

# Chartered Membership Examination



Friday 13 APRIL 2007

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## Structural Engineering Design and Practice

9.30a.m. – 1p.m. and 1.30 – 5p.m. (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 books, 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 in the bottom right-hand corner. Only the answer book(s) 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. 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 books 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*



## **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.

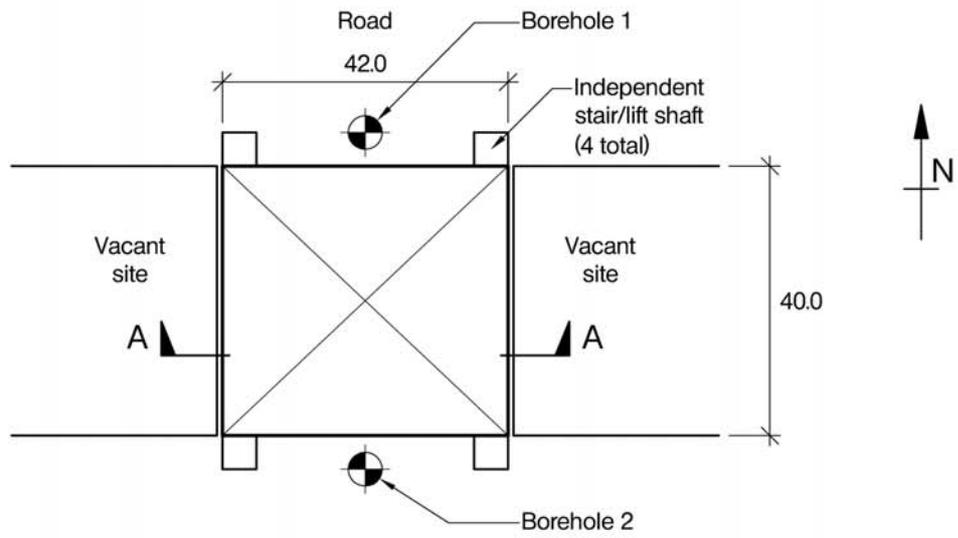
The unusual requirement of the examination is that you demonstrate the validity of the training and experience that you have acquired in recent years. The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural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

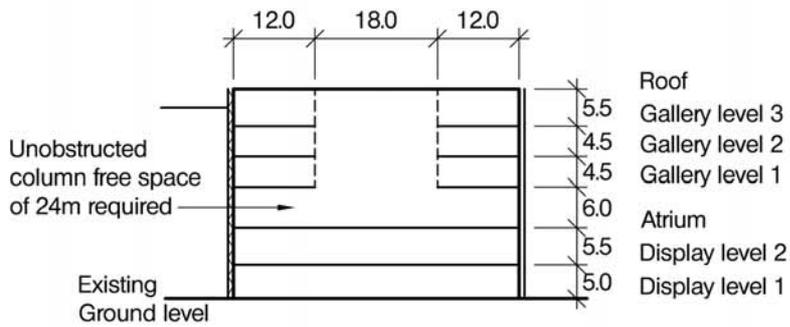
In selecting and developing your design you should also remember the guidance given in the Institution's report, Aims of Structural Design, and in particular:

- (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”.

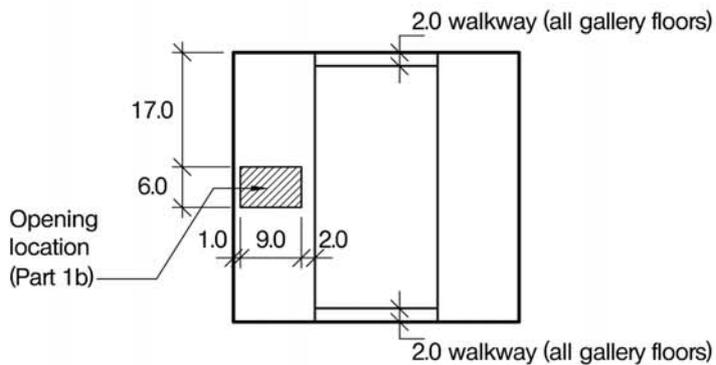
If you have difficulty in deciding the correct interpretation of a question, pay particular attention to point 6. notes to candidates, on the front cover. The examiners will take into account your interpretation – and the design you base on this – if this is clearly stated at the beginning of your answer.



SITE PLAN



SECTION A-A



FLOOR PLAN AT GALLERY LEVEL 1

NOTE: All dimensions are in metres

FIGURE Q1

# Question 1. Library and Exhibition Centre

## Client's requirements

1. A library and exhibition centre to be constructed in a city centre; see Figure Q1.
2. The client has stipulated that cross bracing is not permitted within the interior of the building.
3. A fully glazed structurally independent staircase and lift/elevator shaft is to be located outside each corner of the building.
4. Columns are permitted in the external elevations. Internal columns are to be located at a minimum of 8.0m centres and at least 8.0 m from an external wall. A maximum of three rows of internal columns are permitted on the two Display Levels in the north/south direction
5. At the atrium level, an unobstructed column free space of 24.0 m width is required with a 18.0 m column free opening up to roof level, as shown on section A-A, figure Q1. The roof over the atrium is to be glazed.
6. The north and south elevations are to be glazed, the east and west walls are to be clad in masonry.
7. Clear floor heights of 3.7 m are required for all gallery levels and 4.2 m for all display levels. The minimum clear height at the Atrium level under the Gallery Floors is 5.2 m.

## Imposed Loading

- |                         |                       |
|-------------------------|-----------------------|
| 8. Roof                 | 5.0 kN/m <sup>2</sup> |
| Gallery, Display Floors | 5.0 kN/m <sup>2</sup> |
| Atrium Floor Loading    | 1.0 kN/m <sup>2</sup> |

Loadings include an allowance for partitions, finishes, services and ceilings where appropriate.

## Site Conditions

9. The site is level and located in a city centre. Roads run past the north and south faces of the building. Vacant sites are present on the east and west.  
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:  
Borehole 1  
Ground level – 1.5m                      made ground  
1.5 m – 5.0 m                              Firm to stiff fissured clay  $C = 75 \text{ kN/m}^2$   
Below 5.0 m                                Rock – allowable safe bearing pressure 1000 kN/m<sup>2</sup>  
  
Borehole 2  
Ground level – 1.0m                      made ground  
1.0 m – 4.0 m                              Firm to stiff fissured clay  $C = 75 \text{ kN/m}^2$   
4.0 m – 6.0 m                              Stiff to very stiff clay  $C = 125 \text{ kN/m}^2$   
Below 6.0 m                                Rock – bearing pressure 1000 kN/m<sup>2</sup>

## Omit from consideration

11. Detailed design of stairs and independent lift/elevator shafts.

*continued overleaf*



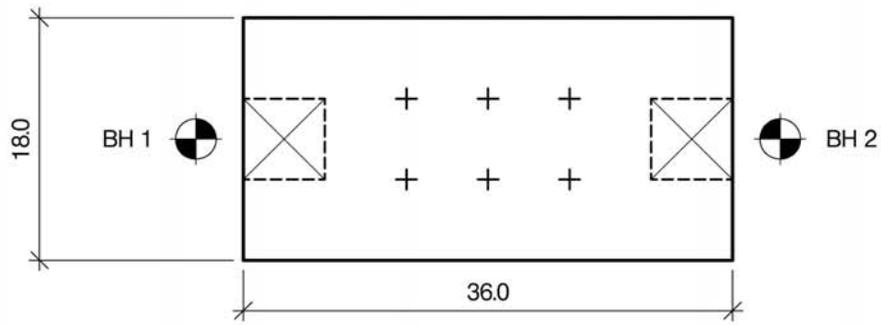
**SECTION 1****(50 marks)**

- 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. (40 marks)
- b. After completion of the design, the client wishes to install a large opening in the floor immediately above the atrium (see Figure Q1 - Floor plan at Gallery Level 1). Write a letter to your client advising him of the implications of this change. (10 marks)

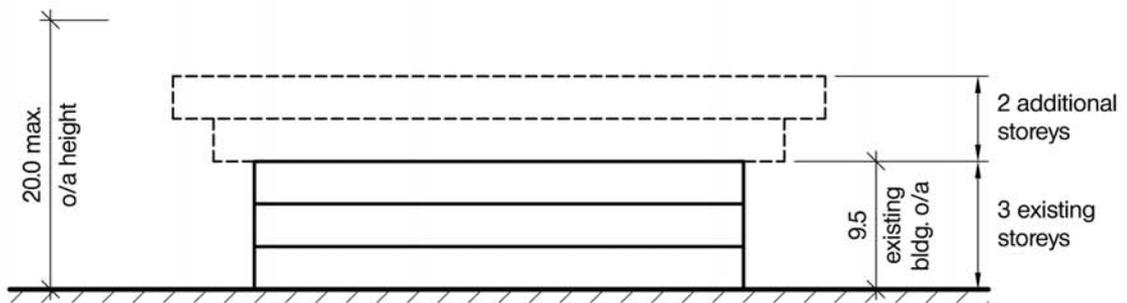
**SECTION 2****(50 marks)**

For the solution recommended in Section 1(a):

