

## Chartered Membership Examination

Thursday, 4 January 2018

### Structural Engineering Design and Practice

09.30 – 13.00 and 13.30 – 17.00 (Discussion between individuals is not permitted during lunch period). A period of fifteen minutes is provided for reading the question paper immediately before the commencement of the examination. Candidates are not permitted to write in answer sheets, or on drawing paper or to use a calculator during this time. Candidates must satisfy the Examiners in ONE question.

#### Important

The written answer to the question selected and any A3 drawings must bear the candidate's number and the question number at the bottom of the page. Only the answer sheets supplied by the Institution may be used. The candidate's name should not appear anywhere in the script.

#### Notes to Candidates

1. TO PASS THE EXAMINATION, CANDIDATES MUST SATISFY THE EXAMINERS IN BOTH PARTS OF THE QUESTION ATTEMPTED.
2. Candidates should note that Figures are produced to illustrate the question and are not necessarily drawn to scale. Figured dimensions should be followed.
3. A fair proportion of marks will be awarded for the demonstration of an understanding of fundamental engineering concepts, as distinct from calculation of member forces and sizes. NOTE: In the calculation part of all questions, establishing "form and size" is taken to mean compliance with all relevant design criteria, i.e. bending, shear, deflection, etc.
4. In all questions 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. Clear drawings and sketches are required. They do not have to be to a defined scale, but should be in proportion.
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.**



2 Chartered Membership Examination



# 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.

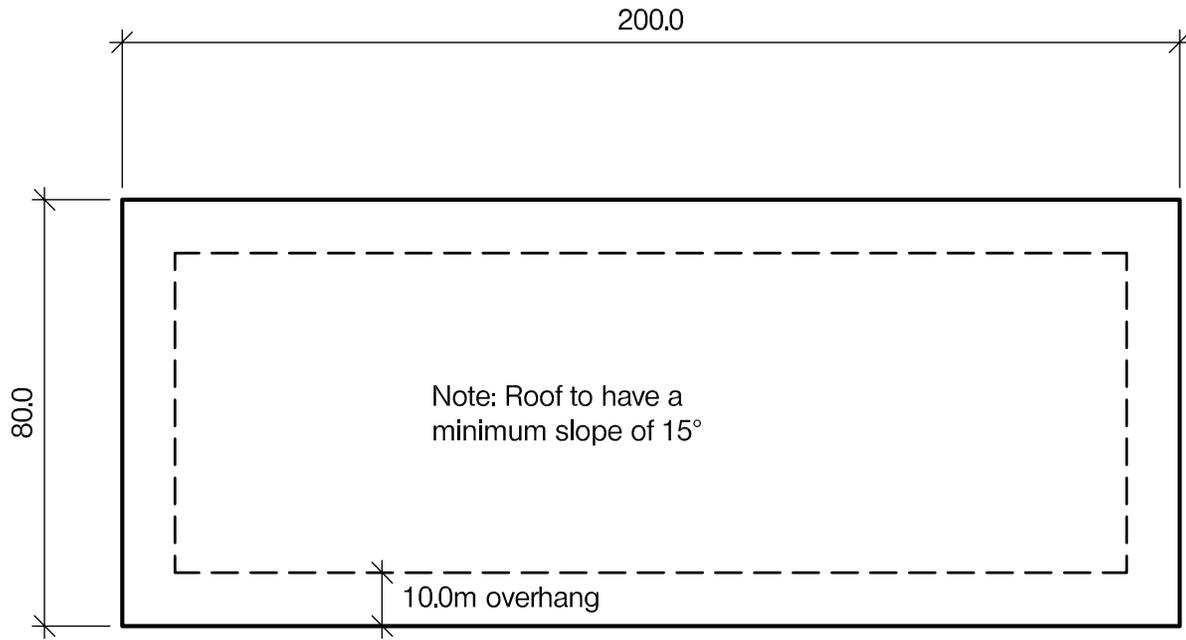
The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural design problems – whether or not the problem is presented in terms that are within your actual experience.

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.

