

Chartered Membership Examination

Friday 8 July 2016

Structural Engineering Design and Practice

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

Important

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

Notes to Candidates

1. TO PASS THE EXAMINATION, CANDIDATES MUST SATISFY THE EXAMINERS IN BOTH PARTS OF THE QUESTION ATTEMPTED.
2. Examiners will only mark work written by hand during the examination.
3. A fair proportion of marks will be awarded for the demonstration of an understanding of fundamental engineering concepts, as distinct from calculation of member forces and sizes. NOTE: In the calculation part of all questions, establishing "form and size" is taken to mean compliance with all relevant design criteria, i.e. bending, shear, deflection, etc.
4. In all questions 50 marks are allocated to Section 1 and 50 marks to Section 2.

5. The Examiners are looking for sound structural designs. It should also be remembered that aesthetics, economy and function are important in any competent engineering scheme.
6. Any assumptions made and the design data and criteria adopted must be stated.
7. Good clear drawings and sketches are required; they should show all salient and structural features to suitable scales and should incorporate adequate details.
8. Candidates will not be allowed to include any previously prepared calculations, notes, sketches, diagrams, computer output or other similar material in their answer sheets or A3 drawings. Any previously prepared information submitted by candidates will be ignored by the examiners.
9. Candidates may not bring into the examination room any electronic devices capable of wireless communication, optical photography or scanning.

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

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

10. This paper is set in SI Units.

Now read 'Reminder' on page 3.

Chartered Membership Examination, a reminder from your Examiners

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

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

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

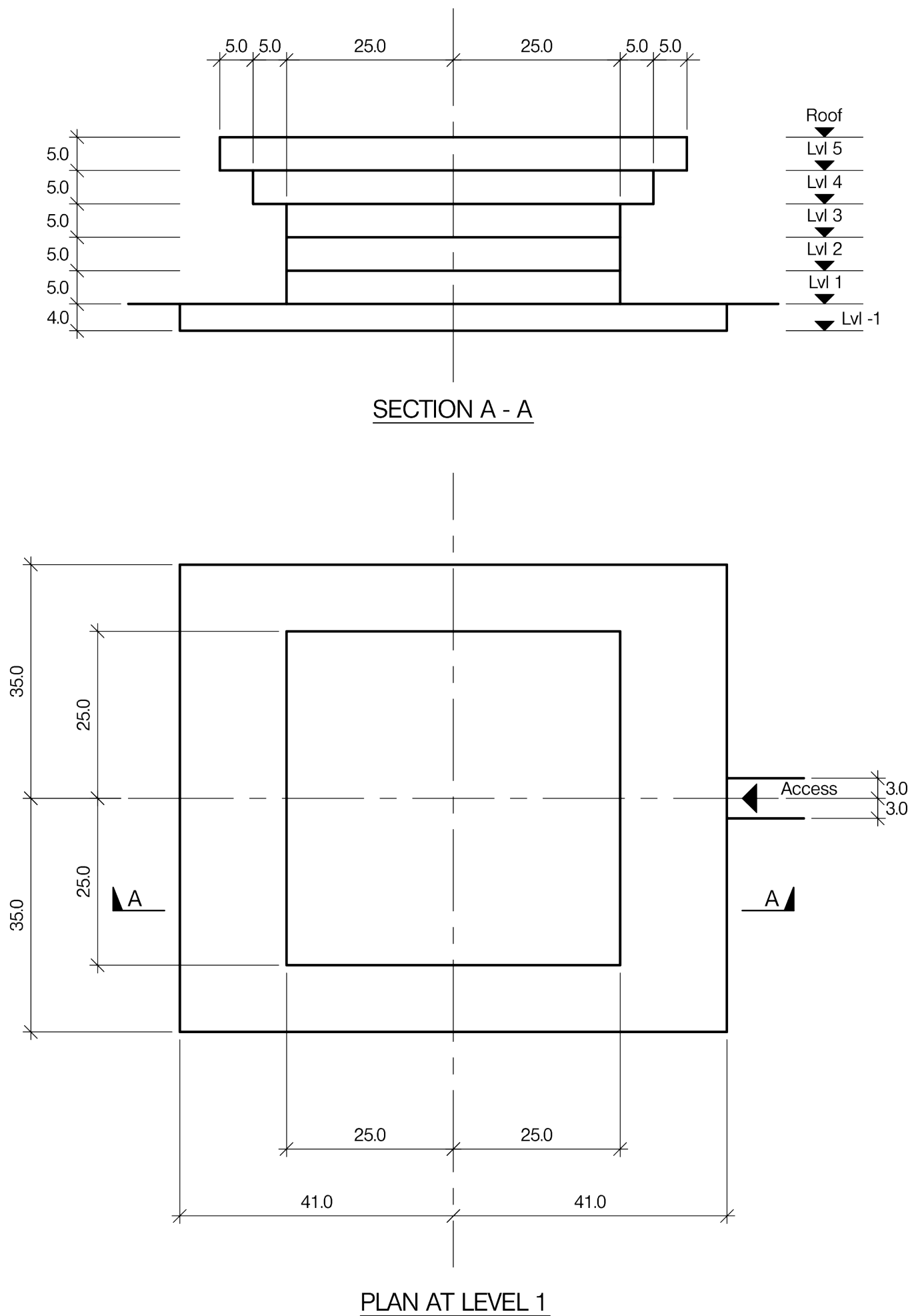
The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural design problems – whether or not the problem is presented in terms that are within your actual experience.

