

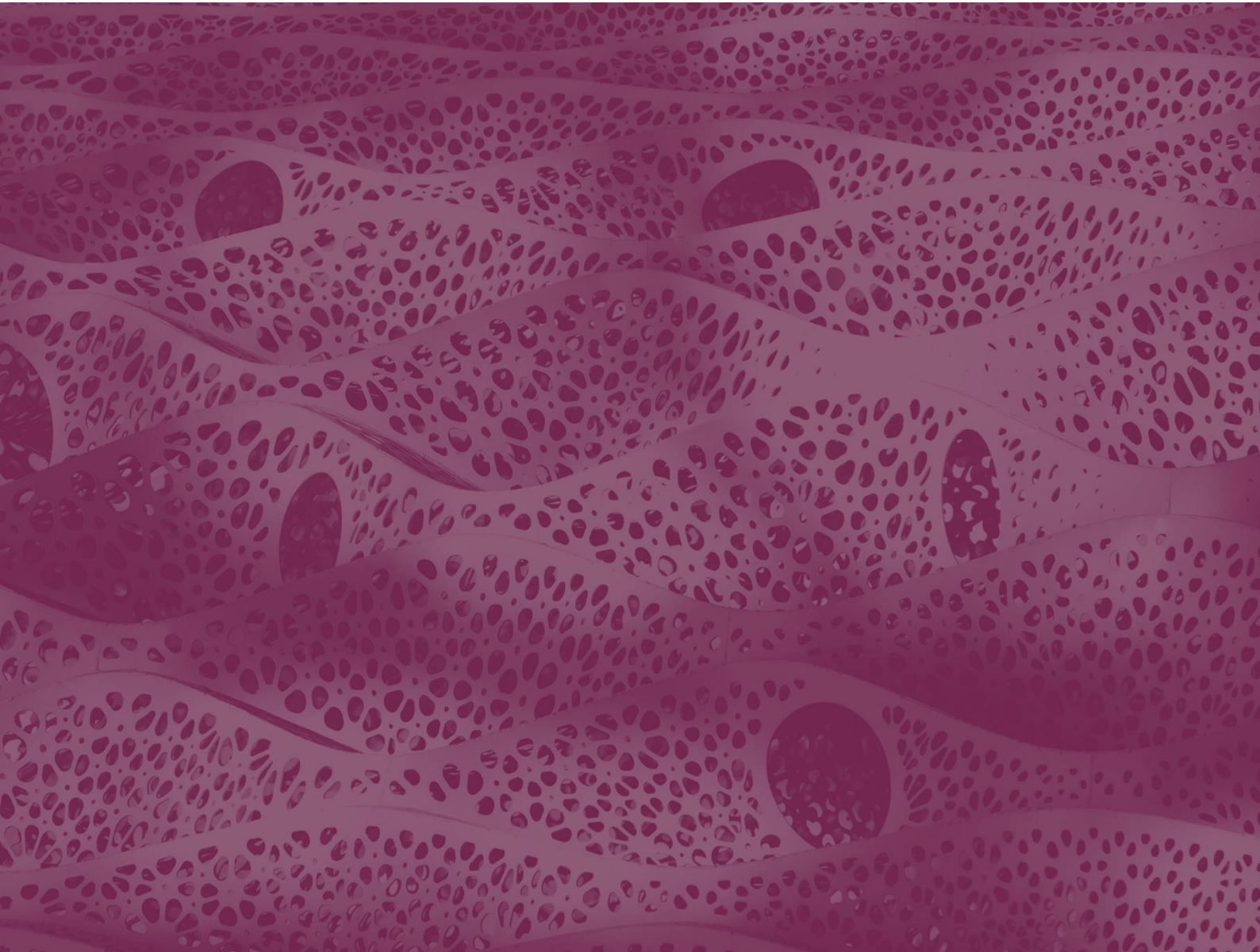
# Exam Preparation Guidance

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Chartered Membership Examination

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## Disclaimer

**This document has been produced by the Institution’s Examinations Panel and is designed to aid you in your preparation. It contains vital hints and tips for each section of the exam but does not constitute a complete ‘how-to’ guide to answer the questions. This guidance should be used in conjunction with your other chosen methods of preparation and can be taken into the Examination as a handy reminder of the basics.**

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## Introduction to the exam, general tips, and time management

### Introduction to the Exam

The Institution of Structural Engineers' Chartered Membership Examination forms one half of the Professional Review process required for election to Chartered Membership (MIStructE).

The Examination tasks you with demonstrating the validity of your training and experience. Examiners must be satisfied that you have conveyed an understanding of structural engineering principles, an ability to initiate and communicate structural design and provide an effective solution to a structural design problem.

The Examination is seven hours in duration. Candidates must answer one question from a choice of five. All questions have two sections and BOTH parts of the question must be satisfactorily answered to achieve a pass:

**Section 1** (50% of total mark) covers design concept, presentation, identification of various structural forms (including stability and load transfer aspects) and a selection of the most appropriate materials. Candidates are required to propose two distinct, viable and sustainable solutions to a complex brief. These must be reviewed and critically appraised before reasons are given for taking forward the recommended solution. Recommendations on how to reduce material usage will need to be communicated to the client in a professional manner.

**Section 2** (50% of total mark) requires you to provide relevant design calculations, general arrangement drawings and appropriate details together with comment on possible construction methods, choice of materials, specifications, estimates, management procedures, site control and safety and supervision of works in progress.

The Examination presents three main challenges which will be covered throughout this guidance:

- ▶ Ensuring that all aspects of the brief are fully understood
- ▶ Being able to propose two distinct, viable and sustainable schemes that both satisfy the brief
- ▶ Producing detailed answers to all five parts of the Examination in the time available

### General Tips

Past papers are added to the website to enable candidates to practise questions and familiarise themselves with the demands of the Examination. Marking Examiner reports are also provided for each of the Examinations. These are a useful insight into the Marking Examiners' views on how the questions were answered and where points were gained and lost and should help future candidates avoid making the same mistakes as past candidates.

The Examination is open book, but candidates should note that this can lead to a false sense of security; there is a lot to cover in the Examination and candidates may waste valuable time searching through reference books. To save time, candidates should prepare a folder with key reference documents and a contents page or index to help them locate information quickly.

Any design code or standard may be used to answer the questions in the paper, so long as reference to that code is consistent throughout and any assumptions made, or design data adopted (including loadings other than those specified in the question) are stated at the beginning of the answer.

When practising questions and during the Examination, candidates should be mindful of the following examples of what can be found in a poor solution, and will result in candidates losing marks:

- ▶ Unsafe structural schemes (this will result in automatic failure of the Examination)
- ▶ Only one solution, or an alternative solution that is simply a variation of the first, such as using a change of material or grid dimensions without other distinctive variations such as stability considerations and foundation options
- ▶ Lack of alternative forms of stability options being considered, e.g., braced, or unbraced structures
- ▶ The structure must include all elements of the building; the roof and ground slab are an integral part and should be considered
- ▶ Where a question defines the external finish as curtain walling or full height glazing, avoid the use of obtrusive diagonal bracing, unless the question clearly permits
- ▶ Lack of understanding of the geotechnical information provided in assessing foundation requirements
- ▶ The unnecessary use of piling where pads or raft foundations would be quicker and more economical
- ▶ Rambling essays that provide no clear picture of the structural integrity or viability of the schemes
- ▶ Design statements which are then contradicted by the calculations and/or details
- ▶ Unnecessary re-writing of the question or extracts from the codes of practice and standards
- ▶ No identification of scheme choice or reasons for selection
- ▶ Too much time spent on non-critical or unrealistic loading cases
- ▶ Too many repetitive calculations, or calculations of a simple nature and not of the principal elements
- ▶ Poor general arrangement layout and details with insufficient information for estimating purposes
- ▶ Answers to the final sections of Sections 1 and/or 2 which are composed of generalities and do not relate specifically to the problem stated

The Institution asked candidates who passed the exam in July 2016 and January 2017 for their “top-tips”. Tips relating to the Examination in general are shown below and should be helpful to candidates who are about to embark on their own exam preparation:

- ▶ ‘Attend a preparation course. I think this was invaluable.’
- ▶ ‘Start collating your design notes in a paper file early in your career. The temptation these days is to rely on digital copies, but you won't have access to these in the exam.’
- ▶ ‘As you prepare for the exam, keep a note pad of things you need to research etc. I found this an invaluable tool. As I did questions, I constantly wrote notes of things I needed to read up on, then tried to spend one evening a week researching them. Lots of things repeat themselves in questions so patterns do emerge.’
- ▶ ‘Ask someone to review your practice attempts and give you feedback. It's important to know that you are expressing your ideas and knowledge in an understandable way. It's no use knowing good solutions if you can't present them well under the time pressure.’

