

# Associate-Membership Examination

Friday, 7 July 2017

## 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. Good clear drawings and sketches are required; they should show all salient and structural features to suitable scales and should incorporate adequate details.
8. Candidates will not be allowed to include any previously prepared calculations, notes, sketches, diagrams, computer output or other similar material in their answer sheets or A3 drawings. Any previously prepared information submitted by candidates will be ignored by the examiners.
9. Candidates may not bring into the examination room any electronic devices capable of wireless communication, optical photography or scanning.  
  
The following devices are not permitted: Mobile phones, Laptops, notebooks or portable computers and similar devices, iPads, tablets and similar devices, E-readers (e.g. Kindle) and similar devices, Cameras, optical scanners and similar devices.  
  
Any candidates arriving at the examination room with such devices will be asked to switch them off and place them in a sealed bag kept by the Invigilator for the duration of the exam, which includes the lunch period.
10. This paper is set in SI Units.

**Now read 'Reminder' on page 3.**



# 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.

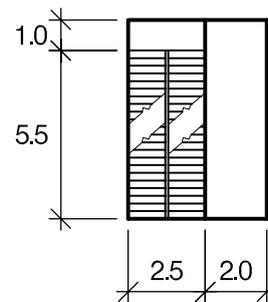
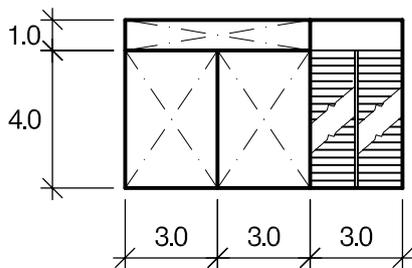
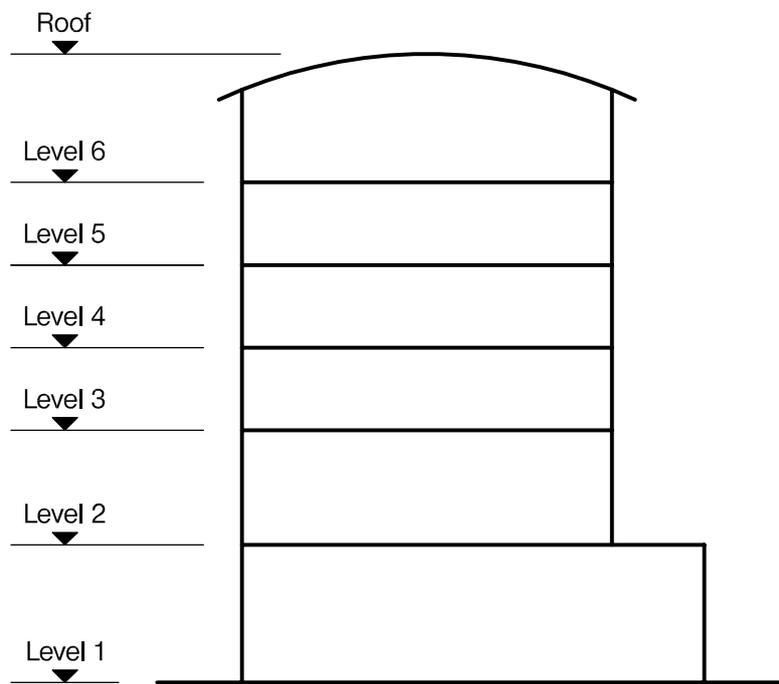
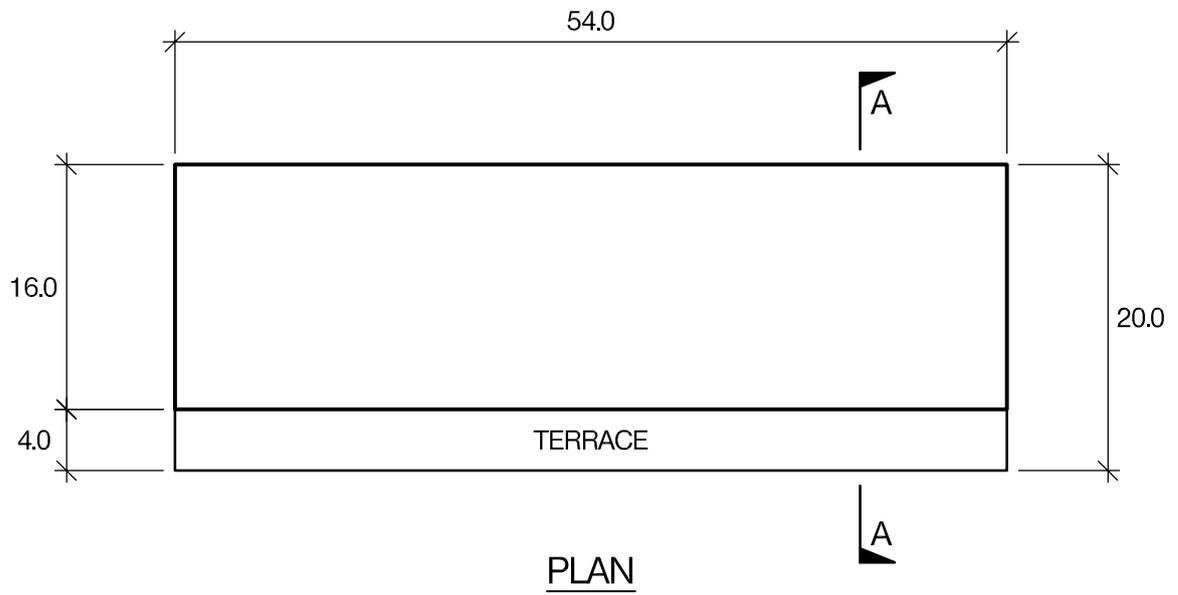
The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural design problems whether or not the problem is presented in terms that are within your actual experience.

