

Associate-Membership Examination

Friday 9 April 2010

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 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.

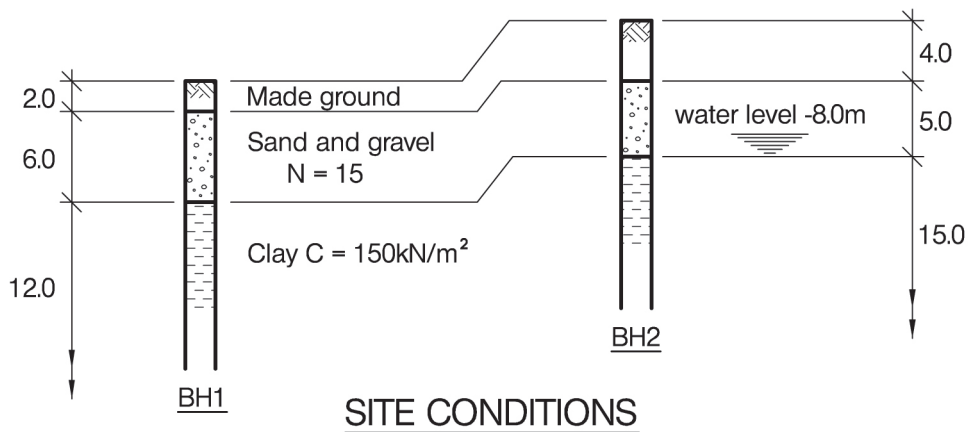
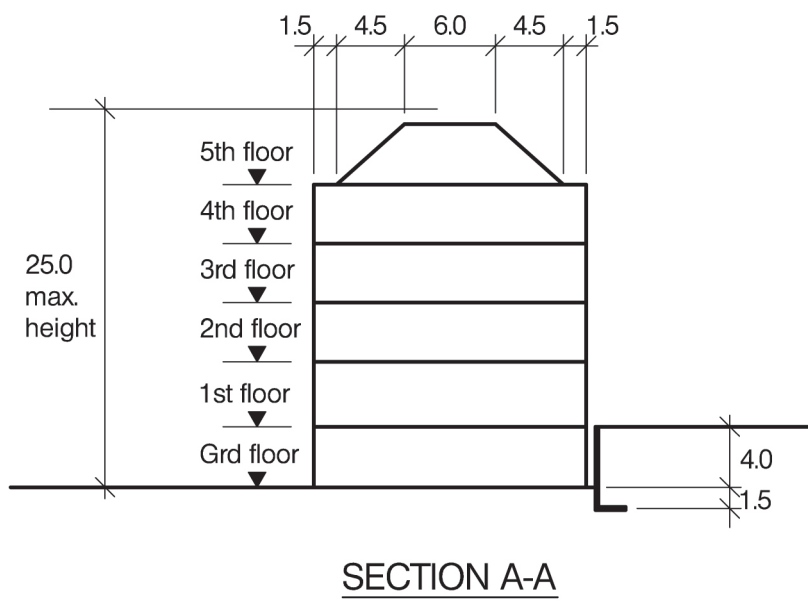
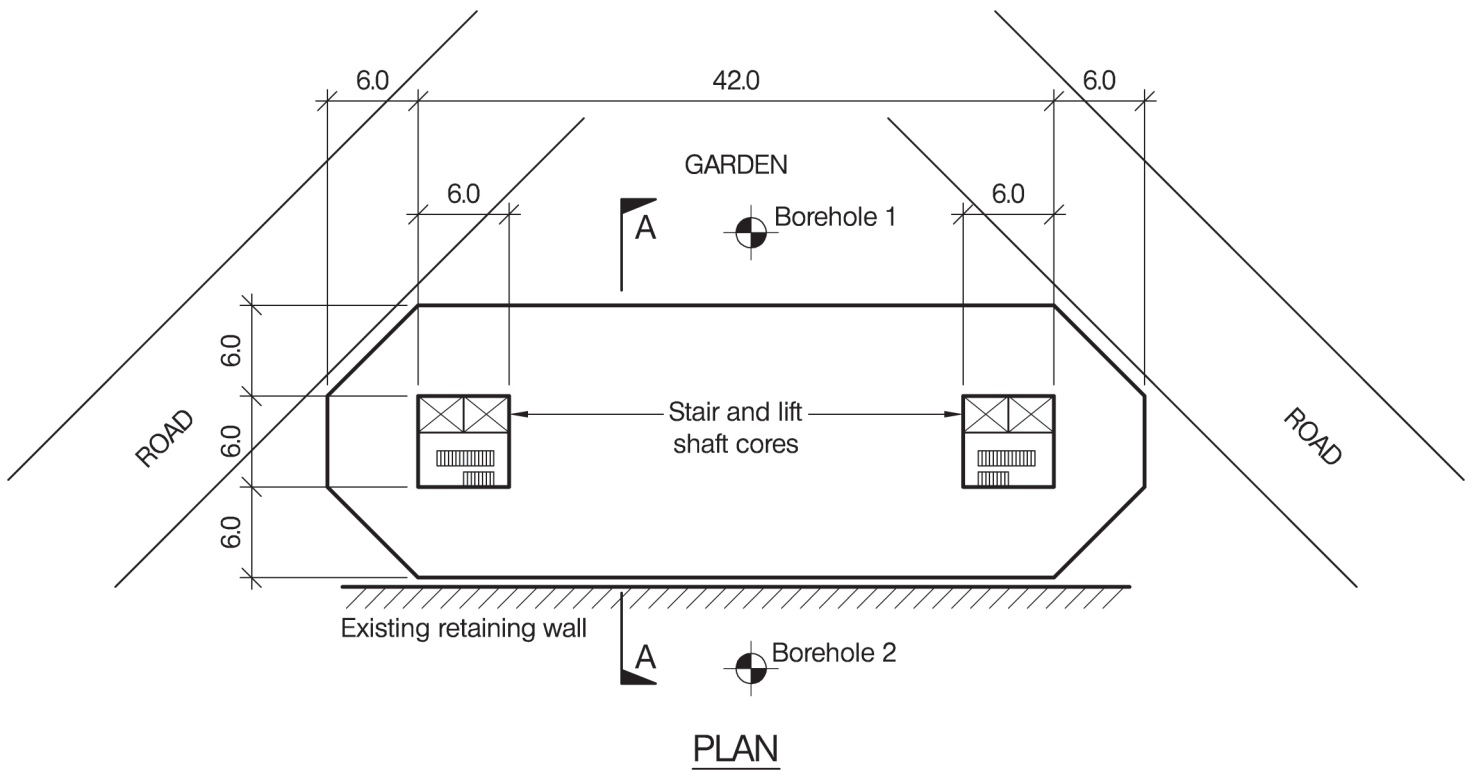
The unusual requirement of the examination is that you demonstrate the validity of the training and experience that you have acquired in recent years. The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural 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 describe structural solutions 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 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. Office Development

