The Institution of Structural Engineers

Associate Membership Examination

(Old examination format for reference only)

9 APRIL 1999

INSTRUCTIONS TO CANDIDATE

1. The examination comprises two sessions separated by a lunch break of ½ hour, during which time candidates are not permitted to converse together. The morning session is from 9.30 a.m. to 1.00 p.m. and the afternoon session from 1.30 p.m. to 4.00 p.m. 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, on drawing paper or use a calculator during this time.

2. The candidate's index number, together with the question number and the date must be entered in the spaces provided in the answer book. The candidate's index number must also be written in the top right-hand corner of any drawings submitted.

3. One question only is to be answered; the candidate must answer parts A and B of that question and should attempt all the various sections of each part as indicated. TO OBTAIN A PASS MARK IN THE EXAMINATION A CANDIDATE MUST SATISFY THE EXAMINERS IN BOTH PARTS A AND B OF THE QUESTION SELECTED. Mark distribution is indicated by the figure against each section of the questions in the right-hand margin.

4. A proportion of marks is awarded for sound and workmanlike solutions to problems. The candidate should recognise his/her responsibility for interpreting the designer's requirements and developing them as instructions for fabrication or construction.

5. It is in the interest of the candidate that any data adopted and their source should be stated.

6. The candidate should note that data are given in both SI and British Units. Calculations may be worked in either set and answers given in either SI or British Units, but it should be noted that the two sets of data do not necessarily correspond. This is to avoid complicated arithmetic in one set of units.

7. Clear drawings are required; where sketches are asked for these should be in proportion.

8. Any calculations must be shown in the answer book.

9. A separate answer book must be used for Part A and Part B of the question.

Now read 'Reminder' on Page 3 ☞

A Reminder from Your Examiners

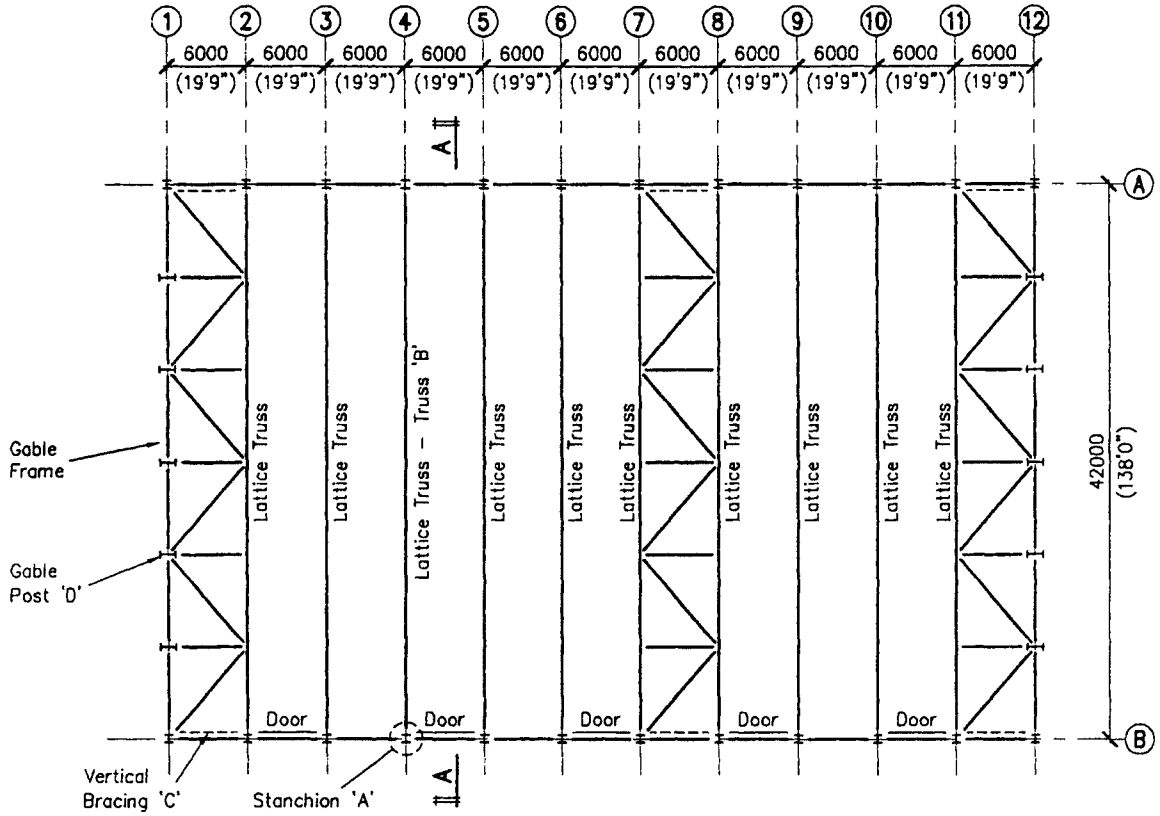
The work you are about to start has many features in common with other examinations which you have tackled successfully but it is also has some which are unusual.

