

Associate Membership Examination

Friday 17 April 2009

Structural Engineering Design and Practice

9.30a.m. – 1p.m. and 1.30 – 5p.m. (Discussion between individuals is not permitted during lunch period). A period of fifteen minutes is provided for reading the question paper, immediately before the commencement of the examination. Candidates are not permitted to write on 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 30 marks are allocated to Section 1 and 70 marks to Section 2.
5. The Examiners are looking for sound structural designs. It should also be remembered that aesthetics, economy and function are important in any competent engineering scheme.
6. Any assumptions made and the design data and criteria adopted must be stated.
7. Portable computers or programmable calculators may be used but sufficient calculations must be submitted to substantiate the design, and these should be set out as in practice.
8. Good clear drawings and sketches are required; they should show all salient and structural features to suitable scales and should incorporate adequate details.
9. Candidates will not be allowed to include any previously prepared calculations, notes, sketches, diagrams, computer output or other similar material in their answer sheets or A3 drawings. Any previously prepared information submitted by candidates will be ignored by the examiners.
10. Strictly no external electronic contact is allowed between a candidate and anyone outside the examination venue. Mobile phones must be switched off throughout the duration of the examination.
11. This paper is set in SI Units. Now read 'Reminder' on page 3

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 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.

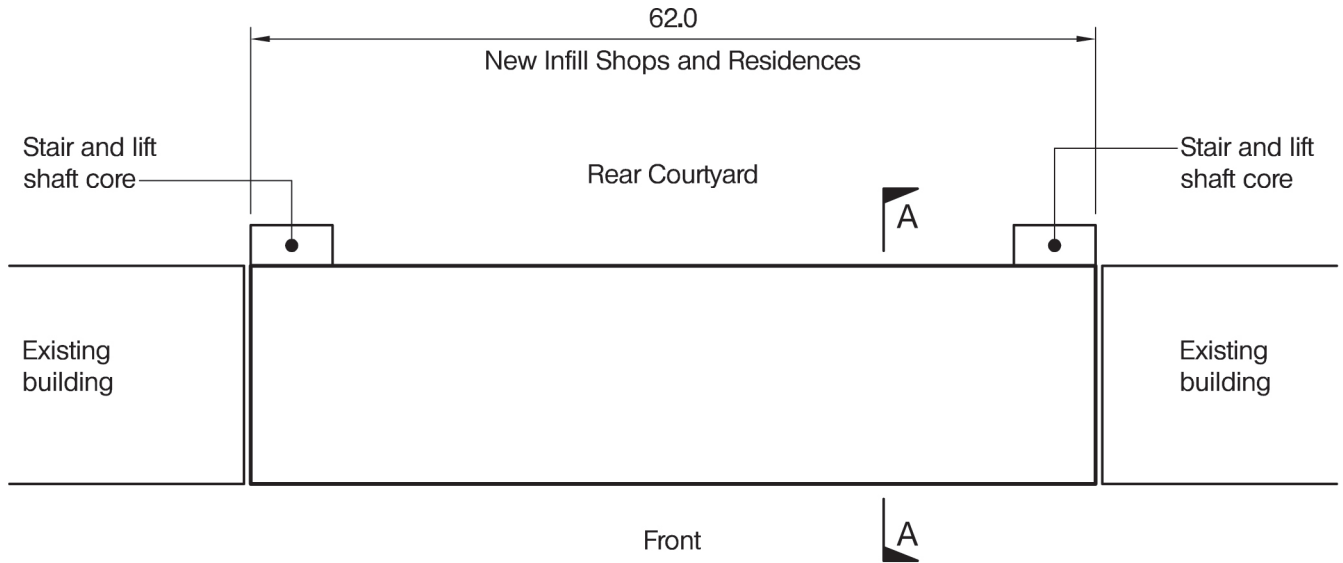
The unusual requirement of the examination is that you demonstrate the validity of the training and experience that you have acquired in recent years. The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural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