- ▶ ‘Practise different methods/ styles of sketching and drawing schemes, plans and details under time pressure. Certain sized buildings/scales of drawing require different techniques to present your ideas in a clear fashion and within the time available. Get some coloured pens and practice with them.’

## Time Management

In his article [“Chartered membership exam – an examiner’s perspective”](#), Dr Tendayi Munyebvu suggests that creating a timetable for the Examination will help candidates ensure sufficient time is allocated to each section of the Examination.

As candidates need to play to their own strengths, timetables need to be personalised and reviewed after “mock exams” to provide a bespoke guide on the day of the Examination. Table 1 shows an indicative timetable which candidates may find a helpful starting point when preparing their own timetable.

**Table 1: Indicative timetable**

Question Section	Activity	Mark allocation (%)	Time allocation – based on marks (minutes)	Rationalised time allocation (minutes)
	Option investigations			30
<b>1a</b>	Option 1 appraisal	16	67.2	50
	Option 2 appraisal	16	67.2	50
	Recommendation	8	33.6	20
<b>1b</b>	Professional communication	10	42	30
<b>2c</b>	Calculations	22	92.4	90
<b>2d</b>	Drawings	20	84	90
<b>2e</b>	Method Statement	8	33.6	30
	Checking			30
<b>Total</b>		100	420	420

Several candidates who have passed the Examination provided their tips for time management:

- ▶ ‘Take a watch to the exam - you can't always see the clock depending on where you sit in the exam room.’
- ▶ ‘Sit full mocks in exam conditions – no phone, bring a lunch and everything you need. Select several years and do not look at them before you sit down, so you can recreate the environment of opening a new exam paper on the day. I think I did four of these. Not fun, but it made the actual day run like clockwork - I didn't have a problem sticking to my time and had 15 mins to review at the end as planned.’
- ▶ ‘Rule of thumb, simple equations and design charts are very handy, as you will have very limited time to prepare your calculations. Condense and compile them in an orderly manner for easy access.’
- ▶ ‘In the exam, if you think you're running behind and won't finish, don't panic! Just get the essential points down and keep going. Make sure you have a stab at all parts even if it's just a few notes.’
- ▶ ‘Timing is crucial. Plan out your day, write this down and take it into the exam with you. Allow for 10 to 15 minutes to think through your solutions. You don't want to decide part way through your answer you have picked the wrong solution. Allow some time for checking.’

## Providing distinct, viable and sustainable solutions

Part 1a asks candidates to prepare ‘two distinct, viable and sustainable solutions for the proposed structure’ and then to recommend one of the schemes. This section has a total allocation of 40 marks, which is divided into 16 marks for each respective distinct and viable solution, and 8 marks for the comparative analysis.

This is the most important part of the examination and should be considered as such as it sets the scene for the remainder of the answers required in the paper. Use the time allocated wisely and sensibly. Candidates must be competent in concept design and experienced in using a variety of materials; concrete, steel, timber, and load bearing masonry. Experience in differing construction techniques, such as prefabricated or insitu, is required. Stability options must be considered, such as braced or unbraced structures, and varying types of foundations; raft, pads, strip footings, or piling, both load bearing and retaining.

The following outlines the philosophy behind this section, as contained in the Exam Guidance and Instructions document:

*‘For the building structure questions, significant differences between the two schemes must be presented. Depending on the type of structure, significant differences may include, but are not limited to:*

- ▶ *Stability: shear walls, cross-bracing, sway frames, monolithic rc frames*
- ▶ *Framing: column spacing and spans layout, precast, in-situ*
- ▶ *Foundations: piled, pad, strip, raft, ground improvement. Ground-bearing slabs versus suspended*
- ▶ *Materials: concrete (reinforced concrete, prestressed etc), steel, masonry, timber*
- ▶ *Load path*
- ▶ *Construction method: precast, modular, off-site, segmental, etc.*

*Changing just one of these would not be enough to make a solution distinct. Candidates will gain higher marks by providing as many significant differences as possible, depending on the type of structure, and demonstrating their viability. The differences chosen should be relevant to the overall solution.*

*For the bridge question, each scheme should be based on a different form of bridge structure with different spans and/or different load paths to the foundations. Changing only the material of the bridge structure would not be enough to make a solution distinct.*

*Sketches may be used alongside text to describe the proposed schemes. These may be free-hand and are not required to be to scale but they must clearly convey the design principles being proposed. Calculations of a detailed nature are not required in this part of the question; member sizing to indicate the principal elements for each proposed scheme may be sized using engineering judgement. or rule of thumb, e.g., span to depth ratio.*

Structural stability is a fundamental aspect of the scheme designs, and an unsafe structure, or instances where stability is ignored, will result in an automatic fail.

Candidates should demonstrate approaches in their designs which minimise the use of material through structural efficiency. Candidates should consider which materials are most likely to be appropriate for the brief, however this would not need to extend to undertaking carbon comparisons at this stage. Where a reuse opportunity is provided in the question it is expected that candidates will take advantage of this in their schemes and include the benefits in identifying the most suitable solution.

The examiners are looking for candidates to clearly identify and address the main structural challenges contained within the question and marks will not be awarded for generic answers to any part of this section.

The statement above outlines the need for the two structures proposed to be distinct, utilising as many of the variables outlined as possible. Changes for each scheme should be significant, and not just a minor variation of the same, using alternative material, or a change of grid etc. The following gives a brief but not exhaustive indication of what could be considered in developing the schemes.

- ▶ For a long span question such as a warehouse, factory etc., depending on the span, the material alternatives could be steel, timber, or precast concrete, with the design being either a portal frame, column and truss, a two or three pinned arch, or cable stayed. The stability could be braced or unbraced, with foundation alternatives of pad or piled foundations. The grid centres will depend on the external finishes and the economic span of the supporting members, usually purlins and sheeting rails. Consideration must also be given to the centres of material expansion joints, such as blockwork, which may dictate a non-variable grid. If the building is long and requires a vertical expansion joint, then both parts of the structure must be stable.
- ▶ A multi storey building structure has many material alternatives and varying construction techniques that can be considered. These include insitu concrete, one-way or two-way spanning slabs, post-tension slabs, a steel frame with composite or precast concrete floors, timber frame post and floors, and load bearing masonry with insitu or precast concrete floors. An alternative may be the use of a combination of these materials such as part concrete, part steel superstructure, particularly where a penthouse or dormer roof is required. Stability options for any of the above could be braced, unbraced, or via a lift shaft. Often the grid may be predefined by the geometry of the building, or the end use such as a hotel or apartment building with defined bedroom locations. Changing the grid such that a column falls in the middle of an internal or external wall of a bedroom etc., where a window or door would be located, is an automatic mark down. The same applies for any diagonal bracing. The grid centres again may be dictated by the external finishes. If cavity wall construction is defined, the expansion joints for blockwork and masonry/stonework are normally at 6.0m and 12.0m centres, which defines a grid, whereas curtainwall has secondary support mullions so the grids could vary. The foundations, depending on the geotechnical information, could be pads, raft or piles. The combinations of distinct and variable options are endless, and candidates must be flexible and consider the above and any other alternatives.
- ▶ Where the building is of a low rise and conventional construction, such as masonry external elevations, then domestic type construction could be considered. This would include load bearing masonry with timber or precast concrete floors, total timber construction, or a light steel frame. Usually, this form of building is a braced structure using internal and external walls as bracing, diaphragms, or buttressing. If the building is low rise and fully glazed externally then an unbraced structure could be considered. Foundations should be either strip footings, pads, or raft foundations.
- ▶ The ground slabs for any development are an integral part of the building and must be considered as part of the design. The geotechnical information will give clear indication of the types of construction that could be considered, such as site strip and ground bearing slab with edge beams, site strip, ground improvement and ground bearing slab with edge beams, or a suspended slab supported by internal and edge ground beams. If piled foundations are proposed with individual pile caps, then balancing beams must be considered to take out the moment due to construction tolerances permitted for piling.
- ▶ Similar considerations are required for the bridge question, again depending on the form of the question. Construction techniques, along with erection and installation considerations, are important for each scheme, plus health and safety considerations. The material considerations are usually precast or insitu concrete decking, with precast prestressed concrete beams, reinforced precast concrete beams, or insitu concrete beams and steel beams. Stability can be provided by bracing, diaphragm action or post tensioning.