Client's Requirements

1. A five storey office development on a corner plot with an enclosed area at roof level for plant and for storage. See Figure Q1.
2. The building elevations are to be of glass curtain walling, except for the elevation facing an existing retaining wall, which is to be of 260mm cavity wall construction. The sloping roof is to incorporate solar panels.
3. Column spacing throughout the building is to be at least 6.0m.
4. One row of columns is permitted internally at all floor levels.
5. No columns are permitted within the plant and storage area.
6. The office is to have a floor to ceiling clear height of 2.75m. The overall floor depth is to include a 150mm raised floor and 400mm deep service zone between the ceiling and the underside of the floor construction.
7. No foundations are permitted beyond the building faces adjacent to the roads and the retaining wall.

Imposed Loading

8. Roof 1.5kN/m²
Floors 5.0kN/m²
Imposed loading includes allowances for finishes, services and partitions.

Site Conditions

9. The site is level and located on the outskirts of a major city.
10. Basic wind speed 40m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20m/s.
11. Ground conditions:
See Figure Q1.

Omit From Consideration

12. Detailed design of the stair and lift shafts, although their contribution (if any) to the overall stability and load transfer must be stated in Section 1(a).

SECTION 1

(30 marks)

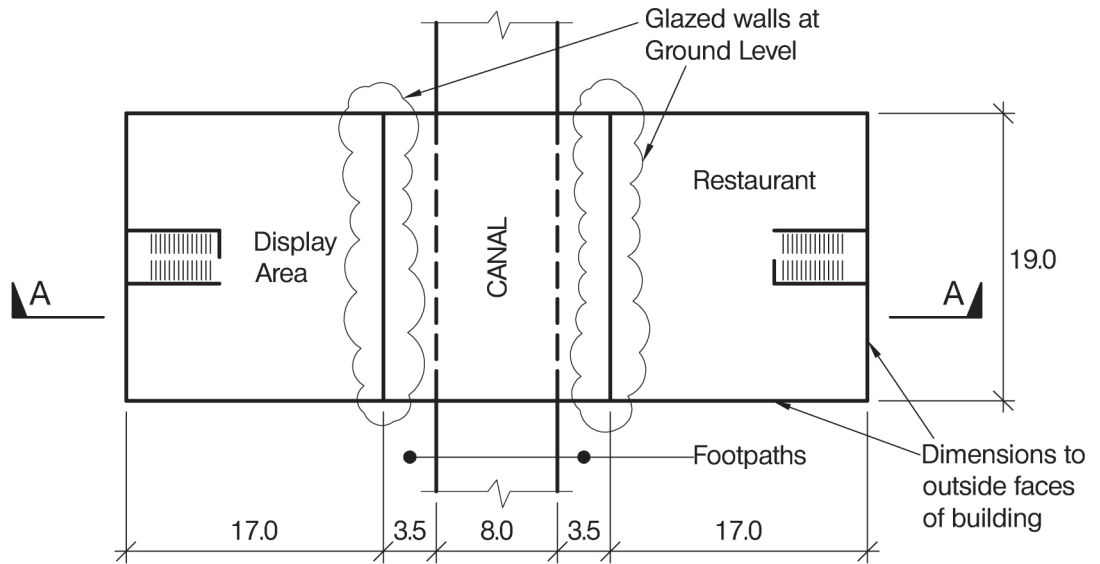
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (20 marks)
- b. The client proposes, after completion of the design and before construction, that the first floor be turned into a column-free conference area and that the floor height clearance is increased to 5.0m. Explain the effect this will have on the design and outline any resulting changes to your original proposal. (10 marks)

SECTION 2

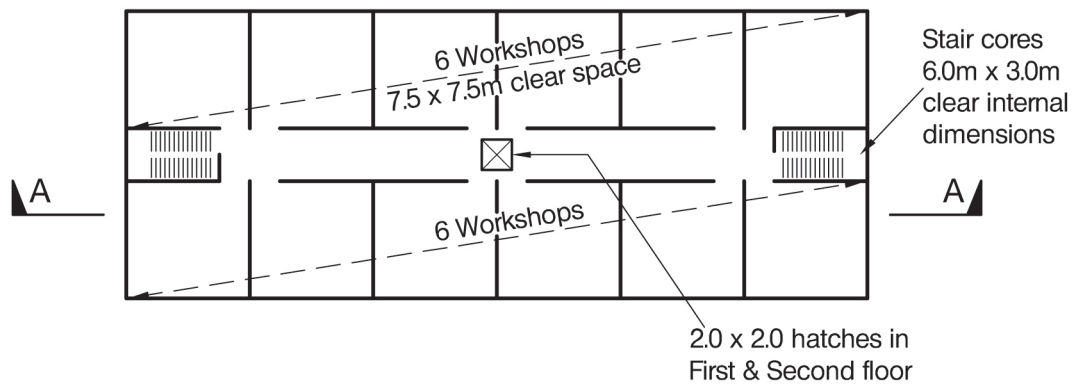
(70 marks)

For the solution recommended in Section 1(a):

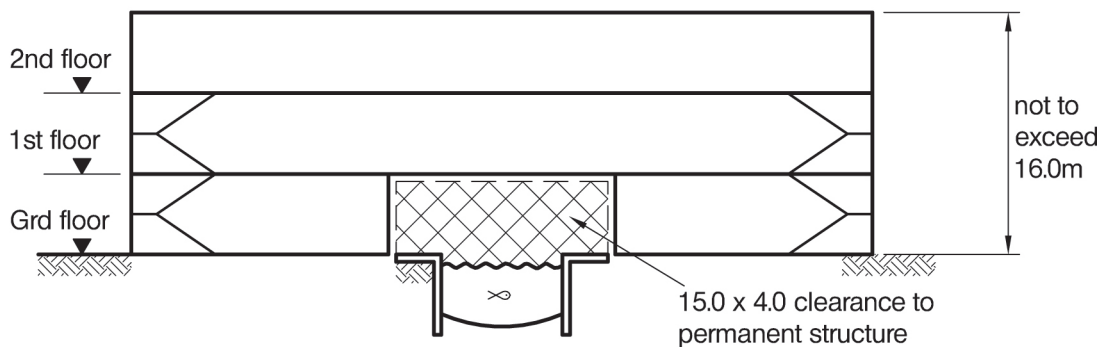
- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (30 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
 - (i) Typical external column to floor detail at 5th floor level.
 - (ii) Typical foundation detail adjacent to existing retaining wall. (30 marks)
- e. Prepare a detailed method statement for the safe construction of the building. (10 marks)



