

## Chartered Membership Examination

Friday 8 January 2016

### 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 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. 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.**



# 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.

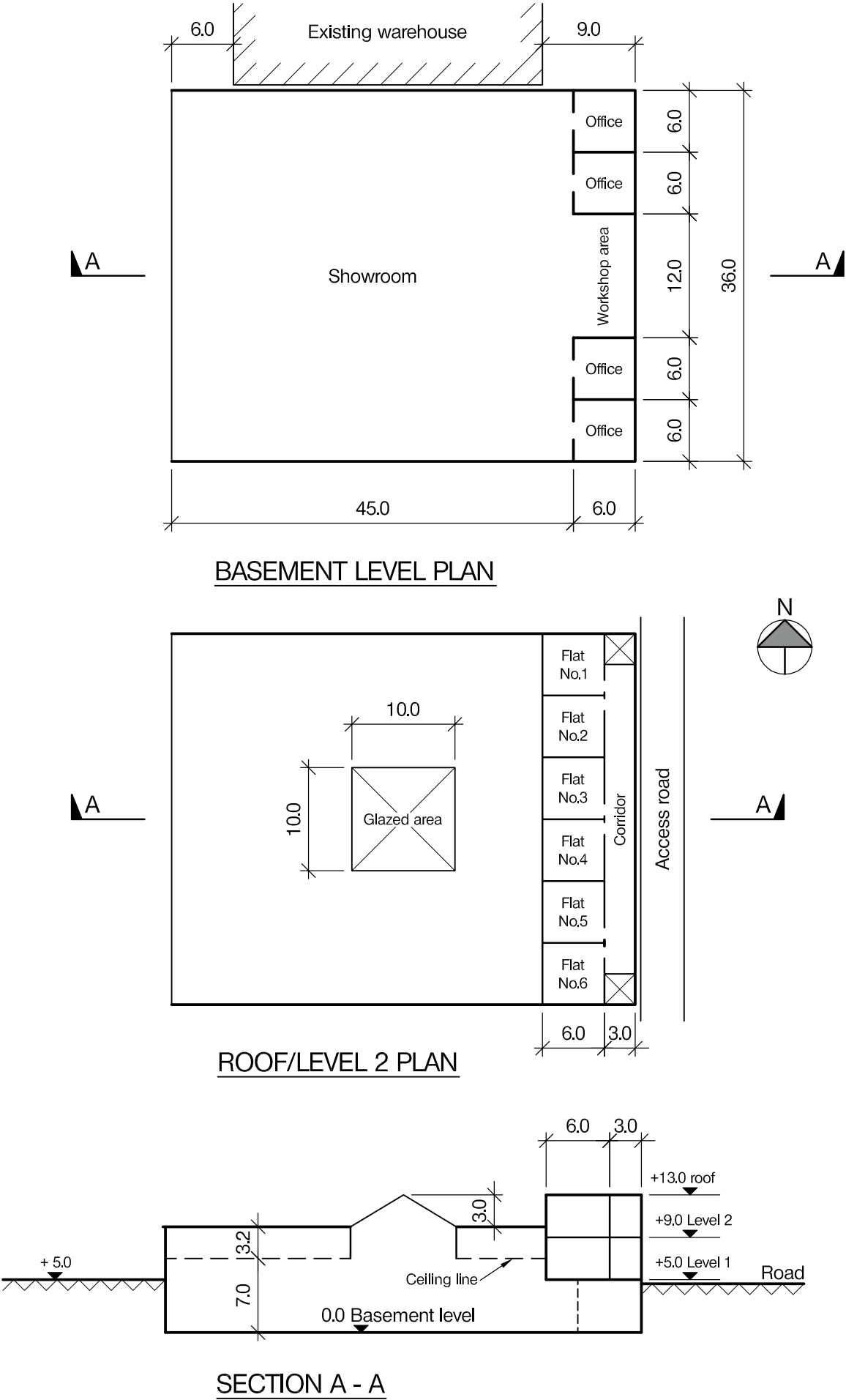
The unusual requirement of the examination is that you demonstrate the validity of the training and experience that you have acquired in recent years. The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural 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.



