The Institution of Structural Engineers

Associate-Membership Examination

Thursday 3 APRIL 2008

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 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 35 marks are allocated to Section 1 and 65 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 describe your structural solution you must show by brief, clear, logical and systematic presentation that you understood the general structural engineering principles involved.

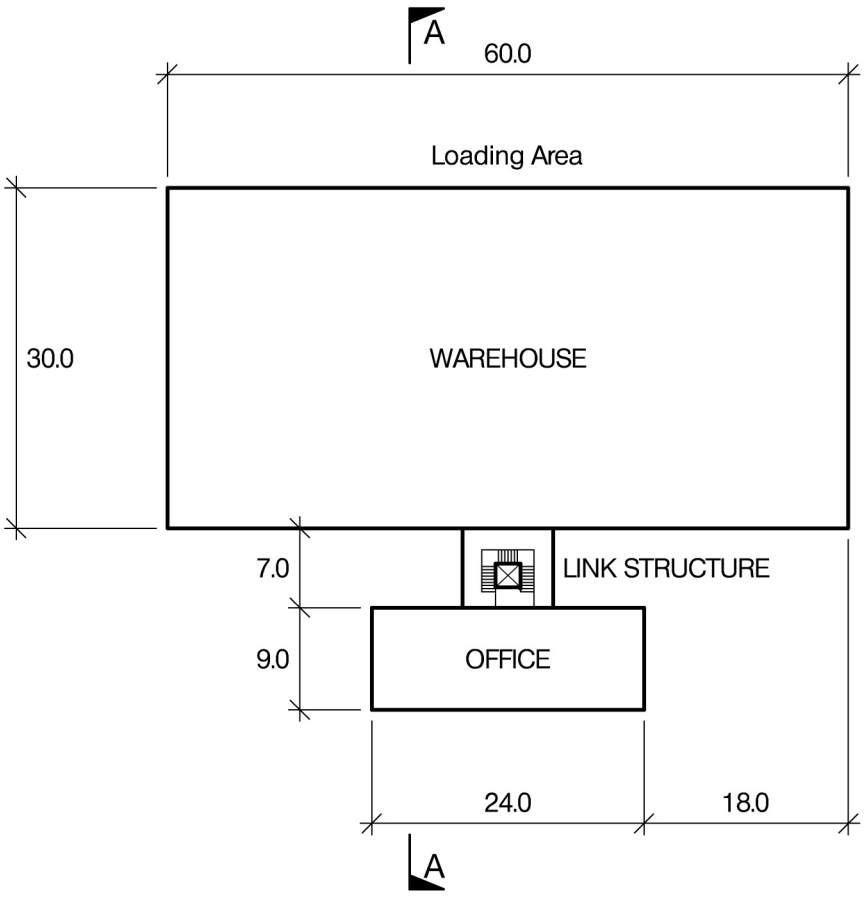
In selecting and developing your design you should also remember the guidance given in the Institution's report, Aims of Structural Design, and in particular:

(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.



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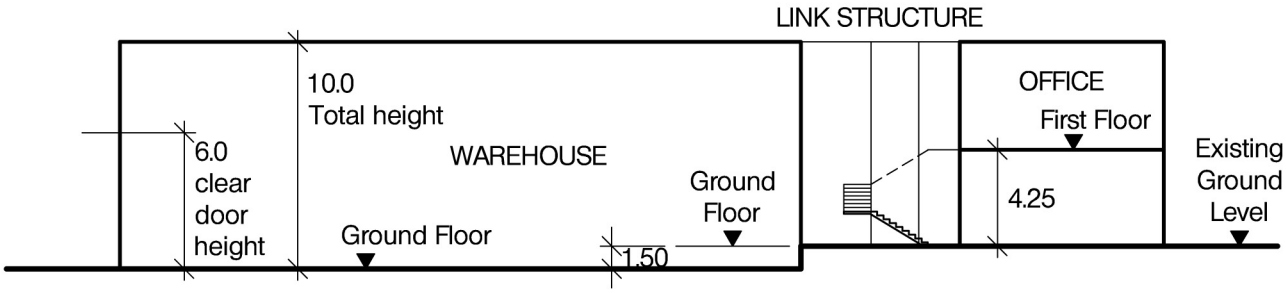


SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q1

Question 1. Warehouse and Office

Client's requirements

1. A new warehouse with adjoining two storey open plan office. See Figure Q1.
2. The warehouse roof and office roof are to be clear span construction with insulated composite steel cladding.
3. No columns are permitted within the warehouse and office areas.
4. The external cladding to the warehouse is to be of insulated composite steel cladding with a single skin of 140mm concrete blockwork to a height of 3.0m above ground floor level to the inside face.
5. The external cladding to the office is to be of cavity wall construction comprising 102mm brickwork and 140mm blockwork with 60mm cavity, extending 600mm above roof level.
6. The ground floor level of the warehouse and the loading area is to be 1.5m below existing ground level.
7. Delivery doors 6.0m high and 5.0m wide are required throughout the loading area elevation of the warehouse.