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.

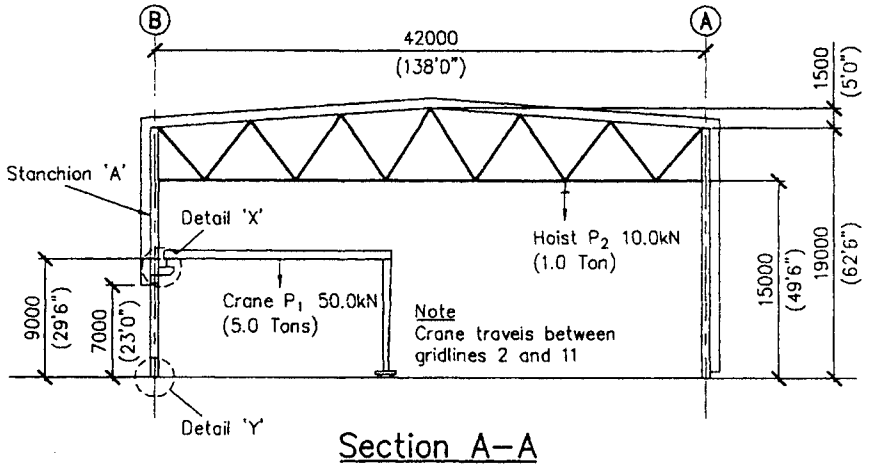
The special requirement of the examination is that you must demonstrate the validity of the training and experience that you have acquired in recent years. The Institution must be satisfied that you are able to bring all the various skills and techniques you are expected to possess to the effective solution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

An Incorporated Structural Engineer must be able to interpret instructions from an Engineer into practical structural designs and details and in addition, attend to site surveys, conditions reports on existing buildings, materials and works inspection and the supervision of new works etc.

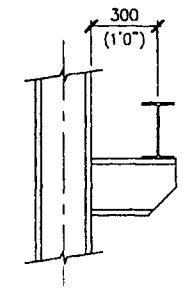
When answering the selected question in part A and B of the paper you are required to present design calculations in logical sequence so that they can be easily checked. Sketches and details must be neatly drawn and contain all the relevant information called for. Where discussion or written comment is required this must be brief, precise and clear and contain all the necessary relevant facts.



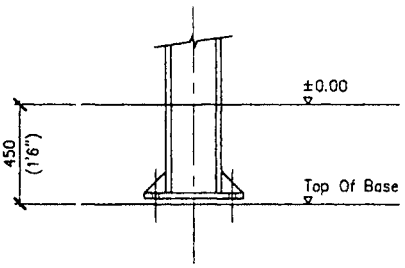
Plan



Section A–A



Detail 'X'



Detail 'Y'

FIGURE Q1

Question 1
Structural Steelwork

Figure Q1 shows the layout of a proposed industrial workshop of cantilever stanchion and lattice roof truss construction with an independent travelling crane.

Design Data

Loadings

Roof dead loading including services	0.50kN/m²	(10.0lb f/ft²)
Roof imposed load	0.60kN/m²	(12.0lb f/ft²)
Wall cladding and sheeting rails	0.25kN/m²	(5.0lb f/ft²)
Wind loading	0.60kN/m²	(12.0lb f/ft²)

Travelling crane	P1 lifting capacity	50.0kN	(5.0 Tons)
Static hoist	P2 lifting capacity	10.0kN	(1.0 Tons)
Safe ground bearing capacity at 1.50m (5'-0") depth		100kN/m²	(1 Ton f/ft²)

Steel to be S275 (Grade 43).

PART A

(i) Design the main roof lattice truss 'B', determine suitable sizes for all members for the load case 'dead and imposed' including static hoist load P2. (35)

(ii) Determine suitable sizes for:
- (a) stanchion 'A'.
- (b) gable post 'D'.
- (c) wind bracing members in roof end bay.
- (d) vertical bracing 'C' (taking account of horizontal force from crane). (20)

(iii) Prepare a detailed drawing of roof lattice truss 'B' which should also include:
- (a) fully annotated and detailed connection between truss and stanchion.
- (b) detail of splice connections between truss members with trusses delivered and erected in three sections. (25)

(iv) Prepare annotated and dimensioned details showing:
- (a) the crane rail support bracket to the stanchion.
- (b) the vertical bracing and connections to the stanchion.
- (c) the wind bracing connections to the truss at roof level. (20)

