

# The Institution of Structural Engineers

## Chartered Membership Examination

Friday 17 April 2009

### 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 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. 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



## **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.

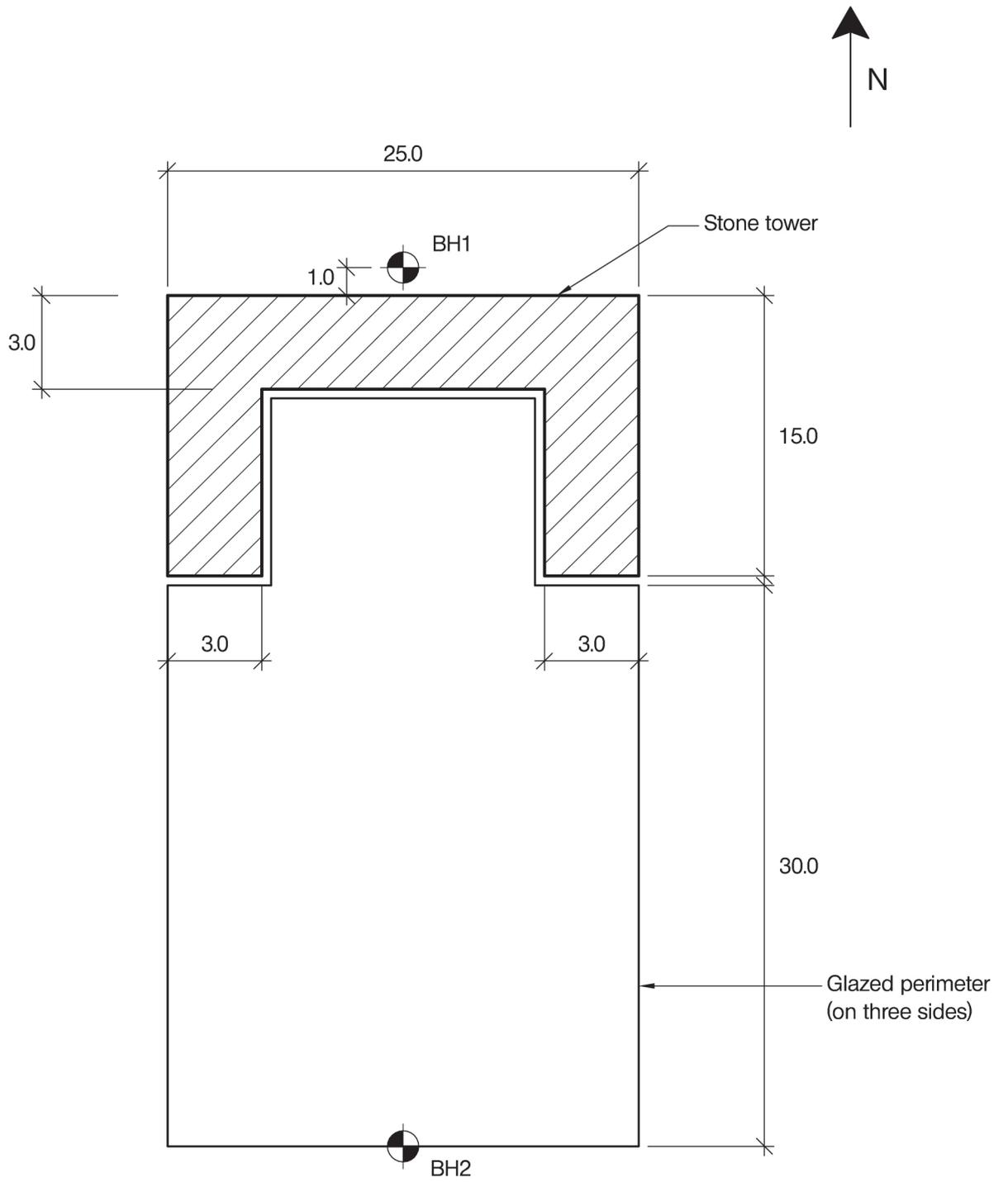
The unusual requirement of the examination is that you demonstrate the validity of the training and experience that you have acquired in recent years. The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural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

NOTE: All dimensions are in metres

FIGURE Q1

# Question 1. Office building incorporating an Existing Stone Tower

## Client's requirements

1. An existing stone tower is to be used in a new office development; see Figure Q1.
2. The tower is made from stone set in mortar and cannot be used to support the new office structure in any form. The new building is to be set partially into the interior of the tower as shown on Figure Q1.
3. The Architect wishes to retain the smallest floor depth possible and to have the building clad entirely in glass. The Architect has also stipulated that there is to be no visible structure around the glazed perimeter other than columns and the floor plate. Columns are to be spaced at least 8.0m apart.
4. The building is to have a 3.1m clear height between each floor and ceiling and is to be 4 storeys high. The height of the tower is 16.5m. The Architect has requested that the maximum level of the roof line of the building matches the height of the tower.
5. The existing stone tower is founded at a constant depth of 1.0m below ground level. The foundation of the tower does not extend beyond its plan area.

## Imposed loading

6. Roof 2.5kN/m<sup>2</sup>  
Floor loading 6.0kN/m<sup>2</sup>  
Loadings include an allowance for partitions, finishes, services and ceilings.

## Site conditions

7. The site is level and located in a park in the centre of a town. Basic wind speed is 40m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20m/s.
8. Ground conditions – Assumed to vary linearly between boreholes
 

Borehole 1	Ground – 1.0m	Made ground
	Below 1.0m	Rock. Allowable bearing pressure = 1000kN/m <sup>2</sup>
Borehole 2	Ground – 5.0m	Made ground
	5.0m - 8.0m	Stiff clay C = 80kN/m <sup>2</sup>
	Below 10.0m	Rock. Allowable bearing pressure = 1000kN/m <sup>2</sup>

## Omit from consideration

9. Detailed design of staircases

## SECTION 1

**(50 marks)**

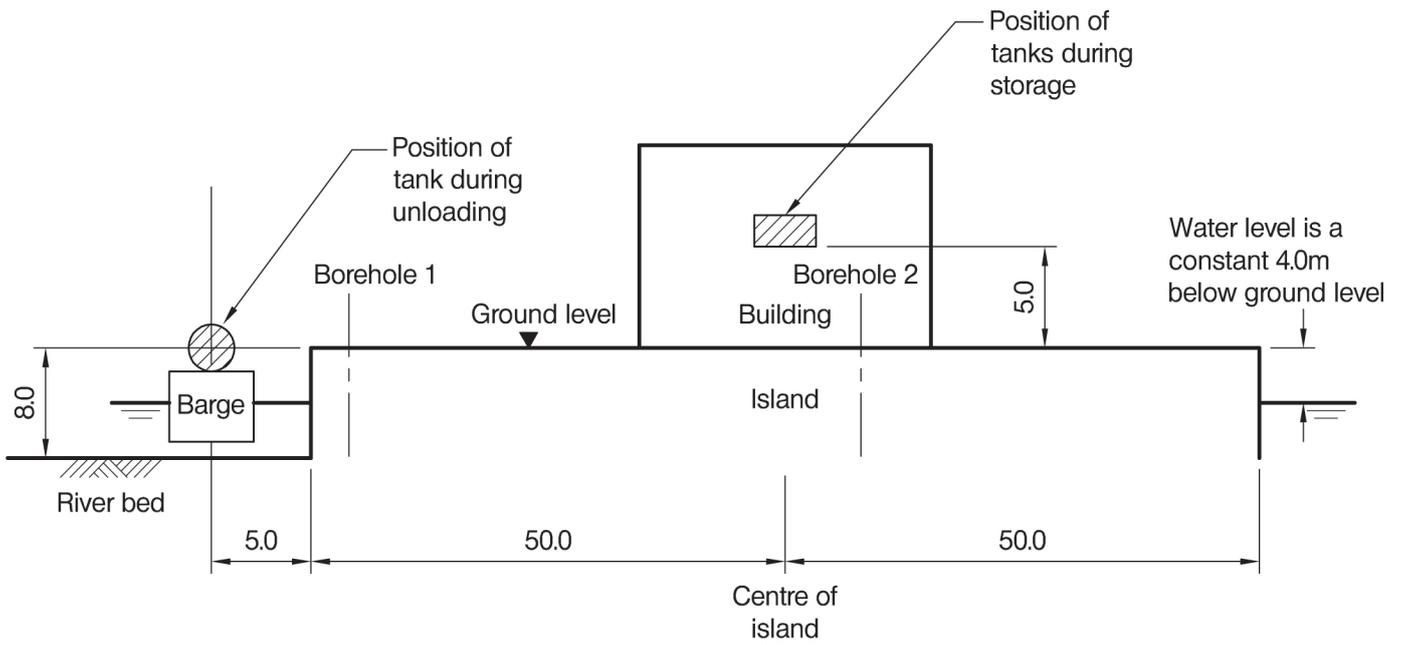
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. **(40 marks)**
- b. After the design has been completed, the Client advises you that he wishes to include an atrium opening of the full width of the building at the south end with the floors set back by 5.0m from the south wall. Write a letter to the Client explaining how this might 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 for the safe construction of the office building and an outline construction programme. **(10 marks)**