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.



NOTE: All dimensions are in metres

FIGURE Q1

# Question 1. New Hotel

## Client's requirements

1. A new six storey hotel. See Figure Q1.
2. The hotel is to have four floors of bedrooms, each bedroom measuring 6.5m long × 4.5m wide, with twenty bedrooms along each floor accessed by a 3.0m wide central corridor.
3. Access to the upper floors is by a central main core. At the end of each bedroom floor there is to be a cupboard and staircase in a secondary core with the staircase providing access to all floors.
4. Restaurants, lounges and the reception are located at Level 1. Only one longitudinal row of internal columns is permitted at this level spaced at 9.0m centres and at least 9.0m clear of the external walls.
5. Conference and meeting facilities are located at Level 2. No internal columns are permitted at this level.
6. Only one longitudinal row of internal columns is permitted at the bedroom floor levels
7. The following minimum clear internal heights are required: 2.6m to each bedroom floor level, 4.0m to Level 2, and 5.0m to Level 1. Each floor is to have a false ceiling service zone of 0.4m below any structure.
8. The elevations are to be clad in a composite cladding system and the perimeter columns are to have a minimum spacing of 4.5m.
9. No foundations are permitted outside the plan profile of the building.
10. The roof line is to be radial with a rise of 2.0m from eaves to ridge and an overhang of 1.0m beyond the eaves.

## Imposed loading

- |                         |                       |
|-------------------------|-----------------------|
| 11. Roof                | 0.75kN/m <sup>2</sup> |
| Bedroom floor loading   | 2.50kN/m <sup>2</sup> |
| All other floor loading | 4.0kN/m <sup>2</sup>  |
- Roof and floor loadings include allowances for finishes and services.

## Site conditions

12. The site is located in the centre 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.
13. Ground conditions are constant across the site:
 

Ground level – 2.0m	Existing basements / fill
2.0m – 7.0m	Sand and gravel N = 15
Below 7.0m	Dense silty sand N = 30

No ground water was encountered.