Imposed Loading

8.

Roof	1.0kN/m^2
Office floor	5.0kN/m^2
Warehouse floor	15.0kN/m^2

Imposed loadings include allowances for finishes and services.

Site Conditions

9. The site is level and located on the outskirts of a large city.
10. Basic wind speed is 40m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20m/s.
11. Ground conditions:

Ground level – 0.5m	Top soil and fill
0.5m – 2.0m	Alluvial deposits C = 20kN/m^2
2.0m – 5.0m	Sand and gravel N = 10
5.0m – 10.0m	Firm to stiff clay C = 150kN/m^2

Ground water was encountered 3.5m below ground level.

Omit from consideration

12. Detail design of stair and lift shaft core and link structure.

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. On completion of the design the client asks if it is feasible to incorporate an electric overhead travelling crane with a lifting capacity of 5 tonnes within the warehouse. Describe the implications this will have on the original design. (10 marks)

SECTION 2 **(65 marks)**

For the solution recommended in Section 1(a):

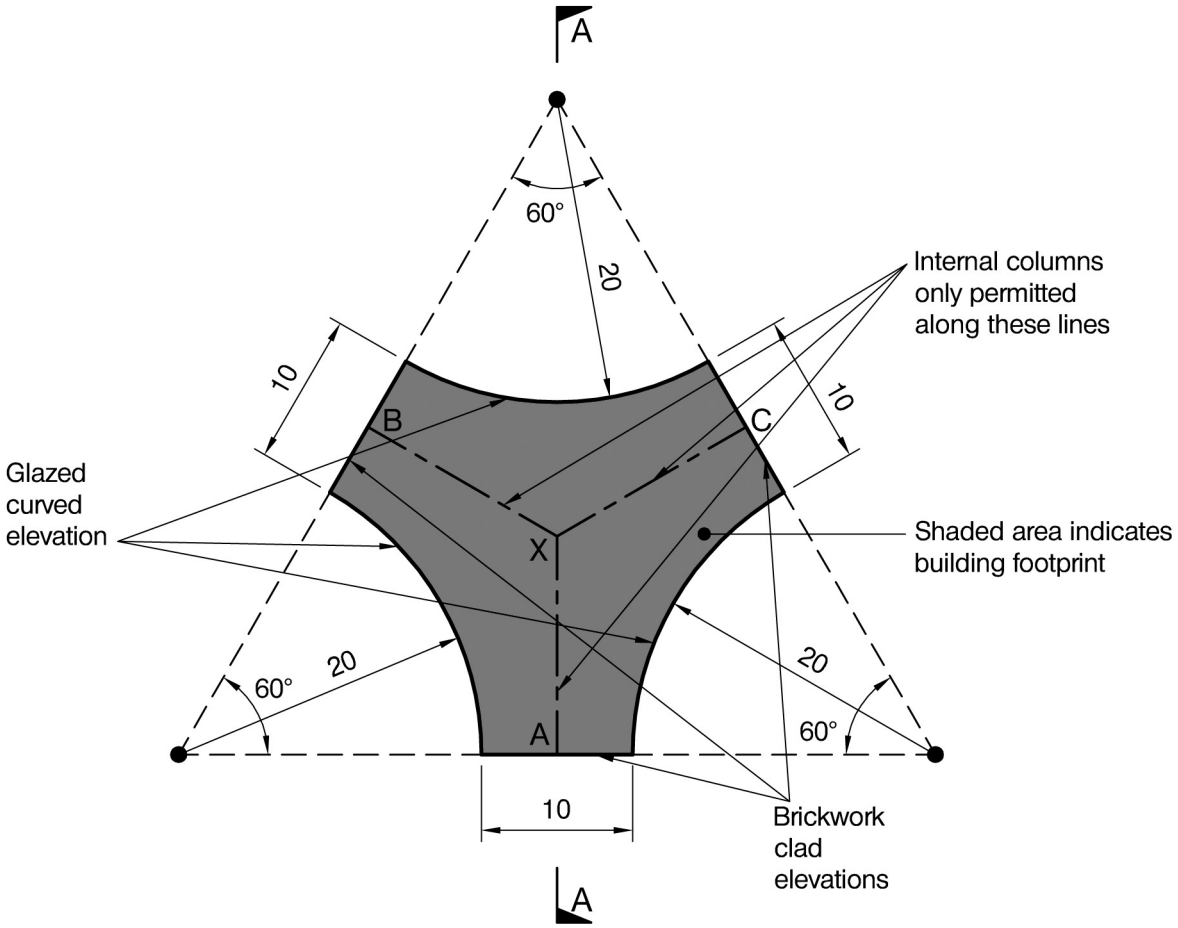
c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (30 marks)

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 for the office at first floor level.

