The Institution of Structural Engineers

Associate-Membership Examination

Thursday, 5 July 2018

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 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. 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.

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 structural solutions you must show by brief, clear, logical and systematic presentation that you understood the general structural engineering principles involved.

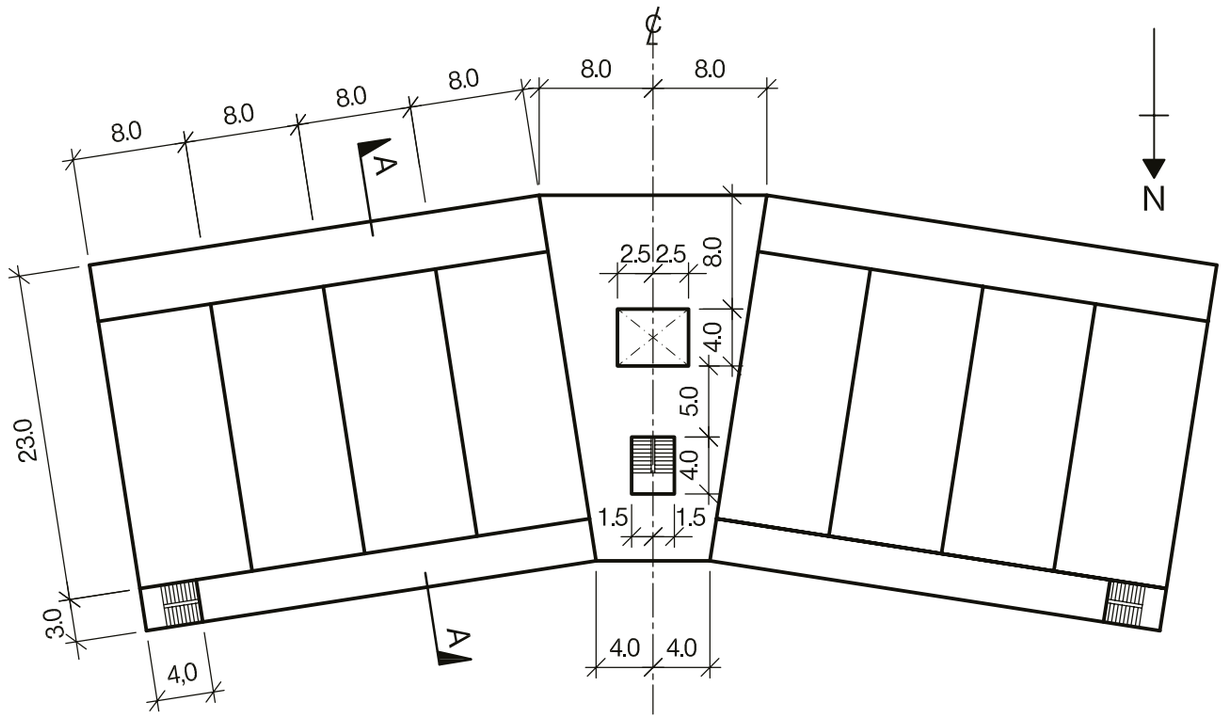
In selecting and developing your design you should also remember the guidance given in the Institution's report, Aims of Structural Design, and in particular:

(1) "the structure must be safe",

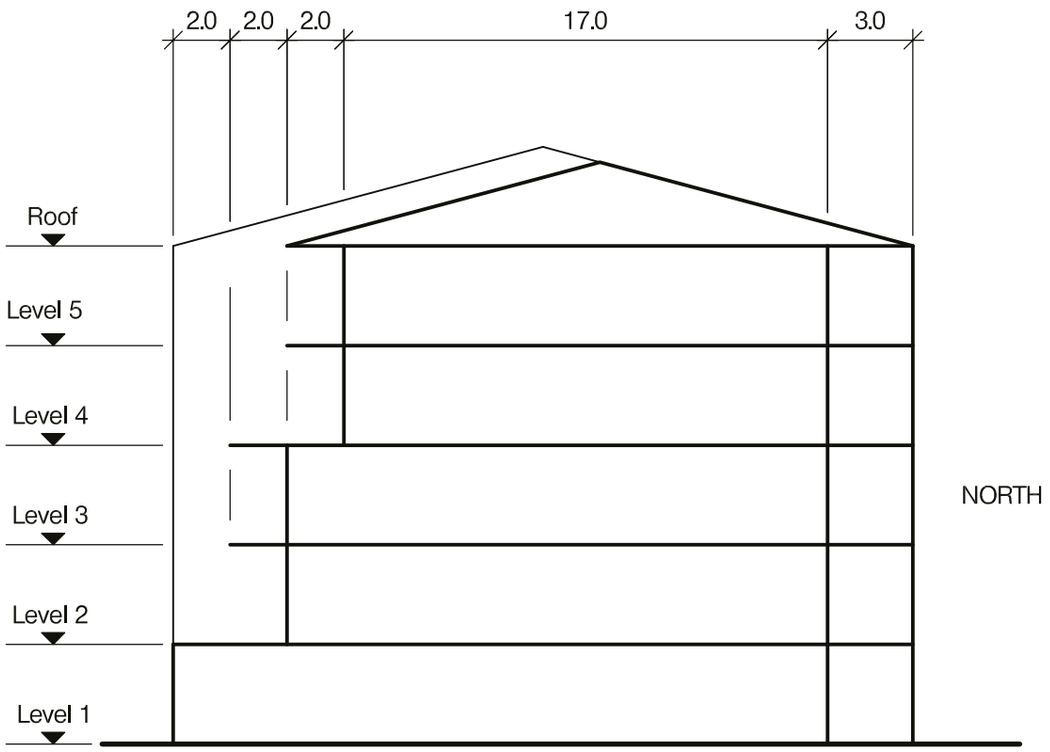
(2) "a good design has certain typical features – simplicity, unity and necessity",

(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.



PLAN AT LEVEL 2



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q1

Question 1. Residential Development

Client's requirements

1. A new five-storey residential development consisting of 40 apartments. See Figure Q1.
2. The development is to have eight apartments per floor, four located each side of a central atrium. Upper floors have balconies and are set back from those below: see Fig. Q1.
3. Access to the upper floors is by a lift and a main staircase located in the central atrium and by staircases located at the end of each 3.0m-wide corridor.
4. No columns are permitted in the central atrium area or in any of the apartments. Internal and perimeter columns are to have a minimum spacing of 6.0m.
5. A minimum clear internal height of 2.6m is required to each apartment floor. Each floor is to have a false ceiling service zone of 0.4m below any structure.
6. The south elevation of the apartments and the north and south elevations of the atrium are to be fully glazed. The remaining elevations are to be clad in a composite cladding system.
7. No foundations are permitted outside the plan profile of the building
8. The roof is to have an overhang of 2.0m beyond the eaves on the south elevation over the apartment balconies and to have a pitch of 15 degrees.

Imposed Loading

9.

Roof	0.75kN/m^2
Apartments	2.5kN/m^2
All other areas	4.0kN/m^2

Site Conditions

10. The site is located in open countryside. Basic wind speed is 52.0m/s based on a 3-second gust; the equivalent mean hourly wind speed is 26.0m/s.
11. Ground conditions are constant across the site: No ground water was encountered

Ground level – 0.5m	made ground
0.5m – 2.0m	soft silty sand N=3
Below 2.0m	dense silty sand N=15

Omit from Consideration

12. Detailed design of the lift and stairs.

SECTION 1 (30 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.

(20 marks)

b. After the construction has commenced the client advises you that he wishes to add a 4.0m-deep basement under the atrium area for storage. Write a letter to the Client explaining the implications on your design and the construction.