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



NOTE: All dimensions are in metres

FIGURE Q1

Question 1. New Headquarters Building

Client's requirements

1. A new five storey office and underground car park. See Figure Q1.
2. The building is to be located on the outskirts of a large city in a landscaped area.
3. A minimum clear internal height of 3.0m is required to each office floor and the car park. The finished floor to floor height for the offices is 5.0m and the car park 4.0m.
4. Four core areas each measuring 5.0m x 5.0m are required internally for stairs, lifts and services.
5. The columns to the fully glazed elevations are to be at a minimum spacing of 5.0m. The spacing of the internal columns is to suit the underground car park layout and is to be kept to a minimum.
6. At least 200 car parking spaces are required and each car parking space is to be 5.0m x 2.5m with 6.0m wide circulation aisles.

Imposed loading

- | | |
|----------|----------------------|
| 7. Roof | 1.5kN/m ² |
| Floors | 5.0kN/m ² |
| Car park | 2.5kN/m ² |

Site conditions

8. 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.
9. Ground conditions:

Ground level – 1.0m	top soil / fill
1.0m – 5.0m	sand and gravel N = 10
5.0m – 9.0m	sand and gravel N = 35
Below 9.0m	sandstone, characteristic compressive strength 1500kN/m ²
Ground water was encountered at 5.0m below ground level.	

Omit from consideration

10. Detail design of the lift and stairs.

SECTION 1

(50 marks)

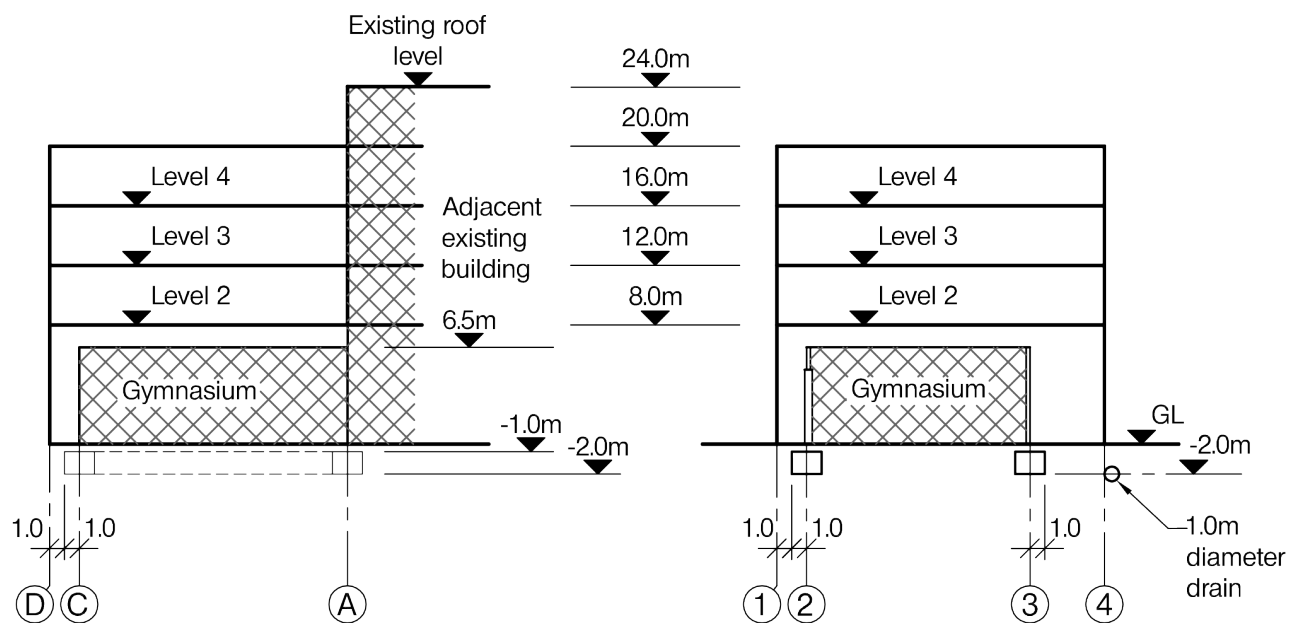
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After the design has been completed the client advises you that he wishes to add landscaping around the building with 1.0m of topsoil on the car park roof, thus lowering the car park by a further 1.0 m into the ground and also to landscape the office roof with 0.3m of topsoil. Write a letter to the Client explaining the implications on your design. (10 marks)

