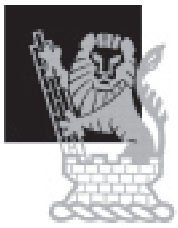


The Institution of Structural Engineers

Chartered Membership (Part 3) Examination

12 APRIL 2002

(Old examination format for reference only)

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 luncheon 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 bottom right-hand corner. 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, ie bending, shear, deflection, etc.
3. In all questions 40 marks are allocated to Part 1 and 60 marks to Part 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 ☞

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 is also has some which are unusual.

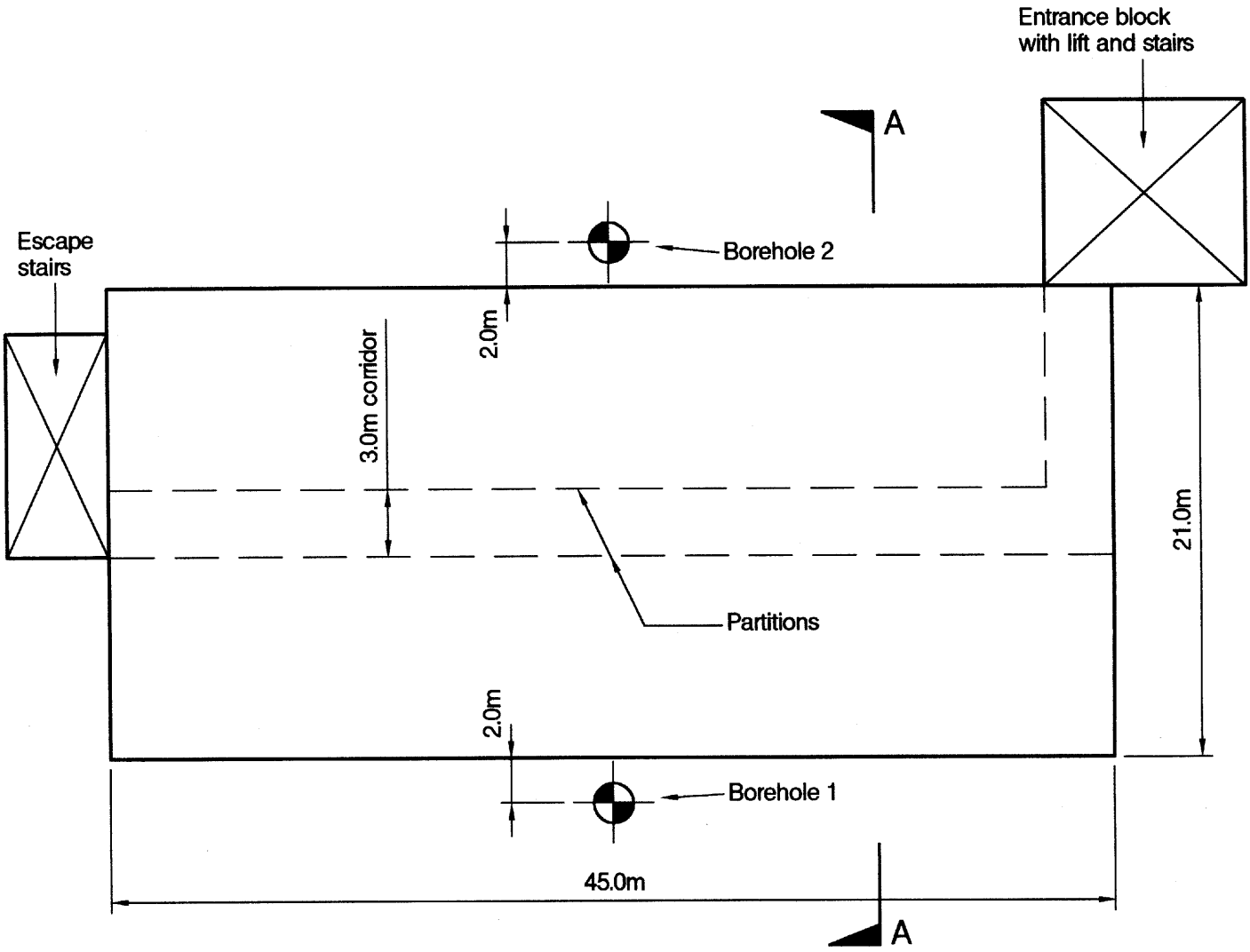
As in every examination you *must* follow carefully the NOTES FOR CANDIDATES set out for your guidance on the front cover of this paper; allocate the available time sensibly and set out your work in a logical and clear way.

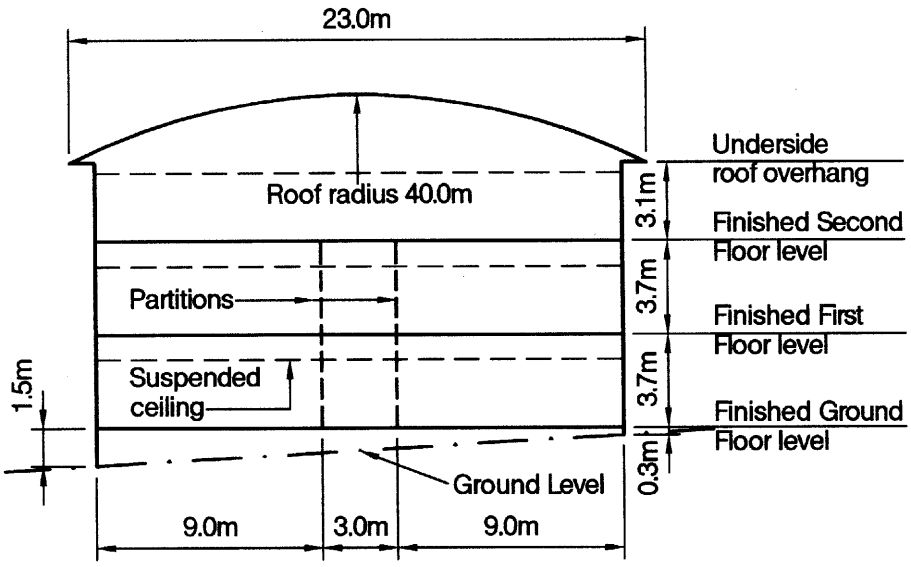
The unusual requirement of the examination is that you must demonstrate the validity of the training and experience that you have acquired in recent years. The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural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

Chartered Structural Engineers must have an 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 understand the general structural engineering design 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.





SECTION A-A

FIGURE Q1

Question 1
New Science Building

Client's requirements

1. A three storey science building with a curved roof; see Figure Q1.
2. The roof is to be clad in metal decking. The external cladding to the elevations is to be appropriate to the proposed use of the building and must incorporate a minimum height of 1.5m glazing per storey. The glazing must not be obstructed by any structural members other than columns.
3. A 0.3m clear service zone must be provided below the roof and floor structures. The clear floor to ceiling height is to be 2.7m.
4. Only one line of internal columns at first floor level and one internal column at ground floor level will be permitted.
5. The entrance block and escape stairs must not be relied on to assist in the overall stability of the building.

Imposed loading

6. Roof 1.0kN/m^2
   All floors 5.0kN/m^2
   Loading includes an allowance for partitions, finishes, services and ceilings.

Site conditions

7. The site is sloping and is situated on the outskirts of a large city.
   Basic wind speed is 44m/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 should choose an appropriate value.

8. Ground conditions:

Borehole 1	Ground level - 0.75m	Loose fill
	0.75m - 5.0m	Clay C = 100 kN/m^2
	Below 5.0m	Clay C = 150 kN/m^2
Borehole 2	Ground level - 1.0m	Loose fill
	1.0m - 4.0m	Clay C = 40kN/m^2
	Below 4.0m	Clay C = 100kN/m^2

Groundwater was encountered at 3.5m below ground level in both boreholes. The soil profile varies linearly between the two boreholes and is representative of the whole site.

