The Institution of
StructuralEngineers

International HQ,
47-58 Bastwick Street,
London EC1V 3PS, UK

T +44 (0)20 7235 4535
E membership@istructe.org

www.istructe.org

Chartered Membership Examination

Monday 6 January 2020

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. Clear drawings and sketches are required. They do not have to be to a defined scale, but should be in proportion.
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.

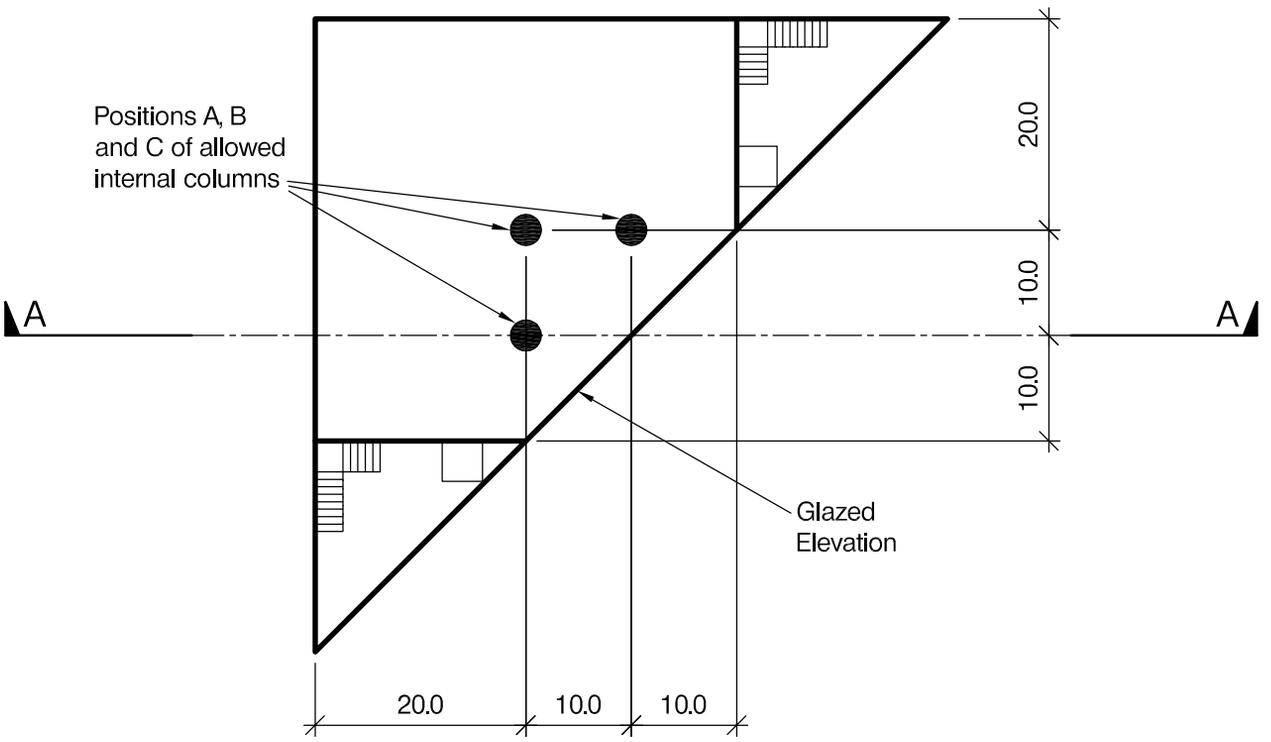
In selecting and developing your design you should also remember the guidance given in the Institution's report, Structural design - achieving excellence, and in particular:

(1) "the structure must be safe",

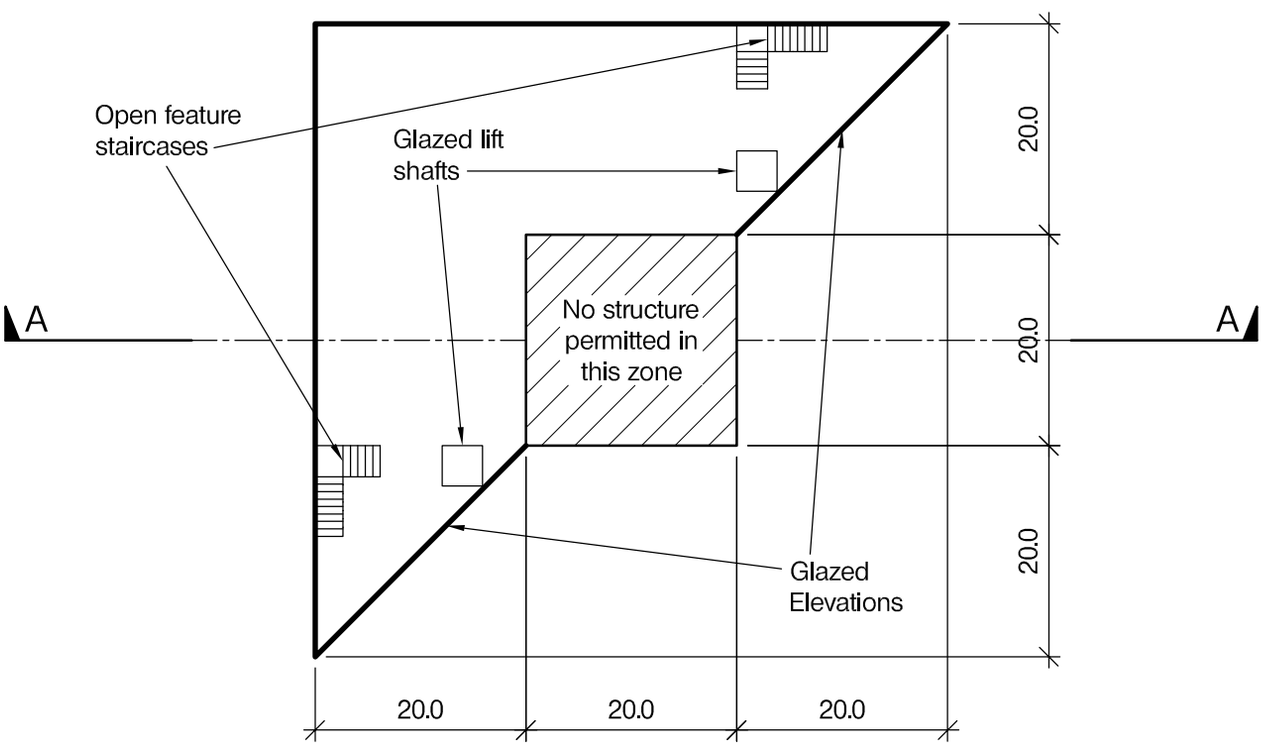
(2) "a good design has certain typical features – simplicity, unity and necessity",