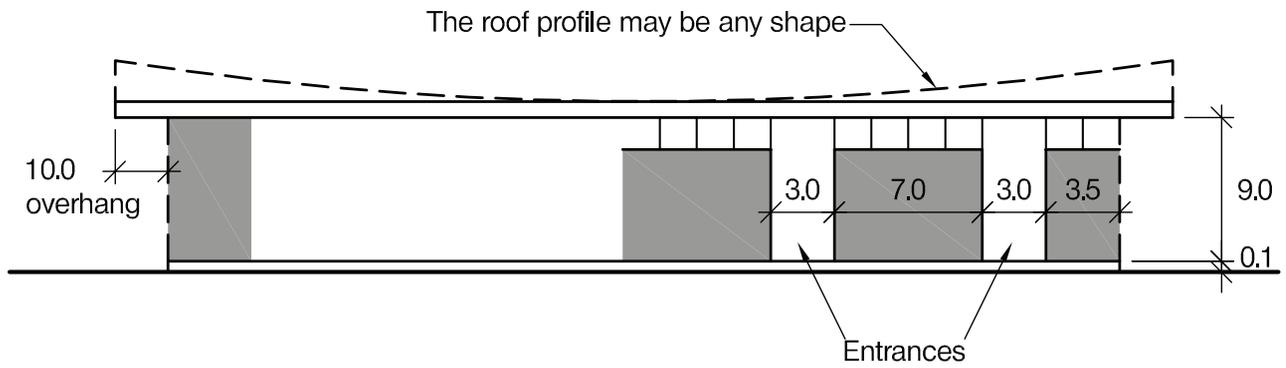
In selecting and developing your design you should also remember the guidance given in the Institution's report, Structural design - achieving excellence, and in particular:

- (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.



ROOF PLAN



ELEVATION

NOTE: All dimensions are in metres

FIGURE Q1

# Question 1. Covered Market

## Client's requirements

1. A roofed market area on the outskirts of a city. As shown in figure Q1, the roofed area is to be 200.0m long x 80.0m wide with a clear roof height of 9.0m and a 15 degree minimum slope for roof drainage.
2. The perimeter enclosure must have high-level windows and must not be load-bearing. Entrances 3.0m wide are required between 7.0m-long sections of wall. The roof is required to overhang the perimeter enclosure by 10.0m on all sides. Supporting columns are to have a minimum spacing of 20.0m internally and externally along the perimeter of the enclosure.
3. The ground floor of the market will be raised above general ground level by 100mm and will be cleaned using high-pressure power hoses.

## Imposed Loading

4. Roof generally 0.6 kN/m<sup>2</sup>  
Ground floor 5.0kN/m<sup>2</sup>

## Site Conditions

5. The site is flat. The basic wind speed is 40m/s based on a 3-second gust; the equivalent hourly wind speed is 20m/s. The temperature on the roof surface is expected to vary between 0°C and 50°C.
6. Ground conditions:
 

0.0m to 1.5m	made ground with reinforced concrete slab 0.2m thick at various depths
1.5m to 5.0m	medium dense sand, N = 20
Below 5.0m	very dense sand and gravel, N = 50

No ground water was encountered.

