

## Chartered 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 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.**



2 Chartered-Membership Examination





# 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.

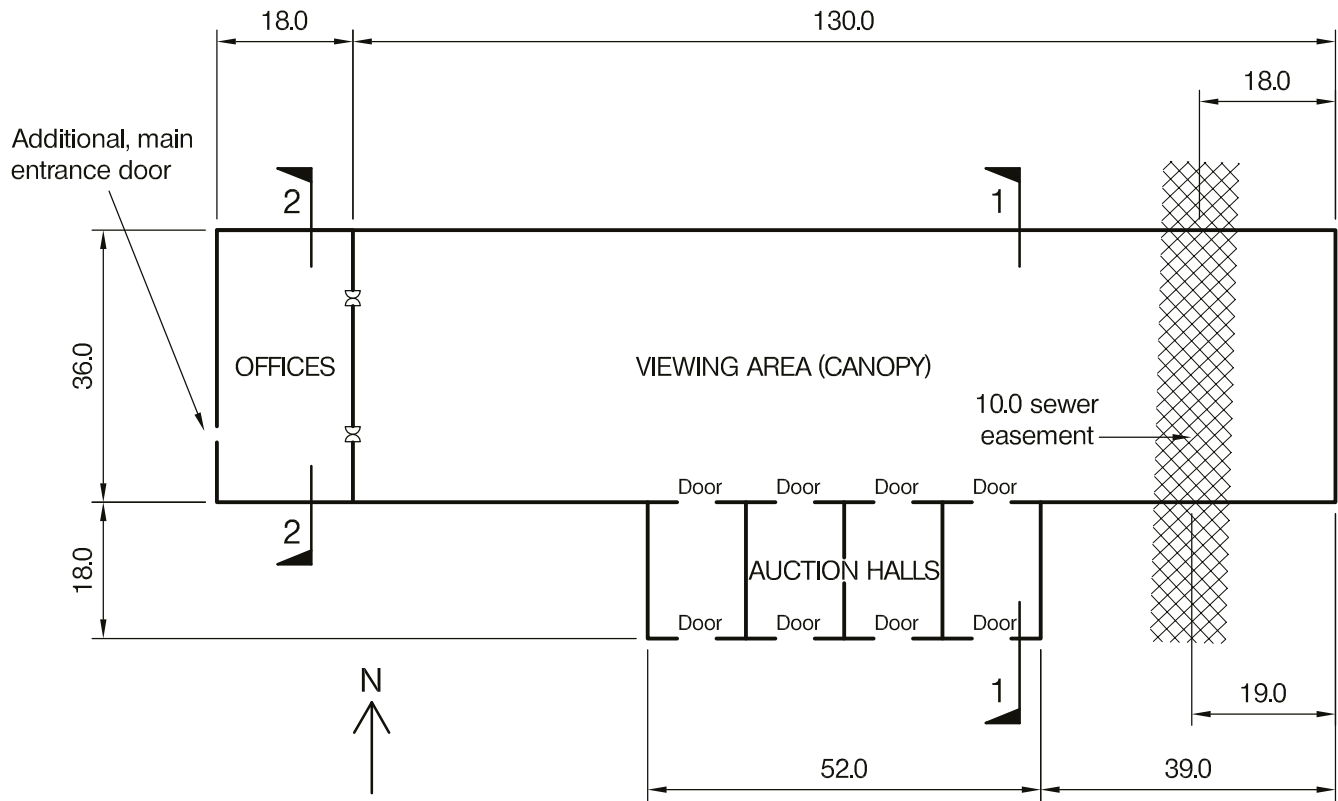
Chartered Structural Engineers must have the ability to design and a facility to communicate their design intentions. Where you are required to list and discuss possible structural solutions you must show by brief, clear, logical and systematic presentation that you understand the general structural 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:

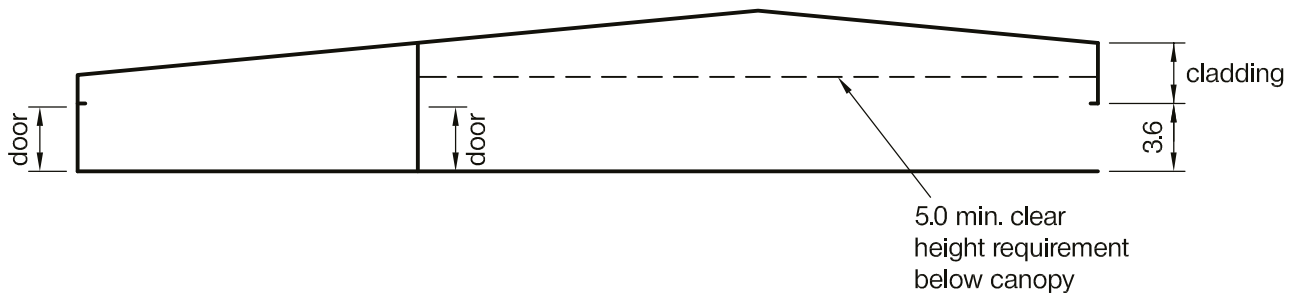
- (1) "the structure must be safe",
- (2) "a good design has certain typical features – simplicity, unity and necessity",
- (3) "the structure must fulfil its intended function".