Omit from consideration

9. Detailed design of entrance block and escape stairs.

PART 1 (40 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, the load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice.

b. After construction is complete, the client requests whether a basement storey can be constructed beneath the whole of the building. Write a letter to the client outlining how this might be achieved.

PART 2 (60 marks)

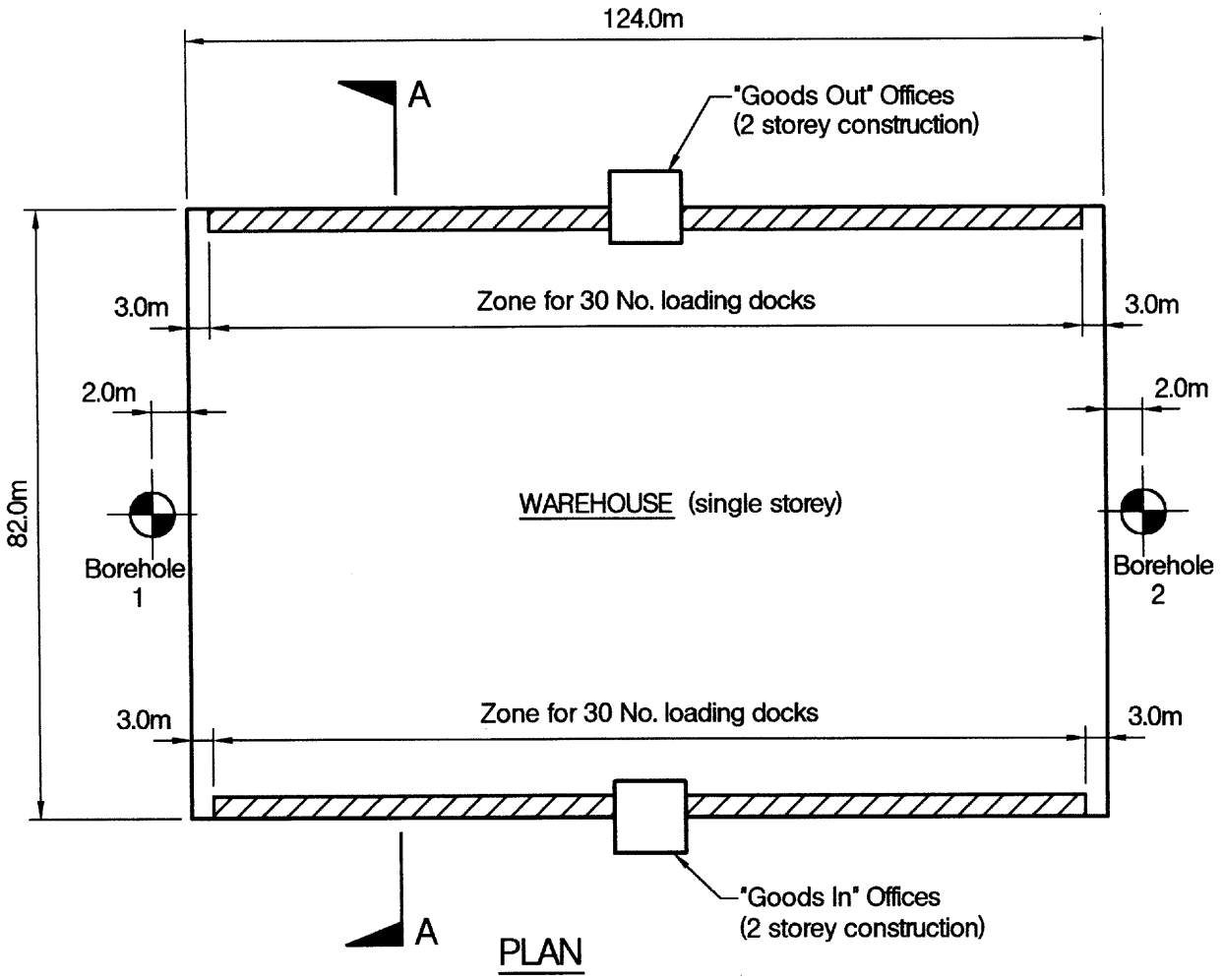
For the solution recommended in Part 1(a):

c. Prepare sufficient design calculations to establish the form and size of all principal structural elements.

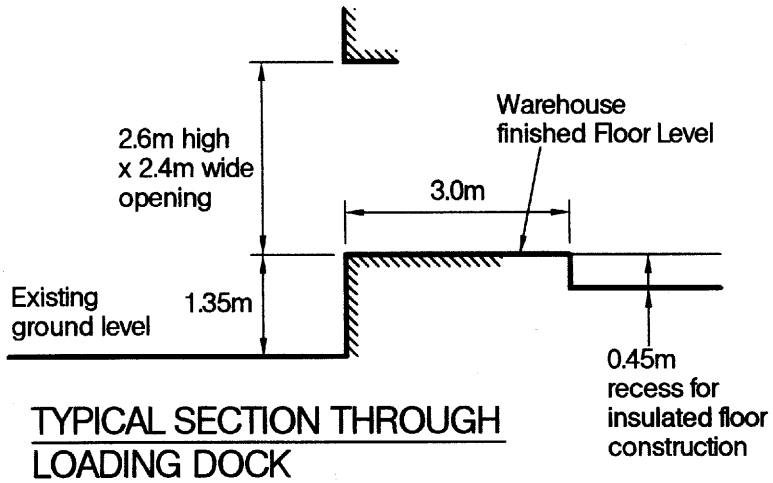
d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes.

e. Prepare clearly annotated sketches to illustrate details of:
   (i) The connection between an external column and the roof structure.
   (ii) A storey height section through the external wall showing the position of the adjacent structural elements.

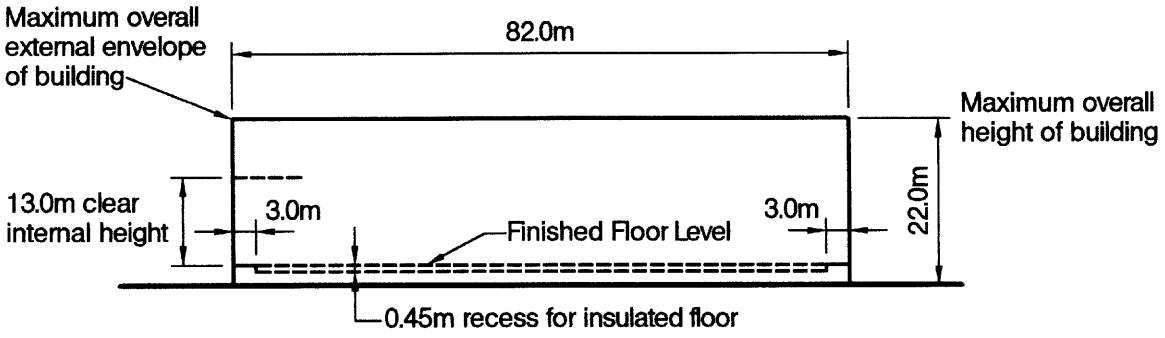
f. Prepare a detailed method statement for the safe erection of the building and give an outline construction programme.



PLAN



TYPICAL SECTION THROUGH LOADING DOCK



SECTION A-A

FIGURE Q2

Question 2
Distribution Warehouse

Client's requirements

1. A single storey distribution warehouse for frozen foods with two storey offices; see Figure Q2. The client has stated that the external walls and roof can be of any material, subject to the requirement to minimise maintenance costs and maintain hygienic conditions.
2. Two storey goods-in and goods-out offices are to be provided, each with a total floor area of 180m^2.
3. The warehouse is to be designed for flow-through of goods, and, to accommodate this, 30 loading docks are required on each side of the building. A typical detail of a loading dock is given in Figure Q2. Each loading dock comprises a 2.4m wide by 2.6m high opening in the external wall.
4. The building is limited to an overall height of 22.0m (measured above existing ground level) and must have a minimum clear internal height of 13.0m (measured between the warehouse finished floor level to the underside of any structural element, excluding the offices). The main warehouse floor slab is to be recessed 450mm to accommodate insulated floor construction.
5. No more than five internal columns will be permitted in the warehouse and the external column spacing must not be less than 7.0m (centre to centre).