SECTION 2

(50 marks)

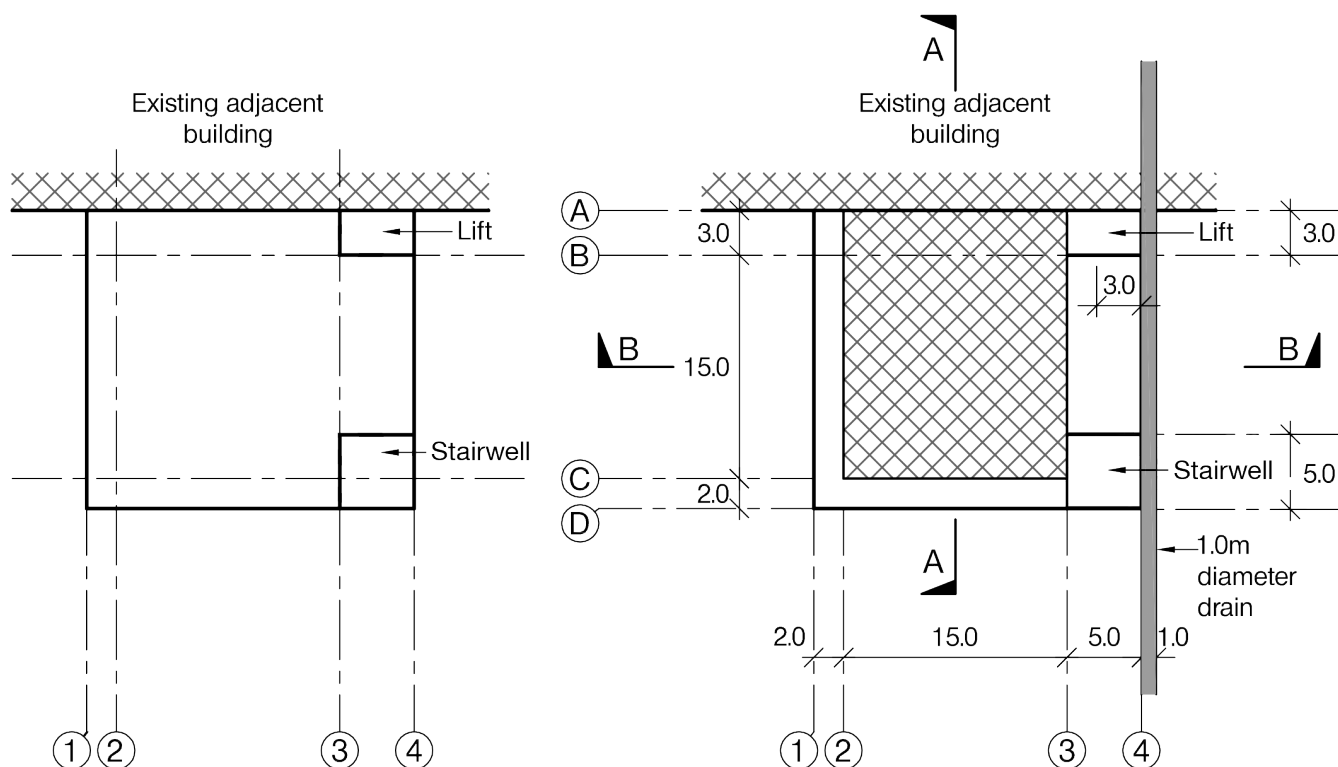
For the solution recommended in Section 1(a):

- 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 building and an outline construction programme. (10 marks)



SECTION A - A

SECTION B - B



PLAN AT LEVELS 2, 3 & 4

GROUND FLOOR (LEVEL 1) PLAN

NOTE: All dimensions are in metres

FIGURE Q2

Question 2. Hospital Extension

Client's requirements

1. The design of an extension building for a hospital, to be constructed over an existing physiotherapy gymnasium which comprises a single space with no internal columns, see Figure Q2.
2. The extension is to comprise three new storeys above the existing gymnasium, with each new storey matching and linking in to the levels of the existing adjacent hospital building, these levels being at 8.0m, 12.0m and 16.0m above ground floor level. The floor to ceiling height of the extension is to be 2.9m. A new stairwell and a lift are needed to serve the extension building and also to provide additional lift access to the existing adjacent hospital building.
3. No structure should be present between floor and ceiling levels on Gridline A, between Gridlines 2 and 3.
4. The existing gymnasium, the top of the roof of which is 6.0m above ground floor level, is to be kept fully operational during the construction of the extension. There is an existing drain running alongside the adjacent building's foundations, which also must be kept operational during construction of the extension.
5. The top of the roof of the extension building must be no higher than the existing adjacent building at 24.0m above ground floor level.
6. The new building cladding is to extend around the new storeys and down to ground level, to form a common façade around the existing gymnasium.
7. The existing building should not be relied on to provide stability for the extension.
8. A minimum of 1 hour fire resistance is needed.