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.

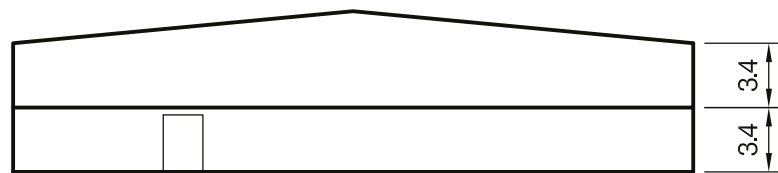




PLAN



SECTION 1 -1



SECTION 2 -2

NOTE: All dimensions are in metres

FIGURE Q1

# Question 1. Car Auction Facility

## Client's requirements

1. A new car auction facility comprising offices, auction halls and a covered viewing area canopy; see Figure Q1. The building is to be located on the outskirts of a large city on a previously-developed site.
2. A minimum clear internal height of 2.6m is required to each office level. The finished floor-to-floor height for the offices is to be 3.4m. The minimum clear height under the covered canopy is to be 5.0m. There is no restriction on roof height.
3. No internal columns are permitted within the viewing area and perimeter columns are to be at a minimum spacing of 6.5m. The viewing area is open on all sides (where not abutting adjoining buildings) to a height of 3.6m with cladding above.
4. Four auction halls are required. Each hall is to have two door openings, each 5.2m wide by 3.6m high, to allow for movement of vehicles through the building.
5. An existing sewer crosses the site at a slight skew below the proposed building. The approximate invert level is -5.0m, which requires a 10.0m-wide easement in which no below-ground structure can be located.

## Imposed Loading

- |                                |   |
|--------------------------------|---|
| 6. Roof                        | 0.6kN/m <sup>2</sup>  |
| Offices                        | 3.5kN/m <sup>2</sup> (including allowance for lightweight partitions) |
| Viewing area and auction halls | 5.0kN/m <sup>2</sup>  |

## Site Conditions

7. The site is located on the outskirts of a large city. Basic wind speed is 40m/s based on a 3-second gust; the equivalent mean hourly wind speed is 20m/s.
8. Ground conditions are constant across the site:
 

Ground level – 0.15m	surfacing
0.15m – 6.0m	historic granular fill material, N=5
Below 6.0m	very dense sand, N=50+

 No ground water was encountered.

## Omit from Consideration

9. Detail design of lift and stair cores.

## SECTION 1

**(50 marks)**

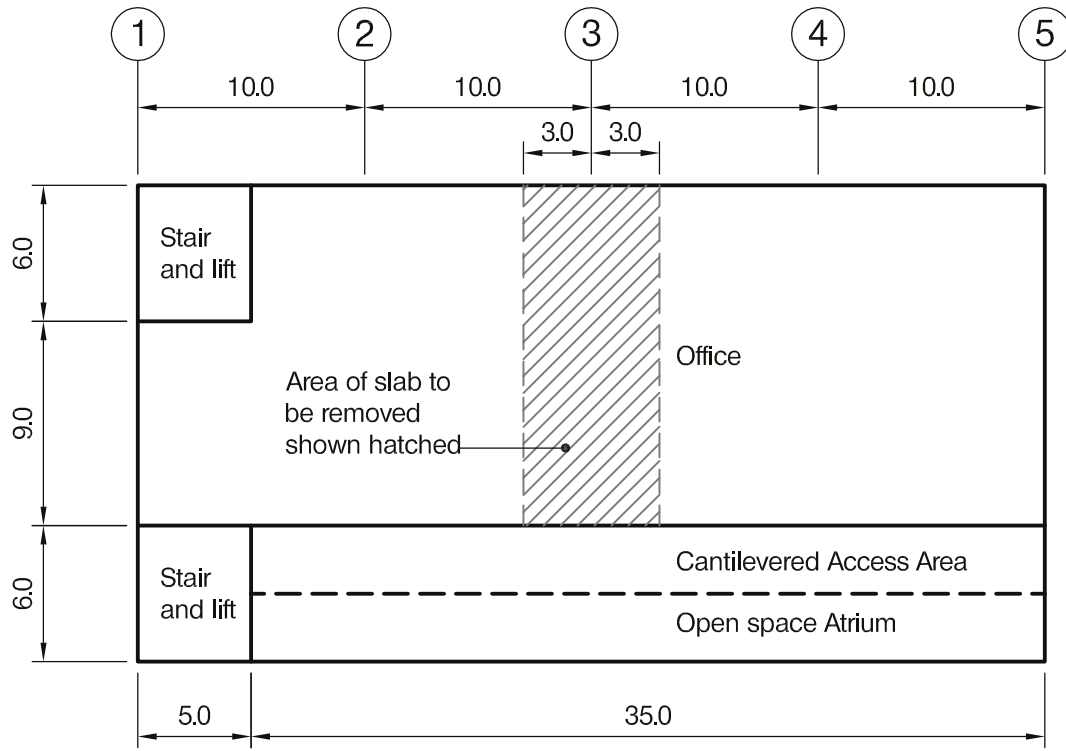
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes and identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After the design has been completed it is discovered that the sewer is not where originally thought. Measured along the north elevation the dimension from the east elevation of the building to the centre line of the easement is reduced from 18.0m to 10.0m. The corresponding dimension measured along the south elevation remains at 19.0m as previously. Write a letter to the Client explaining the implications on your design. (10 marks)