## Omit from consideration

14. Detail design of the lift and stairs.

## SECTION 1

**(30 marks)**

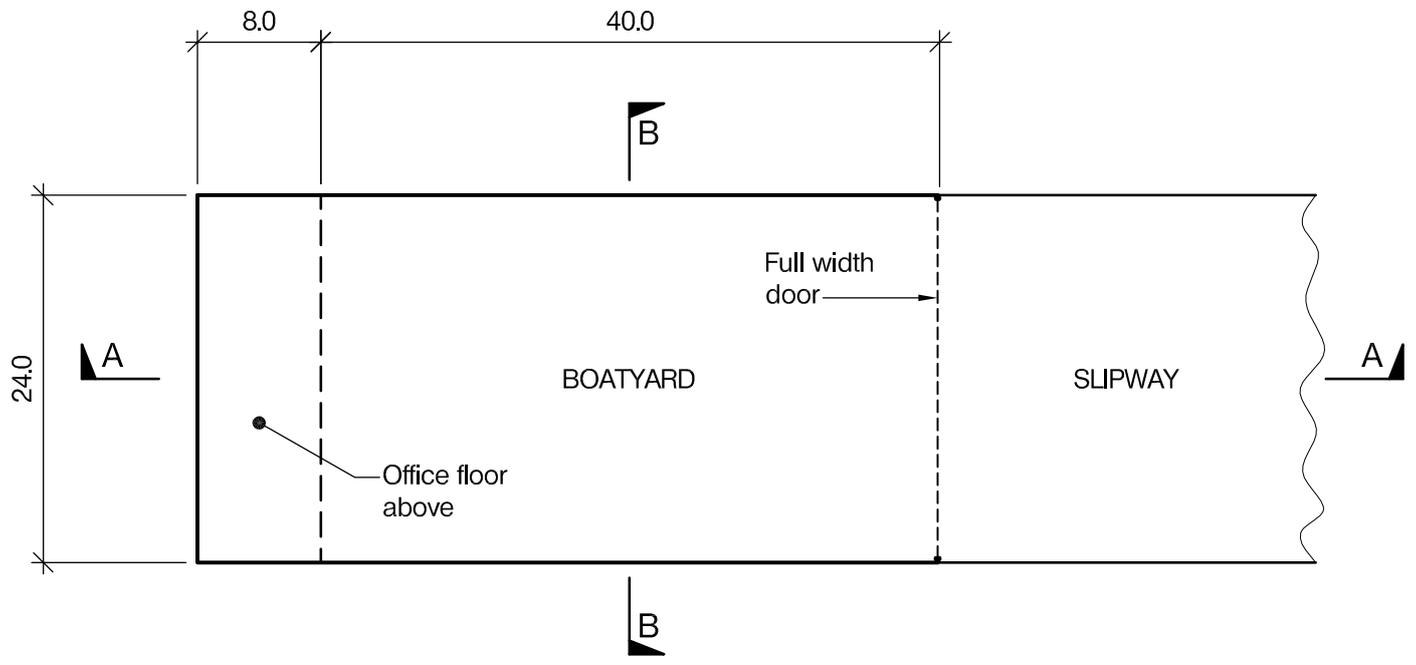
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for the solution. (20 marks)
- b. After the construction has commenced the client advises you that they wish to add another level of bedrooms. Write a letter to the Client explaining the implications on your design and the construction. (10 marks)