PLAN - GROUND FLOOR



PLAN - FIRST AND SECOND FLOORS



SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q2

Question 2. Craft Workshops

Client's Requirements

- The owner of a canal requires a new building to accommodate a restaurant, historical display area and 24 workshops. See Figure Q2.
- The ground floor is to contain the restaurant and historical display area. There will be 12 workshops on the first floor and 12 more on the second floor. Each workshop must provide at least 7.5m by 7.5m of column free space. A central 2m square hatch is required in the first and second floors to allow workshop equipment to be lifted off canal barges.
- The building spans the canal. The sides of the restaurant and display area facing the canal will be glazed. The number of internal columns at ground floor should be minimised. As much natural lighting as possible is required for the workshops.
- A clear floor to ceiling height 4.0m is required at each floor. Floors are to incorporate a 500mm deep service zone. No part of the structure shall be higher than 16m above ground level.
- No foundations or permanent structure are allowed within a 15m wide zone containing the canal and adjacent footpaths. The permanent structure must leave clear headroom of 4m above ground level.
- The canal must be kept open at all times with 3m high clearance under any temporary works over the full 8m width of the canal.

Imposed Loading

- | | |
|-----------------|-----------------------|
| 7. Roof | 1.5kN/m ² |
| Workshop floors | 10.0kN/m ² |
| Ground floor | 5.0kN/m ² |
- In addition the centre of the roof shall be designed for a single 20kN point load in order to allow for lifting equipment through the hatches.
The roof and floor loadings include allowances for finishes, services and partitions.

Site Conditions

- The site is level and open apart from the canal.
- Basic wind speed is 50m/s based on a 3 second gust; the equivalent mean hourly wind speed is 25m/s.
- Ground conditions:

Ground level – 1.0m	Topsoil
1.0m – 10.0m	Firm clay, C = 75kN/m ²
10.0m – 35.0m	Stiff clay, C = 150kN/m ²

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

Omit From Consideration

- Design of the stairs to the workshops.

SECTION 1

(30 marks)

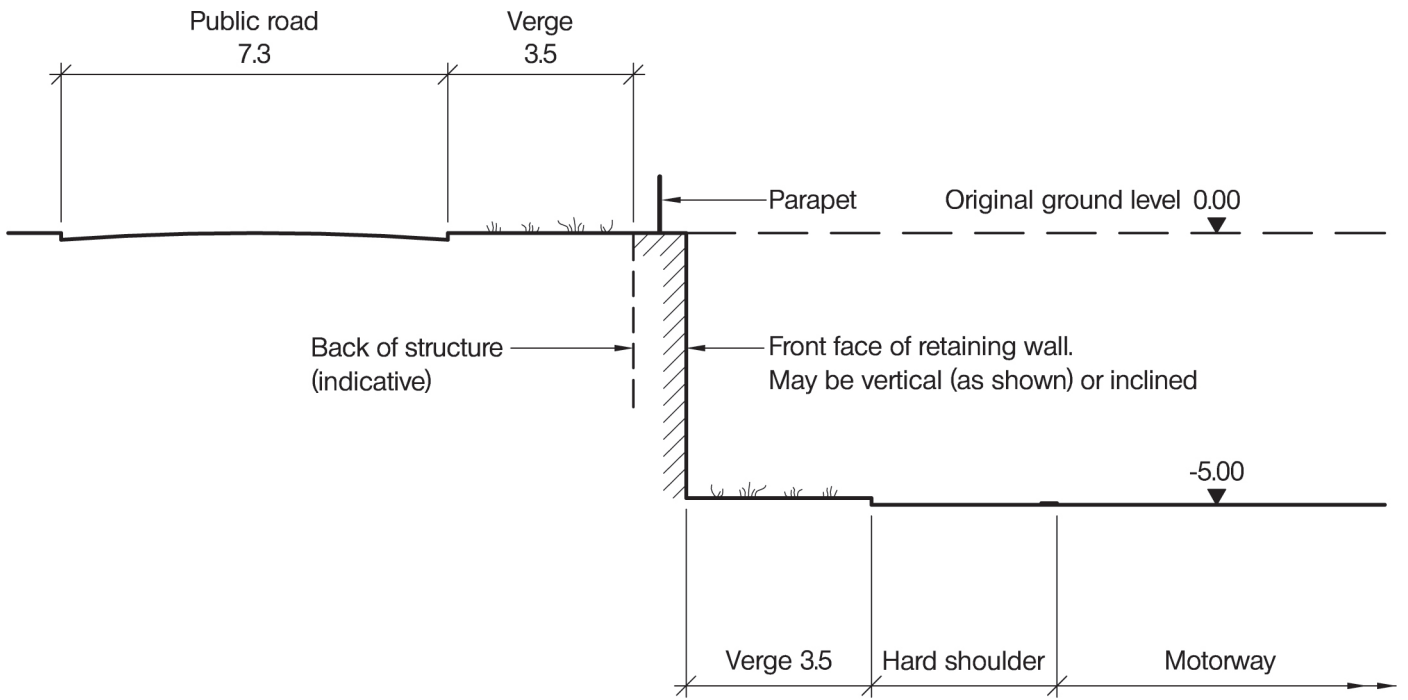
- Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (20 marks)
- The owner proposes a change to the brief. This requires that all internal columns on the glazed sides of the restaurant and display area between ground and first floor be omitted. Describe how this change could be achieved, using sketches to illustrate your solution. (10 marks)

