

# Associate-Membership Examination

Friday 5 April 2013

## 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. 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 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. 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 sheets 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.

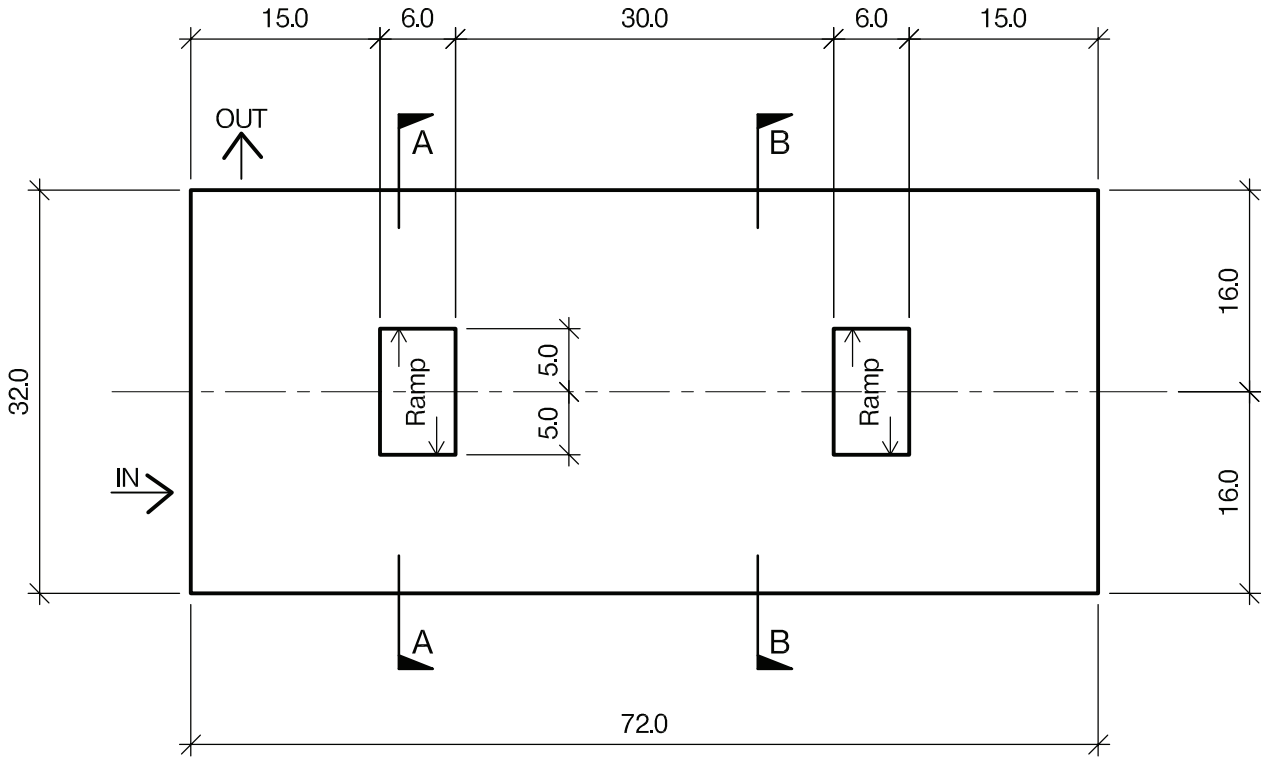
The unusual requirement of the examination is that you demonstrate the validity of the training and experience that you have acquired in recent years. The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural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

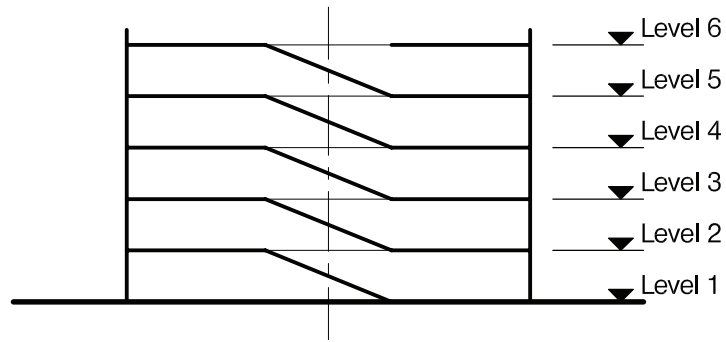
In selecting and developing your design you should also remember the guidance given in the Institution's report, Aims of Structural Design, and in particular:

- (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".

