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Chartered Membership Supplementary Examination

Tuesday 21 January 2025

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 wireles 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.

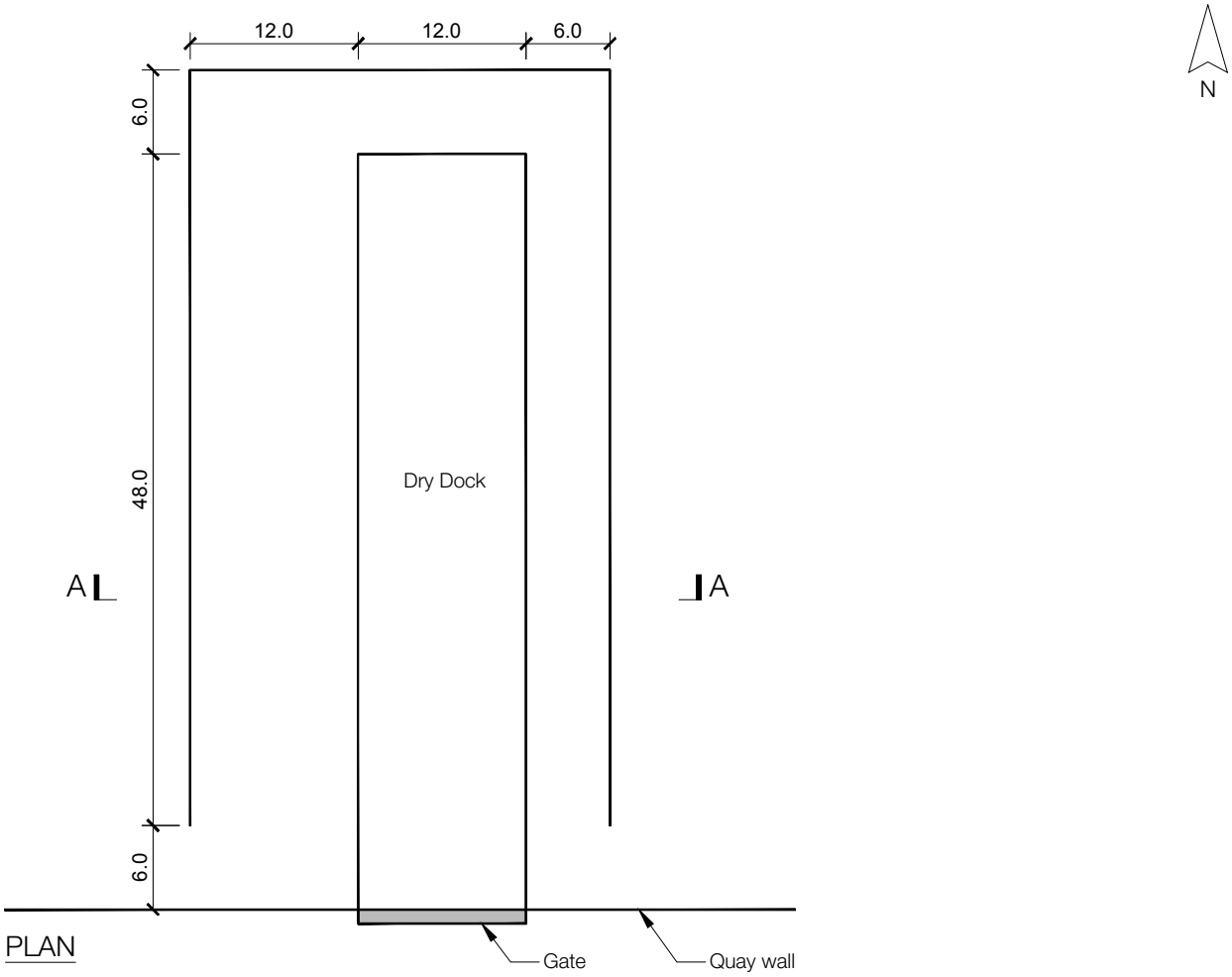
In selecting and developing your design you should also remember the guidance given in the Institution's report, Structural design - achieving excellence, and in particular:

(1) "the structure must be safe",

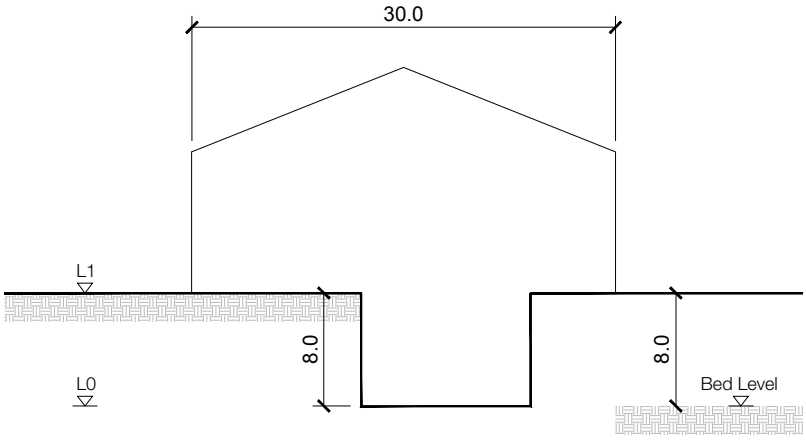
(2) "a good design has certain typical features – simplicity, unity and necessity",

(3) "the structure must fulfil its intended function".

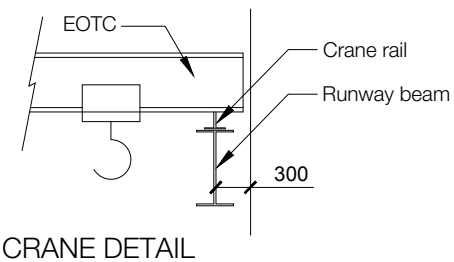
If you have difficulty in deciding the correct interpretation of a question, pay particular attention to point 6. notes to candidates, on the front cover. The examiners will take into account your interpretation – and the design you base on this – if this is clearly stated at the beginning of your answer.



PLAN



SECTION A-A



CRANE DETAIL

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

FIGURE Q1

Q1. New lakeside marine workshop

Client's requirements

1. A new lakeside marine workshop on a level site. See Figure Q1.
2. The development consists of a building over a dry dock, which is open at the South end. Inside the building at the West side of the dry dock there is a workshop area.
3. The building over the dry dock is to have two single girder Electric Overhead Travelling Cranes (EOTC) which can travel North to South along the length of the building. Each crane has a lifting capacity of 50kN and a self-weight of 15kN. Both cranes can be used independently or in tandem and are stored at the North end of the building when not in use.
4. Each end of the crane girders is supported on two wheels spaced 3.0m apart and a minimum of 300mm from supporting column face. The minimum distance between the wheels of two cranes in the direction of travel is 1.0m. The crane rail on top of the crane beam is 90mm high and weighs 0.18kN/m.
5. The clear height beneath the crane girder beam shall be 15m and a clear height of 2.0m shall be provided between top of crane girder beam and underside of roof structure to allow operating space for the cranes.
6. Lightweight external cladding with 25% glazing and 10% roof lights. Two roller shutter doors are required, 11m in width and 8m in height on the West elevation.

Imposed loading

7. Roof including services 1.50kN/m^2
8. Workshop and dry dock surround 50.0kN/m^2
9. Equivalent Line Load at centre line of dry dock for keel blocks 75kN/m.
10. A floating dry dock gate is to be provided which can be considered to apply water pressure to the side walls of the dry dock only.

Site conditions

11. The site is on a level surface with an existing concrete quay wall. Basic wind speed is 40m/s based on a 3-second gust; the equivalent mean hourly wind speed is 20m/s.
12. Ground conditions

Ground level –0.3m	topsoil
0.3m – 3.0m	very loose sand SPT = 2
3.0m – 8.0m	very dense sand and gravel SPT > 50
Below 8.0m	stiff clay Cu = 150kN/m^2

The highest water level in the lake is 1m below ground level, the water level in the ground is to be considered the same as the lake. Bed level of the lake is 8m below ground level.