(10 marks)

SECTION 2 (70 marks)

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

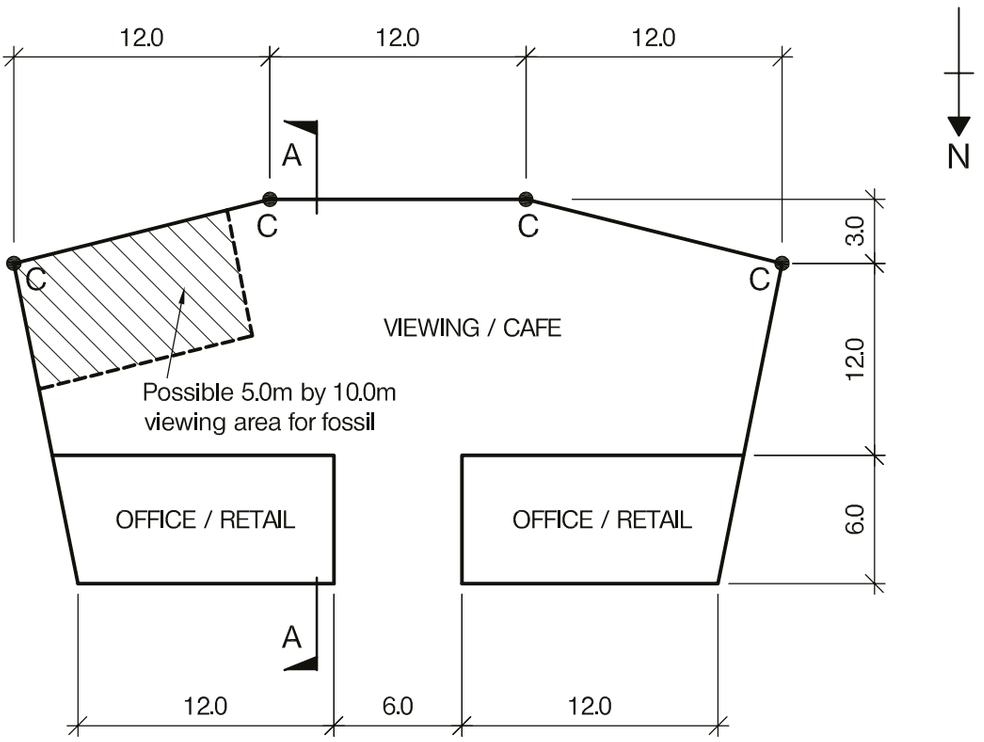
(30 marks)

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:
   i. The roof projection over the Level 5 balconies
   ii. A perimeter column and foundation detail

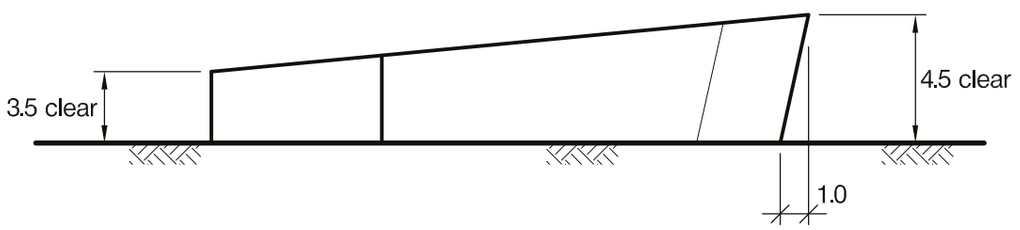
(30 marks)

e. Prepare a detailed method statement for the safe construction of the building

(10 marks)



PLAN AT GROUND LEVEL



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q2

Question 2: Bird Sanctuary Viewing Centre

Client's requirements

1. An open-plan viewing centre and cafe with a separate area for offices and retail use is required for a bird sanctuary at an inland lake. See Figure Q2.
2. The south-facing elevation is to be fully-glazed and is to have a clear height of 4.5m. Columns are only permitted along this elevation at locations marked "C": see Figure Q2.
3. Internal columns are only permitted along the partition walls separating the viewing/cafe area and the office/retail areas.
4. The minimum clear headroom on the north wall is to be 3.5m. See Figure Q2.
5. A "green" roof is required consisting of 0.5m depth of soil and grass on a drainage layer and waterproof membrane.
6. Elevations other than the glazed south-facing elevation may be of brickwork, timber or composite cladding panels

Imposed loading

7. Roof 10 kN/m^2 which includes the weight of the green roof
   Ground floor 7.5kN/m^2
   The roof and floor loadings include allowances for finishes and services.