   (ii) A perimeter column for the warehouse at ground floor adjacent to the link structure. (25 marks)

e. Prepare a detailed method statement for the safe construction of the building. (10 marks)



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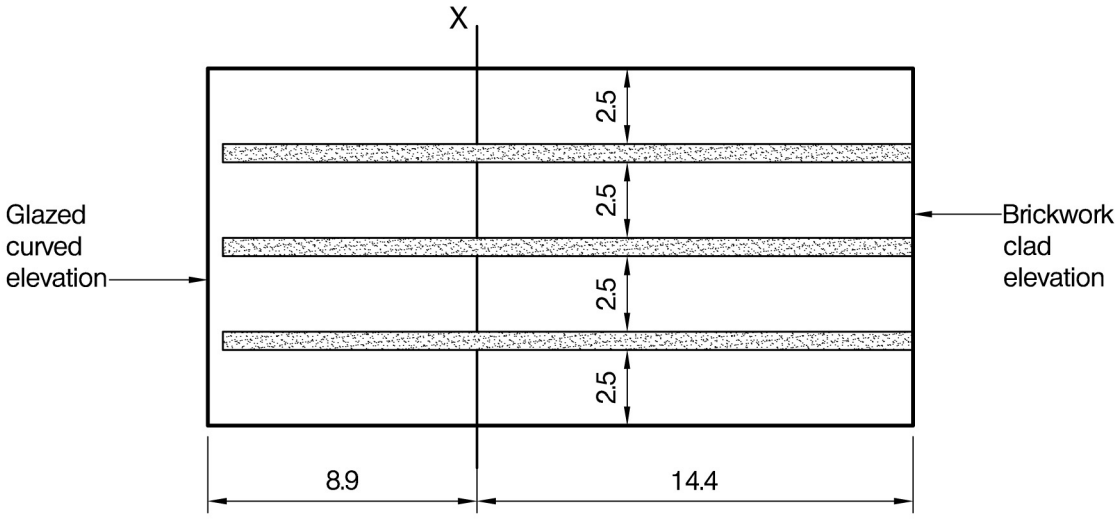


SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q2

Question 2. Office Building

Client's requirements

1. A new four-storey office development. See Figure Q2.
2. The curved elevations are to have full height glazing. The straight elevations are to have brick cladding.
3. Each floor is to have a 2.5m high clear height between floor and ceiling.
4. A single line of internal columns is permitted along the lines AX, BX and CX shown in Figure Q2. Minimum column spacing for internal and external columns is 5 metres centre to centre.
5. Bracing is only permitted in elevations with brickwork. Bracing is not permitted in the office space or in the glazed elevations. Staircases and lifts are outside the building line and structurally independent of the office development.

Imposed Loading

6. Roof $1.0kN/m^2$
   Floor $5.0kN/m^2$
   Imposed loadings include allowances for finishes and services.

Site Conditions

7. The site is level and located in an inland city centre.
8. Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s.
9. Ground conditions:

Ground level – 0.5m	Top soil
0.5m – 5.0m	Sand and gravel N = 20
Below 5.0m	Stiff clay C = $150kN/m^2$

Ground water was not encountered.

Omit from consideration

10. Detailed consideration of stairs and lift shafts.

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 developer asks if it is possible to locate the columns so as not to be visible on the curved glazed elevations. 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):

