developed and included in the calculations.
11. Detailed design of stair and lift cores.
12. Detailed settlement design.

## SECTION 1

(35 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. (25 marks)
- b. The Client proposes a change to the brief. This requires a single-level basement under the structural base with clear headroom of 3.0m. Describe how this change could be achieved. (10 marks)

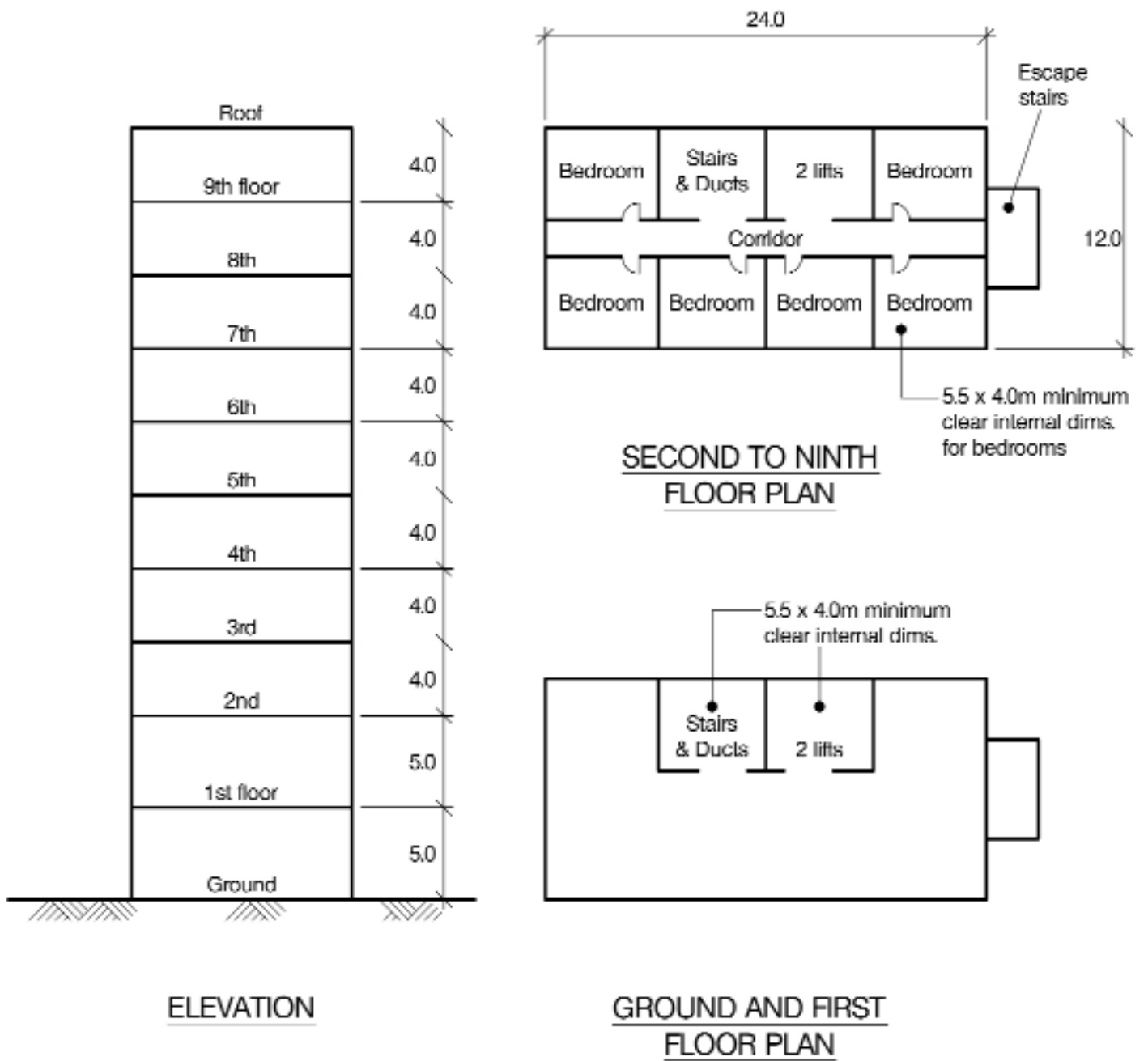
*continued overleaf*



**SECTION 2****(65 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 edge of the structural base at Detail B
  - (ii) The edge of the mezzanine slab and column head (25 marks)
- e. Prepare a detailed method statement for the safe construction of the structural base and mezzanine floor. (10 marks)



