

The Institution of Structural Engineers

Associate-Membership

Examination



8th APRIL 2005

Structural Engineering Design and Practice

9.30 a.m. - 1 p.m. and 1.30 - 5 p.m. (Discussion between individuals is not permitted during the lunch period).

A period of fifteen minutes is provided for reading the question paper, immediately before the commencement of the examination. Candidates are not permitted to write in answer books, or on drawing paper or to use a calculator during this time.

Candidates must satisfy the Examiners in ONE question.

Important

The written answer to the question selected and any drawings must bear the candidate's index number and the question number in the spaces provided. Only the answer book(s) supplied by the Institution may be used. The candidate's name should not appear anywhere in the script.

Notes to Candidates

1. TO PASS THE EXAMINATION, CANDIDATES MUST SATISFY THE EXAMINERS IN BOTH PARTS OF THE QUESTION ATTEMPTED.
2. 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.
3. In all questions 35 marks are allocated to Section 1 and 65 marks to Section 2.
4. 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. Candidates should read carefully the examiners' reminder on Page 3.
5. Any assumptions made and the design data and criteria adopted must be stated.
6. Portable battery calculators may be used but sufficient calculations must be submitted to substantiate the design, and these should be set out as in practice.
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. This paper is set in SI Units.

Now read 'Reminder' on Page 3 +

Associate-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 TO 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.

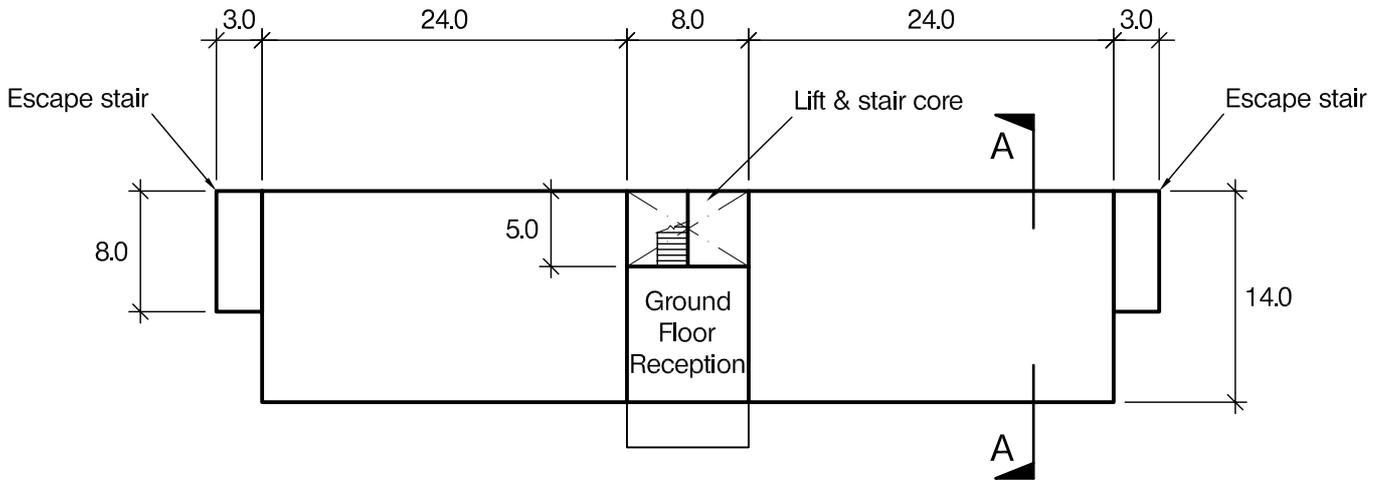
The unusual requirement of the examination is that you demonstrate the validity of the training and experience that you have acquired in recent years. The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural design problems – whether or not the problem is presented in terms within your actual experience.

An Incorporated Structural Engineer must have the ability to design and a facility to communicate their design intentions. Where you are required to describe your structural solution you must show by brief, clear, logical and systematic presentation that you understand the general structural engineering principles involved.

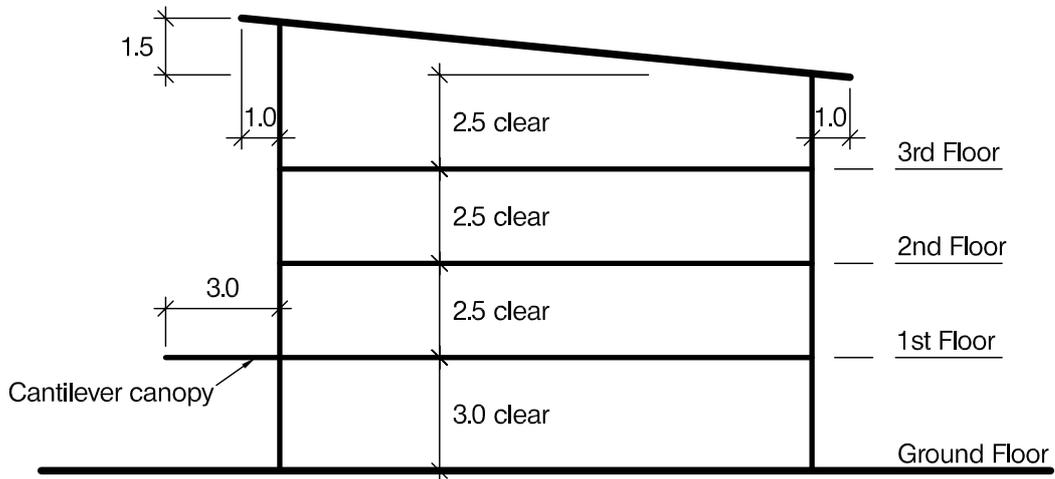
In selecting and developing your design you should also remember the guidance given in the Institution's report, Aims of Structural Design, and in particular:

- (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 5, 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



SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q1

Question 1

Hotel Development

Client's requirements

1. A new hotel development consisting of a four storey building with a flat roof and a cantilever glazed canopy to the entrance. See Figure Q1.
2. Each of the three upper floors is to be arranged to accommodate 26 bedrooms of dimensions 4.0m wide by 6.0m long accessed from a 2.0m wide corridor running the length of the building.
3. No columns are permitted in any of the bedrooms.
4. The ground floor is to have 12 bedrooms to one side of the reception and a clear column-free space to the other side of the reception to accommodate a restaurant and meeting rooms.
5. The reception area at ground floor is to be column-free.
6. The external cladding of the building is to be cavity wall construction consisting of 102mm brickwork and 140mm insulating blockwork with a 60mm cavity.