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

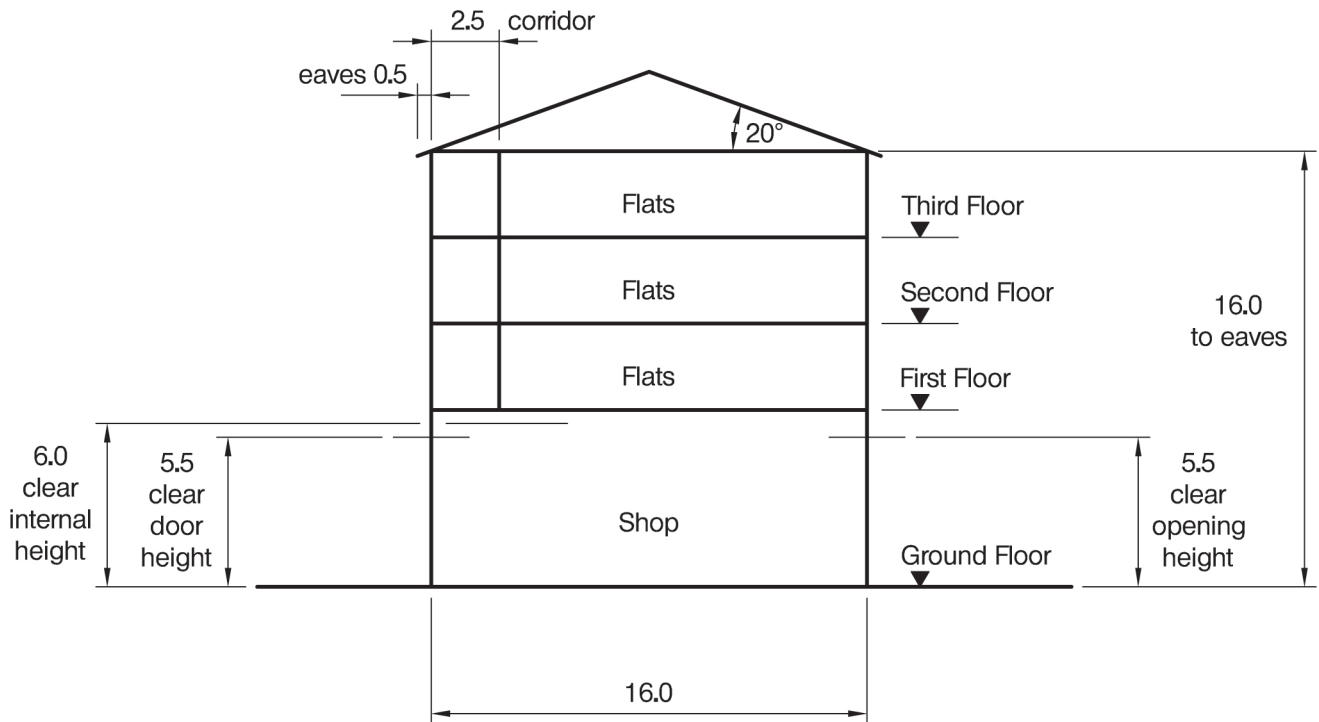
In selecting and developing your design you should also remember the guidance given in the Institution's report, Aims of Structural Design, and in particular:

- (1) "the structure must be safe",
- (2) "a good design has certain typical features – simplicity, unity and necessity",
- (3) "the structure must fulfil its intended function".

If you have difficulty in deciding the correct interpretation of a question, pay particular attention to point 6. notes to candidates, on the front cover. The examiners will take into account your interpretation – and the design you base on this – if this is clearly stated at the beginning of your answer.



PLAN



SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q1

Question 1. New Shops and Residences

Client's requirements

1. A new town centre infill parade of shop units with residential flats above. The development consists of 5 shops and 30 flats in total, with 10 flats on each level above the shops. See Figure Q1.
2. The shop units are to have an internal clear width of 12.0m. No columns are permitted within the floor area of each shop unit.
3. Each shop unit is to have a clear opening to the front elevation, 12.0m wide \times 5.5m high and a 4.0m wide \times 5.5m high door opening to the rear elevation.
4. Each residential flat is to have the maximum clear internal width with no projections and is to be column free. The clear internal height is to be 2.3m.
5. The external cladding to the development is to be of cavity wall construction comprising 102mm brickwork and 140mm blockwork with 60mm insulated cavity.
6. The roof construction is to be concrete pantiles on battens with insulation supported by timber rafters.
7. No part of the structure to the new development is to go extend the site boundary.