SECTION THROUGH ISLAND

NOTE: All dimensions are in metres

FIGURE Q2

## Question 2. Hazardous Liquid Storage Building

### Client's requirements

1. A waterproof building is required to store two tanks containing hazardous liquids.
2. The tanks are 2 metres in diameter, 5 metres long and each weigh 400kN.
3. The tanks must be stored so that the underside of each tank is at an elevation of 5.0m above ground level. No internal columns are permitted either within the building or beneath the tanks. A 6.0 m clear space is required around each tank for inspection and the tanks must have at least 4.0m clear space between them.
4. The building is to be situated at the centre of an island approximately 100.0m square protected by sheet piling.
5. The tanks will be delivered by barge at a minimum distance of 5.0m from the edge of the island and then stored in the building for approximately one month. During this period the access doors of the building must be kept shut.

### Imposed loading

6. Roof loading 1.5kN/m<sup>2</sup> (including imposed and services)

### Floor loading

Candidate to advise

### Site conditions

7. The site is located in a river estuary. Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s.
8. Mobile crane capacity on the island is limited to 20 tonnes due to the poor ground conditions. No suitable barge mounted cranes are available in this location.
9. Borehole 1 at island edge
 

Ground level – 1.5 m	River silt
1.5 m to 6.0 m –	Soft clay C = 25 kN/m <sup>2</sup>
6.0 m - depth –	Rock – allowable safe bearing pressure 1000 kN/m <sup>2</sup>
Water was found at 4.0m depth	
- Borehole 2 at island centre
 

Ground level – 0.5 m –	Topsoil
0.5 m – 3.0 m	Soft clay C = 25 kN/m <sup>2</sup>
3.0 m - depth	Rock – allowable safe bearing pressure 1000 kN/m <sup>2</sup>
Water was found at 2.0m depth	

### Omit from consideration

10. Detailed design of cranes although any support structure must be considered.

### SECTION 1

**(50 marks)**

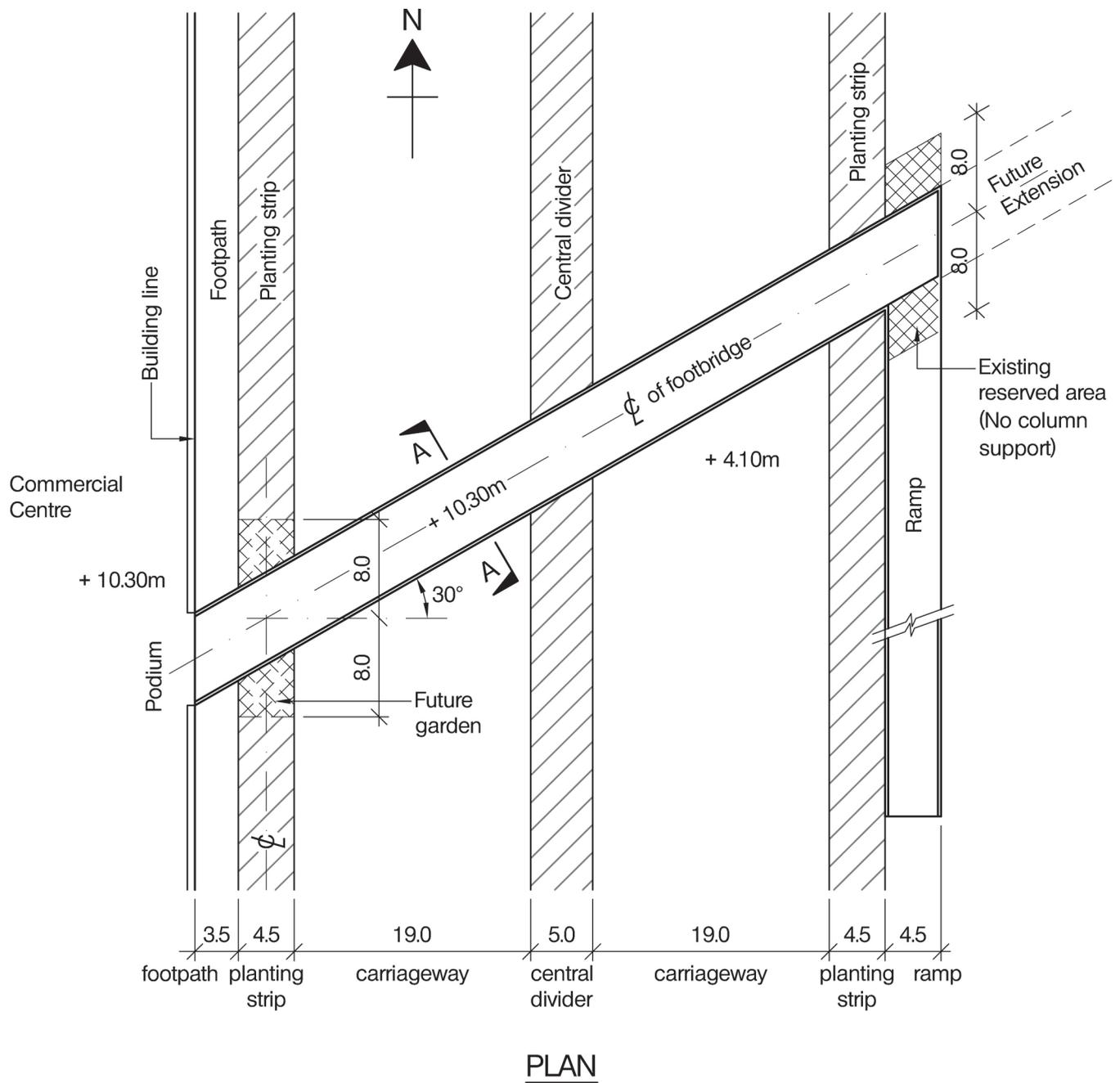
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including a suitable structure to enable the tanks to be lifted from the Barge and transported to their final position within the building. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. **(40 marks)**
- b. After your design is complete, the client explains that he wishes to store a third tank inside the building at ground level for a week. Write a letter to your client advising him of the implications of this change. **(10 marks)**

### SECTION 2

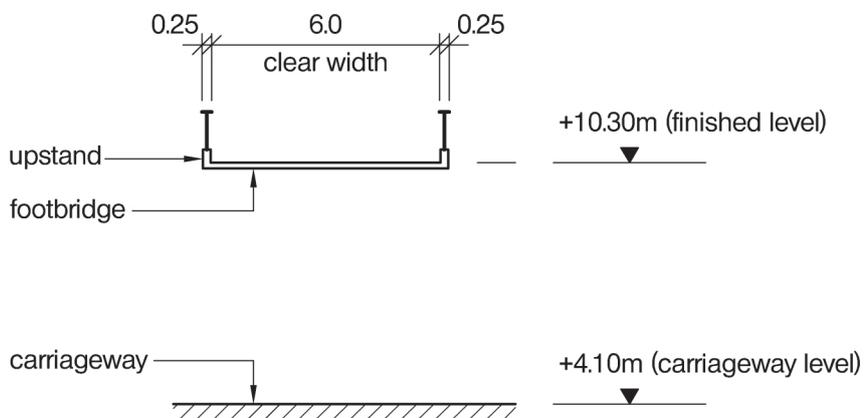
**(50 marks)**

For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all 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**