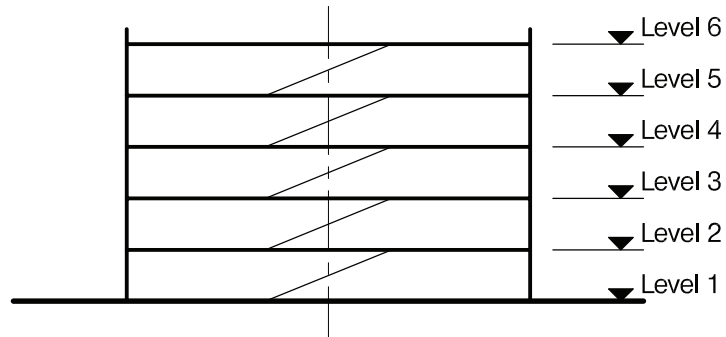
If you have difficulty in deciding the correct interpretation of a question, pay particular attention to point 6. notes to candidates, on the front cover. The examiners will take into account your interpretation – and the design you base on this – if this is clearly stated at the beginning of your answer.



PLAN



SECTION A-A



SECTION B-B

NOTE: All dimensions are in metres

FIGURE Q1

# Question 1. Multi-storey car park

## Client's requirements

1. A new multi-storey car park situated in a town centre. See Figure Q1.
2. Parking is to be provided on 6 levels and there are to be at least 600 car parking spaces. Each car parking space is to be at least 2.4m x 4.8m in plan.
3. All external columns and any columns proposed within the car parking areas are to be at a minimum spacing of 6.0m centre-to-centre.
4. The internal clear height from each floor to the underside of the horizontal floor support structure above is to be at least 2.3m. There is no overall height restriction to the building.
5. The external cladding to the building is to be of cavity wall construction comprising 102mm brickwork and 100mm blockwork constructed to 1.2m above and 0.6m below each floor level. The external columns are to be clad in 100mm blockwork. Internal proprietary crash barriers are to be provided around the perimeter of each floor.

## Imposed loading

6. Each floor 2.50kN/m<sup>2</sup>

## Site conditions

7. The site is level and located in a town centre.
8. Basic wind speed is 40m/s based on a 3-second gust: the mean hourly wind speed is 20m/s.
9. Ground Conditions:
 

Ground - 2.0m	Made ground
2.0 -7.0m	Sand and gravel N20
Below 7.0m	Firm to stiff clay C=250kN/m <sup>2</sup>

 Ground water was encountered at 4.0m below ground level.

## Omit from consideration

10. Detail design of the stair and lift shafts, which are external to the building and do not contribute to its overall stability. Design of the crash barriers.

