

Chartered Membership Examination

Thursday 3 March 2022

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. Good clear drawings and sketches are required; they should show all salient and structural features to suitable scales and should incorporate adequate details.
8. Candidates will not be allowed to include any previously prepared calculations, notes, sketches, diagrams, computer output or other similar material in their answer sheets or A3 drawings. Any previously prepared information submitted by candidates will be ignored by the examiners.
9. Candidates may not bring into the examination room any electronic devices capable of wireless communication, optical photography or scanning.

The following devices are not permitted: Mobile phones, Laptops, notebooks or portable computers and similar devices, iPads, tablets and similar devices, E-readers (e.g. Kindle) and similar devices, Cameras, optical scanners and similar devices.

Any candidates arriving at the examination room with such devices will be asked to switch them off and place them in a sealed bag kept by the Invigilator for the duration of the exam, which includes the lunch period.

10. This paper is set in SI Units.

Now read 'Reminder' on page 3.

Chartered Membership Examination, a reminder from your Examiners

The work you are about to start has many features in common with other examinations which you have tackled successfully but it also has some which are unusual.

As in every examination you must follow carefully the NOTES FOR CANDIDATES set out for your guidance on the front cover of this paper; allocate the available time sensibly and set out your work in a logical and clear way.

The unusual requirement of the examination is that you demonstrate the validity of the training and experience that you have acquired in recent years.

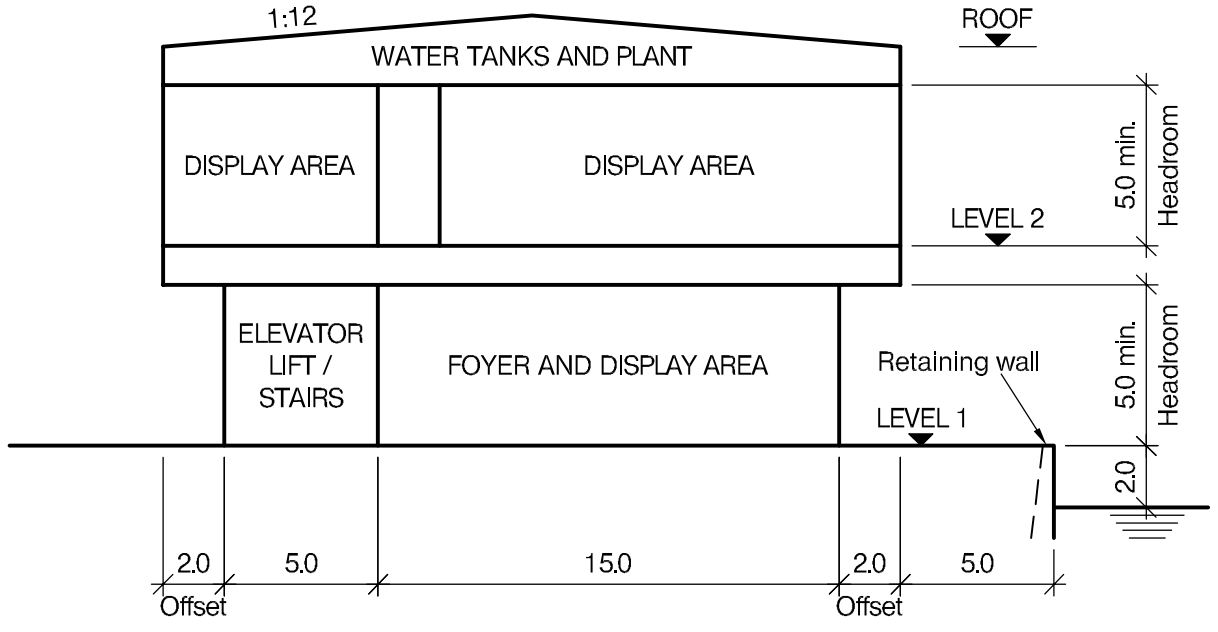
The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural design problems, whether or not the problem is presented in terms that are within your actual experience.

Chartered Structural Engineers must have the ability to design and a facility to communicate their design intentions. Where you are required to list and discuss possible structural solutions you must show by brief, clear, logical and systematic presentation that you understood the general structural engineering principles involved.

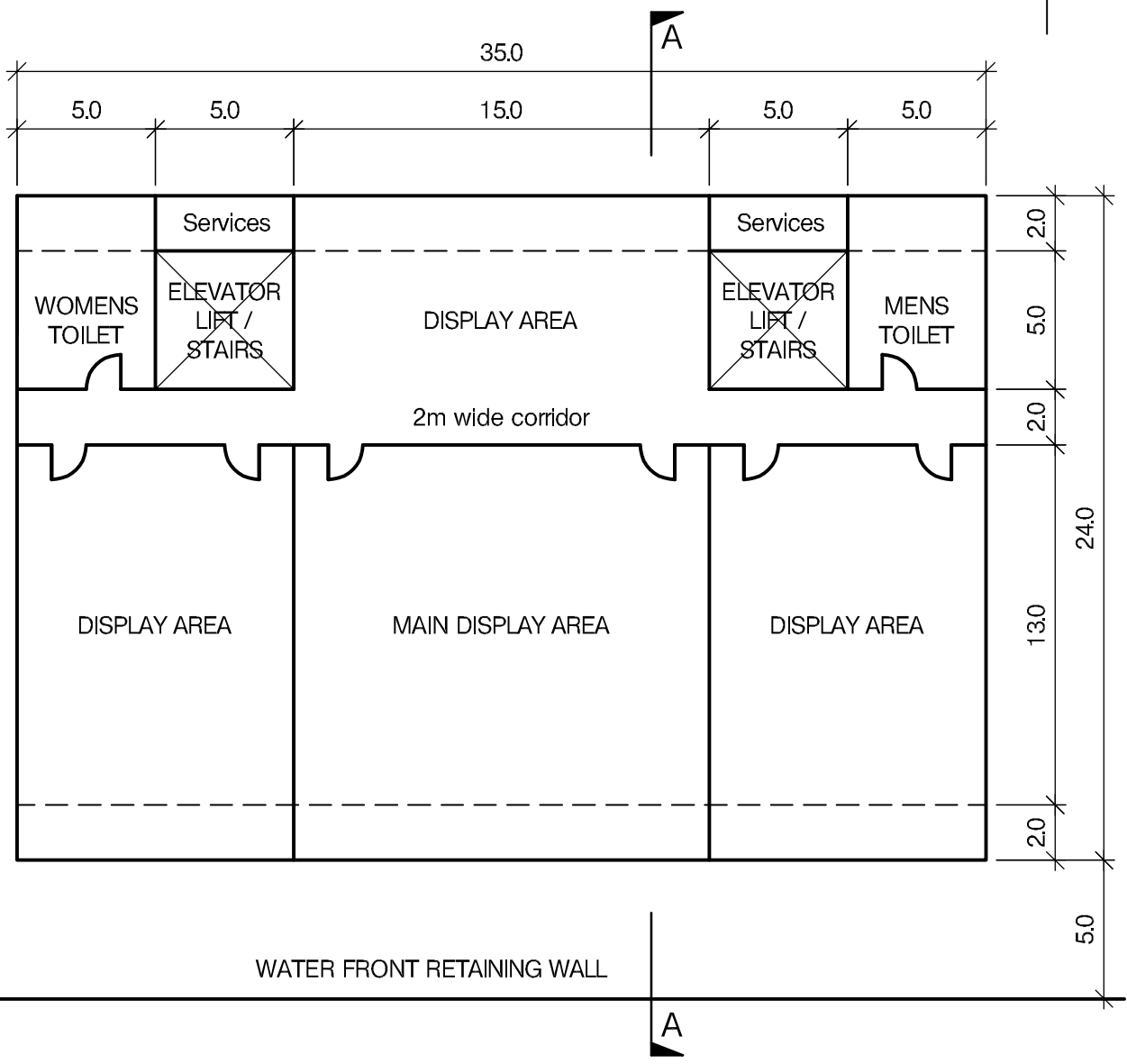
In selecting and developing your design you should also remember the guidance given in the Institution's report, Structural design - achieving excellence, and in particular:

- (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.