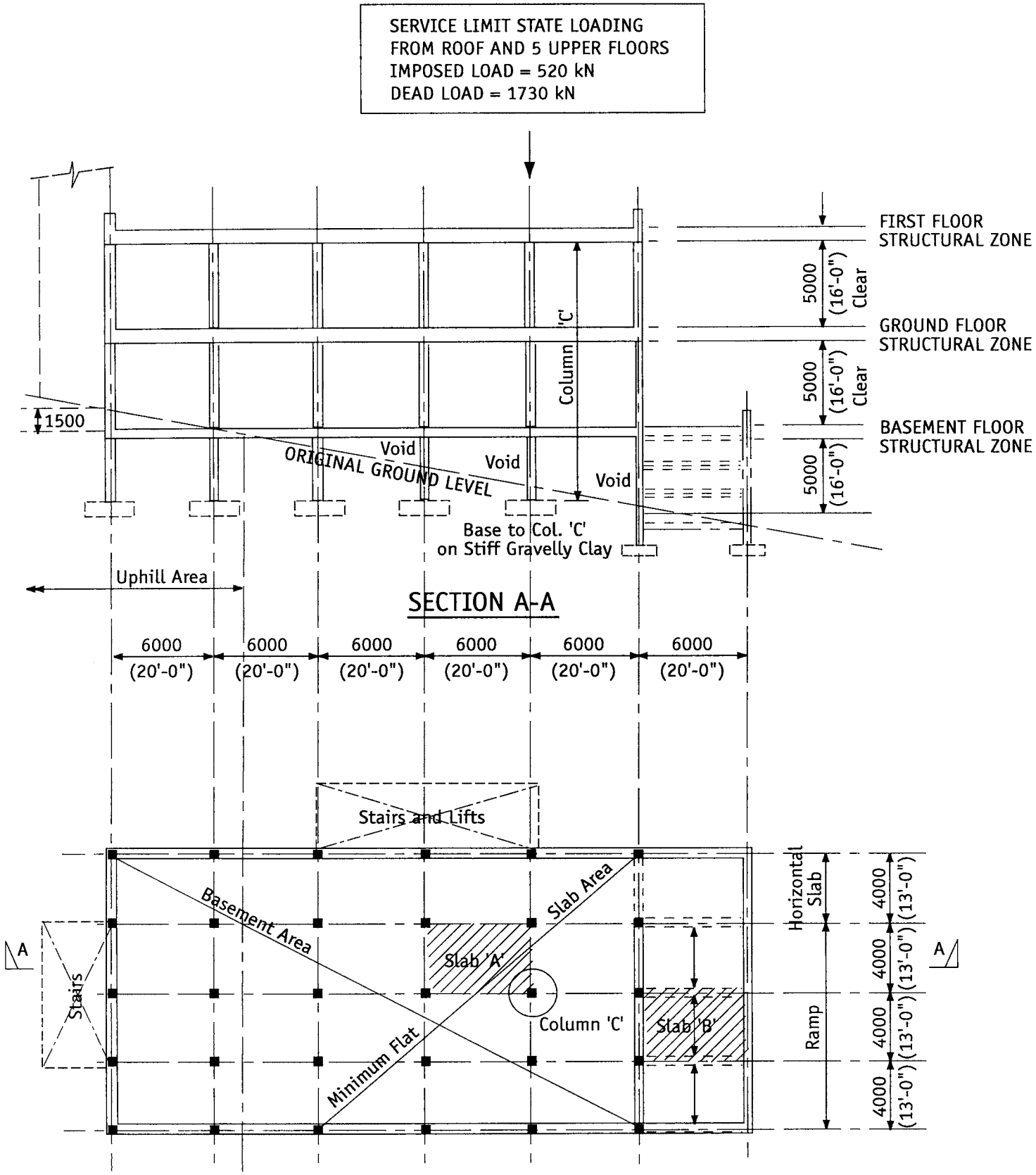
PART B

(i) (a) Determine suitable foundation sizes for stanchion 'A' and gable post 'D'.
- (b) Explain how the horizontal thrust at the foot of stanchion 'A' can be catered for without affecting the foundation design.
- (c) Prepare a typical base plate to foundation detail for a gable post. (35)

(ii) Determine the steelwork quantities for the building and present in a Bill of Quantities format. (15)

(iii) After completion the client decides to extend the building from Grid line 12 by two bays, including crane travel. Prepare a written method statement with sketches to show the sequence of the proposed work. (25)

(iv) (a) The local planners require a constant level parapet with concealed gutters to hide the roof pitch. Sketch a suitable solution and discuss the effects that this may have on the original design.
- (b) The protection to the steelwork is to have a minimum of 15 years to first maintenance. Outline two alternative paint protection systems that could be used. (25)



PLAN ON BASEMENT AREA AND RAMP

FIGURE Q2

Question 2
Reinforced Concrete

Figure Q2 shows the Plan and Elevation of a proposed car park basement for a new office building. The upper five floors are to be a steel framed structure standing on the reinforced concrete structure shown. The loads from this structure are given.