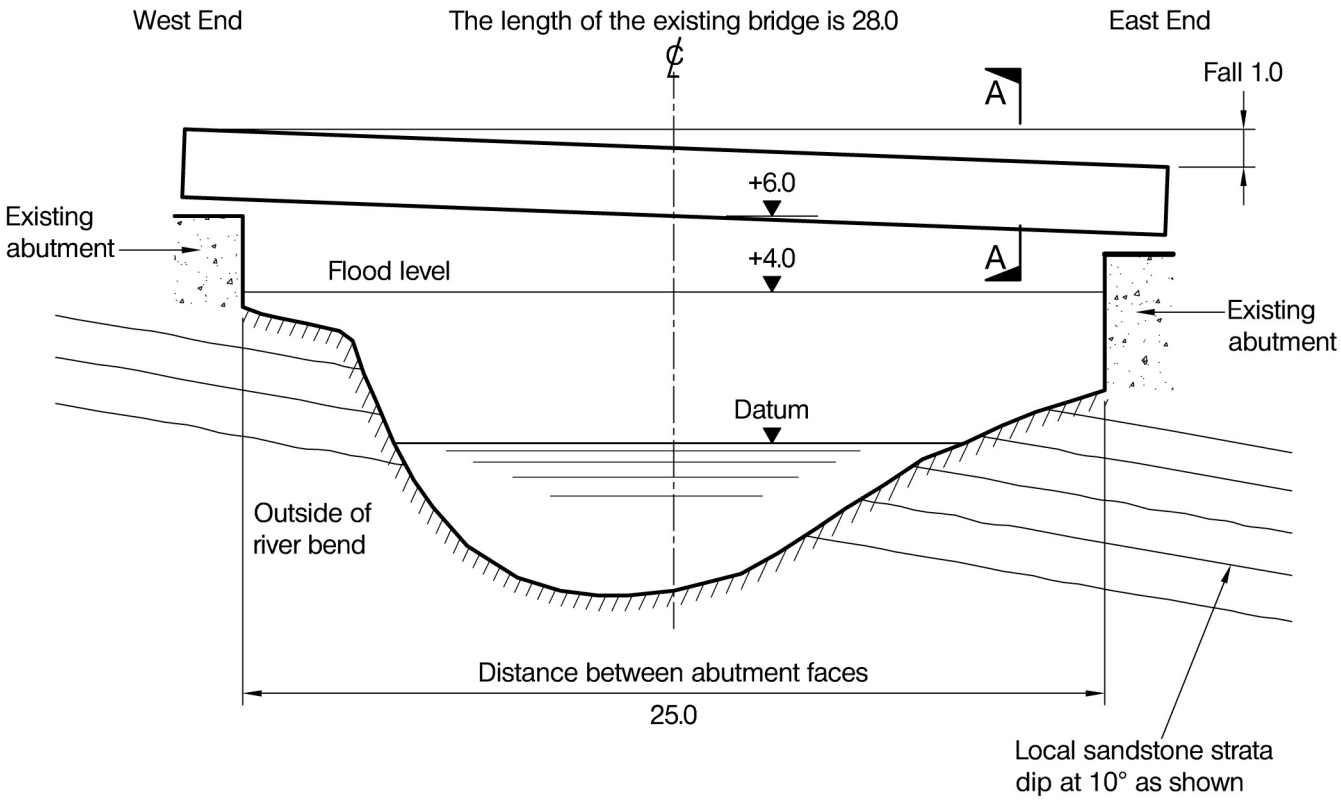
c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (30 marks)

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 of a column in the glazed elevation to a floor beam.

   (ii) Connection of the column closest to point X (see Figure Q2) to the adjacent floor beams. (25 marks)

e. Prepare a detailed method statement for the safe construction of the building. (10 marks)



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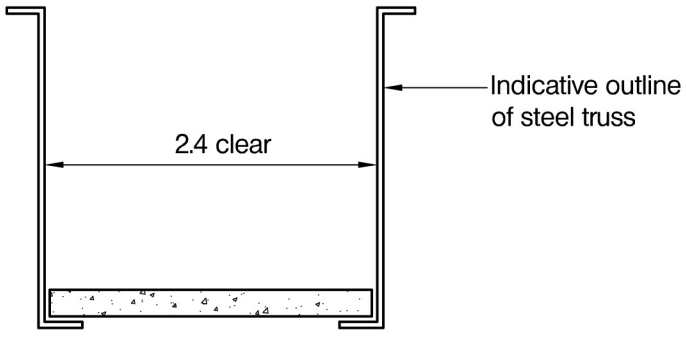


SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q3

Question 3. Replacement Pedestrian and Cycle Bridge

Client's requirements

1. A replacement pedestrian and cycle bridge for a national cycleway crossing a river. See Figure Q3.
2. The existing bridge has been damaged by an exceptional flood. The superstructure needs to be completely replaced. However, the existing abutments which are of mass concrete construction appear to be sound and reusable.
3. The existing superstructure that is to be replaced comprises a half through steel truss with a concrete deck.
4. No new piers are permitted.

Imposed Loading

5. Pedestrian and cycle $5.0kN/m^2$

Site Conditions

6. The site is located beside a golf course on the west side of the river and otherwise inaccessible scrubland on the east side. Access to the west side of the bridge is along a footpath that is used by pedestrians and cyclists from the nearest public road, which is approximately 2km from the bridge.
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:

   The existing foundations are located on strong sandstone, see Figure Q3.

Omit from consideration

9. Detailed assessment of the existing abutments and foundations.

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. On completion of the design the client asks if it is feasible for the bridge to support a 300mm diameter water main crossing the river. Describe the implications this change will have on the original design. (10 marks)

SECTION 2 **(65 marks)**

For the solution recommended in Section 1(a):