Omit from consideration

9. Design of the roof and wall cladding panels which may be assumed to be capable of spanning 3.0m.

Imposed loading

- | | |
|-----------------------------------|-----------------------|
| 10. Floor and internal partitions | 5.0kN/m ² |
| Roof | 0.6 kN/m ² |

Site conditions

11. The site is a busy hospital, with limited space for temporary storage of construction materials. The basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s
12. The existing gymnasium foundations are strip footings around its perimeter, projecting 1.0m from its façade and founded 2.0m below ground level.
13. The ground is level across the site and ground conditions are:

Ground level to 2.0m	Made ground
2.0m to 3.0m	Firm Clay C = 75kN/m ²
3.0m to 4.0m	Stiff Clay C = 125kN/m ²
Below 4.0m	Weathered rock, presumed safe bearing capacity 400kN/m ²

SECTION 1

(50 marks)

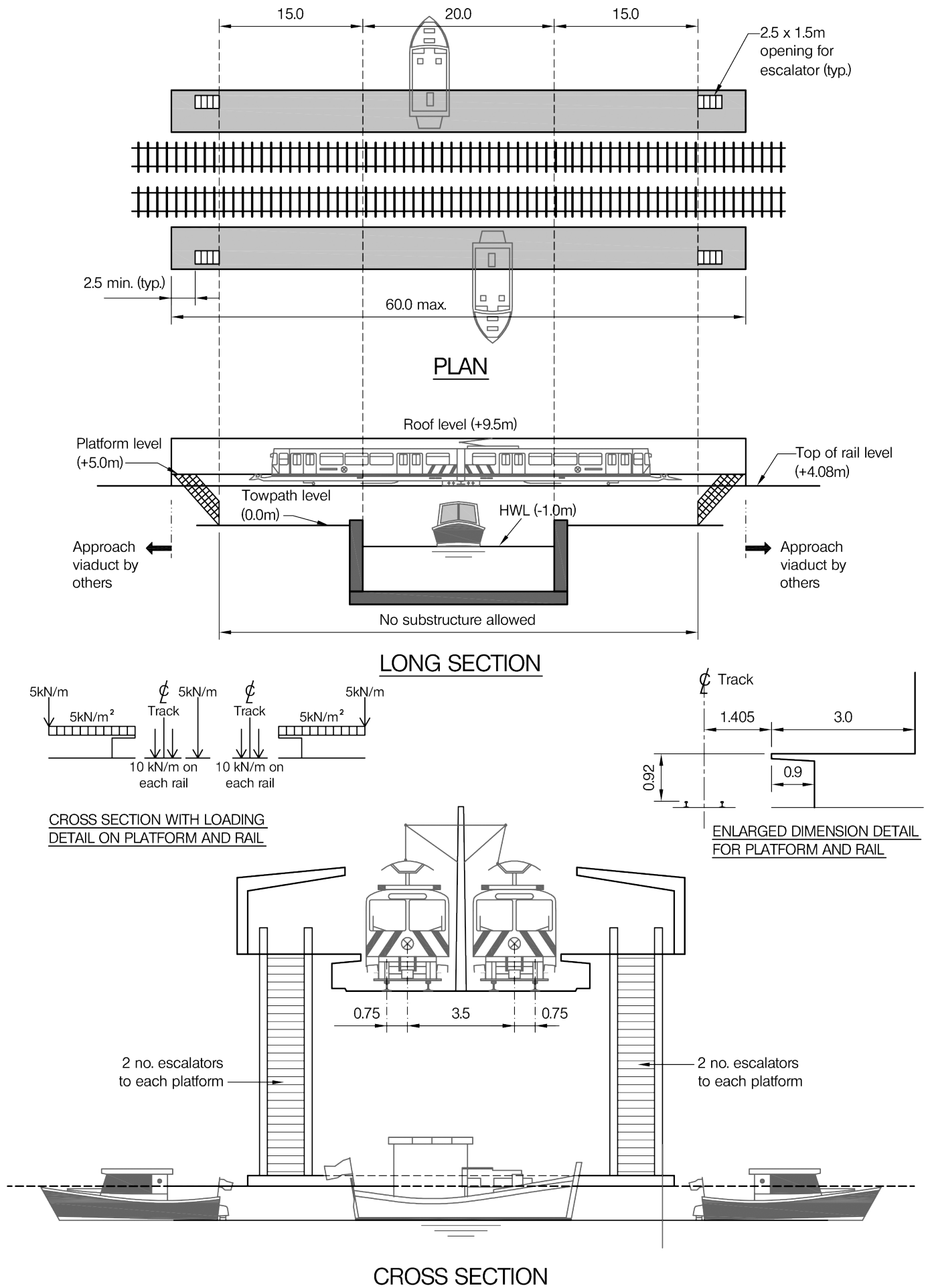
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After you have completed your design, the client asks you to consider the construction of the building incorporating as much off-site fabrication as possible. Write a letter to your client explaining the implications, advantages and any disadvantages of this potential change, including the effect on sustainability and health & safety. (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 programme. (10 marks)