A uniform **Imposed** loading of 5kN/m^2 (100 lbf/ft^2) applies throughout the basement and on the ramp. Impact loads and wind forces are to be omitted. Lateral stability is provided by the staircase shearwalls.

The exposure rating is to be **severe**.

The allowable bearing pressure on the stiff gravely clay under the pad foundations is 250kN/m^2 (2.5 Tons f/ft^2).

All other relevant data is to be determined by the candidate and clearly stated at the beginning of the calculations concerned.

PART A

(i) (a) Determine suitable thicknesses for the **suspended** solid slabs in the basement (slab A – a "flat" slab) and the ramp (slab B – spanning one way, see Figure Q2).
(b) Determine the approximate design bending moments and shear forces in Slab A and in Slab B.
(c) Determine the reinforcement required for Slab A and also in Slab B.
(d) Determine the size and reinforcement required for a beam supporting Slab B. (25)

(ii) Determine the size and reinforcement for Column C including a square pad foundation. (15)

(iii) Draw to a suitable scale a plan and section of Slab A, giving details of reinforcement and leading dimensions. Prepare a bending schedule that includes continuity steel. Hence, prepare an estimate of slab reinforcement tonnage for the whole basement area and present this estimate in a form suitable for incorporating into a Bill of Quantities. (35)

(iv) Draw to a suitable scale an elevation, with sections, of Column C and a plan and section of the pad base. Give details of reinforcement and leading dimensions. Prepare a bending schedule. (25)

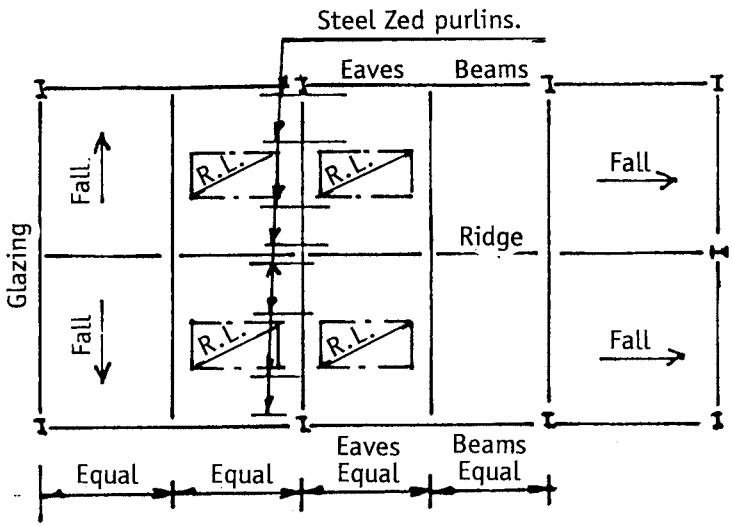
PART B

(i) With well-proportioned annotated sketches detail the construction of the basement slab in the uphill area where the existing ground has been dug away to form the basement. Include details of any joint between this slab and the suspended areas. (30)

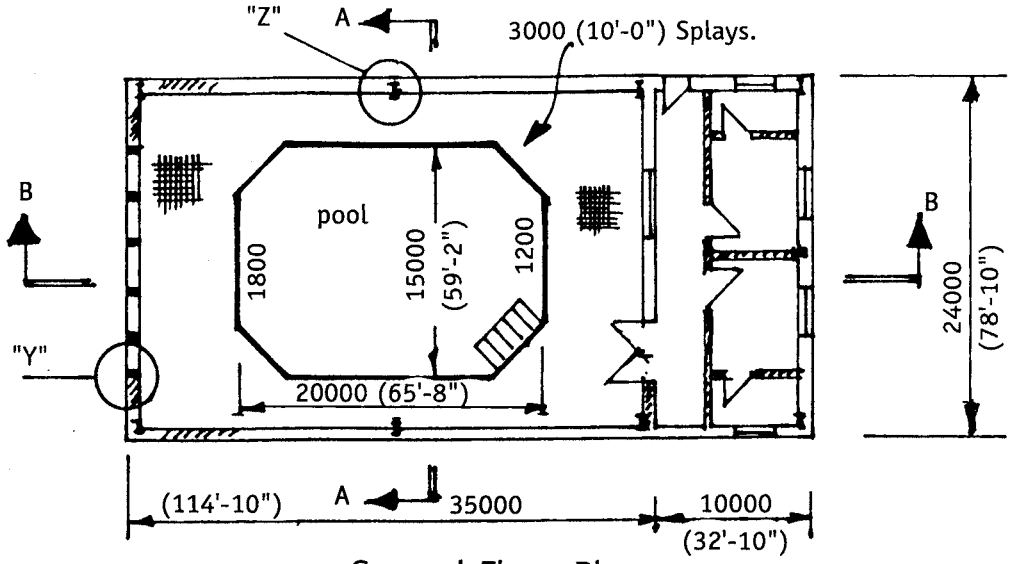
(ii) Explain how the ramp up to the basement is to be constructed safely. Illustrate each stage of the work with freehand sketches. Include details of proposed falsework and formwork. (40)