## SECTION 1

**(30 marks)**

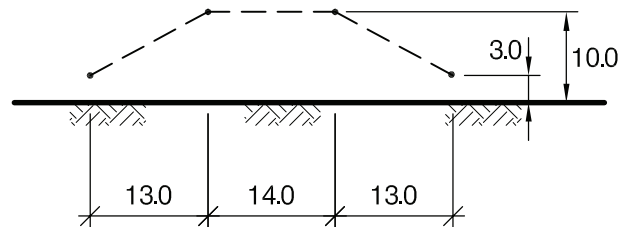
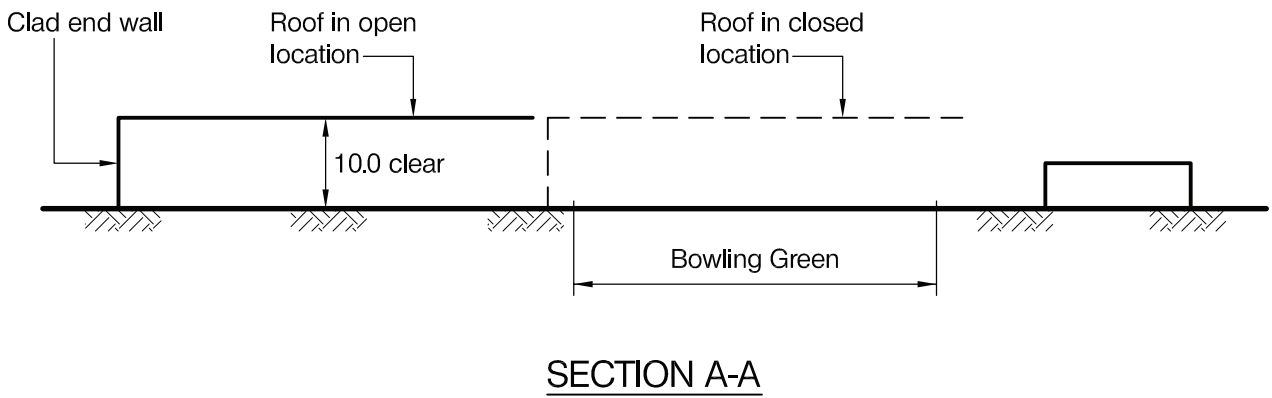
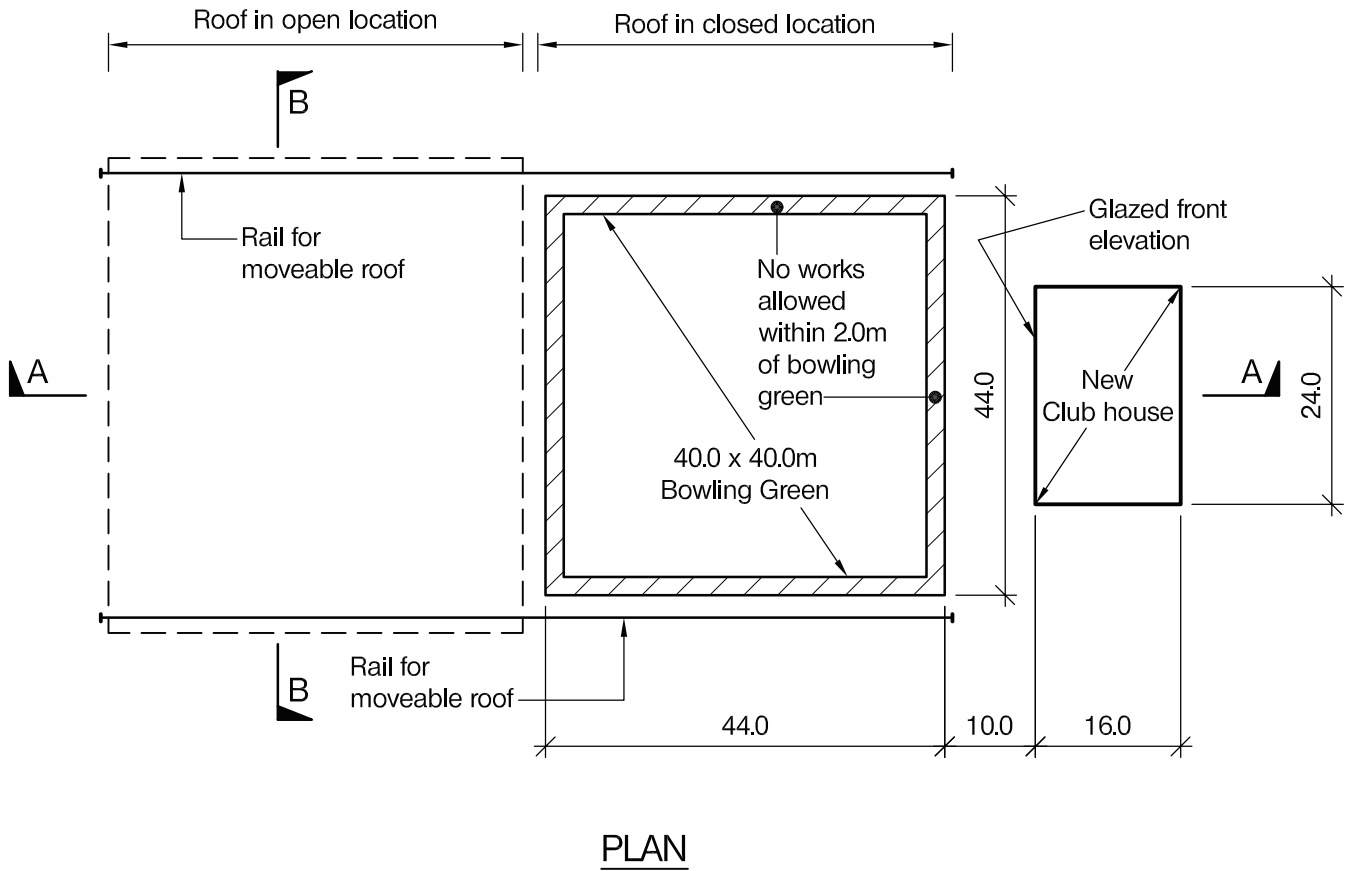
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for the solution. (20 marks)
- b. The client proposes, after completion of the construction, that an additional floor could be added above Level 6. Explain the effect this will have on the design of the building. (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 top floor perimeter parapet cladding detail.
  - (ii) A perimeter column at ground floor level. (30 marks)
- e. Prepare a detailed method statement for the safe construction of the building. (10 marks)