Imposed loading

- | | |
|--------------------|-----------------------|
| 8. Roof | 1.0kN/m ² |
| Flats and corridor | 2.5kN/m ² |
| Shops | 10.0kN/m ² |
- Imposed loading includes allowances for finishes and services.

Site conditions

9. The site is level and located in the centre of a small town.
10. Basic wind speed 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s.
11. Ground conditions:

Ground level – 3.0m	Made ground / fill
3.0m – 6.0m	Sand and gravel, N = 10
6.0m – 8.0m	Weathered clay, C = 100kN/m ²
Below 8.0m	Stiff clay, C = 300kN/m ²

 Ground water was encountered 3.5m below ground level.

Omit from consideration

12. Detail design of the stair and lift shaft core.

SECTION 1

(30 marks)

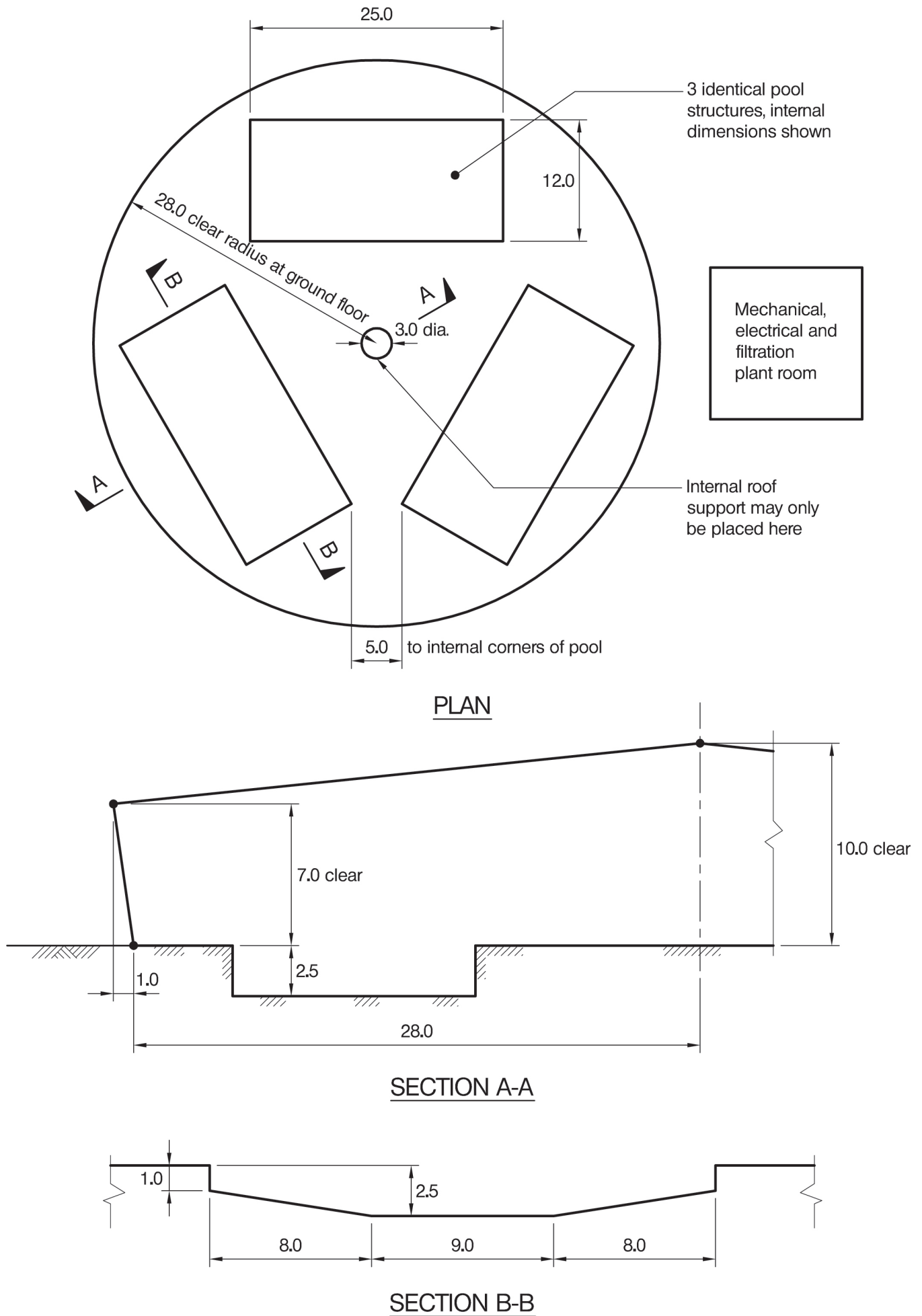
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. **(20 marks)**
- b. On completion of the design the client asks if it is feasible to integrate two of the shop units into one with a column free internal area and shop front. Describe the implications this will have on the original design. **(10 marks)**