## SECTION 2

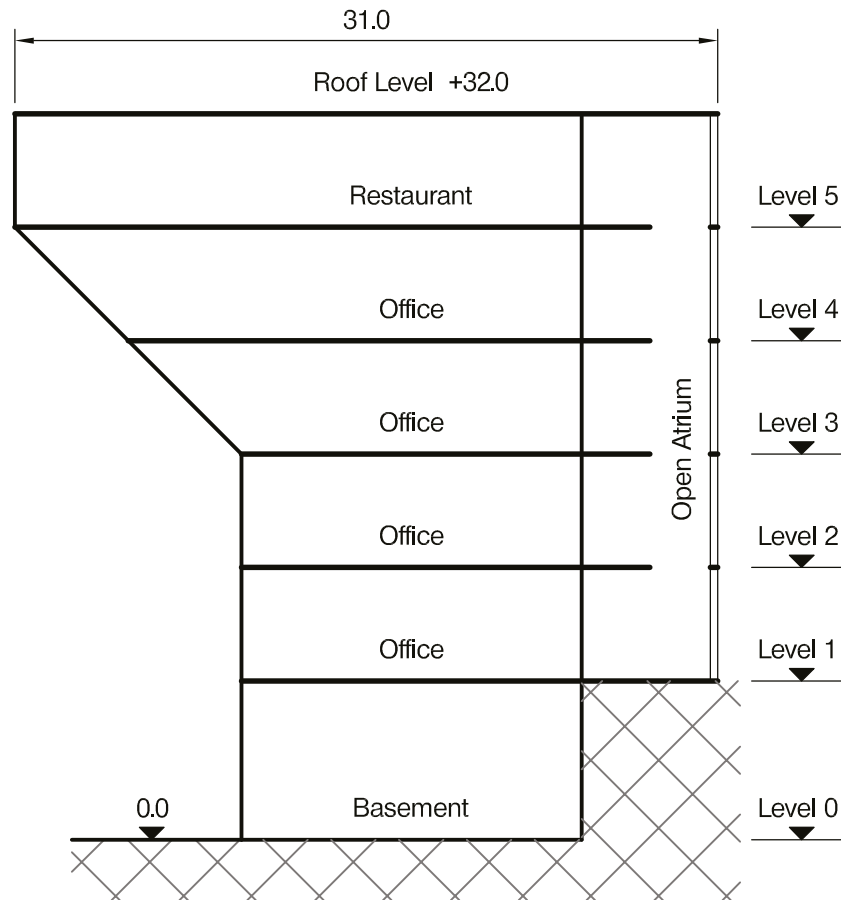
**(50 marks)**

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 works and an outline construction programme to include consideration of any temporary works that may be required. (10 marks)



LEVEL 1 PLAN



CROSS SECTION

NOTE: All dimensions are in metres

FIGURE Q2

## Question 2: Mixed-Use Development

### Client's requirements

1. A mixed-use development consisting of a basement and five additional levels: see Figure Q2. The basement is to be kept clear of any internal structure, other than stair and lift core, to maximise parking spaces. All other floors are to be sub-divided into four equal units. The top level is to be used for restaurants and the remaining levels as offices for general use.
2. Access to the front of the building is through a glazed atrium at Level 1.
3. Columns, if used, are to be contained in walls. No isolated column will be accepted anywhere. Stability elements may be placed around the lift core.
4. The maximum overall height of the building is 32.0m with a floor-to-floor height of 5.0m on all levels except Level 0, where it is to be 7.0m. A service zone of 0.3m is to be provided at each level.
5. The atrium is to be open-plan with a fully-glazed front elevation. Lateral restraint to the glazing may be provided from the cantilever floors at any two levels only. The rest of the building is to be clad using lightweight metal cladding with 50% glazing.
6. To achieve some future flexibility of use, the Client requires that it must be possible for any one of the walls on grid lines 2, 3 and 4 to be removable at each floor from Level 3 and above. This includes any internal bracing; however, any internal columns on these grid lines may remain. It may be required to remove a wall on a different grid line on each floor.

### Imposed loading

7. Roof	1.5 kN/m <sup>2</sup>
Upper Floors	5.0 kN/m <sup>2</sup>
Basement floor	7.5 kN/m <sup>2</sup>

### Site conditions

8. The site is located on the outskirts of a large city approximately 15 km from the coast. The basic wind speed is 42m/s based on a 3-second gust; the equivalent mean hourly wind speed is 21m/s.
9. Ground conditions are the same across the site:
 

Level 1 – 2.0m	topsoil and fill
2.0m – 10.0m	loose gravel, N=10
10.0m -15m	gravel, N=30
15.0m-depth	rock, characteristic compressive strength 2,000kN/m <sup>2</sup>

 Ground water was encountered at -8.0m below Level 1.