Imposed loading

7. Roof 1.0kN/m²
First, second and third floors 4.0kN/m²
Ground floor 5.0kN/m²
Floor loadings include an allowance for finishes, services and partitions.

Site conditions

8. Site is level and 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.
Note: The 3 second gust speed is used in the British Standard CP3 and the mean hourly wind speed is used in the British Standard 6399. Candidates using other codes and standards should choose an appropriate wind speed.
9. Ground conditions:
Ground level – 1.0m Topsoil and fill
1.0m – 3.0m Soft alluvial deposits $C = 10\text{kN/m}^2$
3.0m – 7.0m Sand and gravel N values vary linearly with depth from 10 at 3.0m to 20 at 7.0m.
7.0m – 15.0m Firm to stiff clay $C = 100\text{kN/m}^2$
Below 15.0m Mudstone with an allowable bearing pressure 1500kN/m²
Ground water was encountered 5.0m below ground level.

Omit from consideration

10. Detailed design of the lift and stair core and the escape stairs, although their contribution, if any, to the lateral stability of the building must be explained in Section 1a.
11. Design of the glazed canopy.

SECTION 1

(35 marks)

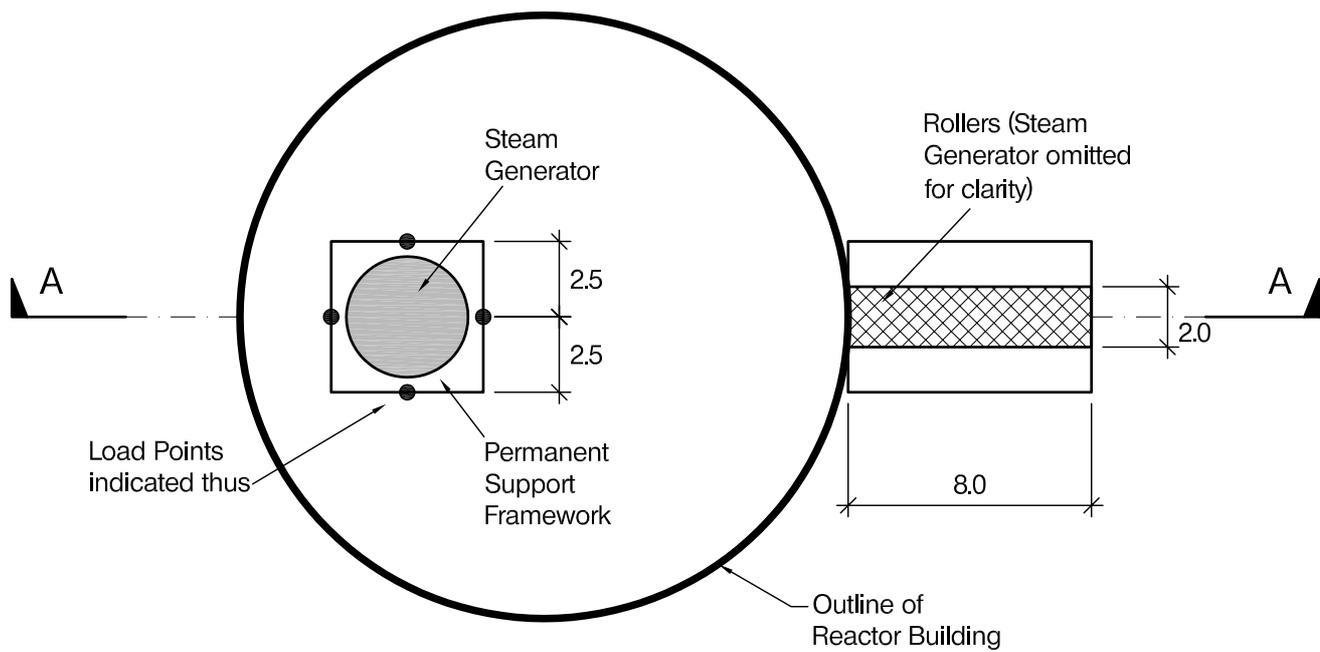
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (25 marks)
- b. Upon completion of the design, the client asks if it is feasible to add another storey to the building to provide an additional 26 bedrooms. Describe the implications this will have on the original design using sketches if necessary to illustrate your ideas. (10 marks)