Site conditions

8. The site is in level and open countryside. Basic wind speed is 44m/s based on a 3-second gust; the equivalent mean hourly wind speed is 22 m/s.
9. Ground conditions:
   Ground level – 1.0m Topsoil
   1.0m – 20.0m Porous rock, allowable safe bearing pressure 600kN/m^2
   The highest recorded ground water level is 1.8m below ground level.

Omit from consideration

10. Design of the internal partition walls. The supporting structure to the south elevation glazing and the cladding support to all other elevations should be designed but the design of the actual glazing panels and cladding may be omitted.

SECTION 1 (30 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.

(20 marks)

b. During foundation works, fossilised remains of a dinosaur are found under the south-east corner of the building footprint and 1.5m below the proposed ground floor. The Client asks how these could be left in-situ and displayed under a 5.0m by 10.0m glass floor viewing area. Write a letter to the client outlining possible measures to achieve this and how it would affect the structure. Illustrate your reply with sketches as necessary.

(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 principal structural elements and foundations.

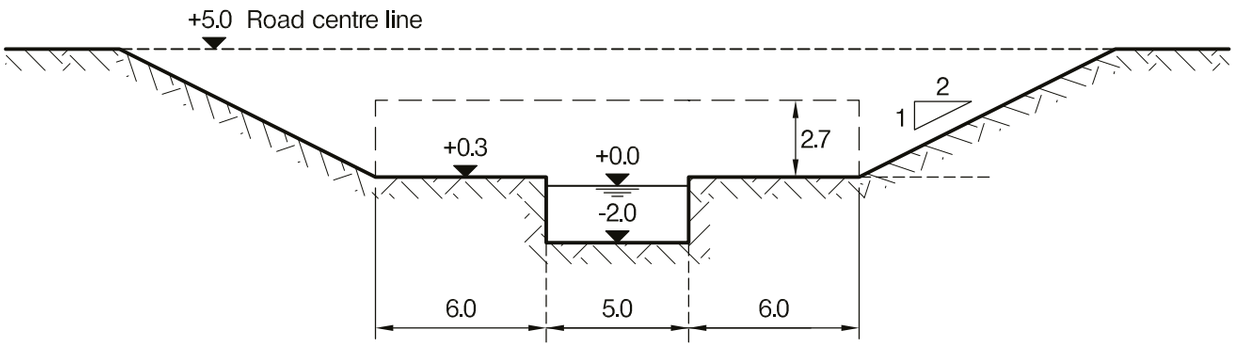
(30 marks)

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:
   (i) The connection between a main south-facing column and a main structural element supporting the roof.
   (ii) The connection between the foundation, the ground floor and a typical column including any arrangements for placing the column accurately.

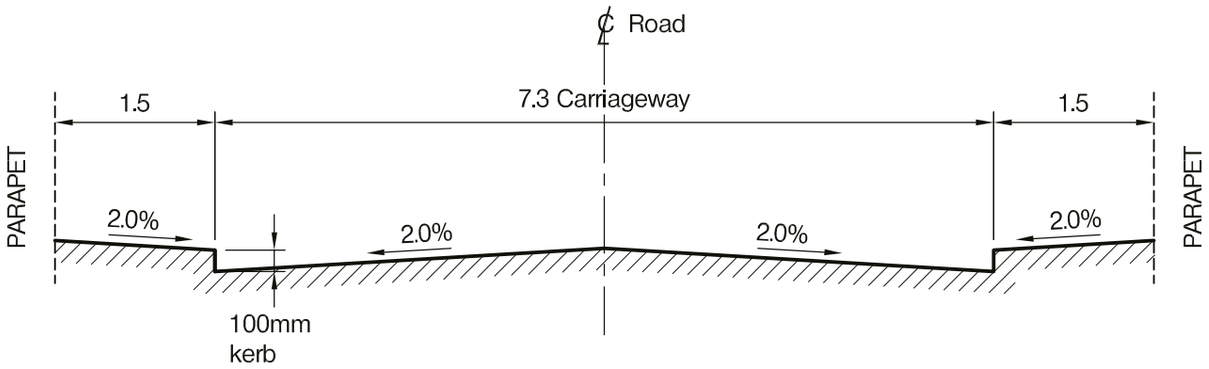
(30 marks)

e. Prepare a method statement for construction of the structure and foundations including any temporary measures required.