### Omit from consideration

10. Detailed design of the lift and access stairs. Parking layouts.

### SECTION 1

**(50 marks)**

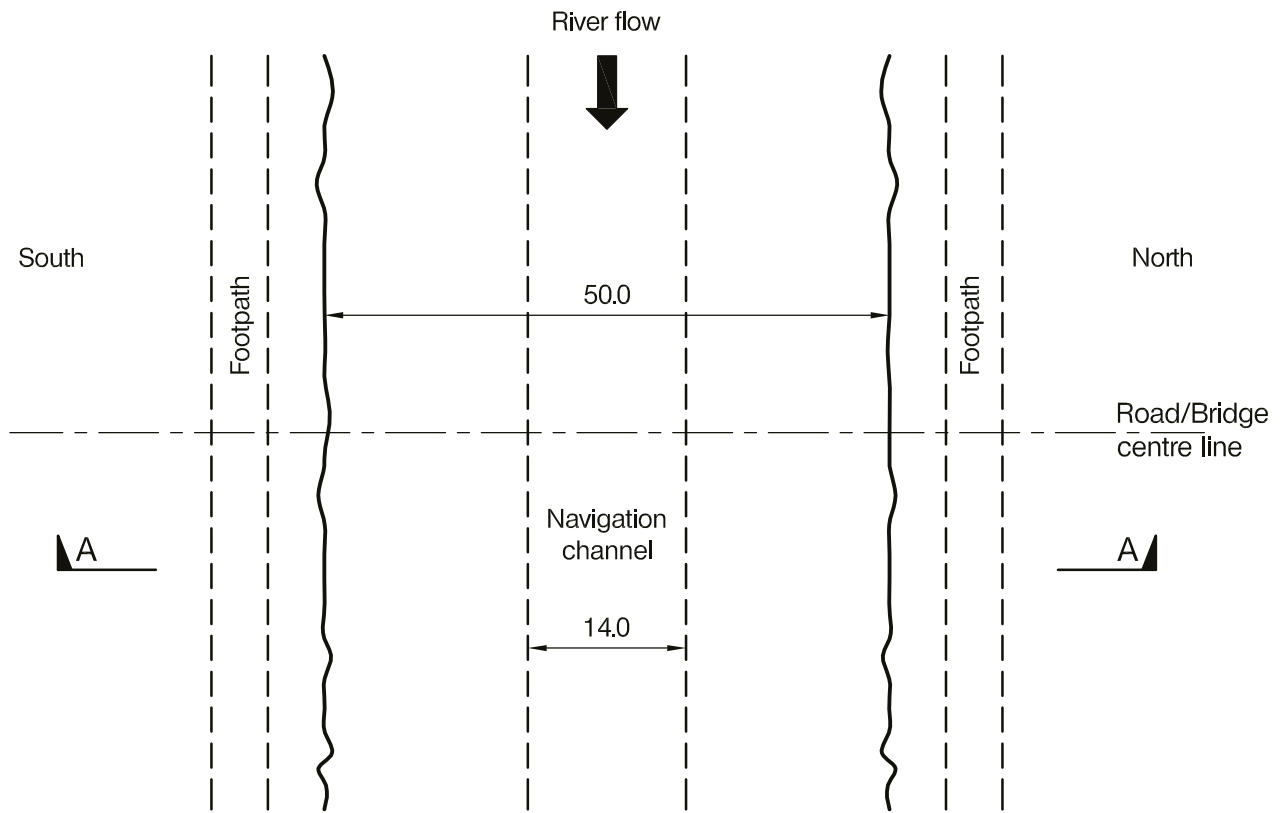
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes and identify the solution you recommend, giving reasons for your choice. (40 Marks)
- b. After completion of construction, the Client decides that he wishes to remove a 6.0m-wide area of Level 1 slab centred on grid line 3; see Figure Q2. Write a letter to the Client explaining the implications on your design. (10 marks)

### SECTION 2

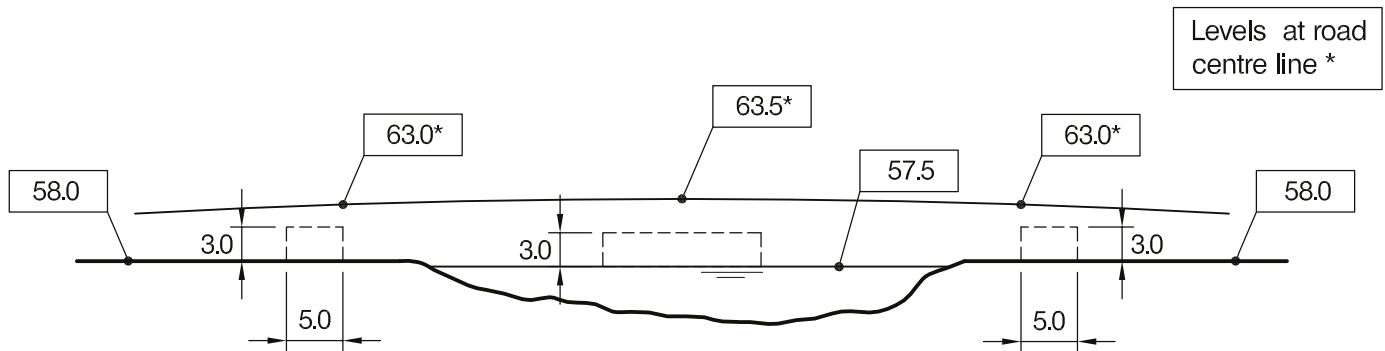
**(50 marks)**

For the solution recommended in Section 1(a):