NOTE: All dimensions are in metres

FIGURE Q1

# Question 1. New Car Showroom with Residential Accommodation

## Client's Requirements

1. A new development on the outskirts of a large city, consisting of a car showroom located below ground level and 12 equal size residential units located above level 1 as shown on Figure Q1.
2. The site is restricted along the East elevation by an access road serving a storage warehouse located along the North elevation which has to remain operational. There is limited information available for this existing building which is believed to be mainly of masonry construction with shallow foundations.
3. Floor to floor height for the residential units is to be 4.0m which includes 0.3m for a service zone and a clear floor to ceiling height of 2.6m. Offices and workshop areas are to have a minimum floor to floor height of 5.0m with a minimum floor to ceiling height of 3.5m and a 0.5m service zone. The showroom area generally, is to have a clear height to the underside of the ceiling of 7.0m, reducing locally to the same level as the underside of the residential units.
4. External perimeter columns are to be located no closer than 6.0m centres. The internal space to the showroom with the 7.0m clear height is to remain column free. Two internal columns will be allowed elsewhere. No internal columns are allowed within the internal space of the residential units.
5. The roof to the showroom is to be in lightweight metal cladding with a 10.0m x 10.0m zone to house a fully glazed pyramid located centrally over the showroom. This zone is to remain clear and unobstructed by any structural members except around the perimeter of the glazed area.

## Imposed Loading

6. Roof	1.5kN/m <sup>2</sup>
Residential units	2.5kN/m <sup>2</sup>
Basement slab	15.0kN/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, measured from road level, are constant across the site:
 

Road level – 7.0m	top soil with contaminated fill
7.0m – 8.0m	soft sand and peat
8.0m – 10.0m	Silty sand, N = 5
Below 10.0m	Rock, allowable bearing pressure 3,500kN/m <sup>2</sup>

 Ground water was encountered at 7.0m below road level.

## Omit from Consideration

9. Detail design of access core to upper floors and stairs.
10. Access to showroom.

## 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 and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After completion, and removal of the temporary covering, the owner of the adjacent building reports some major cracking to his walls. The suspicion is that the construction of the new building has caused the cracking. Write a letter to the client explaining the precautions you have taken in your design to safeguard against undermining the adjacent building. (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 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)