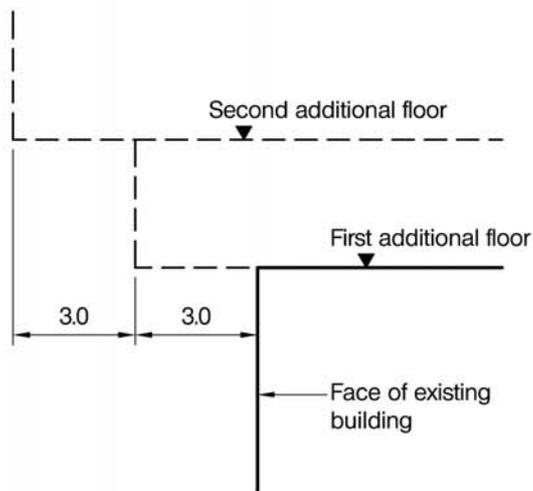
- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (20 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
  - (i) The perimeter walkway connection at gallery level 1 to the edge of the cantilever floor slab.
  - (ii) The connection between the floor and an interior column at gallery level 1 (20 marks)
- e. Prepare a detailed method statement for the safe construction of the structure and an outline construction programme. (10 marks)



EXISTING PLAN



ELEVATION



DETAIL OF EDGE OVERHANG FOR NEW EXTENSION

NOTE: All dimensions are in metres

FIGURE Q2

# Question 2. Office Building Extension

## Client's requirements

1. An existing 3-storey office building is to be extended to 5-storeys. The two new floors overhang the edge of the existing building by 3.0m and 6.0m respectively on all 4 sides; see Figure Q2.
2. The overall plan size of the existing building is 36.0m by 18.0m, and incorporates 2 rows of internal columns on a 6.0m x 6.0m grid to the lower two storeys. The existing floors are 250mm thick supported by 600mm deep (from top of slab to underside of beam) by 300mm wide beams spanning between the columns. The existing lightweight roof spans across the full width of the building and is supported by 600mm deep by 300mm wide steel beams at 6.0m centres. There is a staircase and service core at each end of the building.
3. Limited details are available of the existing construction. It is known that the foundations are 2.5m square pad footings extending to a maximum depth of 3.0m below existing slab level and that the top surface of all foundations is 1.0m below slab level. Records indicate that the floors were designed for an imposed loading of 5.0 kN/m<sup>2</sup>, and the roof for an imposed loading of 1.5 kN/m<sup>2</sup>.
4. A maximum of 8 new internal columns will be permitted within the existing building and these must not be located more than 1.5m from an existing column. There is no limit on the number of columns within the new extension, but these must be located at a minimum spacing of 6.0 m in each direction. External columns (if required) must be at a minimum spacing of 6.0m although there is no restriction on their distance from the edge of the existing building.
5. The existing external elevations of the building are clad in brickwork and incorporate a 1.5m high band of continuous glazing per storey. The cladding for the new extension must be visually compatible with the existing elevations and must incorporate a similar glazing provision. The roof is to be clad in metal decking with a waterproof membrane covering.
6. The floor-to-floor height within the existing building is 3.0m and the total height is 9.5m. The clear floor to ceiling height within the new extension is to be 2.5m, with an additional 200mm depth being provided for services above the ceilings. The overall building height is limited to 20.0m.
7. The existing cores can be extended upwards on the existing foundations to support the new floors and roof but cannot be used to provide lateral stability.
8. A minimum 1-hour fire resistance is required for all structural elements.

## Imposed Loading

- |            |                       |
|------------|-----------------------|
| 9. Roof    | 1.5 kN/m <sup>2</sup> |
| All floors | 4.0 kN/m <sup>2</sup> |

Loadings include an allowance for partitions, finishes, services and ceilings.

## Site Conditions

10. The site is flat and located in the centre of a small city 100km from the sea.  
Basic wind speed is 46 m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23 m/s.
11. Ground conditions:

Borehole 1	Ground – 0.2m	Made ground
	0.2m – 1.5m	Loose Sand and Gravel. N values vary linearly between 3 and 8
	Below 1.5m	Rock. Allowable bearing pressure = 1500 kN/m <sup>2</sup>
Borehole 2	Ground – 0.2m	Made ground
	0.2m – 2.8m	Loose Sand and Gravel. N values vary linearly between 3 and 8
	2.8m – 4.8m	Dense Sand and Gravel. N values vary linearly between 35 and 40
	Below 4.8m	Rock. Allowable bearing pressure = 1500 kN/m <sup>2</sup>

Groundwater was encountered at 3.0m in BH2

## Omit from consideration

12. Detailed design of staircases and lifts.

*continued overleaf*



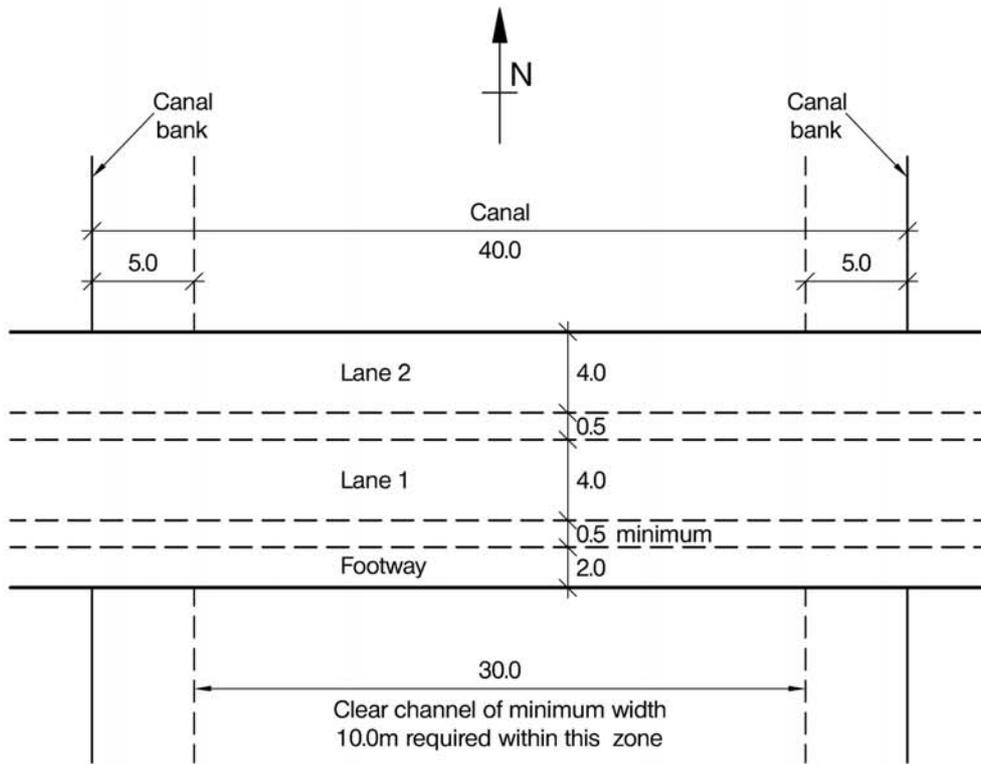
**PART 1****(50 marks)**

- 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 design has been completed, the Client advises you that he wishes the existing building to remain occupied during the alteration works. Write a letter to the Client explaining the effect this would have on the proposed works and how his requirements might be accommodated. (10 marks)

