Examiner Report

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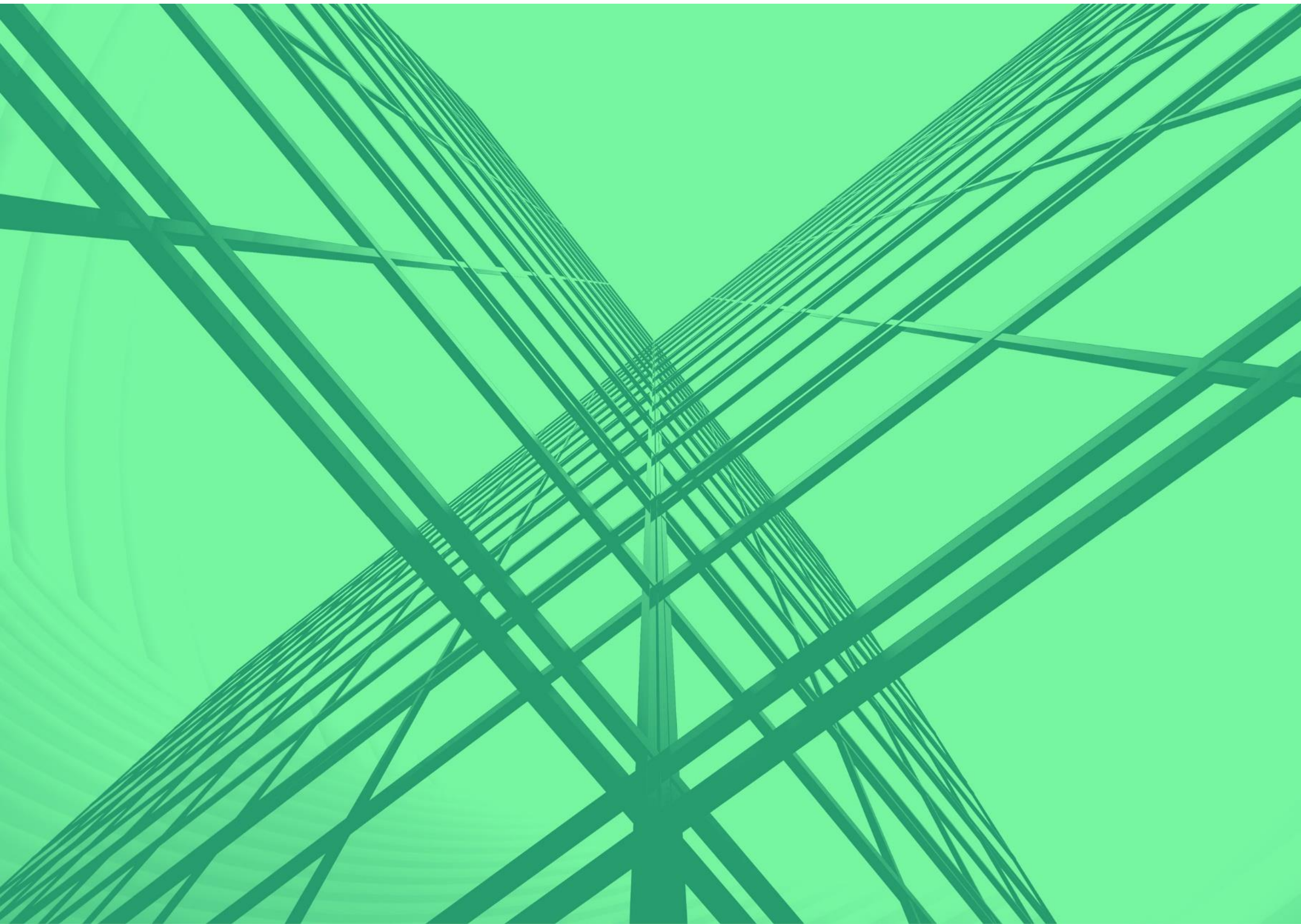

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Notes on the reports

The Examinations Panel on behalf of The Institution of Structural Engineers continues to review all aspects relating to the Chartered Membership, Associate-Membership, and Associate-Membership to Chartered Membership Supplementary Examinations and their relevance and role in assisting structural engineers to gain Chartered and Incorporated status within a worldwide professional structural engineering organisation.

Candidates should note that the Chartered Membership examinations, regardless of when produced, are of equal standing and are developed via the same rigorous process.

Comments from the Examinations Manager

All candidate exam papers were received back from the exam centres in good time and all scripts and pages were accounted for.

Candidates should ensure that all pages of their exam script have the candidate number on them, and they should also ensure that the pages are numbered in a logical and consistent way. In addition, several candidates included their full name on the cover sheet. Candidates are reminded that in order to preserve the anonymity of the marking process they should only put their initials (e.g. JS and <u>not</u> John Smith) on the front page and not their full name.

A general observation from examiners is that many candidates adopt a formulaic approach in their responses to Part 1a and Part 2e, using ‘standard’ wording and sketches possibly taken from an exam preparation course. Candidates should note that examiners are looking for bespoke solutions which address the specific requirements of the brief and marks will not be awarded for generic answers.

Chartered Membership exam

Question 1: Residential building with basement car park

The question required the candidate to support the building's upper floors from a smaller footprint at Level 1. This required some form of cantilevering structure, probably located at the underside of Level 2 or at roof level. A 2-metre-high parapet was required at roof level, which gave the opportunity to hide structure within that height.

Critically the column spacing requirements in the basement Level -1 meant that a further transfer structure would be required. Some candidates sought to avoid this by supporting the upper levels from the eccentric core only, but this created different structural challenges and a more complex load path.

