The new Associate-Member (A-M) and Chartered Member (CM) examinations

In *The Structural Engineer* 5 November 2002, an article on 'A revised route to Membership: the Professional Review' announced that a new A-M examination will be introduced in April 2003 and a new CM examination will be introduced in April 2004.

The principal purpose of this article is to describe the format of these new examinations with the aid of example questions. Explanatory notes for the standard terms and phrases used in the new examinations are also provided.

The new examinations were developed by the Institution's Examinations Panel which reports to the Membership Committee. The development process is outlined below.

a) Two A-M questions and two CM questions were written as a first draft. The Engineering Council's requirements for Incorporated Engineer and Chartered Engineer as defined in the 1997 edition of Standards and Routes to Registration (SARTOR) informed the development of the first draft questions.
b) A second draft was developed to take account of the feedback provided by several senior members of the Institution.
c) The third draft was produced following extensive discussions with the current chief examiners for the A-M and the Part 3 examinations. The chief examiners have considerable experience in marking and setting the current A-M and Part 3 examinations.
d) Further feedback on the third draft proposals was obtained from the Council of the Institution and many of its Branches and Divisions (UK and overseas).

The final versions of the example questions are presented below. The new examinations will be subjected to the same rigorous procedures used by the Institution as described in the article 'An overview of the Institution's examination's process' published in *The Structural Engineer* 19 March 2002.

Candidates sitting the new A-M and CM examinations will each be permitted a maximum of 7 hours to answer one question. A-M candidates will be able to choose from six questions whereas CM candidates will have a choice of seven questions as is the case with the current CM (part 3) paper.

A commentary on the example questions

A-M Examinations – general matters
These questions aim to test the candidate's ability to develop a detailed solution for a relatively routine, non-trivial structural engineering problem. Successful candidates will have demonstrated a thorough grasp of the principles of structural engineering design and practice. It is expected that several alternative solutions will be considered before the single viable solution is proposed by the candidate. It is expected that candidates will make use of annotated sketches when developing their proposed solution.

The detailed design of the principal structural elements, including the foundations, should not present a major problem to the experienced candidates but will, nevertheless, demonstrate a level of competence expected of an Incorporated Engineer (and Associate Member of the Institution). Candidates are expected to demonstrate that they can produce coherent, logical and sufficient calculations to substantiate the proportions and form of their structure in accord with the provision of a robust, stable and buildable solution.

In addition to demonstrating their drawing and sketching ability, the drawings provide an opportunity for candidates to demonstrate the importance of specifying details that are appropriate for stable, robust and buildable forms of construction. The candidate's knowledge of construction, construction process and temporary and permanent stability will also be tested in 2e.

Question 1 - River Footbridge (A-M Examination)
The span between the top of the river banks is approximately 46m and so it is possible to offer a number of single span alternatives. Alternatively, single or double supporting piers may be provided with a simple or continuous deck. It is stated that the bridge is in an area of 'scenic beauty' and so consideration of aesthetics is expected. A range of materials and their relative merits should be considered. The ground conditions are not particularly onerous. It would be a violation of the brief to place the piers within the high water limit.

Although a more sophisticated solution might be considered, for example a cable stayed footbridge, A-M candidates would not be expected to offer this as their proposed solution.

The client's request (in SECTION 1b) should not present too many problems for a competent candidate who should be aware of the consequences of the point loads from the vehicle wheel loads as compared to the uniformly distributed loading quoted in the original brief.

Question 2 - University Engineering Building (A-M Examination)
This question has a relatively closed form, i.e. a construction envelope and minimum column centres are defined. Nevertheless the candidate has the freedom to develop a roof profile and a structural arrangement for the building that will require a fairly broad knowledge and experience of structural engineering design and construction.

The candidate is also required to have a knowledge of simple ground conditions, including the influence of groundwater, and how these can be interpreted to form a set of parameters for the design of the foundations for the building.

A range of different structural solutions is possible; these could involve various combinations of *in situ* concrete, precast concrete and structural steelwork including composite action. The candidate is expected to demonstrate a knowledge of providing stability against lateral loading through the use of floor plate action and the lift shafts and stair wells.

The client's request (in SECTION 1b) requires the candidate to demonstrate a broad knowledge of basement construction in water-bearing ground.