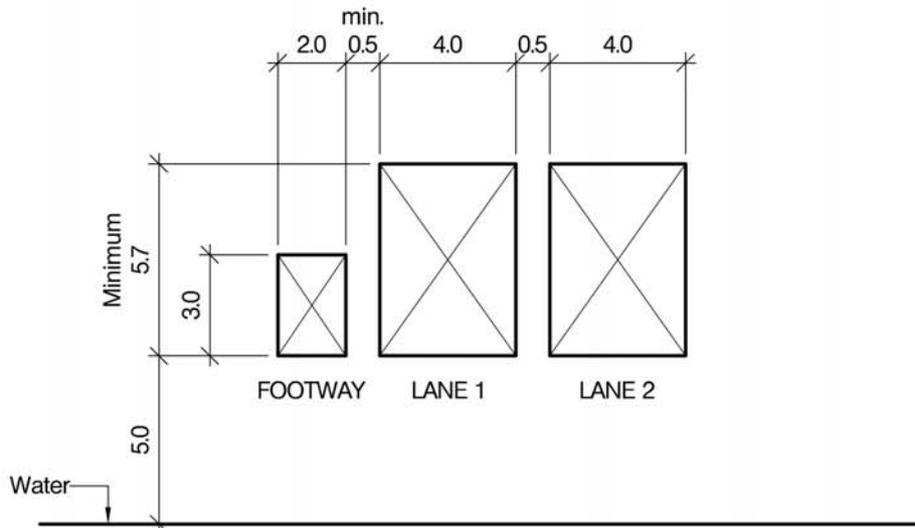
**PART 2****(50 marks)**

For the solution recommended in Part 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (20 marks)
- d. Prepare sufficient 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



CROSS SECTION

NOTE: All dimensions are in metres

FIGURE Q3 (Sheet 1 of 2)





# Question 3. Access Bridge with opening span

## Client's requirements

1. A bridge carrying two 4.0m-wide traffic lanes and a 2.0m-wide footpath over a canal to provide access to a new waterside development: see Figure Q3.
2. The minimum headroom required above water level is 4.5m when the bridge is closed and 15.0m when the bridge is open.
3. The minimum clear channel width required is 10.0m. The water depth in the clear channel is 3.0m. The clear channel must not be closer than 5.0m to either bank.
4. There are no restrictions to the overall size or height of the bridge in either the open or closed positions.
5. The minimum headroom required for road vehicles is 5.7m
6. Approach ramps should be kept to a minimum height with a maximum gradient of 1:12.

## Imposed Loading

- |                             |                        |
|-----------------------------|------------------------|
| 7. Vertical traffic loading | 10.0 kN/m <sup>2</sup> |
| Footpath loading            | 5.0 kN/m <sup>2</sup>  |

## Site Conditions

8. The site is located in a marine environment adjacent to a seaside town. Basic wind speed is 46m/s based on a 3-second gust; the equivalent mean hourly wind speed is 23m/s.

9. Ground Conditions:

East side	Existing ground level to 0.2 m depth	Made Ground
	0.2 m to 10.0 m	Limestone, allowable safe bearing pressure 1000kN/m <sup>2</sup>
West side	Borehole No. 1	
	0.0 to 2.0m	Topsoil
	2.0m – 30.0m	Loose Sand and Gravel, N=5 to 10
	30.0m	Limestone

Groundwater was encountered at 2.0m below ground level.

## Omit from consideration

10. Detailed consideration of the mechanical means of opening and closing the bridge.  
Accidental impact on bridge and supports.

## SECTION 1

(50 marks)

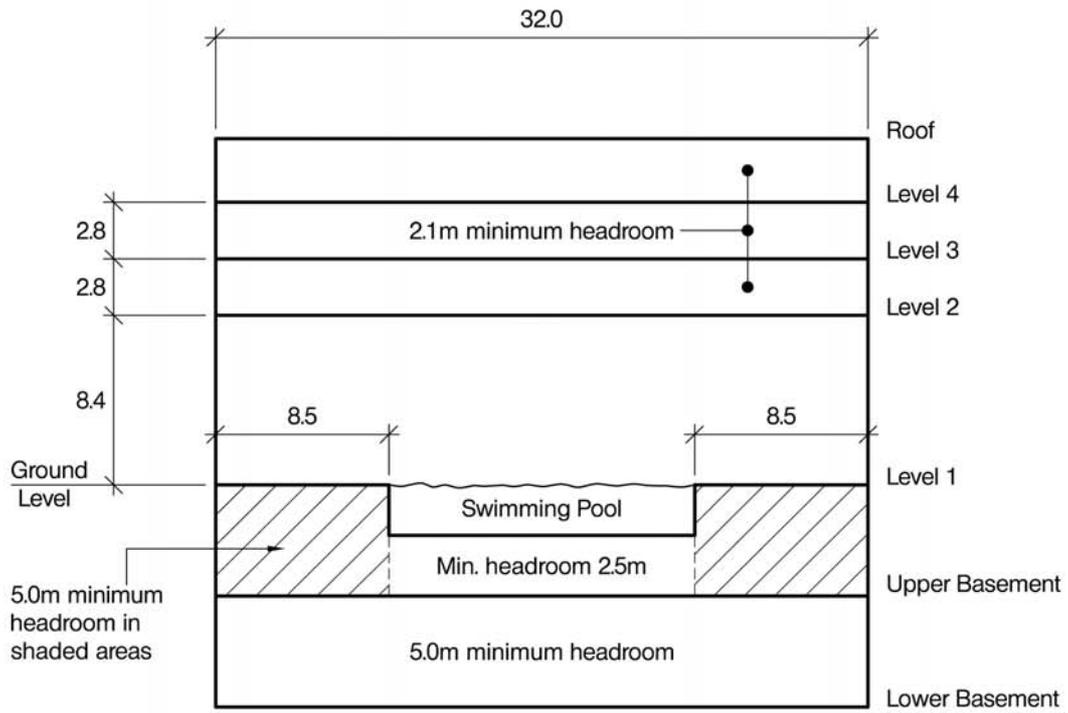
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. The client has asked you to consider increasing the headroom above water level to 6.0m when the bridge is closed. Write a letter to your client explaining how this could be achieved. (10 marks)

## SECTION 2

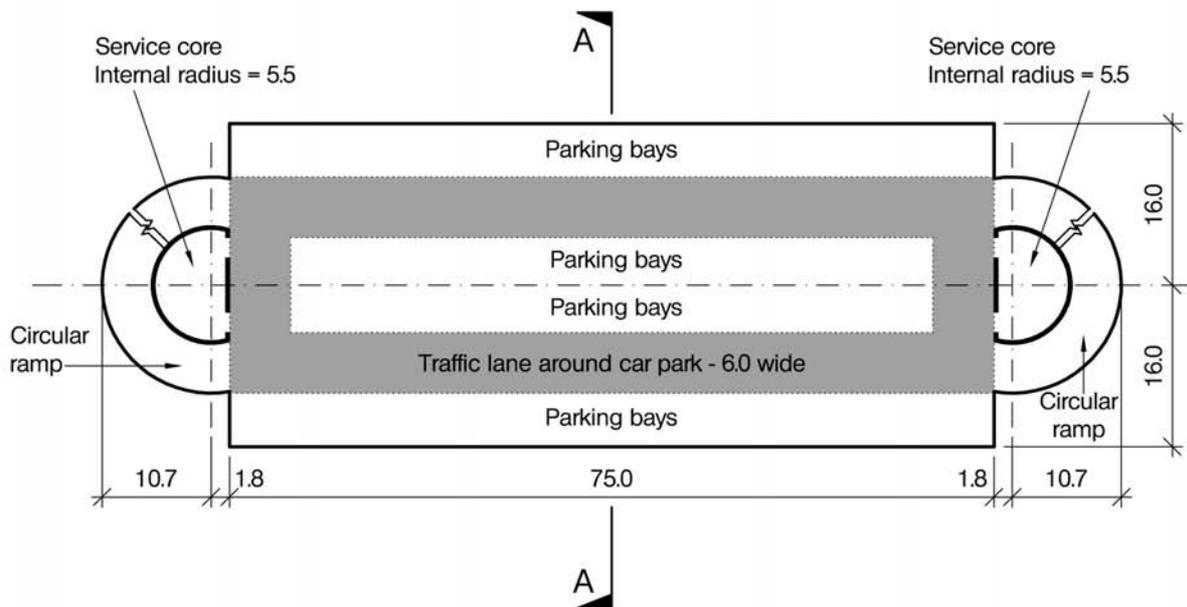
(50 marks)

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 with diagrams showing the key elements of temporary works for the safe construction of the bridge. (10 marks)