SECTION 2

(70 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) The new foundations adjacent to the existing buildings
 - (ii) The roof and external wall at eaves level **(30 marks)**
- e. Prepare a detailed method statement for the safe construction of the building. **(10 marks)**



NOTE: All dimensions are in metres

FIGURE Q2

Question 2. Leisure Swimming Facility

Client's requirements

1. A covered swimming pool complex is required for recreational use by a local council. See Figure Q2.
2. A wave pool, a toddlers' pool and a pool for general swimming are required. Each pool is to have a similar structure. Differences of use will be accommodated with non structural infill finishes.
3. The three pools are to be arranged symmetrically as shown in Figure Q2 with a ground slab between to provide space for sitting out, retail outlets, internal landscaping and changing rooms. There will be a separate building for mechanical, electrical and pool filtration plant.
4. The perimeter wall and roof structure may be of steel or concrete construction and will carry proprietary ETFE glazing panels. These panels can span an area up to 5m by 5m.
5. No internal columns are allowed except for a central support placed within a central area 3m in diameter. Clear heights of 7m at the perimeter and 10m in the centre are required, see figure Q2.

Imposed loading

- | | | |
|----|------------------------------|-----------------------|
| 6. | Roof | 1.5kN/m ² |
| | Ground floor | 20.0kN/m ² |
| | Swimming pool floor finishes | 10.0kN/m ² |

The roof and ground floor loadings include allowances for finishes, services, partitions and soil for internal landscaping. The swimming pool floor finishes do not include the loading from water.

Site conditions

7. The site is open with good access for construction plant and the building is within a larger area which will be landscaped later.
8. Basic wind speed is 40 m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20 m/s.
9. Ground conditions:

Ground level – 0.3m	Topsoil
0.3m – 21.0m	Sand and gravel, N = 25
Below 21.0m	Rock with an allowable bearing capacity of 1500kN/m ²

 The highest recorded ground level is 0.8m below ground level.

Omit from consideration

10. Design of the external building to contain the mechanical, electrical and filtration plant and design of proprietary ETFE cladding panels for the roof and perimeter wall.

SECTION 1

(30 marks)