Omit from consideration

13. Design of dock gates.
14. Draw down channel in the base of the dry dock or pump house.
15. Access into the dry dock.

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.

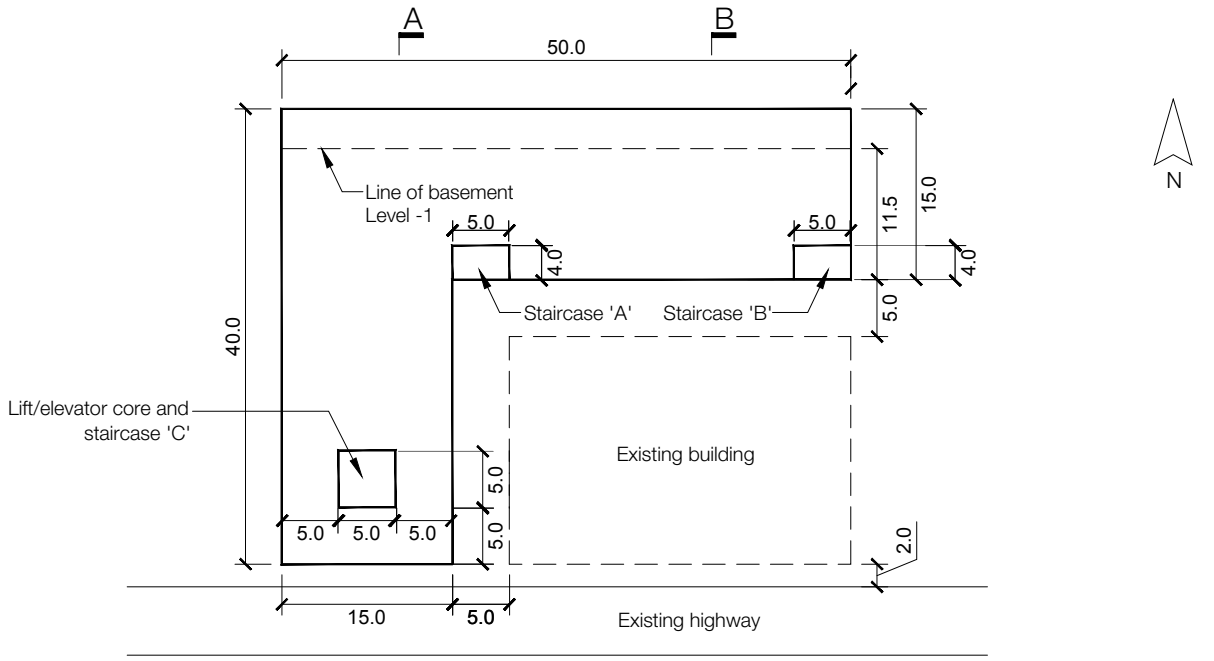
(54 marks)

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

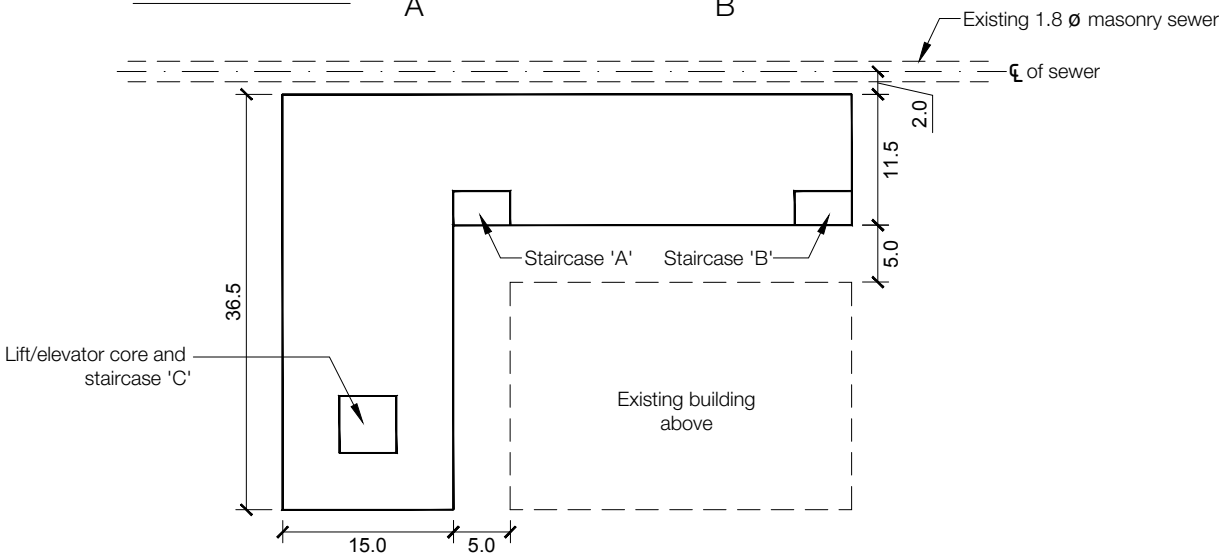
(20 marks)