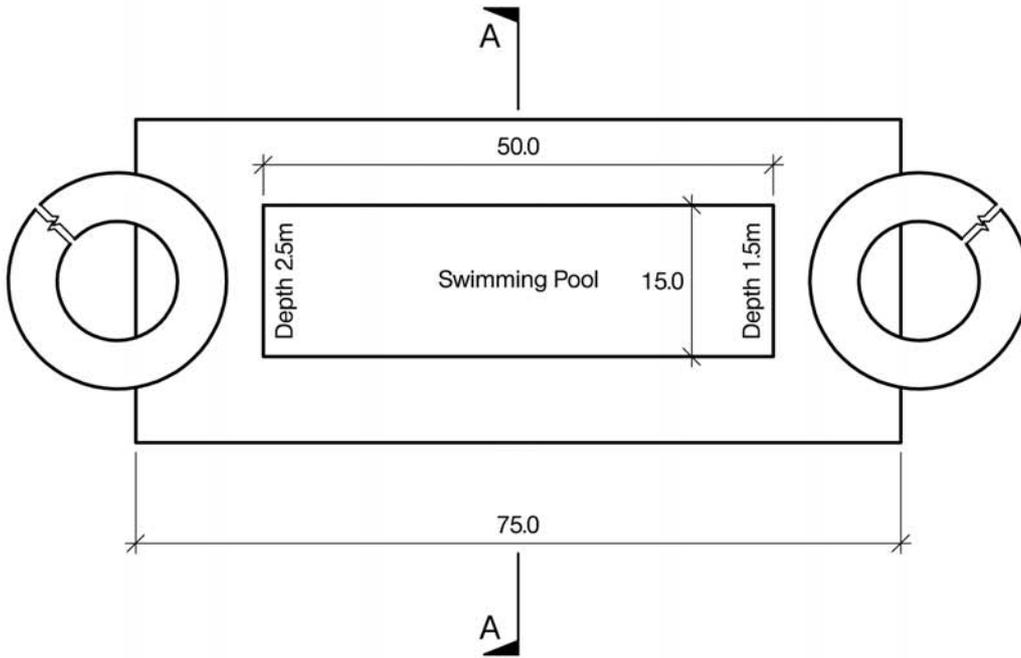
SECTION A-A



TYPICAL FLOOR PLAN OF CAR PARK (LEVELS 2 TO 4)

NOTE: All dimensions are in metres

FIGURE Q4 (Sheet 1 of 2)



PLAN ON LEVEL 1

NOTE: All dimensions are in metres

FIGURE Q4 (Sheet 2 of 2)



# Question 4. Swimming Pool

## Client's requirements

1. A swimming pool with car-parking and a 2-storey basement: see Figure Q4
2. Car-parking is required on levels 2 to 4. Entry and exit to the car-park is via two curved access ramps, integral with services cores, lifts and staircases. The services cores serve all levels including the roof. A swimming pool 50.0m long and 15.0m wide is required on level 1. The pool depth is to vary linearly from 1.5m to 2.5m. Floor-to-floor heights and minimum headroom requirements are shown in Figure Q4. There is no restriction on the roof height.
3. Each parking bay is to be a minimum of 2.5m wide and 4.8m long. 6.0m wide traffic lanes are required on each parking level as shown in Figure Q4. No structure is permitted in any parking bay or traffic lane.
4. A fire resistance of 2 hours is required for all structural elements.

## Imposed Loading

- |                                   |                      |
|-----------------------------------|----------------------|
| 5. Roof                           | 1.5kN/m <sup>2</sup> |
| Car park floors and ramps         | 2.5kN/m <sup>2</sup> |
| Level 1 floor and basement floors | 5.0kN/m <sup>2</sup> |

## Site Conditions

6. The site is level and is located in a city centre.  
Basic wind speed is 40 m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20 m/s.
7. Ground conditions:

Ground level – 1.0m	Made ground
1.0m – 18.0m	Sand and gravel. N values vary from 10 to 40
Below 18.0m	Rock. Allowable bearing pressure = 1500kN/m <sup>2</sup>

Groundwater was encountered at 6.0m below ground level

## Omit from consideration

8. Detailed design of the lifts and staircases.

## SECTION 1

**(50 marks)**

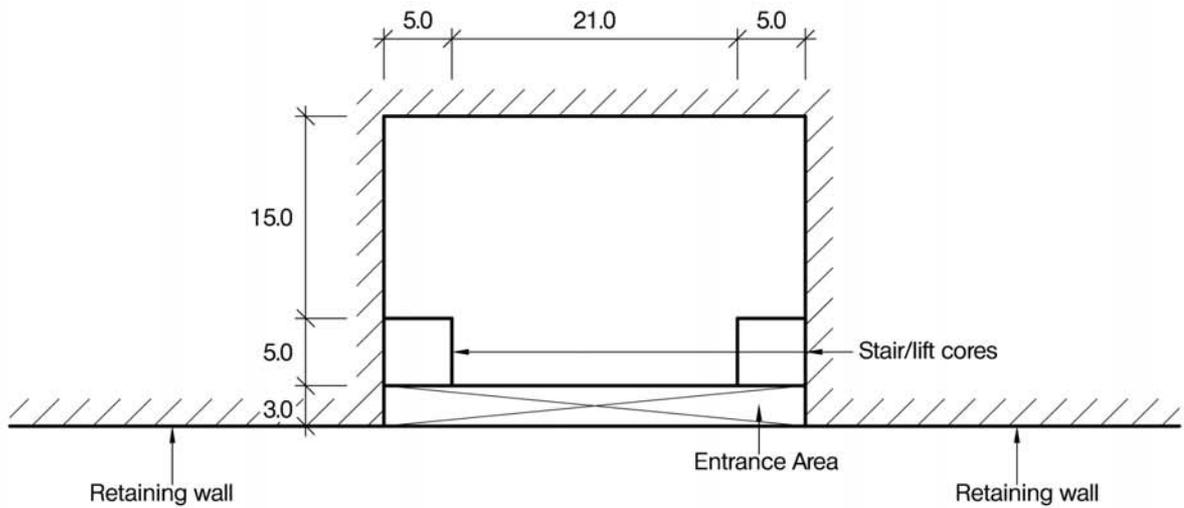
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After completion of your design, it is discovered that groundwater levels are slowly rising and are predicted to reach 1.0m below ground level in the long-term. Write a letter to the client explaining the implications and how your design could be modified to accommodate the rising groundwater. (10 marks)

## SECTION 2

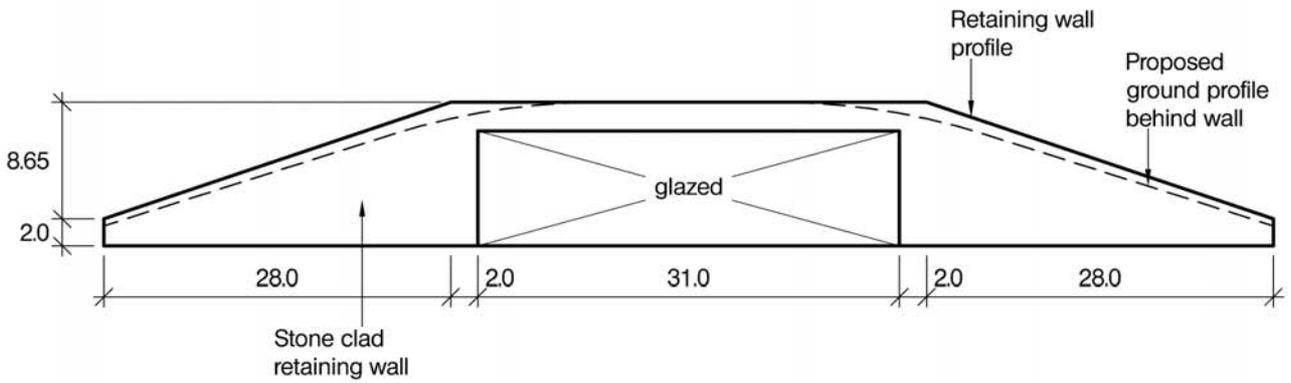
**(50 marks)**

For the solution recommended in Section 1(a):