(iii) The concrete placed in some of the basement columns and suspended basement slabs has failed to comply with the cube strengths specified. Construction has continued. Write a letter recommending the actions that are now necessary. (20)

(iv) Draft specification clauses for the finishing of the basement and ramp concrete slab top surfaces. (10)



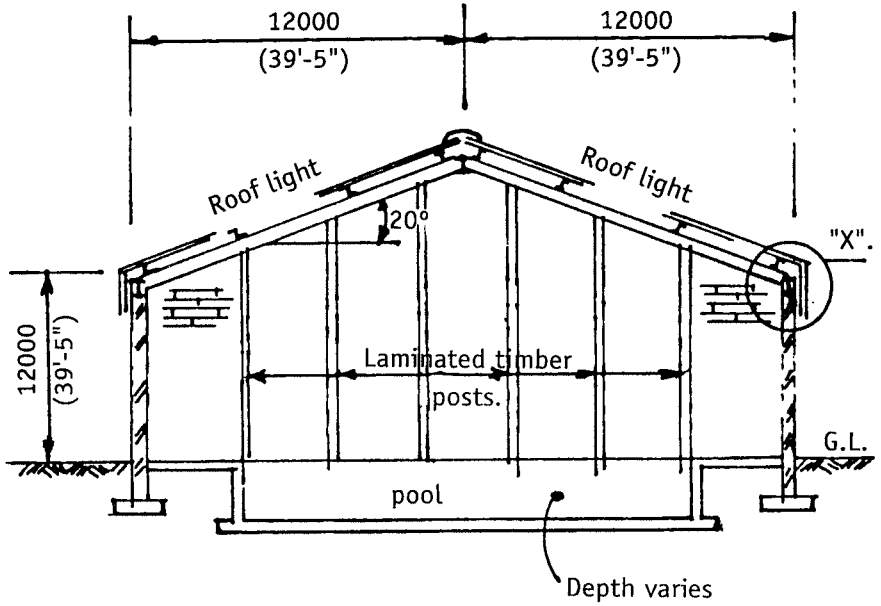
Roof Plan



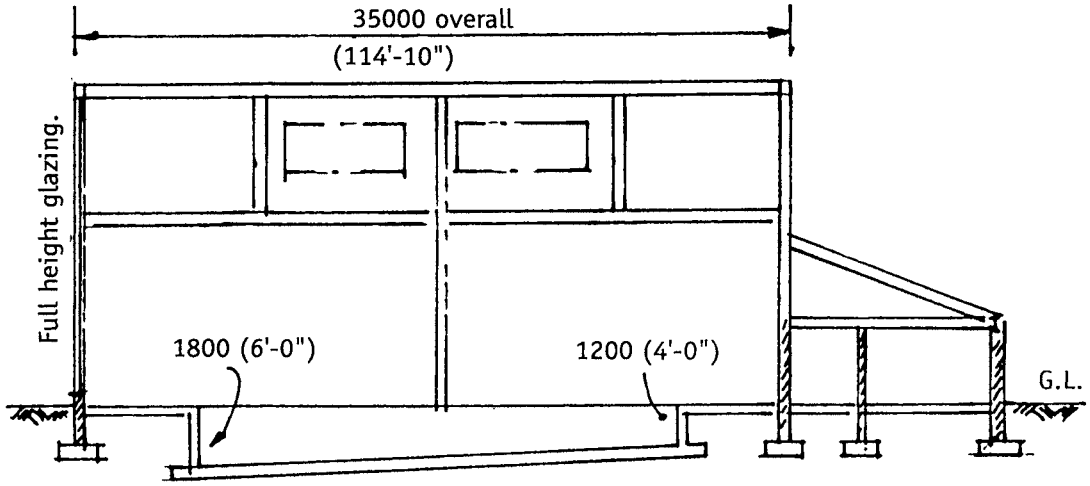
Ground Floor Plan

External wall comprises 112mm (4.5") thick outer leaf in clay bricks 50mm (2") wide cavity and dense concrete blocks inner leaf.