SECTION 2

(70 marks)

For the solution recommended in Section 1(a):

- Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (30 marks)
- 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:
 - A main element of structure spanning across the canal at first floor level.
 - A typical internal foundation, ground floor and column connection at ground floor level. (30 marks)
- Prepare a detailed method statement for the safe construction of the structure focusing on the construction across the canal. (10 marks)



NOTE: All dimensions are in metres

FIGURE Q3

Question 3. Retaining Wall

Client's Requirements

1. A retaining wall beside a section of new motorway. See figure Q3.
2. Typically, the wall is 5.0m high and supports a new local public road that runs parallel to the motorway and is aligned to suit the wall construction.
3. It retains crushed rock fill, which has an angle of shearing resistance of 40° and a unit weight of between 18kN/m^3 and 20kN/m^3 .
4. There is a grassed verge, 3.5m wide at the base of the wall, next to the hard shoulder of the motorway.
5. There is to be a similar verge, also 3.5m wide, inside the top of the wall between the wall and the public road. This verge is subject to a load of 10kN/m^2 .
6. A parapet is required along the top of the wall.
7. The facing and ends of the wall are required to blend with natural surroundings. For example, cast concrete finishes must have a profile depth of at least 100mm. Stone masonry finishes must have a rustic appearance. Walls with green planted finishes are acceptable but must be maintenance free.

Imposed Loading

8. All ground surfaces 10.0kN/m^2

Site Conditions

9. The site is level and located in an isolated upland countryside.
10. Ground conditions:

Ground level – 1.0m	Moorland peat
1.0m – 6.5m	Weathered shale
Below 6.5m	Horizontally bedded weathered shale, unconfined compressive strength 12.5MN/m^2

 Groundwater was encountered within the peat and weathered shale.

Omit From Consideration

11. Detailed design of the parapet.

SECTION 1

(30 marks)