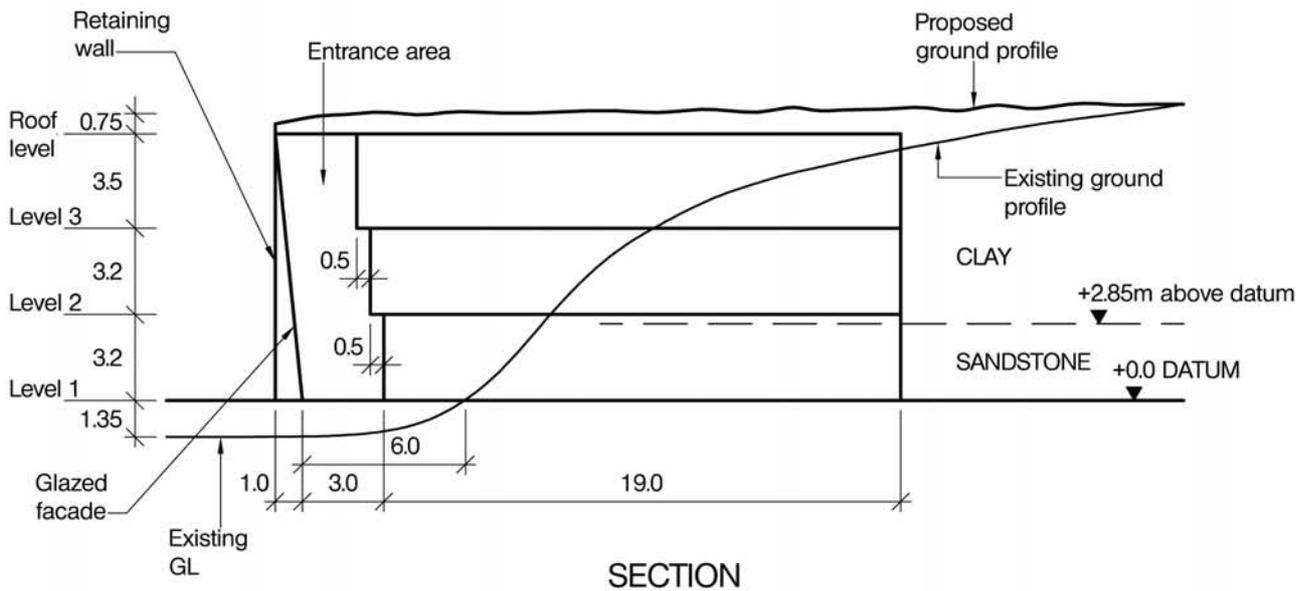
- c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical 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 ON LEVEL 3



FRONT ELEVATION



SECTION

NOTE: All dimensions are in metres

FIGURE Q5

# Question 5. Visitors' Centre

## Client's requirements

1. A visitors' centre is to be constructed on a hillside: see Figure Q5.
2. The roof will be covered with 0.2m of topsoil over fill to a maximum total thickness of 0.75m. The ground level is to be raised around the building on three sides so that the finished building will appear to be set into the hillside.
3. The front retaining wall is to be stone-clad. The three-storey entrance area and the internal walls overlooking the entrance area are to be glazed.
4. No columns are permitted inside the entrance area. Elsewhere columns must be spaced at not less than 5.0m centres in either direction and must be positioned not less than 5.0m from the rear and side walls.
5. Allowable structural zones:

Level 2	0.7m
Level 3	0.7m
Roof	1.0m

## Loadings

6. Imposed loading

Roof	5.0kN/m <sup>2</sup>
Floors	5.0kN/m <sup>2</sup>

Loadings include an allowance for partitions, finishes, services and ceilings where appropriate.

## Site Conditions

7. The site is located in open country. Basic wind speed is 46m/s based on a 3-second gust; the equivalent mean hourly wind speed is 23m/s.
8. Typical ground conditions relative to floor level 1 at +0.0m datum:

Below +2.85m	Sandstone, allowable safe bearing capacity 3000kN/m <sup>2</sup>
Above +2.85m	Glacial clay, internal angle of friction $\phi' = 28^\circ$ , bulk density = 1950kg/m <sup>3</sup> .

Topsoil and vegetation 0.2m deep overlie the hillside. Groundwater level is at the top of the sandstone.

## Omit from consideration

9. Detailed design of the service cores and staircases..

## SECTION 1

(50 marks)

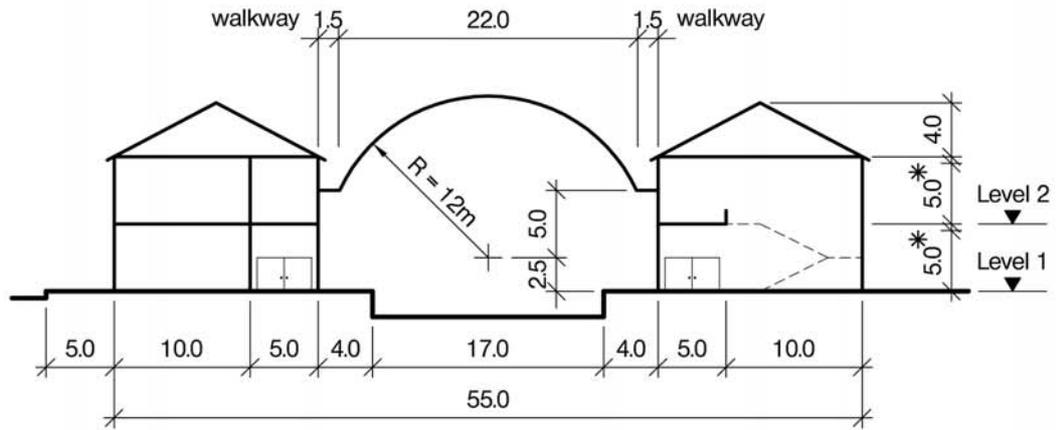
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After you have completed your design the client wishes to add a further 1.0m depth of fill over the building. Write a letter to your client advising the implications of the proposal. (10 marks)

## SECTION 2

(50 marks)

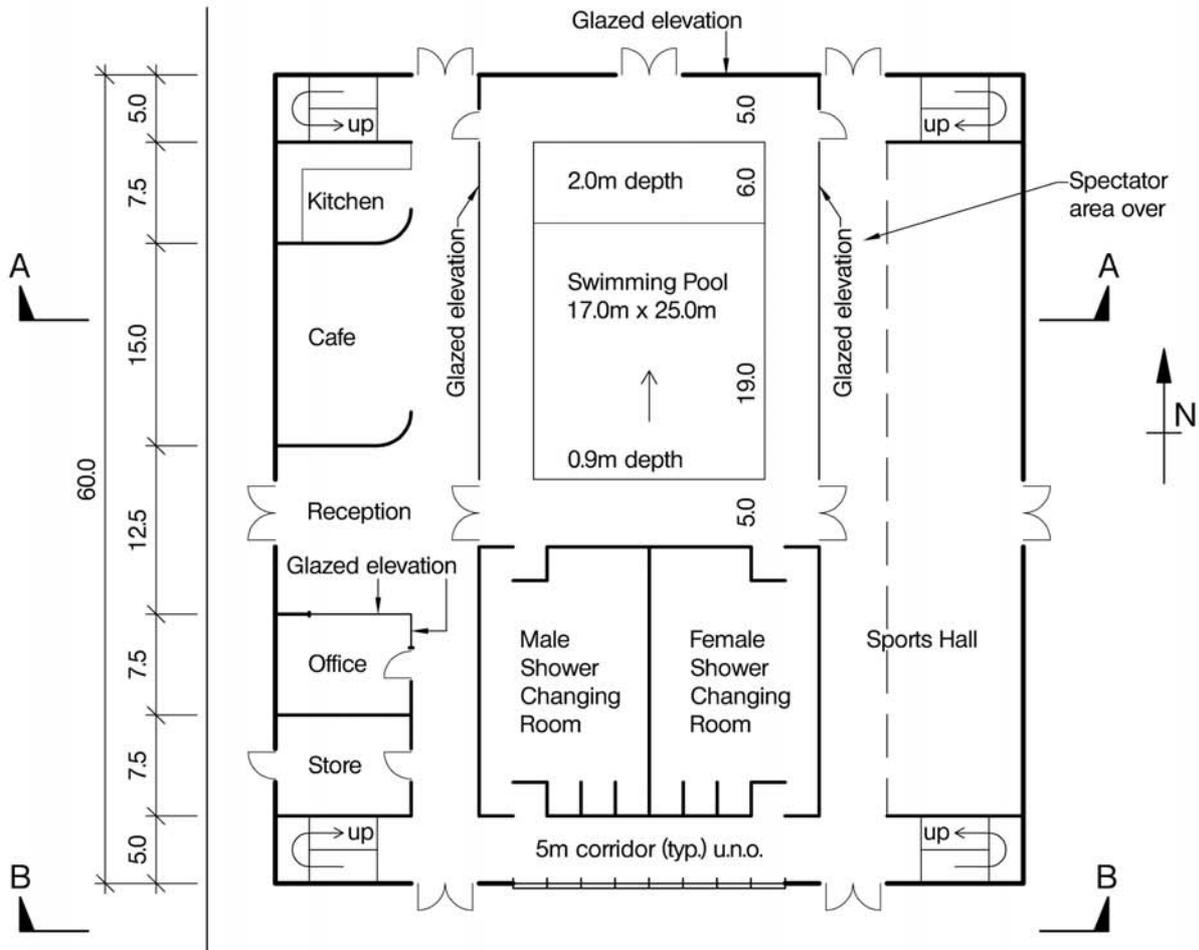
For the solution recommended in Section 1(a):