Showing required clearances for roof

NOTE: All dimensions are in metres

**FIGURE Q2**

## Question 2. New roof and clubhouse for a lawn bowls club

### Client's requirements

1. A new clubhouse for a bowling club, and a moveable roof over their bowling green. See Figure Q2.
2. The clubhouse building is to be single-storey with a flat roof. It is to contain a bar and changing facilities. The front elevation is to be fully glazed and the roof will be grassed over. Columns, if used, may be placed internally and around the perimeter between 6.0m and 8.0m apart.
3. The roof over the green is moveable to allow play, when closed, at night and during rain, but will allow wind and sunlight on the grass when opened. It will move on parallel rails and must span clear over the green.
4. The moveable roof will be clad 50% with solar panels and 50% with clear glazing. Each proprietary roof panel will span a maximum of 2.5m x 2.5m.
5. The minimum clear headroom required at the sides of the green is 3.0m. Over the central 14m of the span the minimum headroom is to be 10.0m. One end of the roof is to be clad down to ground level to act as a windbreak during use.
6. It is essential that the green is protected from damage at all times and no temporary or permanent works are permitted within 2.0m of the edge of the green.

### Imposed loading

- |  |                       |
|--|-----------------------|
| 7. Moveable roof including self-weight of glazing & solar panels | 1.75kN/m <sup>2</sup> |
| Roof of clubhouse, including the self-weight of soil and grass   | 6.0kN/m <sup>2</sup>  |
| Ground floor of clubhouse  | 6.0kN/m <sup>2</sup>  |
- The roof and floor loadings include allowances for finishes, partitions and services.

### Site conditions

8. The site is level and open and at the edge of a small town.
9. Basic wind speed is 40 m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20 m/s.
10. Ground conditions:
 

Ground level – 1.0m	Topsoil and fill
1.0m – 3.0m	Soft clay, C=15kN/m <sup>2</sup>
3.0m – 30.0m	Firm to stiff clay, C=200kN/m <sup>2</sup>

Ground water was not found.

### Omit from consideration

11. Design of the moveable roof mechanism; design of the proprietary roof panels.

### SECTION 1

**(30 marks)**

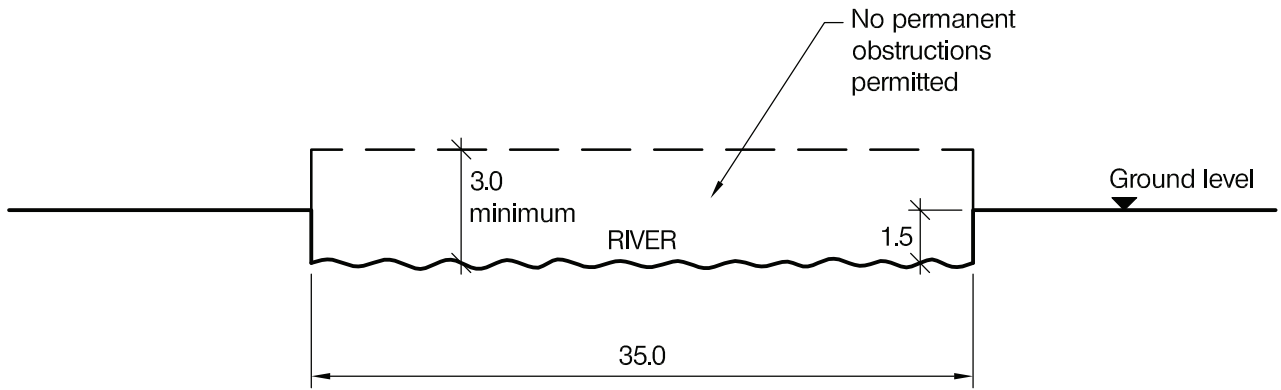
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (20 marks)
- b. After seeing the Architect's drawings for the roof a club benefactor asks if a large sculpture weighing 100kN could be placed on the centre of the clubhouse roof. Explain how this could be achieved, using sketches as necessary to illustrate your solution. (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 including the rail support structure 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 the clubhouse roof perimeter and a vertical supporting element under it.
  - (ii) The rail support and connection to the foundations. (30 marks)
- e. Prepare an outline programme and method statement for construction of the moveable roof. (10 marks)