(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.



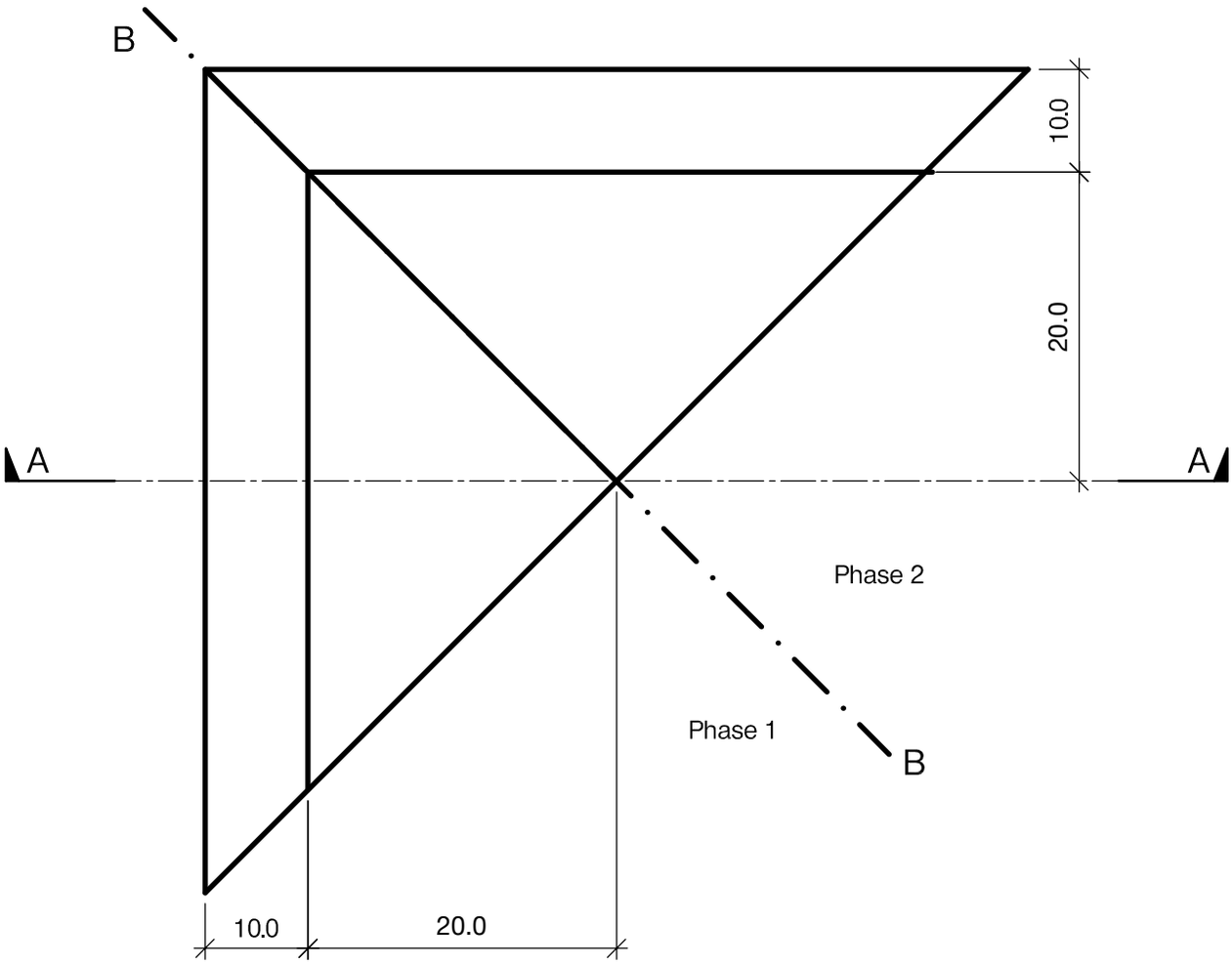
PLAN AT LEVELS 2 & 4



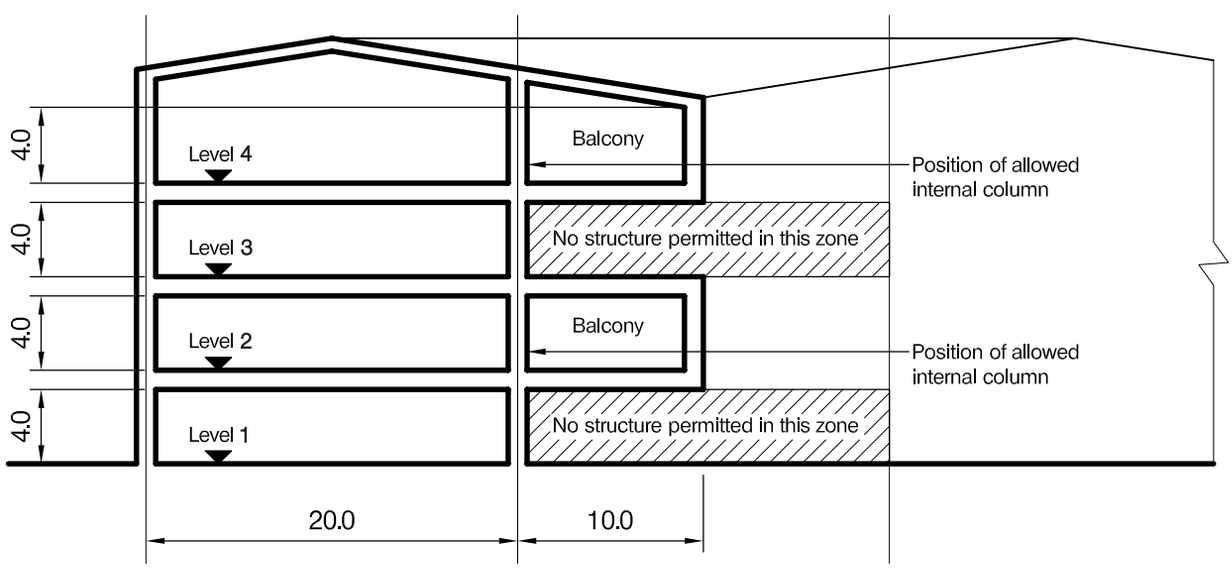
PLAN AT LEVEL 1

NOTE: All dimensions are in metres

FIGURE Q1-1



PLAN AT ROOF LEVEL



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q1-2

BLANK PAGE

Question 1. New Headquarters Building

Client's requirements

1. A new four-storey development consists of open plan offices. See Figure Q1.
2. All floors are to have a 4.0m clear height.
3. Levels 2 and 4 are to have a balcony. No structure is permitted between Levels 1 and 3 under the balcony area.
4. No internal columns are permitted except at three positions marked A, B and C in Figure Q1-1.
5. At the end of each building, a full-height triangular partially-glazed atrium is required. Access to the upper floors is by a glazed lift and an open staircase in each atrium. The staircase and lift shaft may not be used to provide stability to the building.
6. The roof is to be covered with metal sheeting with a maximum slope of 18.5 degrees.