## SECTION 2

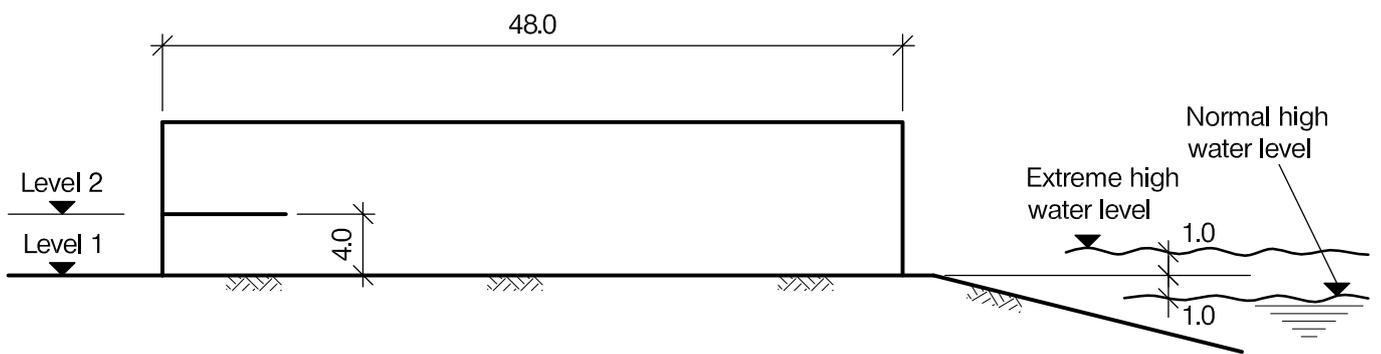
**(70 marks)**

For the solution recommended in Section 1(a):

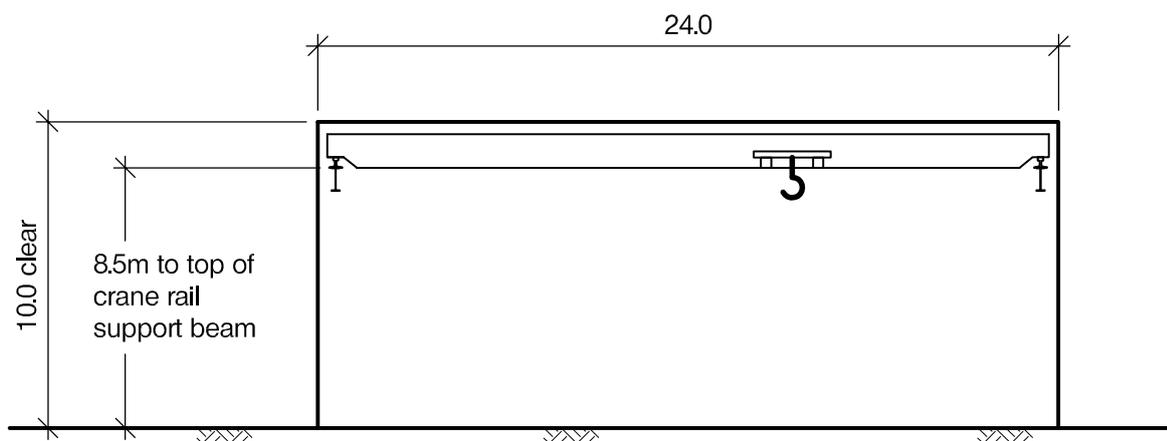
- c. Prepare sufficient design calculations to establish the form and size of the principal structural elements including the foundations. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
  - (i) The roof to perimeter column detail
  - (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 LEVEL 1



SECTION A - A



SECTION B - B

NOTE: All dimensions are in metres

FIGURE Q2

## Question 2. Boatyard maintenance shed

### Client's requirements

1. A new shed is required in an existing boatyard in order to maintain boats weighing up to 10 tonnes under cover. See Figure Q2.
2. The shed is to be placed with its entrance at an existing slipway which slopes down to a river. A near-full width roller shutter door is required at the entrance.
3. The internal plan dimensions of the shed are to be 24.0m by 48.0m. A completely column-free interior space of 40.0m by 24.0m is required. A Level 2 office 8.0m by 24.0m is to be provided at the opposite end of the shed from the entrance. To provide sufficient working space the clear headroom from the floor to the lowest part of the roof structure shall be 10.0m.
4. The Client would be delighted to see the structure expressed externally.
5. The building is to be clad in a flat composite cladding system and the roof is to be clad with composite profile sheeting.