Imposed loadings

6. Roof 1.5kN/m^2
   First Floor (offices) 5kN/m^2
   Ground floor 50kN/m^2
   Loadings include an allowance for services and finishes.

Site conditions

7. The site is level and situated on an undeveloped site which has regular periods of rainfall.
   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 is used in the British Standard CP3 and the mean hourly wind speed is used in the British Standard BS6399. Candidates using other codes should choose an appropriate wind speed.
8. Ground conditions:

Borehole 1	Ground level - 3.0m	Firm to stiff, becoming soft silty clay. C = 80kN/m^2 at 1m; C = 30kN/m^2 at 3m.
	3.0m - 5.0m	Highly compressive organic material.
	5.0m - 7.0m	Very soft silty clay. C = 10kN/m^2
	7.0m - 9.0m	Weathered mudstone. N = 40
	Below 9.0m	Mudstone. Allowable bearing pressure = 1500kN/m^2
Borehole 2	Ground level - 2.0m	Firm to stiff, clay. C = 80kN/m^2
	2.0m - 4.0m	Weathered mudstone. N = 40
	Below 4.0m	Mudstone. Allowable bearing pressure = 1500kN/m^2

   Groundwater was encountered at 2.0m below ground level in both boreholes. The soil profile varies linearly between the two boreholes and is representative of the whole site.

Omit from consideration

9. Detailed design of lifts and staircases and offices.

PART 1 (40 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, the load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice.

b. Following completion of construction of the foundations, the client decides that it will be necessary to reduce the internal columns to a maximum of three (excluding any in the offices). Write a letter to the client outlining how this might be achieved.

PART 2 (60 marks)

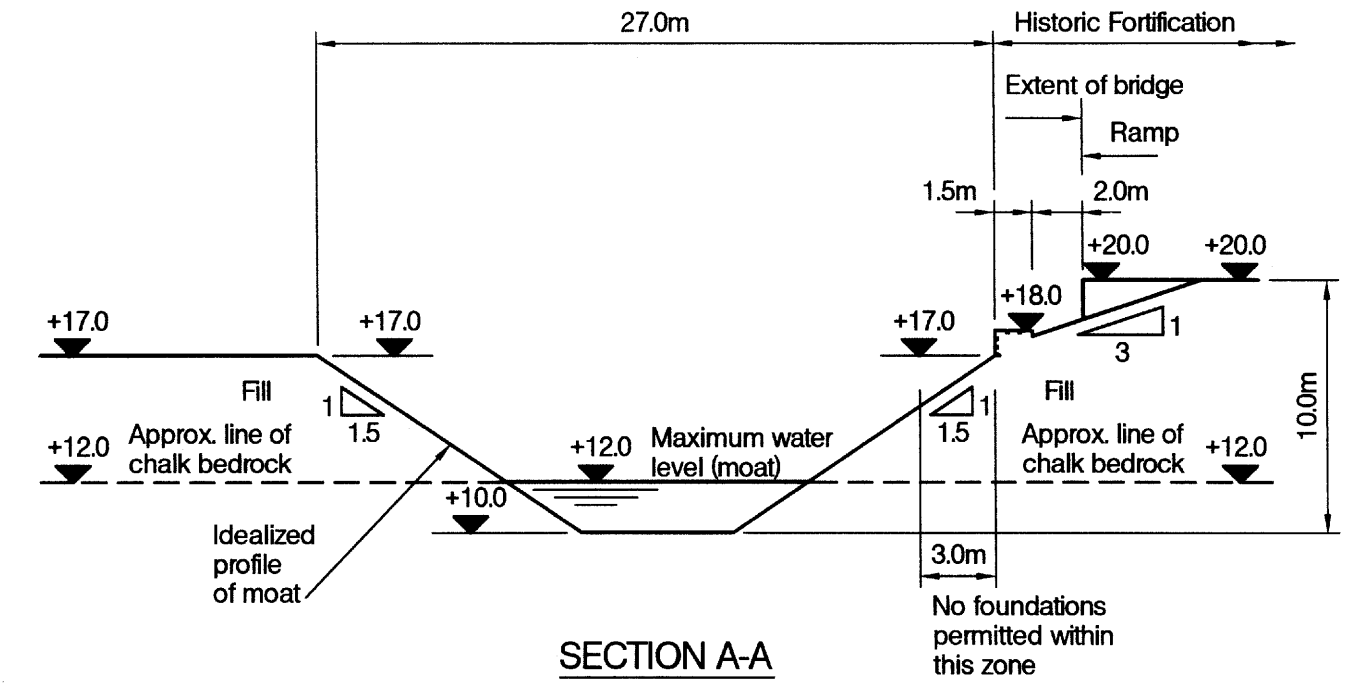
For the solution recommended in Part 1(a):

c. Prepare sufficient design calculations to establish the form and size of all principal structural elements.

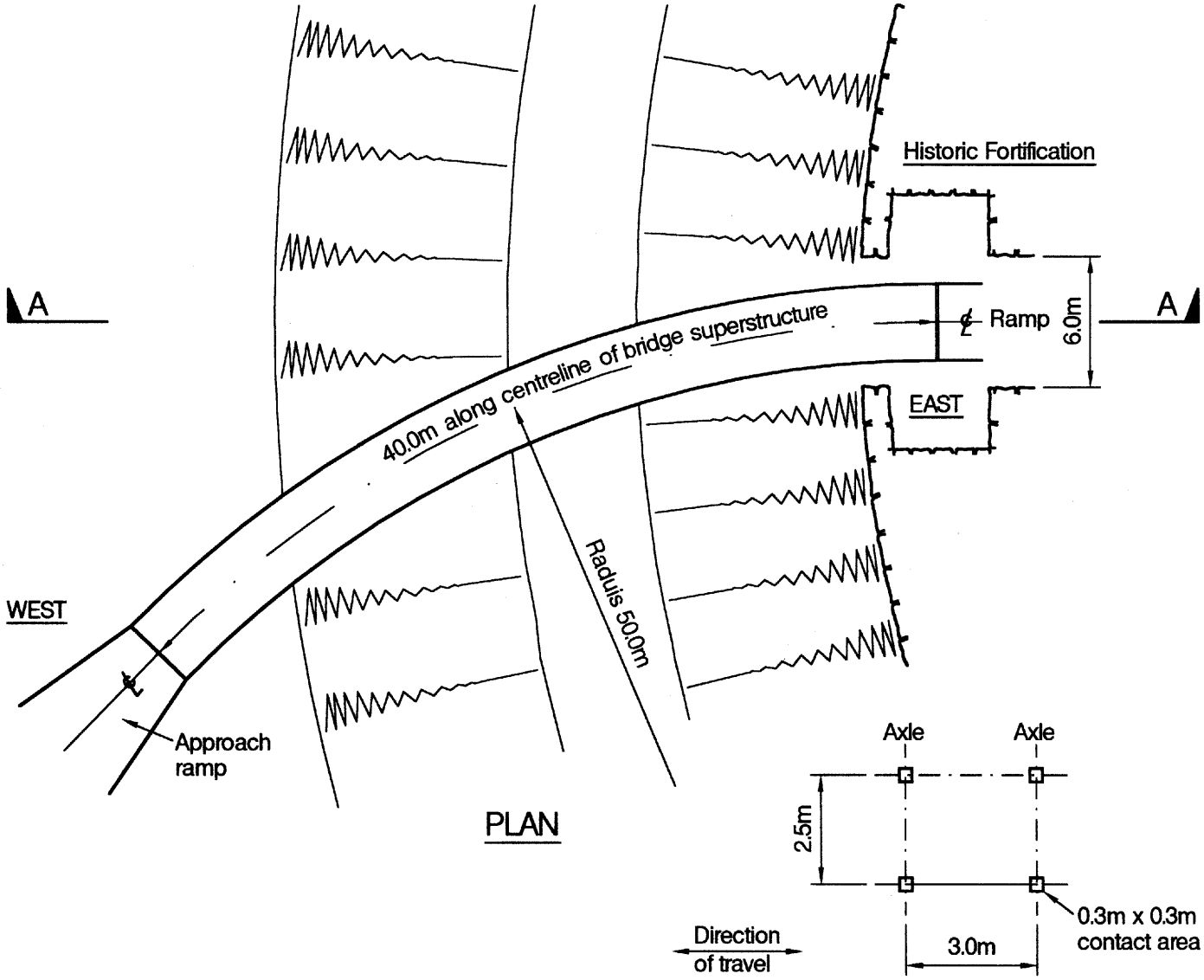
d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes.