**SECTION A-A**

**NOTE:** All dimensions are in metres

**FIGURE Q3**

## Question 3. Footbridge

### Client's requirements

1. A new footbridge is required to cross a major urban highway to provide access to a commercial centre: see Fig. Q3
2. The footbridge is to cross the highway at an angle of 30 degrees. At the east end of the bridge a ramp is required to descend to ground level. Provision is to be made for a future extension of the bridge further to the east.
3. No loading may be transferred from the footbridge to the commercial centre building and an expansion joint is required at this junction. Column supports to the footbridge are permitted only within the highway planting strips and the central carriageway divider. No columns are permitted under the east end of the bridge.
4. The maximum permitted gradient of the ramp is 1:12. Horizontal landings are required in the ramp at vertical intervals of not more than 3.5m, and the length of each landing must be not less than 2.0 m.
5. A 1.0m high parapet is required for both the footbridge and the ramp. The clear widths of the footbridge and ramp are to be 6.0m and 4.0m respectively.
6. A minimum clearance of 0.8m is required from the edge of carriageway to the face of any structure. The minimum required headroom under the footbridge is 5.1m above the carriageway level.
7. Temporary access to the highway carriageways is available each night between midnight and 5:00am.

### Imposed loading

8. Footbridge loading 5.0kN/m<sup>2</sup>

### Site conditions

9. The site is located in the centre of a city. Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s.
10. Ground Conditions
 

Ground level - 0.5m	Made ground
0.5m – 30.0m	Sandstone. Allowable bearing pressure 1000kN/m <sup>2</sup>

### Omit from consideration

11. Detailed structural design of the footings for the ramp.

### SECTION 1

**(50 marks)**

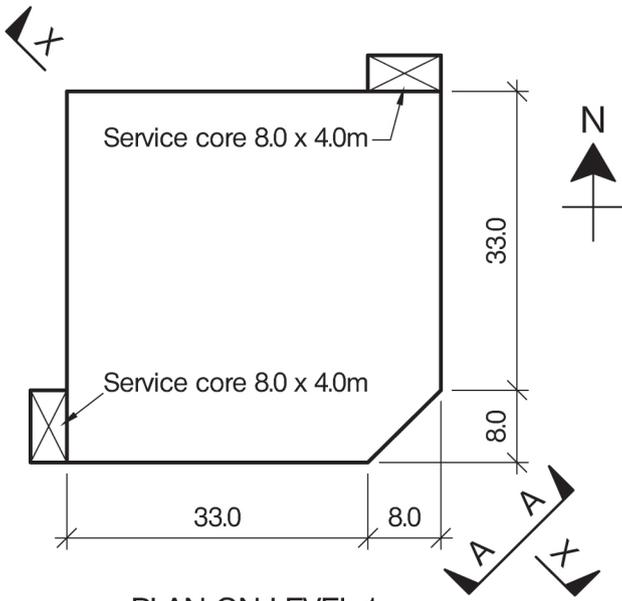
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. **(40 marks)**
- b. After the design has been completed, the client advises that he wishes to create a garden under the west end of the footbridge and wishes to avoid any columns in this area (shown as the dotted line in Figure Q3). Write a letter to the client explaining how your design could be modified to accommodate this change. **(10 marks)**

### SECTION 2

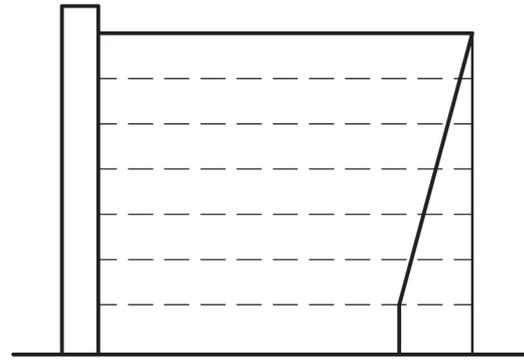
**(50 marks)**

For the solution recommended in Section 1(a):

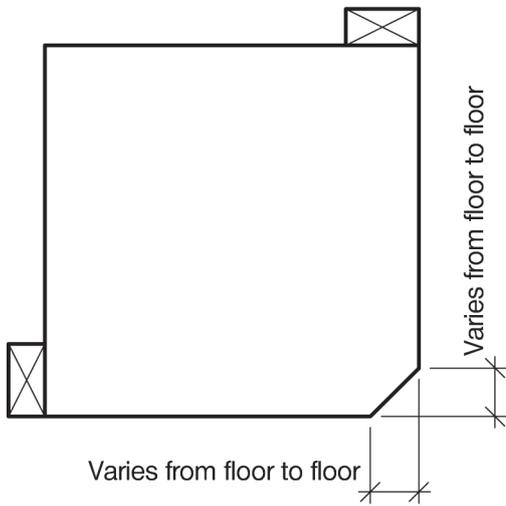
- c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the bridge foundations and the ramp. **(20 marks)**
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. **(20 marks)**
- e. Prepare a detailed method statement for the safe construction of the footbridge and its ramp and an outline construction programme. **(10 marks)**



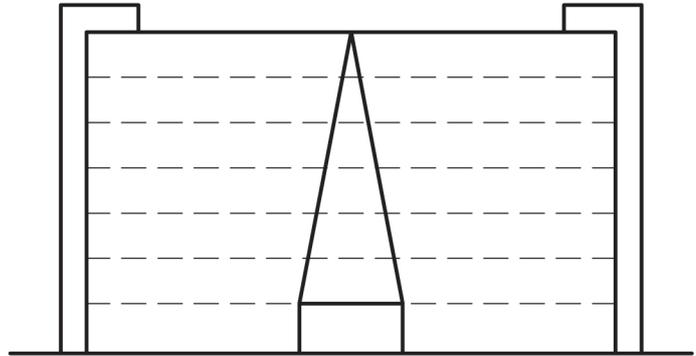
PLAN ON LEVEL 1  
(PLAN ON LEVEL 2 SIMILAR)