SECTION A - A



LEVEL 2 FLOOR PLAN

NOTE: All dimensions are in metres

FIGURE Q1

Q1. Waterfront Exhibition Building

Client's requirements

1. A 2-storey exhibition centre is to be constructed near a lake; see Figure Q1.
2. Outline dimensions are shown in Figure Q1; there is no restriction on the overall height of the building. A minimum headroom of 5.0m is required for Level 1 and Level 2.
3. Level 1 is for entrance foyer and administration offices with as few internal columns as possible and a minimum spacing of 5.0m.
4. Level 2 is for display areas. No internal columns are permitted at Level 2 within the display areas. No internal columns are allowed within the men's and women's toilets and lift/elevator/staircases at both Levels 1 and 2.
5. The external wall between Levels 1 and 2 is to be offset to cantilever by 2.0m from the north and south elevations of the building as shown in Figure Q1. No exterior columns are allowed.
6. The building is to have glazed elevations at Level 1. Cladding to Level 2 elevations and the roof is to be selected to maximise the use of natural lighting and for minimum maintenance costs.
7. Water tanks and mechanical and electrical equipment are to be located above Level 2 toilet and lift/elevator areas.
8. The building is to have a 1-hour fire rating.

Imposed Loading

- | | |
|----------------------|-----------------------|
| 9. Roof | 0.6 kN/m ² |
| Level 1 and 2 floors | 5.0 kN/m ² |
| Plant Services areas | 2.5 kN/m ² |

Site Conditions

10. The site is level and located on the outskirts of a city. Initial investigations show that there are no major services under the proposed footprint of the building. Basic wind speed is 40.0m/s based on a 3-second gust; the equivalent mean hourly speed is 20.0m/s.

Ground conditions

- | | |
|-------------------------|---|
| 11. Ground level – 1.0m | Topsoil and Made ground |
| 1.0 m – 4.0 m | Medium dense to dense SAND. N values increase linearly with depth from 20 to 40. |
| Below 4.0 m | Stiff Clay. C = 200 kN/m ² . Groundwater was encountered at 2.0m below ground level. |

Omit from consideration

12. Design of lift/elevator and stairs.

SECTION 1

(50 marks)

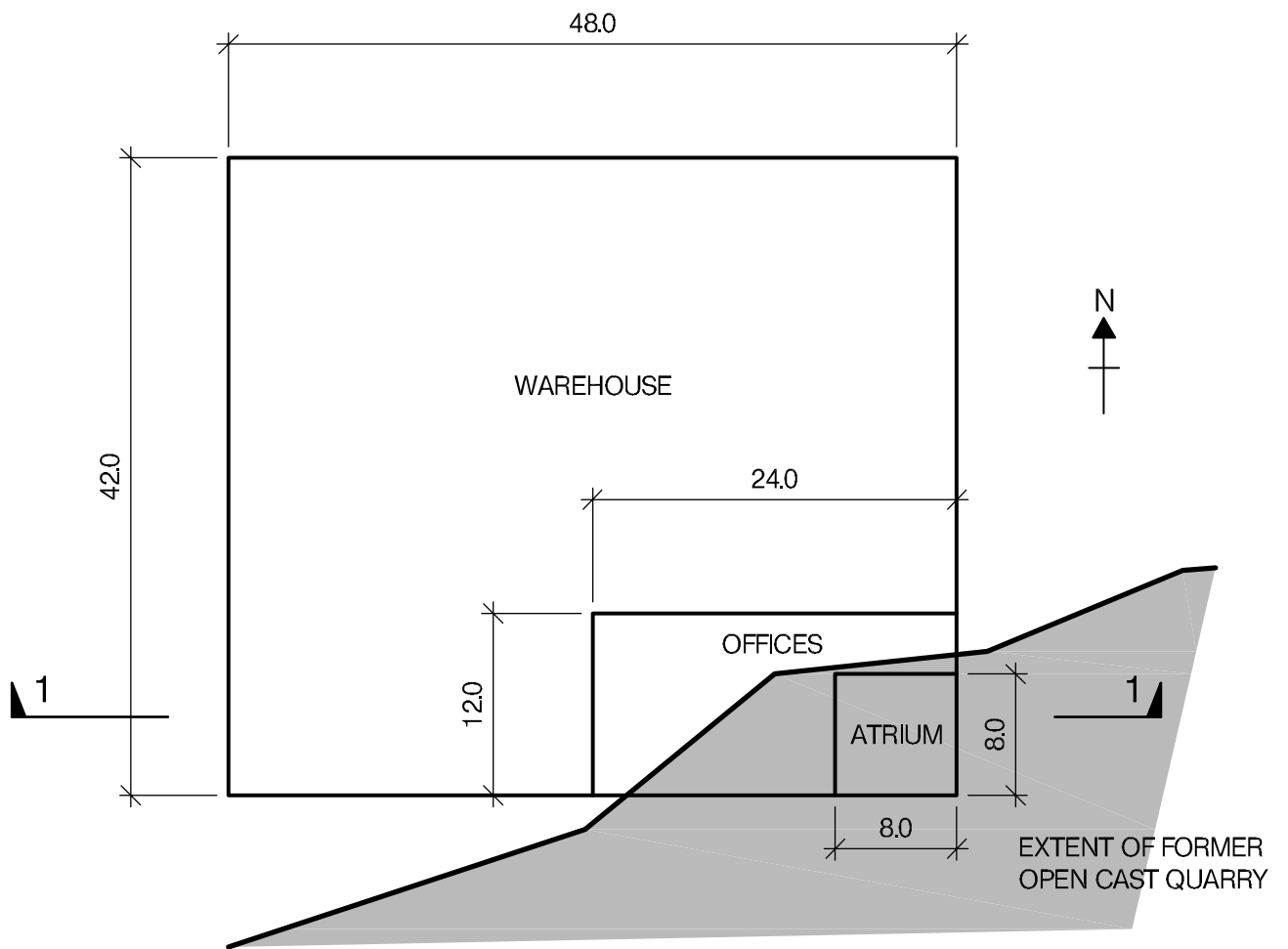
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions including the foundations. Indicate clearly the functional framing, load transfer, serviceability and stability aspects of each scheme. Review and critically appraise the schemes and identify the solution you recommend giving reasons for your choice. (40 marks)
- b. After the scheme design is complete, the Client asks if a basement for storage could be added with an area of 100 square metres and a clear headroom of 4m. Write a letter to the Client explaining the implications on your design and the construction and any recommendations. (10 marks)