### Imposed loading

- |                     |  |
|---------------------|--|
| 6. Roof             | 1.5 kN/m <sup>2</sup>  |
| Ground floor        | 15.0 kN/m <sup>2</sup>   |
| Office floor        | 5.0kN/m <sup>2</sup>   |
| Crane rail          | 110kN point load applied anywhere along crane rail support beam. |
| Roller shutter door | 2.0kN/m across width of door.                                    |

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

### Site conditions

7. The site is level and open and near the mouth of a river facing open sea.
8. Basic wind speed is 58m/s based on a 3 second gust; the equivalent mean hourly wind speed is 29 m/s.
9. Ground conditions:
 

Ground level – 1.5m	Soft muddy topsoil
1.5m – 20m (proved)	Moderately strong granite with an allowable bearing pressure of 2000kN/m <sup>2</sup>

### Omit from consideration

10. Design of the roof and wall cladding panels, which may be assumed to be capable of spanning 2.5m. Design of the crane and crane rails, but the crane rail support beam should be designed. Design of the roller shutter entrance door.

### SECTION 1

**(30 marks)**

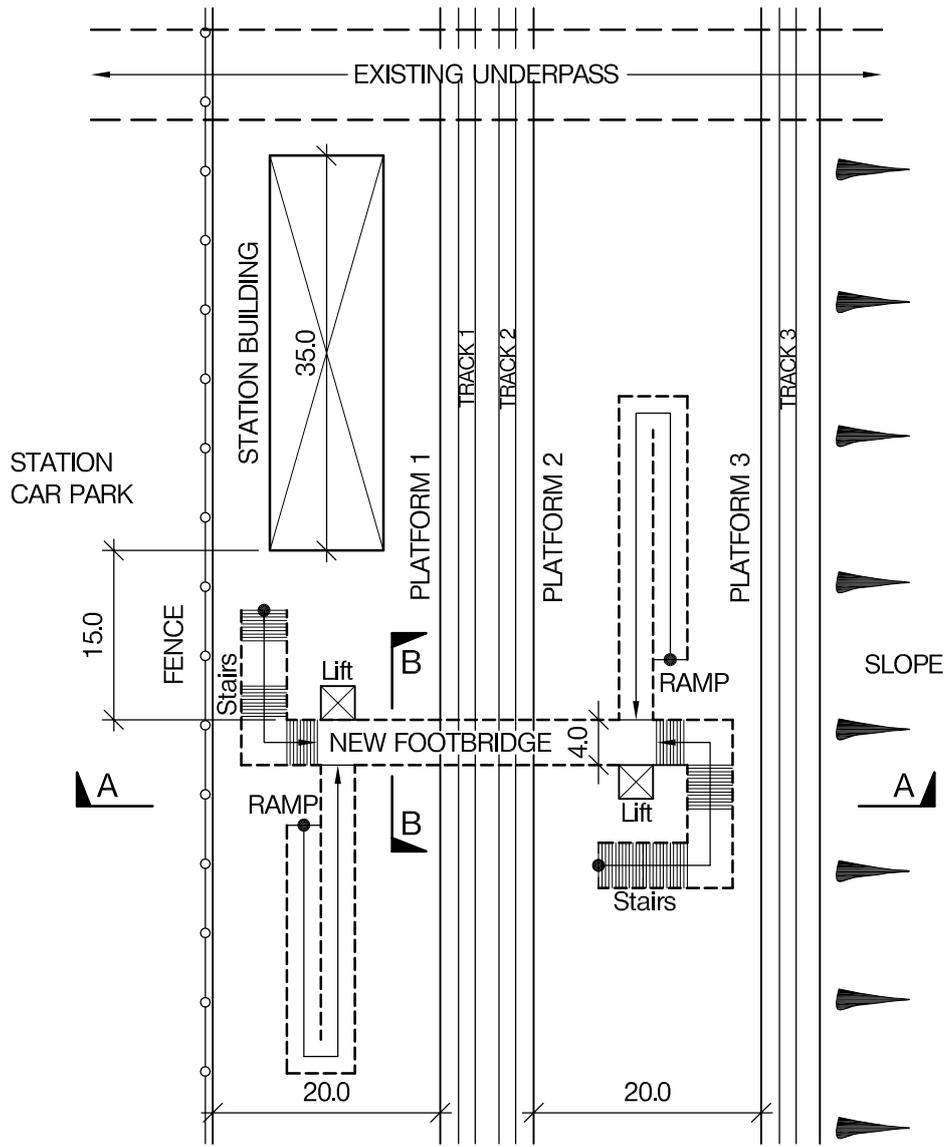
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (20 marks)
- b. During the design period the client asks what measures could be implemented to prevent the shed being flooded if an extreme high tide or tsunami were to increase the high water level by 2.0m. Write a note to the client outlining possible measures to achieve this and how this would affect the structure. Illustrate your reply with sketches as necessary. (10 marks)