7. The balcony elevation is to be fully glazed as shown in Figure Q1-1.

Imposed loading

8. Roof — 0.75 kN/m^2
   Offices — 2.5 kN/m^2 + 1.0 kN/m^2 for partitions

Site conditions

9. The site is located in a city centre site. Basic wind speed is 40.0m/s based on a 3-second gust; the equivalent mean hourly wind speed is 20.0m/s.
10. Ground conditions are constant across the site:

Ground level – 1.5m	Silty sand N = 10
1.5m – 5.0m	Dense sand and gravel N = 20
Below 5.0m	Very dense sand and gravel N = 45

Groundwater was not encountered

Omit from consideration

11. Design of the lift 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 design is complete, the Client advises you that there are not enough finances to complete the whole scheme and the Client wishes to construct the building in two phases as shown by the line B-B in Figure Q1-2. 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.

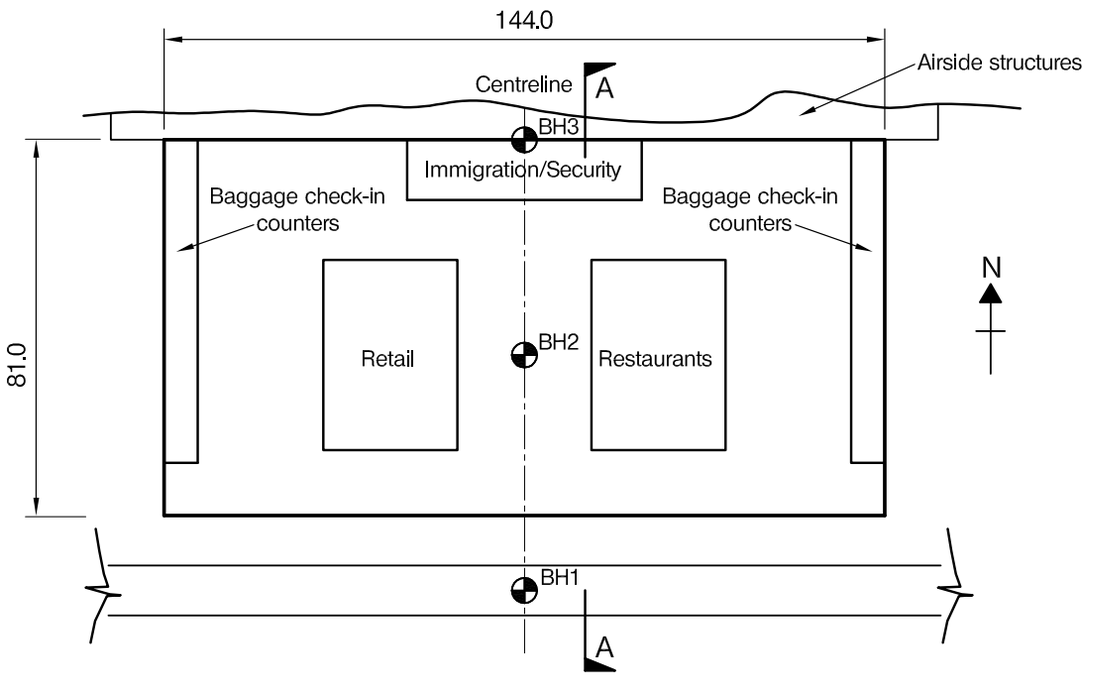
(20 marks)

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.