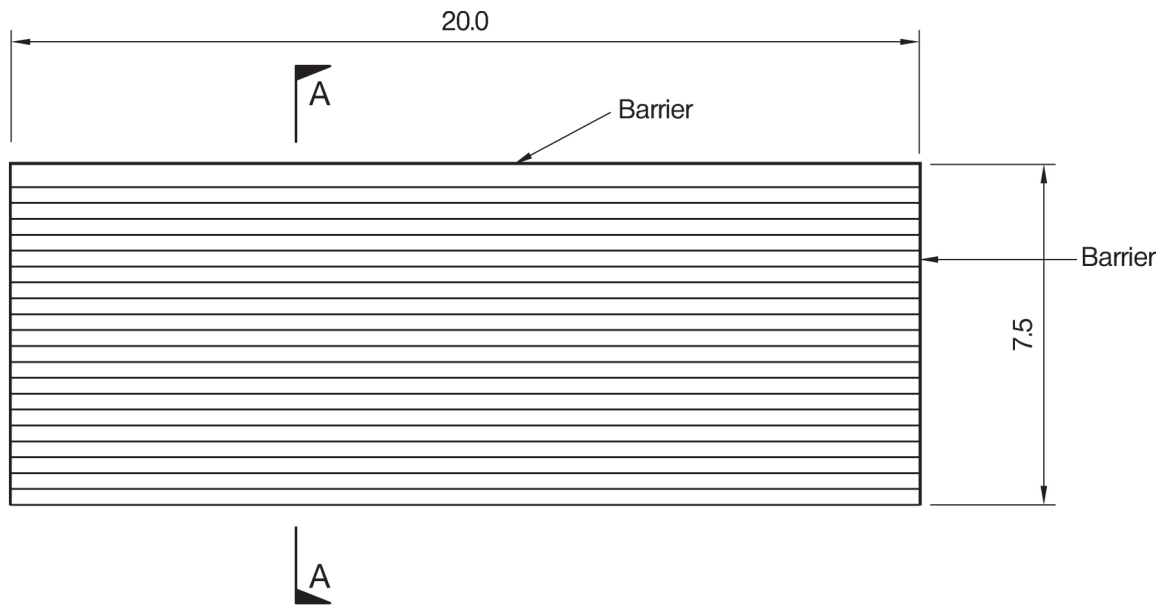
- a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. (20 marks)
- b. Upon completion of the design the client asks if it is feasible to build a lay-by beside the public road overlooking the motorway. The loading will be 15kN/m^2 . Describe the implications this will have on the original design. (10 marks)

SECTION 2

(70 marks)

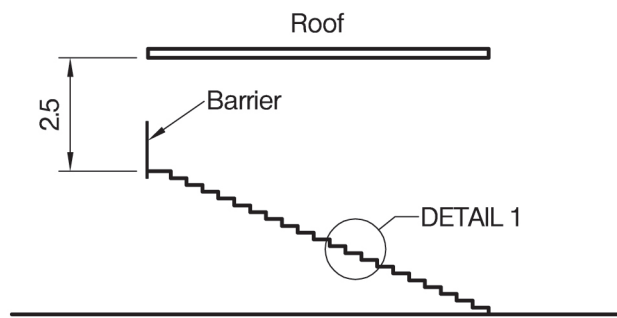
For the solution recommended in Section 1(a):

- 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) Drainage of the retained fill.
 - (ii) The wall facing. (30 marks)
- e. Prepare a detailed method statement for the safe construction of the retaining wall. (10 marks)

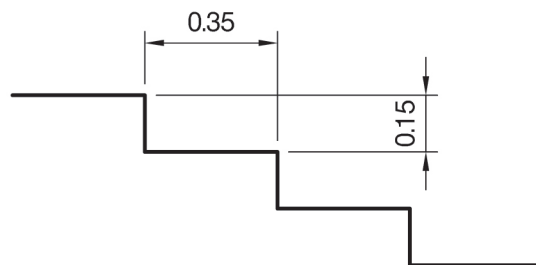


Football pitch

PLAN



SECTION A-A



DETAIL 1

NOTE: All dimensions are in metres

FIGURE Q4

Question 4. Sports Stand

Client's Requirements

1. A small stand is required on one side of a football pitch at a local sports ground. See figure Q4.
2. A roof is required over the entire area of the stand.
3. The front and sides of the stand are to be constructed with the minimum of obstructions.

Imposed Loading

- | | |
|------------|-----------------------|
| 4. Roof | 0.75kN/m ² |
| Stand area | 5.0kN/m ² |

Site Conditions

5. The site is level and located on the outskirts of a town.
6. Basic wind speed is 44m/s based on a 3 second gust; the equivalent mean hourly wind speed is 22m/s.
7. Ground conditions:

Ground level – 1.0m	Topsoil and soft silty clay
Below 1.0m	Firm clay, C = 75kN/m ²

 Groundwater was encountered 4m below ground level.

Omit From Consideration

8. Design of access to the stand.

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. Upon completion of the design the client asks whether the sides of the stand could be clad with glass, 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 connection of the flooring with the main structure.
 - (ii) The connection of the barrier railing with the supporting structure. (30 marks)
- e. Prepare a detailed method statement for the safe construction of the stand. (10 marks)

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