C-M Examinations – general matters
These questions aim to test the candidate's ability to develop detailed solutions for challenging structural engineering problems. Successful candidates will have demonstrated a thorough grasp of the principles of structural engineering design and practice. It is expected that several alternative solutions will be considered before the viable solutions are proposed by the candidate. It is expected that candidates will make use of annotated sketches when developing their proposed solutions.

Candidates are expected to demonstrate that they can produce coherent, logical and sufficient calculations to substantiate the proportions and form of their structure in accord with the provision of a robust, stable and buildable solution.

In addition to demonstrating their drawing ability, the drawings provide an opportunity for candidates to demonstrate their ability to identify the critical elements of their proposed solution. The candidate's knowledge of construction, construction process and temporary and permanent stability will also be tested in 2e.

Question 3 - River Footbridge (CM Examination)
There are a number of constraints imposed by the brief which make this question challenging: the difference in level between the upper bridge and the river bank; the restrictions on the length of any of the members to 12m; and the provision of access to and from the riverside footpath. Candidates are expected to consider a range of possible materials including steel, aluminium, concrete, timber, composites etc. and a range of structural forms (mindful that the bridge is in a beauty spot) including Vierendeel and truss girders, cable stayed, suspension, space frames etc. A discussion of the relative merits of the possible schemes is a central element of a successful script and this should be substantiated by 'rough' calculations. Two distinct and viable solutions should be offered. This should not be difficult for a competent candidate but he or she should present a robust discussion substantiated by appropriate and sufficient calculations.

The requirements to reconsider the efficacy of the solution in the light of the new loading will test the candidate's attention to detail, particularly with regard to connections and load distribution.

Calculations should substantiate principal members and global stability – both for the complete structure

and also for the critical temporary condition during construction. The general arrangement drawing should allude to the construction procedure as it is critical to the appropriateness of the solution. It will also enable the answer to 2e to be presented more easily.

Question 4 – Headquarters Office (CM Examination)
The disused quarry provides the main challenge in this question. The 20m zone between the quarry bottom and the ground floor of the proposed building will provide ample opportunity for good candidates to propose alternative foundation solutions ranging from piling through the filled quarry to the use of a braced frame support. The upper part of the superstructure has overhanging floors. This will permit candidates to offer a range of solutions including suspension from the upper floors. No specific details for the central core of the building have been provided in order to allow the candidate freedom to consider a range of possible alternatives which must be clearly described and appraised when developing the two viable solutions.

Section 1b provides the opportunity for candidates to use the quarry space to provide the required car parking spaces over four floors.

terms and phrases used in the questions

Design appraisal
A detailed description of a viable structural solution for the scheme (A-M exam) or schemes (CM exam). This will normally include consideration of a number of ideas and a reasoned argument to demonstrate the evolution of the candidate's preferred solution(s). Reference should be made to stability, economy, robustness, buildability, durability and safety. With the CM examination, candidates will be expected to consider a broader range of alternative materials and structural forms than an A-M candidate. In addition, the challenges posed by the CM examination questions will require a more innovative, less standardised approach than the A-M examination questions. This reflects some of the principal differences between Chartered and Incorporated Engineers (Associate-Members) identified by the Engineering Council.

Appropriate sketches
It is expected that these will be free-hand sketches that are approximately to scale. They should normally have sufficient detail to clarify the main points referred to in the design appraisal.

Viable structural solutions
These are economical structures that comply with the client's brief and that can be constructed safely. In the case of the CM examination, two distinct and viable solutions are required. It is expected that distinctly different solutions will involve the use of different structural arrangements and action to transfer all the applied loads to the supporting ground. It will not be acceptable to propose two solutions with relatively minor differences, e.g. the use of reinforced concrete flat slab floors instead of beam and slab floors. Similarly, replacing structural steel beams and columns with insitu reinforced concrete beams and columns in a building frame would also not be considered to be distinctly different as the basic structural arrangement and actions are very similar in both cases.

Functional framing
How the structure is idealised or modelled in terms of structural behaviour and function, e.g. the type of connections, the stiffness of the individual structural elements and the entire structure, support conditions and the nature of the foundations.

Load transfer
How loads from any direction and source (e.g. dead, imposed, wind, thermal, wave, seismic, etc, as appropriate) are distributed through the structure from their point of application to the supporting ground.

Stability aspects
This refers to both global and local stability of the structure and its elements.