## Omit from Consideration

7. Design of the market stalls.

## SECTION 1

**(50 marks)**

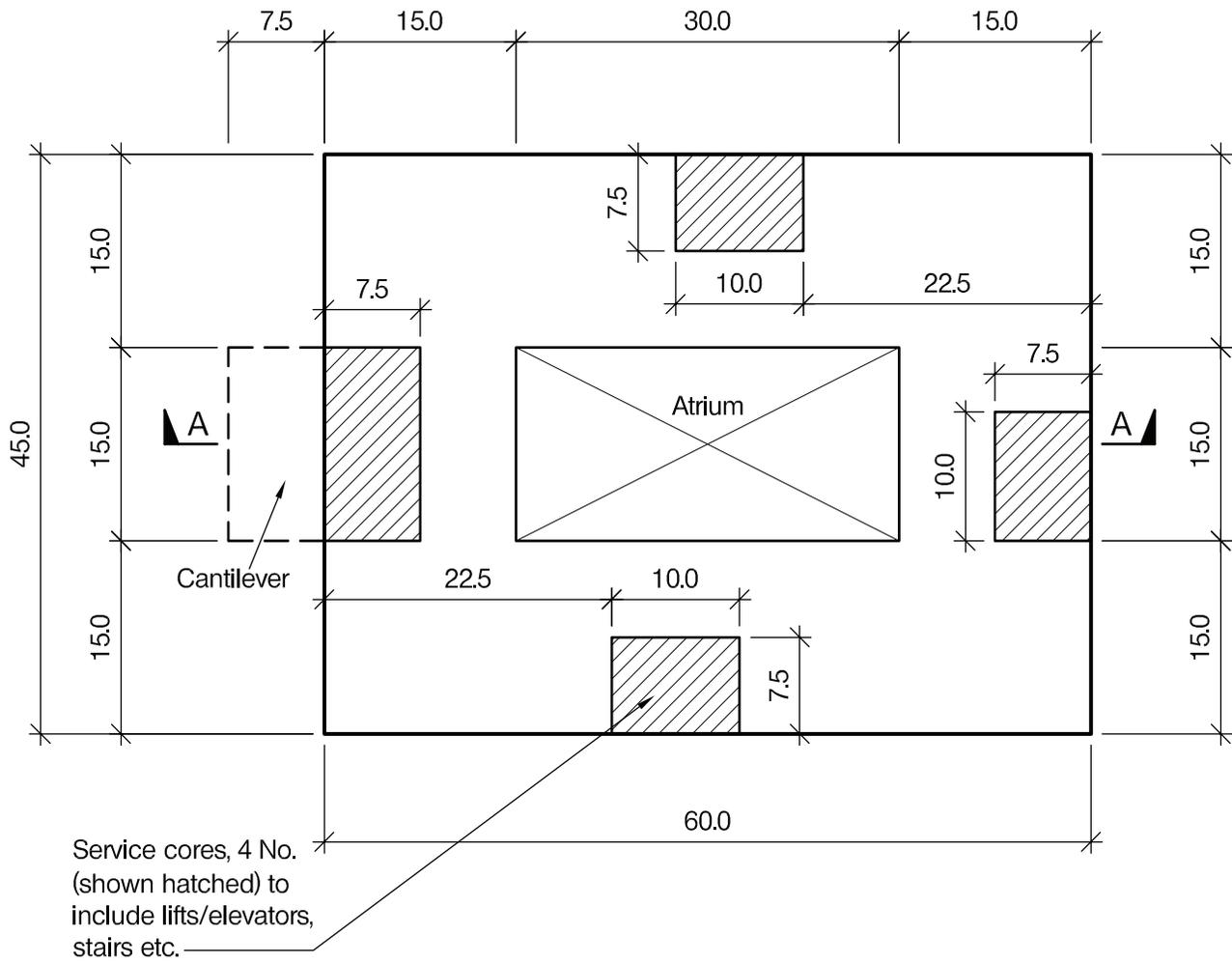
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes, and identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After completion of the scheme design for the structure, the Client enquires whether permanent access to the roof area can be provided, along with a 2.0m high perimeter barrier. Write a letter to the Client advising on the structural implications of this change and describe how it might be accommodated. (10 marks)