(10 marks)



ELEVATION



NEW ROAD CROSS SECTION

NOTE: All dimensions are in metres

FIGURE Q3

Question 3. Road Bridge over a Canal

Client's requirements

1. A new road bridge is required to span over an existing canal: see Figure Q3.
2. A 3.0m vertical clearance is required above water level for navigation.
3. Horizontal clearances of 6.0m are required for the cyclist/pedestrian paths on each side of the canal as shown in Figure Q3.
4. The bridge deck needs to accommodate a 7.3m-wide central carriageway with 1.5m-wide footpaths on each side.
5. The new bridge must not impose any direct load on to the existing walls of the canal.
6. Schemes which minimise interference to public operation of the canal would be preferred by the Client.

Imposed Loading

7. Carriageway loading 10.0kN/m^2
   Pedestrian loading 5.0kN/m^2

Site Conditions

8. The site is level and located in an open countryside. Basic wind speed is 40.0m/s based on a 3-second gust; the equivalent mean hourly wind speed is 20.0m/s.
9. Ground conditions:
   +5.0m to +0.3m: Made ground embankment, Firm clay, C = 75kN/m^2
   +0.3m to - 2.0m: Stiff clay, C = 150kN/m^2
   -2.0m to -10.0m: Very Stiff clay, C = 275kN/m^2
   Ground water was not found.

Omit from consideration

10. Detailed consideration of parapets and approach road safety fence.

SECTION 1 (30 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 the solution.

(20 marks)

b. Before completion of the design, the Client requests that each canal footpath is to be widened by an additional 2.0m. Explain how this will affect the design and details of the scheme.

(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 the principal structural elements including the foundations.

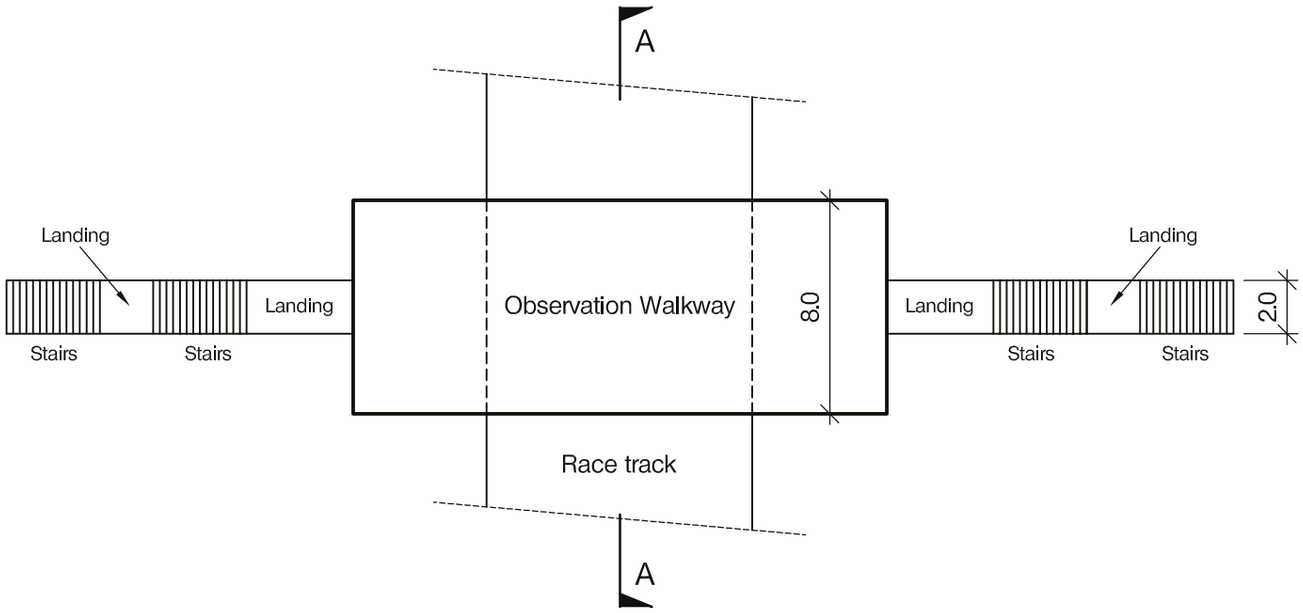
(30 marks)

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:
   (i) The junction between an abutment and the deck superstructure.
   (ii) A connection between two structural elements of deck superstructure.