SECTION 2

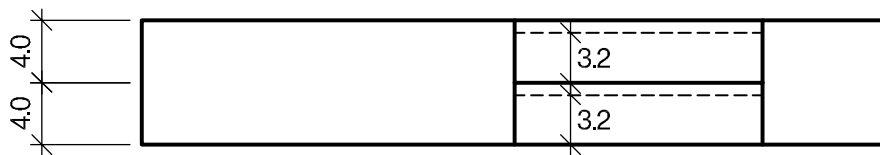
(50 marks)

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 should include plans, sections and elevations to show the dimensions and layout 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



SECTION 1 - 1

NOTE: All dimensions are in metres

FIGURE Q2

Q2. New Commercial Building

Client's Requirements

1. A new, large span commercial unit comprising warehouse area and two storey office area. See Figure Q2.
2. The building is to be located on a previously developed site. The site is on the outskirts of a large city.
3. A minimum clear internal height of 3.2m is required to each office floor, the finished floor to floor height for the offices is 4.0m. Consideration of services integration is required.
4. No internal columns are permitted apart from the area where the offices are located. There is to be an 8 x 8m column free atrium to the entrance of the office area. No bracing elements are permitted to the façade of the building where the offices are located. Perimeter columns are to be at a minimum spacing of 6.0m.
5. The proposed building location crosses the extent of a former open cast quarry.

Imposed Loading

- | | |
|-----------|---|
| 6. Roof | 0.60kN/m ² |
| Offices | 3.50kN/m ² (2.50kN/m ² imposed load and 1.00kN/m ² allowance for partitions) |
| Warehouse | 37.5kN/m ² |

Site Conditions

7. The site is located on the outskirts of a large city. Basic wind speed is 40m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20m/s.
8. Ground conditions vary across the site, see Figure Q2:

General site conditions	Ground level – 0.20m	topsoil
	0.20m – 3.0m	stiff clays, N value 15
	Below 3.0m	mudstone, N value 50+
Former quarry area	Ground level – 0.20m	topsoil
	0.20m – 8.0m	historic granular fill material, N value 5
	Below 8.0m	mudstone, N value 50+

No ground water was encountered.

Omit from Consideration

9. Detailed design of lift/elevator and stair cores.

SECTION 1

(50 marks)

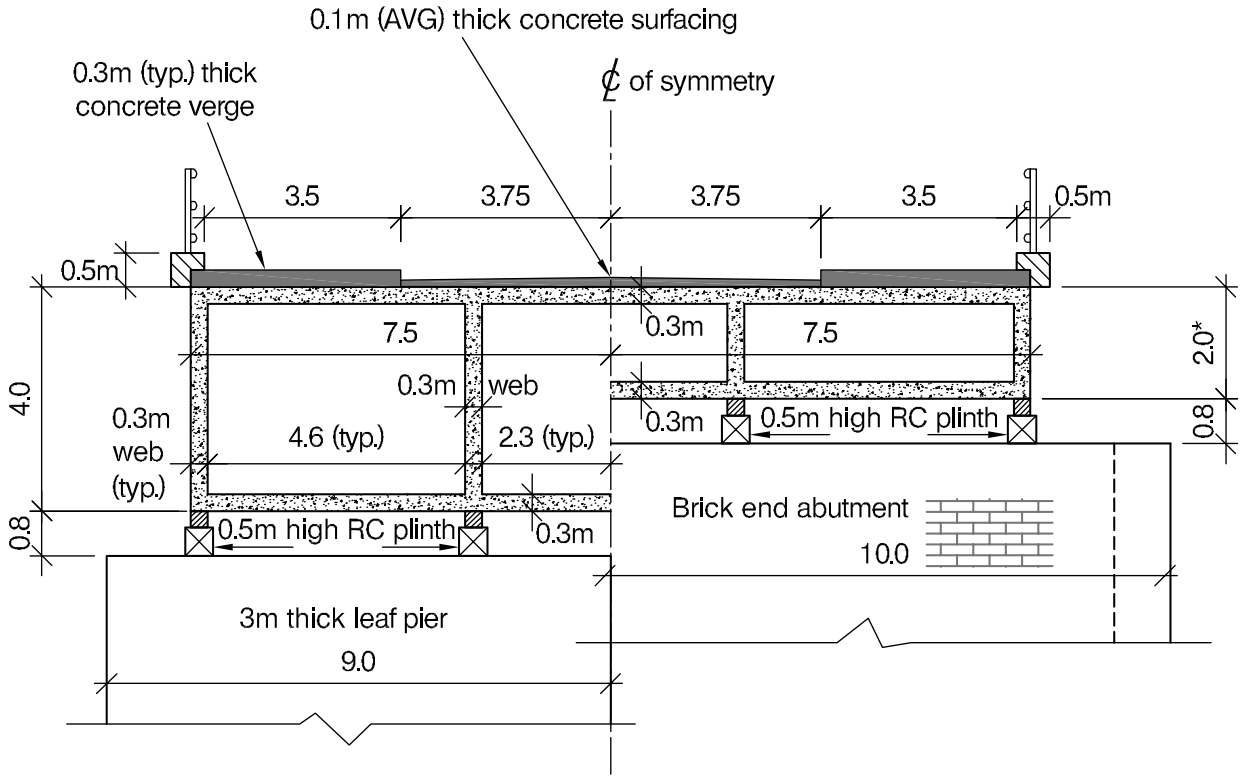
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. At the outset of construction, the client suggests that due to a business model change, in the next two years they will likely require double the amount of office space for additional support staff. As such, they want to understand the implications of how this future flexibility can be incorporated within the project. Write a letter to the Client explaining the implications on your design. (10 marks)

SECTION 2

(50 marks)

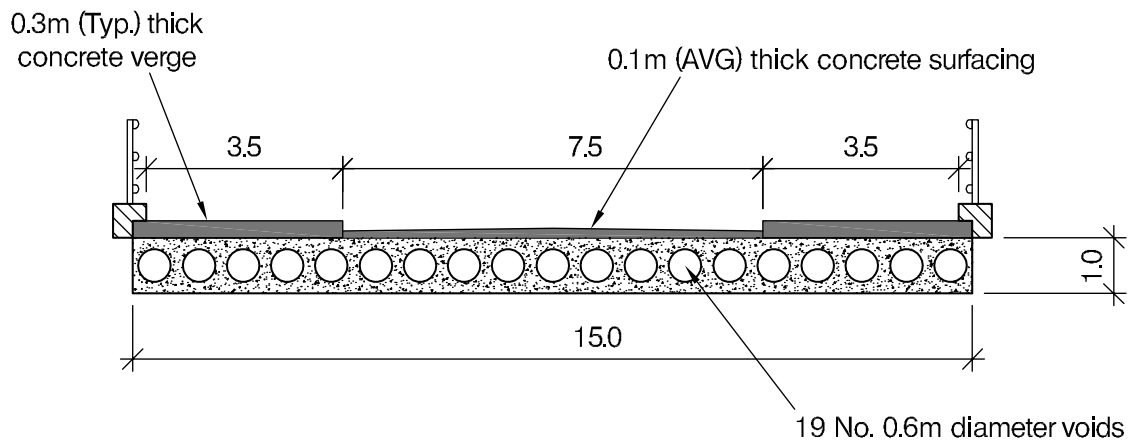
For the solution recommended in Section 1(a):