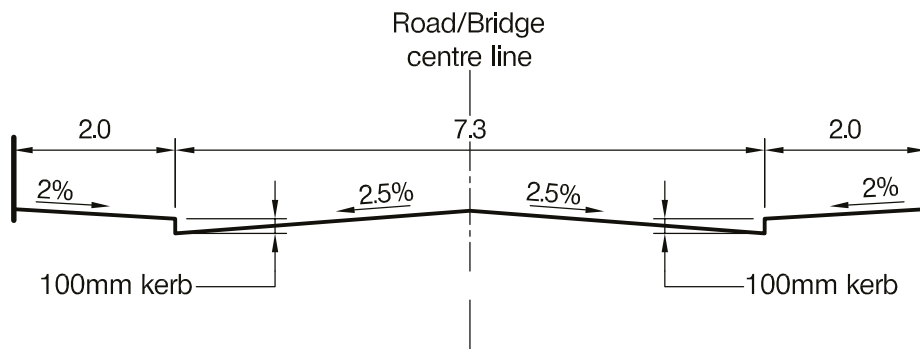
- c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)
- d. Prepare general arrangement drawings, which may include plans, sections and elevations, to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20 marks)
- e. Prepare a detailed method statement for the safe construction of the works and an outline construction programme to include consideration of any temporary works that may be required. (10 marks)



PLAN VIEW



ELEVATION A - A



ROAD / FOOTPATHS CROSS SECTION

NOTE: All dimensions are in metres

FIGURE Q3



## Question 3. Road crossing over river

### Client's requirements

1. A river crossing to provide main-road access to a new housing development south of the river: see Figure Q3.
2. The overall distance between river banks is 50.0m which includes a central navigation channel 14.0m wide. 3.0m headroom above normal water level is required for the passage of leisure boats. The normal water level is 57.5m and the maximum flood level is 59.0m.
3. There are no constraints on abutment positions other than that any visible parts above footpath levels cannot be positioned closer than 7.5m to the river bank. An earth embankment will be provided to take traffic down to grade from the abutments.
4. The structure must accommodate pedestrian walkways 5.0m wide on each bank at level 58.0m and with 3.0m headroom. The walkways may be aligned to suit the structure. The vertical profile of the centreline of the new road is to have a level of 63.5m at midspan and 63.0m at each river bank as shown in Fig. Q3. The new deck is required to have a 7.3m-wide carriageway with 2.0m-wide raised footpaths on each side. Containment parapets are to be provided along the edge of the deck.
5. Due to environmental constraints, navigational clearances must be maintained except for limited periods during construction. No permanent support can be positioned in the river. As part of the new housing development, the access bridge is required to be elegant and aesthetically pleasing.
6. There is limited access to the south side of the river via an existing bridge that has a 20 tonnes weight restriction.

### Imposed Loading

7. Traffic load on carriageway  $10.0\text{kN/m}^2$   
Pedestrian load on footpath  $5.0\text{kN/m}^2$   
An accidental horizontal impact load of 500kN shall be considered in the design, acting perpendicular to the road 3.0m above maximum flood level at any position within the normal width of the river.

### Site Conditions

8. The site is in a rural area. Basic wind speed is 46m/s based on a 3-second gust; the equivalent mean hourly wind speed is 23 m/s.
9. Ground conditions (from level 58.0m):
 

0.0m – 1.0m	top soil
1.0m – 3.5m	loose gravel, N=5
3.5m – 15.0m	sand and gravel, N=20
Below 15.0m	dense sand and gravel, N=40