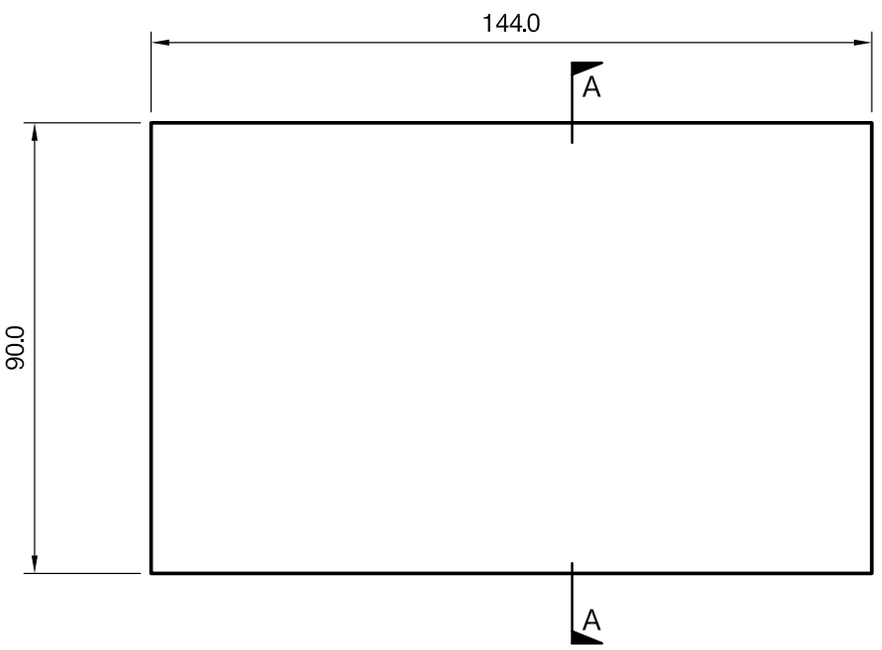
(20 marks)

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.

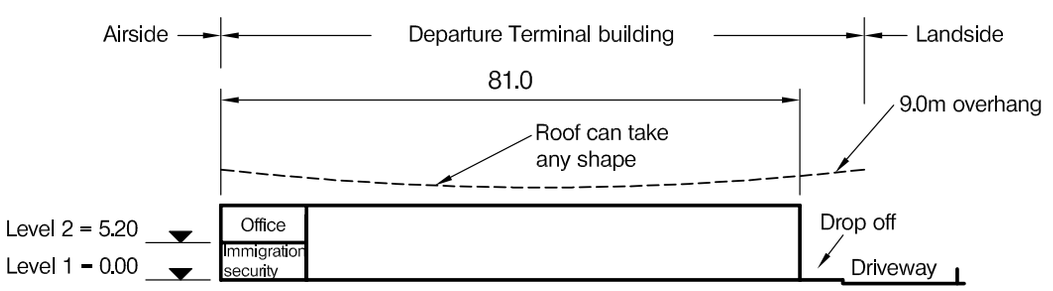
(10 marks)



LEVEL 1 PLAN



ROOF PLAN



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q2

Question 2. Airport departure terminal

Client's requirements

1. A new airport departure terminal building is to be constructed within a 144.0m by 81.0m footprint on the outskirts of a city. See Figure Q2. The roof of the terminal needs to have a 9.0m overhang on the landside to cover the drop off area. The terminal building will be adjacent to existing airside structures.
2. The facility will accommodate baggage check-in counters, security clearance/immigration control, retail and restaurants at Level 1 and offices at Level 2. The security clearance/immigration control at Level 1 and offices at Level 2 are to have a minimum plan area of 850m^2 per floor.
3. The clear height outside the security clearance/immigration control and office areas shall be 11.4m and internally uninterrupted. The roof can take any shape without inducing water ponding. However, the top of the roof cladding level must not exceed 15.0m.
4. Clear floor to ceiling height in the security clearance/immigration control area is to be 3.55m. A structure-free ceiling zone of 0.4m is required in this storey.
5. The building is to be clad with glazing on the south elevation. Other elevations and the roof are to be clad with insulated cladding panels.
6. Only two rows of internal columns with spacing not less than 45.0m in the North-South direction are allowed within the building. Internal and external columns spacing in the East-West direction shall not be less than 12.0m.
7. A minimum 2-hour fire resistance is required for all the principal structural elements.

Imposed loadings

8.

Roof	1.5 kN/m^2
Level 2	5.0 kN/m^2
Level 1	7.5 kN/m

Site conditions

9. The site is flat and level and located on the outskirts of a city. Basic wind speed is 40.0m/s based on a 3-second gust; the equivalent mean hourly wind speed is 20.0m/s.
10. Ground conditions vary across the site.

Borehole 1:

Ground level – 3.2m	Loose sand and gravel. N values vary between 4 and 8
3.2m – 6.2m	Medium dense sand and gravel. N values vary between 20 and 30
Below 6.2m	Rock. safe bearing capacity 7500 kN/m^2

Borehole 2:

Ground level – 0.3m	Topsoil
0.3m – 1.0m	Medium dense sand and gravel. N values vary between 20 and 30
Below 1.0m	Rock. safe bearing capacity 7500 kN/m^2

Borehole 3:

Ground level – 0.3m	Topsoil
Below 0.3m	Rock. safe bearing capacity 7500 kN/m^2

Ground water observed at 3.5m below ground level.

Omit from consideration

11. Detailed design of façade elements and interfacing with airside structures. However, the design appraisal shall address the structural implications.

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 design has been completed the Client advises you that the architect has proposed to add a basement under half the area of the building. This is to relocate the retail and restaurant facilities, allowing more baggage check-in counters and lounges at Level 1. Write a letter to the Client explaining the implications on your design.

