

Chartered Membership Supplementary Examination

Wednesday 28 January 2026

Structural Engineering Design and Practice

09.30 – 13.00

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 on the question paper, 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 ACHIEVE AT LEAST 32 MARKS.
2. Candidates should note that Figures are produced to illustrate the question and are not necessarily drawn to scale. Figured dimensions should be followed.
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.
4. In all questions 80 marks are allocated across three parts.

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. Good clear drawings and sketches are required; they should show all salient and structural features to suitable scales and should incorporate adequate details.
8. 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.
9. Candidates may not bring into the examination room any electronic devices capable of wireless communication, optical photography or scanning.

The following devices are not permitted: Mobile phones, Laptops, notebooks or portable computers and similar devices, iPads, tablets and similar devices, E-readers (e.g. Kindle) and similar devices, Cameras, optical scanners and similar devices.

Any candidates arriving at the examination room with such devices will be asked to switch them off and place them in a sealed bag kept by the Invigilator for the duration of the exam, which includes the lunch period.

10. This paper is set in SI Units.

Now read 'Reminder' on page 3.

Chartered Membership Supplementary 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.

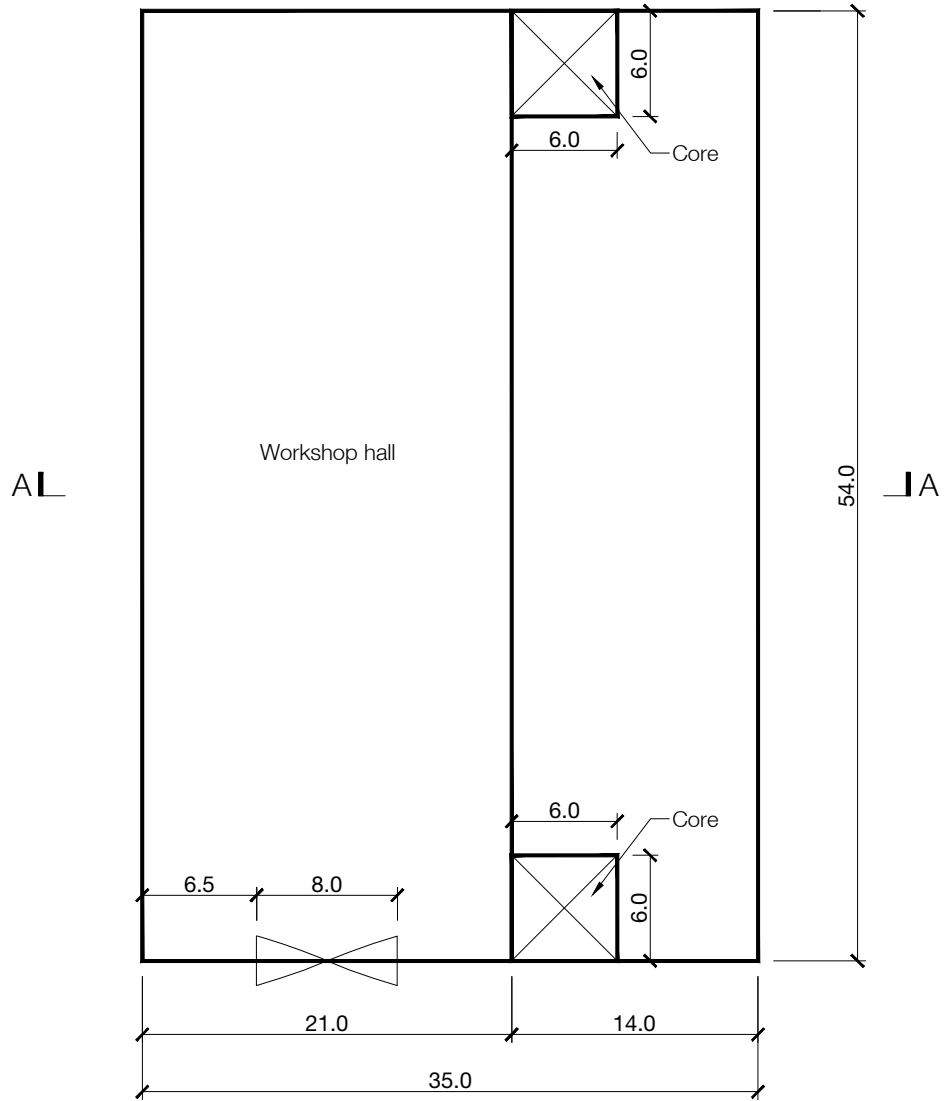
The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of structural design problems whether or not the problem is presented in terms that are within your actual experience.