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.

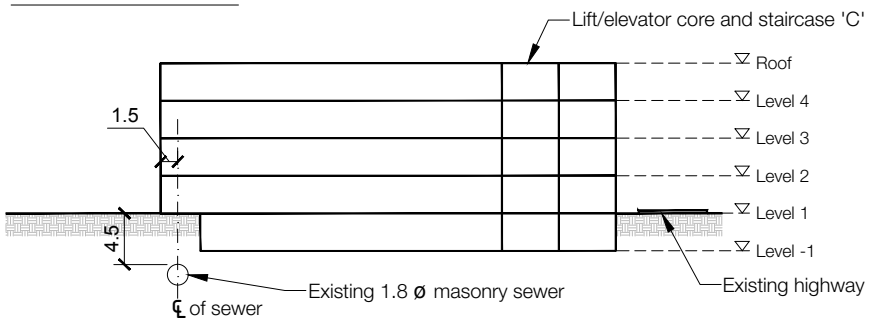
(6 marks)



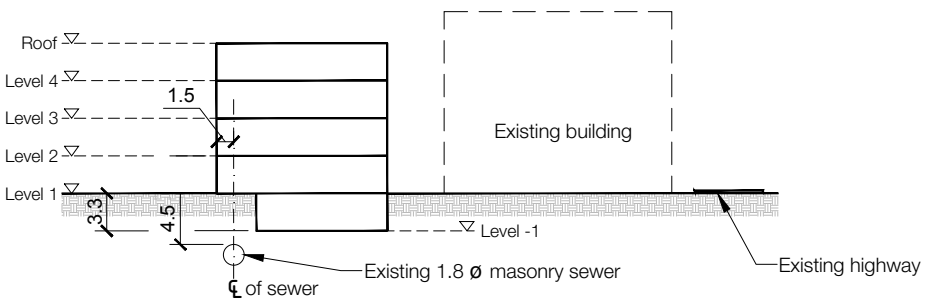
PLAN AT LEVEL 1



PLAN AT LEVEL -1



SECTION A-A



SECTION B-B

NOTE: All dimensions are in metres.

FIGURE Q2

Q2. New library and study hall

Client's requirements

1. A new five-storey library and study hall development within a city centre. See Figure Q2.
2. The building is located over an existing masonry sewer that cannot have any additional vertical load applied to its crown.
3. External and internal columns are to have a minimum spacing of 5.0m.
4. No excavations deeper than 300mm are permitted over the crown of the sewer.
5. The minimum clear floor-to-ceiling height is to be 2.75m and the services zone is to be 300mm deep.
6. The depth to the top of the basement substructure is to be 3.3m from Level 1.
7. Access to the building is via the highway to the south of the structure.
8. The basement area acts as a plantroom that serves the entire building.