SECTION 2

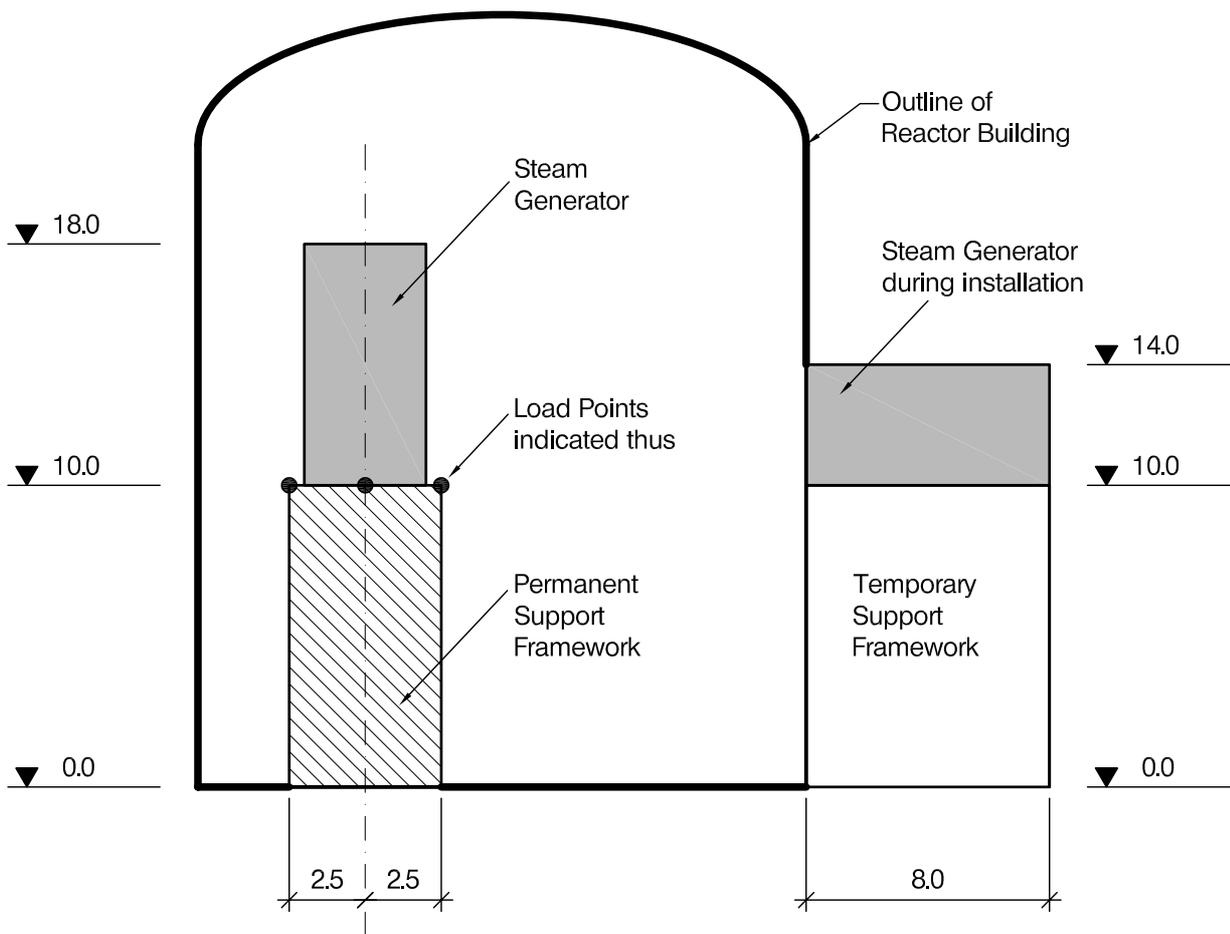
(65 marks)

For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
 - (i) A perimeter column to roof structure connection
 - (ii) A perimeter column at ground floor level (25 marks)
- e. Prepare a detailed method statement for the safe construction of the building. (10 marks)



PLAN



SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q2

Question 2

Steam Generator Support Frame

Client's requirements

1. During a routine shutdown of a nuclear power station a new steam generator is to be installed. A permanent support frame is required inside the reactor building. See Figure Q2.
2. The permanent support frame is to be within a volume 5m by 5m and 10m high under the steam generator. No structural elements are allowed outside this volume. The frame is to be constructed on existing foundations. An adequate allowance for the new steam generator was included in the original design of these foundations.
3. The permanent support frame is to be constructed during a three-week period before the installation of the steam generator. For safety reasons all structural elements must enter the reactor building through an air lock during this period. The maximum size that can be accommodated in the airlock is 6m.
4. The client's seismic specialist requires that the permanent support frame be designed for an equivalent horizontal static load of 20 percent of the vertical load from the steam generator. The specialist will carry out a detailed seismic analysis when details of the frame are known.
5. A temporary support frame is required outside the reactor building to support the steam generator horizontally on rollers during installation. This frame must be independent of the reactor building and be available for a one week period before the installation of the steam generator.

Imposed loading

6. Steam generator in operation 1000kN at each load point
Horizontal seismic load 200kN at each load point
Steam generator during installation 3000kN spread evenly over rollers 2m wide and 8m long
Imposed loadings include an allowance for services.

Site conditions

7. The site is level and located in a remote area within 1km of the sea.
Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 22m/s.
Note: The 3 second gust speed is used in the British Standard CP3 and the mean hourly wind speed is used in the British Standard 6399. Candidates using other codes and standards should choose an appropriate wind speed.
8. Ground conditions:
Ground level - 0.5m Topsoil
Below 0.5m Stiff Clay $C = 150\text{kN/m}^2$
Groundwater was detected 5.0m below ground level.

Omit from consideration

9. Evaluation of the effect of additional loads on existing foundations, under the permanent support frame.
10. Detailed consideration of seismic loads.
11. Design of rollers or cranes for installing the steam generator.