- 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 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)



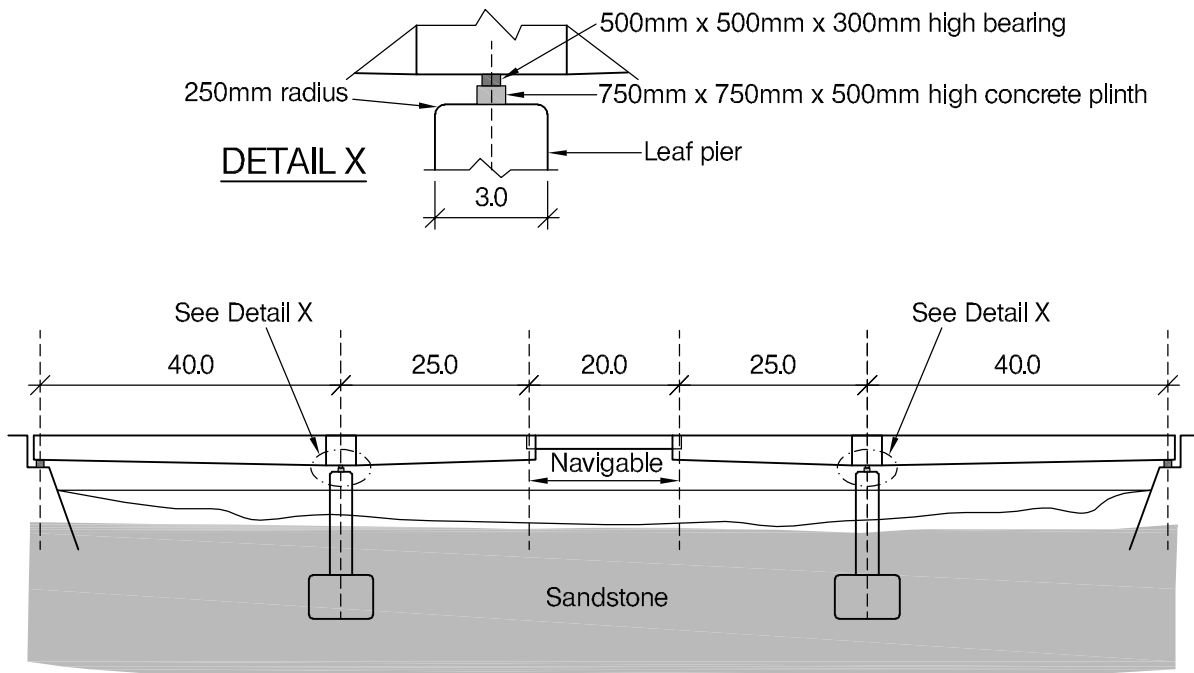
SUPERSTRUCTURE CROSS SECTION AT PIER AND ABUTMENT

*SAME SUPERSTRUCTURE DEPTH AT HALF JOINT

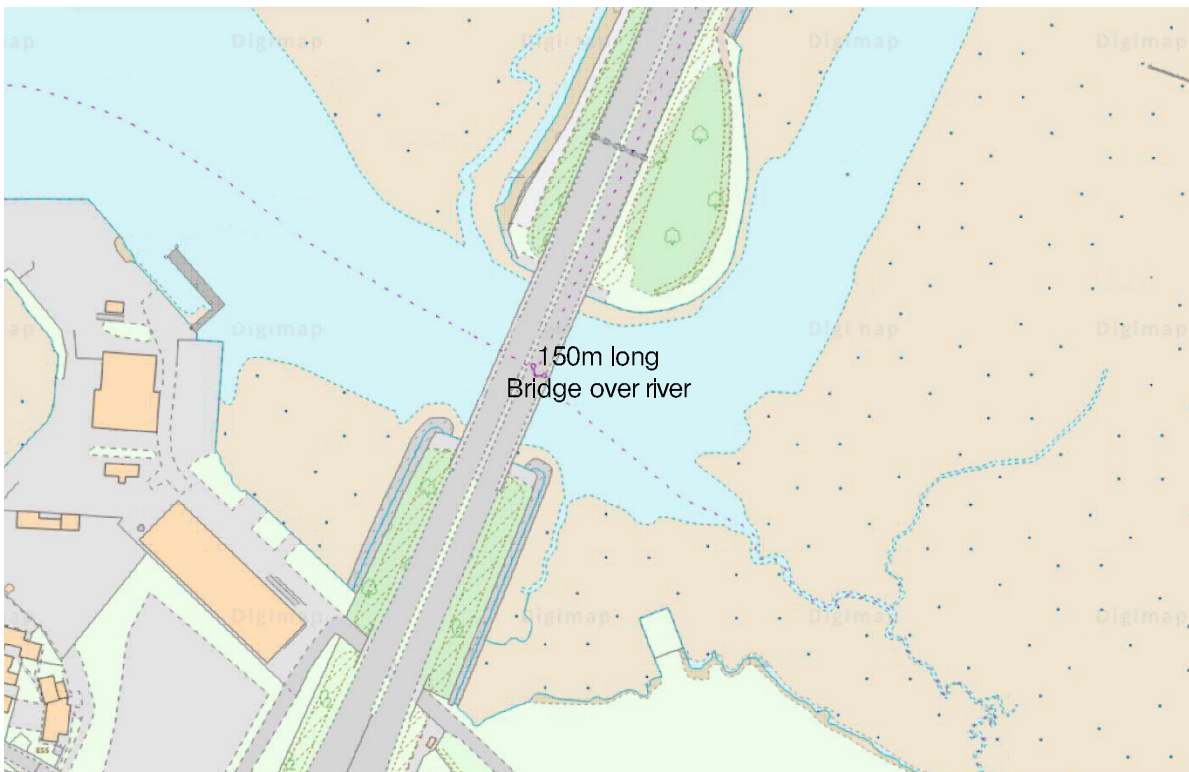


SUSPENDED SPAN CROSS SECTION *

*NOTE Detailed dimensions are from as built drawings including associated text.