(10 marks)

SECTION 2 (50 marks)

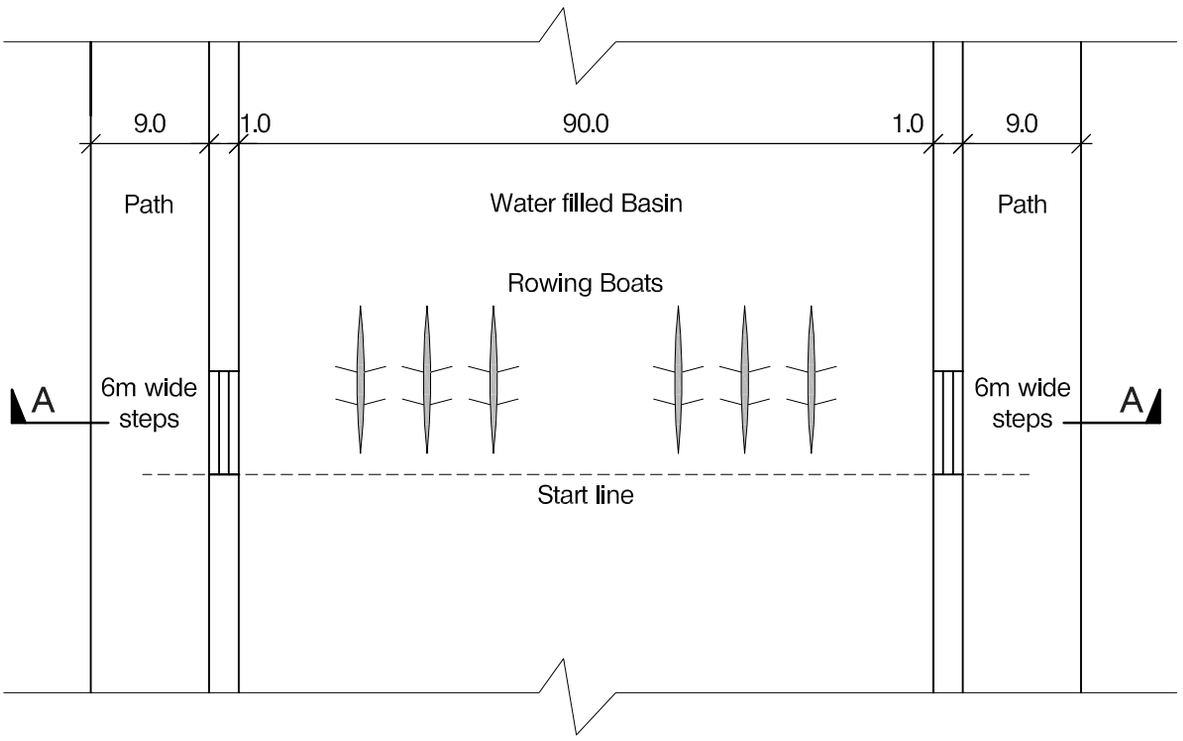
For the solution recommended in Section 1(a)

c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including foundations.
(20 marks)

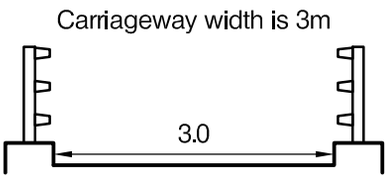
d. Prepare general arrangement drawings, which may include plans, section and elevations, to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes.
(20 marks)

e. Prepare a detailed method statement for the safe construction of the building and an outline construction programme.
(10 marks)