Explain the effect of…
This should be a detailed technical explanation, in terms understood by a non-engineer, of the implications of the change outlined in the question.

Sufficient design calculations
This is not intended to be a very detailed set of calculations to satisfy every clause in a code of practice! It is expected that the candidate will identify the principal structural elements (see below) and produce calculations to verify the resistance of each to the major load effects such as bending, shear, axial load, torsion and buckling, as appropriate. It is expected that the candidate will use and justify approximate methods of analysis to determine the major load effects. Candidates should not waste time producing repetitive calculations. They should identify the critical parts of their proposed structure and concentrate on demonstrating adequate strength and stiffness.

Form and size of all principal structural elements
The principal structural elements means all the main structural members, e.g. beams, columns, slabs, trusses, frames, foundations (including piles, where appropriate), etc.

Explanatory Notes - standard

Question 1: River footbridge

Client's requirements
1. A new footbridge to provide pedestrian access across a river in a region of scenic beauty: see Figure Q1.
2. The bridge must have no permanent support in the central regions below the higher water level.
3. Pedestrian guard rails 1.5 m high shall be provided at both edges of the bridge deck.
4. The footbridge must have a clear width of 2.0m between the inside faces of the pedestrian guard rails.

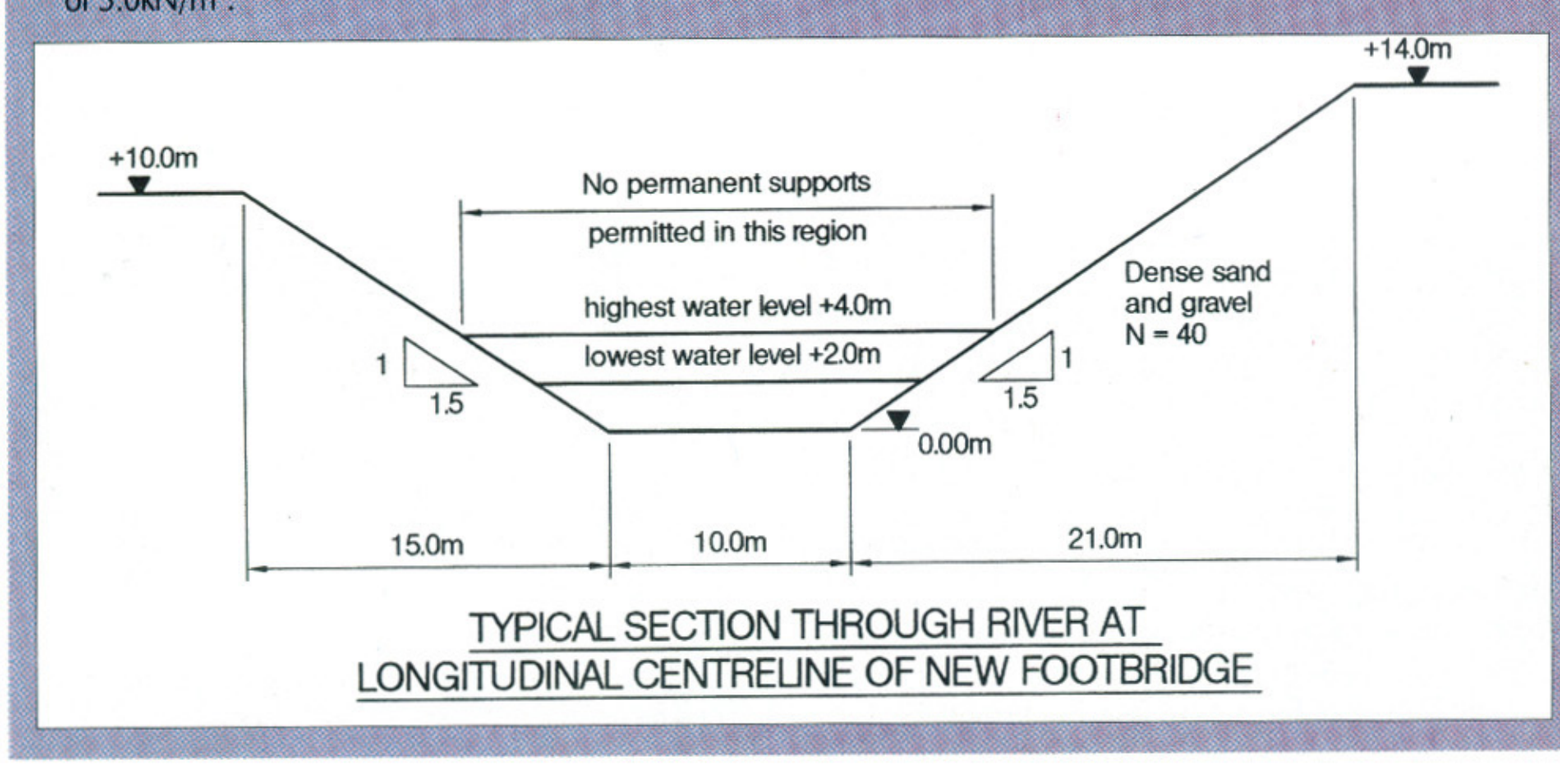
Imposed Loading
5. Imposed vertical loading on the bridge shall comprise a uniformly distributed pedestrian loading of 5.0kN/m^2.