LONGITUDINAL ELEVATION



PLAN & LOCATION PLAN OF THE EXISTING BRIDGE OVER THE RIVER

NOTE: All dimensions are in metres

Q3. Capacity Improvement of Bridge over River

Client's requirements

1. An existing bridge over the river as shown in Figure Q3 needs its capacity enhanced from 2 traffic lanes to 4 traffic lanes. The footpaths are important and must be retained but may be narrowed to 2m either side. The new proposed four traffic lanes are to be 3.5m wide.
2. A new bridge can be constructed at either side, but no temporary or permanent support is allowed within the river. The existing substructures were originally designed for a bridge with 6 traffic lanes with Grade 40 concrete and adequate reinforcement.
3. River is tidal but during high tide boats do pass underneath, hence the depth of superstructure at the location of suspended span should not exceed more than its current depth.
4. Existing parapets with 500mm wide precast coping units were found to be substandard. Two traffic lanes are essential to remain open except every night from 11 pm to 6am and one week each in Christmas and Easter.
5. Central suspended span can carry only one fifth of the load it should carry from normal traffic, as per its recent load assessment.

Imposed loading

- | | |
|-------------|-----------------------|
| 6. Footways | 5.0 kN/m ² |
| 7. Roadway | 10.0N/m ² |

Site conditions

8. The site is in a rural area. Basic wind speed is 46.0m/s based on a 3-second gust; the equivalent mean hourly wind speed is 23.0m/s.

Ground conditions

9. Weak rock, safe bearing capacity 1,000kN/m².

Omit from consideration

10. Design against loads from ship impact.

SECTION 1

(50 marks)

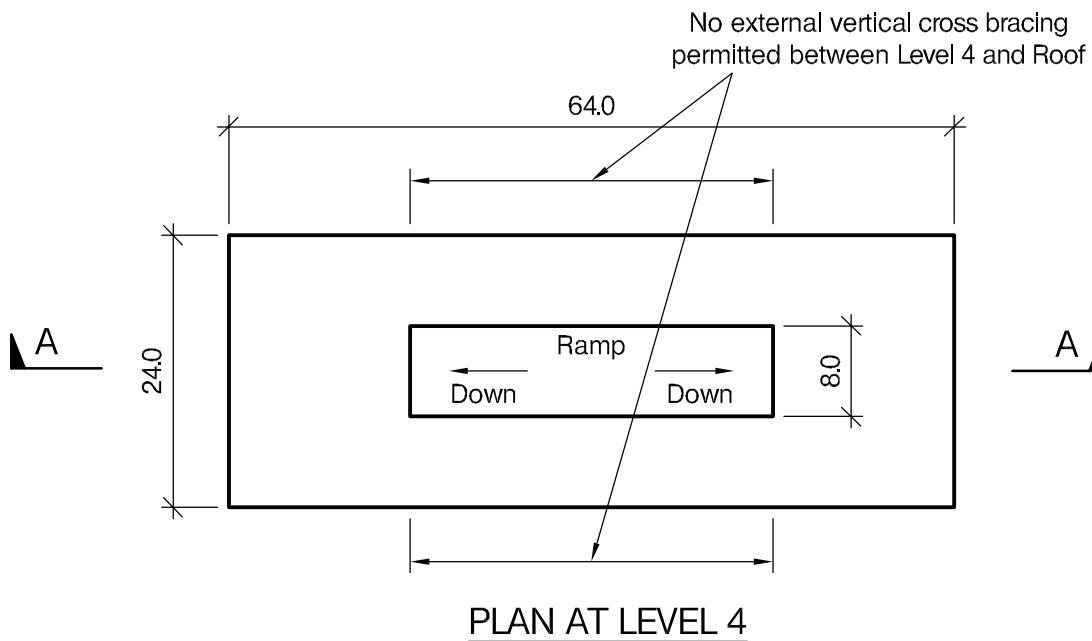
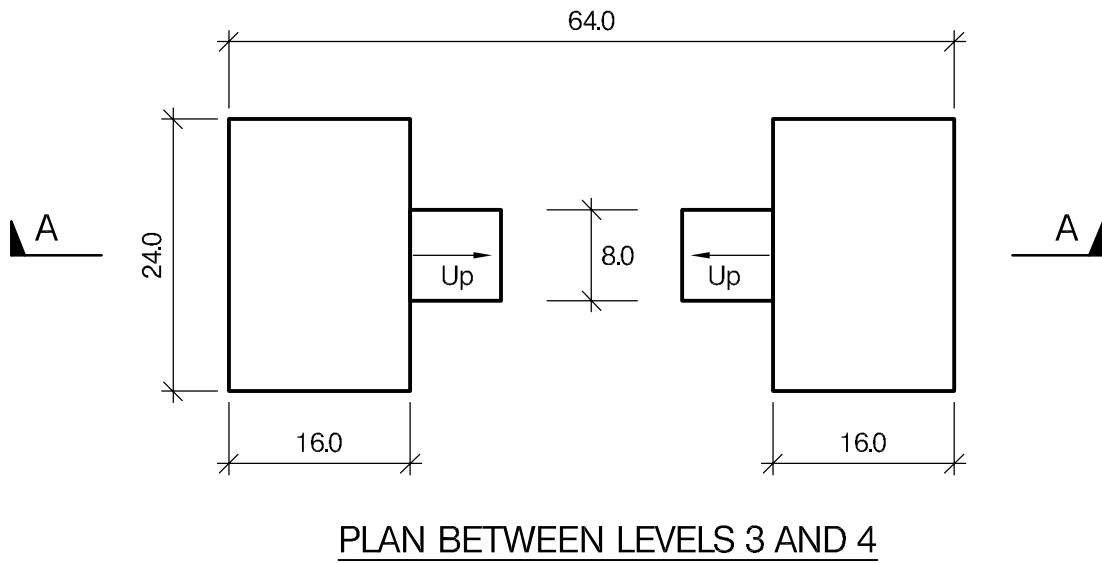
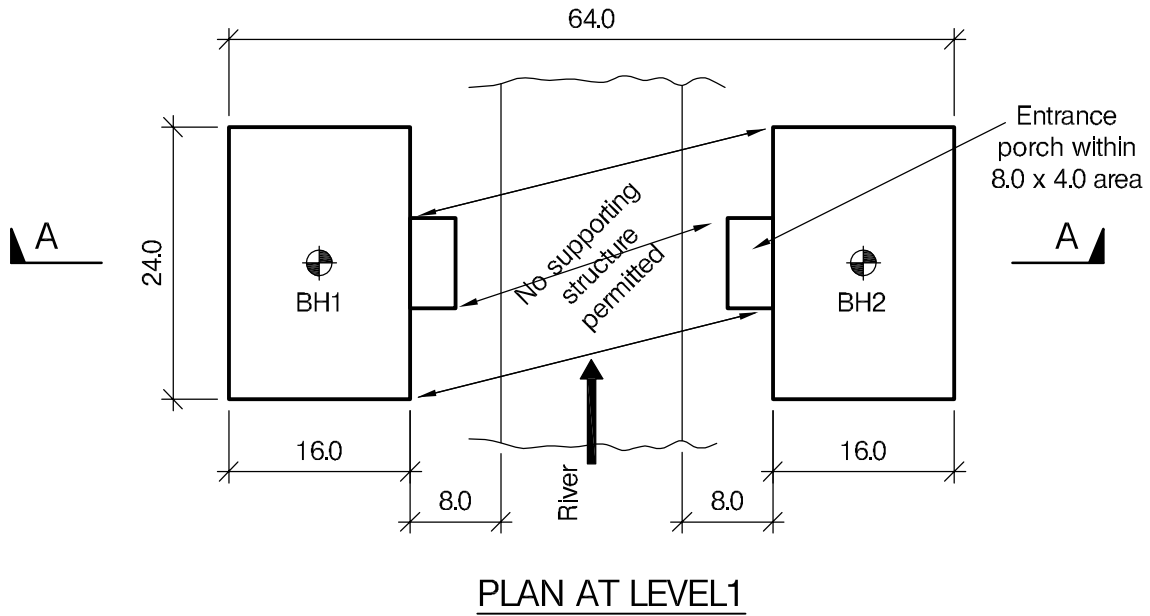
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes and identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After completion of the design, the client forwards you the original as built drawings shows half joint of the bridge can only take 200kN/m along its length. Write a letter to the client advising them on the implications of the design. (10 marks)