Chartered Structural Engineers must have the 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 understood the general structural engineering principles involved.

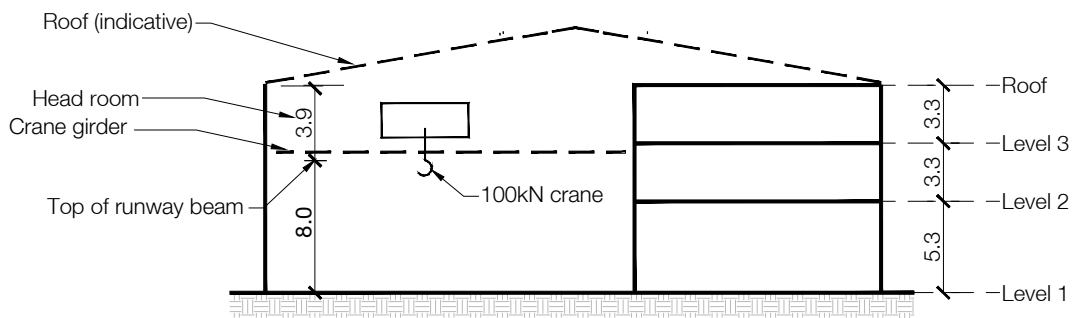
In selecting and developing your design you should also remember the guidance given in the Institution's report, Structural design - achieving excellence, and in particular:

- (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".

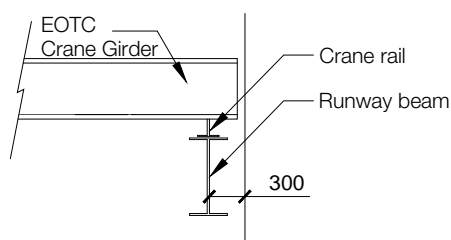
If you have difficulty in deciding the correct interpretation of a question, pay particular attention to point 6. notes to candidates, on the front cover. The examiners will take into account your interpretation – and the design you base on this – if this is clearly stated at the beginning of your answer.



FLOOR PLAN



SECTION A-A



CRANE DETAIL

NOTE: All dimensions on details are in millimetres. All other dimensions are in metres.

FIGURE Q1

Q1. Manufacturing building

Client's requirements

1. A new manufacturing building comprising a workshop hall area and an adjacent 3-storey office/storage/showroom area. The building has a plan dimension of 54m by 35m, see Figure Q1.
2. The 3-storey area is used for showroom at Level 1, light storage facility at Level 2, and offices at Level 3.
3. No internal columns are permitted in the workshop hall and show room. In the storage and office areas up to two lines of internal columns are permitted. The minimum column spacing in external elevations is 6m. An 8m wide and 3m high door is required to give vehicle access to the workshop. Standard personal doors will be required to give access to the showroom.
4. An Electric Overhead Travelling Crane (EOTC) is needed across the full width of the workshop hall with a lifting capacity of 100kN and total self weight of 190kN (including a 20kN crane trolley). Each ends of the crane girder is supported on two wheels at 2.5m centres and 300mm from the column face.
5. The shape of the roof is to be decided to give the best economical solution but must be continuous over the entire building. No suspended ceiling is required in the workshop hall.
6. The minimum clear floor to ceiling height in the 3-storey area shall be 4m at Level 1, and 2.5m in other levels. No mechanical services zones are required. The height of the building and floor heights are shown in Figure Q1.
7. No internal bracings or shear walls are permitted, except around the cores and along the separating wall between the workshop hall and the 3-storey area. The external elevation of the showroom area must be kept clear of bracings or walls. Cores to accommodate stairs and lift/elevator.
8. The crane hall is clad externally by a 3m high masonry wall and insulated metal cladding to the area above and to the whole roof area. The 3-storey area is clad internally with a masonry wall full height and with a curtain walling system on the external elevations.
9. A minimum fire resistance period of 2 hours is required for structural element.