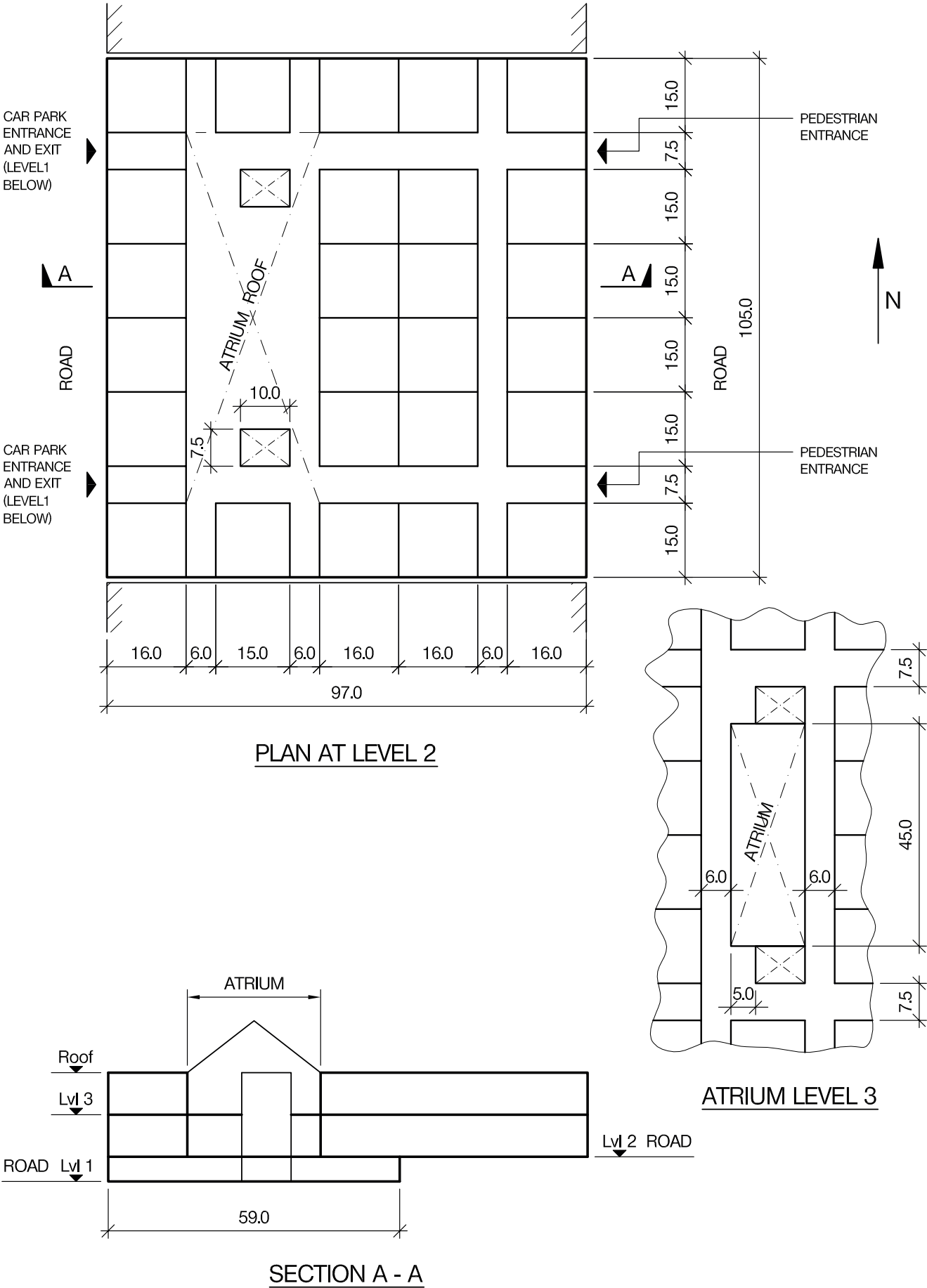


FIGURE Q2

## Question 2. New Infill Shopping Centre

### Client's Requirements

1. A new town-centre infill shopping centre with underground car parking. See Figure Q2.
2. The shopping centre is to be built between two existing roads on a sloping site previously occupied by a warehouse and factory.
3. The Road at Level 1 is 5.0m below the Road at Level 2. The clear internal height required within the car park is 3.0m and the internal column spacing is to be at a minimum of 7.5m. For design purposes the car parking spaces are to be 2.5m x 5.0m.
4. The layout of the proposed shops at Levels 2 & 3 is indicated on Figure Q2. No columns are permitted within the respective shops. Internal columns are to be at a minimum spacing of 6.0m and the finished floor-to-floor height is to be 10.0m. All external columns are to be at a minimum spacing of 6.0m.
5. The core areas can provide support to the floors at Levels 2 and 3, but are freestanding above Level 3 and can not provide support to the roof. At Level 3 there is a walkway around the Atrium void giving access to shops. The void at this level is 15.0m x 45.0m: see Figure Q2. Only one row of columns is permitted within the Atrium area to support the walkways. The roof above the atrium is to be fully glazed and is to have an aesthetically pleasing structure.
6. The exterior of the shopping centre generally is to be clad with brick / blockwork cavity walls except for the shops to the roadside elevation at Level 2 where full glazing is required.

### Imposed Loading

7. Roof	1.50kN/m <sup>2</sup>
Shop floor	5.0kN/m <sup>2</sup>
Car Park	2.5kN/m <sup>2</sup>

### Site Conditions

8. The site is in a city centre. Basic wind speed is 40m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20m/s.
9. Ground conditions vary linearly across the site:
 

Ground level – 3.0m	Made ground
3.0m – 9.0m	Silty sand, N values vary from 5 to 10
Below 9.0m	Rock, allowable bearing pressure 2,000kN/m <sup>2</sup>

 Ground water was encountered at 4.0 m below ground level.

### Omit from Consideration

10. Detail design of the core areas.

### SECTION 1

(50 marks)