e. Prepare clearly annotated sketches to illustrate details of:
   (i) The connection between the roof structure and an internal column.
   (ii) The detail of the junction of the external wall and roof structure.
   (iii) A section showing a main external column, the ground floor slab and foundations.

f. Prepare a detailed method statement for the safe erection of the building and an outline construction programme.



SECTION A-A



PLAN

WHEEL LAYOUT
MAINTENANCE VEHICLE

FIGURE Q3

Question 3
Access Bridge

Client's requirements

1. A new bridge to provide access across a moat to an historic fortification; see Figure Q3.
2. The site is in an area of historic importance.
3. The foundations of the bridge must not affect the historic walls or the stability of the moat.
4. The new bridge must not impose any load on the existing wall or fill within the historic fortification. No foundation shall be closer than 3.0m from the face of the wall of the historic fortification as shown on Figure Q3.
5. A 1.0m high parapet is to be provided along both sides of the bridge. The clear width between parapets is to be 3.5m.

Imposed loading

6. Vertical loading on the structure shall be a uniformly distributed load of 5.0kN/m^2 with an alternative maintenance vehicle loading of 100kN distributed equally through 4 wheels as shown in Figure Q3.

Site conditions

7. The site is on a natural chalk hillside. The chalk has a typical compressive strength of 4000kN/m^2.

Omit from consideration

8. Design of the access ramps at each end of the bridge and detailed consideration of wind loading.

PART 1 (40 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed bridge. 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 your recommended solution has been adopted and preliminary works have commenced on site it is discovered that the western abutment is located over some additional historic remains. The client asks that you increase the length of the bridge by 10.0m to span over the newly revealed historic works. Write a letter to the client explaining the implication of this change on the design, construction and cost of the new bridge.

PART 2 (60 marks)

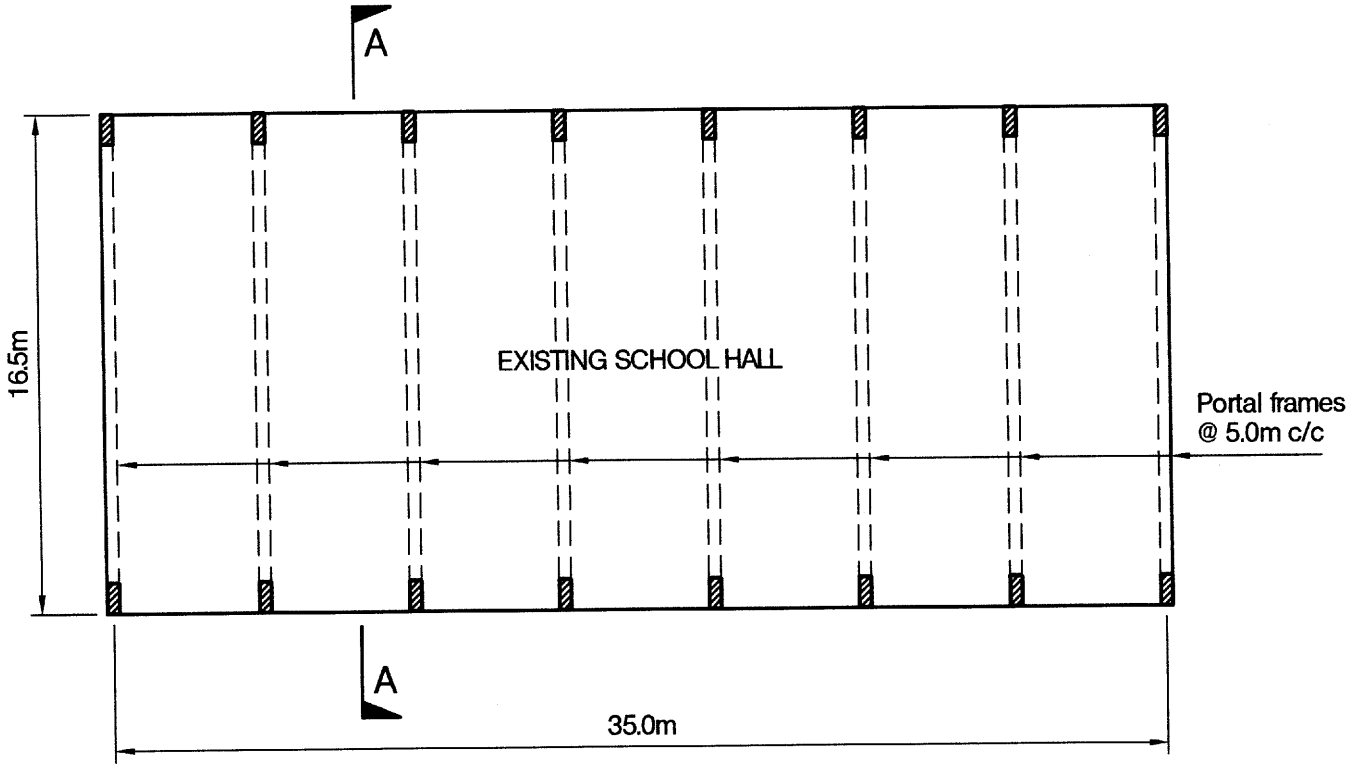
For the solution recommended in Part 1(a):

c. Prepare sufficient design calculations to establish the form and size of all 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 for estimating purposes.

e. Prepare clearly annotated sketches to illustrate details of:
   (i) A typical connection between two primary structural elements.
   (ii) The bearings, joints and provision for inspection and maintenance at the western end of the bridge.

f. Prepare a detailed method statement for the safe construction of the bridge. Describe with the aid of sketches, any major items of temporary works necessary for your recommended solution.