SECTION 1

(35 marks)

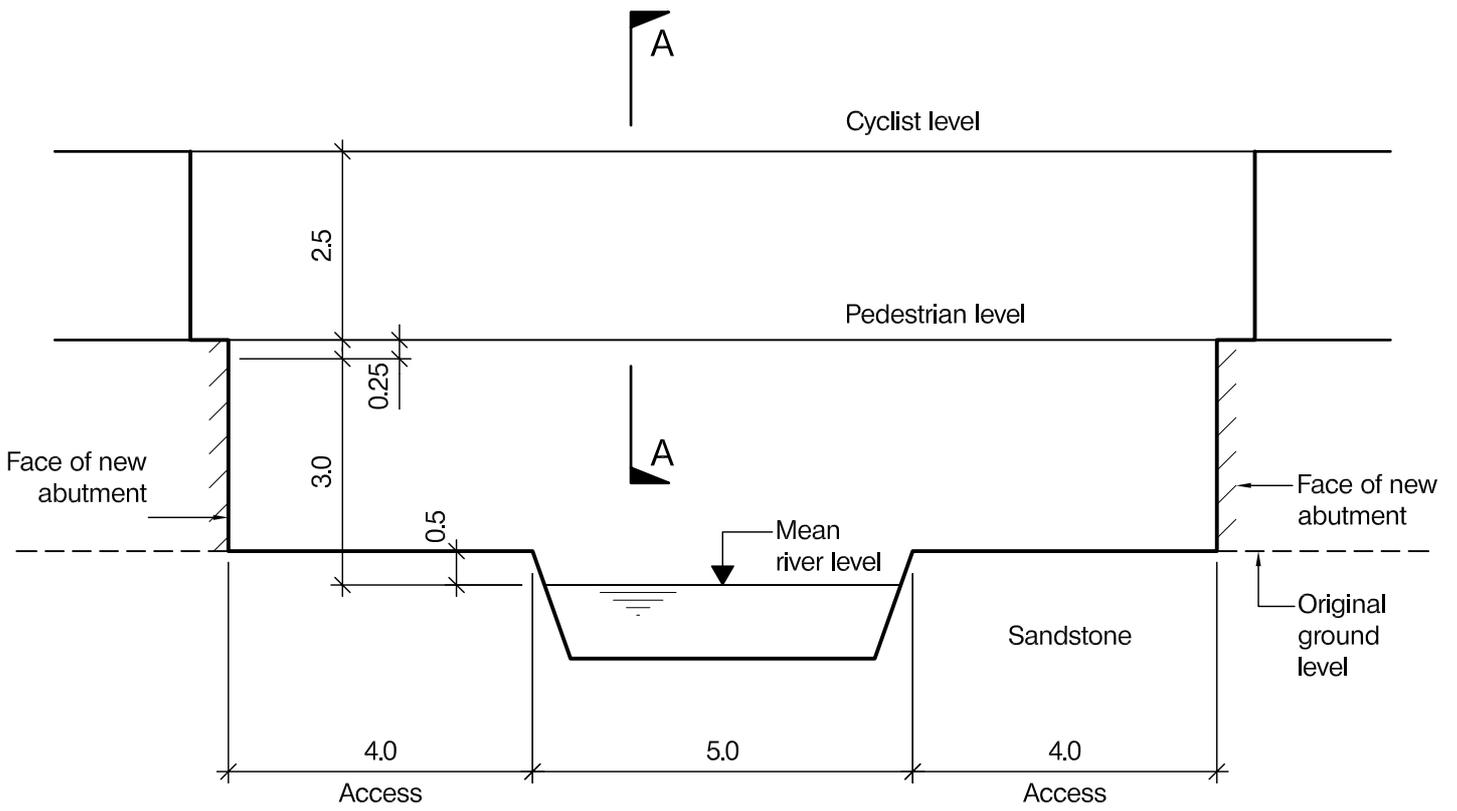
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for both the permanent and temporary support frames. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (25 marks)
- b. After construction of the temporary support frame, the client proposes to postpone the installation of the steam generator by one year. Explain the effect this will have on the design and outline any resulting changes to your original proposal. (10 marks)

SECTION 2

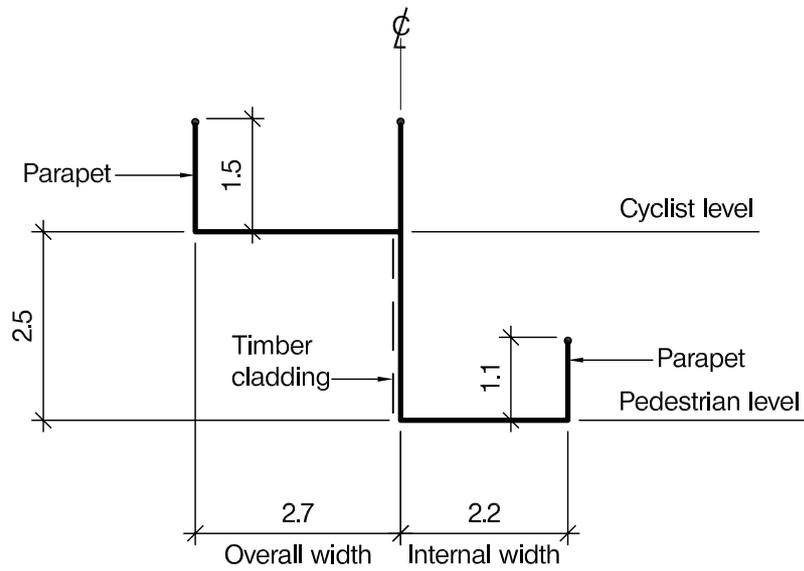
(65 marks)

For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations for the temporary support frame. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
 - (i) Connection at the top of a column in the permanent support frame
 - (ii) Connection of temporary support frame to new foundations (25 marks)
- e. Prepare a detailed method statement for the safe installation of the steam generator. (10 marks)



ELEVATION



SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q3

Question 3

Cyclist-Pedestrian Bridge

Client's requirements

1. A cyclist-pedestrian bridge is required to cross a fast-flowing non-tidal river. See Figure Q3.
2. The bridge is for separate cycle and pedestrian routes which converge at the site of the new bridge. Due to the topography of the site the cycle and pedestrian routes approach the bridge at different levels.
3. The river is 5m wide. A clear height of 3.0m above the mean river level and a 4.0m wide access strip on each bank are required.
4. The bridge is to be installed during a winter season.
5. The pedestrian bridge is to be timber clad on one side.