## How to appraise/differentiate between schemes

Having provided two distinct, viable and sustainable solutions in the first section of Part 1a, you are then asked to appraise your schemes and select one, giving reasons for your choice and using sustainability as a key criterion. There are generally 8 marks allocated to this task, so it is broadly equivalent to the letter in Part 1b and is worth spending some time on.

You can make this part of the exam much easier for yourself by ensuring that your two schemes are sufficiently different in the first place. Candidates often provide very similar schemes, perhaps just changing materials or making small adjustments to the structural grid. Not only will this lose you marks initially, but it also restricts your options when it comes to appraising the schemes. Remember, you are aiming to impress the examiners with your knowledge of different types of construction and their benefits and disadvantages. One word of warning; don't go too far and propose something which is clearly impractical just for the sake of being able to dismiss it in your appraisal.

The question requires you to *'review and critically appraise the scheme and identify the solution you recommend, giving reason for your choice.'* This implies a degree of discussion around the relative merits of each option and requires more than a simple list of the various scheme elements with a tick or cross against each, which is all that some candidates provide. Sustainability must also be a key criterion in your scheme selection.

There are many aspects which can be considered in the appraisal. Try to identify any key features or requirements in the brief of the question you are answering and make sure that you address these in your appraisal; for example, if your structure is in a remote or inaccessible location, availability of materials and skilled labour may influence your choice more than construction cost, whilst aesthetics is likely to be a more important consideration in an art gallery than in an industrial building. Some typical examples of things you might discuss in your answer are listed below; however not all of these will be applicable to every question and the list is by no means exhaustive:

- ▶ **Economics** - Consider the structural efficiency; for example, what are the most economic materials/construction methods for the spans you need to achieve? Also consider the impact choice of structural frame can have on overall cost; for example, flat slab construction may not provide the least expensive structural frame but could simplify service routing and thus reduce servicing costs in a heavily serviced building such as a hospital or could reduce the height of a tall building thus saving on cladding costs.
- ▶ **Programme** - Think not only of speed but also of construction sequence. Are there any restrictions such as outages which would make one of your solutions better than the other?
- ▶ **Construction and demolition** - How do your proposals affect safety during construction? Does either of your schemes require specialist skills or equipment? Does either require extensive temporary works? Similarly, could one of your schemes present challenges for demolition or dismantling, for example post-tensioned structures?
- ▶ **Location** - Does the setting of your structure preclude the use of certain materials or construction techniques? Is transportation of materials difficult?
- ▶ **Maintenance** - Can one of your solutions be maintained more easily or safely than the other?

Other considerations could include robustness, construction quality, aesthetics, flexibility for adaptation or extension, environmental impact.... The list is almost endless, but please make your appraisal relevant to your chosen question's brief and avoid generic discussions.



Finally, don't forget that you are going to have to prepare a scheme design for your chosen solution using nothing more than a calculator. It is therefore clearly best to avoid recommending anything which would require complex software to design, or indeed anything you are not confident you can easily develop a design for in the time available. It is perfectly acceptable to frame your arguments in a way that gives you the outcome you want, i.e., by emphasising the positives and playing down the negatives of your preferred scheme. There are many 'right' answers to every question and you will not be marked down for your choice if your reasoning is sound and clearly explained and your chosen solution is viable.

## Writing a professional communication to the client

The professional communication requested in Section 1b is an important part of the Examination as it constitutes the candidate's direct formal contact with the client. It offers the opportunity for the candidate to demonstrate their understanding of sustainable design alongside their engineering ability, vision, and skill to propose in a clear and concise manner possible beneficial amendments to the brief.

The communication is personal to the client and as such needs to be addressed in a professional manner, therefore it should begin 'Dear Client' and finish with 'Yours sincerely.' It is acceptable for candidates to answer this part of the question in an email format. However, this must still be written in a professional way.

The letter/email and its content is in response to a request from the client to suggest changes to the brief and design in order to reduce the amount of material used. Attention should be paid to which structural design features cannot be altered as these will be made clear in the question text.

Candidates are expected to critically evaluate the brief and propose amendments to the layout rather than fundamentally changing the function of the structure. The candidate should be capable of explaining the impact of their proposals on its operation and on the design.

Often the candidate may need to express quite complicated concepts relating to the answer which should not be covered superficially or in a patronising way. Many concepts and options will be understood more easily if sketches or diagrams are incorporated in the answer.

Comments regarding delays to the programme, costs, professional fees etc. should be included as these are important to the client. However, these are secondary to the question being asked and should not contain excessive remarks about them. The focus of the communication should be on the structure and the proposed changes. 'Text speak' should also be avoided along with abbreviations unless they are recognised terms.

Below is an example of a typical part 1b question and how it may be answered.

### Using the adapted Question 2 from the February 2023 exam – Client's Request Section 1b:

*'In order to reduce project costs, your client asks you to suggest ways in which the brief could be altered to increase structural efficiency and reduce material usage, whilst maintaining the inset roof at 8th floor. Write to your client proposing possible changes. As part of any proposals made, explain the effect this may have on the design.'*

The full question can be found at the back of this guidance document.

While answering Section 1a of this question, candidates would have already explored the various sustainability options to provide the client with their selected scheme design. Considerations may have included the following:

- ▶ Use of the existing foundation as found by the desk study. Discussing the implications of this and if possible, incorporating it into the design

- ▶ Minimising the transfer/cantilever tonnage and looking to find the most efficient option
- ▶ Discussing the material options available, possibly making the top floor more lightweight

### Example communication

To: [client@company.com](mailto:client@company.com)

Re: Project Cost Reduction

Dear Client,

Thank you for your recent email in which you have asked me to review the structural design in order to reduce project costs. My understanding is that in order to achieve more structural efficiency and reduced material usage, you would be willing to look at alterations to the brief. I also note that you wish to keep the inset on the 8<sup>th</sup> floor, so my recommendations below are considerate of this.

I have listed some options below, with a brief description and potential implications.

1) Introduce 2 external columns

By introducing 2 external columns, 2 corners of the building would no longer need to cantilever from the adjacent columns. This would make a significant cost saving on the structural design. The external columns could be detailed elegantly to minimise visual impact on the scheme and I would be happy to investigate this further with the architect.

2) Increase internal column allowance

Currently the brief is to minimise columns at ground floor with only 2 columns allowed internally outside of the core. By increasing this column allowance, we would be able to investigate more efficient floor structures, including looking at other materials such as timber. If shallower floor depths can be achieved as part of this, then the overall height of the building also reduces with a resulting reduction in cladding material. There would also be the potential to avoid transfer structure at the inset top floor, by taking columns straight down to foundations. If this option is of interest, we could look at some options for costing.

3) Reduce extent of glazing

By reducing the extent of glazing, more vertical bracing would be possible, which would make the bracing system more efficient compared to the current scheme which confines vertical bracing to the core. I note that this probably offers a lesser material saving than options 1 and 2 above. Smaller glazed areas may also result in reduced deflection requirements, which would offer a reduction in beam sizes. There may also be material cost savings in the cladding by reducing amount of glazing.

I would be more than happy to discuss these options in more detail with you and the design team. The added benefit of these options would be to greatly reduce the embodied carbon for the structural frame design.

Yours sincerely

Engineer

NB. A Sketch outlining the proposal would be a benefit.

## Calculations

This is the first section in part 2 of the exam and is where you start to develop in more detail the scheme you selected in Part 1a.

This part of the exam attracts 22 marks and so, assuming you have prepared an examination timetable that allocates time generally in proportion to marks available, and with an allowance for checking, you are going to have around an hour and a half to spend on this section. Use this time wisely! The question asks the candidate to '*prepare sufficient design calculations to establish the form, size and approximate A1-A3 carbon footprints of all the principal structural elements including the foundations*', therefore the first task is to decide which are the principal structural elements. Do not waste time designing non-critical members or carrying out repetitive and simple calculations.

For the building structures questions the principal structural elements will be different for each scheme proposed, but the following gives an indication of the likely elements:

- ▶ Main members in trusses, portal frames, arches etc.
- ▶ Transition members / transfer structures, members with high point loads
- ▶ Cantilever members
- ▶ Vertical structures where there is a high concentration of load and/or significant out of balance moments
- ▶ Members of stability systems
- ▶ Foundations including piles and pile caps, reinforced rafts and pads, balancing beams within the foundation system. Ground slab if appropriate
- ▶ Retaining walls
- ▶ Any special structural elements unique to the scheme

For the bridge structure question the principal structural elements will again be different for each scheme proposed, but the following gives an indication of the likely elements:

- ▶ Bridge deck
- ▶ Main deck support structure
- ▶ Vertical structure
- ▶ Stability system
- ▶ Foundations including piles and pile caps, reinforced pads, retaining walls, etc.