Imposed loading

10. Roof	1.00 kN/m ²
Floors	5.0 kN/m ²
Ground floor	10.0 kN/m ²
EOT crane data:	Longitudinal surge 5%, Transverse surge 10% (perpendicular to crane rails)
Max static wheel load	100kN
Min static wheel load	50kN
Vertical impact	25%

Site conditions

11. The site is level in an open area with the basic wind speed of 46m/s on a 3-second gust; the equivalent mean hourly wind speed is 23m/s.
12. Ground Conditions:

0.0m – 1m	Made Ground
1m – 3.0m	Medium sand and gravel N=10
3.0m - 8.0m	dense sandy gravel, N=50
Below 8m	Sandstone, allowable bearing pressure 3000 kN/m ²

 Ground water was not encountered.

Omit from consideration

Design of stairs and lifts/elevators, and façade cladding/glazing.

DESIGN

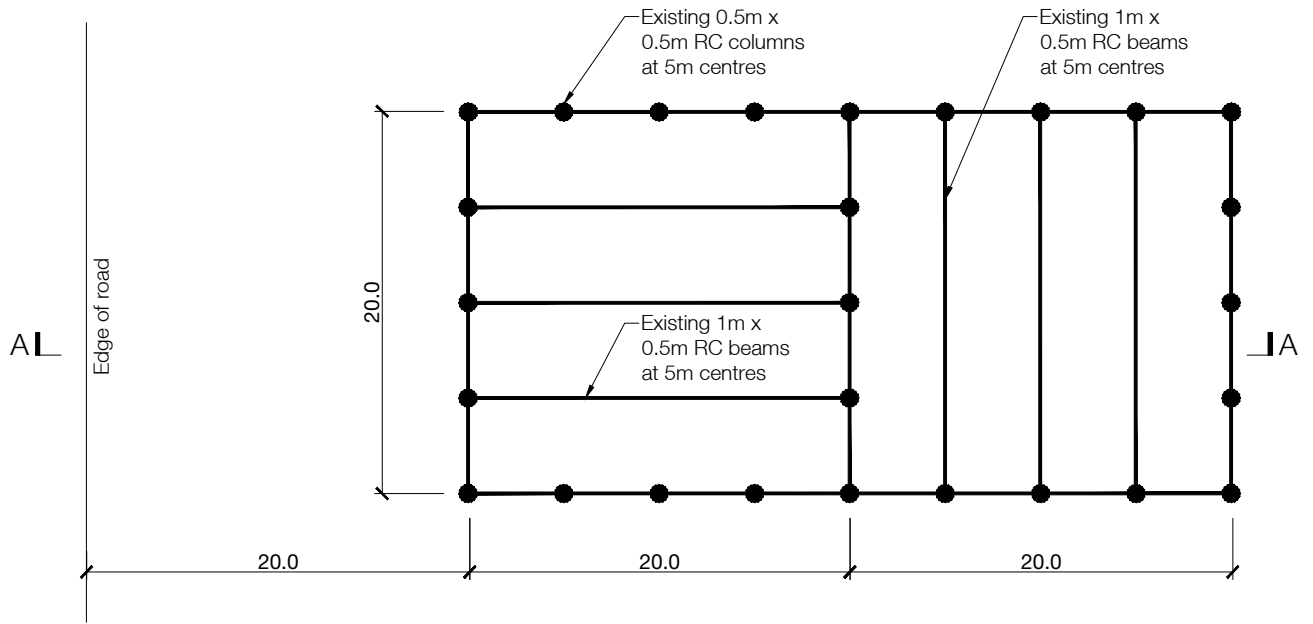
(80 marks)

- a) Prepare a design appraisal with appropriate sketches indicating two distinct, viable, and sustainable solutions for the proposed structure including the foundations. These must include appropriate concept calculations to justify each scheme. Using sustainability as a key criterion, review and critically appraise the schemes and identify the solution you recommend, giving reasons for your choice.