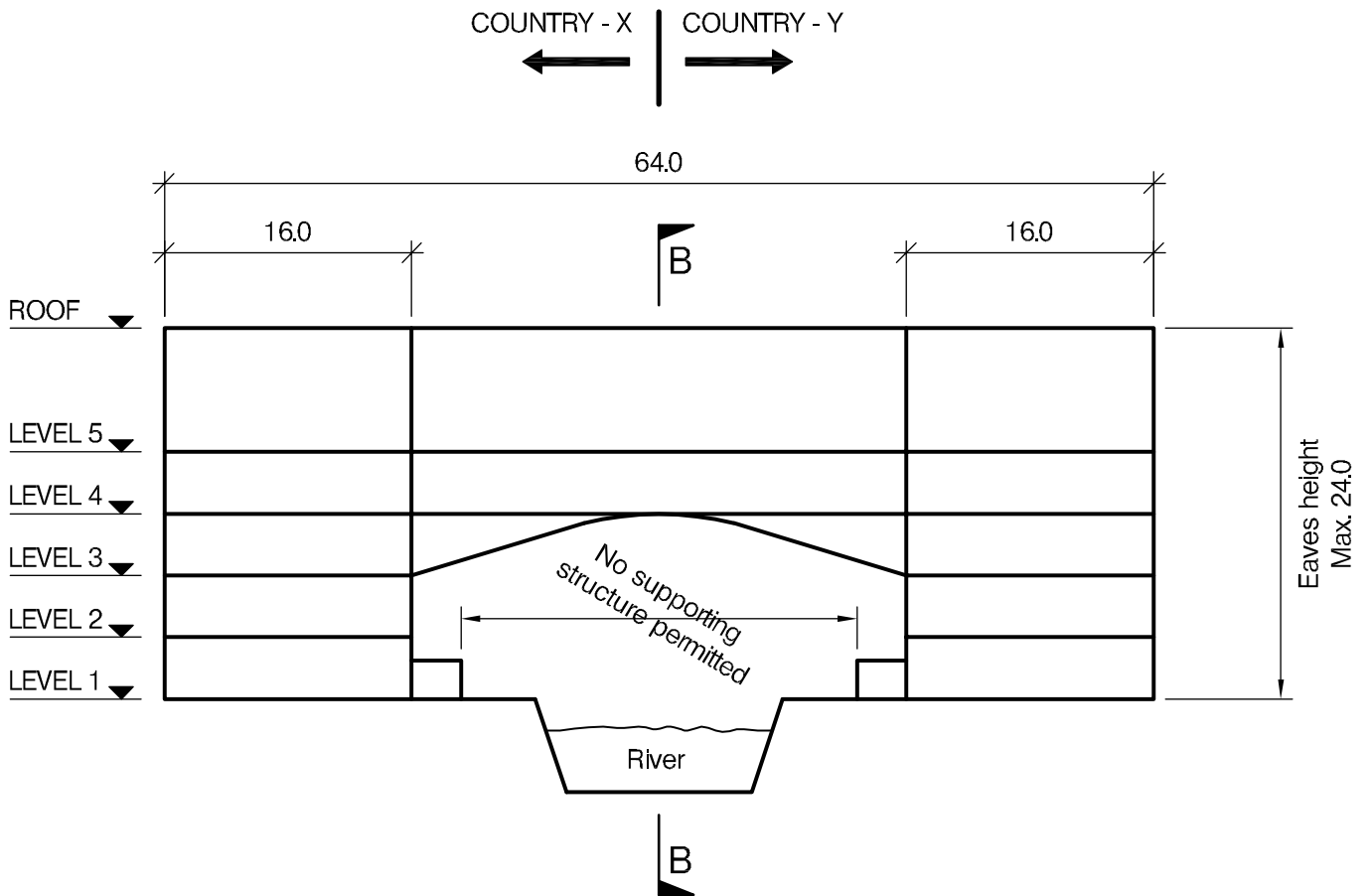
SECTION 2

(50 marks)

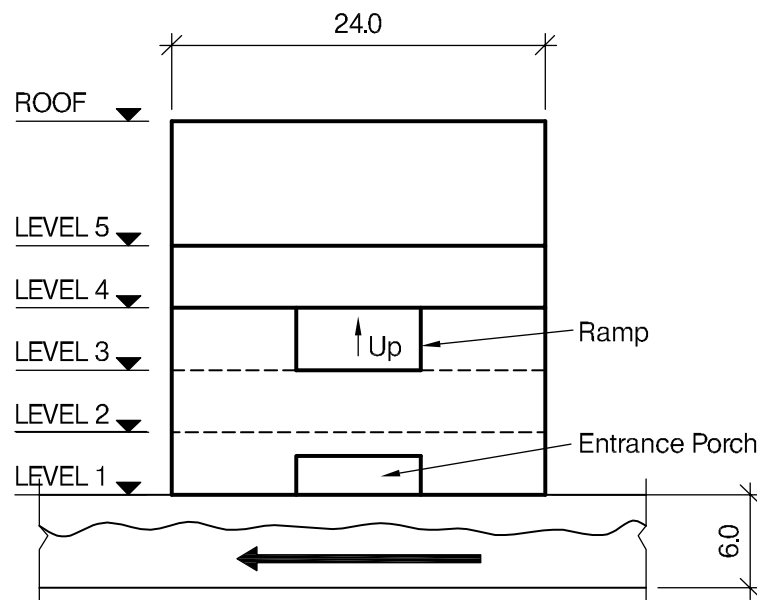
For the solution recommended in Section 1(a):

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



SECTION B - B

NOTE: All dimensions are in metres

Q4. Peace Dialogue Station

Client's Requirements

1. A new five-storey building is required, in a remote site falling equally in two countries, to function as a venue to promote tranquillity between them and facilitate peace dialogue between other disputed countries. The facility is to be 64.0m long and 24.0m wide. See Figure Q4.
2. 8.0m wide arch shaped ramp is needed in the middle of the building for connecting Level 3 and Level 4 and both sides as shown in Figure 4. No supporting structure is permitted in the zone shown in Figure Q4.
3. Two internal lift/elevator/stair/service cores measuring 8.0m x 4.0m are to be provided, one each on either side, to serve all the floors. Column/wall spacing must not be less than 7.0m. No internal vertical cross bracing obstructing floor space is allowed anywhere within the building.
4. Clear floor to ceiling height is to be 2.7m in Level 1 to Level 4 and 4.0m in Level 5. A structure-free ceiling zone of minimum 400mm is required in all levels for services.
5. The maximum height of the eaves of the building above Level 1 is 24.0m. No roof supporting structure is permitted above Roof Level and all other superstructures must be within the building footprint.
6. Doors at entrance porches on both sides are to be at least 4m wide and 2.5m high.
7. 75% of the areas of all external sides will be glazed and the remainder will be clad in stone panels.
8. The site is easily accessible within 45-minute drive from nearby established industrial areas of both countries.
9. Both countries agreed to adopt building design codes from any country in the world.