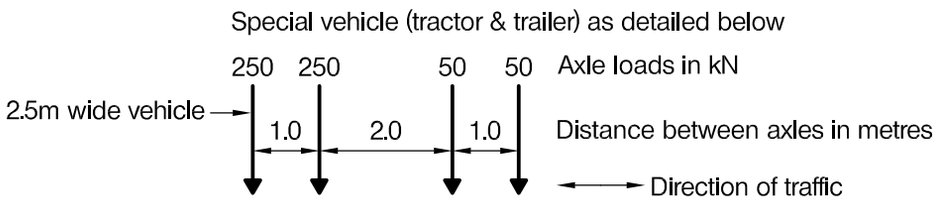
BLANK PAGE

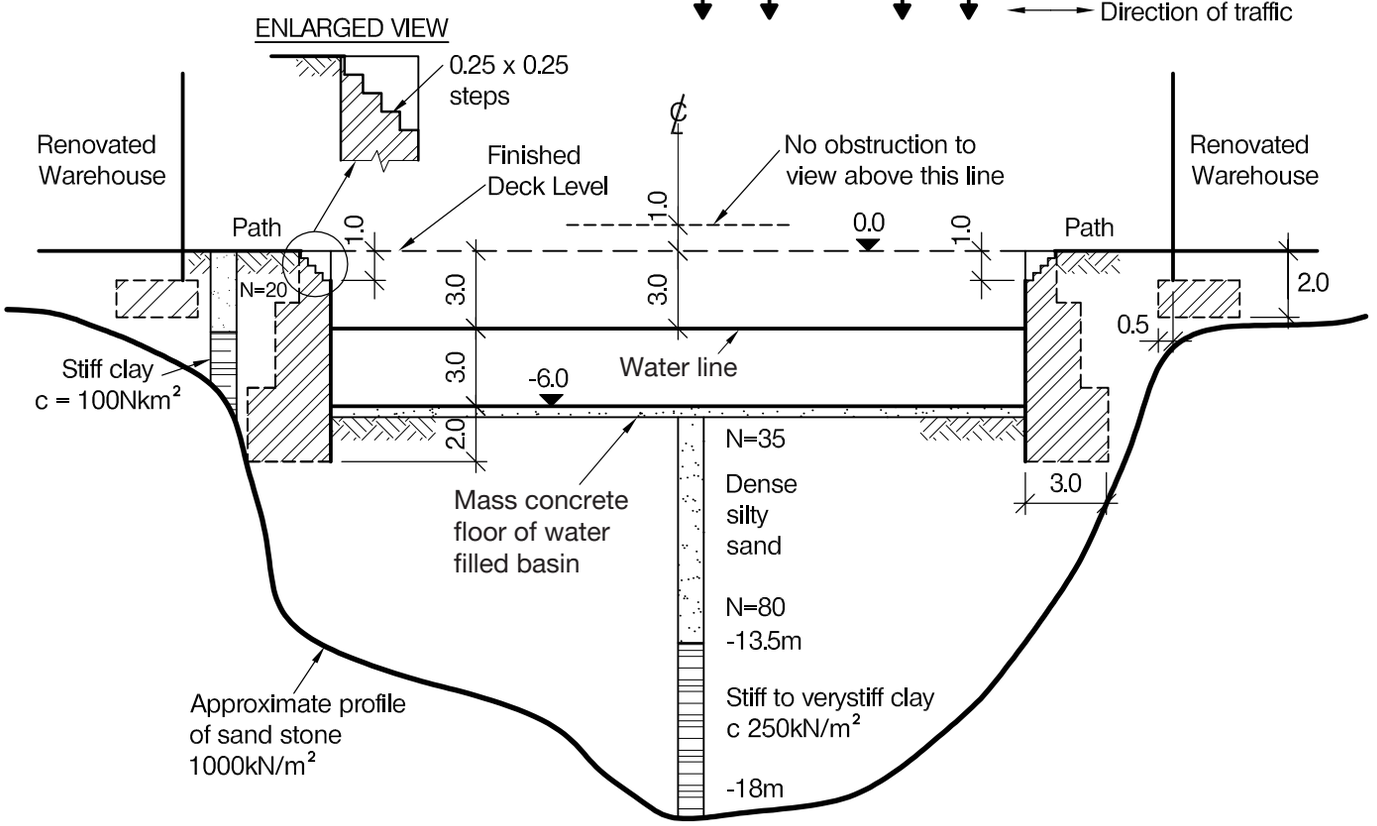


PLAN VIEW



TYPICAL X-section





SECTION A - A through the steps

NOTE: All dimensions are in metres

FIGURE Q3

Question 3. Bridge over water filled basin

Client's requirements

1. An existing 90.0m-wide basin is used for rowing race events. The client requires a 3.0m-wide multipurpose bridge and viewing platform across the basin above the race start line, see Figure Q3. The bridge will be used to transport goods between the warehouses at each side using the special vehicle as shown in Figure Q3, and as a viewing platform during racing.
2. The existing basin must remain in use during weekdays throughout the year except for a week in December and a week in April.
3. The existing basin walls are of brickwork stepped at the rear from 1.0m wide at the top to 3.0m wide at the base: see Figure Q3. The walls can carry a safe vertical working load of 150kN/m along their length. They are legally-protected structures and cannot be altered except for minor modifications to accommodate the bridge.
4. Permanent substructures may be constructed in the basin only in the central 10.0m width or up to 10.0m from either side. The stability of the walls must not be impaired by new structures.
5. Bridge superstructure must be at least 2.0m above the water level shown. The basin water level is kept constant. There is an access path around the basin which must not be obstructed by permanent structures.

Site conditions

6. The site is in an urban area. Basic wind speed is 40m/s based on a 3-second gust; the equivalent mean hourly wind speed is 20m/s.
7. Imposed loading: 5 kN/m^2 crowd loading, or the special vehicle (tractor trailer) as shown in Figure Q3.
8. Ground conditions: See details shown in Figure Q3 with borehole logs. Sandstone underlying the basin has a safe bearing capacity of 1,000kN/m^2

Omit from consideration

9. Design against loads from ship or boat impact.

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 completion of the design, the Client decides that no permanent structures may be placed on the paths around the basin, nor in the basin. 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.

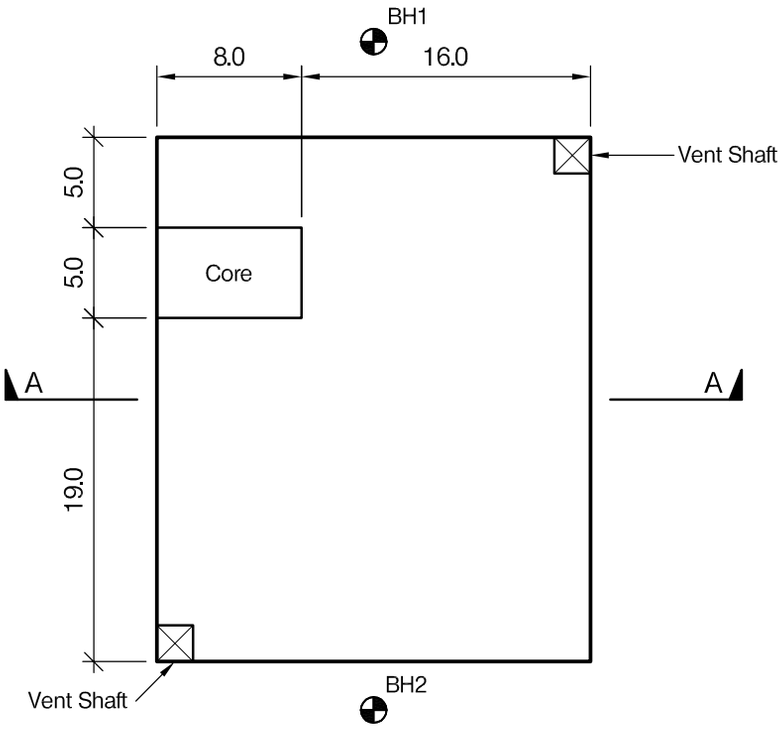
(20 Marks)

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.

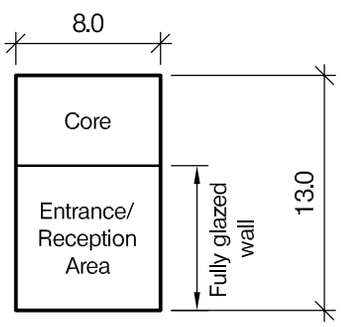
(20 Marks)

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.