Clearly most schemes will not include all the above and, as a guide, candidates would be expected to design between five and seven elements depending on the question.

Having established which elements you are going to design, you are then expected to use your judgement and experience to decide the extent of the design checks required. Note that these are NOT supposed to be detailed design calculations; they are only required to '*establish form and size*' of the elements under consideration. Remember also that you only have on average between ten and fifteen minutes to spend on each element. For most members, checks of bending and shear alongside a span/depth deflection check will be adequate; however, candidates will gain extra marks for recognizing when additional checks are appropriate; for

example, web buckling of a steel beam under a concentrated load. Use your judgement to assess and check worst-case load combinations rather than including multiple load cases. These will eat up valuable time without gaining you extra marks.

The design calculations can be prepared in accordance with any current recognized national code of practice. The use of design guides shall not be used as the primary source of member sizing, but can be used to justify the actual sizing once the calculated design parameters are established for each principal element. Reference to such design guides or manufacturers literature should be noted where used. Please state clearly which design codes you are using and any reasonable assumptions you have made, such as loadings other than those specified in the question.

The approximate A1-A3 carbon footprints for key elements can be assessed using a straightforward calculation of the element mass multiplied by the embodied carbon factor (ECF) of the material. Candidates can refer to the Institution's '[How to Calculate Embodied Carbon](#)' document for suitable methodology and ECF values. Industry average ECF values are recommended, but other suitable values can be used. Candidates are encouraged to take advantage of the Institution's free on-line [embodied carbon basics course](#) in preparation. You will need to state clearly which ECF values you are using when preparing your calculations.

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### Embodied carbon (kgCO<sub>2e</sub>) = Mass (kg) x Embodied Carbon Factor (kgCO<sub>2e</sub>/kg)

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A carbon calculation for a pile cap may be presented as follows (using recommended default value of material from the 'How to Calculate Embodied Carbon' guidance):

Material	Type	Specification/details	Recommended default value
Concrete	<i>In situ</i> concrete (unreinforced) <sup>a</sup>	UK C40/50	0.138 25% GGBS <sup>b</sup>
Steel	Reinforcement bars	UK CARES sector average (EAF production)	0.760

2100x900x1400 C40/50 concrete – reinforcement 115kg/m<sup>3</sup>

ECF for C40/50 concrete = 0.138

ECF for Steel reinforcement bars = 0.760

Concrete:  $2.1 \times 0.9 \times 1.4 \times 2400 \times 0.138 = 876$  kgCO<sub>2e</sub> per pile cap

+

Reinforcement:  $2.1 \times 0.9 \times 1.4 \times 115 \times 0.760 = 231$  kgCO<sub>2e</sub> per pile cap.

Total A1-A3 upfront embodied carbon = 1107 kgCO<sub>2e</sub> per pile cap.

Finally, make sure that your calculations are clear, legible, and set out in a logical manner so that they can be easily followed and understood by a marking examiner. They should be of a standard that they could be sent for checking by an external third party without that party having to raise any questions. Add explanatory text where appropriate and don't skip steps. Remember, it is your job to demonstrate your design knowledge; it is not the examiner's job to try to interpret what you have done and if it is not clear to an examiner how you have arrived at your answer you will not get marks for it.

## Preparation of Proposed Scheme General Arrangement Drawings

One of the most important aspects of the Examination is the diagrammatic presentation of the proposed chosen structural scheme. This is the candidate's opportunity to convey their knowledge and experience in concept design and the preparation of schematic information from a brief. There are 20 marks allocated to Section 2d which give an allocation of around an hour and a half in which to produce such general arrangements and details as appropriate.

So why is it an important part of the question? There are various reasons which include the following:

- ▶ Demonstrates that the client's brief has been correctly interpreted
- ▶ Helps to ensure that the proposed concept design is structurally safe and practical
- ▶ Shows that the candidate has considered any critical details that may need design consideration
- ▶ Communicates the candidate's chosen scheme to other members of the design team
- ▶ Enables a budget cost estimate to be prepared for the overall project

In each of the questions in the Examination paper, Section 2d states:

*'Prepare general arrangement drawings, **which may include** plans, sections and elevations, to show the dimensions, layout and disposition of the structural elements and critical details **for estimating purpose**'.*

The requirement as outlined leaves the exact extent of the arrangement drawings and details that need to be produced up to the candidate and permits them to use their own discretion. This also includes the way they present that information; the question simply steers them as to what information may be appropriate for them to convey the outline structural scheme that they propose.

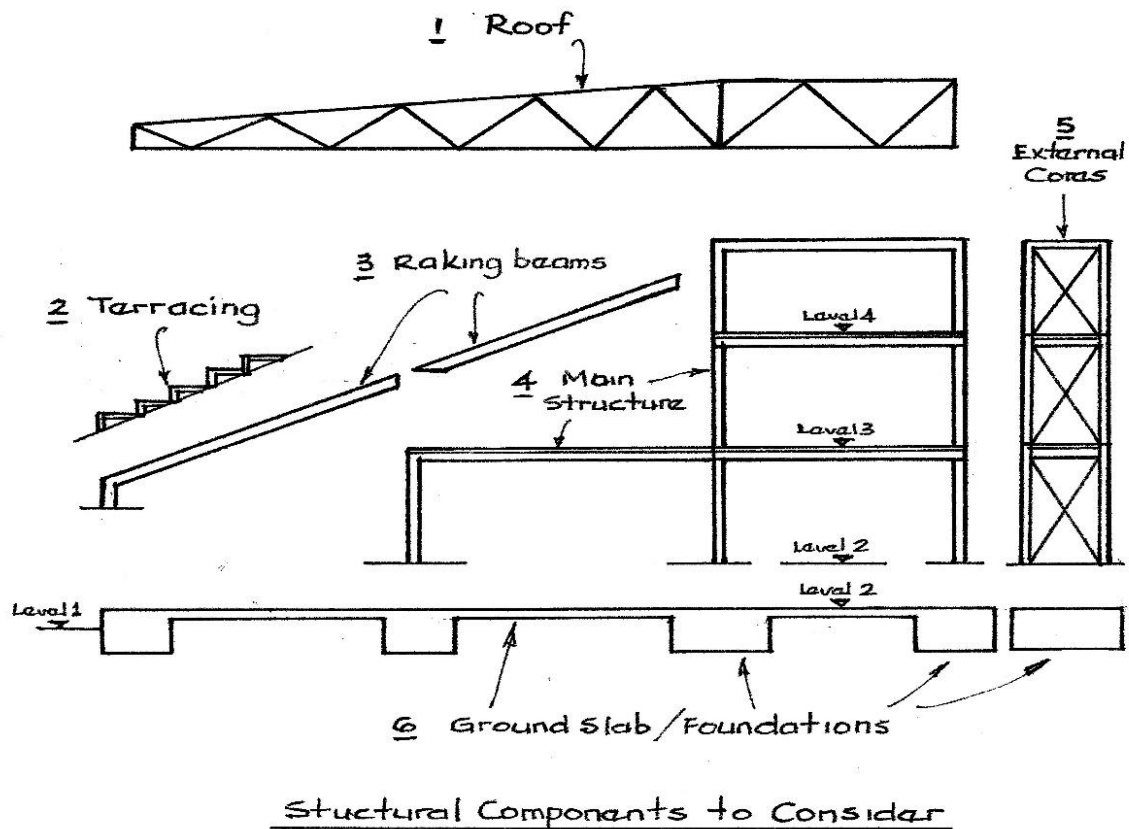
The drawings and details do not need to be to scale but should generally be in proportion and should be dimensioned. In the Examination, graph paper is provided with clear horizontal and vertical lines to a set dimensional grid. Candidates should practise before the examination preparing scheme outlines from past papers using such graph paper and become familiar with the preparation of arrangements and details using freehand techniques.

In general, the arrangement drawings should include all appropriate plans including the foundations, and a typical section and elevation if it is felt they are beneficial in conveying essential information pertinent to the proposed scheme. It may be appropriate to draw part plans where the structure is symmetrical, or to draw a single plan to represent several identical floors in a building structure. Obviously, economy of time in preparing the information is essential. Critical details should also be included. These will vary depending on the question but may include cantilever connections, major splices, retaining wall details, or a reinforcement detail that has significant design considerations etc. A minimum of three details would ordinarily be expected.

The plans and details should include all relevant dimensions and member sizes. The member sizing can be in tabular form with coding on the plans and details.

As an example of the type of response that would be expected to this part of the question, the following has been prepared as an indication only of the type of answer anticipated.