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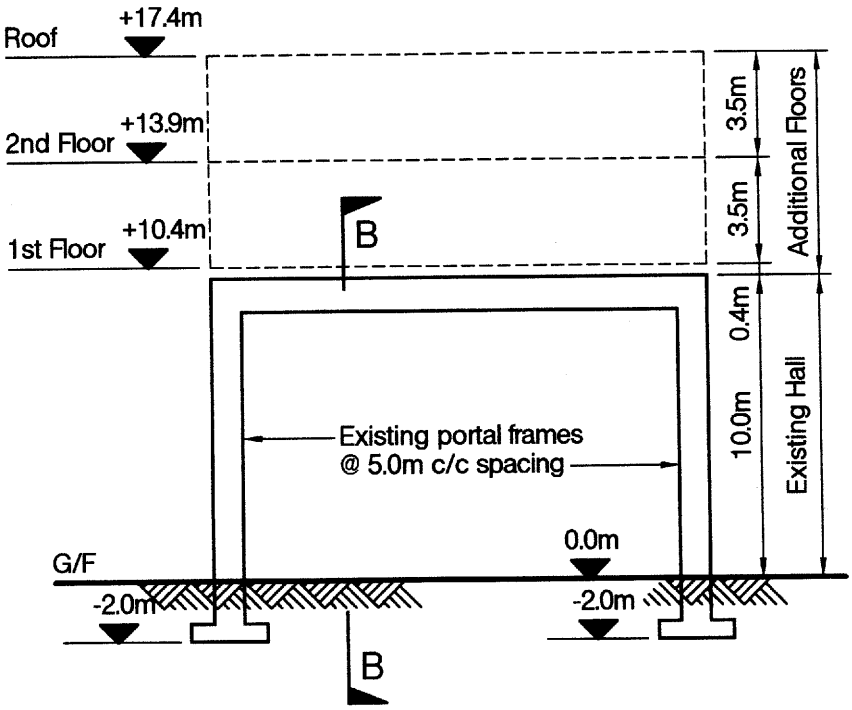
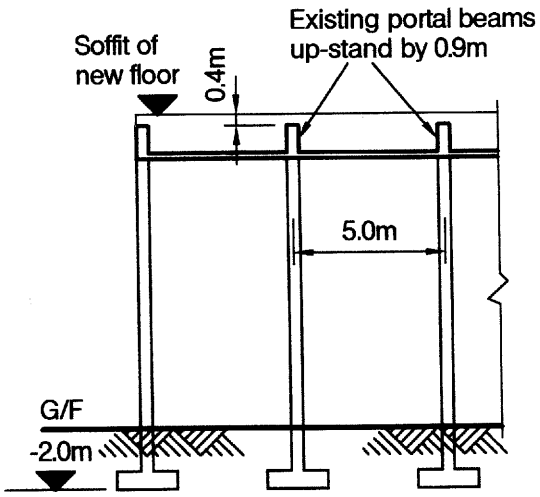


SECTION A-A



SECTION B-B

FIGURE Q4

Question 4
School Hall Extension

Client's requirements

1. A school is to be extended by adding two floors above the existing school hall for 16 additional classrooms; see Figure Q4. The proposed extension is to be clad in a lightweight proprietary sheeting.
2. The existing school hall is 35.0m long by 16.5m wide and consists of portal frames spaced at 5.0m centres. The frames are supported by 2.0m x 2.0m isolated shallow pad footings founded 2.0m below ground level.
3. The school hall must continue to operate fully during the construction period.
4. The new extension must not rely on any part of the existing hall (including its foundations) for any measure of temporary or permanent support.
5. The new extension must incorporate provision for 3 No. new staircase enclosures, each of 3m x 6m plan dimensions. There are no specific restrictions on the space to be occupied by the new structure, however, due consideration must be given to minimising the space used.
6. Cross bracing, if required, will only be permitted in the staircase enclosures.
7. A minimum structural clear headroom of 2.9m for the new classrooms is required.

Imposed loading

8. Roof $1.0kN/m^2$
   Floors $3.5kN/m^2$
   Loadings include an allowance for services and finishes.
9. The site is level and is located in a city centre.
   Basic wind speed is 44m/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 should choose an appropriate value.

Site conditions

10. Ground conditions:

Ground level - 1.5m	Made ground.
1.5m - 10.0m	Dense sand and gravel. N values vary linearly with depth from 20 to 50.
Below 10.0m	Bedrock, allowable bearing pressure = $1500kN/m^2$.

Groundwater is encountered at 5.0m below ground level.

PART 1 (40 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Identify 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 your design, the client wishes to provide an open air recreation area on the new roof. Write a letter to the client outlining how this might be achieved structurally.

PART 2 (60 marks)

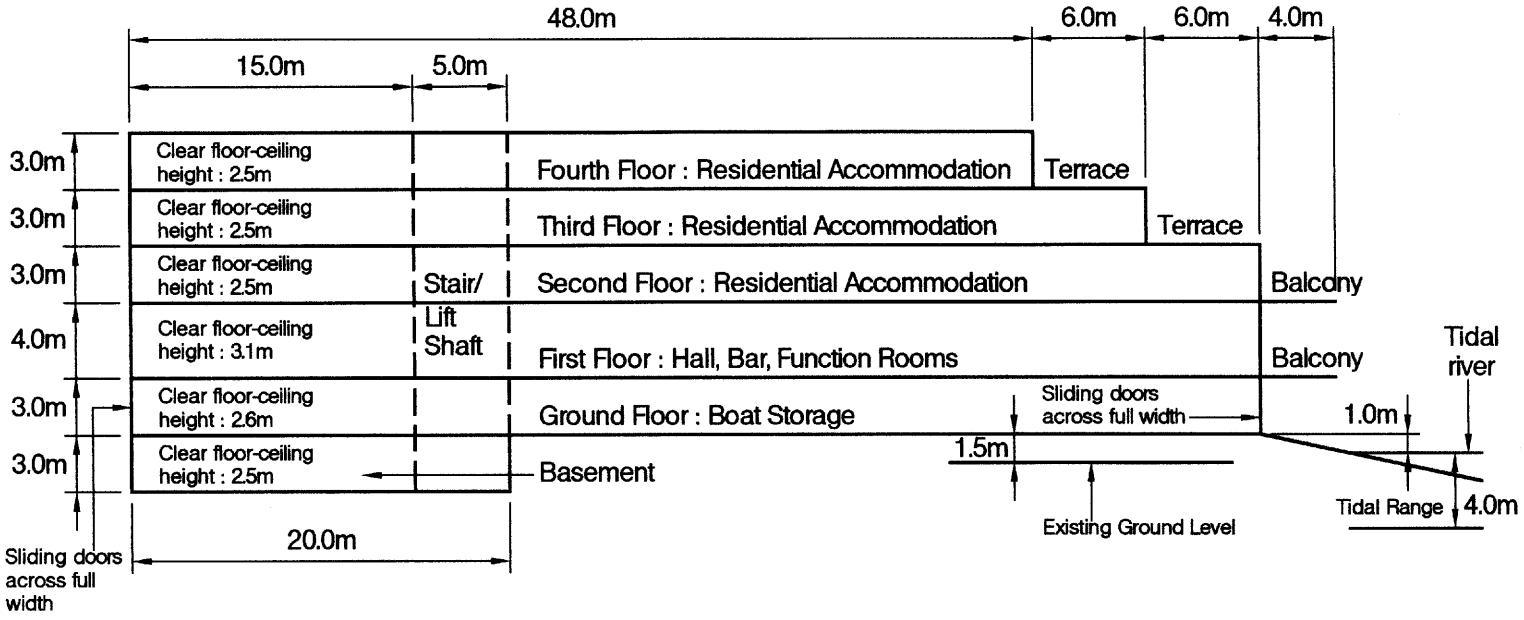
For the solution recommended in Part 1(a):

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

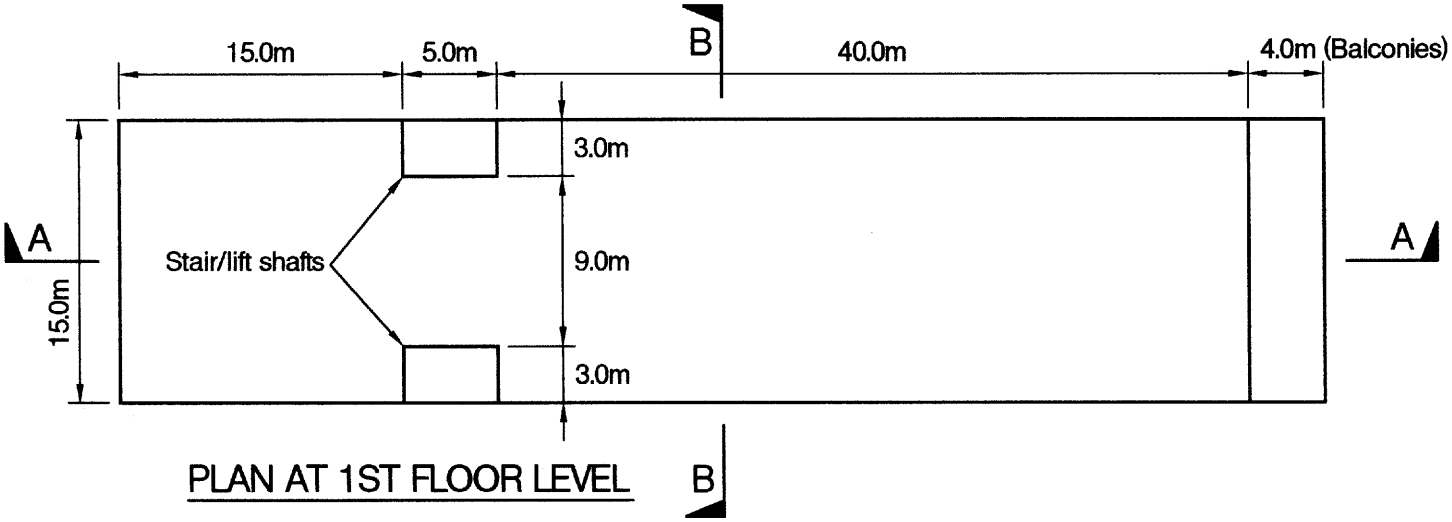
d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes.