### SECTION 2

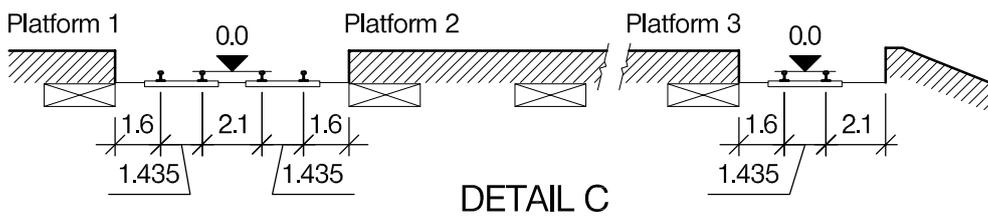
**(70 marks)**

For the solution recommended in Section 1(a):

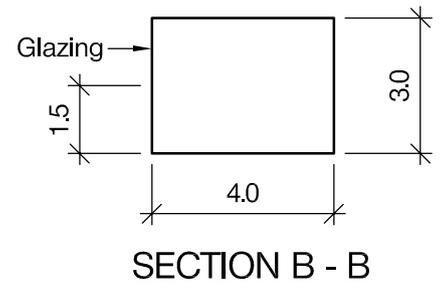
- c. Prepare sufficient design calculations to establish the form and size of the principal structural elements and foundations. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
  - (i) The connection between a typical perimeter column and crane rail support beam.
  - (ii) A cross section through the structure containing the office floor from roof to foundation and including attachment of cladding. (30 marks)
- e. Prepare a method statement for construction of the structure and foundations including any temporary measures required. (10 marks)