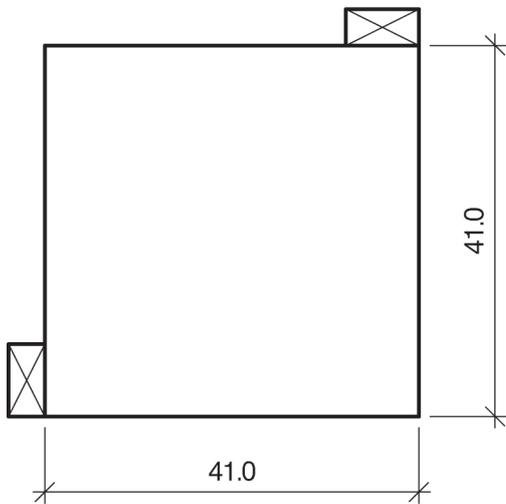
ELEVATION FACING SOUTH



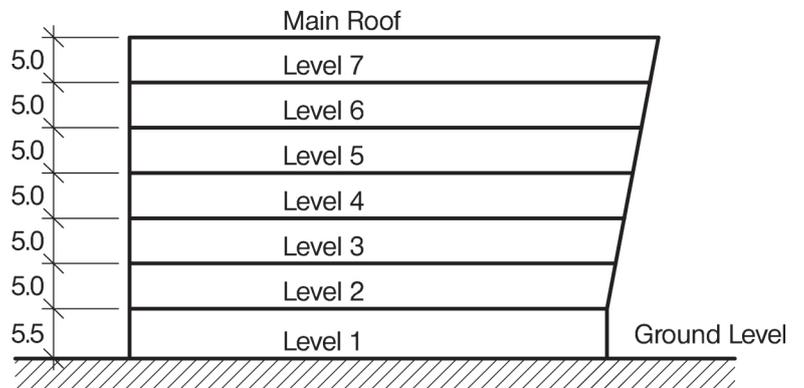
PLAN ON LEVELS 3 TO 7



VIEW LOOKING FROM A-A



PLAN ON MAIN ROOF



SECTION X-X

NOTE: All dimensions are in metres

FIGURE Q4

## Question 4. Commercial Building

### Client's requirements

1. A seven-storey commercial building on a square site 45.0m x 45.0m: see Fig. Q4.
2. The facade at the south-east corner is to be inclined between level 2 and the roof. All other facades are to be vertical. All facades are required to be fully-glazed between level 2 and the roof.
3. To provide flexibility for building entry points, the clear distance between external columns on level 1 must be a minimum of 8.0m. External columns on level 2 and above, if required, must be evenly-spaced. No column is permitted on any level at the north-west corner of the building.
4. Neither external nor internal structural walls are permitted. A clear distance of at least 7.0m is required between an internal column and any other column or external enclosure. The service cores are to be structurally independent of the main building.
5. No foundations may extend beyond the site boundary.
6. Allowable structural floor zones are:  
Level 2: 1.7m  
Other levels and roof: 1.2m
7. A minimum fire resistance of 2 hours is required for all structural elements.

### Imposed loading

8. Roof 2.5kN/m<sup>2</sup>  
All floors 5.0 kN/m<sup>2</sup>

### Site conditions

9. The site is level and is located in the suburban area of a town 200km from the sea. 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 – 2.0m Loose fill  
2.0m – 5.0m Sandy gravel. N varies from 10 to 20  
5.0m – 8.0m Weathered rock. Allowable bearing pressure 500kN/m<sup>2</sup>  
Below 8.0m Rock. Allowable bearing pressure 1500kN/m<sup>2</sup>  
Ground water was encountered at 2.5m below ground level.

### Omit from consideration

11. Detailed design of the service cores.

### SECTION 1

**(50 marks)**

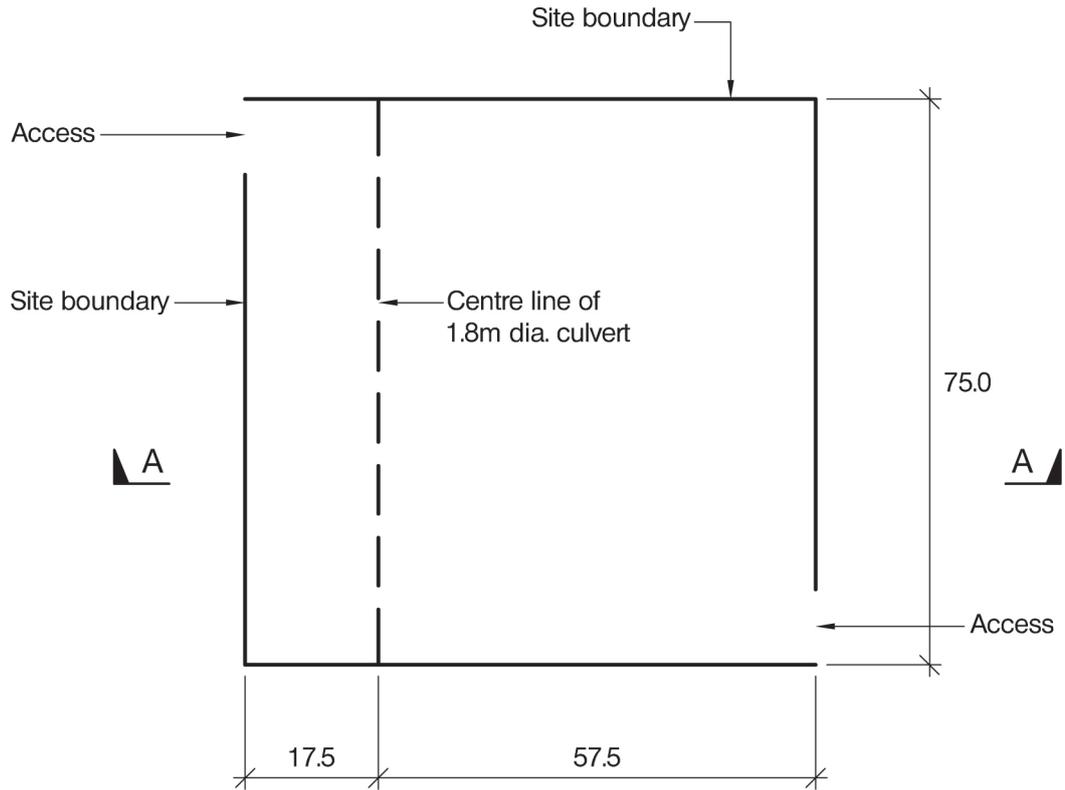
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. **(40 marks)**
- b. Before construction begins, a group of piles forming the foundations of a previous building on the site are discovered. The group comprises 49 concrete piles each 600mm diameter in a 7 x 7 grid spaced at 3.0m centres in both directions and the centre of the group is located at the north-west corner of the site. The client wishes to know whether the piles can be re-used. Write a letter to the client advising him of the implications of the discovery and the practicality of re-using the piles. **(10 marks)**

### SECTION 2

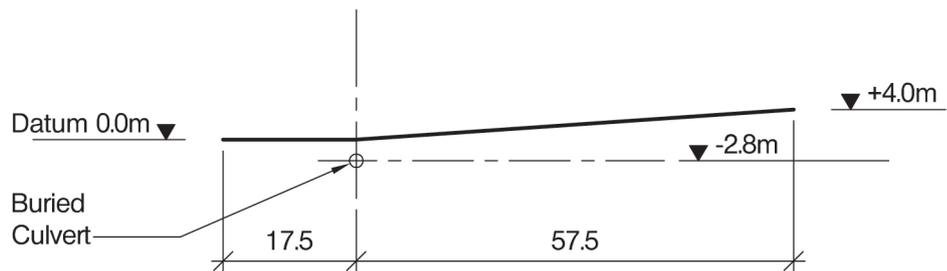
**(50 marks)**

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)**



SITE PLAN



SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q5

## Question 5. Art Gallery

### Client's requirements

1. A two-storey art gallery is to be constructed on a sloping city-centre site containing a buried culvert: see Fig. Q5.
2. Level 1 is to have plan dimensions of 56.0m x 35.0m with columns at a minimum centre-to-centre spacing of 7.0m in each direction. Level 2 is to have plan dimensions of 50.0m x 12.0m with no internal columns. An allowance for lift and stair cores is included within these plan dimensions.
3. The floor-to-floor height from levels 1 to 2, and the floor-to-eaves height from level 2 to the roof is to be 4.5m. A maximum structural zone of 0.75m is permitted.
4. A flat, level access route of minimum width 3m is to be provided around the perimeter of the building at level 1.
5. A single car park with plan dimensions of 20.0m x 50.0m is required.
6. Access to the site is to be provided at the two locations shown on Fig. Q5, one for vehicles and one for pedestrians.
7. The culvert may be built over but may not be diverted and no additional loads may be applied to it either vertically or laterally. No construction may approach horizontally closer than 4.0m to the centreline of the culvert.

### Imposed loading

- |                                   |                      |
|-----------------------------------|----------------------|
| 8. Gallery floors, levels 1 and 2 | 5.0kN/m <sup>2</sup> |
| Roof                              | 1.5kN/m <sup>2</sup> |
| Car park                          | 2.5kN/m <sup>2</sup> |

### Site conditions

9. The site is located in a city 100km from the sea. Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s.
10. Ground conditions:  
Datum level - 12.0m sandy clay,  $C = 100\text{kN/m}^2$ ,  $\phi = 15^\circ$   
Below -12.0m rock, allowable bearing capacity = 2000kN/m<sup>2</sup>  
Groundwater was found at 3.0m below ground level. The soil strata and ground water level may be assumed to follow the slope of the ground.