FIGURE Q3



SECTION A-A



SECTION B-B

Question 3
General Construction

Figure Q3 shows cross-sections and plans of a swimming pool with ancillary rooms.

The roof comprises of profiled metal decking with roof lights supported by steel zed purlins on steel portal frames. The ground floor and swimming pool are to be of reinforced concrete construction with full height glazing and laminated timber posts at the deep end. The depth of pool varies from 1.2 metres (4'-0") to 1.8 metres (6'-0").

Site investigation has revealed stiff clay with a safe bearing capacity of 150kN/m² (1½ Tons f/ft²)

Design Data

Superimposed load on roof, plan area	0.75kN/m²	(15 lbf/ft²)
Self weight of decking, insulation etc	0.4kN/m²	(8 lbf/ft²)
Wind pressure	0.45kN/m²	(9 lbf/ft²)
Timber for laminated members to have a permissible bending stress parallel to the grain	7.5N/mm²	(1100 lbf/in²)
Laminates to be 38mm (1½")		
Steelwork Grade S275 (43)		
Ground floor to be 50mm (2") thick		
Tiles on 75mm (3") screed		
Characteristic compressive strength (fk) of clay bricks outer leaf	20N/mm²	(3000 lbf/in²)
Characteristic compressive strength (fk) of blockwork inner leaf	7.0N/mm²	(1020 lbf/in²)
Mortar generally 1:1:6 (cement:lime:sand)		
Density of blockwork/brickwork	20kN/m³	(120 lbf/ft³)
Earth pressure at rest coefficient (Ko) 0.5		

All other design data to be determined by the candidate and clearly stated at the beginning of the answer.

PART A

(i) Design the following elements:
  (a) Masonry wall between portal frames.
  (b) Laminated timber posts to full height glazing elevation.
  (c) Steel portal frame over the pool area.
  (d) Swimming pool walls for empty and full condition. (30)

(ii) Design the ridge connection of the steel portal frame over pool area. (10)

(iii) Prepare drawings showing the proposed reinforcement details and bending schedules for one long wall together with a splay junction and ground slab. (30)

(iv) (a) Prepare sketches to illustrate the stability bracing system to roof and portal frames.
  (b) Detail the following connections:
    Ridge to steel portal frames,
    Masonry walling to column of portal frame,
    Lateral restraint to rafters of portal frame. (30)