Imposed Loadings

10. Roof	0.6 kN/m ²
Level 1 to Level 5	3.0 kN/m ²
Ramp	3.0 kN/m ²

Loadings include allowances for finishes, ceiling and services.

Site Conditions

11. The site is situated on a heavily wooded remote site across a perennial river, which flows through international border between the two countries. The site needs clearing of trees partly. Basic wind speed is 46m/s based on a 3-second gust; the equivalent mean hourly wind speed is 23m/s.

Ground condition

12. Borehole 1:

Ground level – 0.5m	Top soil
0.5m – 2.0m	Stiff clay C = 100 kN/m ²
2.0m – 6.0m	Stiff clay C = 150 kN/m ²
Below 6.0m	Rock, characteristic bearing strength = 4500 kN/m ²

- Borehole 2:

Ground level – 0.5m	Topsoil
0.5m – 2.0m	Firm clay C = 75 kN/m ²
2.0m – 6.0m	Stiff clay C = 125 kN/m ²
Below 6.0m	Rock, characteristic bearing strength = 4500 kN/m ²

Ground water was observed 3.0m below ground level in both boreholes.

Omit from consideration

13. Detailed design of staircases, roof of entrance porches, lift/elevators within cores and glazed facades, earth retaining systems and river protection. However, the design appraisal should address their structural implications. Also omit expansion joint from consideration.

Q4. Peace Dialogue Station

SECTION 1

(50 marks)

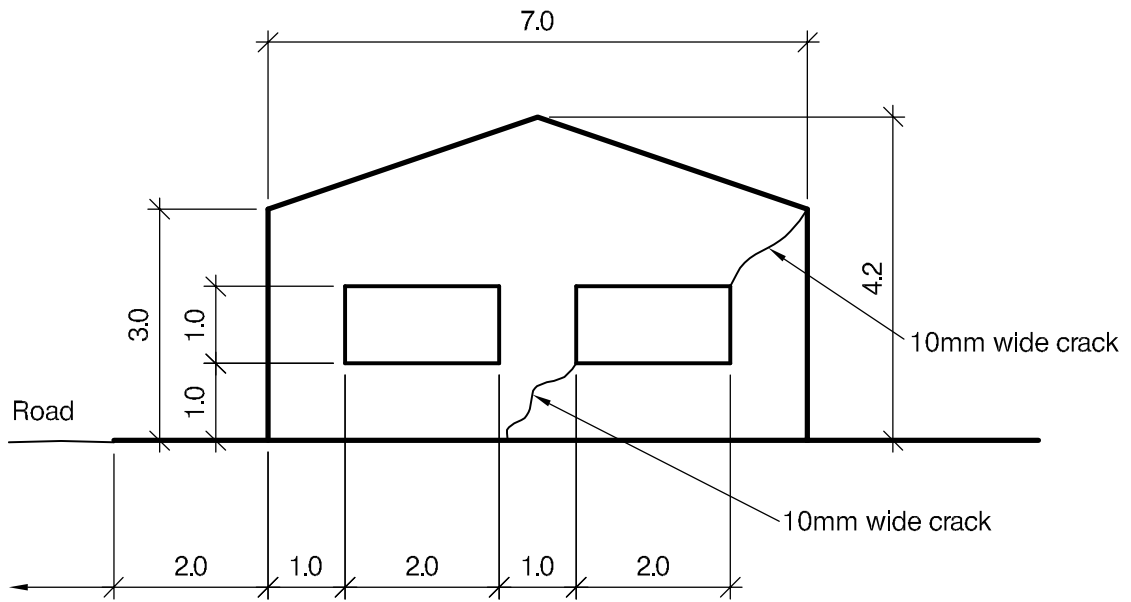
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer, serviceability and stability aspects of each scheme. Review and critically appraise the schemes, and identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After you have completed your design, the client informs you that geotechnical investigation works in progress at nearby sites in both countries have revealed the presence of ground cavities. Write a letter to the client explaining the design and construction implications and advising how the design could be modified to overcome this phenomenon. (10 marks)

SECTION 2

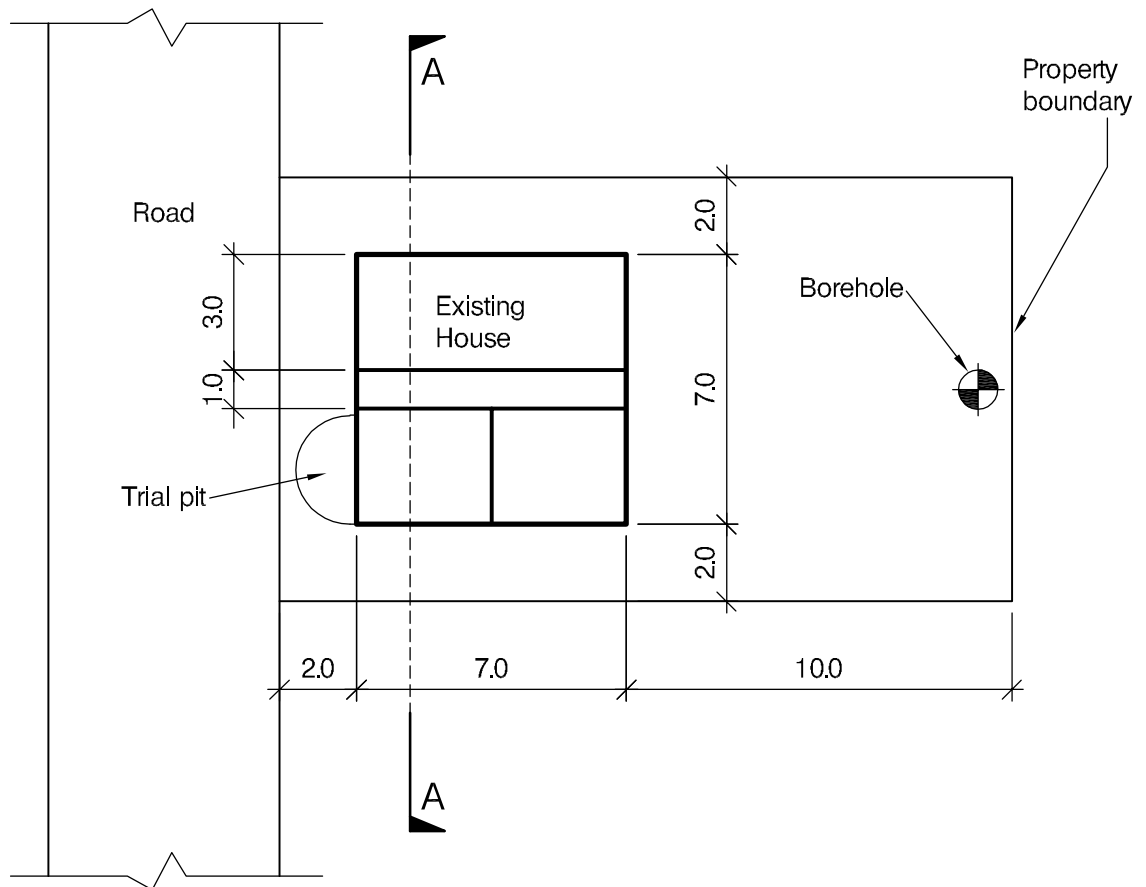
(50 marks)