### Omit from consideration

11. Detailed design of stair and lift cores.

### SECTION 1

**(50 marks)**

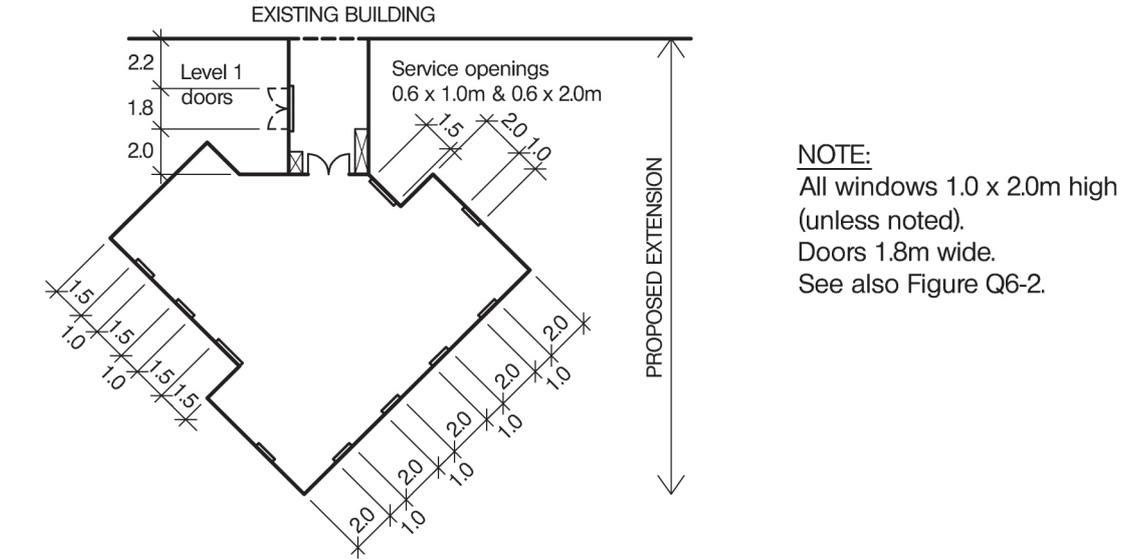
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the site layout, functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. **(40 marks)**
- b. After the design has been completed, the Client advises that he wishes to consider adding a further area of parking of plan dimensions 20.0m x 50.0m. Write a letter to your client advising how this may be achieved. **(10 marks)**

### SECTION 2

**(50 marks)**

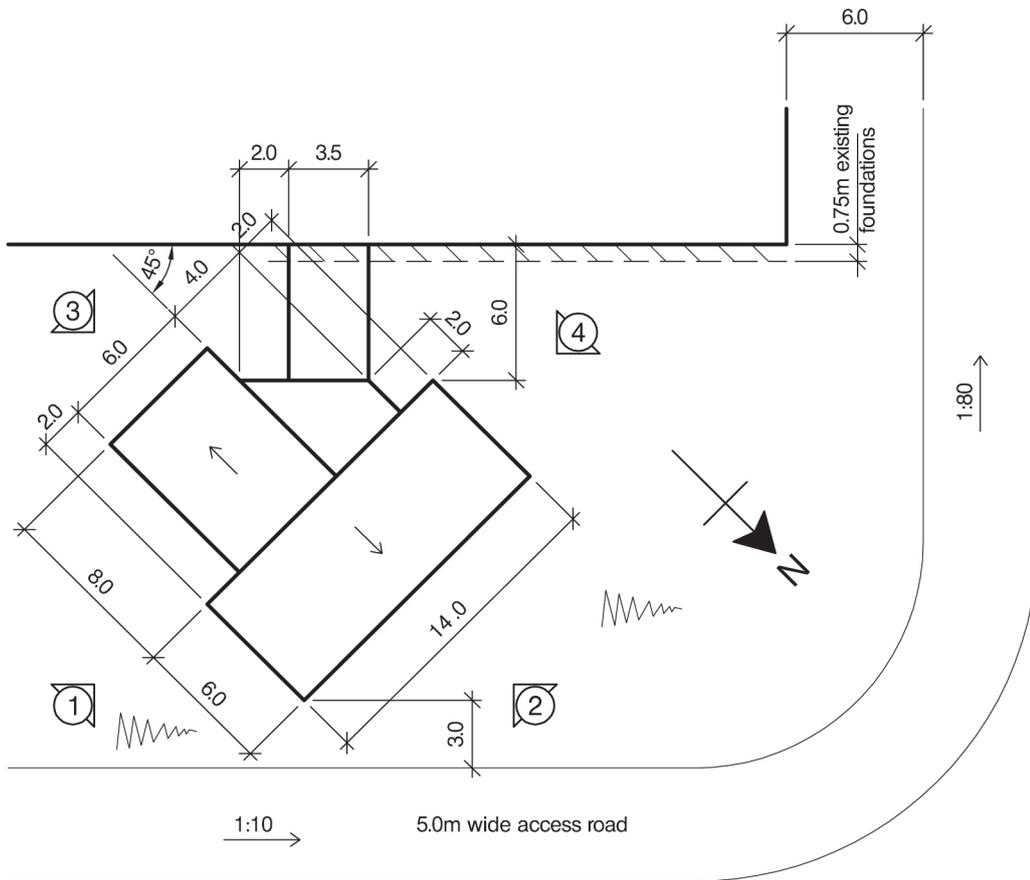
For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including foundations, any structure associated with the car park and any significant retaining structures. **(20 marks)**
- d. Prepare general arrangement plans, sections and elevations to show the site layout, 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)**