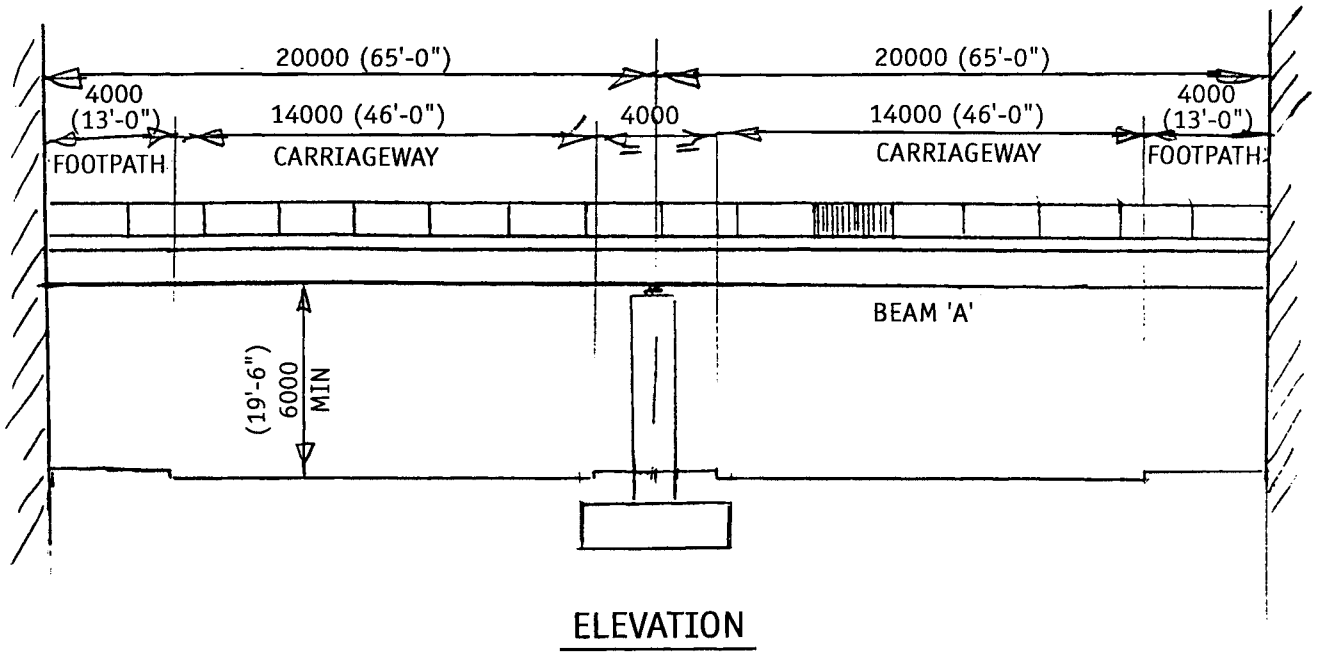
PART B

(i) With the aid of the floor plans and cross-sections describe the temporary works requirement for construction of the swimming pool. (25)

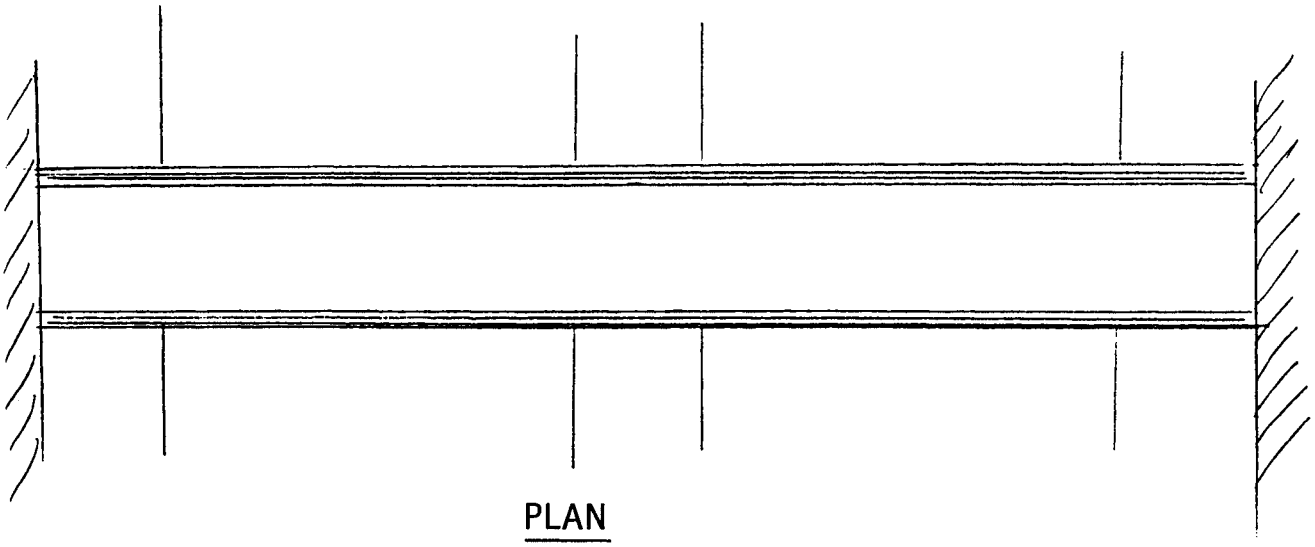
(ii) Sketch construction details at locations X, Y and Z. (25)

(iii) (a) Specify the protective paint system for the steelwork over the pool area including surface treatment to the steelwork.
  (b) Prepare a specification for the waterproofing membrane to the pool. (20)