NOTE: All dimensions are in metres

FIGURE Q3

Question 3. Light Railway Bridge and Station

Client's requirements

1. Construction of a railway bridge and elevated railway station above a canal, see Figure Q3.
2. The station is to have 60m long x 3m wide covered platforms to each side of the track. The platforms can be supported independently from the bridge, or the platforms and bridge can be an integral structure.
3. Approach viaducts at each end of the bridge may be assumed to provide lateral support.
4. Clearances of 2.5m above high water level and 2.0m above towpath level are to be maintained.
5. The canal and towpaths can be closed for construction each night from 8.00pm to 6.00am.

Imposed loading

6. Platforms - A uniformly distributed load of 5kN/m² plus a line load of 5kN/m along the outer edge to allow for the load from the canopy.
Railway tracks – 10kN/m per rail (20kN/m per track).
Overhead cable support structure 5kN/m.

Site conditions

7. The site is in an urban location. Basic wind speed is 50m/s based on a 3 second gust; the equivalent mean hourly wind speed is 25 m/s.
8. Ground Conditions
Ground level – 10m Granular material, N = 20.
Below 10m Sandstone, allowable safe bearing pressure 1000kN/m²
No groundwater is present

Omit from consideration

9. Platform canopies and escalators.

SECTION 1

(50 marks)

- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including foundations. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice.
- b. After completion of the design and before construction has started, the client advises that the existing lock gates at the nearby port are to be removed which will result in a maximum high water level at towpath level. Write a letter to the Client advising him of the implications on the design assuming that the rail level cannot be changed.

(40 marks)

(10 marks)

SECTION 2

(50 marks)