## Example - CM Question 1 July 2019

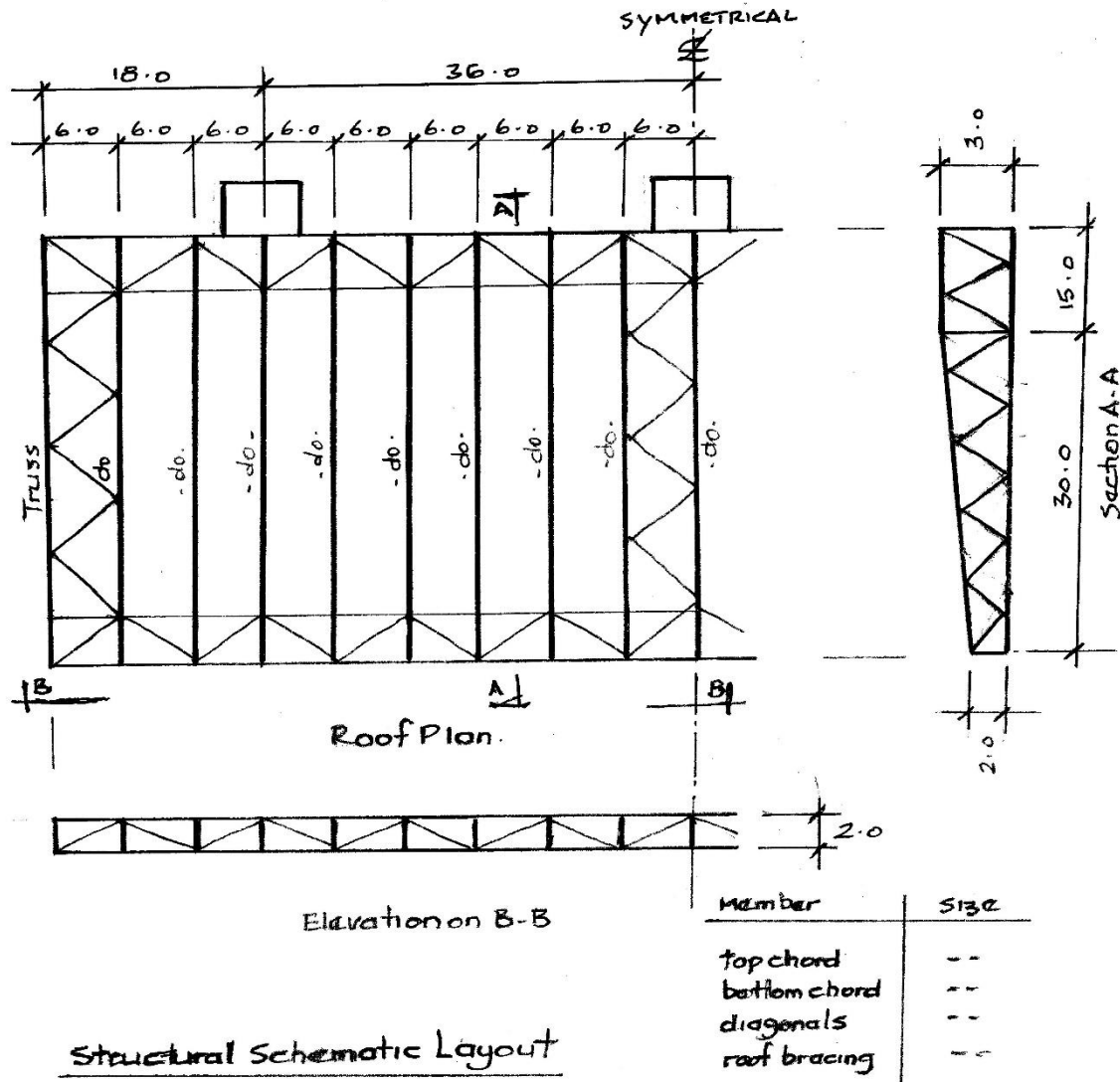


Structural Components for Arrangement and Details Consideration:

- 1) Roof Arrangement
- 2) Terracing
- 3) Raking Terrace Beams
- 4) Main Structure and Floors
- 5) External Cores (Stability Braced Structure)
- 6) Ground Slab and Foundations

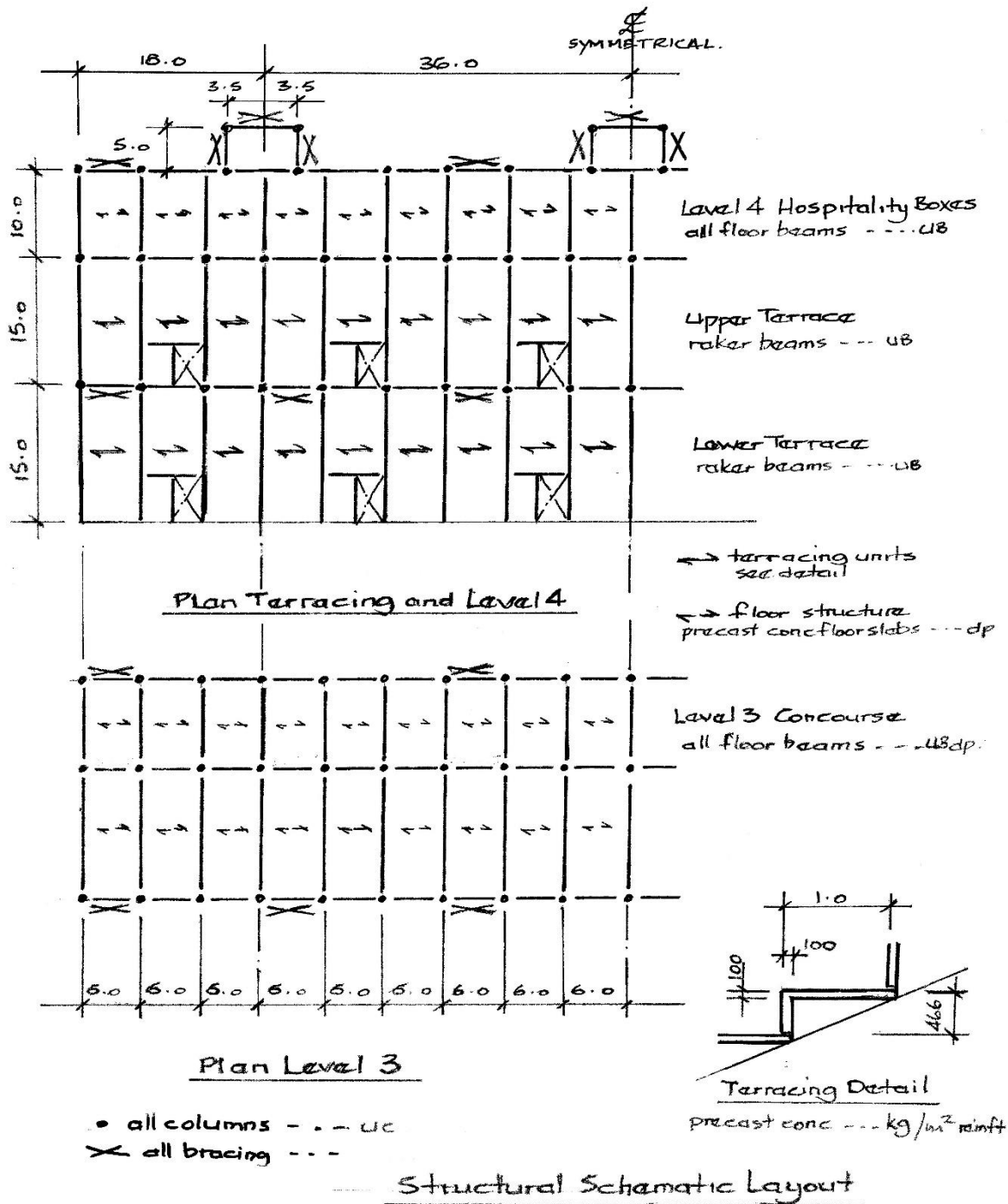
The above sketch breaks down the outline structure into individual component parts that need to be considered when preparing the respective plans, sections, and details. There are many structural scheme outlines that will satisfy the client's requirements, but for this exercise only one is being considered and the outline sketches are included below.

As outlined, all sketch layouts can be freehand using the graph paper provided at the time of the examination and should be in proportion, which means that for a rectangular building the ratio of the building's length to its breadth should be approximately correct. The plans should be dimensioned with some form of grid system.