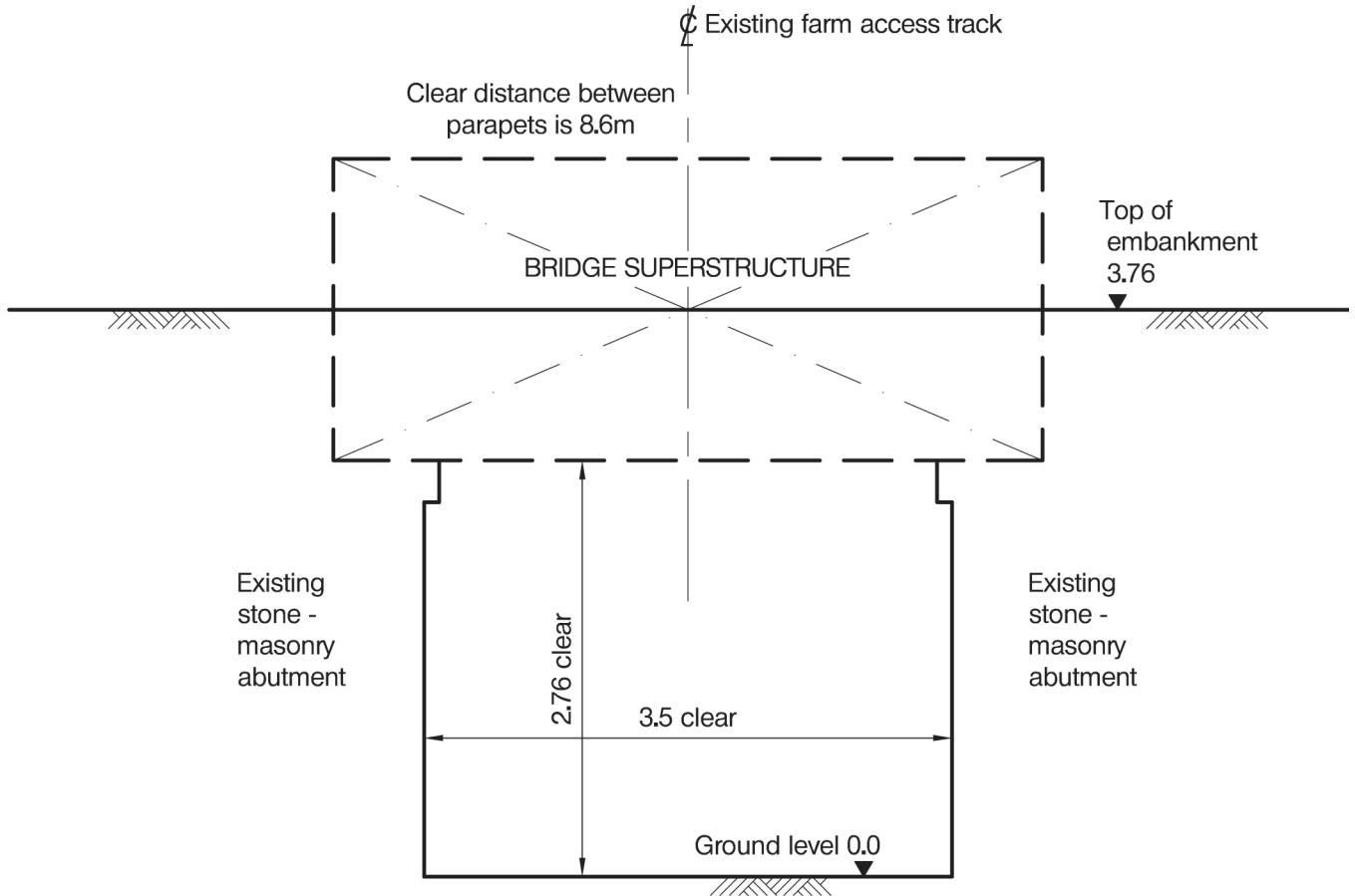
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. **(20 marks)**
- b. The Client asks for advice on the implications of omitting any central support to the roof. Write a note explaining how this could be done and what the implications would be, using sketches to illustrate your solution. **(10 marks)**

SECTION 2

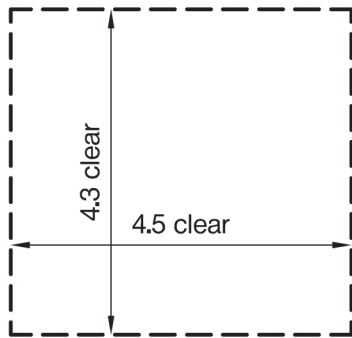
(70 marks)

For the solution recommended in Section 1(a):

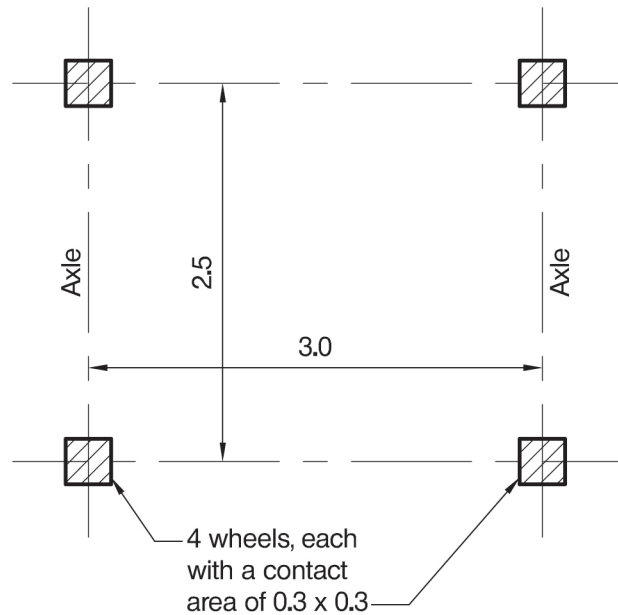
- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. **(30 marks)**
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
 - (i) The connection of the pool walls to the ground slab
 - (ii) The connection of the roof structure to the central support **(30 marks)**
- e. Prepare a detailed method statement for the safe construction of the structure focusing on construction of the pools and ground slab and erection of the roof structure. **(10 marks)**