Imposed loading

6. Cyclist and pedestrian loading 5.0kN/m²

Site conditions

7. Site is located in the centre of a large forest.
Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 22m/s.
Note: The 3 second gust speed is used in the British Standard CP3 and the mean hourly wind speed is used in the British Standard 6399. Candidates using other codes and standards should choose an appropriate wind speed.
8. Ground conditions:
Ground level - 0.45m Top soil
Below 0.45m Horizontally-bedded weak sandstone, with an allowable bearing pressure of 500kN/m². The sandstone was proved to a depth of 10m.

Omit from consideration

9. Detailed design of the cladding and parapets.
10. Access ramps.

SECTION 1

(35 marks)

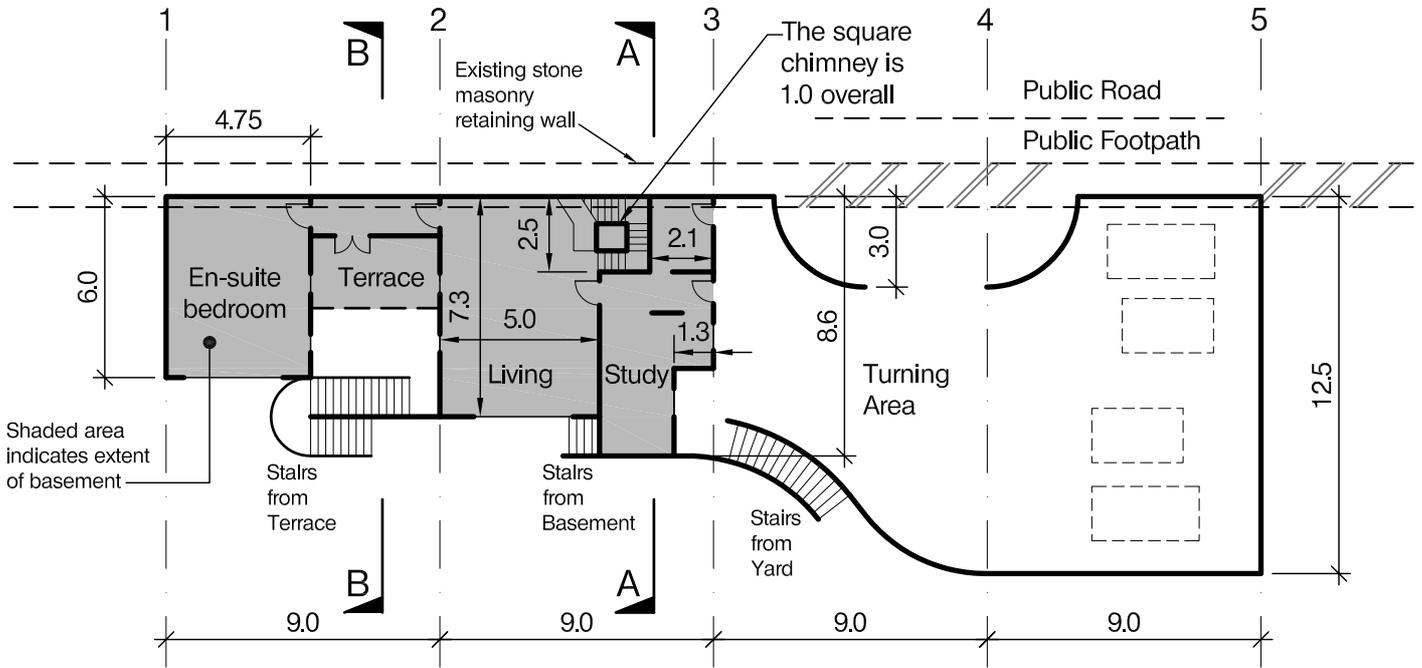
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (25 marks)
- b. The Client proposes a change to the brief. This requires a 400mm diameter gas main to be carried below the cyclist level of the bridge. The maximum permitted deflection for the gas main is 80mm. Explain the effect this will have on the design and outline any resulting changes to your original proposal. (10 marks)

SECTION 2

(65 marks)

For the solution recommended in Section 1(a):

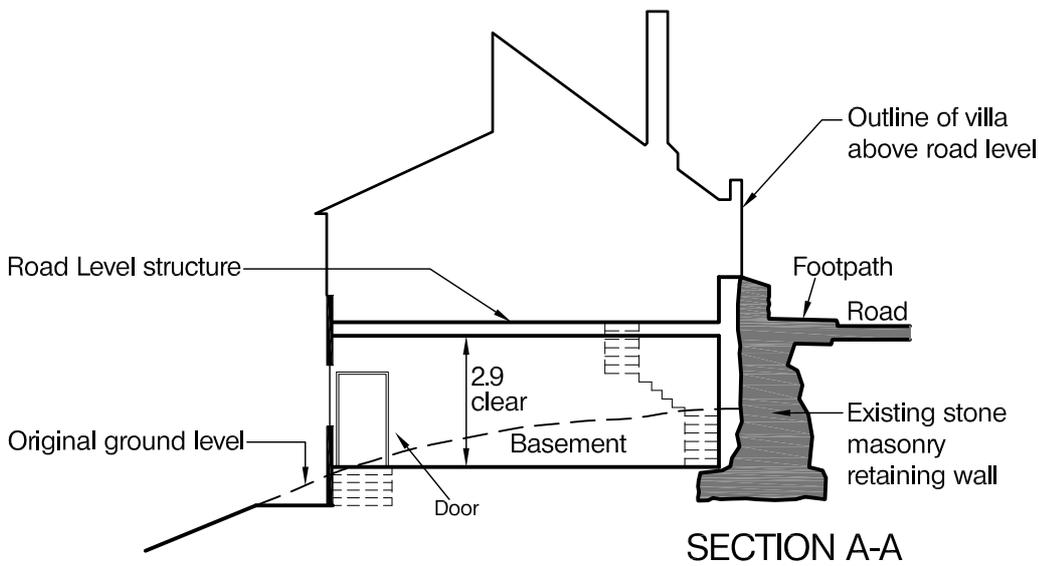
- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the abutments and foundations. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
 - (i) Bearing arrangements at the abutments
 - (ii) Cladding fixings (25 marks)
- e. Prepare a detailed method statement for the safe erection of the bridge. (10 marks)