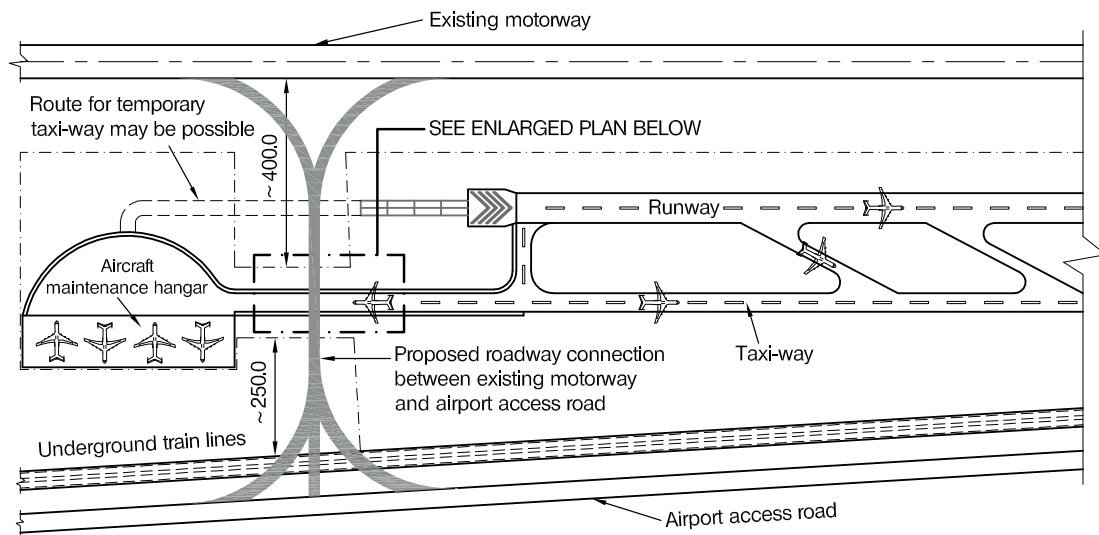
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40marks)
- b. After construction is complete the Client advises that he wishes to construct a restaurant on the roof over the entire plan area except for the Atrium. The structure would be fully-glazed. Write a letter to the Client explaining the effect this would have on the structure and how his request could be accommodated. (10 marks)

### SECTION 2

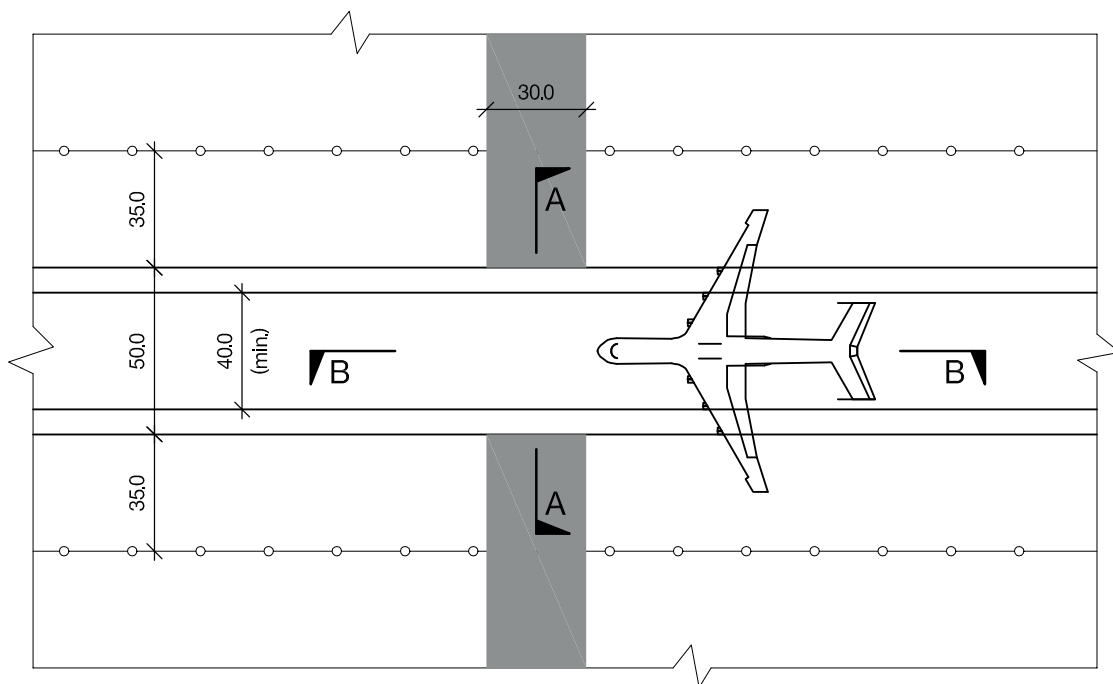
(50 marks)

For the solution recommended in Section 1(a):