Imposed loading

9. Roof 1.0kN/m^2
10. Floors 5.0kN/m^2 (storage) + 1kN/m^2 for internal partitions
11. Plantroom 7.5kN/m^2

Site conditions

12. The site is located in a city centre. Basic wind speed is 42m/s based on a 3-second gust; the equivalent mean hourly wind speed is 21m/s.
13. Ground conditions:

Ground level – 2.0m	made ground
2.0m – 10.0m	weak silty clay Cu = 75kN/m^2
10.0m - 15.0m	firm clay Cu = 125kN/m^2
15.0m – 30.0m	stiff clay Cu = 200kN/m^2

No ground water was encountered.

Omit from Consideration

14. Detail design of the stairs and lift/elevator.

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)

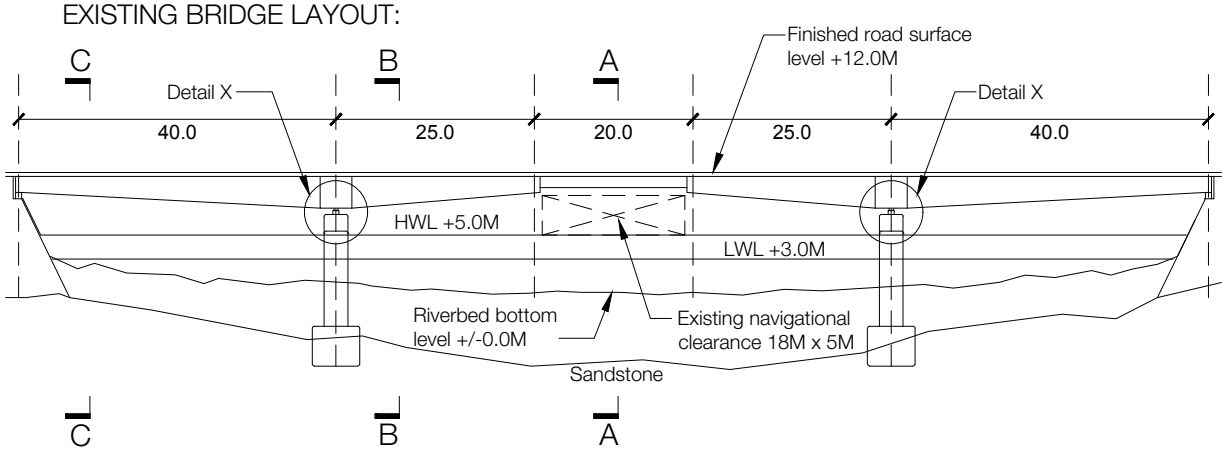
b) Identify and prepare detailed drawings to outline the critical structural details within the chosen scheme.

(20 marks)

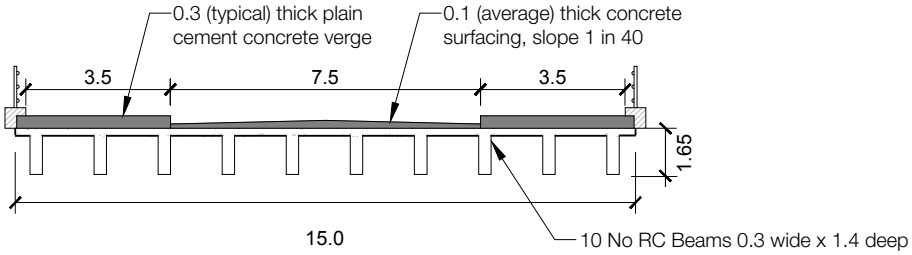
c) Prepare sufficient design calculations to establish the form and size of two principal elements, include approximate A1-A3 carbon calculations for each of the principal elements.