**NOTE:**  
 All windows 1.0 x 2.0m high  
 (unless noted).  
 Doors 1.8m wide.  
 See also Figure Q6-2.

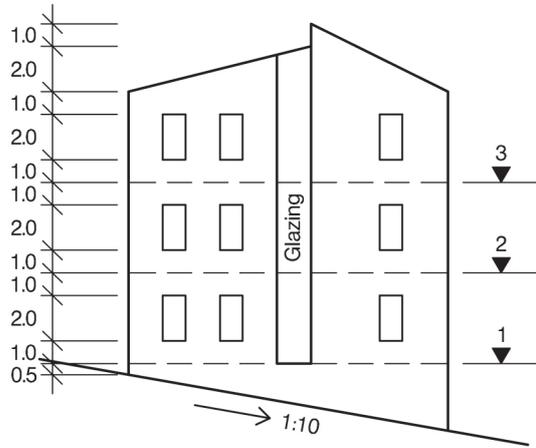
TYPICAL FLOOR PLAN



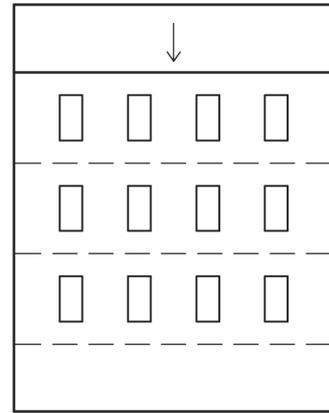
ROOF PLAN

NOTE: All dimensions are in metres

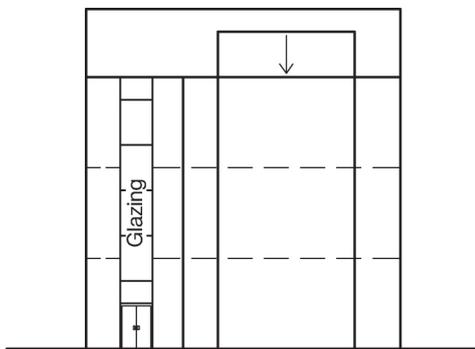
FIGURE Q6-1



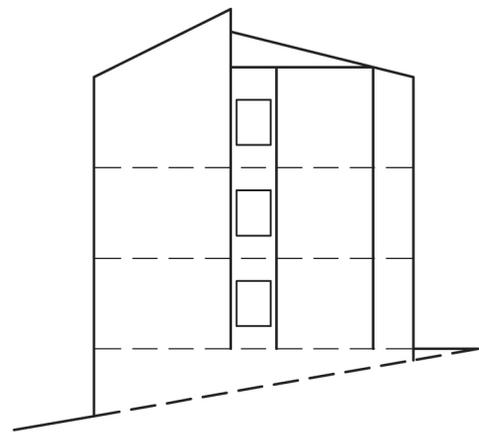
ELEVATION 1



ELEVATION 2



ELEVATION 3



ELEVATION 4

NOTE: All dimensions are in metres

FIGURE Q6-2



## Question 6. Research Building Extension

### Client's requirements

1. A 3-storey extension is to be constructed with link corridors to an existing 5-storey building used for medical research: see Figs. Q1 and Q2. The extension is close to a steep access road. There is an area available for the contractor's compound to the north-east of the road.
2. The extension is to be structurally independent from the existing building. Access to each floor in the extension is via stairs and lifts in the existing building. The extension is to contain as few internal columns as possible. There are to be vertical glazing bays as shown on Fig. Q6.
3. Cladding to the extension roof and elevations is to be selected to minimise energy consumption and maintenance costs. A minimum fire protection of 1 hour is required for all structural elements.
4. The positions of the main services openings in the link corridors are shown in Fig. Q6.
5. Floor-to-floor heights for levels 1 to 3 are each 4.0m.
6. The existing building has spread footings extending 0.75m beyond the face of the building.

### Imposed loading

- |                   |                      |
|-------------------|----------------------|
| 7. Roof           | 0.6kN/m <sup>2</sup> |
| All floors        | 5.0kN/m <sup>2</sup> |
| Building services | 0.6kN/m <sup>2</sup> |

### Site conditions

8. The site is on the edge of a town 3km from the sea. Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s.
9. Ground conditions:  
 Ground level – 1.0m Loose clayey sand,  $N = 4$ .  
 1.0m – 6.0m Stiff clay,  $C = 250$  to  $400\text{kN/m}^2$  increasing with depth.  $\phi = 0$ .  
 Below 6.0m Very stiff clay,  $C = 500\text{kN/m}^2$ .  
 Groundwater was found at 3.0m below the ground surface datum. Soil strata and groundwater level may be assumed to follow the slope of the ground.

### Omit from consideration

10. Modifications to the existing building.

### SECTION 1

**(50 marks)**

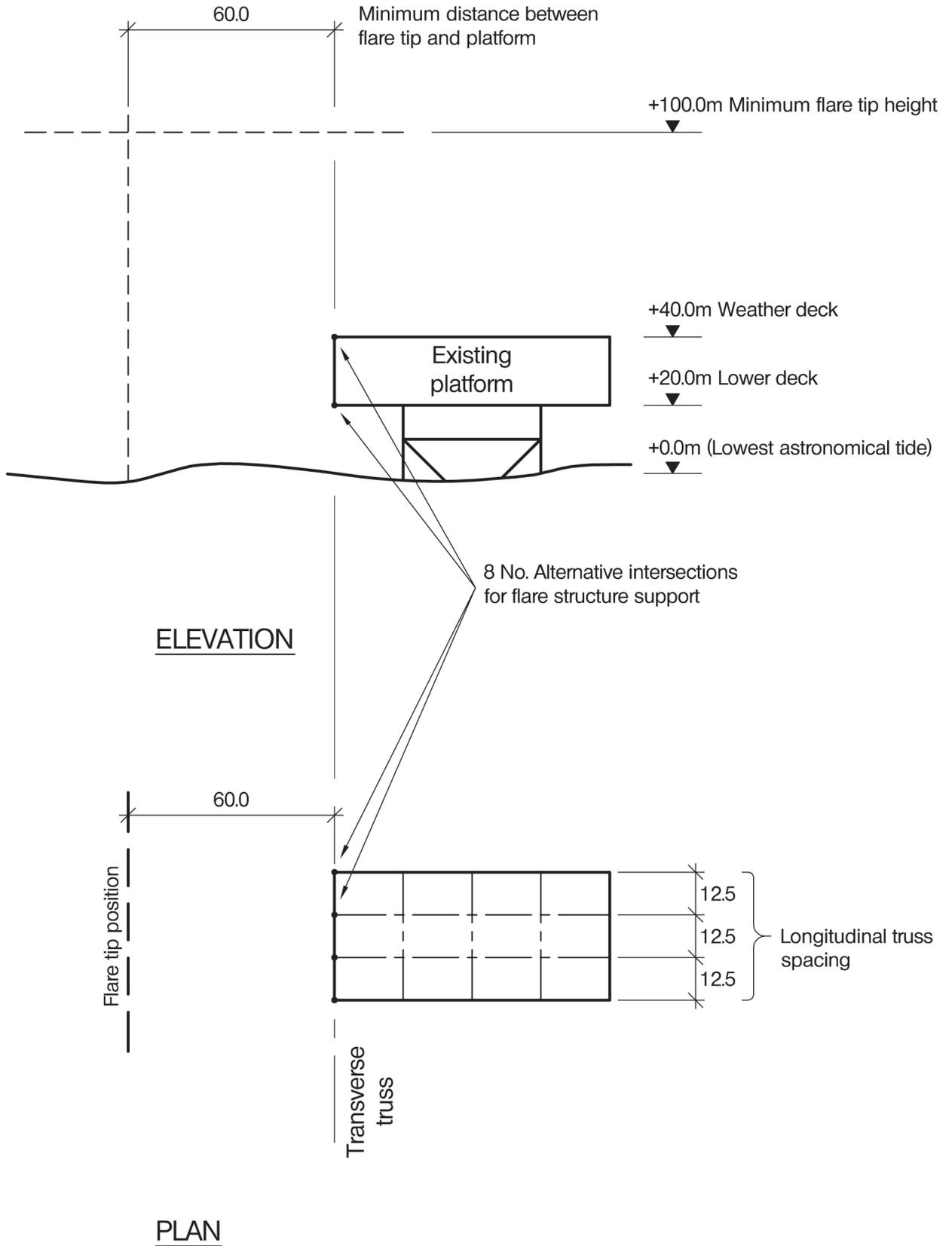
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. **(40 marks)**
- b. After completion of your design, the client requires a basement 6.0m x 14.0m to be incorporated to house building services equipment. Write a letter to the client explaining the implications of this request on your design and how the modification might 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 for the safe construction of the extension building and an outline construction programme. **(10 marks)**



NOTE: All dimensions are in metres

FIGURE Q7

## Question 7. New flare for an existing offshore platform

### Client's requirements

1. A new flare is to be offshore installed on an existing platform. In order to limit thermal radiation on the existing structure, the flare tip is to be located at a height of 60.0m outboard and 60.0m above the Weather Deck; see Figure Q7.
2. The flare tip, and pipe, are to be supported by a structure which also provides access to the Flare Tip. A Top Platform, measuring 6m x 6m provides a Tip maintenance area and thermal shielding. The flare pipe will be 508mm diameter and the flare tip opening will be 3.0m above the Top platform.
3. The main structure of the existing Platform comprises four longitudinal frames, spaced at 12.5m, and 20.0m deep. Any of the intersections at the end transverse frame may be used as support points for the flare structure, Figure Q7.

### Imposed loading

4. The Top Platform Dead Weight is 100kN.
5. The Flare line Dead weight is 3kN/m length.
6. The Flare Tip Dead Weight is 10kN.

### Site conditions

7. Extreme wind speed, at +10m reference elevation, is 46m/sec, based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s. The wind occurs from any direction.

### Omit from consideration

8. Snow and ice.
9. Structure vibration induced by vortex shedding.
10. The influence of thermal radiation on the flare structure.
11. Fatigue calculations (but not the influence of fatigue on structural details).
12. Flare thrust.