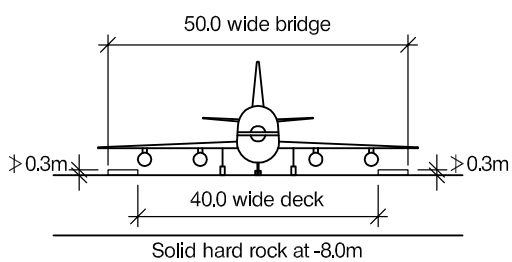
- c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical 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)



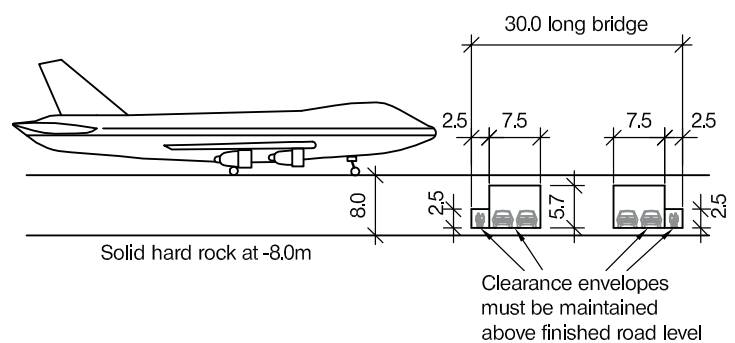
## PLAN



ENLARGED PLAN



SECTION A - A



SECTION B - B

**NOTE:** All dimensions are in metres

FIGURE Q3



## Question 3. Taxiway Bridge

### Client's requirements

1. An existing motorway is to be connected with the main access road to the airport as shown in Figure Q3 and a bridge is required to support the taxiway over the new road. The existing maintenance hangar should remain in position and the taxiway connection to the hangar is to be interrupted as little as possible.
2. The airport will allow a maximum of seven days' continuous closure of the taxiway to the hangar once in a year. No other closure will be allowed. However a temporary taxiway route (as shown in Figure Q3) may be built before the bridge construction, but the airport will charge the contractor a very high price if this option is chosen as it would disrupt aircraft landing and take-off.
3. Aircraft moving to and from the hangar should not have any obstruction 50.0m either side of the centreline of the existing taxiway.
4. Two 7.0m diameter concrete tubes, constructed on top of existing bed rock at 8.0m depth from the surface of the runway / taxiway, carry the underground railway service. This must remain uninterrupted at all times.
5. The taxiway bridge must achieve the clearance envelopes as shown in figure Q3.

### Imposed loading

6. Design Live load on bridge deck-  $20.0\text{kN/m}^2$  over entire deck.

### Site conditions

7. The site is located in open countryside. Basic windspeed is  $44.0\text{m/s}$  based on a 3-second gust; the equivalent mean hourly wind speed is  $22.0\text{m/s}$ .
8. Ground conditions
 

Ground level – 8.0m	stiff clay, $C = 200\text{kN/m}^2$
Below 8.0m	Rock, characteristic compressive strength $2,000\text{kN/m}^2$

### Omit from consideration

9. Longitudinal braking load.

### SECTION 1

**(50 marks)**

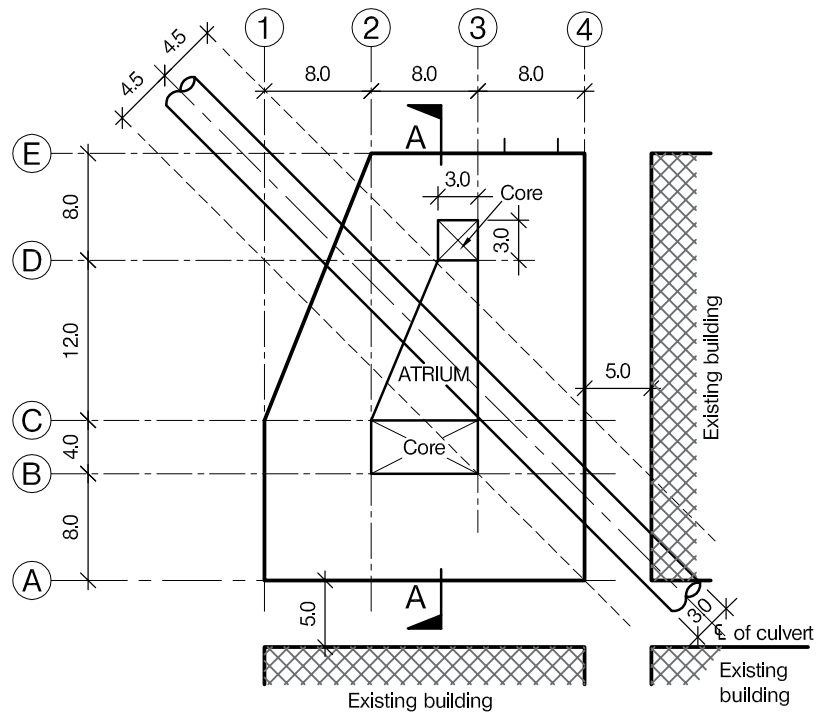
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After the completion of the design, the client informs you that the deck should be checked for a single wheel load of  $500\text{kN}$  over an area  $500\text{mm}$  square. Write a letter to your client advising on the design implications and ways in which the design would need to be modified. (10 marks)