 Groundwater found at the River Level ie; 57.5 due to the granular conditions

### Omit from consideration

10. Detailed consideration of scour effects from the river.
11. Design of the embankments.

### SECTION 1

**(50 marks)**

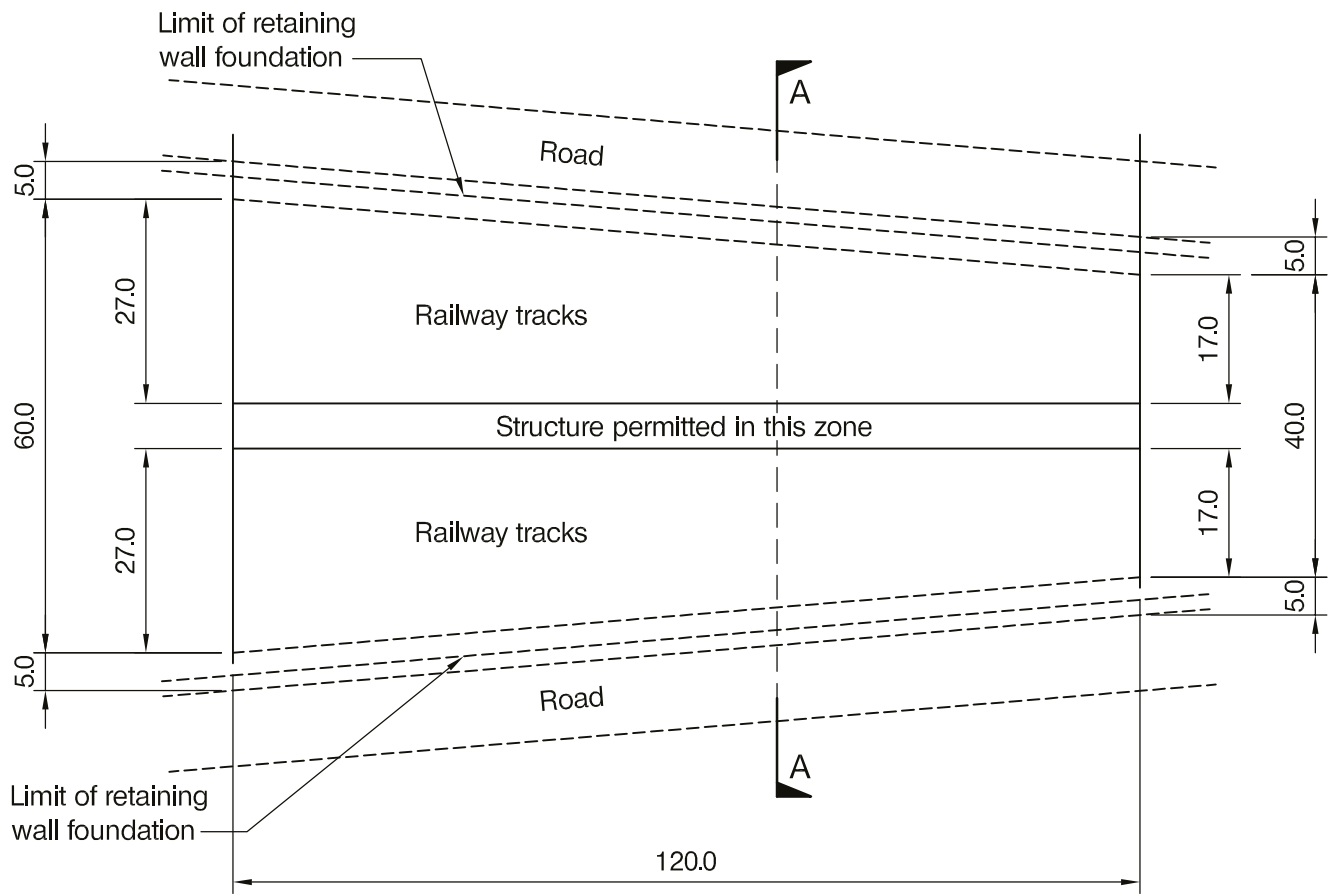
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes, and identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After your recommended solution has been accepted in principle, the Client advises that live high-voltage cables have been found below ground on the north bank running parallel to the river, creating a 20.0m-wide exclusion zone from the river edge. Write a letter to the Client explaining the design implications and advising in which way the design would need to be modified to accommodate the discovery. (10 marks)

### SECTION 2

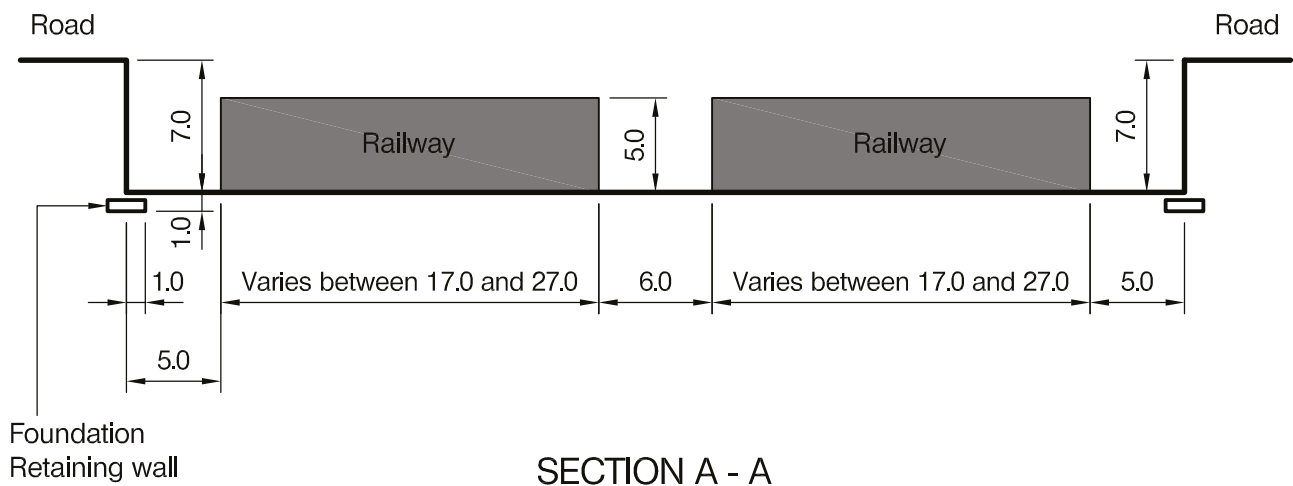
**(50 marks)**

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. Identify any navigation possession requirements and any principal temporary works necessary during the works. (10 marks)