e. Prepare clearly annotated sketches to illustrate details of:
   (i) The junction between an external support and a floor element of the new structure.
   (ii) The foundation for the supports to the new structure.

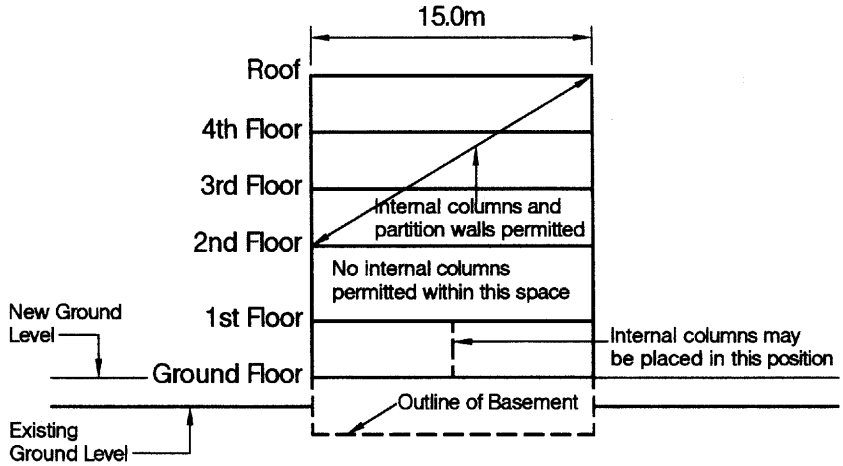
f. Prepare a detailed method statement for the safe construction of the new structure.



SECTION A-A



PLAN AT 1ST FLOOR LEVEL



SECTION B-B

FIGURE Q5

Question 5
Boathouse

Client's requirements

1. A new 6-storey boathouse for a rowing club adjacent to a tidal river: see Figure Q5.
2. The accommodation required includes a partial basement, a hall and function rooms on the first floor and residential accommodation on the upper floors.
3. The site is currently marshland, often flooded at high tide and the surrounding ground level within a 20m distance from the building is to be raised so that it is level with the ground floor of the boathouse.
4. No columns are permitted within the interior of the building on the first floor. Columns on the ground floor are permitted only along the long sides and in a single row along the building centreline. Both ends of the building at ground floor level are to have sliding doors as shown in Figure Q5.
5. A fire resistance of 2 hours is required for all structural elements.
6. Two stairwells/lift-shafts are required at the positions shown in Figure Q5, each serving all the floors.
7. Clear floor to ceiling heights are required as shown in Figure Q5.

Imposed loading

8. Roof $0.6kN/m^2$
   Residential floors (2nd floor and above),
   including residential balconies and terraces: $1.5kN/m^2$
   First floor including balcony: $5.0kN/m^2$ throughout
   Ground floor and basement: $5.0kN/m^2$ throughout
   Loadings include an allowance for services and finishes.

Site conditions

9. A level site in open countryside.
   Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/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 BS6399. Candidates using other codes and standards should choose an appropriate wind speed.
10. Ground conditions measured from existing ground level downwards:

Ground level - 3.0m	Soft mud and silt
3.0m - 5.0m	Sand, N = 8
5.0m - 8.0m	Clay, $C = 75kN/m^2$
8.0m - 15.0m	Sand, N = 12
Below 15.0m	Clay, $C = 100kN/m^2$

Omit from consideration

11. Detailed design of stairs, stairwells and lift-shafts, although their contribution (if any) to overall stability and load transfer must be stated in Part 1(a).

PART 1 (40 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure, including the proposed method of land reclamation. 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 your recommended solution has been accepted, the client requests that the basement be extended under the whole building. Write a letter to the client explaining the effects that this would have on the design of the structure.

PART 2 (60 marks)

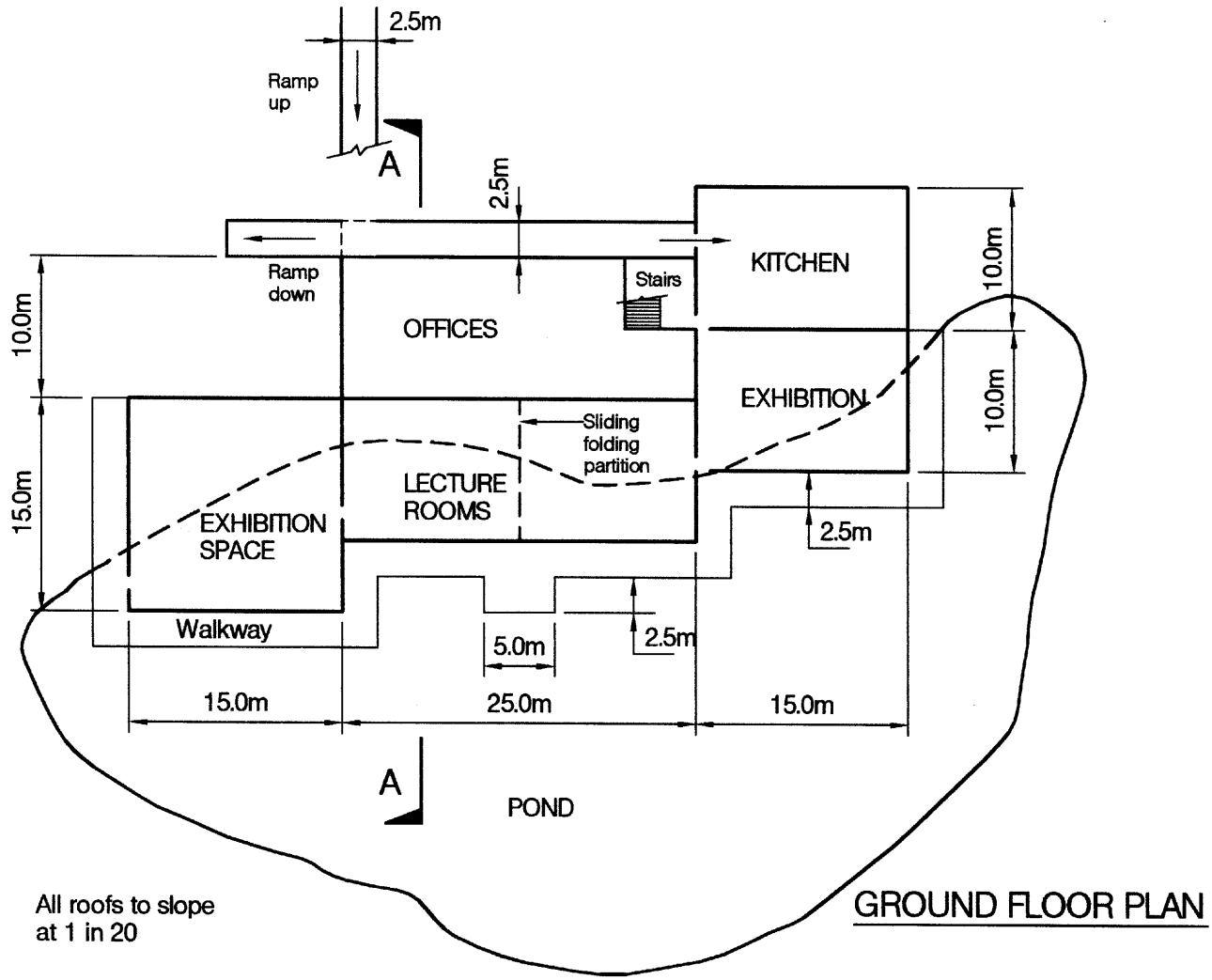
For the solution recommended in Part 1(a):