### SECTION 2

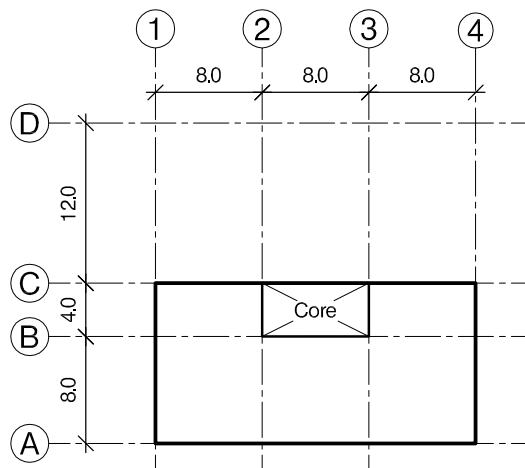
**(50 marks)**

For the solution recommended in Section 1(a):

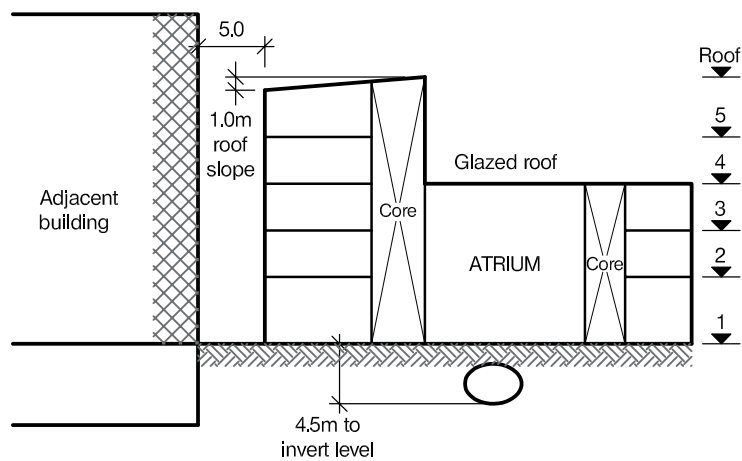
- c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical 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)



GROUND FLOOR PLAN



LEVEL 5 PLAN



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q4

## Question 4. New City Hospital Building

### Client's requirements

1. A new city centre 5 storey hospital building– see Fig Q4. The building is to step in height as shown in Figure Q4. The roof to level 5 is sloped as shown in Figure Q4.
2. The building will have full height glazed cladding to the perimeter and also to the atrium above Level 2. The atrium will have a glazed roof. No bracing is allowed where there is glazed cladding.
3. Internal floor to floor heights are to be kept to a minimum to minimise cladding costs. Floor to ceiling height is to be 2.8m, except level 1 where the floor to ceiling height will be 4.5m. A 300mm deep clear service zone is required within the ceiling voids. No structure is allowed within the service zone.
4. Two stair and lift cores extend the full height of the building and may be used to provide lateral stability.
5. No columns are allowed within the floor footprints.
6. There is a 3m diameter culvert under the site, with an invert level at 4.5m below level 1, see Figure Q4. The culvert cannot withstand any additional loads and any foundations must be placed outside the 9.0m exclusion zone shown on Figure Q4.
7. A minimum fire rating of 2 hours is required throughout.

### Imposed Loading

8. Roof 3.0kN/m<sup>2</sup>  
Floors 6.0kN/m<sup>2</sup>  
Loadings include allowances for floor finishes, ceilings and services.