NOTE: All dimensions are in metres

FIGURE Q5

# Question 5. Hotel and Restaurant

## Client's requirements

1. A celebrity chef requires a new 10 storey building as a restaurant and boutique hotel. See figure Q5.
2. The building is sited on the bank of an estuary with beautiful views.
3. Ground and first floor are for reception, kitchens and restaurant and must be as open as possible. On these floors, apart from the lift / stair core no internal walls are permitted and no more than two internal columns are permitted.
4. Second to ninth floors are each to contain 6 bedrooms.
5. External bedroom walls are to be as open as possible to maximize views.
6. Heavy weight solid construction materials are preferred for reasons of durability and to reduce noise transmission.

## Imposed Loading

- |                        |                      |
|------------------------|----------------------|
| 7. Roof                | 1.5kN/m <sup>2</sup> |
| Second to ninth floors | 4.0kN/m <sup>2</sup> |
| Ground and first floor | 6.0kN/m <sup>2</sup> |

The roof and floor loadings include allowances for finishes, services and partitions.

## Site Conditions

8. Basic wind speed is 56m/s based on a 3 second gust; the equivalent mean hourly wind speed is 28m/s.  
Note: The 3 second gust speed is used in the British Standard CP3 and the mean hourly wind speed is used in the British Standard 6399. Candidates using other codes and standards should choose an appropriate wind speed.
9. Ground conditions:

Ground level – 1.5m	Topsoil
1.5m – 5m	Soft clay, C=35kN/m <sup>2</sup>
Below 5m	Granite with an allowable bearing pressure of 4000kN/m <sup>2</sup>

The highest recorded groundwater level is at 1.0m below ground level.

## Omit from consideration

10. Detailed design of main stairs and cladding although the weight of any cladding should be allowed for.
11. Design of the fire escape stairs.

## SECTION 1

(35 marks)

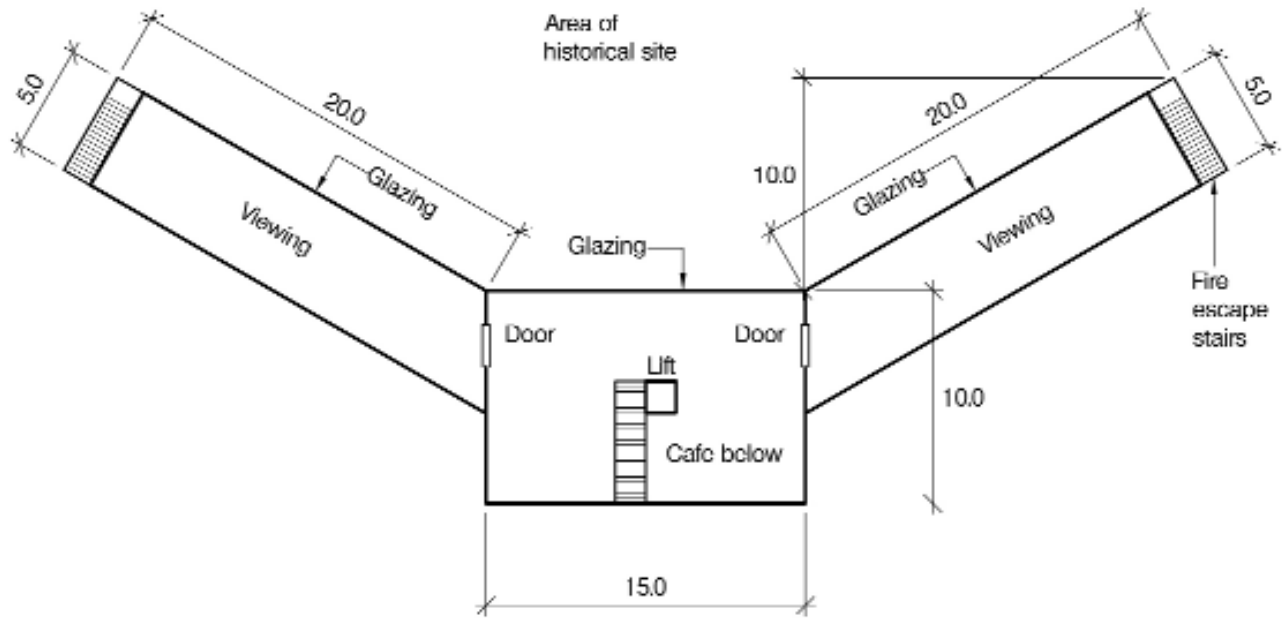
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (25 marks)
- b. During the design process a seismologist predicts that an earthquake offshore would cause a Tsunami wave 4m above ground level to sweep up the estuary. Describe how the structure could be revised to deal with this, using sketches if necessary to illustrate your ideas. (10 marks)