## SECTION 2

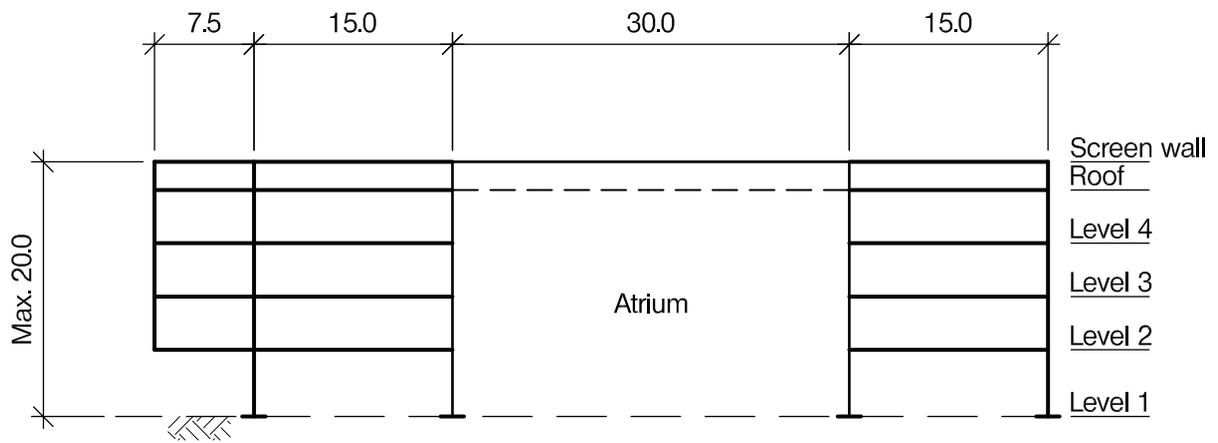
**(50 marks)**

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 drawings, which may include 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 to include consideration of any temporary works that may be required. (10 marks)



PLAN ON LEVEL 1 - GROUND FLOOR



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q2

## Question 2. Science Park Development

### Client's requirements

1. The client requires a 4-storey building in a science park on the outskirts of a city. The building is rectangular in plan, and is to have a large cantilever above the main entrance and a glazed atrium; see Figure Q2.
2. Four service cores are to be provided, containing stairs, lifts/elevators, services and risers.
3. No internal columns are allowed except around service cores and the atrium.
4. The clear height between each floor and ceiling shall be 3.0m. The total height of the building including a 2.0m high roof screen wall shall not exceed 20.0m. The roof is to be flat and is required to accommodate plant. A mechanical services zone of at least 0.6m depth is required below each floor. A 75mm thick screed is required on each floor to contain an under-floor heating system.
5. The external elevations and atrium are to be fully-glazed. No bracing is permitted on external elevations, except that feature bracing is permitted around the atrium and the full-height cantilever. Internal bracing is only allowed around service cores.
6. The roof over the atrium shall be glazed.
7. A minimum fire resistance period of 2 hours is required for structural elements.

### Imposed loading

- |                      |  |
|----------------------|--|
| 8. Floors            | 5.0 kN/m <sup>2</sup> (including partitions) |
| 9. Roof plant        | 2.5 kN/m <sup>2</sup>                        |
| 10. Corridors/stairs | 4.0 kN/m <sup>2</sup>                        |

### Site conditions

11. The basic wind speed is 50m/s on a 3-second gust; the equivalent mean hourly wind speed is 25m/s.
12. Ground Conditions:
 

0.0m – 1.0m	Organic rich top soil
1.0m – 2.0m	Medium dense sand, N=20.
Below 2.0m	Very dense sand and gravel, N=50.

Ground water was encountered at 3.0m below ground level.