### Site Conditions

9. The site is in a city centre. Basic wind speed is 40m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20m/s.
10. Ground Conditions
 

Ground level – 0.5m	Top soil/made ground
0.5m – 3.0m	Sands and Gravels, N = 15
3.0m – 20.0m	Dense Gravels, N = 40
Below 20.0m	Rock, allowable safe bearing pressure 500kN/m <sup>2</sup>
Ground water is present 4.5m below Level 1 (ground level)	

### Omit from consideration

11. Detailed design for staircases and lifts within cores; glazed facades.

### SECTION 1

**(50 marks)**

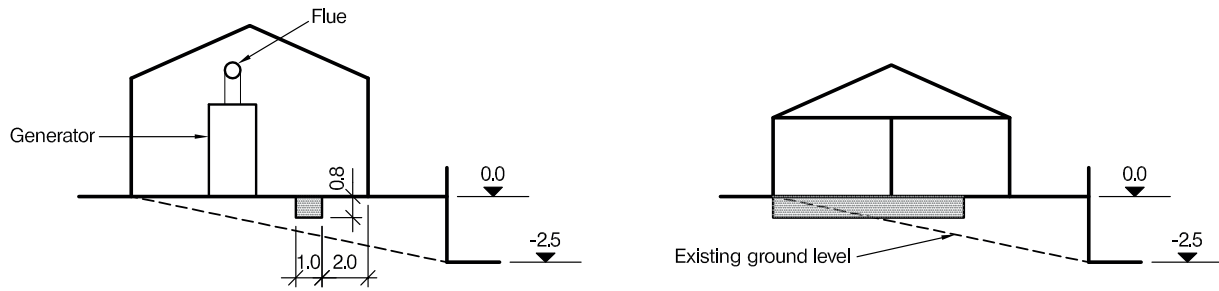
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the fundamental framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After completion of the design and before construction has started, the Client states that he may wish to infill the atrium at a later date in order to increase floor space. Write a letter to the Client advising him of the implications on the design. (10 marks)

### SECTION 2

**(50 marks)**

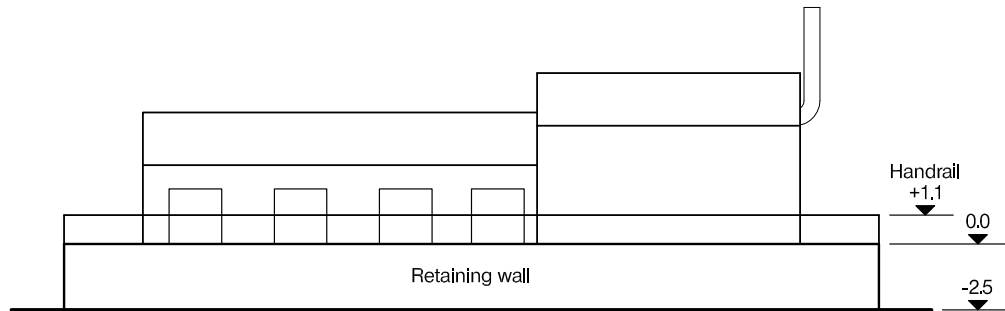
For the solution recommended in Section 1(a):

- 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 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)