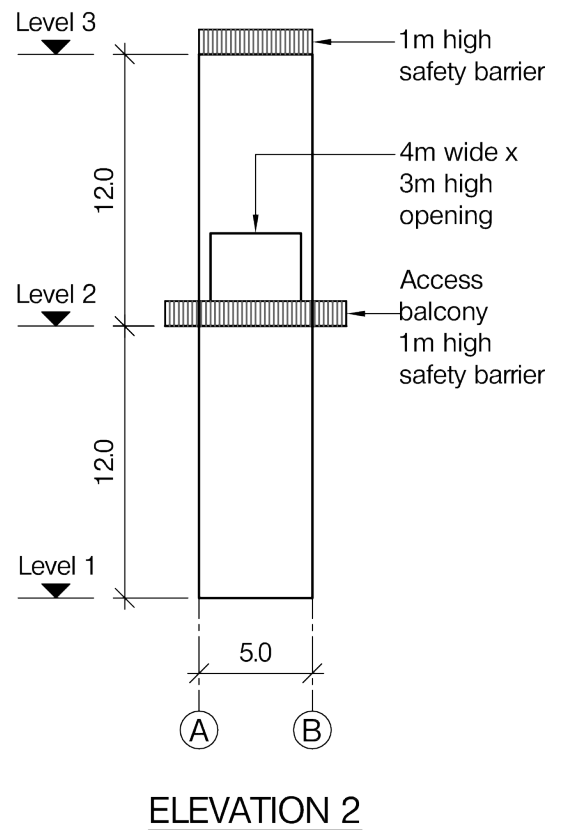
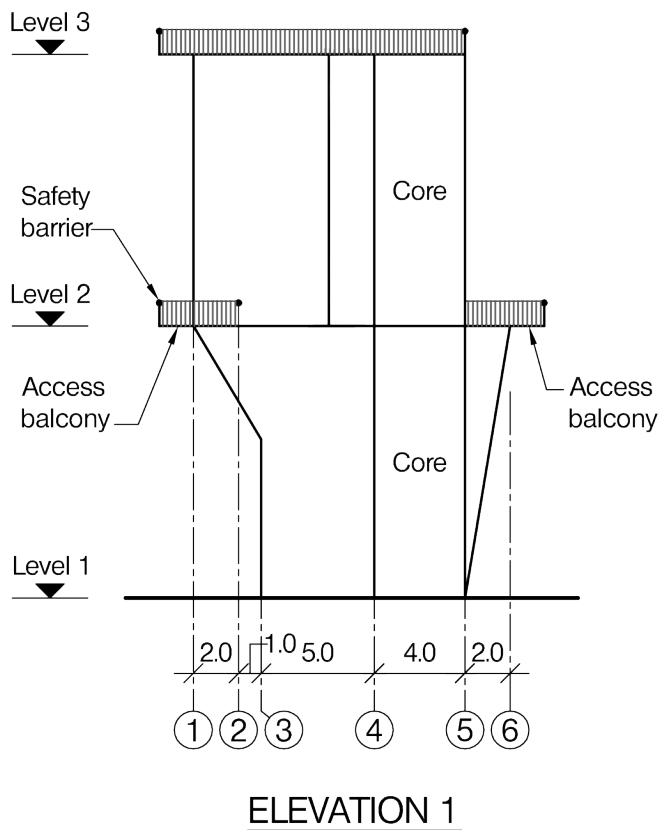
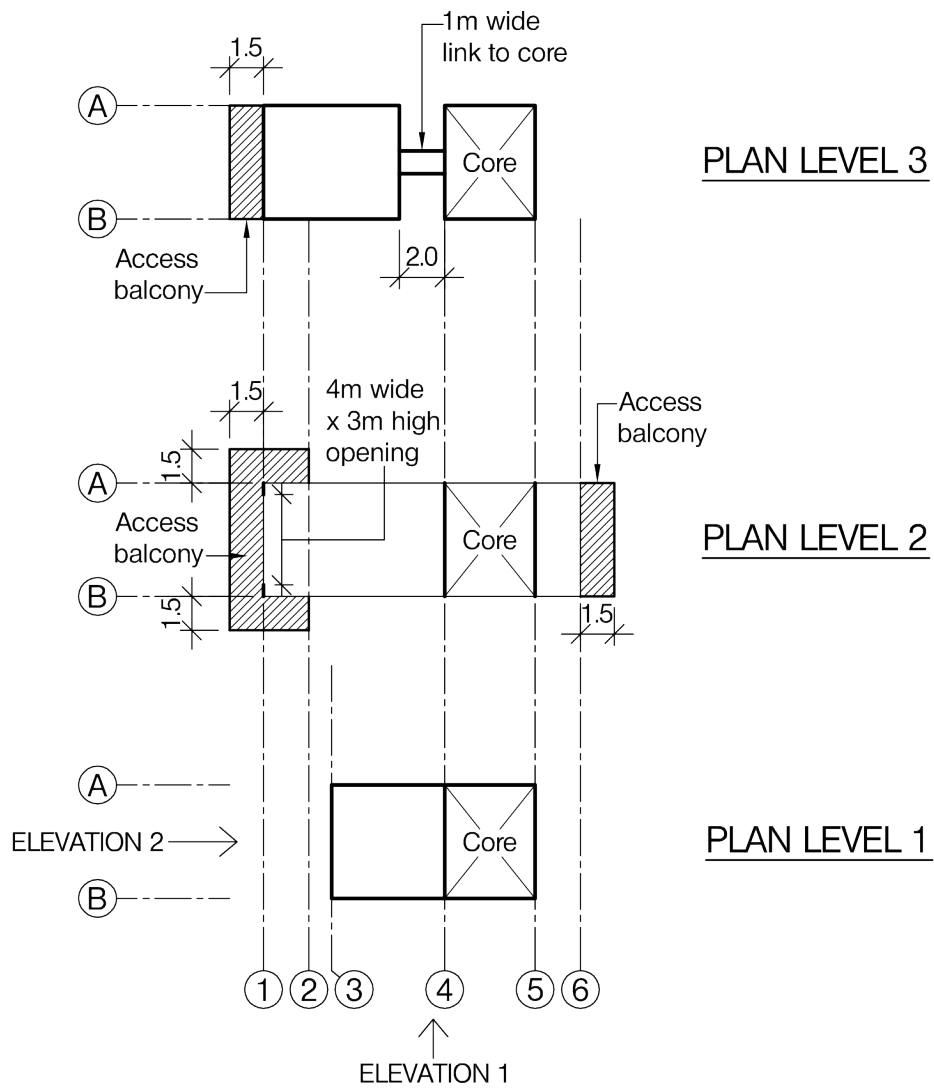
For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations.
- 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.
- e. Prepare a detailed method statement for the safe construction of the bridge and station and an outline construction programme.

(20 marks)

(20 marks)

(10 marks)



NOTE: All dimensions are in metres

FIGURE Q4

Question 4. Climbing Wall

Client's requirements

1. A free-standing climbing wall structure in a countryside setting – see Figure Q4.
2. The structure will be clad in solid specialist cladding.
3. A 4.0m x 5.0m access core is to be provided with access at all levels as shown. At Level 3 the core is accessed by a 1.0m wide walkway. There is a 4.0m wide x 3.0m high clear opening required on Grid Line 1 at Level 2.
4. Vertical structure is to be restricted to the facades and core perimeter. No internal or external columns are allowed.
5. Cantilever access balconies are to be provided as shown at Levels 2 and 3. A 1.1m safety barrier should be provided to balconies and the full perimeter of Level 3.
6. A minimum fire rating of 1 hour is required throughout.