**ROOF**

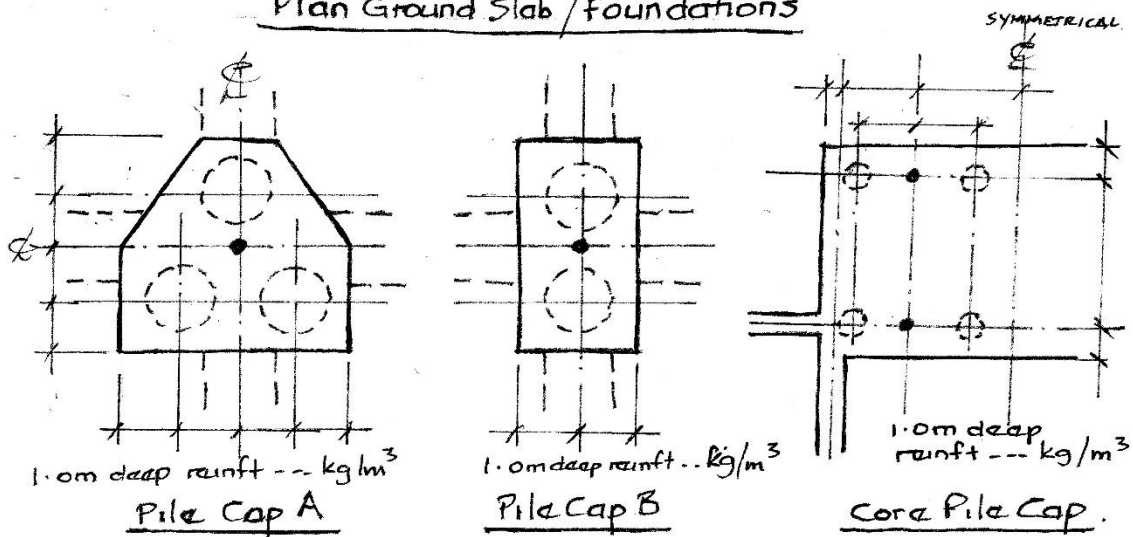
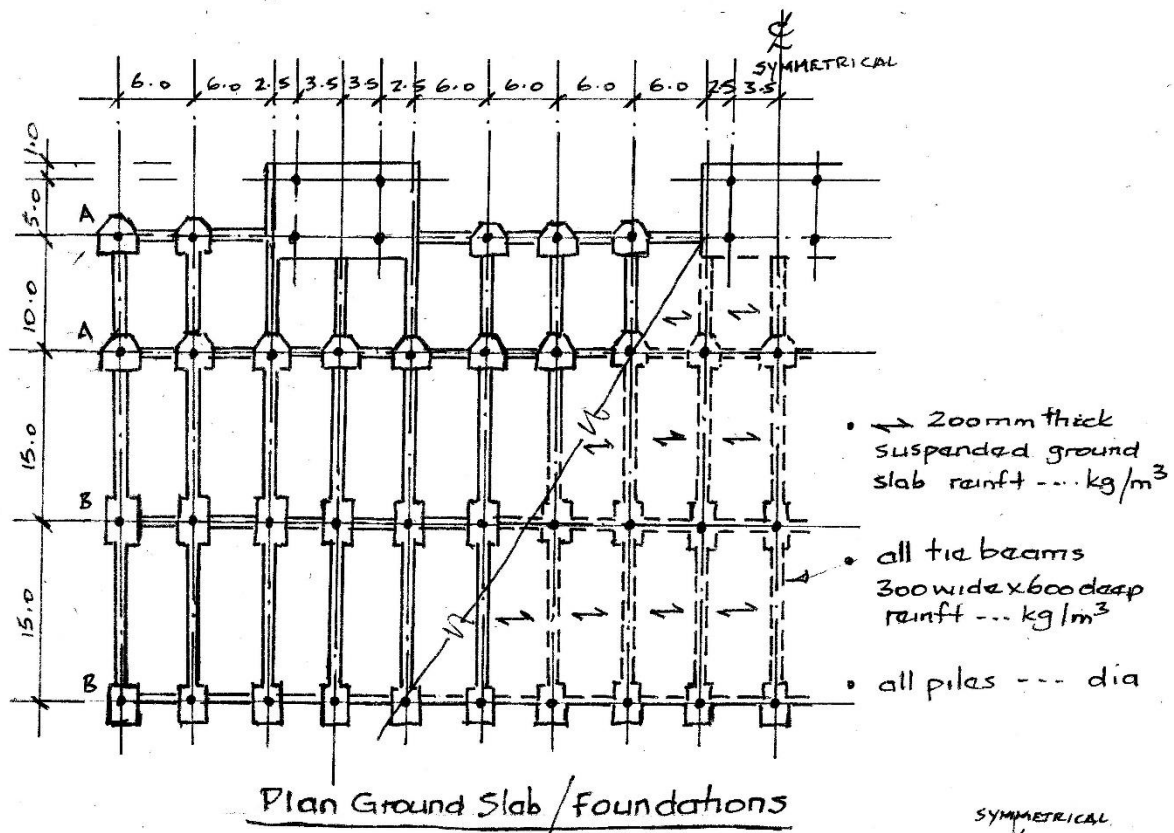
The above schematic roof arrangement shows a system of simple cantilever trusses at regular centres to suit the overall grid dimensions and bracing for stability. For estimating purposes, a simple table could be included to indicate the respective member sizes. For this exercise each individual member does not have to be designed, only the critical elements such as the top and bottom chords and worst-case diagonal members for the truss, and rule of thumb sizing for the bracing not included in the stability calculations.



**FLOORS AND TERRACING**

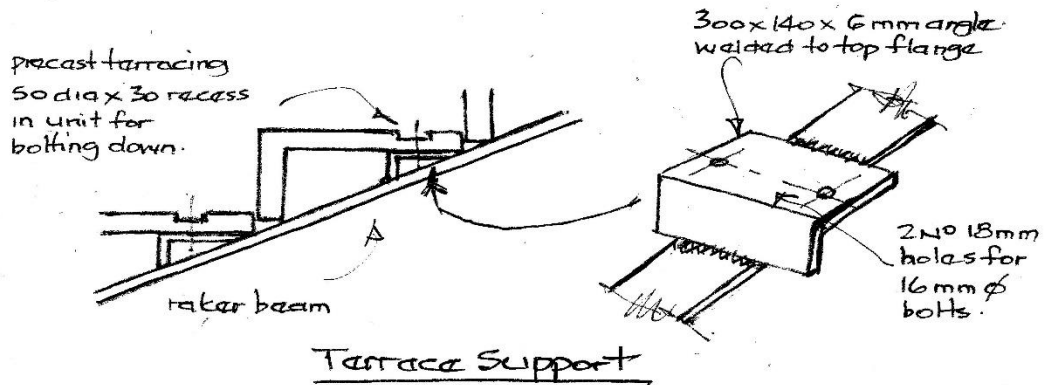
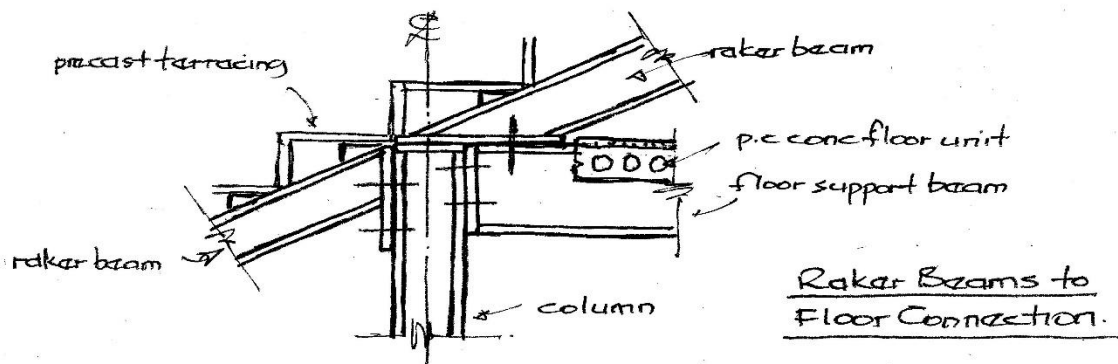
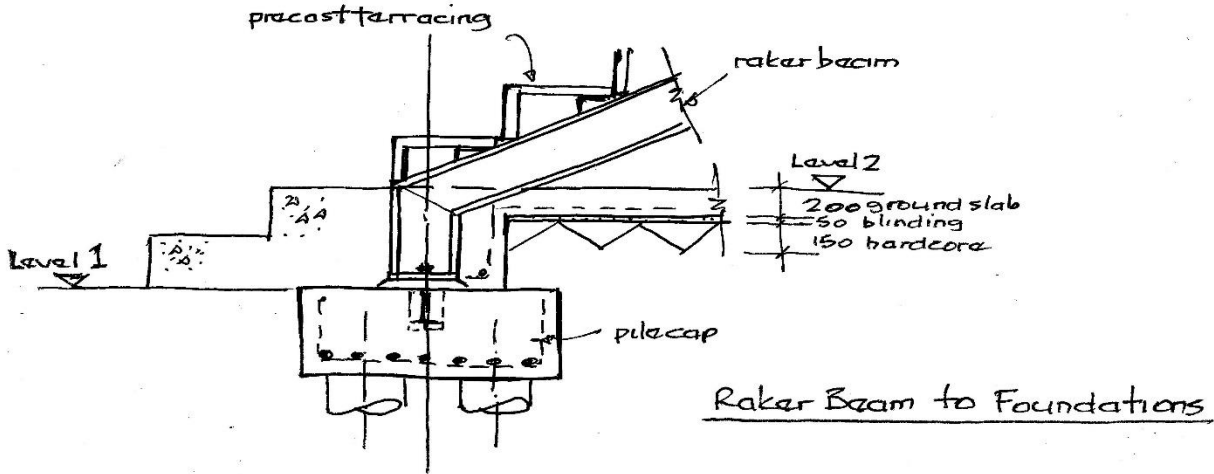
As for the roof structure, a simple plan, or plans, outlining the schematic structural layout, with dimensions and indicative member sizes for the respective elements is required. Floor slabs and concrete elements thicknesses should be included with a notional weight of reinforcement per m<sup>3</sup>.