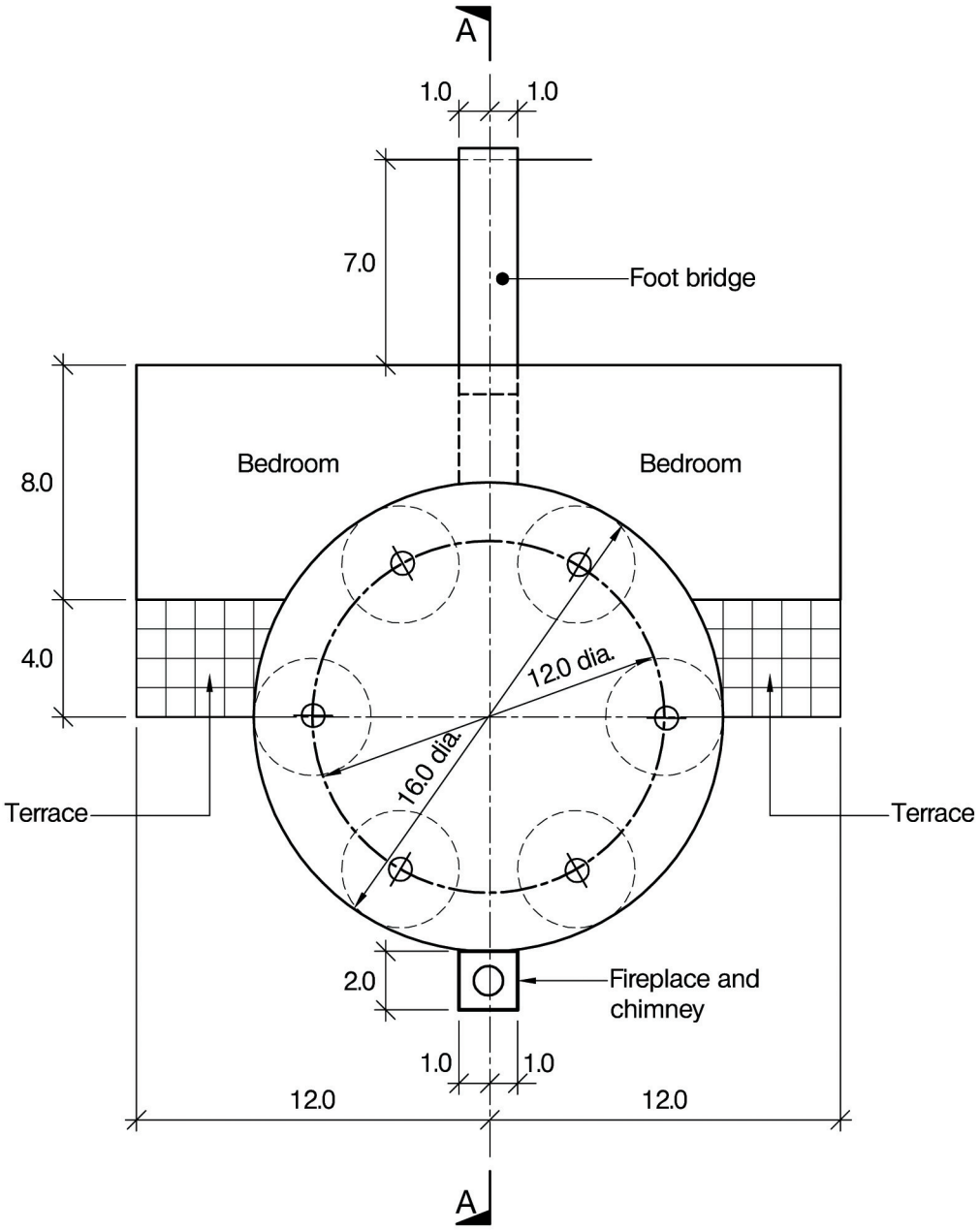
c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including connections to the existing abutments. (30 marks)

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 at the east end of the bridge.

   (ii) The bridge deck. (25 marks)

e. Prepare a detailed method statement for the safe construction of the bridge. (10 marks)



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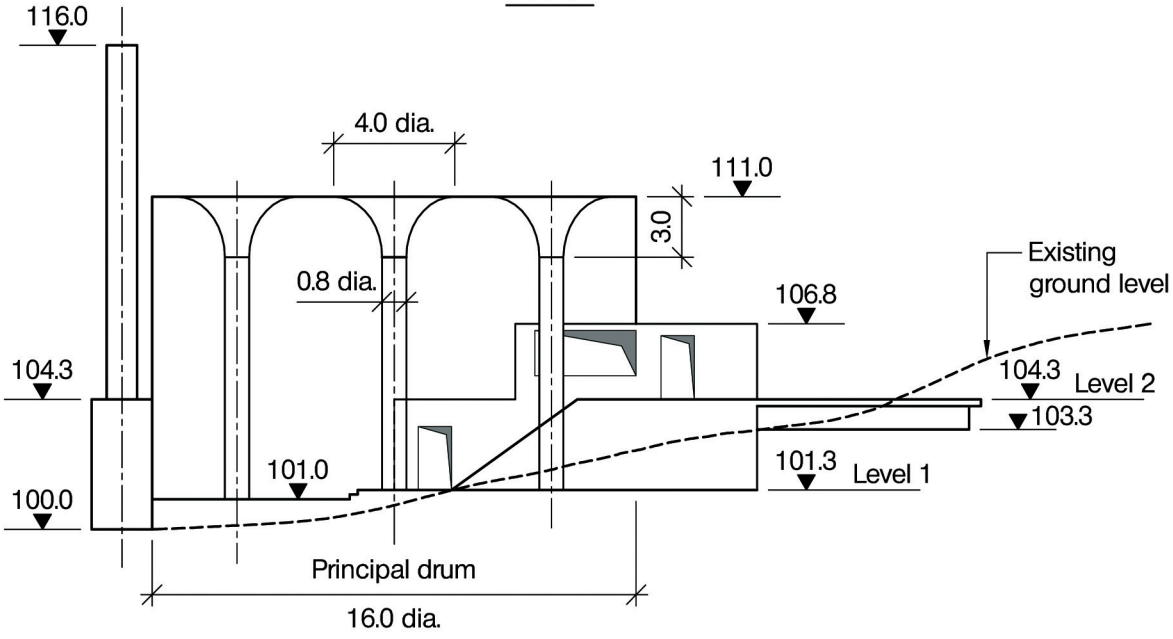


SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q4

Question 4. Custom-built House

Client's requirements

1. A custom-built house comprising slabs, walls and a group of six columns with flared heads supporting the roof of the curtain wall clad 'principal drum' containing the living area. See Figure Q4.
2. The elements of the 'principal drum' are to be cast in white concrete.
3. Two bedrooms are located on Level 2. Each has a terrace area.
4. Other domestic facilities are located on Level 1, which is built into an existing hillside.
5. The house is accessed via a footbridge that descends into the living area via stairs.
6. The living area has a fireplace incorporating a free-standing chimney.

Imposed Loading

7.

Roof	1.0kN/m^2
Level 2 floor and terrace	2.0kN/m^2
Level 1 floor	2.5kN/m^2

Imposed loadings include allowances for finishes and services.

Site Conditions

8. The site is located in gently undulating parkland.
9. Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s.
10. Ground conditions:

Ground level – 0.2m	Top soil
0.2m – 6.0m	Boulder clay or till C = 200kN/m^2

No ground water was encountered.

Omit from consideration

11. Detailed design of the curtain wall.

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. On completion of the design the architect proposes a change to the brief. This requires that each of the six columns be circular, 500mm in diameter and without flared heads. Describe the implications this will have on the original design. (10 marks)

SECTION 2 **(65 marks)**

For the solution recommended in Section 1(a):

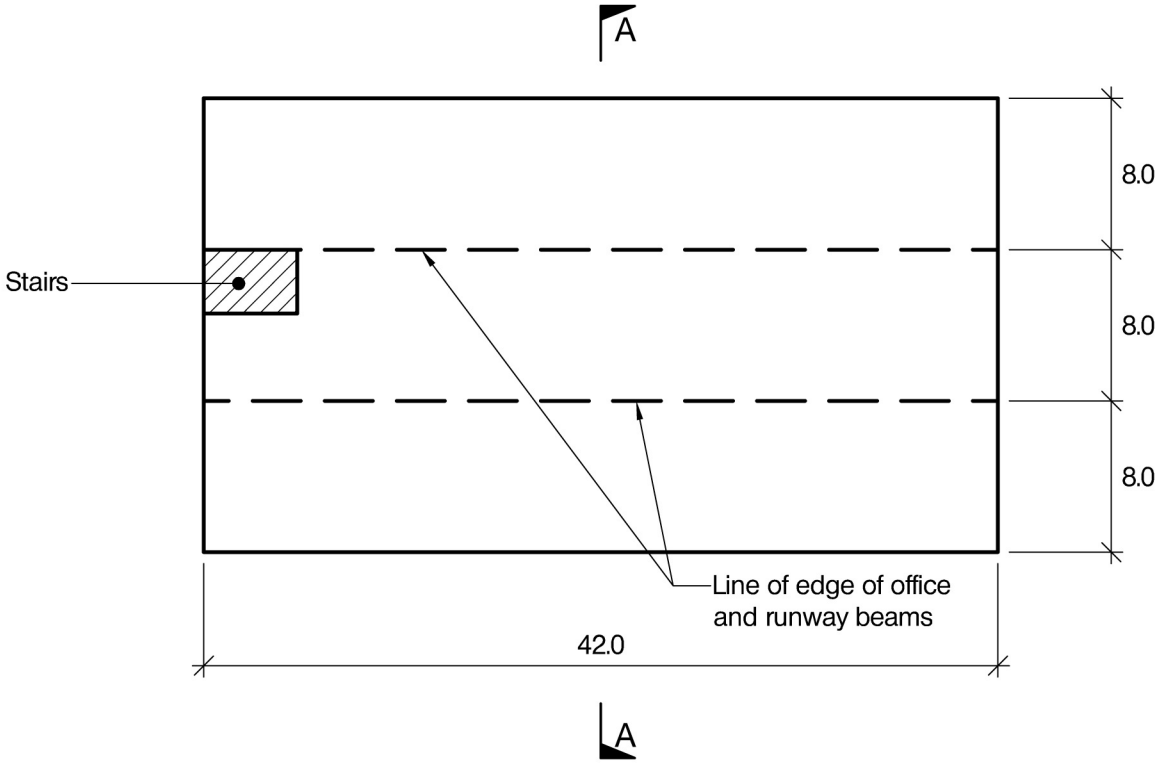
c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (30 marks)

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 landward support for the footbridge.