SECTION

NOTE: All dimensions are in metres

FIGURE Q3



## Question 3. Pipe bridge over a river

### Client's requirements

1. A bridge over a non-tidal river to carry a pipe containing drinkable water. See Figure Q3.
2. The ground on both sides of the river is liable to flooding.
3. The river is 35.0m wide at mean water level and must not be permanently obstructed.
4. Clearance of at least 3.0m must be provided under the bridge for the full width of the river to allow floating debris to pass during floods.
5. The water pipe is required to be of steel, of minimum 400mm diameter. A minimum wall thickness of 15mm is required. A low self-weight design is required for the superstructure.

### Imposed loading

6. On the projected plan area of the bridge  $0.75\text{kN/m}^2$ . This loading is for erection and maintenance purposes only and does not include the weight of the pipe and its contents.

### Site conditions

7. The ground on both sides of the river is flat and is used for farming. The river flows through a wide inland valley. The nearest public road is 2.5km away.
8. Ground conditions:
 

0 – 0.4m	Top soil
0.4m – 1.7m	Fine sand and gravel, $N= 6$
1.7 – 2.2m	Firm clay, $C=100\text{kN/m}^2$
2.2m – 6.0m	Medium dense gravel, $N= 20$
Below 6.0m rock, allowable bearing pressure $3000\text{kN/m}^2$ .	
Ground water was encountered at 1.5m below ground level.	
9. The ground water was tested for the presence of soluble sulphates and acids and the following results were reported: soluble sulphates 2.1 g/l and "near neutral" acidity.

### Omit from consideration

10. Wind forces on the bridge.

### 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. Before completion of your design, the client requests that pedestrians should be able to use the bridge to cross the river. Explain how this will affect the design and detail of the bridge. (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 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 jointing needed to allow for transportation and erection.
  - (ii) The connection of the superstructure to the foundation. (30 marks)
- e. Prepare a detailed method statement for the safe construction of the pipe bridge and its foundations. (10 marks)