Imposed loading

7. Levels 1 and 2 – 5.0kN/m² (includes allowances for floor finishes, ceilings and services).
Cladding – a vertical load of 5.0kN/m² applied across the elevation (includes allowance for self-weight and for imposed load from climbers).

Site conditions

8. The site is in a countryside location. Basic wind speed is 44m/s based on a 3 second gust; the equivalent mean hourly wind speed is 22m/s.

Ground Conditions

9. Ground level – 1.5m Top soil/made ground
1.5m – 5m Firm Clay C = 70kN/m²
5m - 8m Stiff Clay C = 120kN/m²
Below 8m Mudstone - allowable safe bearing pressure 300kN/m²
No groundwater is present.

Omit from consideration

10. Detailed design of staircases and lifts within cores
11. Detailed design of safety barriers to balconies and roof
12. Fixing of specialist cladding.

SECTION 1

(50 marks)

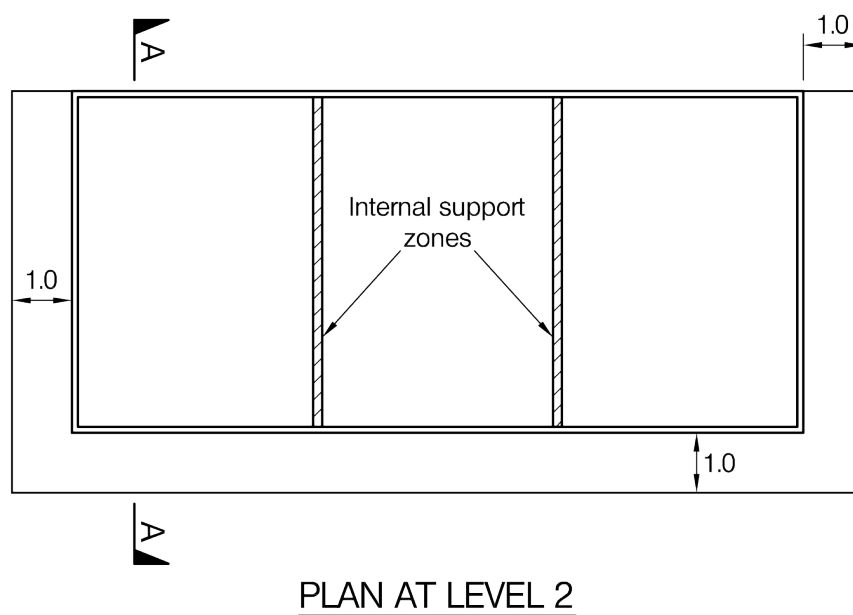
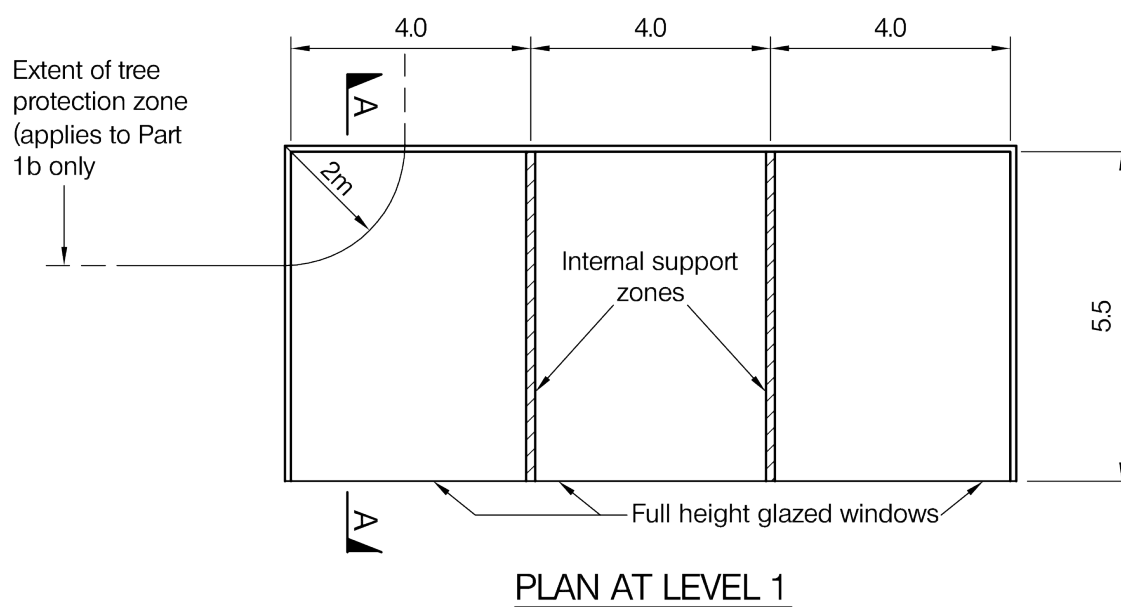
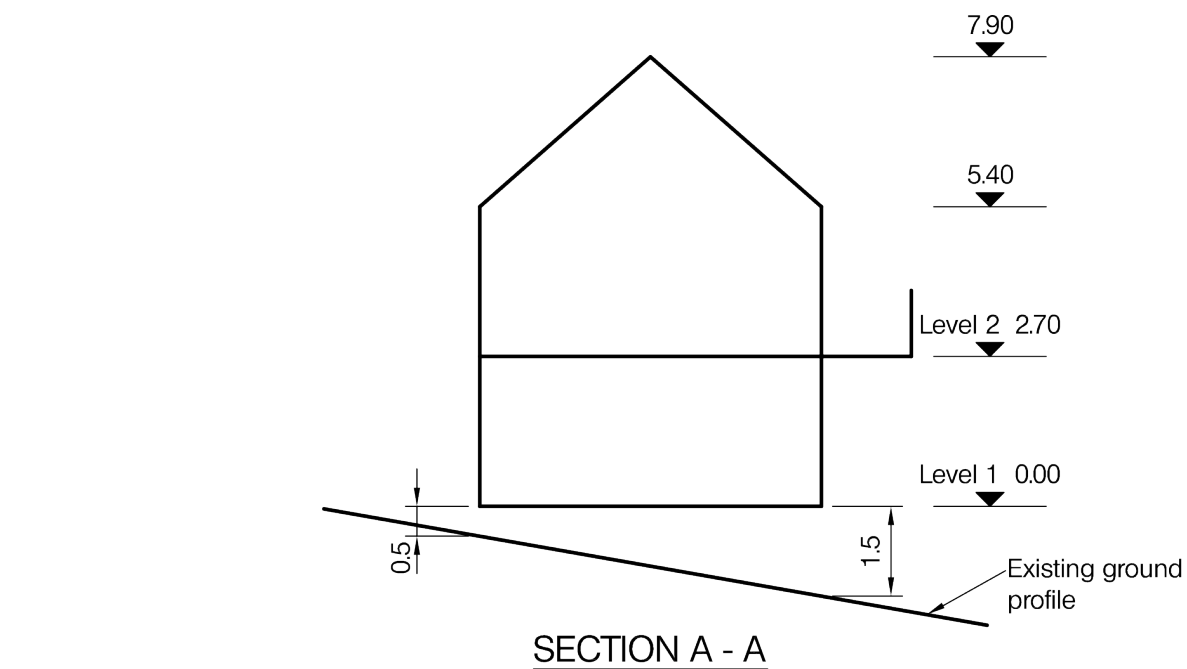
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After completion of the design and before construction has started, the client states that he would like you to consider how the structural design could be altered to allow the structure to be dismantled and moved at a later date.
Write a letter to the Client advising him of the implications on the design. (10 marks)