(6 marks)

EXISTING BRIDGE LAYOUT:

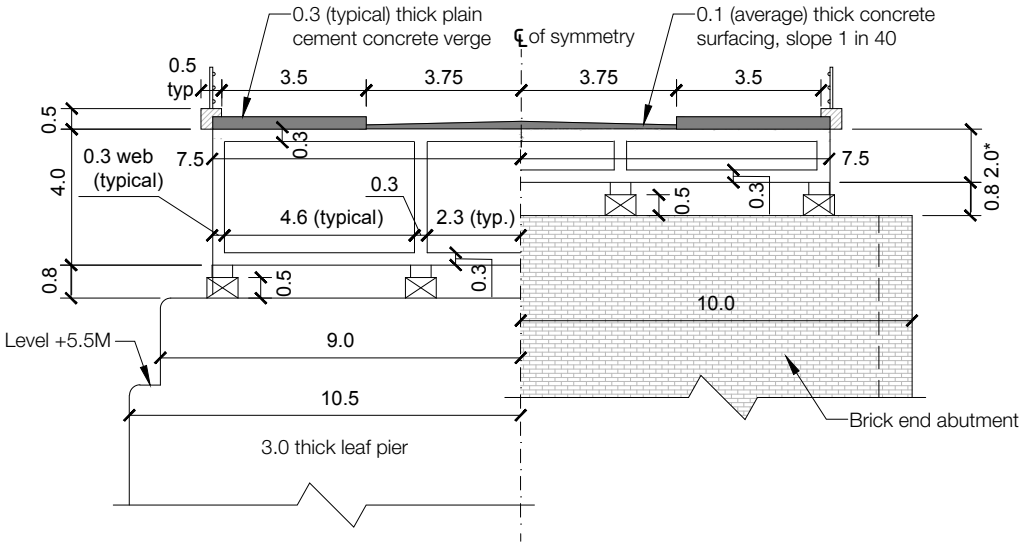


ELEVATION



SECTION A-A
SUSPENDED SPAN CROSS SECTION

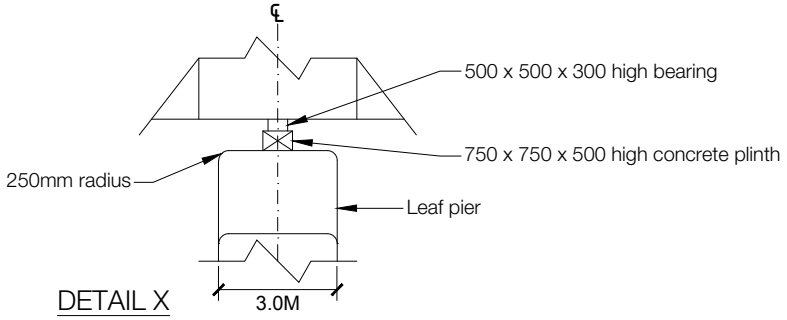
NOTE: Detailed dimensions are from as-built drawings, including associated text.



SECTION B-B
HALF X-SECTION AT PIER

SECTION C-C
HALF X-SECTION AT ABUTMENT

NOTE: *Same super structure depth at half joint.