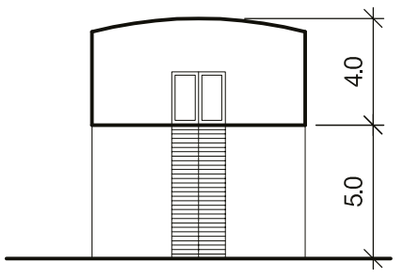
(30 marks)

e. Prepare a detailed method statement for the safe construction of the canal bridge

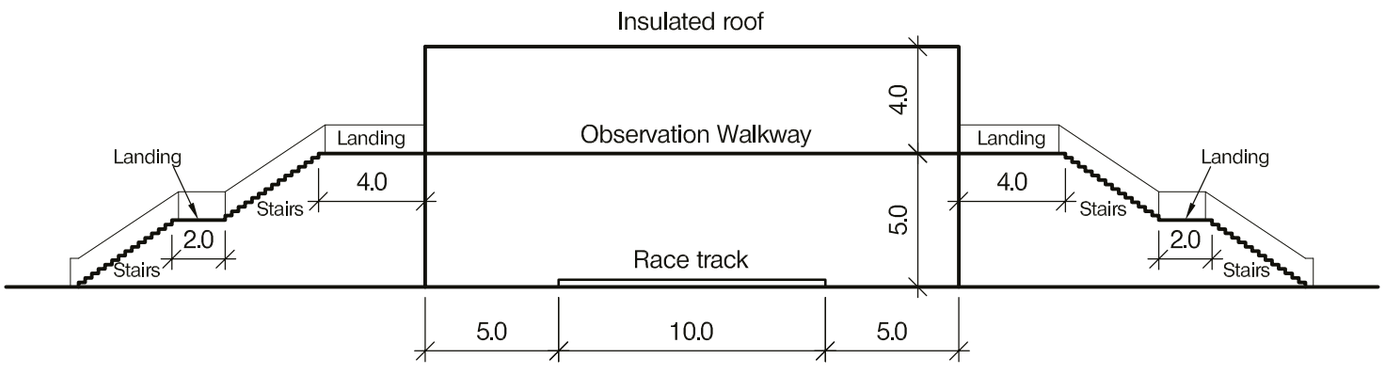
(10 marks)



PLAN



SECTION A - A



ELEVATION

NOTE: All dimensions are in metres

FIGURE Q4

Question 4 - Observation Walkway over Racetrack

Client's requirements

1. An enclosed observation walkway with access stairs is required above a motor-racing circuit which will allow spectators to cross the racetrack and watch the racing from above. See Figure Q4
2. The observation area of the walkway is to be free of any internal obstructions and is to have a clear internal height of 4.0m. No obstructions are permitted under the walkway except at each end.
3. It is envisaged that the sides of the walkway will be clad with glazing and the roof will be covered with insulated cladding.
4. The maximum vertical span of the glazing is 3.0m. The maximum span of the roof cladding is 2.0m.

Imposed Loading

5. Roof 0 .75kN/m^2
   Floor and access stairs 5.0kN/m^2

Site Conditions

6. The site is level and is in open countryside.

Basic wind speed is 44 m/s based on a 3-second gust; the mean equivalent hourly wind speed is 22 m/s.

Ground Conditions

7. Ground Level - 1.0m Loose fill material.
   Below 1.0 m Dense sand N=30.

Omit from consideration

8. Detailed design of the glazing and cladding.

SECTION 1 (30 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 each scheme. Justify the reasons for your solution.

(20 marks)

b. Upon completion of the design the client asks whether the clear height below the building can be increased to 6.0m. Write a letter to the Client explaining the implications on your design and the construction.

(10 marks)

SECTION 2 (70 marks)

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

(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:
   (i) The junction of the floor and the supporting members.
   (ii) The junction of the floor and the perimeter structure.

(30 marks)

e. Prepare a detailed method statement for the safe construction of the walkway.

(10 marks)

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