### Omit from consideration

13. Detailed design of staircase, lift/elevator, and façade cladding.

### SECTION 1

**(50 marks)**

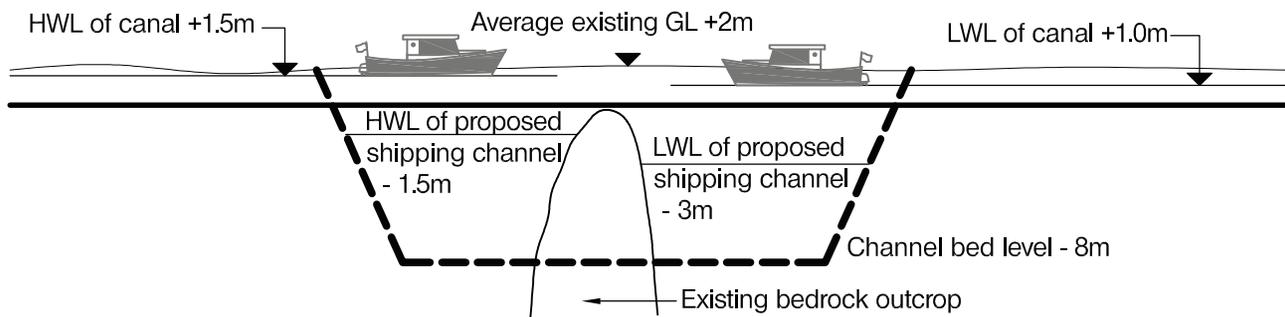
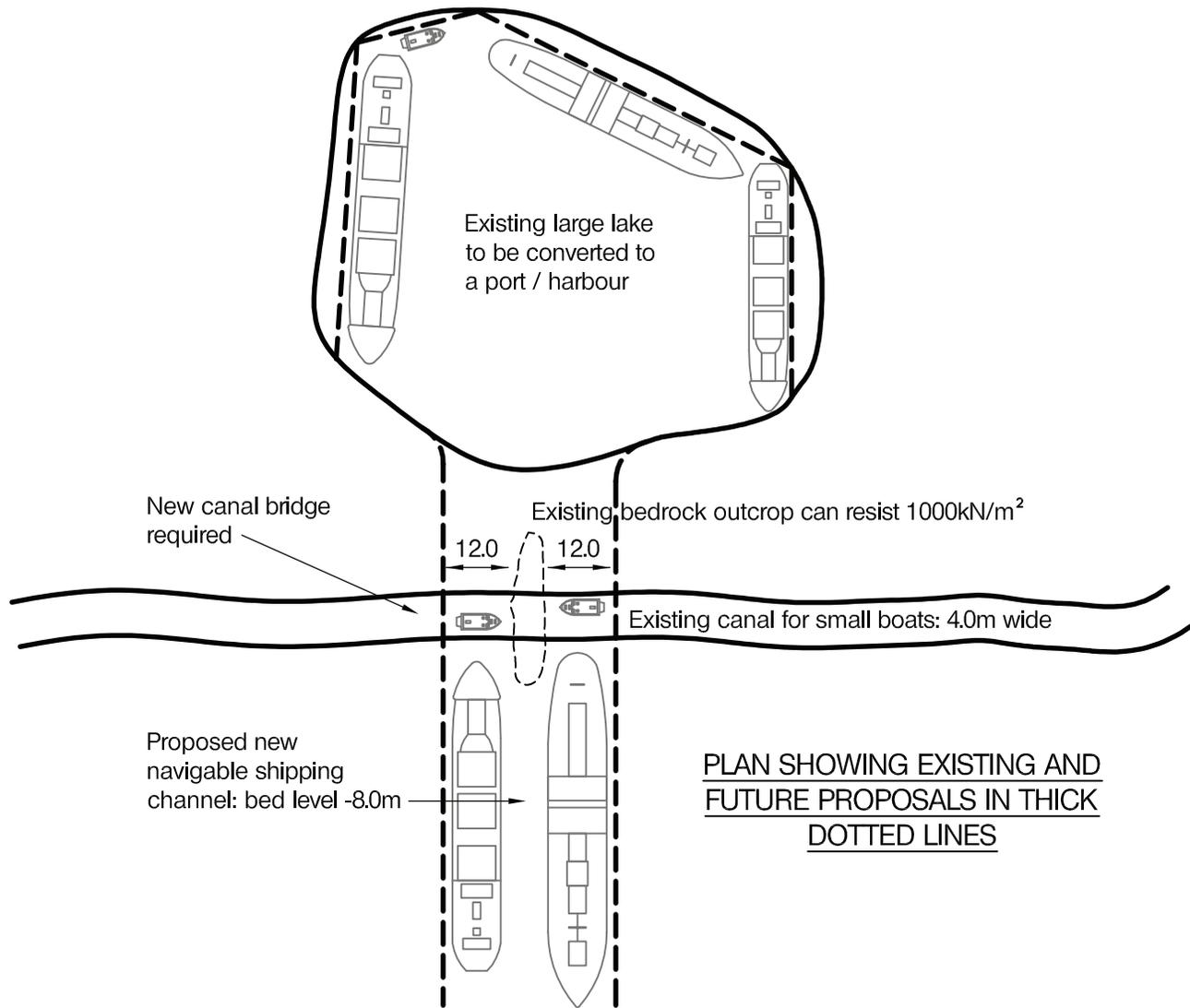
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes, and identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After completion of scheme design for the structure, the client enquires whether a basement for car-parking can be provided under the ground floor. Write a letter to the client, advising on the structural implications of this change, with a description of ways of accommodating it. (10 marks)