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

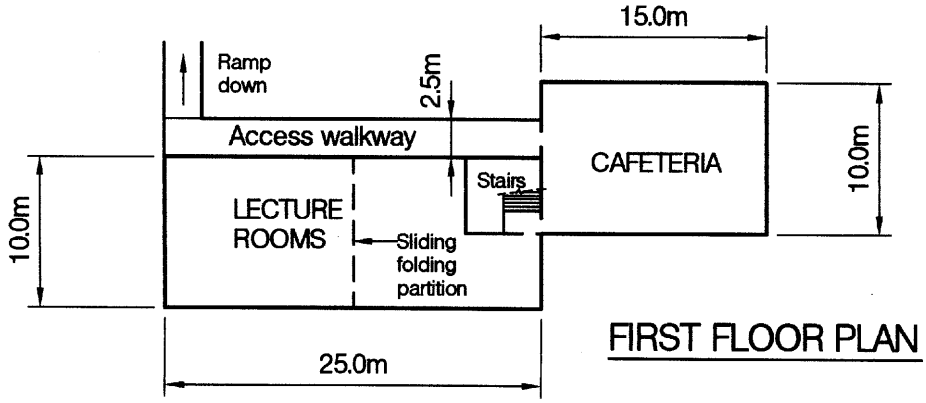
d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes.

e. Prepare clearly annotated sketches to illustrate details of:
   (i) The connection between a balcony and the main structure.
   (ii) The junction between a perimeter column and the second floor.
   (iii) The junction between the basement floor and an external basement wall.

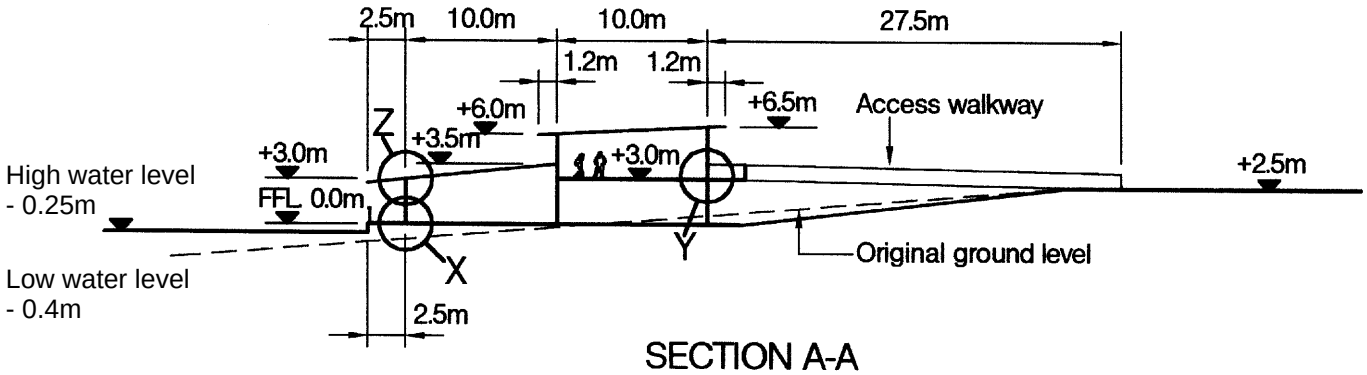
f. Prepare a detailed method statement for the safe construction of the structure, from first taking possession of the site to the stage where the ground floor has been constructed.



GROUND FLOOR PLAN



FIRST FLOOR PLAN



SECTION A-A

FIGURE Q6

Question 6
Visitors Centre

Client's requirements

1. A visitor centre building to be constructed on a sloping site in a wetlands area containing a number of open ponds; see Figure Q6. The ponds are subject to seasonal fluctuations in water level of up to 150mm. The building will house exhibitions relating to the flora and fauna of the surrounding area and will be used for lectures to students on field trips.
2. The building accommodation is on two storeys with column free spaces required in the lecture rooms and exhibition areas.
3. Clear views are required towards the ponds through glazed external walls. The materials selected for construction are to be sympathetic to the countryside setting. A preference for a grass roof covering has been expressed by the client.
4. External access to the upper floor is via a raised walkway.
5. A minimum of one-hour fire resistance is required for all structural elements.

Imposed loadings

6. Roof $0.75kN/m^2$
   Floors $3.0kN/m^2$
   Access walkway $3.0kN/m^2$
   Loadings include an allowance for services and finishes (but not the grass roof covering).

Site conditions

7. Basic wind speed is 44m/s based upon 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 established from trial pits excavated outside the existing pond areas show the following:-
   Ground level - 0.5m Soft sandy silt.
   0.5m - 2.0m Soft to firm grey silty clay. $C = 40kN/m^2$
   Below 2.0m Dense brown sandy silty gravel. $N = 30$.
   Groundwater was encountered at 0.6m below ground level in all the trial pits. Sulphate concentrations in ground water samples averaged 1.6 g/l.

Omit from consideration

9. Design of internal staircase.

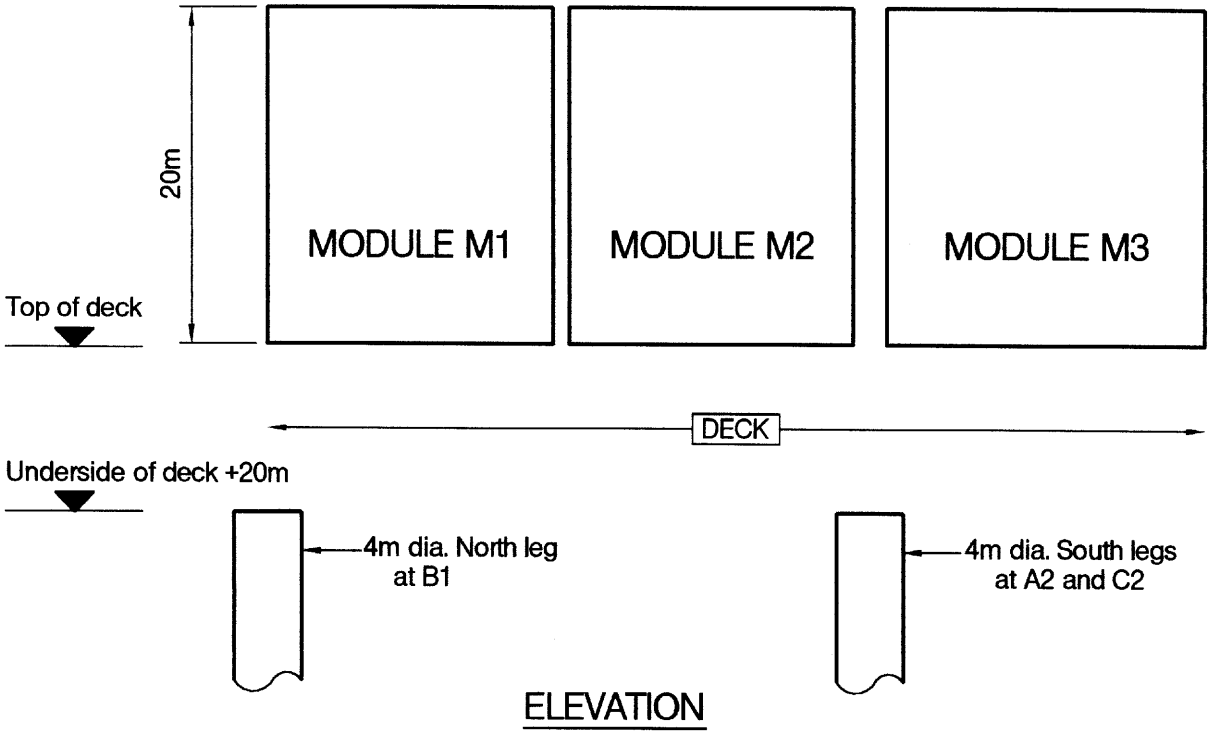
PART 1 (40 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the building. 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 the calculations and working drawings for your recommended solution have been prepared, the client asks for advice on the creation of an additional floor area of $35m^2$, having views of the ponds. Write a letter to your client explaining how this might be achieved.