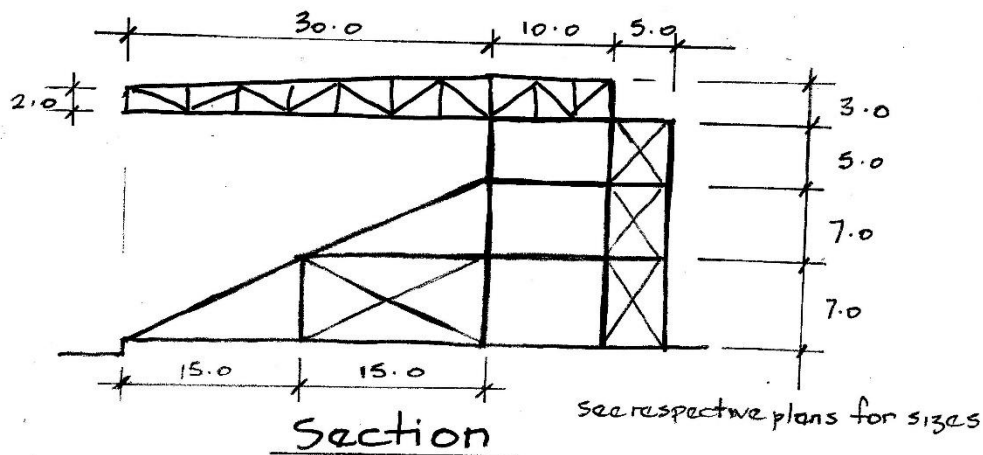
**FOUNDATIONS and GROUND SLAB**

One of the most important aspects of any scheme design is the foundations and ground slab, and all too often this is overlooked by candidates in the examination. The above shows an outline indicating what would normally be expected. The foundation plan could be simplified by showing typically two bays and then coding the pile caps and ground beam from the outline details. Simplicity and efficiency of information is the key.



**CRITICAL DETAILS**

The critical details are subjective and unique to each individual scheme, and it is up to the candidate to identify such details appropriate to their scheme. The above outlines the type of detail expected and usually three would be required. They can be sketched and do not have to be to scale, but again should be in proportion and should indicate sizes and thicknesses with notes for clarification.



### SECTIONS and ELEVATIONS

Sections and elevations are not always required, and it is up to each individual candidate to decide whether they are necessary to clarify and enhance the proposed scheme information. They can again be simple and drawn freehand. Above is a simple section which outlines the vertical height and horizontal dimensions.

### Method Statement

The final part of the examination, Section 2e, has 8 marks allocated and therefore a period of around 30 minutes to produce this should be sufficient. The aim of the method statement is to consider the proposed construction sequence to enable the works to be carried out in a safe and controlled manner. The sequence assumes that notices to the Local Authority and H&S etc. have been given. The following considerations could be included, if applicable, to your selected scheme proposal. The list is not exhaustive, and candidates are expected to include activities unique to their chosen scheme:

#### Site Set Up

- ▶ Clear the site and erect perimeter hoarding to secure the site
- ▶ Carry out a site survey and provide survey stations
- ▶ Provide H&S signs and notices
- ▶ Prepare an area and erect the Site Compound Facilities
- ▶ Provide hard standing around the compound, including the access road and storage areas
- ▶ Install temporary service to the site facilities

#### Site Investigation

- ▶ Check for existing above and below ground service, cap or divert as necessary
- ▶ Check site investigation for any special requirements or existing below ground obstructions
- ▶ Carry out any special pre-construction requirements
- ▶ Check ground conditions to verify design assumptions

**Foundations**

- ▶ Level the site and set out the building
- ▶ Provide oversite for movement of plant and machinery
- ▶ Excavate foundations in a predefined sequence, trim the sides and base to the required profile and blind the bottom
- ▶ Provide temporary support to the excavations
- ▶ Construct reinforcement cages and place in excavations
- ▶ Locate and place the holding down bolts for casting in the foundations
- ▶ Place and vibrate the concrete foundations

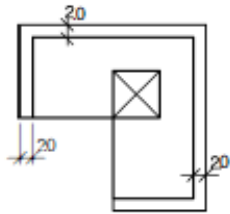
**Superstructure**

The method of construction for the superstructure will again be unique to the scheme chosen and would follow in a similar style and pattern as for the foundations with careful consideration given to the sequencing of construction while ensuring stability at all stages. Any special requirements that have a time implication in the programme should be included. The roof may be of a separate form of construction from the floors and therefore must be treated as an individual programme item.

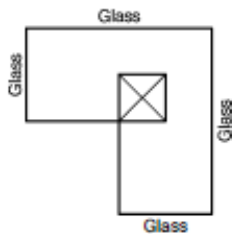
The external finishes can be consolidated depending on the client's requirements. Curtain walling could be considered as a single installation item, whereas cavity wall construction requires external scaffolding and access platforms for material storage and placement.

This is to show that you have a safe method to construct the structure.

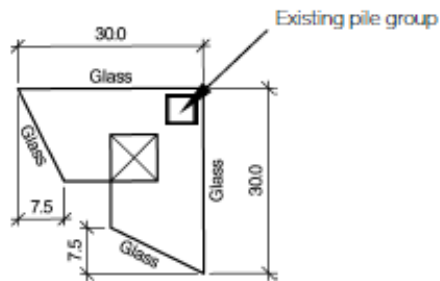
Example Question – adapted from February 2023



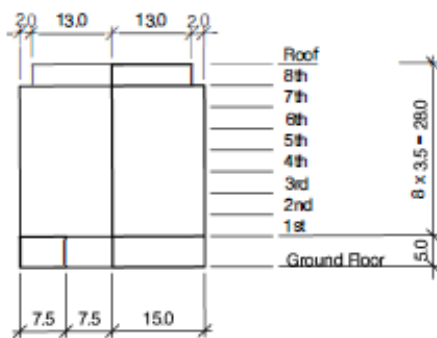
8th FLOOR TO ROOF



1st to 7th FLOOR



GROUND FLOOR



ELEVATION

NOTE All dimensions are in metres

FIGURE Q2

## Q2. Office Building

### Client's requirements

1. An 8-storey office block is to be constructed. See Figure Q2.
2. All elevations are to be glazed. No bracing is permitted in glazed facades
3. Minimum column spacing is 6m. Only 2 internal columns are permitted at ground floor level. No columns are permitted outside the perimeter of the building
4. The first floor is to be 5m above the ground floor level. Other floors are to have a 3.5m floor to floor height.
5. On the 8th floor the façade is to be set back 2m from the lower floors. See Figure Q2.

### Imposed loading

6. Roof 4 kN/m<sup>2</sup>
7. Floors 10 kN/m<sup>2</sup> on ground floor and 4kN/m<sup>2</sup> on other floors

### Site conditions

8. The site is in the centre of a large city. Basic wind speed is 40.0m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20.0m/s.
9. The ground conditions are as follows:
 

Ground level – 5m	Heavily contaminated made ground N=2
-5m –to -10m	Firm clay C=50kN/m <sup>2</sup>
Below -10m	Mudstone C= 150 kN/m <sup>2</sup>

 No water was discovered.
10. A desk study reveals an existing pile group and pile cap from a previous construction project. The foundation's approximate location is shown on the plan, and records indicate an expected capacity of at least 10MN.