- 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**

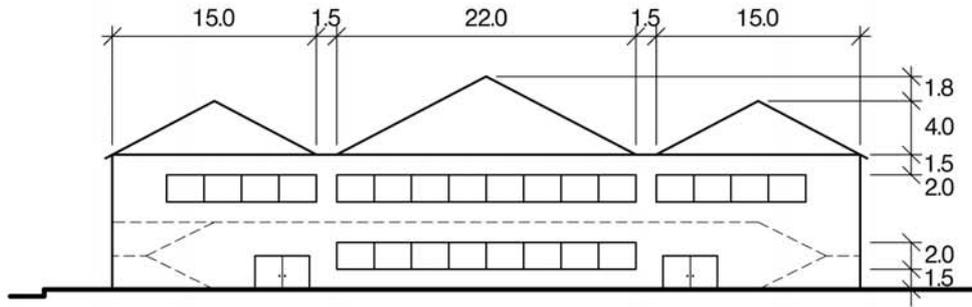
\* N.B. clear headroom



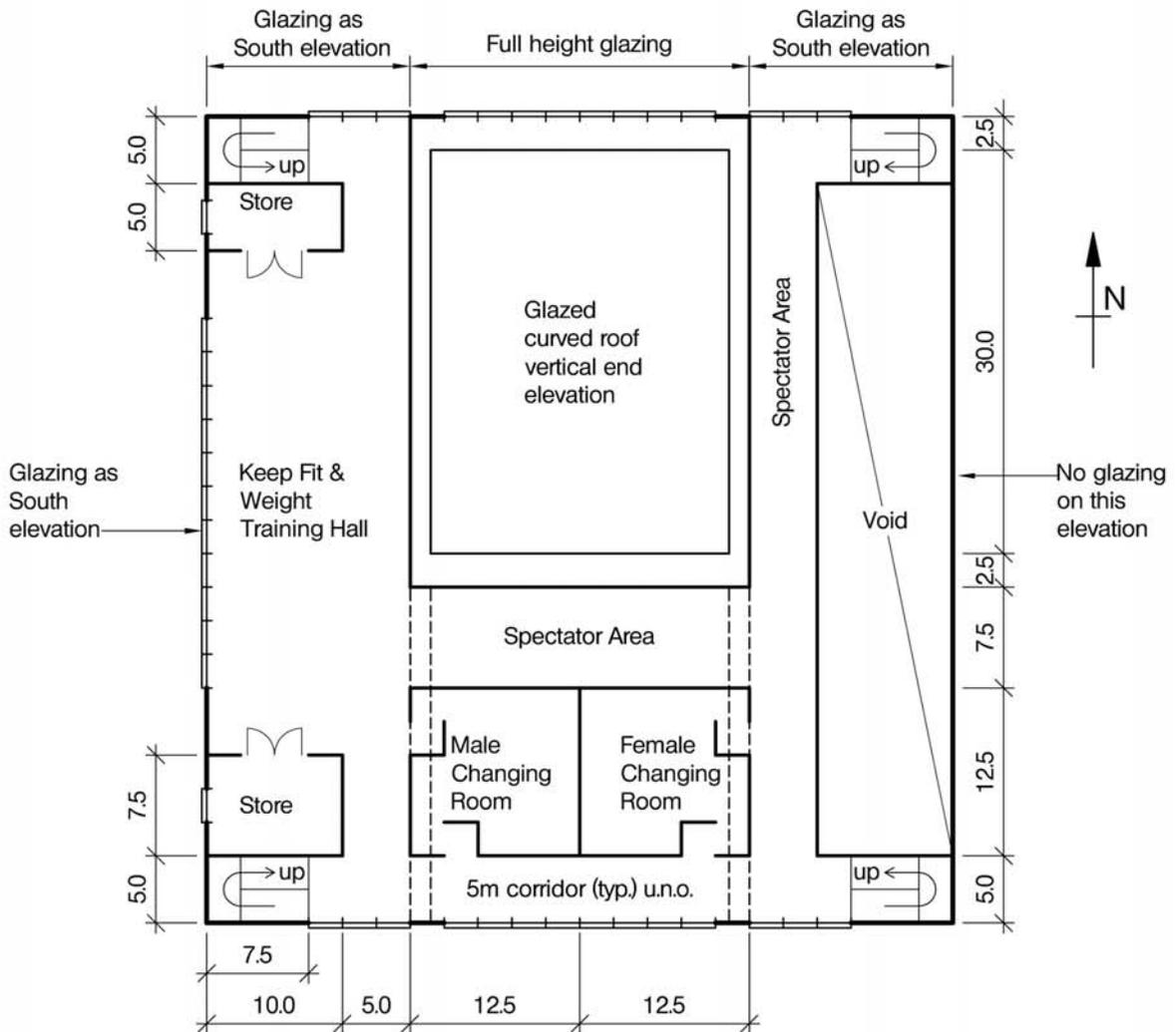
**LEVEL 1 FLOOR PLAN**

**NOTE:** All dimensions are in metres

**FIGURE Q6** (Sheet 1 of 2)



**SOUTH END ELEVATION B-B**



**LEVEL 2 FLOOR PLAN & ROOF OVER POOL**

**NOTE:** All dimensions are in metres

**FIGURE Q6** (Sheet 2 of 2)



# Question 6. Community Sports Centre

## Client's requirements

1. A new community sports centre which has 2-storey height east and west wings either side of a single storey swimming pool hall and changing room facilities: see Fig Q6.
2. The swimming pool is to have a curved glazed roof which is supported by the adjacent east and west wing structures, with a perimeter maintenance walkway. The north, east and west elevations to the pool hall are to be glazed over their whole height. The south elevation of the pool hall is to be glazed above floor level 2.
3. A minimum clear internal headroom of 5.0m is to be provided to all floors in the east and west wings, spectator areas and changing facilities. A minimum clear internal headroom of 10.0m is required in the sports hall (5.0m beneath the spectator area)
4. Internal columns are only permitted in the internal walls of the building. No internal columns are permitted in the sports or pool halls. External columns are to be kept to a minimum.
5. Cladding to the roof and elevations is to be selected to minimise energy consumption and maintenance costs. A 2.0m high window zone is to be provided at floor levels 1 and 2 along the south and west elevations and part of the north elevation.
6. Water tanks and plant room are to be located in the roof space above the level 2 changing rooms.
7. A minimum 1 hour fire resistance is required for all principal structural elements.

## Loadings

- |                                  |  |
|----------------------------------|--|
| 8. Roof                          | 0.6 kN/m <sup>2</sup>  |
| Level 1 and 2 Floors & pool area | 5.0 kN/m <sup>2</sup> (10.0 kN/m <sup>2</sup> in store areas and plant over second floor changing rooms) |

## Site Conditions

9. The site is flat and level in an out-of-town location.  
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 to 0.5m	Made ground
0.5m to 5.0m	Sand & Gravel N values 10 at 0.5m increasing linearly to 25 at 5.0m
5.0m to 12.0m	Stiff Clay. C = 200 kN/m <sup>2</sup>

Standing water was encountered in trial excavations at 1.5m below existing ground level.

## Omit from consideration

11. Detailed design of staircases.

## SECTION 1

(50 marks)

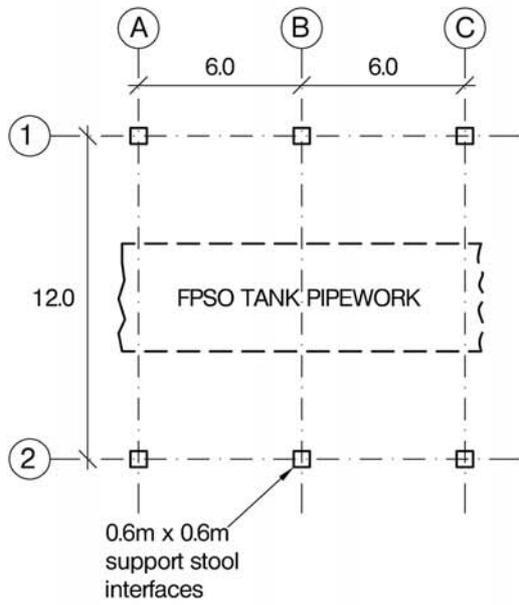
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After you have completed your design, the client informs you that he is considering a sun terrace together with a 10m wide by 15m long and 2m maximum depth pool on the west wing to replace the pitched roof in that area. Write a letter to your client explaining how your design could be modified to accommodate this change and the structural implications. (10 marks)