Site Conditions
6. The site is situated in a region of great natural beauty. 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 6399. Candidates using other codes and standards should choose an appropriate equivalent wind speed.

7. Ground conditions:
   Typical ground conditions are shown in Figure Q1.

Omit from consideration
8. Detailed design of the pedestrian guard rails.



TYPICAL SECTION THROUGH RIVER AT LONGITUDINAL CENTRELINE OF NEW FOOTBRIDGE

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. After your recommended solution has been approved in principle, the client asks if it is possible to adapt the design to accommodate a 1.5m wide maintenance vehicle with a maximum weight of 50kN supported on 2 axles, each with a 2.5m wheel base. 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) The bridge deck articulation /bearing details.
(ii) The pedestrian guard rail and its connection to the deck. (25 marks)
e. Prepare a detailed method statement for the safe construction of the bridge. (10 marks)

The form of these members refers to their shape, i.e. I-sections, tubular sections, box girders, etc.

General arrangement plans, sections and elevations… for estimating purposes
It is expected that these would include all the principal structural members (including the foundations), any bracing, outline connection details, cladding, roofing and other structural engineering features together with supporting notes to enable an estimator to derive a budget cost for the structure.

Critical details (CM examination only)
The onus is on the candidate to select what he or she considers to be the critical structural details, i.e. those that have a major influence on the construction and performance and that influence other disciplines, e.g. building services engineers, architects and specialist contractors.

Annotated sketches (A-M examination only)
These hand-drawn sketches must be accompanied by a series of descriptive notes to convey to the examiners the important aspects of each detail.

Detailed method statement for the safe construction of...
This is a step-by-step description of the logical sequence of the main construction operations required to build the proposed structure. The description should include reference to any major items of temporary works and, where appropriate, clear reference must be made to specific measures required to ensure the safety and stability of the structure and the health and safety of site staff and members of the public.

Question 2: University Engineering Building

Client's requirements

1. A three storey building for a university civil and structural engineering department; see Figure Q2.
2. The local planning authority has stipulated that none of the permanent works must extend beyond the permitted construction envelope shown on section A-A of Figure Q.2. The roof can be of any shape but no part of it must have a gradient of less than 1 (vertical) to 10 (horizontal).
3. The ground floor of the building is to accommodate a variety of laboratory facilities and is to have a minimum clear headroom of 6.0m throughout. The first and second floors, which will be used to support classrooms and staff offices, are to have a minimum clear headroom of 3.0m and a corridor which is to be at least 3.0 m wide and free of columns, as shown on section A-A of Figure Q.2.
4. Columns must be spaced at least at 5.0m centres throughout the building.
5. The building elevations are to be clad in brickwork and the roof is to support clay or concrete tiling. All rooms, including the laboratories are to have elevations with clear glazing forming at least 50% of the elevation.

Imposed Loading

6. Roof: 1.5kN/m²
   First and second floors: 4.0 kN/m²
   Ground floor: 20.0kN/m²
   The roof and floor loads include an allowance for partitions, finishes, services and ceilings.