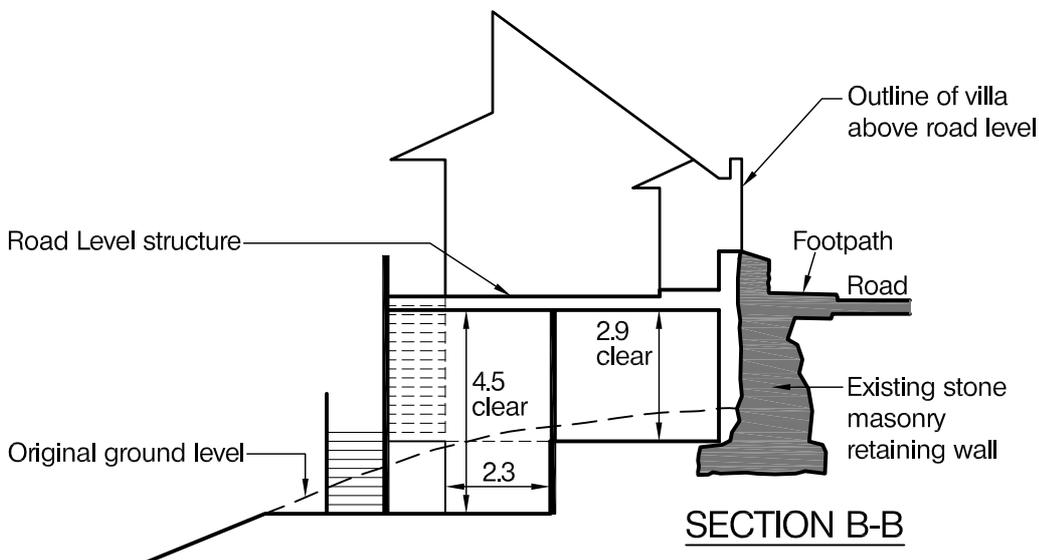
Dimensions given on plan are clear between walls, unless noted otherwise

PLAN AT ROAD LEVEL

External stairways are 1.3 wide clear



SECTION A-A



SECTION B-B

NOTE: All dimensions are in metres

FIGURE Q4

Question 4

Retirement Villa

Client's requirements

1. A retirement villa is to be built on land adjacent to a public road and footpath. See Figure Q4.
2. The principal living and sleeping areas are to be at road level. A basement is required beneath the living and sleeping areas for storage and other utility purposes.
3. The client requires parking at road level for four cars, together with a turning and washing area.
4. The roadside boundary is formed by a stone masonry retaining wall of considerable age that is reported to be in a stable condition and serviceable. The wall is approximately 3.0m high with a stone parapet 0.8m high beside the public footpath.

Imposed loading

5. All road level areas 7.5kN/m^2
Loading includes an allowance for finishes, services and the walls and roof of the villa above road level.

Site conditions

6. The site slopes down away from the foot of the existing wall.
Basic wind speed is 40m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20m/s.
Note: The 3 second gust speed is used in the British Standard CP3 and the mean hourly wind speed is used in the British Standard 6399. Candidates using other codes and standards should choose an appropriate wind speed.
7. Ground conditions:
Ground level – 0.6m Topsoil
Below 0.6m Mudstone with an allowable bearing pressure 500kN/m^2

Omit from consideration

8. The walls and roof of the villa above road level.

SECTION 1

(35 marks)