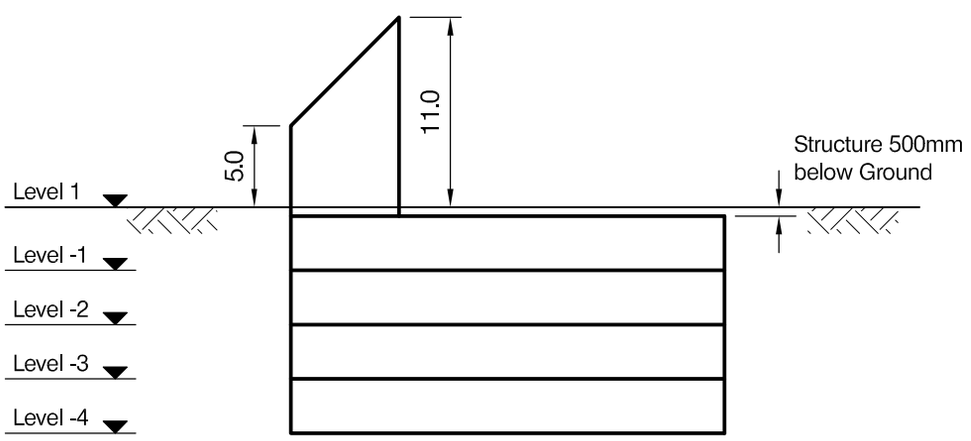
(10 Marks)



PLAN (Below Ground)



PLAN (Above Ground)



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q4

Question 4. Underground storage facility

Client's requirements

1. A new underground storage facility on the edge of a town – see Figure Q4. A feature entrance will be the only visible structure at ground level.
2. The ground floor entrance area features a sloping roof, and a fully glazed wall as defined in Figure Q4. The sloping roof extends over the core area. No structure is permitted along the length of the glazed wall.
3. External heights are given for the ground-floor entrance building. The building is intended to be aesthetically-pleasing. Structural element depths should be kept to a minimum.
4. The underground structure is a storage facility and no dampness or water penetration is allowable. There are two ventilation shafts as shown in Figure Q4. Each shaft is to have a clear area of 5m^2 at each floor. The internal walls of the shaft will have large and regular openings.
5. Internal floor-to-floor heights for the underground structure are to be kept to a minimum. A minimum ceiling height of 2.5m is required, with a 0.5m zone for celling and services.
6. Any internal columns must have a clear separation of at least 8.0m.
7. The top of the underground structure must be at least 0.5m below ground level. The ground will be surfaced for a car park on completion of construction.
8. A single stair and lift core extends the full height of the building.
9. A minimum fire rating of 2 hours is required throughout.

Imposed loading

10. Roof to entrance — 0.6 kN/m^2 (plant)
    Levels -1 to -4 — 7.5 kN/m^2
    Car park — 2.5 kN/m^2
    Ground floor entrance — 4.0 kN/m^2

Loadings include allowances for floor finishes, ceilings and services.

Site conditions

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

Ground conditions

12. Two boreholes are available

    Borehole 1:

Ground level – 2m	Topsoil/made ground
2m – 4m	Silty sand N =10
4m – 9m	Dense silty sand N = 35
Below 9m	Rock, safe bearing capacity 2000 kN/m^2

    Borehole 2:

Ground level – 4m	Topsoil/made ground
4m – 6m	Silty sand N =10
6m – 14m	Dense silty sand N = 35
Below 14m	Rock, safe bearing capacity 2000 kN/m^2

    Ground water – 2m below ground level in both bore holes.

Omit from consideration

13. Detailed design for staircases and lifts within cores.
    Glazed façade.

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 completion of the design and before construction has started, the client states that they may wish to build a 3-storey residential unit over the underground storage at a later date. Write a letter to the Client explaining the implications on 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)

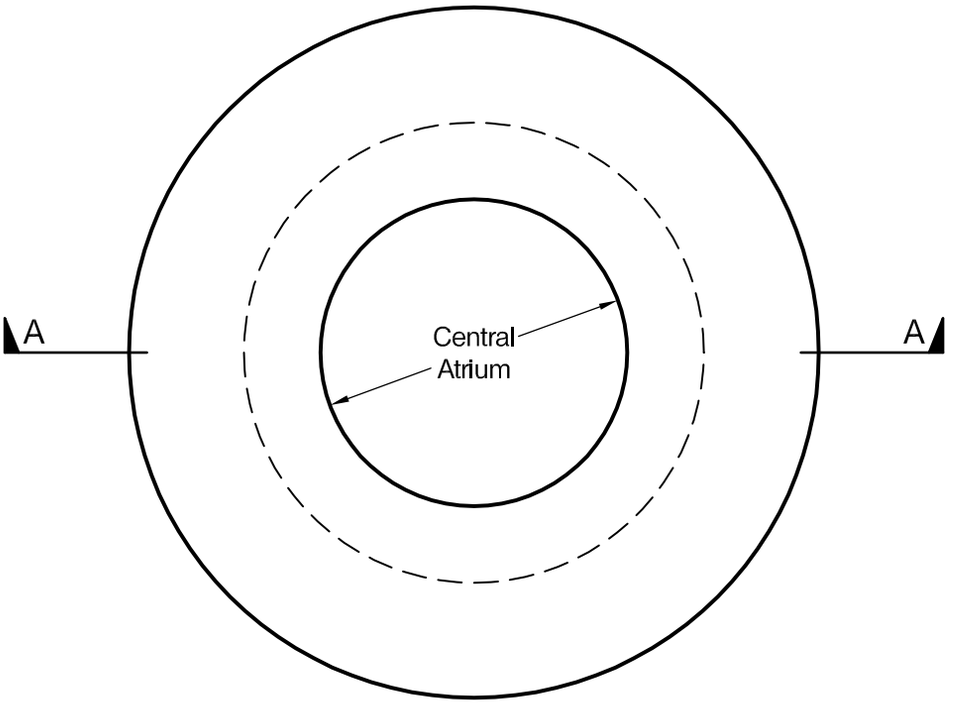
d. Prepare general arrangement drawings, which may include plans, sections and elevations, to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes.