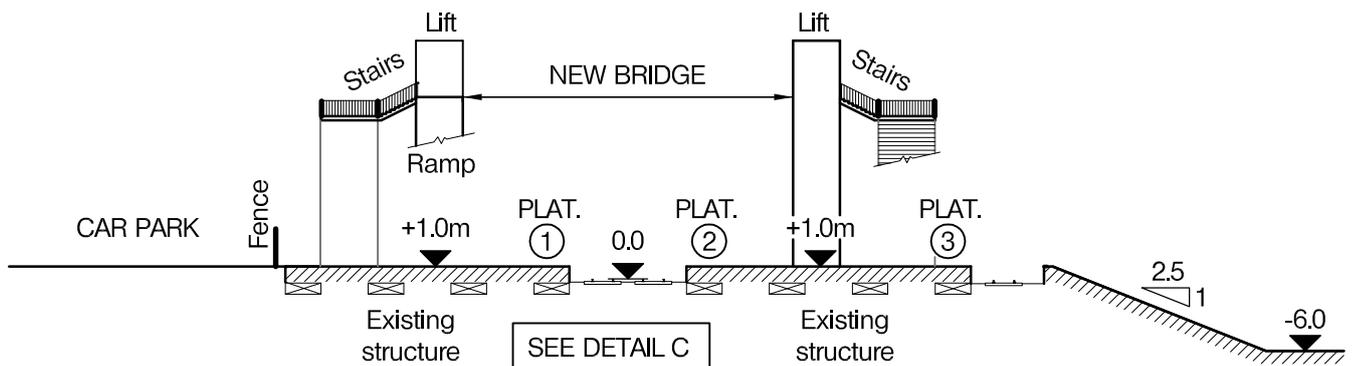
PLAN



DETAIL C



SECTION B - B



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q3

## Question 3. Station footbridge

### Client's requirements

1. A single span footbridge is required as part of a railway station re-development to provide access to platforms 2 and 3, spanning tracks 1 and 2. The footbridge incorporates stairs, a ramp and a lift at each end. See Figure Q3.
2. An existing underpass that used to provide access to these platforms can be used during construction but it will need to be abandoned as part of the new works once the footbridge is fully operational.
3. The footbridge, including the stairs and ramps, is to have a clear width between parapets of 4.0m. It is to be accessible by wheelchairs and will be used by large numbers of people.
4. A minimum vertical clearance of 5m is to be provided above the tracks and any supports to the footbridge must be at least 4.5m clear from the nearest rail.
5. The footbridge may be constructed in any material or combination of materials. However, the railway station must remain in operation as much as possible. A low maintenance bridge with a design life of 120 years is required.
6. The footbridge is to be fully enclosed with minimum headroom of 3m and be provided with glazing for the upper part as shown in Figure Q3.

### Imposed loading

7. Finishes and roofing 2.5kN/m<sup>2</sup>  
Pedestrian loading 5.0kN/m<sup>2</sup>

### Site conditions

8. The site is level and located in an open countryside. Basic wind speed is 35.0m/s based on a 3-second gust; the equivalent mean hourly wind speed is 17.5m/s.
9. Ground conditions:
 

Track level – 3.0m	Made ground and existing foundations
3.0m – 12.0m	Silty sand, N varies from 10 to 20
Below 12.0m	Stiff to very stiff clay, C = 250kN/m <sup>2</sup> .

### Omit from consideration

10. Detailed consideration of lift shafts, stairs and ramps.

### SECTION 1

(30 marks)

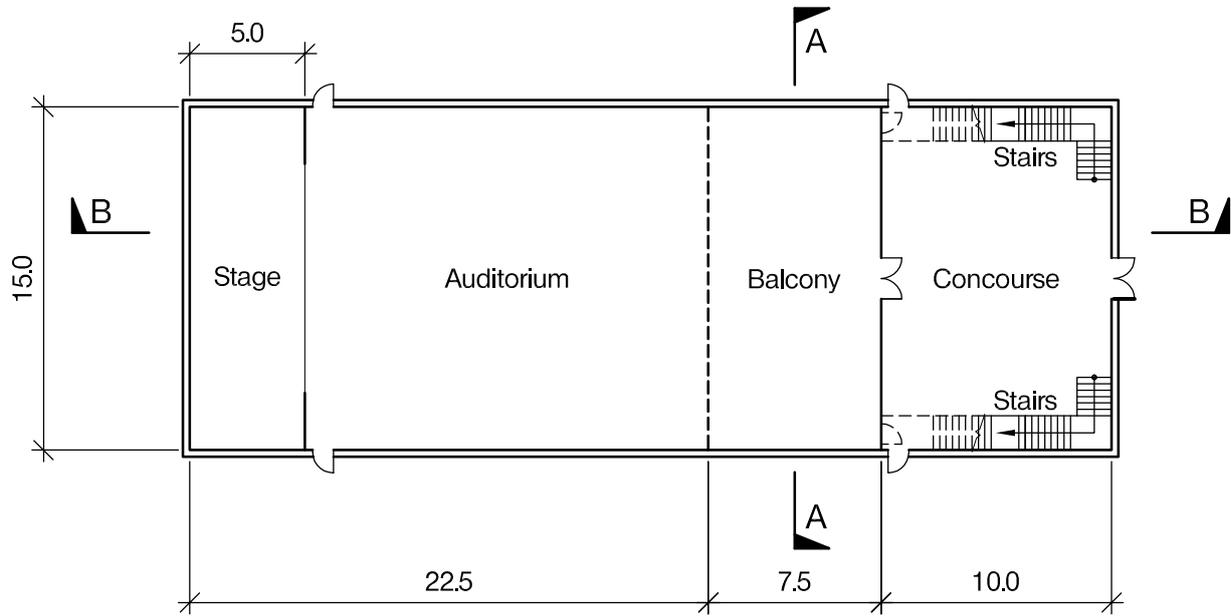
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for the solution. (20 marks)
- b. Before completion of the design, the client requests that the vertical clearance to the tracks be raised from 5m to 7m to accommodate potential future electrification of the lines. Explain how this will affect the design and details of the scheme. (10 marks)