### SECTION 2

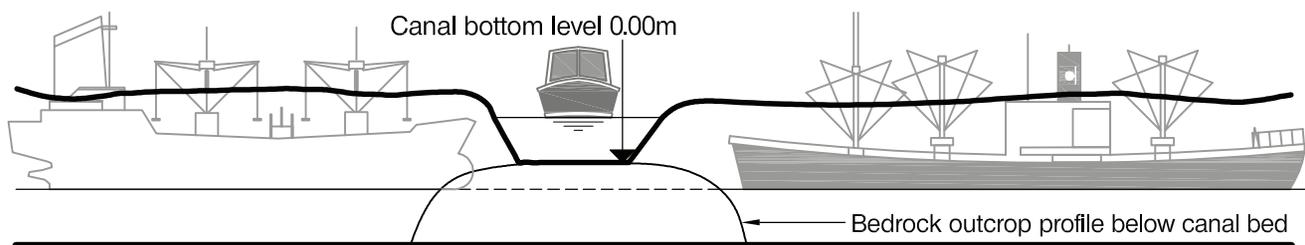
**(50 marks)**

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 drawings, which may include 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 to include consideration of any temporary works that may be required. (10 marks)



SECTION THROUGH EXISTING RIVER SHOWING FUTURE PROPOSAL IN THICK DOTTED LINES



SECTION THROUGH PROPOSED SHIPPING CHANNEL SHOWING EXISTING AND FUTURE PROPOSAL

NOTE: All dimensions are in metres

FIGURE Q3

## Question 3. Canal Bridge over new Shipping Channel

### Client's requirements

1. An existing large lake is to be converted into a port / harbour by constructing a deep navigable shipping channel to link it to the sea. The new channel must pass under an existing canal used by small boats, as shown in Figure Q3. A new bridge is required to carry the canal over the new channel, and which will also allow the passage of ships along the new channel.
2. The existing canal must remain in its present location, as shown in plan in Figure Q3, and cannot be connected to the new channel.
3. The new channel must be at least 24.0m wide to allow ships to pass. Ships using the new channel will be a maximum of 10.0m wide and need a maximum 25.0m clearance above water level.
4. It is not expected that access along the existing canal will be maintained during construction of the new channel. Once the new channel has been completed, access must be restored along the existing canal for boats having a maximum clearance of 3.0m above water level.
5. A massive bedrock outcrop has been found during the site investigation, 5.0m wide x 30.0m long in the position shown in Figure Q3. It is expected to remain in place as an island in the new channel. The rock has a safe bearing capacity of 1,000kN/m<sup>2</sup>. The new channel may be widened to pass around the outcrop.

### Site conditions

6. The site is in a rural area close to the sea. Basic wind speed is 50m/s based on a 3-second gust; the equivalent mean hourly wind speed is 25m/s.
7. Ground conditions:  
 0-20.0m sand and gravel, N=20.  
 Below 20.0m sandstone with safe bearing capacity 1,000kN/m<sup>2</sup>