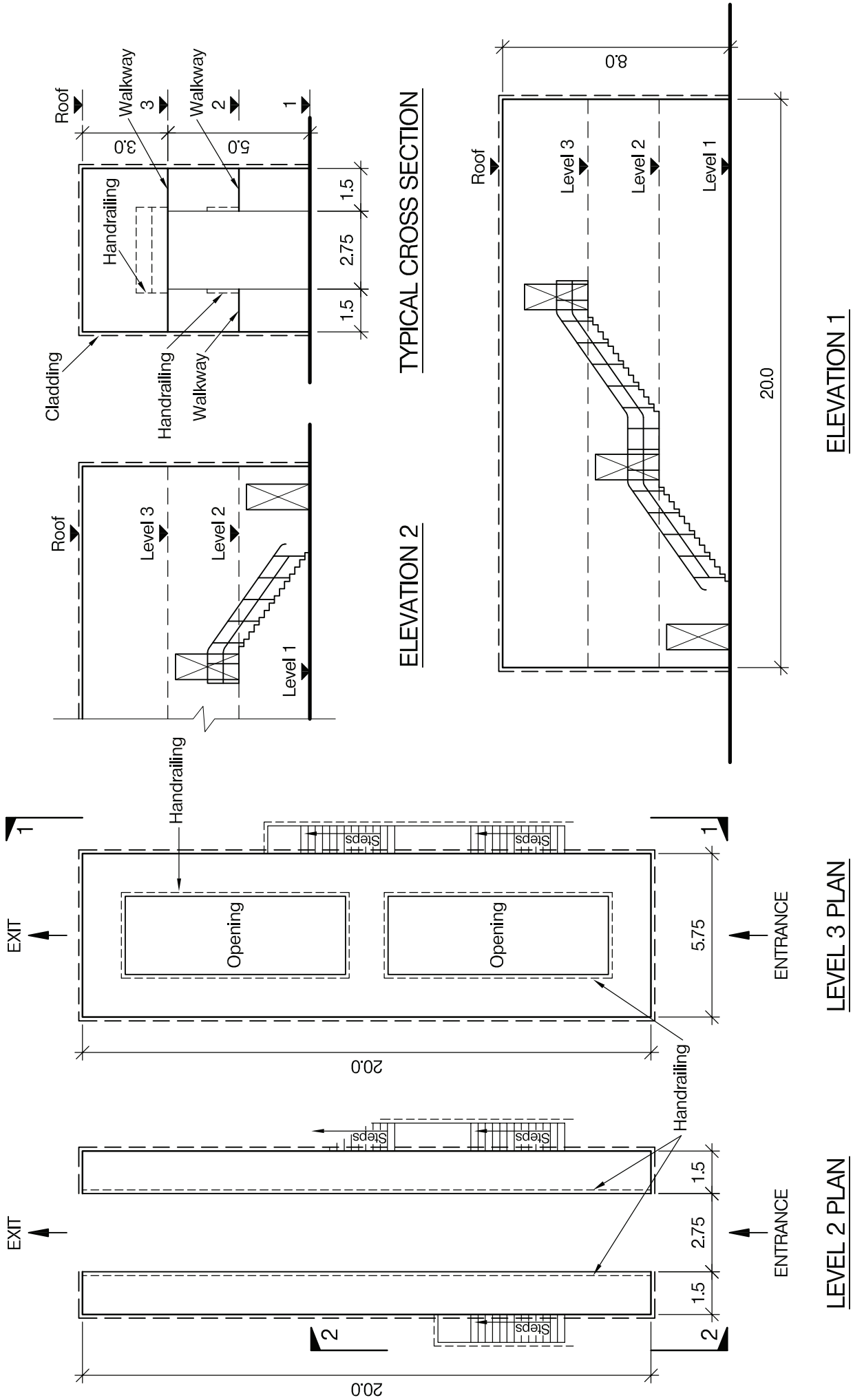


FIGURE Q4

NOTE: All dimensions are in metres

## Question 4. Bus maintenance building

### Client's requirements

1. A large weatherproof structure is required where maintenance of double-decker passenger buses can be undertaken. See Figure Q4.
2. To provide good access to the vehicles when parked inside the building, there should be a minimum of obstructions between the walkways and the vehicles. The bus entrance and exit openings are not required to have doors.
3. Hand railing is required to the perimeters of the walkways and to the external staircase.

### Imposed loading

- |                        |                       |
|------------------------|-----------------------|
| 4. Loading on walkways | 5.0kN/m <sup>2</sup>  |
| Loading to roof        | 0.75kN/m <sup>2</sup> |

### Site conditions

5. The site is level and is on the outskirts of a large city. The basic wind speed is 44m/s based on a 3 second gust; the mean equivalent hourly wind speed is 22m/sec.

### Ground conditions

- |   |   |
|---|---|
| 6. Ground level – 2.0m                            | Loose fill material                                     |
| Below 2.0m  | Gravel, allowable bearing pressure 100kN/m <sup>2</sup> |
| Groundwater was found at 1.0m below ground level. |   |

### Omit from consideration

7. Detailed design of 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 the scheme. Justify the reasons for your solution. (20 marks)
- b. Upon completion of the design the client asks whether the width of the internal opening can be increased to 3.5m. Describe the implications this will have on the original design. (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 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 junction between the walkways and the perimeter structure.
  - (ii) The junction between the staircase landings and the perimeter structure. (30 marks)
- e. Prepare a detailed method statement for the safe construction of the structure. (10 marks)

The Institution of Structural Engineers  
International HQ  
11 Upper Belgrave Street  
London SW1X 8BH  
United Kingdom  
tel: +44 (0)20 7235 4535  
fax: +44 (0)20 7235 4294  
mail@istructe.org  
www.istructe.org  
Registered Charity