### SECTION 2

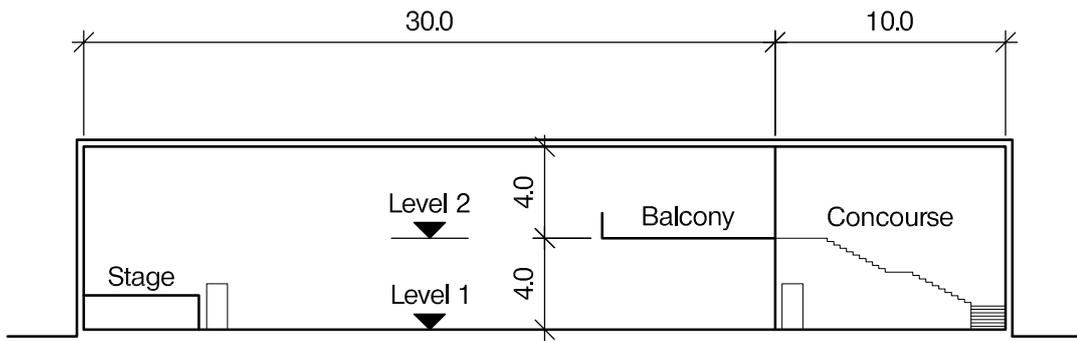
(70 marks)

For the solution recommended in Section 1(a):

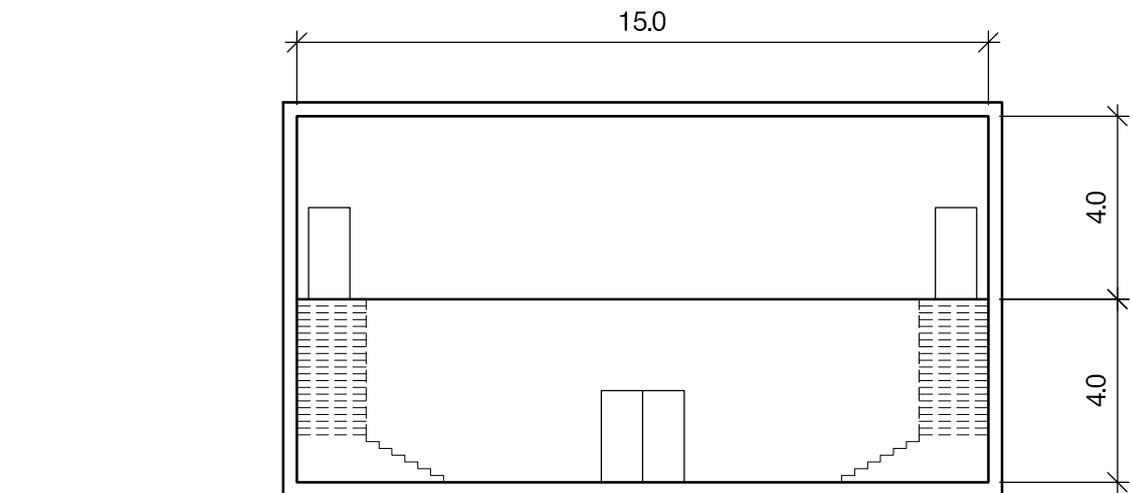
- c. Prepare sufficient design calculations to establish the form and size of the principal structural elements including the foundations. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
  - (i) Junction between the footbridge superstructure and the approach ramps.
  - (ii) A connection between two structural elements of the footbridge superstructure. (30 marks)
- e. Prepare a detailed method statement for the safe construction of the footbridge. (10 marks)



PLAN



SECTION B - B



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q4



The Institution of Structural Engineers  
International HQ  
47-58 Bastwick Street  
London, EC1V 3PS  
United Kingdom  
tel: +44 (0)20 7235 4535  
mail@istructe.org  
www.istructe.org  
Registered Charity