### SECTION 1

**(50 marks)**

- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed flare structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme for the temporary and permanent design phases to be considered i.e. loadout, transport, offshore installation 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 he wishes to use the flare structure to support an exhaust duct from a Gas Turbine power unit near-by. The duct is to be 1.6m in diameter, weighing 3kN/m length and will be supported on the flare between elevations +44m and +70m; the duct is to be installed in the Fabrication yard. Write a letter to the client explaining how this could be accomplished and the effects this would have on your chosen solution. **(10 marks)**

### SECTION 2

**(50 marks)**

For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations, for both the temporary and permanent conditions, to establish the form and size of all the principal structural elements and connections, including the support points. **(20 marks)**
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details such as the lift points and structure tie-ins to the existing Platform. **(20 marks)**
- e. With the aid of annotated sketches, prepare a detailed method statement for the safe transport and installation of the flare structure onto the existing Platform at the Field location. **(10 marks)**

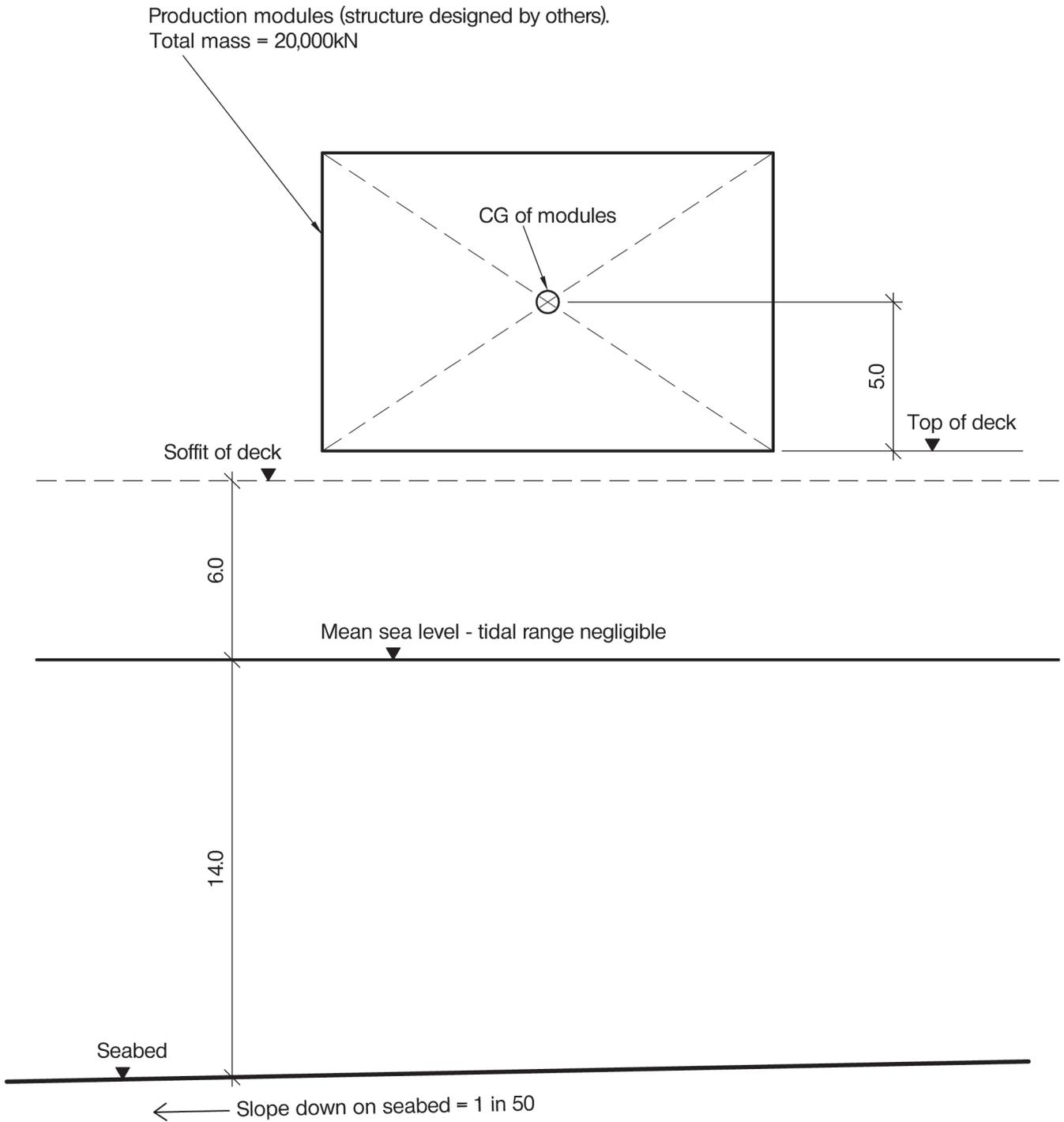
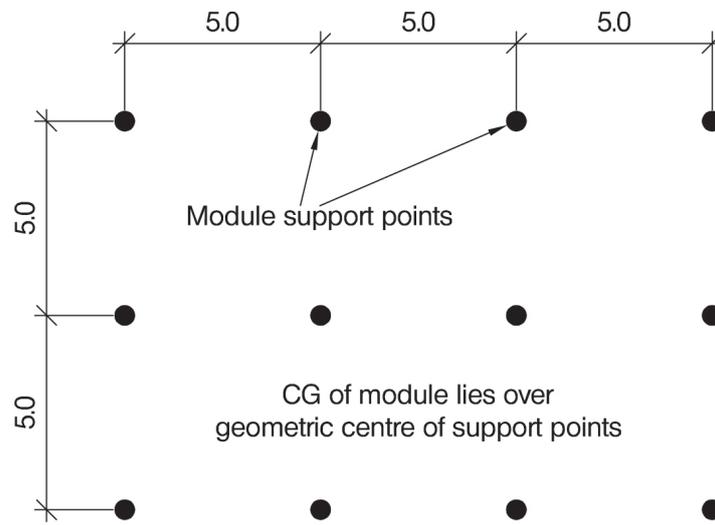