   (ii) The edge of the roof of the 'principal drum'. (25 marks)

e. Prepare a detailed method statement for the safe construction of the 'principal drum'. (10 marks)



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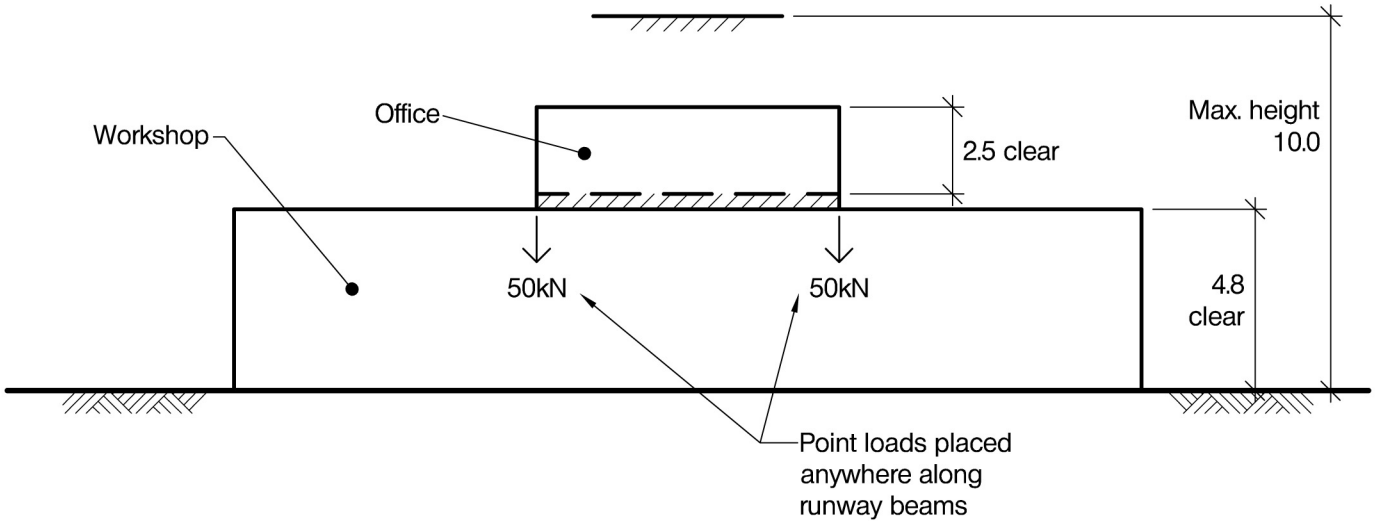


SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q5

Question 5. Workshop and Office

Client's requirements

1. A concrete raft and boat systems supplier requires a new workshop and office building to be located on part of a large site in a light industrial area. See Figure Q5.
2. The client has a strong preference for use of concrete where possible. As much natural lighting as possible is required in the office and workshop.
3. The ground floor workshop area is to provide a 24m by 42m area with no internal columns apart from stairs as shown in Figure Q5. An 8m wide office area is required at first floor, running along the centre of the building.
4. Clear headroom of 4.8m is required for the workshop and 2.5m for the office. No part of the structure shall be higher than 10m above ground level.
5. Perimeter columns shall not be spaced closer than 6.0m.

Imposed Loading

6. Roof 1.5 kN/m^2

   Office floor 4.0 kN/m^2

   Workshop ground floor 20.0 kN/m^2

   Two overhead runway beams run along the workshop roof as shown in Figure Q5. A point load of 50kN can act at any point along each runway beam.

   Imposed loadings include allowances for finishes, services and partitions.

Site Conditions

7. The site for the workshop is level and open.
8. Basic wind speed is 50m/s based on a 3 second gust; the equivalent mean hourly wind speed is 25m/s.
9. Ground conditions:

Ground level – 1.0m	Top soil
1.0m – 10.0m	Sand and gravel N = 15
10.0m – 35.0m	Sand and gravel N = 25

The highest recorded ground water level is 6.0m below ground level.

Omit from consideration

10. Design of the access stairs to the office, which are non structural and shall not be used to provide lateral stability to the building.