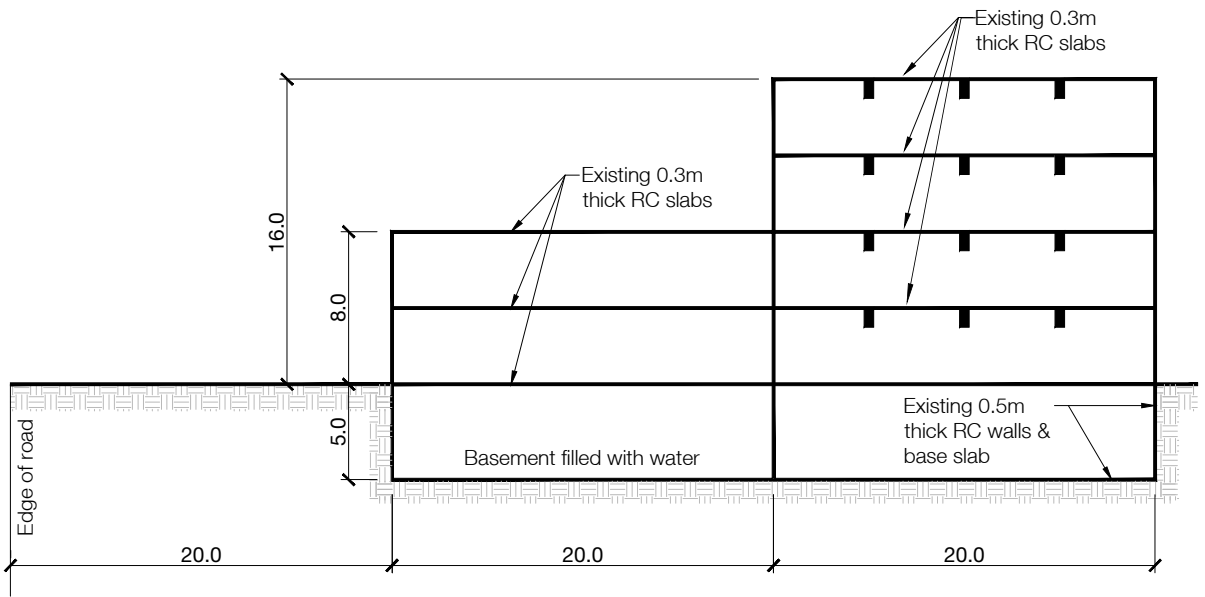
(54 marks)
- b) Identify and prepare detailed drawings to outline the critical structural details within the chosen scheme.

(20 marks)
- c) Prepare sufficient design calculations to establish the form and size of two principal elements, include approximate A1-A3 carbon calculations for each of the principal elements.

(6 marks)



PLAN



SECTION A-A

Q2. Renovation of existing multi-storey building

Client's requirements

1. A recent explosion has done considerable damage to an existing ten-storey residential building with a basement. Part of the building has only two remaining storeys and part has only four remaining stories. Damage includes the fully glazed elevations of the building which are now completely open except for external columns. The beams, columns, and slabs of the remaining floors were found to be undamaged. There are also three existing internal columns. See Figure Q2.
2. The client proposes to convert the building to offices and requires a minimum of 4000 square metres of office space with a minimum floor to ceiling height of 2.8m. The client does not want any additional internal columns in the office space.
3. The previous owner of the building has demolished an existing stair and lift/elevator tower between the building and the adjacent road as it was severely damaged.
4. All offices must have fully glazed elevations. The client does not want internal bracing or shear walls inside the building but will allow feature bracing in glazed elevations.

Imposed loading

5. Existing residential building floors were designed for $1.5\text{kN/m}^2 + 1\text{kN/m}^2$ for internal partitions.
6. Office floors and roof are to be designed for 2.5kN/m^2

Site conditions

7. The site is flat. Basic wind speed is 46m/s based on a 3-second gust, the equivalent mean hourly wind speed is 23m/s .

Ground conditions

0.0m-1m	Concrete rubble from damaged buildings
1m-5m	Sandy gravel (N=45)
5m-20m	Dense sand/gravel (N=60)

Ground water was encountered at 5m below ground level.