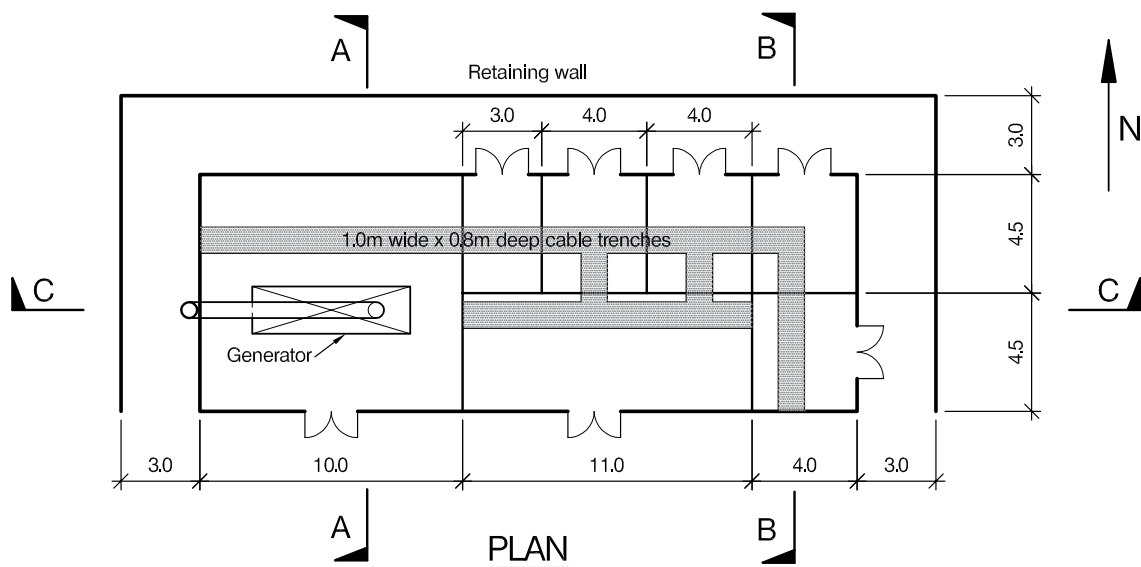


SECTION A - A

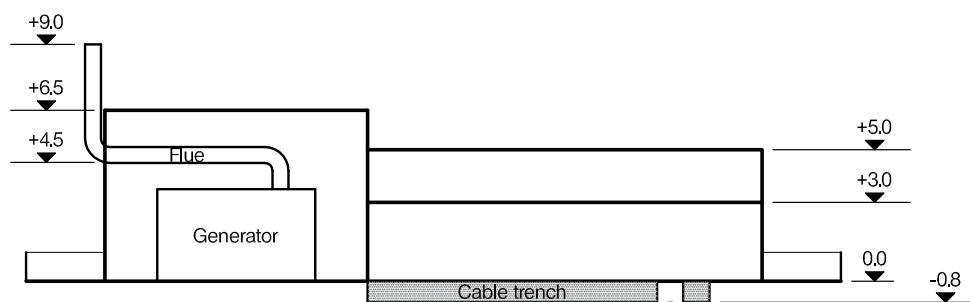
SECTION B - B



NORTH ELEVATION



## PLAN



SECTION C - C

**NOTE:** All dimensions are in metres

FIGURE Q5

## Question 5. Emergency Generator Building

### Client's Requirements

1. Construction of a building to house an emergency electrical generator.
2. The building comprises a generator room and six electrical plant rooms; see Figure Q5. Eaves heights to the generator room are 4.5m, and to the plant rooms 3.0m. Exhaust ducting 0.5m diameter leads from the generator to an external flue.
3. The building and retaining wall are to be clad with brickwork, to match the aesthetics of the surrounding buildings.
4. Access 3.0m wide is required around the entire perimeter of the building, requiring a retaining wall on three sides, owing to the nature of the sloping site.
5. Cable trenches 1.0m wide and 0.8m deep are required to access each room.
6. A handrail 1.1m high is required to the perimeter access around the retaining wall.
7. A minimum of 1 hour fire resistance is needed.

### Omit from Design

8. The design of the support structure for the generator flue.

### Imposed loading

- |                 |                       |
|-----------------|-----------------------|
| 9. Ground floor | 7.5kN/m <sup>2</sup>  |
| Pitched roof    | 0.6 kN/m <sup>2</sup> |

### Site conditions

10. The site is situated on a heavily wooded site, which will need to be partly cleared of trees, and there are some cavities at a shallow depth in unknown positions caused by old mine workings. Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s.
11. The ground conditions at the south boundary of the site are:
 

Ground level to 2.0m	Topsoil and made ground
2.0m to 3.0m	Firm clay C = 75kN/m <sup>2</sup>
3.0m to 4.0m	Stiff Clay C = 125kN/m <sup>2</sup>
Below 4.0m	Mudstone, presumed safe bearing capacity 400kN/m <sup>2</sup>

 Ground water was encountered at 3.0m below ground level.

### SECTION 1

- 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 and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After you have completed your design, the client asks you to install a basement plant room under the entire area of the generator room (10m x 9m), with a clear headroom of 2.5m. Write a letter to your client explaining the implications of this potential change. (10 marks)

### SECTION 2

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 and the retaining wall. (20 marks)
- d. Prepare general arrangement 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 programme. (10 marks)





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