### Omit from consideration

11. Design of the lifts/elevators and stairs.

## SECTION 1

(50 marks)

- a) Prepare a design appraisal with appropriate sketches indicating two distinct, viable and sustainable solutions including the foundations. Reusing existing structures where required, clearly indicate the functional framing, load transfer, serviceability and stability aspects of each scheme. Using sustainability as a key criteria, review and critically appraise the schemes and identify the solution you recommend, giving reasons for your choice.
 

(40 marks)
- b) In order to reduce project costs, your client asks you to suggest ways in which the brief could be altered to increase structural efficiency and reduce material usage, whilst maintaining the inset roof at 8th floor. Write to your client proposing possible changes. As part of any proposals made, explain the effect this may have on the rest of the design.
 

(10 marks)

## SECTION 2

(50 marks)

For the solution recommended in Section 1(a):

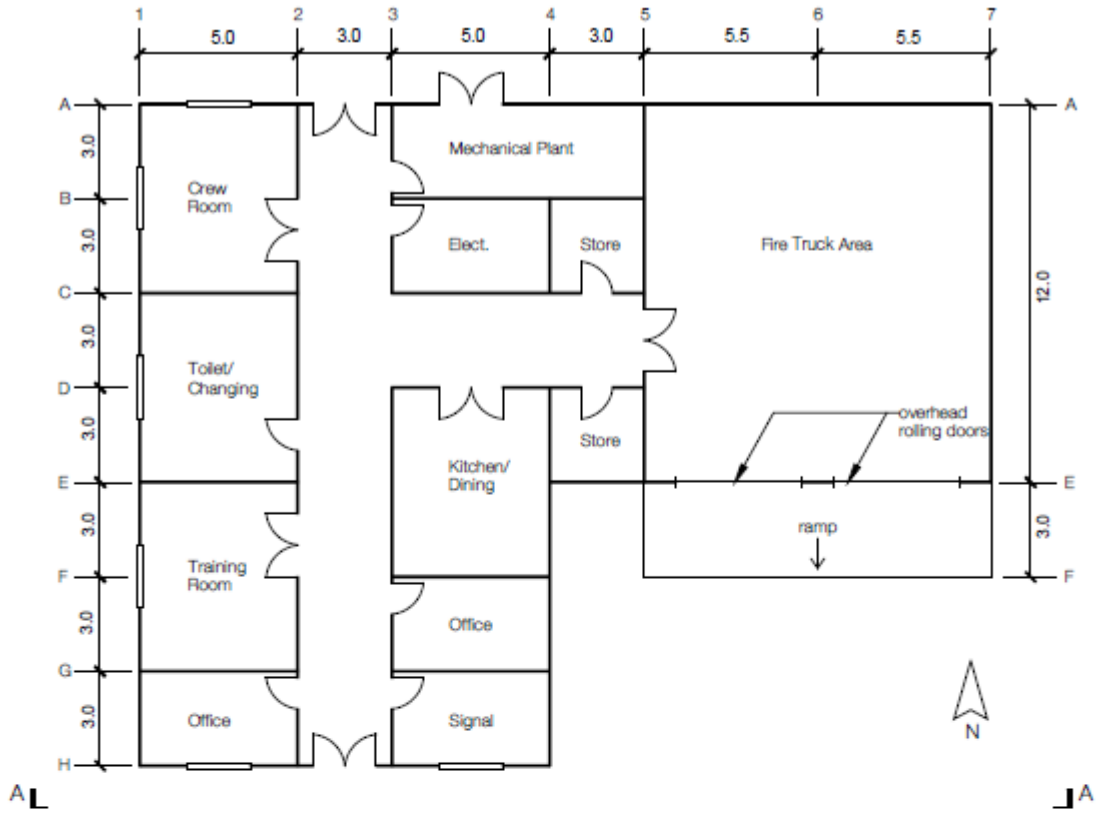
- c) Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. Include approximate A1-A3 carbon calculations for each of your principle elements.
 

(22 marks)
- d) Prepare general arrangement drawings, which may include plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes.
 

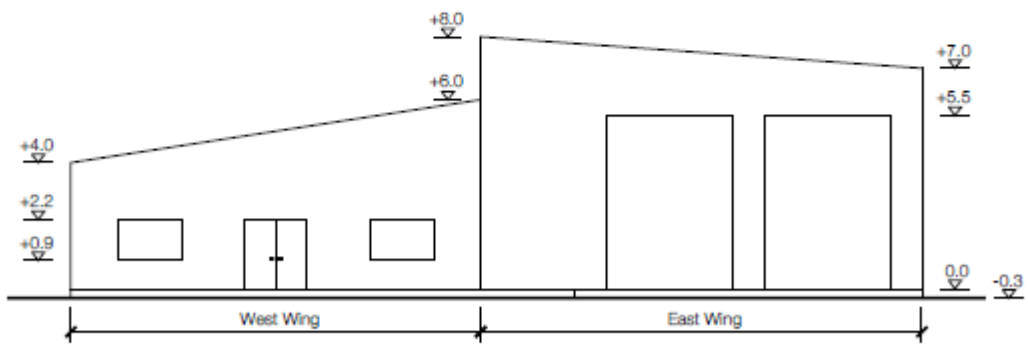
(20 marks)
- e) Prepare a detailed method statement for the safe construction of the works, including consideration of any temporary works that may be required
 

(8 marks)

Example Question – adapted from July 2023



PLAN



SECTION A-A

NOTE: All dimensions are in metres.

FIGURE Q2

## Q2 - Secondary fire station building

1. A secondary fire station building at a regional airport; see Fig Q?.
2. The single storey building comprises two wings. Offices with training and welfare facilities are in the west wing. Garage parking for two fire trucks is located in the east wing; no internal columns are permitted in the fire truck area.
3. Corridors are 3m wide, windows are 2m wide by 1.3m high with windowsills at 0.9m above floor level. Doors are 2.2m high, single doors are 1m wide and double doors 2m wide.
4. A minimum floor to ceiling height of 2.5m is required for the west wing of the building.
5. Two overhead rolling doors to the east wing, each to provide a clear vertical height of 5.5m and a clear width of 4.5m for the fire engines.
6. The sloping roof is for maintenance only access.
7. Materials for the external envelope of the building are to be selected to minimise energy consumption.
8. The building is to have a 1-hour fire rating. Fire doors are to be provided between the fire truck area and the west wing of the building.

### Imposed Loading

9. Roof	0.6 kN/m <sup>2</sup>
Ceilings and services	0.3 kN/m <sup>2</sup>
West section floors including plant	5.0 kN/m <sup>2</sup>
Engine enclosure floor	10.0 kN/m <sup>2</sup>

### Site Conditions

10. The regional airport is located in an open flat area 16 kilometres from the nearest town. Basic wind speed is 42.0m/s based on a 3-second gust; the equivalent mean hourly speed is 21.0m/s.
11. Ground conditions:
 

Ground level – 0.3m	Topsoil
0.3m – 3.0 m	Medium SAND and Gravel. N = 15 increasing to 20 with depth.
Below 3.0 m	Stiff Clay. C = 250 kN/m <sup>2</sup> .

Groundwater was encountered at 2.0m below ground level.

### Omit from Consideration

12. Design of roller doors, associated services and the external ramp.

### SECTION 1

(50 marks)

- a. Prepare a design appraisal with appropriate sketches indicating two distinct, viable and sustainable solutions for the proposed structure including the foundations. Reusing existing structures where required, clearly indicate the functional framing, load transfer, serviceability, and stability aspects of 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. (40 marks)
- b. After the scheme design has been approved, the Client asks whether changes could be made to the brief in order to reduce usage of materials, whilst maintaining the floor plan as indicated. Write to your client proposing possible changes. As part of any proposals made, explain the effect this may have on the rest of the design. (10 marks)

### SECTION 2

(50 marks)

For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. Include approximate A1-A3 carbon calculations for each of your principal elements. (22 marks)
- d. Prepare general arrangement drawings, which may include plans, sections and elevations to show the dimensions and layout of the structural elements and critical details for estimating purposes. (20 marks)
- e. Prepare a detailed method statement for the safe construction of the works to include consideration of any temporary works that may be required. (8 marks)



## Windspeed Conversion Chart

The following chart is to be used for IStructE exams only and is intended as a guide for candidates who are using codes which provide a 10-minute averaging period.