Omit from consideration

8. Design of the staircase and lifts/elevators, and façade cladding.

DESIGN

(80 marks)

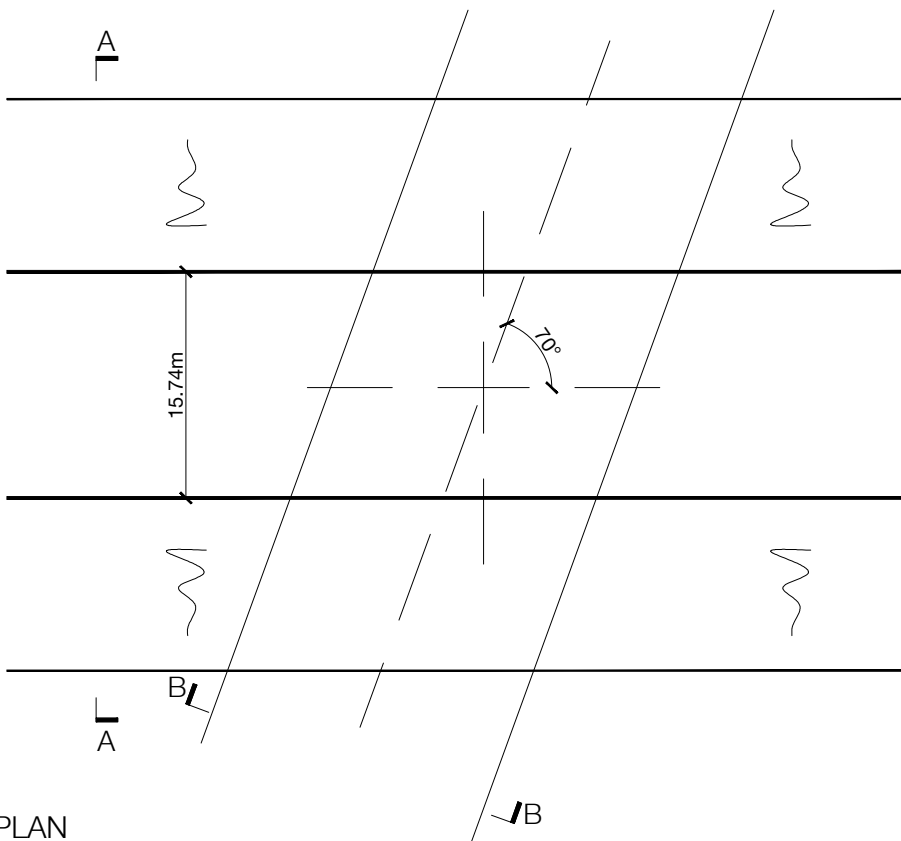
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(54 marks)
- b) Identify and prepare detailed drawings to outline the critical structural details within the chosen scheme.

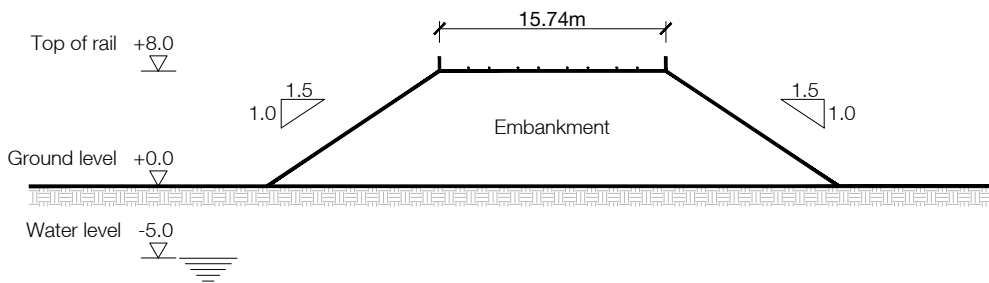
(20 marks)
- c) Prepare sufficient design calculations to establish the form and size of two principal elements, include approximate A1-A3 carbon calculations for each of the principal elements.