## SECTION 2

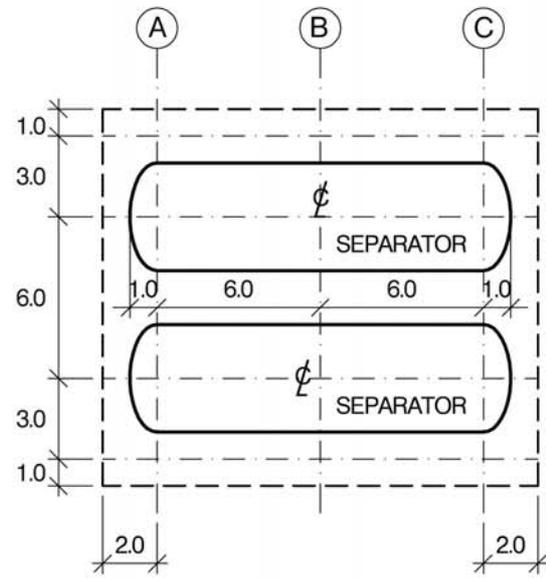
(50 marks)

For the solution recommended in Section 1(a):

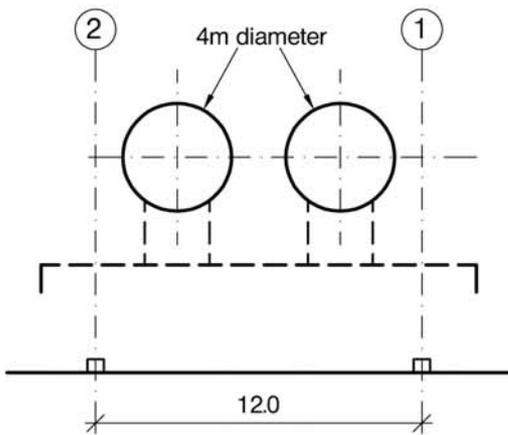
- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (20 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical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



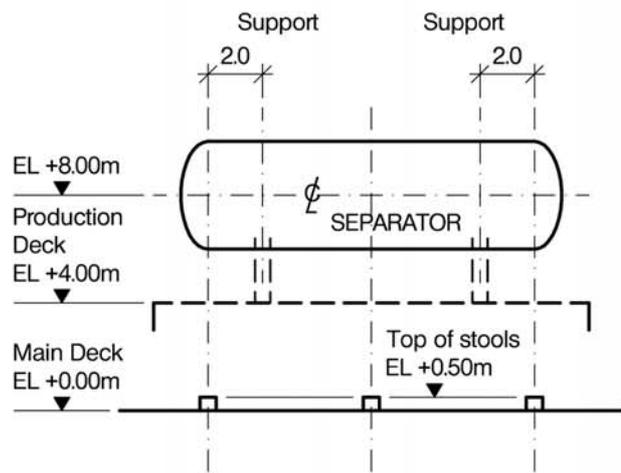
PLAN AT EL + 0.5m



TOP VIEW



ELEVATION LOOKING WEST



ELEVATION LOOKING NORTH

NOTE: All dimensions are in metres

FIGURE Q7

# Question 7. Pre-Assembled Unit for Existing Floating Production Facility

## Client's requirements

1. A new Pre-Assembled Unit (PAU), containing two production separators, is to be installed onto an existing Floating Production Storage Offloading (FPSO) vessel presently in service at an offshore location; see Figure Q7
2. The PAU deck area is 16.0m by 14.0m and is to be supported on existing support stools pre-installed to the FPSO main deck, as shown in Figure Q7. The PAU Top of Steel level (TOS) is located 3.5m above the stool tops.
3. The PAU production deck is to be grated (not plated) to allow free ventilation to minimise gas cloud concentrations.
4. Cargo offloading pipework on the vessel main deck is located underneath the PAU providing an exclusion zone for the PAU support steel as shown in Figure Q7.
5. The PAU is to be Constructed, 'loaded-out' onto a small barge or large supply boat and lifted to the FPSO deck in one piece at the Field Location by a derrick barge.
6. Separators are to remain intact after an explosion event.

## Imposed loading

- |  |  |
|--|--|
| 7. Production Separator Dry Weight   | 80 tonnes each unit (including associated bulks).  |
| 8. Production Separator Operating Weight                                     | 180 tonnes each unit (including associated bulks). |
| 9. Unoccupied deck area for access only, design load                         | 5kN/m <sup>2</sup>                                 |
| 10. Explosion drag pressure loads on the PAU                                 | 0.5 Bar (50kN/m <sup>2</sup> )                     |
| 11. FPSO vessel motions in the 100 Year Return Seastate may be taken as :-   |  |
| • Lateral acceleration from any of eight compass directions.                 | 4.9m/sec <sup>2</sup> (0.5g).                      |
| • Vertical acceleration (acting concurrently with the lateral acceleration). | ±3.9m/sec <sup>2</sup> (0.4g).                     |
| • Vessel motions not concurrent with explosion loads.                        |  |

## Omit from consideration

12. Influence of wind load.
13. Influence of FPSO vessel rotational accelerations.
14. Support settlement at the vessel main deck.
15. Support stool design.
16. Fatigue.

## SECTION 1

(50 marks)

- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable structural solutions for the PAU. Indicate clearly the functional framing, load and moment transfer support restraints and stability aspects of each scheme for all temporary and permanent design phases to be considered i.e. loadout, transport, lift and in-place operation. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After completion of your design, the client informs you that a lightweight grated storage area 12m by 12m is required to be installed above the separators. Live Load Capacity is to be 10kN/m<sup>2</sup>. Write a letter to the client explaining the effects this would have on your chosen solution and present your structural and installation options and discuss their merits. (10 marks)