## SECTION 2

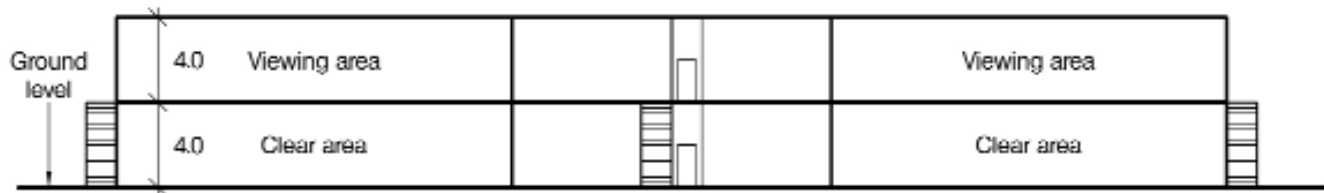
(65 marks)

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 lift / stair core 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 core to foundation connection.
  - (ii) A main floor structural element (beam or slab) at a hotel bedroom floor. (25 marks)
- e. Prepare a detailed method statement for the safe construction of the building. (10 marks)



PLAN



ELEVATION

NOTE: All dimensions are in metres

FIGURE Q6



# Question 6. Visitor Centre for Historical Site

## Client's requirements

1. A visitor / viewing centre for a historical site including access stairs and lift, interpretation centre, café and viewing area. See Figure Q6.
2. The façade facing the site is to be constructed with a minimum of obstructions.
3. The open ground floor areas below the viewing wings are to have the minimum of obstructions.

## Imposed Loading

- |                         |                      |
|-------------------------|----------------------|
| 4. Roof                 | 1.0kN/m <sup>2</sup> |
| First and ground floors | 5.0kN/m <sup>2</sup> |
| Stairs                  | 4.0kN/m <sup>2</sup> |
- Imposed loading includes allowances for finishes and services.

## Site Conditions

5. The site is level.
6. Basic wind speed is 44m/s based on a 3 second gust; the equivalent mean hourly wind speed is 22m/s.  
Note: The 3 second gust speed is used in the British Standard CP3 and the mean hourly wind speed is used in the British Standard 6399. Candidates using other codes and standards should choose an appropriate wind speed.
7. Ground conditions:

Ground level – 1.5m	Topsoil / soft silty clay
Below 1.5m	Dense sand with an allowable bearing pressure of 100kN/m <sup>2</sup>

## SECTION 1

**(35 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. (25 marks)
- b. Upon completion of the design the client asks whether the roof could be used as an additional viewing area. Describe the implications this will have on the original design. (10 marks)

## SECTION 2

**(65 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 stairs 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) Junction of viewing wings and main building
  - (ii) Junction of floor structure to stair /lift area of main building (25 marks)
- e. Prepare a detailed method statement for the safe construction of the building. (10 marks)