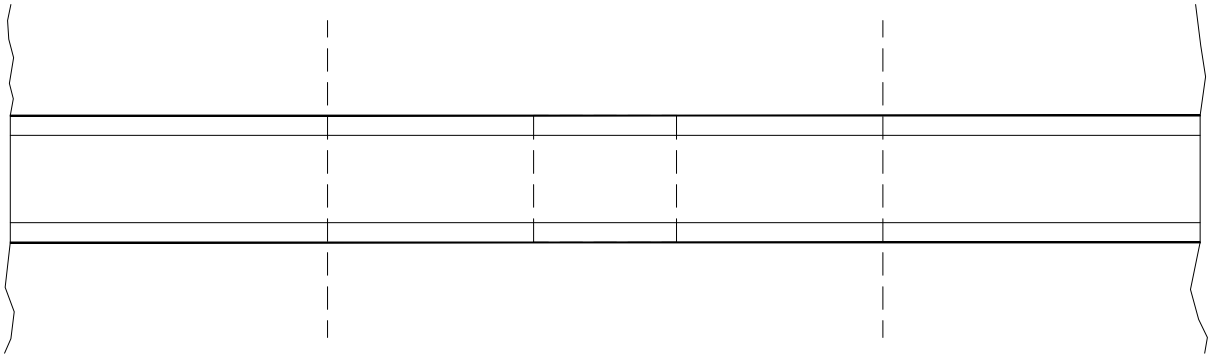


DETAIL X

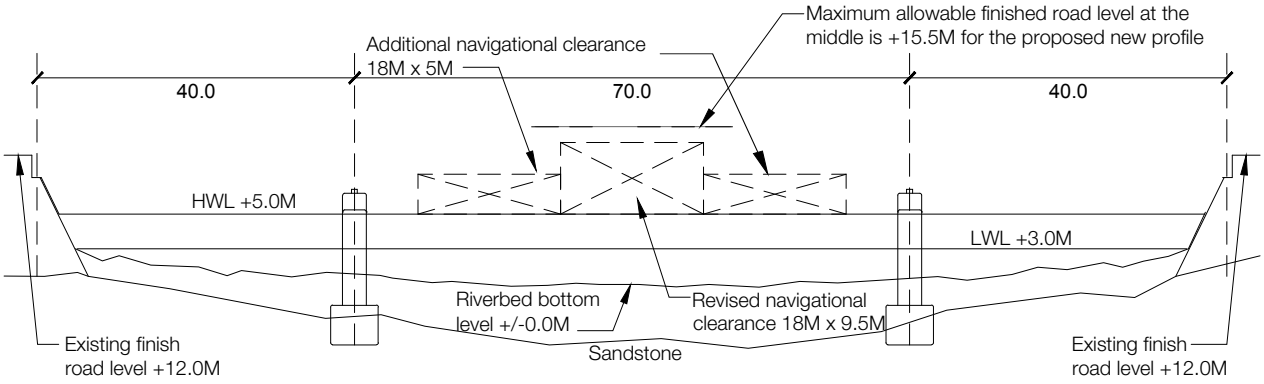
NOTE: All dimensions on details are in millimetres. All other dimensions are in metres.

FIGURE Q3
Sheet 1 of 2

PROPOSED BRIDGE LAYOUT:

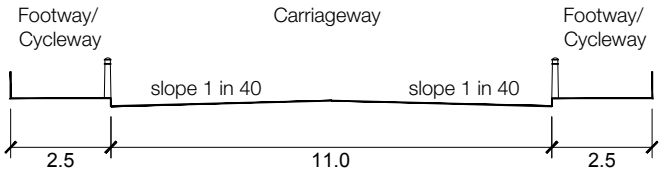


PLAN
OUTLINE PLAN OF THE BRIDGE OVER THE RIVER



ELEVATION

NOTE: Intermediate pier may be reused, but abutment must be reused as shown in cross section of the river. Features (not shown) on side face of concrete box girder must be retained / reproduced on the new bridge.



SECTION
PROPOSED OUTLINE CROSS SECTION OF THE NEW / UPDATED BRIDGE
NOTE: Bollard shown / similar protection must be used. Kerb height minimum 0.2 metres.

NOTE: All dimensions are in metres.

FIGURE Q3
Sheet 2 of 2

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Q3. Improvements to an existing bridge

Client's requirements

1. An existing reinforced concrete box girder bridge over the main river of a large city needs to be replaced or refurbished to make it safer for pedestrians to use and to increase the navigational clearance envelope between the central piers as shown in Figure Q3.
2. The proposed configuration for the revised deck layout includes two 2.5m traffic lanes, two 3m bus lanes and two 2.5m pedestrian/cycleway lanes in total, also shown in Figure Q3.
3. The River Authority will not permit any new foundations in the watercourse; however, if it can be demonstrated that the new applied load is less than that originally designed for, substructures may be reused with necessary alteration. Total closure/shut down for construction is possible but the period must not exceed a total of six weeks over a year.

Imposed loading

4. Footways 5.0kN/m^2.
5. Carriageway 15kN/m^2 was used for design of existing bridge.
   10kN/m^2 may be used for design of bridge for proposed use.

Site conditions

6. The site is in an urban area. Basic wind speed is 46.0m/s based on a 3-second gust, the equivalent mean hourly wind speed is 23.0m/s.

Ground conditions

7. General Sandstone, safe bearing capacity 1,000kN/m^2.

Omit from consideration

8. Design against load for ship impact.

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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