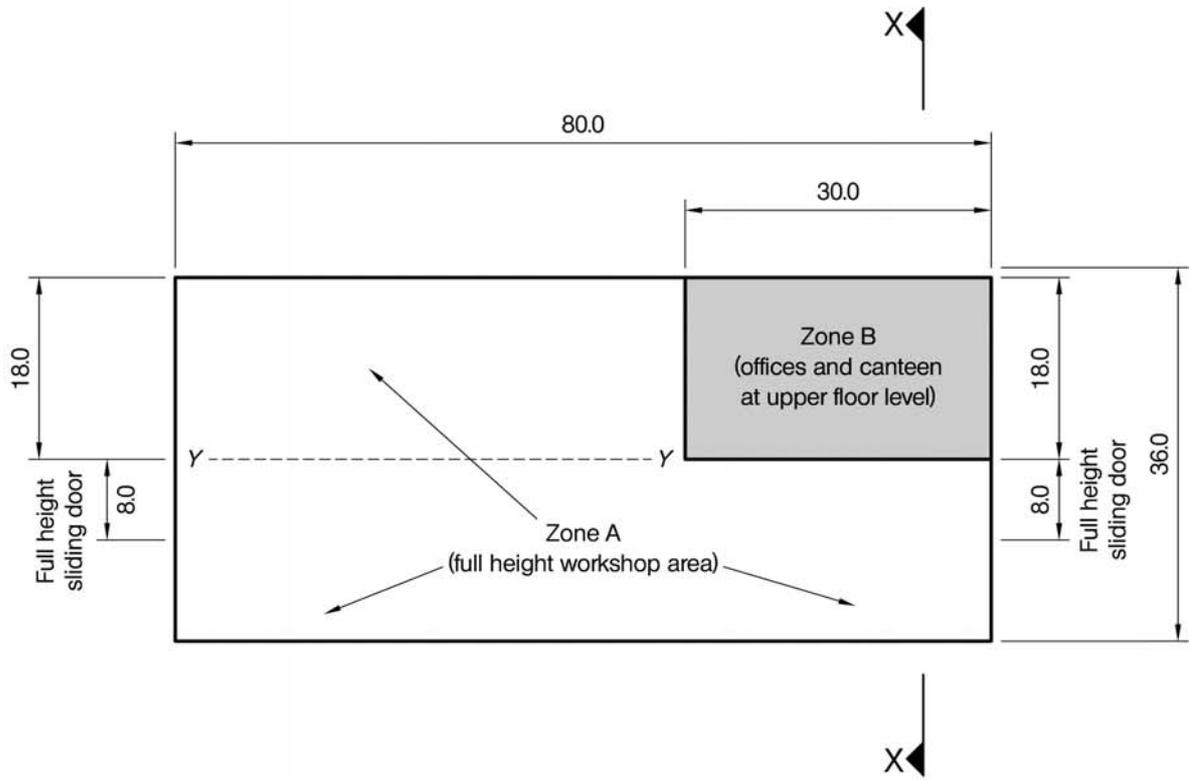
*continued overleaf*



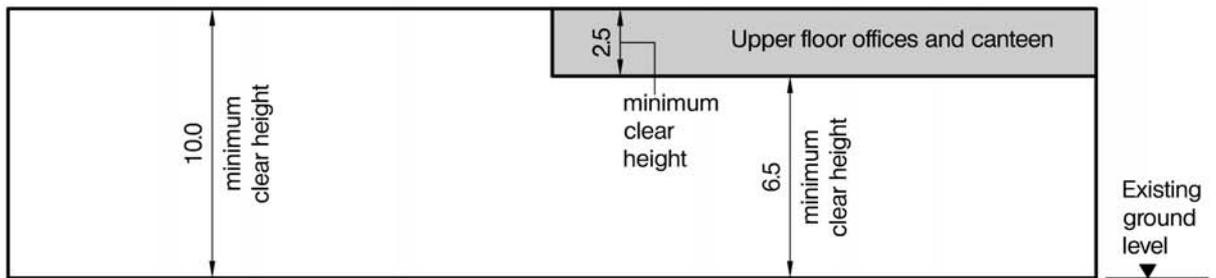
**SECTION 2****(50 marks)**

For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all structural elements for both the temporary and permanent conditions. (20 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and joints. Prepare clearly annotated sketches to illustrate details of:
  - (i) Lift points on the PAU,
  - (ii) Support tie-in details to the existing main deck stools,
  - (iii) Structural detailing of the separator saddles and connections to the PAU deck structure. (20 marks)
- e. With the aid of fully annotated sketches, showing installation aids, describe the installation procedure for the new PAU from arrival at Field location. (10 marks)



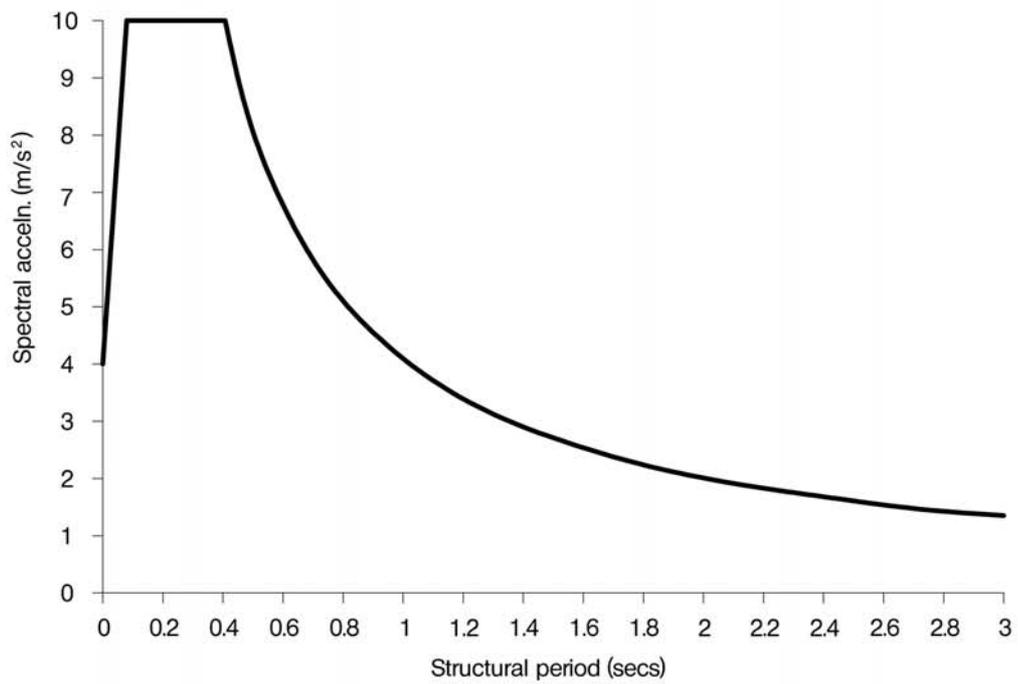
PLAN VIEW OF WORKSHOP



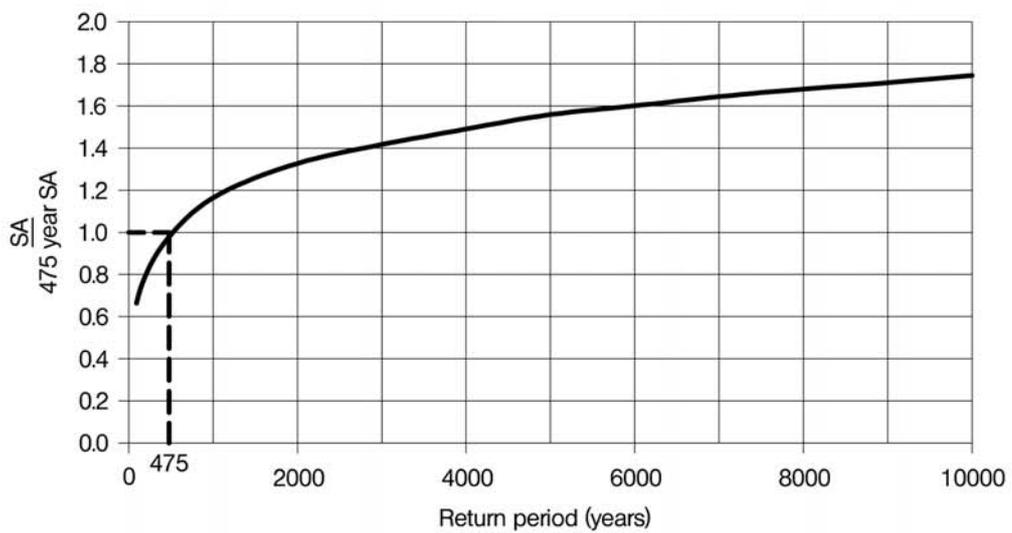
SECTION X-X

NOTE: All dimensions are in metres

FIGURE Q8-1



**FIGURE Q8-2 :** 475 year return period motions for rock outcrop at site



**FIGURE Q8-3 :** Variation of spectral acceleration SA with return period

NOTE: All dimensions are in metres

FIGURE Q8-2 & FIGURE Q8-3

# Question 8. Light manufacturing workshop

## Client's requirements

1. A building to house a light manufacturing facility, offices and canteen: see Figure Q8-1.
2. A minimum clear height of 10.0m is required in Zone A. An upper floor for offices and a canteen is required in Zone B. A minimum clear height of 6.5m is required under the upper floor and a minimum clear height of 2.5m is required above it. There is no restriction on the overall height of the building.
3. Internal columns may be placed not closer than 10.0m apart along line YY shown on Figure Q8-1. Internal columns may be placed not closer than 6.0m apart around the two internal sides of Zone B. A riser shaft 4.0m by 10.0m in plan containing a staircase and services is to be placed at any position adjacent to Zone B and clear of the doors to provide access to the upper floor. No other internal structural columns or walls are permitted.
4. Two openings for sliding doors each a minimum of 8.0m wide and 10.0m high are to be provided where shown on Figure Q8-1.
5. A minimum fire resistance of 1 hour is required for all structural members.

## Imposed loading

- |                            |                        |
|----------------------------|------------------------|
| 6. Workshop – Zone A       | 35.0 kN/m <sup>2</sup> |
| Workshop – Zone B          | 25.0 kN/m <sup>2</sup> |
| Upper floor and staircases | 4.0 kN/m <sup>2</sup>  |

## Site Conditions

7. The site is level, situated in a tropical location subject to earthquakes. Basic wind speed is 70m/s based on a 3-second gust; the equivalent mean hourly wind speed is 35 m/s.
8. Typical ground conditions:

Ground level - 1.0m	Made ground
1.0m – 10.0m	Medium dense to dense sand and gravel, N values vary linearly from 15 to 35
Below 10.0m	Rock. Allowable safe bearing pressure 1200kN/m <sup>2</sup>

Groundwater was not encountered.

## Seismic Design Data

9. The 5% damped seismic response spectrum at ground level for a hypothetical rock outcrop at the site for a 475 year return period is shown in Figure Q8-2. For seismic designs not using a 475 year return period, Figure Q8-3 may be used to factor the response spectrum of Figure Q8-2, or other appropriate assumptions may be made.

## Omit from consideration

10. Detailed design of the sliding doors and the external cladding, although the form of the cladding should be indicated. Detailed design of the staircase, although its location and main structural elements should be indicated.

## 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. Shortly before the contractor is due to commence construction of your chosen solution, the client informs you that an electric overhead travelling crane has been purchased, with a rated lifting capacity of 5 tonnes and a span between crane rails of 20.0m. The client wishes to incorporate the crane in the new workshop to service as large an area of the workshop as possible. Write a letter to the client explaining how the design and construction of the building could be modified to accommodate the crane. (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)