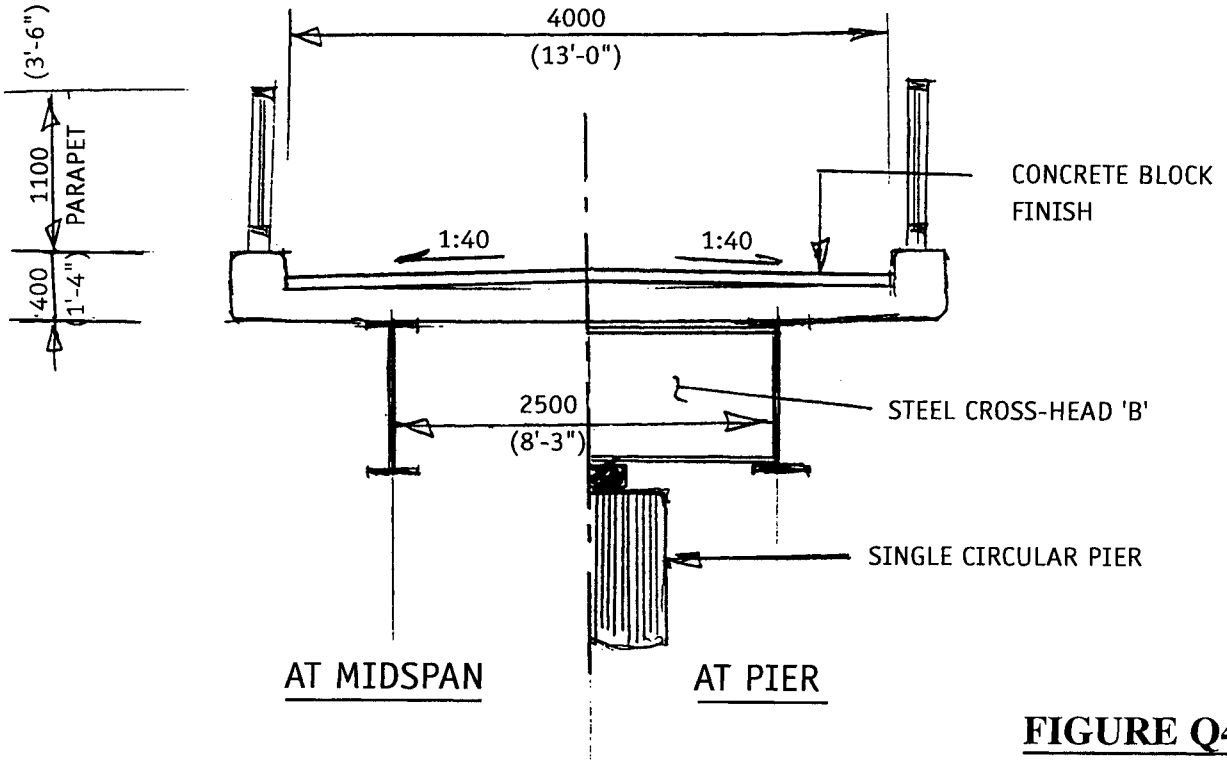
(iv) Write a method statement illustrated by supporting sketches, outlining the sequence of construction operations from start to finish. Include any temporary works except the works itemised in the construction of the pool. (30)



ELEVATION



PLAN



SECTION

FIGURE Q4

Question 4
Bridge

Figure Q4 shows a foot bridge crossing a dual carriageway road between the first floors of two buildings. The bridge is to be supported by each of the buildings on either side of the road and by a central pier in the central reservation of the dual carriageway.

The bridge deck comprises a pair of steel sections together with an in-situ concrete deck which should be designed to act compositely with the steelwork. The bridge beams should be designed continuously over the central support pier and the dead weight of the concrete deck/formwork will be carried by the steel beams during construction.

One lane of each carriageway adjacent to the central reservation may be closed continuously to allow construction of the central pier. In addition to this the entire road can be closed for 24 hour periods at weekends to allow deck construction work to take place.

Design Data

Loadings

Bridge pedestrian loading	5.0kN/m^2	(100 lbf/ft^2)	
Bridge parapet loading	1.5kN/m	(100 lbf/ft)	at the top of the parapet
Pier impact loading	500kN	(50 Tons f)	at 1m (3'-6") above road level
Safe ground bearing pressure	200kN/m^2	(2 tonf/ft^2)	at 1.5m (5'-0") depth

Grade of steel S355 (Grade 50)

Omissions
- Support details in the buildings
- Wind loadings
- Design of shear studs
- Effects of temperature, creep and shrinkage

PART A

(i) Design the suitable sizes for:
  (a) Beam A including any transverse bracings
  (b) Cross-head beam B. (40)

(ii) Determine suitable thicknesses and reinforcement for:
  (a) The deck slab
  (b) The central pier and foundation under normal and impact loads. (20)

(iii) Prepare drawings to a suitable scale showing:
  (a) Plan, sections and elevation on the bridge with all principle dimensions and construction details.
  (b) The articulation arrangements for the bridge including pier bearing shelf details.
  (c) Reinforcement details for the bridge deck, central pier and foundation including bar bending schedules. (40)

PART B

(i) Prepare a method statement, illustrated with sketches, describing the method of construction of the bridge. This should describe how the bridge will be constructed within the closure periods of the existing road and how safety aspects of the constructions will be ensured. (40)

(ii) Determine the quantities for the project and present in a Bill of Quantities. (30)

(iii) After the design of the project has been finalised, the owner of one of the buildings indicates that the structure of their building will not safely support the loading of the bridge. Write a letter to the client indicating what design options are available to resolve this situation. (20)

(iv) Discuss the problems of delivering and installing the long sections of steel beams to the site. Propose suitable locations for splices in these beams. (10)