Site Conditions

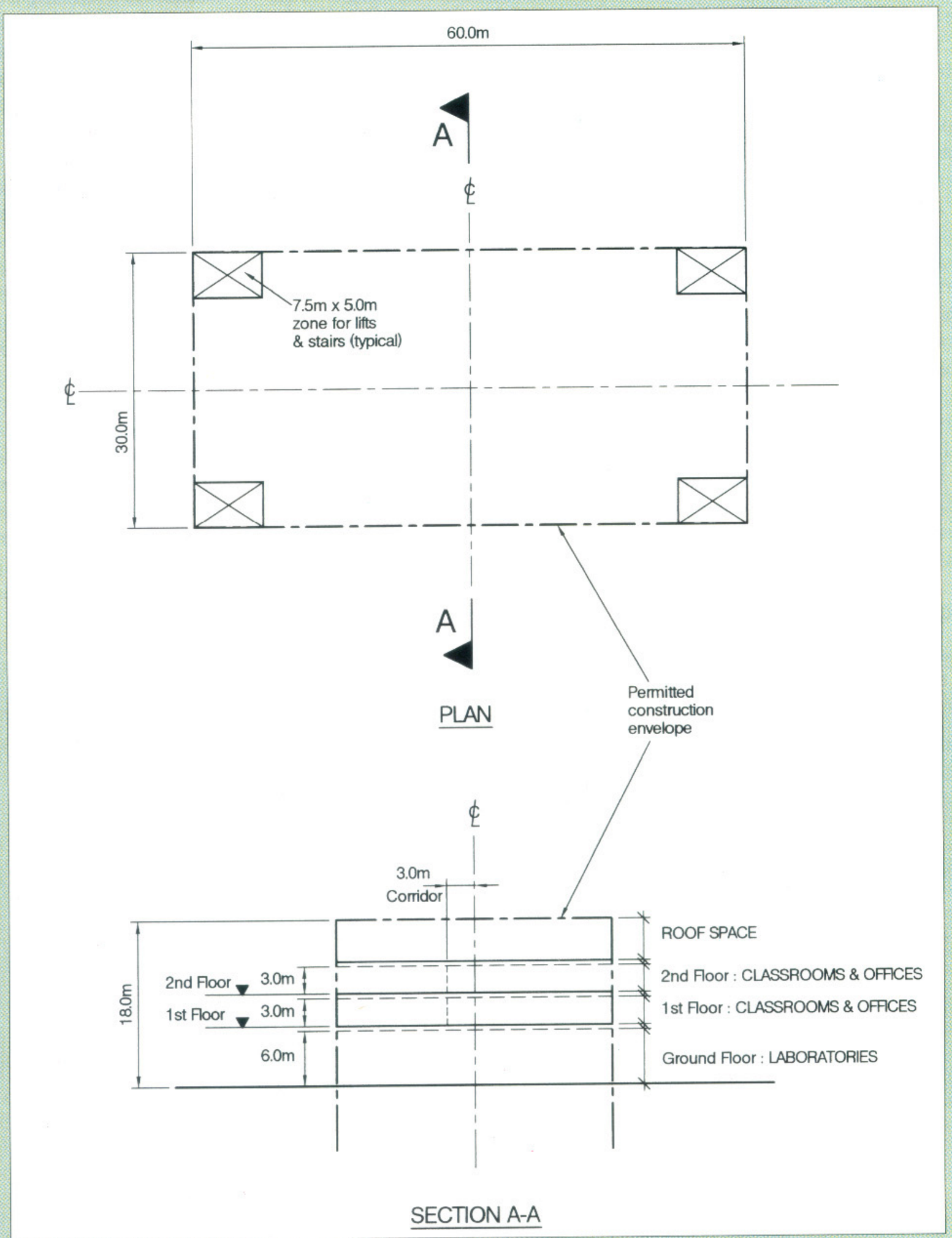
7. The site is level and is located on the outskirts of a large city.
   Basic wind speed is 44m/s based on a 3 second gust; the equivalent mean hourly wind speed is 22m/s.

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 and standards should choose an appropriate equivalent wind speed.

8. Ground conditions:
   Ground level: – 0.5 m Very loose sand and gravel N = 5
   0.5m – 6.0m: Dense to very dense sand and gravel N = 35
   Below 6.0m: Stiff clay C = 300kN/m²
   Groundwater was encountered at 2.0m below ground level in the trial pits and boreholes used in the ground investigation.

Omit from consideration

9. Detailed design of lifts and staircases; detailed consideration of window and door openings; detailed consideration of wind loading.