(20 Marks)

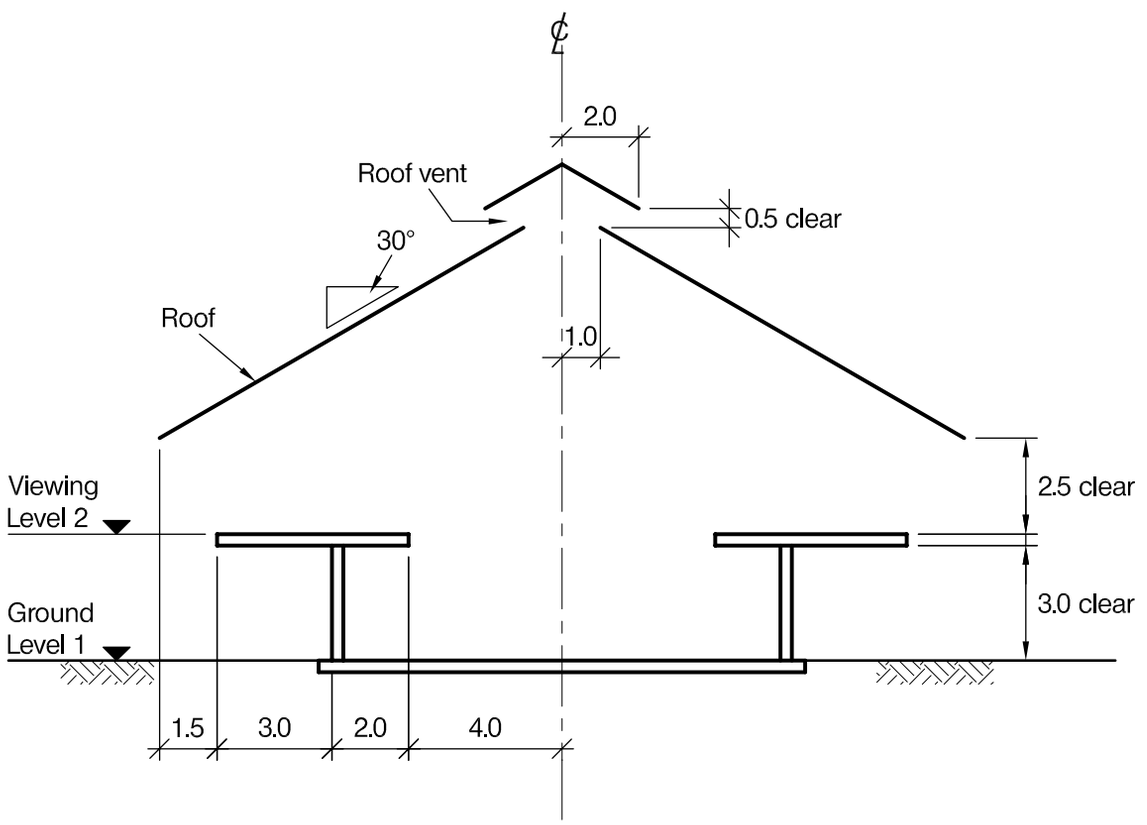
e. Prepare a detailed method statement for the safe construction of the building and an outline construction programme.

(10 Marks)

BLANK PAGE



PLAN AT VIEWING LEVEL 2



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q5

Question 5. Bar and viewing lodge for game park

Client's requirements

1. A big-game park in a remote tropical area requires a new two-storey lodge for viewing animals. The lodge will overlook a lake at a location where animals come to drink. There is to be a central full-height atrium with a centrally placed vent in the roof. See Figure Q5.
2. The lodge building is to be circular, 12.0m in diameter at level one and 18.0m at an open sided viewing area on level two. To provide shade the roof is to overhang the viewing area by 1.5m. No structure is allowed to be outside the 12.0m ground floor perimeter between ground and viewing platform. See Figure Q5.
3. Any timber structure must be kept at least 0.2m above ground to mitigate against attack by termites. The main structural elements must be robust enough to withstand accidental impact from animals.
4. The game park is at one end of a 30km-long lake with poor access by road. A railway runs to a town at the other end of the lake. Stone and timber construction materials are widely available locally whereas steel and concrete must be imported.

Imposed loading

5. Roof 0.5 kN/m^2
   Ground and first floor, including an allowance for finishes and partitions 5.0 kN/m^2

   A single accidental point load of 20.0 kN shall be considered to act horizontally, anywhere within 3.0m from ground level, on a main column or beam. This is for animal impact.

Site conditions

6. The site is in a remote countryside area on the edge of a large lake.
7. Basic wind speed is 46.0m/s based on a 3-second gust; the equivalent mean hourly wind speed is 23.0m/s.
8. Ground conditions

Ground level – 1.0m	Topsoil
1.0m – 18.0m	Clay, varying linearly from firm, c = 40 kN/m^2 to very stiff, c = 200 kN/m^2
Below 18.0m	Bedrock, safe bearing capacity 1800 kN/m^2

Groundwater was not encountered

Omit from consideration

10. Detailed design of 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 design has been completed but before construction starts the District Building Authority points out that a volcano about 25km away may erupt and the roof must be designed for ash live loading of 2.5 kN/m^2. The ash may be hot. Write a letter to the client outlining possible solutions for this problem. Illustrate with sketches as necessary.

(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 material transportation and any temporary works that may be required.

(10 marks)

International HQ,
47-58 Bastwick Street,
London EC1V 3PS, UK

T +44 (0)20 7235 4535
E membership@istructe.org

www.istructe.org