For the solution recommended in Section 1(a):

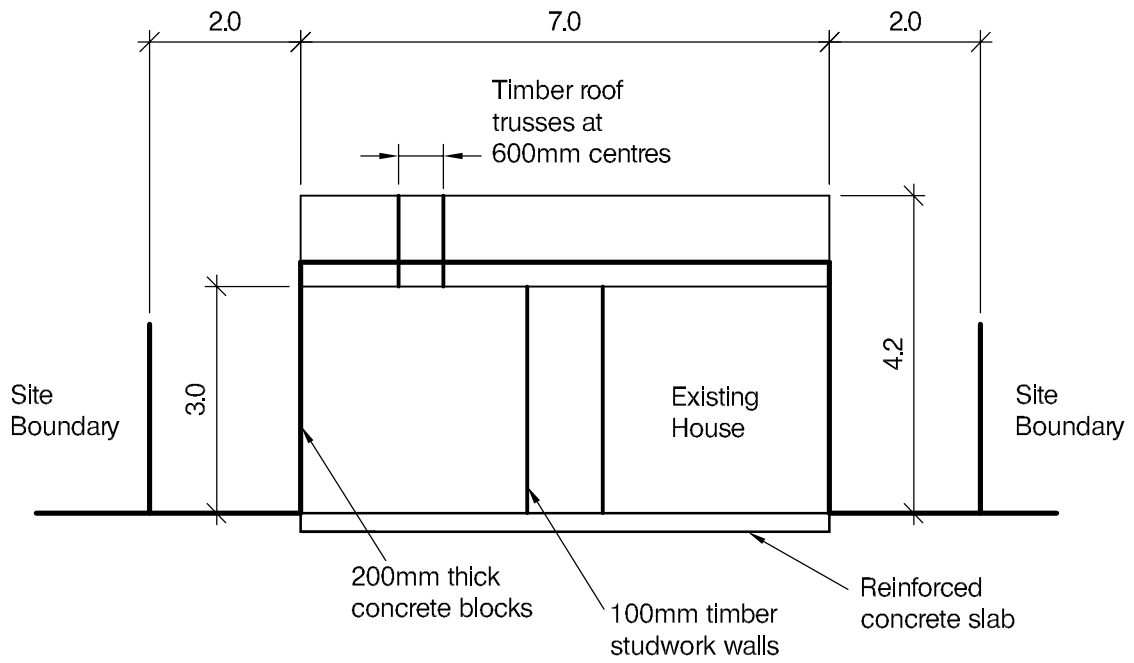
- c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)
- d. Prepare general arrangement drawings, which may include plans, sections and elevations, to show the dimensions, layout and disposition of the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



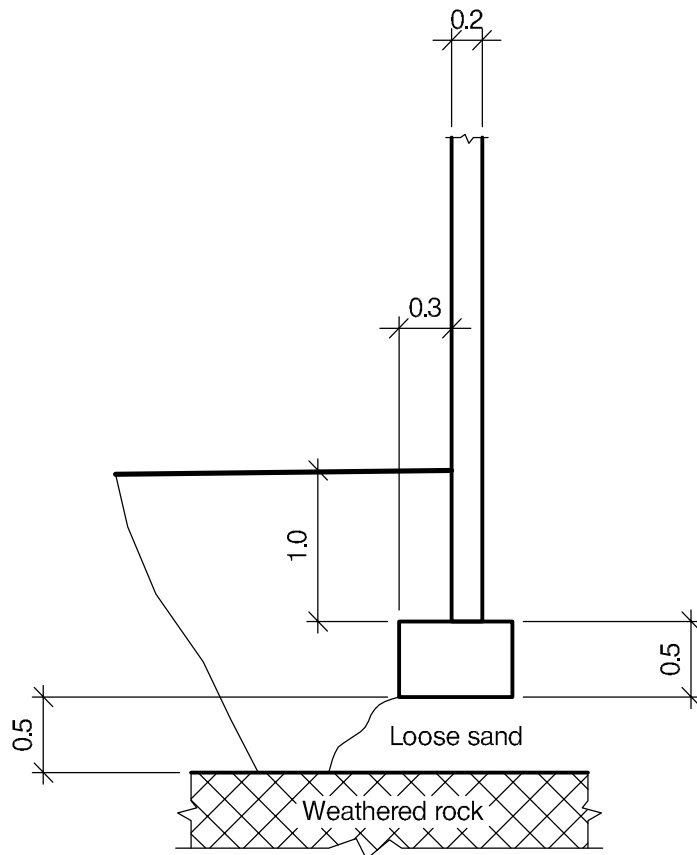
ELEVATION



PLAN VIEW



SECTION A - A



TRIAL PIT

NOTE: All dimensions are in metres

Q5. House Extension

Client's Requirements

1. The client has inherited a single storey house on an 11 x 19m property. They want to increase the habitable floor area to 100m² while minimising the changes to the existing house. See Figure Q5.
2. The existing external walls are made from 200mm thick concrete blockwork with an external cementitious render coating. The internal walls are made from 75mm deep timber framed walls faced with plasterboard.
3. All floors are to have a 3m clear height.
4. No structure is permitted inside the new floor areas to maximise the flexibility of the space.
5. The roof is to be clad with concrete tiles with a minimum slope of 22 degrees.
6. Site access is using the road in front of the house. No access is permitted on adjacent property.

Imposed Loading

7. Roof 0.75kN/m²
8. Floors 1.50kN/m² + 1kN/m² for partitions

Site Conditions

9. The site is located on the outskirts of large city centre. Basic wind speed is 40.0m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20.0m/s.
10. A borehole at the end of the garden indicates the following ground conditions:

Ground level –0.5m	Top soil
0.5m – 6.0m	Made ground N value 5
Below 6.0m	rock safe bearing capacity 2000 kN/m ²

Water was discovered at 4m depth.
11. A trial pit at the front of the house indicates foundations at a depth of 1.5m. Rock was also discovered at a depth of 2m.

Omit from Consideration

12. Design of the lift/elevator and stairs.

SECTION 1

(50 marks)

- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Justify the reasons for your solution. (40 marks)
- b. After the scheme is complete, the client advises you that he has discovered a 10mm wide diagonal crack in a sidewall at 45 degrees from the middle of the wall to the eaves. Write a letter to the Client explaining the implications on your design and the construction. (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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