(6 marks)

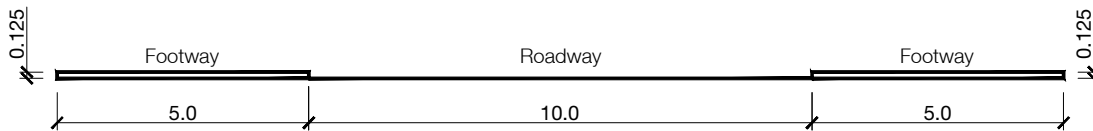
RAILWAY BRIDGE



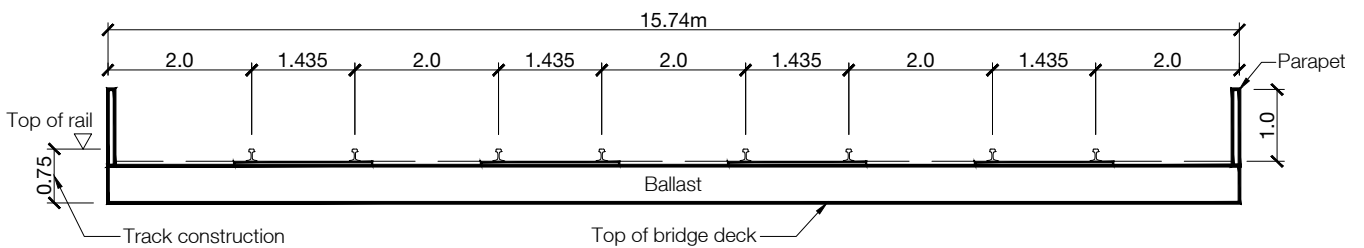
PLAN



SECTION A-A



SECTION B-B



RAILWAY TRACK

NOTE: All other dimensions are in metres.

FIGURE Q3

Q3. Railway bridge and access road

Client's requirements

1. A new road through a railway embankment as part of the first phase of a major land development, which requires a bridge to support the existing four railway tracks. The centreline of the new bridge is to be 70 degrees to the railway line on plan, as shown in Figure Q3.
2. The new access road has a 10.0m wide roadway with a 5.0m wide footpath on each side. The minimum clearance between the underside of the new railway bridge and the roadway is to be 6.0m.
3. Each track, comprising a pair of rails, is supported on concrete sleepers/ties and ballast. The vertical distance between the top of each rail and the top of the new bridge deck is to be 0.75m. The new bridge deck is to have a minimum width of 15.74m measured between the outside faces of the parapets, as shown in Figure Q3.
4. The railway is to remain in service as much as possible during the construction of the new access road and bridge. Closure of the railway for individual or all tracks is available daily between 0:00 hrs to 05:00 hours and at weekends between Saturday 0:00 hours to Monday 05:00 hours as well as a limited number of longer periods of successive 24 hours. Closure or disruption to the rail service is to be minimised as it adds to the project cost.

Imposed loading

5. Vertical live loading for each track: A uniformly distributed load of 100kN/m and a single transverse point load of 300kN shared equally by each rail.
6. Horizontal braking load at top of rail applied to each track: 800kN shared equally by each rail.
7. Rails, sleepers/ties and ballast self-weight of 15.0kN/m².
8. All four railway tracks may carry railway loading at the same time.

The vertical loads are distributed through the sleepers/ties and the ballast at a slope of 2 (vertical) to 1 (horizontal).
Vertical live loading for new access road: roadway 10kN/m² and footway 5kN/m².

Site conditions

9. The site is on the outskirts of a town in open, undeveloped countryside, and accessed via a service road off a major highway to the south of the railway embankment.

Ground conditions

10. Ground conditions:

Ground level – 0.3m	Topsoil.
0.3m – 5.0m	Stiff clay. $C = 100\text{kN/m}^2$ increasing with depth to 150kN/m^2 .
Below 5.0m	Dense sand and gravel $N = 50$.
Ground water level at 5m below ground level.	
Embankment	Dense granular fill, internal friction angle = 35 degrees, bulk unit weight – 20kN/m^3

Omit from consideration

11. Design of track, access road, detailed consideration of wind loading and detailed description of track removal and construction.

DESIGN

(80 marks)

- a) Prepare a design appraisal with appropriate sketches indicating two distinct, viable, and sustainable solutions for the proposed structure including the foundations. These must include appropriate concept calculations to justify each scheme. Using sustainability as a key criterion, review and critically appraise the schemes and identify the solution you recommend, giving reasons for your choice.
(54 marks)
- b) Identify and prepare detailed drawings to outline the critical structural details within the chosen scheme.
(20 marks)
- c) Prepare sufficient design calculations to establish the form and size of two principal elements, include approximate A1-A3 carbon calculations for each of the principal elements.
(6 marks)

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