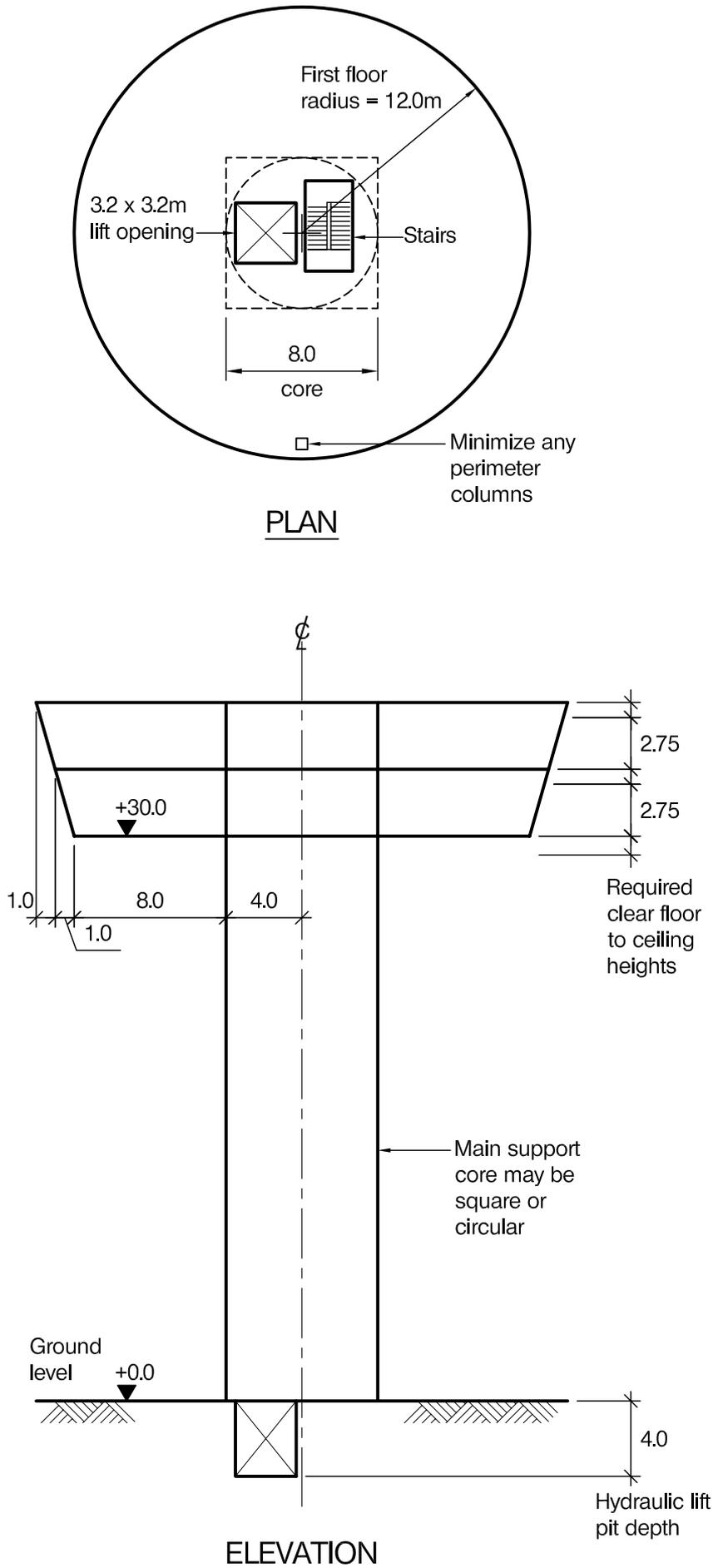
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the road level structure, basement and foundations. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (25 marks)
- b. Following the initial design appraisal the client asks if it feasible to store more cars in an additional basement beneath the yard. Describe how this request might fulfilled, using sketches to illustrate your ideas. (10 marks)

SECTION 2

(65 marks)

For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the road level structure, basement and foundations for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
 - (i) The terrace stairs
 - (ii) The terrace weatherproofing (25 marks)
- e. Prepare a detailed method statement for the safe construction of the foundations, basement and road level structure. (10 marks)



NOTE: All dimensions are in metres

FIGURE Q5

Question 5

Motorway Control Tower

Client's requirements

1. An observation and control tower is required for police, rescue and emergency services at a busy motorway junction. See Figure Q5.
2. The building is to be circular in plan with two operational floors elevated 30m above ground on a support core which contains stairs and a lift shaft.
3. The client has expressed a preference for the building to be of fair-faced concrete construction.
4. To minimise obstructions to views, there should be as few columns as possible at the perimeter and these should be of minimum size.

Imposed loading

5. Roof 1.5kN/m²
All floors 7.0kN/m²

Roof and floor loadings include an allowance for finishes, services, control equipment and partitions. With reference to Part 1b, only the helicopter landing pad shall be designed for a 15.0kN/m² uniformly distributed load or a 150kN point load anywhere on the landing pad.

Site conditions

6. Basic wind speed is 50m/s based on a 3 second gust; the equivalent mean hourly wind speed is 25m/s. Note: The 3 second gust speed is used in the British Standard CP3 and the mean hourly wind speed is used in the British Standard 6399. Candidates using other codes and standards should choose an appropriate wind speed.
7. Ground conditions:
Ground level – 0.5m Topsoil
0.5m – 55.0m Dense sand and gravel N = 30
Below 55.0m Rock with an allowable bearing pressure of 3000kN/m²
Ground water was encountered 10.0m below ground level.

Omit from consideration

8. Detailed design of the stairs and lift shaft may be omitted but the support core itself must be designed.

SECTION 1

(35 marks)