SECTION 2

(50 marks)

For the solution recommended in Section 1(a):

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



NOTE: All dimensions are in metres

FIGURE Q5

Question 5. Residential property in woodland setting

Client's requirements

1. A new residential property is to be built on a site previously covered with trees, see Figure Q5.
2. The planning department has permitted the development, but has stipulated that 'no digging' is permitted to avoid damaging the roots of the trees. The only exception is that individual piles may be used, but these should be as small as possible.
3. The building is to be elevated above the ground level which slopes from front-to-back, and the exposed sub-structure should be aesthetically pleasing and durable.
4. Given the setting, the client would like to use as much timber as possible for the superstructure.
5. Internally there are two zones which may be used for support elements.
6. The front elevation is to have full height glazed windows at Level 1 and is to be column free between the corners and the internal support zones. A 1.0m wide cantilever balcony runs around the front and side elevations of the house at Level 2. No columns are permitted to support the balcony.
7. The ceiling is to be vaulted; i.e. the ceiling is to be fixed to the underside of the pitched roof.

Imposed loading

8. Roof 0.75 kN/m²
 Floors and balcony 1.5 kN/m²
 Loadings exclude allowances for floor finishes, ceilings, services and partitions.

Site conditions

9. The site is in a rural location. Basic wind speed is 46 m/s based on a 3 second gust: the equivalent mean hourly wind speed is 23 m/s.
10. Ground conditions: 0 – depth, Medium dense sand, N = 20.
 No ground water is present.

Omit from consideration

11. Detailed consideration of the stairs.

SECTION 1

(50 marks)

- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the fundamental framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After the design is completed, it becomes apparent that the 'no digging' requirement applies only to those areas of the site that are covered by a tree protection zone as shown in Figure Q5. Write a letter to the Client advising how this relaxation can be exploited to minimise construction costs, whilst still avoiding digging in the tree protection zone. (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)