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. After completion of your design, the client wishes to add an additional storey to the building for staff offices. The planning authority has stipulated that the building must not extend beyond the original permitted construction envelope. Explain the effect this will have on your 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) A typical external column to foundation connection;
   (ii) A typical internal column to 1st floor connection (25 marks)

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

Question 3: River Footbridge

Client's requirements

1. A new footbridge to provide pedestrian access across a gorge from a lower riverside footpath; see Figure Q3.
2. Pedestrian guard rails 1.0m high shall be provided at both edges of the bridge deck.
3. The footbridge must have a clear width of 2.5m between the inside faces of the pedestrian guard rails.
4. Access to the site is restricted so that no structural element longer that 12.0m can be delivered to the site.

Imposed Loading

5. Imposed vertical loading on the bridge shall comprise uniformly distributed pedestrian loading of 5.0kN/m^2

Site Conditions

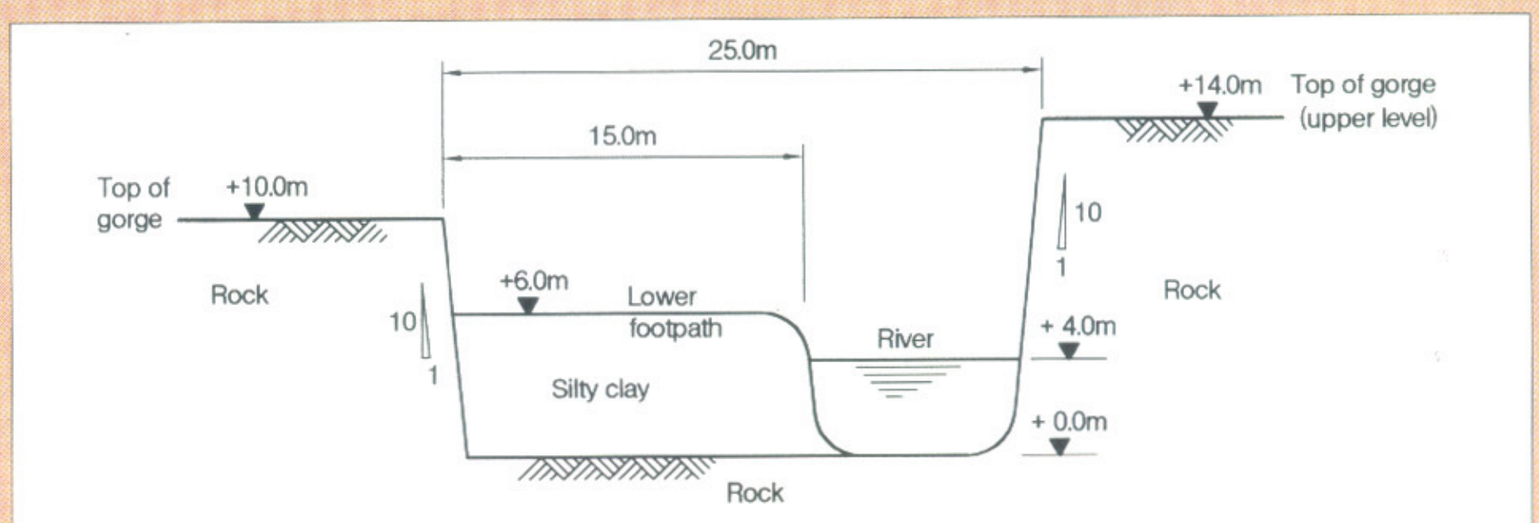
6. The site is situated in an area of natural beauty and is popular with tourists.
   Basic wind speed is 44m/s based on a 3 second gust; the equivalent mean hourly wind speed is 22m/s.

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 and standards should choose an appropriate equivalent wind speed.

7. Ground conditions:
   The ground conditions are as indicated in Figure Q3.
   The gorge sides and underlying rock have a typical compressive strength of 400kN/m^2.
   Adjacent to the river and overlying the rock is a layer of silty clay (C = 50kN/m^2) which is known to contain some boulders.