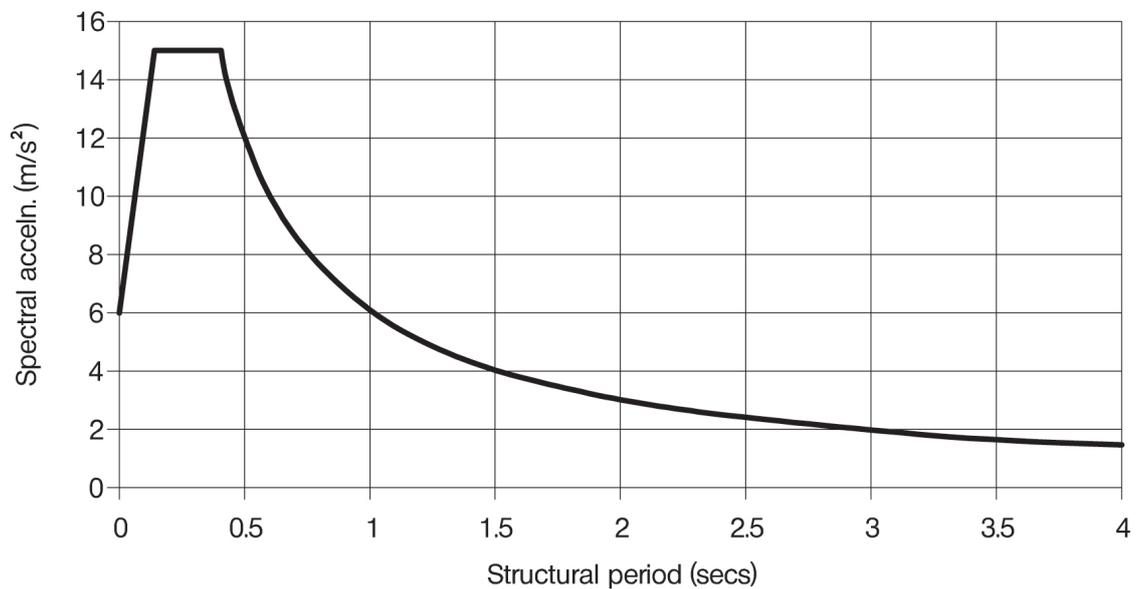
FIGURE Q8-1 : ELEVATION

NOTE: All dimensions are in metres

FIGURE Q8-1



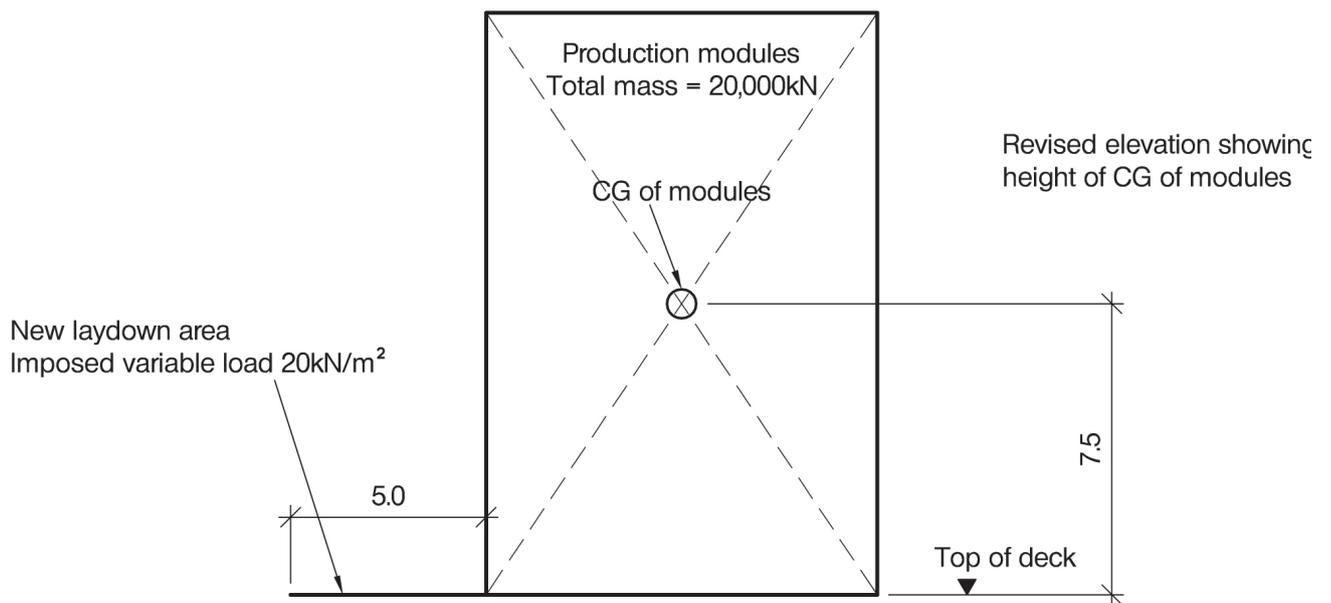
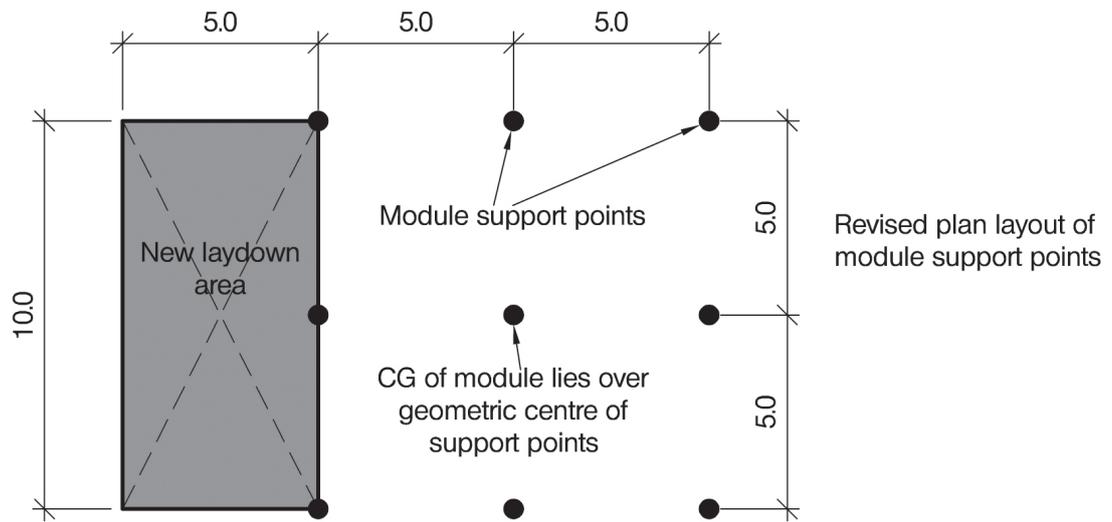
**FIGURE Q8-2 :** Plan showing position of required module support points



**FIGURE Q8-3 :** 5,000 year return period 5% damped spectrum for the region for rock with a shear wave velocity  $V_s$  of at least 800m/s at the surface

NOTE: All dimensions are in metres

FIGURES Q8-2 and Q8-3



**FIGURE Q8-4 :** Modified deck layout (see Section 1b of the question)

NOTE: All dimensions are in metres

FIGURE Q8-4

## Question 8. Support structure to petrochemical processing facility

### Client's requirements

1. A structure to support a petrochemical processing facility located in an inshore sea in an area subject to strong earthquakes (Figure Q8-1). The client specifies that the structure shall achieve a 'life safety' performance level in the 5,000 year return period specified in item 10 below. The facility will not generally be occupied, but will receive occasional visits by maintenance engineers.  
Note: 'Life safety' performance may be taken as commonly defined in seismic codes; it implies that the structure should withstand the design event without local or global collapse, and retain full vertical load bearing capacity after the earthquake and also a residual lateral strength and stiffness to protect life even during strong aftershocks.
2. The facilities to be supported are contained in a number of modules, which together may be taken as rigid for the purposes of the structural design. The modules are to be installed after installation of the support structure. The combined mass of the modules is shown in Figure Q8-1, and Figure Q8-2 shows the points at which support must be provided to the modules. Some of the equipment contained by the modules must be designed to operate during and after the design earthquake, and the process engineering design team have requested that design seismic accelerations in the modules should be minimised as far as possible, to reduce costs.
3. The soffit of the deck supporting the modules must have a minimum clearance of 6m above the sea datum level shown.
4. Fire protection is to be provided by deluge systems and other means; specific ratings are not specified for fire resistance of the support structure.

### Imposed loading

5. The module loading is shown on Figure Q8-2. No other imposed loading due to gravity loads need be considered.

### Site conditions

6. The site is located 150m from the shore. A well equipped port is located within 5km.
7. The basis wind speed is 44m/s on a 3-second gust; the equivalent mean hourly wind speed is 22 m/s.
8. The design wave height is 1.0m.
9. Seabed ground conditions are as follows
 

0 – 1m	Very soft deposits	SPT < 1
1m – 3m	Soft to firm clay	$c_u = 40$ to 70 kN/m <sup>2</sup>
3m – 45m	Medium dense, becoming dense to very dense, sand	SPT 25 to 65. A linear increase with depth may be assumed.
10. Figure Q8-3 shows the design 5% damped seismic response spectrum for the region. It applies to level ground for a 5,000 year return period, assuming the ground surface is rock with a shear wave velocity of not less than 800m/s.

### Omit from consideration

11. Design of the module structures.
12. Vessel impact against the structure.
13. Detailed consideration of the transportation and installation condition.

### 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 completion of scheme design for the structure, the client informs you that the process engineers have modified the layout of the modules to that shown in Figure Q8-4. Write a letter for the client, advising on the structural implications of this extension, with a description of ways of accommodating it, and providing some indication of its impact on cost and construction programme. **(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 facilities and an outline construction programme. **(10 marks)**