### Omit from consideration

8. Design against loads from ship impact.

### SECTION 1

**(50 marks)**

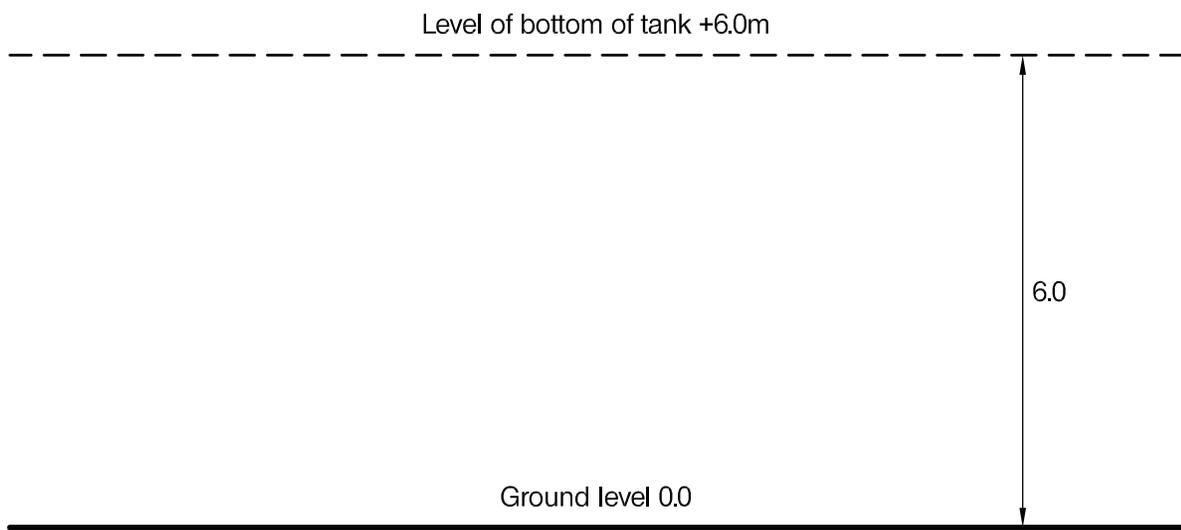
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After completion of the design the Client informs you that, on more detailed investigation, a horizontal band of weaker rock has been discovered 4.0m below the top of the bedrock outcrop. The weaker rock is 0.5m thick and has a safe bearing capacity of 250kN/m<sup>2</sup>. Write a letter to the Client advising how to deal with the situation. (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 drawings which may include 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 to include consideration of any temporary works that may be required. (10 marks)



NOTE: All dimensions are in metres

FIGURE Q4

## Question 4. Water Tank

### Client's requirements

1. An uncovered elevated tank to contain  $9,000\text{m}^3$  of water: see Figure Q4.
2. The bottom of the tank is to be set at 6.0m above ground level.
3. There is no restriction in plan dimensions or height but an economic design is essential.
4. The water supply will be pumped from ground level.

### Imposed loading

5. Allow for 300kg of pumping equipment approximately 2.0m x 2.0m in area to be placed above the water level.

### Site conditions

6. The site is located on the outskirts of a large city. 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 – 0.5m	top soil/fill
0.5m – 5.0m	sand and gravel N = 10
5.0m – 10.0m	sand and gravel N = 20
Below 10.0m	limestone, safe bearing pressure $2,000\text{kN/m}^2$

Ground water was encountered at 2.0m below ground level.

### Omit from consideration

8. Means of access. Details of water inlets and outlets.

### 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, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes, and identify the solution you recommend, giving reasons for your choice.
 

(40 marks)
- b. After the design has been completed the client advises that a roof is required for the water tank. Write a letter to the Client explaining the implications for your 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 drawings, which may include 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 to include consideration of any temporary works that may be required.
 

(10 marks)



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## Question 5. Disaster Relief Field Hospital

### Client's Requirements

1. A well-renowned international humanitarian agency wishes to create a modular-design disaster relief field hospital that can be constructed from elements that can be contained within a single standard shipping container.
2. The shipping container internal dimensions are 2.35m (wide) x 12.04m (long) x 2.39m (high) with a maximum net weight loading allowance of 26.0 tonnes.
3. Each hospital should provide four ward spaces. Each ward should provide a total minimum floor area of 60.0m<sup>2</sup> and have a minimum headroom of 2.2m.
4. Each hospital should have a minimum design life of 2 years.
5. The hospital will be used in wet, cold (-10°C), and hot (40°C) environments.
6. The hospital should be easily demountable.

### Imposed loading

7. Internal Floor Load      2.0kN/m<sup>2</sup>
8. Snow Load                      2.0kN/m<sup>2</sup>

### Site conditions

9. The hospital should be designed to resist loads imposed by winds of basic speed 60m/s based on a 3-second gust; the equivalent mean hourly wind speed is 30m/s.
10. Ground conditions may be variable given the hospitals' worldwide deployment. Provide solutions for rock, medium-stiff clay, and sand. Assume that groundwater will not be present.
11. It can be assumed that there will be demolition rubble available to supplement the foundation design if required.

### Omit from consideration

12. Design of the container.

### 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, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes, and identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After the design has been completed the Client advises you the hospital will be erected by hand using no power tools or mechanical plant, and by unskilled labour. Write a letter to advise the Client of the implications this will have on the design of the hospital. (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 drawings, which may include 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 and dismantling of the hospital including any temporary works needed. (10 marks)

NB: No Figure included in this question



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