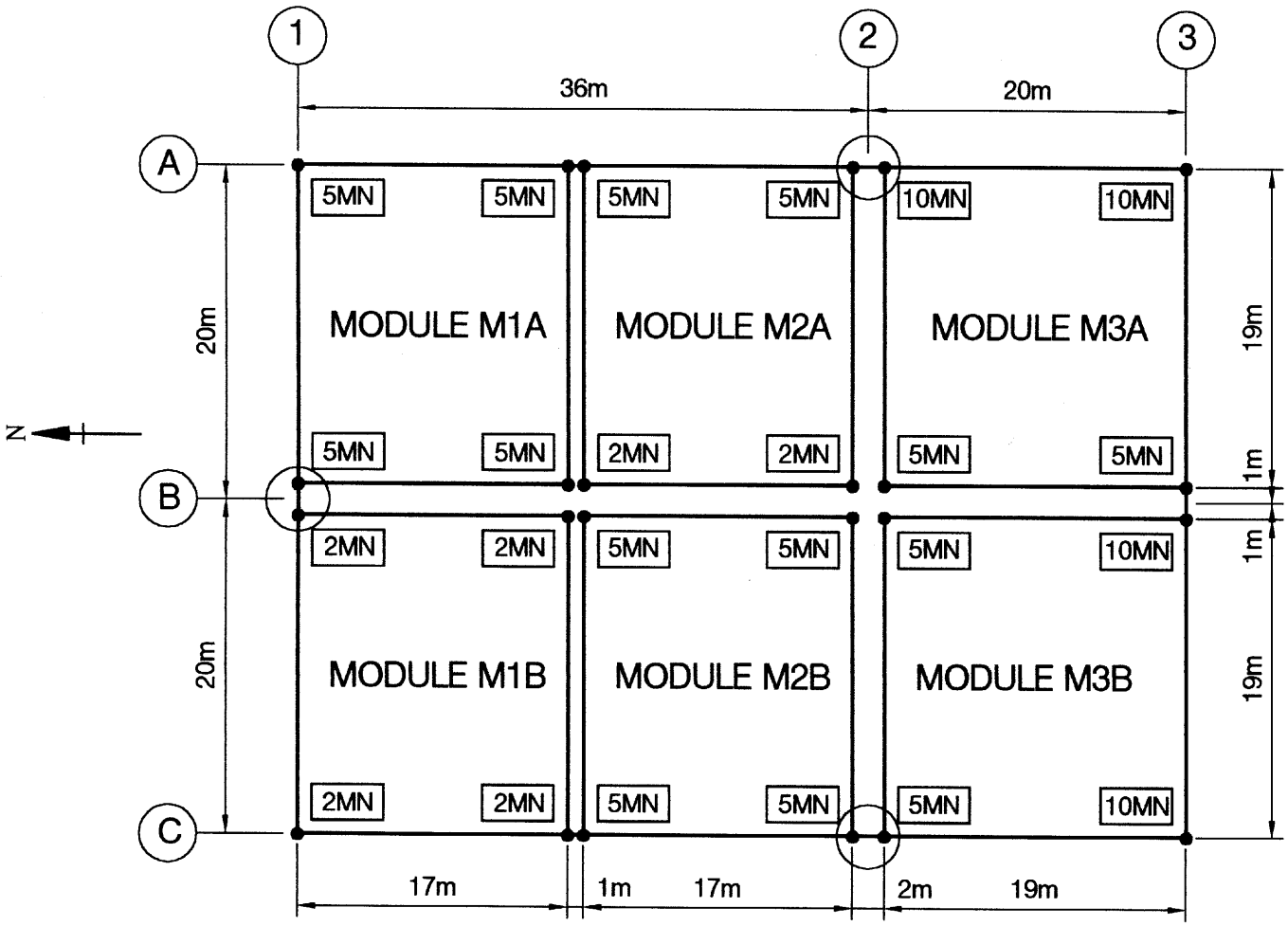
PART 2 (60 marks)

For the solution recommended in Part 1(a):

c. Prepare sufficient design calculations to establish the form and size of all principal structural elements, including the foundations and access walkway.
d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes.
e. Prepare clearly annotated sketches to illustrate details of:-
   (i) The foundation at "X".
   (ii) The connection at "Y".
   (iii) The roof detail at "Z".
f. Prepare a detailed method statement for the safe erection of the building and an outline construction programme.



ELEVATION



PLAN

FIGURE Q7

Question 7
Platform deck structure

Client's requirements

1. A steel deck for an offshore platform to be supported from a 3-leg gravity base substructure; see Figure Q7.
2. The deck, complete with process equipment housed internally, is to be mated with the substructure while the substructure is floating. The mating will take place in sheltered deep water close to the deck fabrication site. The deck will be supported from two barges (one to the North of the deck and one at the South of the deck) during the mating process. Once the deck is connected to the substructure the barges will be disconnected. Six modules (each with 4 support points) will then be installed, by floating crane, on the deck. The assembled platform is then towed to its in-place location and the substructure ballasted to rest on the seabed.
3. Due to the size of equipment to be housed in the deck, a clear volume is required within the entire deck space from grid line A to grid line C and to the South of grid line 2.
4. The top sections of the 3 substructure legs are 4.0m diameter by 50mm wall thickness.

Loading requirements

5. 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.
6. The module reactions on the deck due to self-weight and operating loads are shown on Figure Q7.
7. Equipment is located in all areas of the deck and results in an imposed load of $10kN/m^2$.
8. There is no gas in the process fluids and thus blast loading should not be considered in the design of the deck.

Omit from consideration

9. Design of the modules and the substructure.
10. Design of the deck structure for loads during the towing of the assembled platform.
11. Design of the deck for wave loads and seismic loads acting on the substructure.

PART 1 (40 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed new platform deck. In each case the design of the deck should be discussed for the load-out condition, the mating condition and the final in-place condition. Indicate clearly the functional framing, load transfer and stability aspects for both solutions and for all conditions. Identify the solution you recommend, giving reasons for your choice.

b. Having received your recommended design the client wishes to change the substructure to 4 legs (at A1, C1, A2 and C2) and to modify the deck accordingly. Write a letter to the client outlining the effects that this will have on your chosen solution.

PART 2 (60 marks)

For the solution recommended in Part 1(a):

c. Prepare sufficient design calculations to establish the form and size of all principal structural elements for the temporary and the permanent conditions.

d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements including the support points for the temporary and permanent conditions, for estimating purposes.

e. Prepare clearly annotated sketches to illustrate details of:
   (i) The connection of the deck to the top of one of the substructure columns.
   (ii) A typical module support point on the deck.
   (iii) A typical connection from one of the installation barges to the deck during the mating operation.

f. Describe a detailed installation procedure for the modules including a method that will ensure that the reactions at each of the 4 supports for each module on the (flexible) deck will be equivalent to supporting the modules on a rigid horizontal plane.