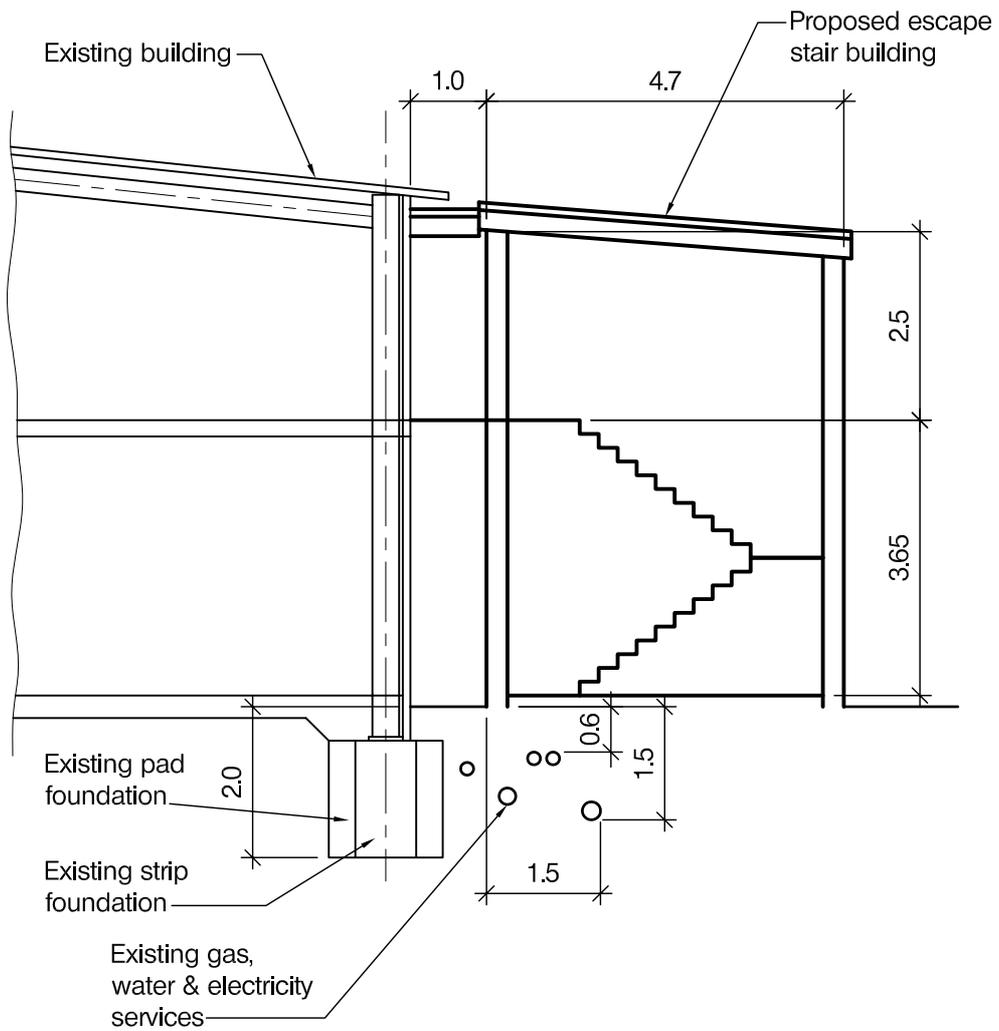
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (25 marks)
- b. During the design process the client asks if it is feasible to revise the design to allow the roof to be used as a helicopter landing pad. Describe the implications this will have on the structure using sketches if necessary to illustrate your ideas. (10 marks)

SECTION 2

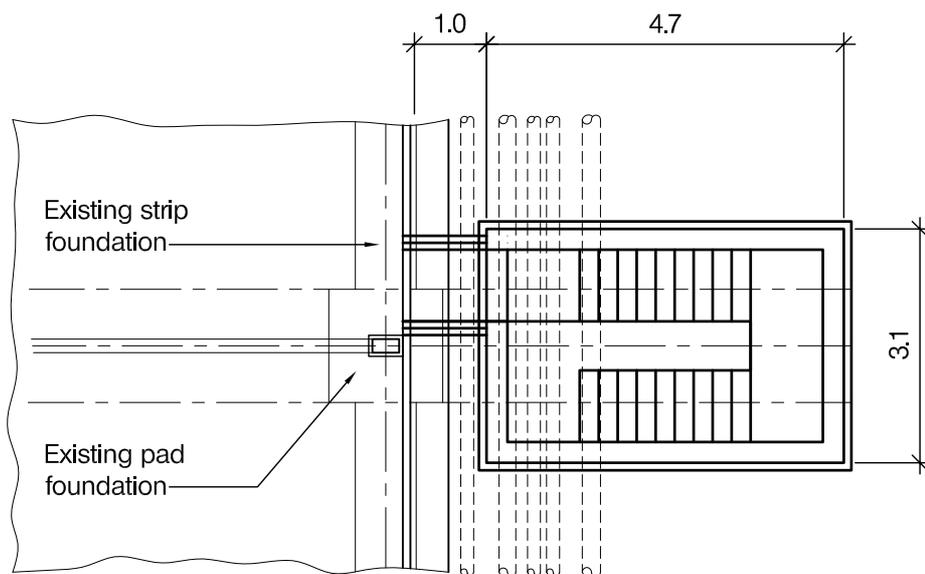
(65 marks)

For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the support core and foundations. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
 - (i) The support core to foundation connection
 - (ii) A perimeter column including glazing and cladding (25 marks)
- e. Prepare a detailed method statement for the safe construction of the building. (10 marks)



SECTION



PLAN

NOTE: All dimensions are in metres

FIGURE Q6

Question 6

Fire Escape/ Access Stair

Client's requirements

1. A fire escape /access stair is required to provide improved access to the first floor of an existing building. See Figure Q6.
2. The structure of the stair needs to provide a minimum resistance against fire of 60 minutes.
3. Extensive gas, water and electricity services exist along the side of the building, which are sensitive to vibration and cannot be relocated.

Imposed loading

- | | |
|---------|----------------------|
| 4. Roof | 1.0kN/m ² |
| Stairs | 4.0kN/m ² |

Site conditions

5. Site is level.
Basic wind speed is 44 m/s based on a 3 second gust; the equivalent mean hourly wind speed is 22 m/s.
Note: The 3 second gust speed is used in the British Standard CP3 and the mean hourly wind speed is used in the British Standard 6399. Candidates using other codes and standards should choose an appropriate wind speed.
6. Ground conditions:
Ground level – 2.0m Topsoil and fill
Below 2.0m Chalk with an allowable bearing pressure 100 kN/m²
Ground water was encountered 5.0m below ground level.

SECTION 1

(35 marks)

- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (25 marks)
- b. After the design has been completed, it becomes apparent that a water main (one of the services) has leaked for some time. Describe the impact this may have on your design. (10 marks)

SECTION 2

(65 marks)

For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the stairs and foundations. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
 - (i) The foundation of the external wall adjacent to the existing building over the existing services.
 - (ii) The connection between the existing first floor structure and the landing at the head of the new staircase (25 marks)
- e. Prepare a detailed method statement for the safe construction of the building. (10 marks)