Omit from consideration

8. The detailed design of the pedestrian guard rails.



SECTION 1 (50 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable structural 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. (40 marks)

b. After your recommended solution has been accepted , the client asks if it is possible to adapt the design to accommodate a 1.5m wide maintenance vehicle with a maximum weight of 50kN supported on 2 axles, each with a 2.5m wheel base. The vehicle is only required to cross between the two sides of the gorge. Write a letter to the client explaining the effects that this would have on the structure. (10 marks)

SECTION 2 (50 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. (20 marks)

d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20 marks)

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

Question 4: Headquarters Office

Client's requirements

1. A headquarters office constructed on the site of a disused quarry; see Figure Q4.
2. The office is to have eight floors arranged as shown on Figure Q4. Floor to floor level is to be 5.0m with a clear headroom of 4.25m at each floor. The external envelope of the office is also shown on Figure Q4 and it should be noted that there are no restrictions (other than for economical reasons) on the height of the structure.
3. The building is to be clad in a proprietary curtain walling system. The roof construction is to be selected having regard to the exposure conditions and the specified loading.
4. The internal columns must be no closer than 8.0m to the internal core and the minimum centre to centre spacing of the columns is to be 8.0m. In addition, columns are not permitted in the external elevations and must not be closer than 2.0m from any external face of the building.
5. Planning restrictions prevent the inclusion of a basement in the design.

Imposed Loading

6. Roof: 10.0kN/m^2
   All floors: 6.0kN/m^2
   Loadings include an allowance for partitions, ceilings, services and floor finishes. The candidate must make an allowance for the type of finishes proposed for the roof.

Site Conditions

7 The site is located on the outskirts of a small coastal town. The building is to be constructed on a 500m wide strip of land that extends into the sea. As a result, 3 sides of the building will face the sea.
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 equivalent wind speed.

8. Ground conditions:
   Borehole 1
   Ground level: – 0.5m Loose fill
   0.5m – 3.5m Weathered rock: allowable bearing pressure = 400kN/m^2.
   Below 3.5m Rock: allowable bearing pressure = 1500kN/m^2
   Borehole 2
   Quarry bottom: – 2.5m: Silt