CROSS SECTION THROUGH EXISTING BRIDGE



CLEARANCE DIMENSIONS FOR THE NEW BRIDGE



MAINTENANCE VEHICLE

NOTE: All dimensions are in metres

FIGURE Q3

Question 3. Bridge Replacement

Client's requirements

1. An abandoned railway track on an embankment is to be reinstated as a bridleway and footpath. One of the old existing railway bridges, which crosses a farm access track, needs to be replaced. See Figure Q3.
2. The clear distance between the parapets of the existing bridge is 8.6m. This may be reduced to 3.5m to accommodate the bridleway and footpath.
3. The new farm access track is level and requires a clear height of 4.3m and a clear width of 4.5m.
4. The proposed bridleway and footpath will be serviced by a maintenance vehicle. See Figure Q3 for the vehicle's axle and wheel configuration.

Imposed loading

5. Pedestrians and horses 5.0kN/m²
Maintenance vehicle 100kN distributed equally through four wheels – see Figure Q3

Site conditions

6. The abandoned railway embankment runs through open farmland and is approximately 0.5km from the nearest public road.
7. Basic wind speed is 40m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20m/s.
8. Ground conditions:
Ground level – 0.2m Topsoil
0.2m – 8.0m Sandy clay, C = 100kN/m²
Below 8.0m Rock with an allowable bearing capacity of 1500kN/m²
Water table is 2m below ground level.

Omit from consideration

9. Detailed description of the removal of the existing bridge.

SECTION 1

(30 marks)

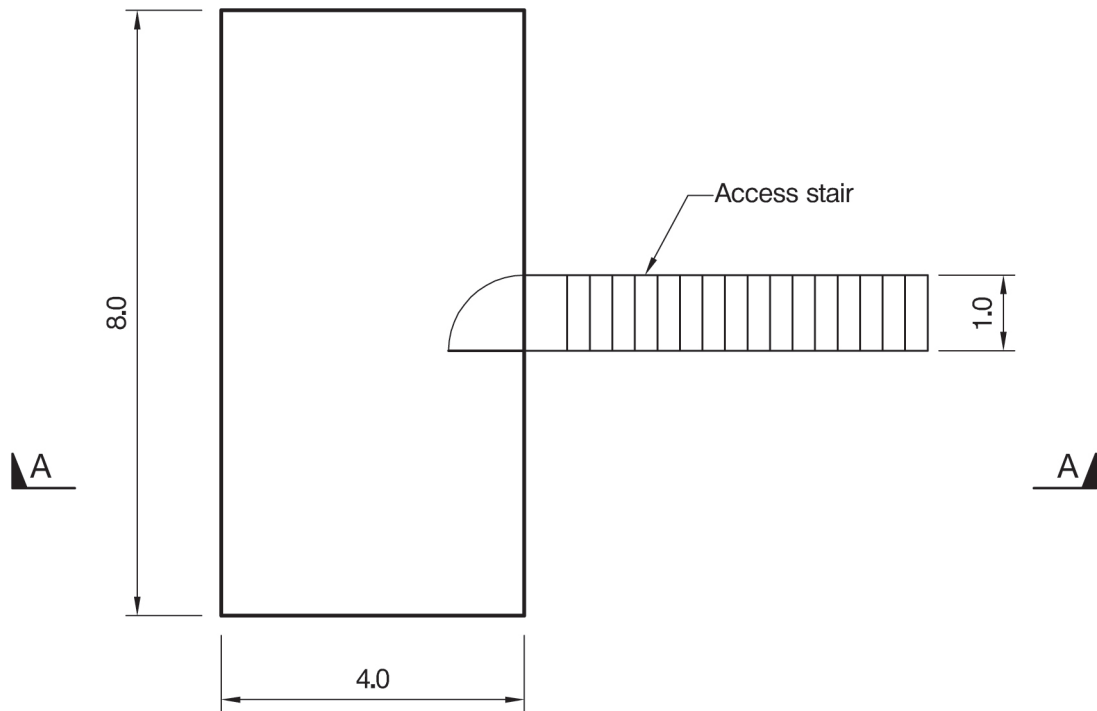
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. **(20 marks)**
- b. After the design is completed it is discovered that the bridge is within a recently extended Conservation Area and as much of the old abutments as possible should be re-used. Describe the implications of this change on the original design. **(10 marks)**