PLAN VIEW



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q4

## Question 4: Supermarket over railway

### Client's requirements

1. A new supermarket is required over existing railway tracks approaching a city centre terminus: see Figure Q4.
2. The supermarket requires 2,500m<sup>2</sup> of floor area with a minimum clear height between the floor and ceiling of 4.0m. The minimum spacing of internal columns is to be 20.0m. No bracing or internal walls are permitted inside the supermarket.
3. In addition, the client requires 2,500m<sup>2</sup> of office space with a minimum clear height between the floor and ceiling of 2.5m. The minimum spacing of internal columns is to be 10.0m.
4. There are no restrictions on the overall height of the building.
5. The minimum clear height above the railway tracks is to be 5.0m. No structure is permitted between the tracks except a 6-metre zone in the centre. See figure Q2.
6. Half the railway tracks may be closed during weekends to allow construction work, but during work days all tracks must be fully operational.
7. At each side of the track there is a road supported by a 7.0m high retaining wall with a foundation that extends 1.0m from the wall. No additional vertical loads must be imposed on this wall or its foundation.

### Imposed Loading

- |                           |                      |
|---------------------------|----------------------|
| 8. Roof loading           | 0.5kN/m <sup>2</sup> |
| Office floor loading      | 2.5kN/m <sup>2</sup> |
| Supermarket floor loading | 5.0kN/m <sup>2</sup> |

### Site Conditions

9. The site is in a city-centre location. Basic wind speed is 46m/s based on a 3-second gust; the equivalent mean hourly wind speed is 23m/s.
10. Ground conditions at the site:
 

0m – 0.5m	Railway ballast
0.5 m – 3.0m	Sand N=20
Below 3.0m	Stiff Clay

 Groundwater was not found.

### Omit from consideration

11. Detailed design of access stairs or lifts.  
Train collision loading

### SECTION 1

**(50 marks)**

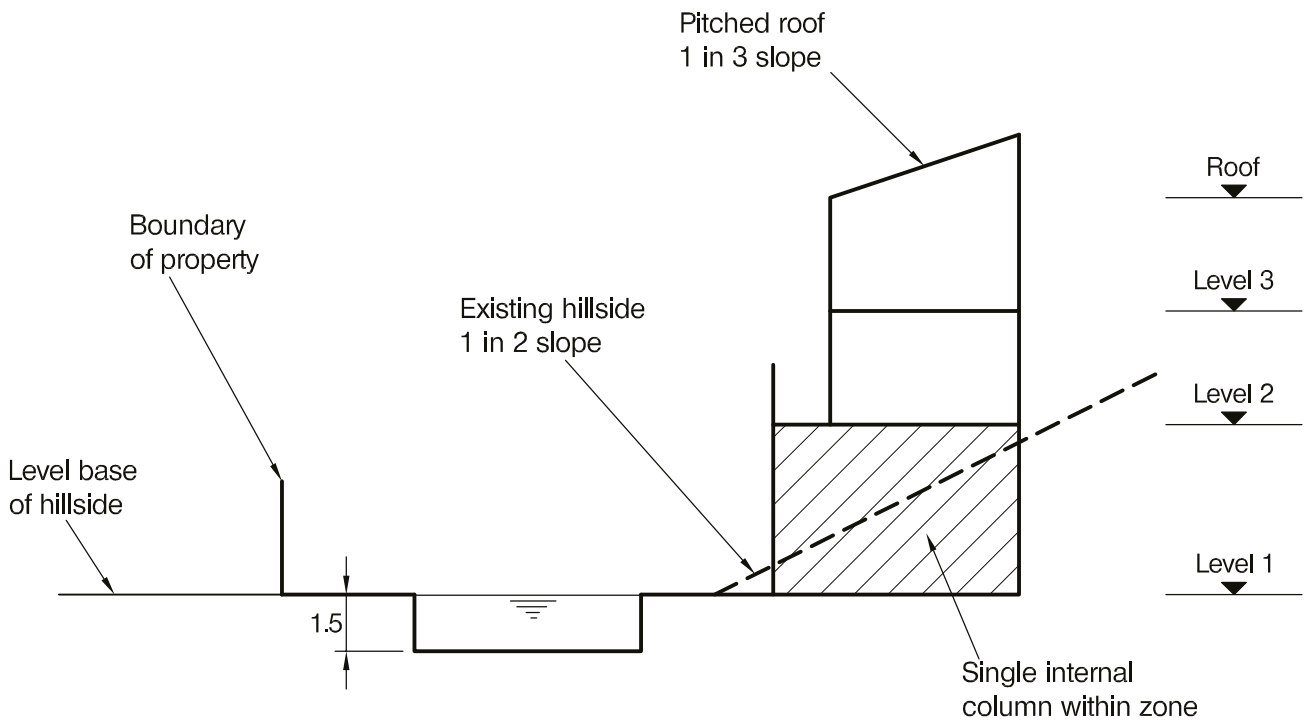
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes, and identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After the completion of the design the client asks if a further 2,500m<sup>2</sup> of offices can be included. Write a letter to your client advising him of the implications of this request on your design. (10 marks)