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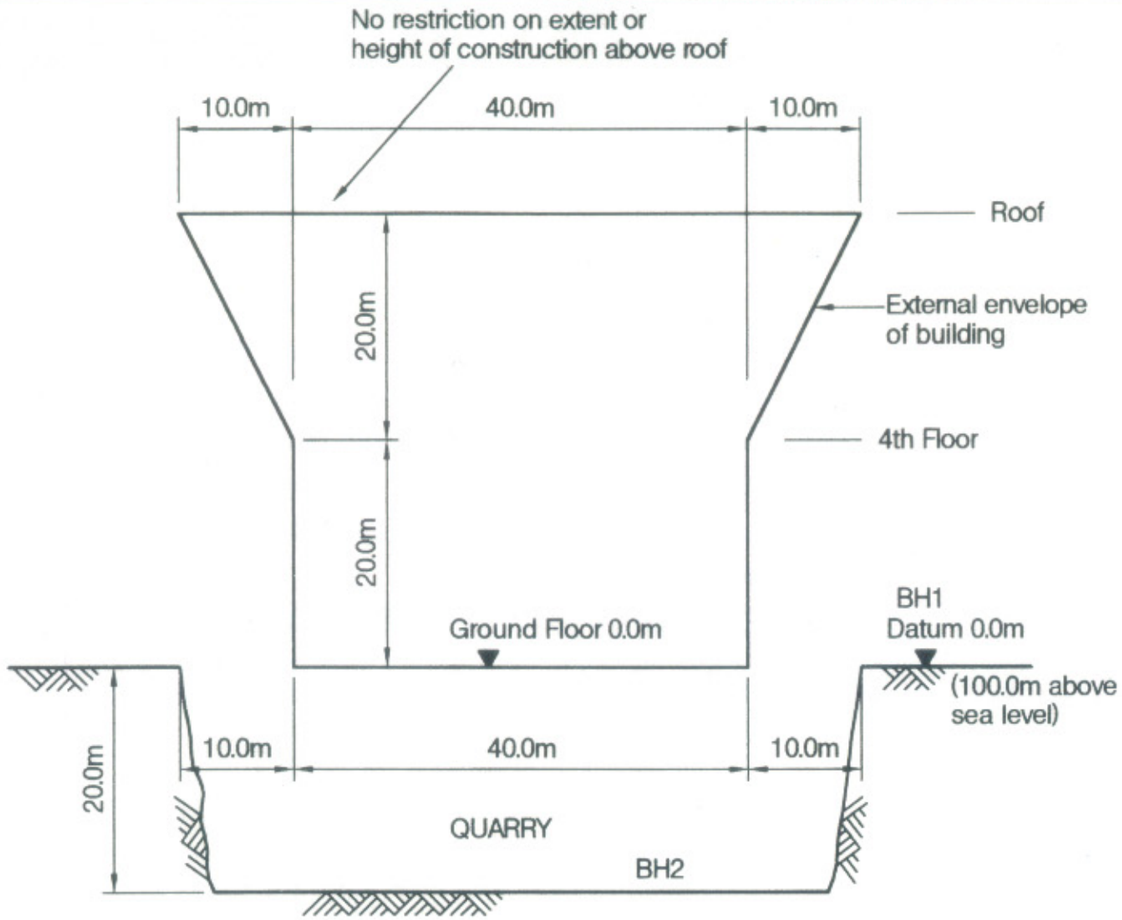
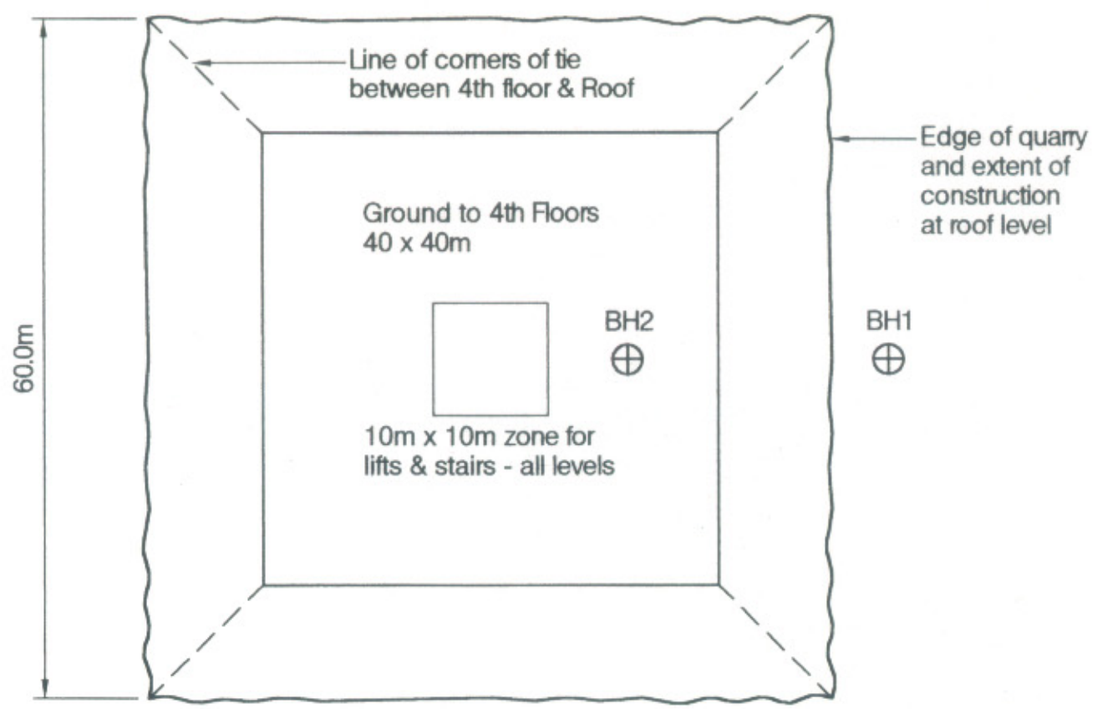


TYPICAL SECTION



PLAN

Below 2.5m: Rock: allowable bearing pressure = 1500kN/m^2.
Groundwater was not encountered.

Omit from consideration

9. Detailed design of the service core facilities (e.g. staircases).

SECTION 1 (50 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable structural solutions for the proposed building. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
b. Before detailed design has started, planning restrictions are reduced so that a basement area is permitted. The client decides to introduce 250 parking spaces beneath the building. Write a letter to the client indicating how this might be achieved. (10 marks)

SECTION 2 (50 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. (20 marks)
d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20 marks)
e. Prepare a detailed method statement for the safe construction of the building up to and including ground floor level (as indicated on Figure Q4). (10 marks)