SECTION 2

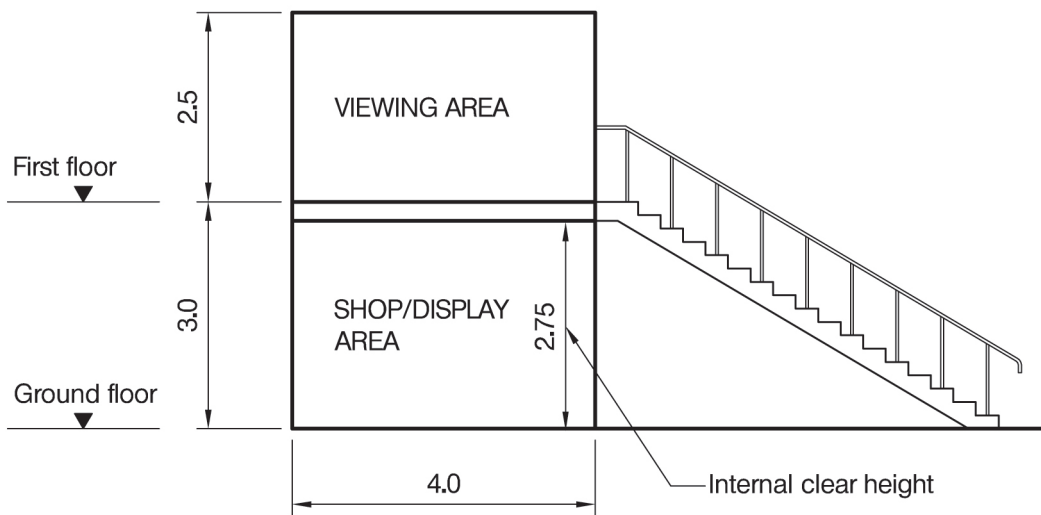
(70 marks)

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) The end support
 - (ii) The parapet**(30 marks)**
- e. Prepare a detailed method statement for the safe construction of the bridge. **(10 marks)**



PLAN



SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q4

Question 4. Bird Hide Structure

Client's requirements

1. An enclosed viewing hide for a bird reserve with enclosed shop/display area below. See Figure Q4.
2. The front and sides are to be constructed with a minimum of obstructions.
3. The interior of the building at ground and first floor levels is to be obstruction free with a minimum clear height of 2.75m at ground floor level.
4. The internal spaces are not heated.
5. The first floor level is to be accessed via a single external stair.

Imposed loading

- | | | |
|----|------------------------|----------------------|
| 6. | Roof | 1.0kN/m ² |
| | First and ground floor | 4.0kN/m ² |
| | Stairs | 4.0kN/m ² |

Site conditions

7. The site is level.
8. Basic wind speed 44m/s based on a 3 second gust; the equivalent mean hourly wind speed is 22m/s.
9. Ground conditions:

Ground level – 0.3m	Topsoil
0.3m – 1.0m	Soft clay
Below 1.0m	Firm clay with an allowable bearing capacity of 100kN/m ²

Omit from consideration

10. Detail design of the stair balustrade.

SECTION 1

(30 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. **(20 marks)**
- b. On completion of the design the client asks if a wind turbine could be built on the roof to provide power to the building. Describe the implications this will have on the original design. **(10 marks)**

SECTION 2

(70 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) The junction of the main structure and the foundations
 - (ii) The junction of the external wall and the roof **(30 marks)**
- e. Prepare a detailed method statement for the safe construction of the building. **(10 marks)**