### SECTION 2

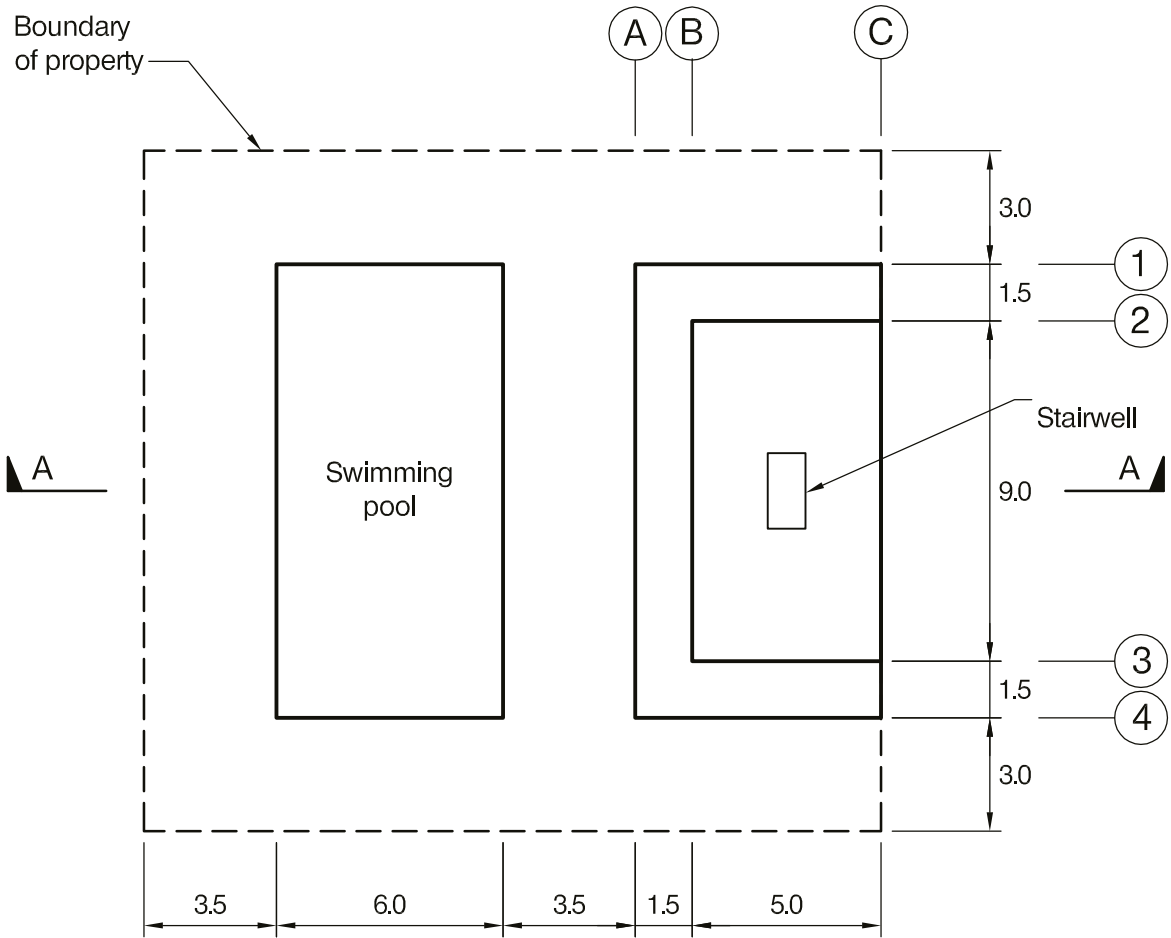
**(50 marks)**

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 works and an outline construction programme to include consideration of any temporary works that may be required. (10 marks)



SECTION A - A



PLAN

NOTE: All dimensions are in metres

FIGURE Q5

## Question 5. House on the Hill

### Client's requirements

1. A new 3-storey residential property with swimming pool– see Fig Q5. The building is to be built into a new cutting on a hillside location.
2. The building is required to have full-height glazed cladding to the perimeter, except along grid line C.
3. Internal floor-to-floor heights are to be 3.0m, except on Level 1 where the floor-to-floor height is to be 4.5m. Structural depths are to be kept to a minimum to maximise the height of glazing.
4. A single stairwell will extend for the full height of the building. The stairwell will be open-sided and cannot be used for stability.
5. A single column is the only internal vertical structure allowed at Level 1.
6. At Level 1 the ground is required to be level within the property boundary.
7. A minimum fire rating of 2 hours is required throughout.

### Imposed Loading

8. All floors 3.0kN/m<sup>2</sup>. Loadings include allowances for floor finishes, ceilings and services.
9. Roof 0.75kN/m<sup>2</sup>

### Site Conditions

10. The site is located in open countryside. The basic wind speed is 40m/s based on a 3-second gust; the equivalent mean hourly wind speed is 20 m/s.

### Ground Conditions

11. Existing ground level – 20.0m Sandy gravel,  $N=25$ ,  $\phi = 35$  degrees, density 19kN/m<sup>3</sup>. Ground water was recorded on the site at 2m below level 1.

### Omit from consideration

12. Detailed design for staircases  
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 informs you that they wish to lower the entire building, swimming pool and building plot by 1.0m. 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 works and an outline construction programme. (10 marks)



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