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 that a 22m wide clear opening be provided at each end of the workshop. Describe how this change could be achieved, using sketches to illustrate your solution. (10 marks)

SECTION 2 **(65 marks)**

For the solution recommended in Section 1(a):

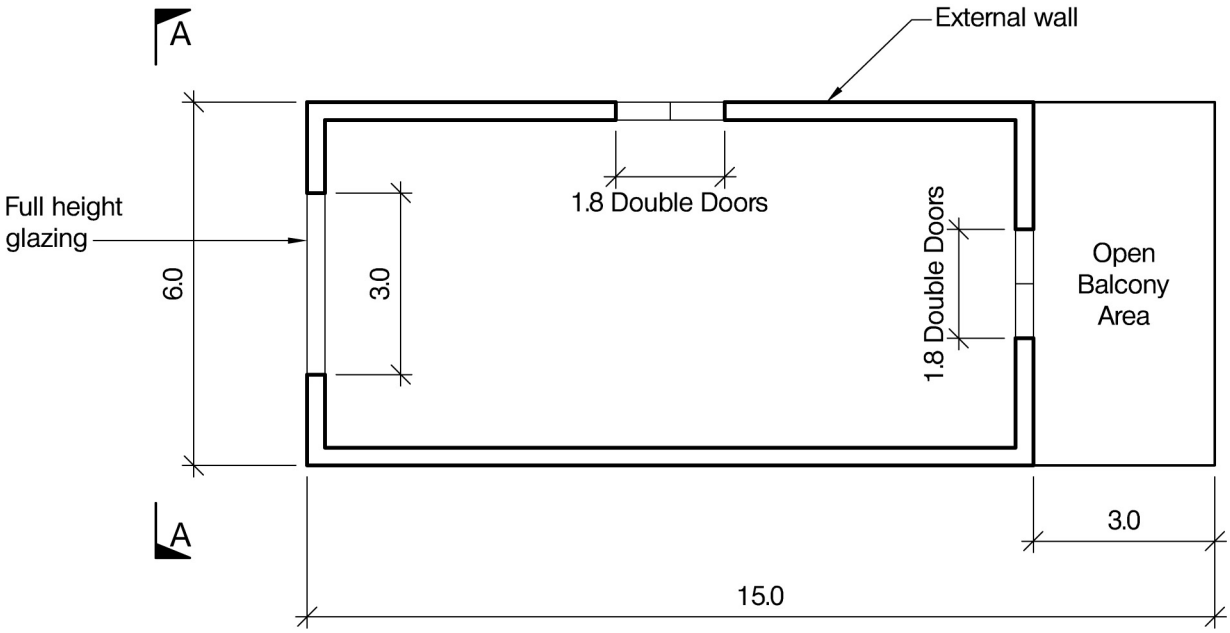
c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (30 marks)

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 main element of roof structure.

   (ii) A typical perimeter foundation. (25 marks)

e. Prepare a detailed method statement for the safe construction of the building. (10 marks)



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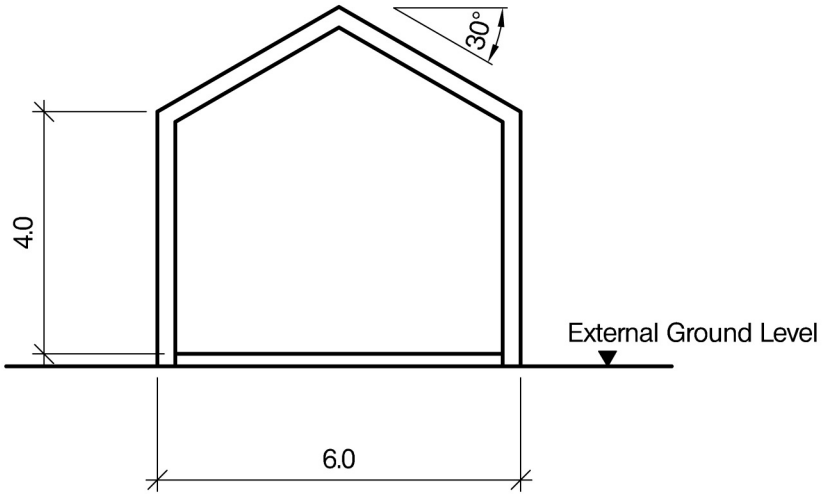

ELEVATION A-A

NOTE: All dimensions are in metres

FIGURE Q6

Question 6. Clubhouse

Client's requirements

1. A local organisation requires a new building for a clubhouse. See Figure Q6.
2. To minimise works on site, the building is to be constructed from prefabricated elements wherever possible.
3. The interior of the building is to be kept free from obstructions.
4. The building will be located within a woodland setting and should be designed sympathetically to this setting.
5. An open balcony area with a minimum of obstructions is required at one end.
6. The site cannot be accessed by large vehicles and heavy construction plant.

Imposed Loading

7. Roof $1.0kN/m^2$
   Floor $5.0kN/m^2$
   Imposed loadings include allowances for finishes and services.

Site Conditions

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

Ground level – 2.5m	Top soil and very soft silty clay
Below 2.5m	Limestone, allowable bearing pressure $300kN/m^2$

Omit from consideration

11. No omissions.

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. On completion of the design it is decided that the building height to the eaves needs to be increased from 4m to 6m. Describe the implications this will have on the original 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 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) Junction of roof and top of walls.

   (ii) Junction of walls and foundations. (25 marks)

e. Prepare a detailed method statement for the safe construction of the building. (10 marks)