Laterally stability could be achieved using the core, which runs the full height of the building. The core is eccentric, and it was possible to introduce other forms of stability on Grids C and 3 as long as this was accounted for in the transfer structure.

Likely foundation solutions included a raft on the dense gravels or piling to the rock. Candidates are expected to know different forms of basement construction, including knowledge of the safe construction of basements.

Section 1b asked the candidates to consider an increased floor plate size from Level 2 upwards. Candidates were expected to discuss how this would make the cantilever structures impractically large. As well as discussing the issues arising from the change, candidates were expected to offer potential solutions, which could include suggesting the introduction of more columns between Levels 1 and 2.

Candidates generally chose the key elements of the structure to design in Part 2c. The basement wall and foundations should not be forgotten in this section. Lateral stability of the building should be included in the calculation.

In Section 2d some candidates attempted to show several levels on a single general arrangement. This does not work well on an asymmetrical building, and it was important for this building to show a clear general arrangement at several levels. Critical details included the transfer structures, basement wall and possibly the parapet wall.

In Section 2e candidates were expected to describe safe construction of a basement which addressed working below the water table. Sequence and propping associated with transfer structures for the superstructure should also have been demonstrated.

Question 2: Airport Main Terminal

The question required the design of a 3-storey large-span main terminal for an airport. It needed a reasonable understanding of the functional requirements of airport facilities, loadings, aesthetics, and architecture. The size/length of the structure implied a requirement for using expansion joint(s). For a steel solution a single centrally located expansion joint would have sufficed, whereas for a concrete solution more frequent expansion joints were needed in both directions. The roof structure was required to be architecturally pleasing, therefore a space structure, glulam beams, or a similar appealing structure was expected to form the roof.

Most candidates produced a decent first solution, generally involving a braced steel structure using steel trusses in both directions, although the point about the roof structure being aesthetically appealing was generally overlooked. The column spacing was specified at 25m to 30m to give the candidates the opportunity to get a good balance of spans; however, the majority of candidates only used 30m column spacing throughout. A 28/34/28m column spacing would have provided a more efficient solution.

Many candidates struggled to propose a distinct second concept solution and generally proposed a second scheme which was very similar to the first scheme. Some candidates opted for uneconomic and unnecessarily complicated second solutions. Few candidates recognised that a simple second solution existed in the form of moment frames at least in the transverse direction in lieu of a braced frame structure.

Many candidates failed to recognise the need for movement joint(s) or the implications of not using movement joint(s) on the main structural elements such as floor, wall, roof, and finishing and the need for special detailing to avoid major cracking. The requirement for a smooth floor construction generally was not addressed.

Many candidates did not satisfactorily address the serviceability requirements or failed to produce sketches to illustrate the functional framings of their proposed schemes and a clear strategy for the overall lateral stability. Inclined columns were proposed by many candidates to support internal long span beams. A more practical and efficient approach was to use vertical columns with cantilevered beams to support the inclined glazing mullions. Some candidates breached the column spacing and structural zone constraints.

Foundation solutions were generally reasonable, although some candidates used insufficient shallow foundations not recognising the reduced capacity of the soil due to the presence of high ground water. Some candidates used uneconomic and, in a few cases, inadequate raft foundations.

The letter presentation was generally satisfactory, however many candidates failed to adequately explain the implications of increasing the inclination of the inclined façade, partly due to the incorrect use of inclined columns. Only few candidates addressed the need for larger cantilevers, impacts on end columns and impact on extra gravity and wind loads on beams, columns and foundations.

The standard of the calculations varied. A few candidates produced sufficient calculations for the overall stability, beams and columns considering the required serviceability and correct column loading. The floor grid layout was of a square form; therefore, it would have been more economical to utilise a two-way spanning floor system, i.e., adopting main beams spanning in both directions between the columns with secondary beams distributing the loads evenly between them.

Most candidates did not take into account the impact of bending moments on columns due to the eccentricity of beam reaction forces, or deep connections required for trusses/beams and particularly for end columns.

As a result, the columns in a number of cases were grossly undersized. The size of the shallow foundations in some cases was inadequate due to the presence of the groundwater.

The beam/column connection details were critical to this question and needed to be presented adequately. The basement details also were critical here. Only a few candidates produced such details. Other drawings such as plans, sections, and details varied in quality and quantity. Plans and sections generally did not address means of the vertical stability properly.

The key issues in Section e were the stability of bare steel frames during the construction and the need for development of a detailed and well worked out sequencing programme to indicate the temporary vertical and possibly horizontal bracings at various stages of the construction work. The need for using spliced connections for large beams and columns and preparation of these connections on the ground (as much as practicable) were amongst other necessary items.

Most candidates reasonably demonstrated their understanding of this section. However, the programme length proposed varied between 1 and 5 years.

Question 3: Crossing over river and railway line

The brief called for a 265m long structure crossing over a 125m wide river and a railway embankment. The spans arrangement needed to respect a 50m wide navigation channel and a 2m clearance from the steep railway embankment. Piers within the river were allowed but had to be designed against ship impact forces. These constraints allowed a variety of possible support locations and corresponding span arrangement to the candidates but required a minimum span of approximately 60m over the navigation channel and around 22m across the railway line. The clearance above the railway was more critical than above the river.

It was therefore expected to see solutions with appropriate span to depth ratios depending on the material adopted and the use of continuous spans with variable depth girders was favoured. Multi-span continuous steel-concrete composite decks with plate girders and prestressed concrete box girders with similar spans arrangements were considered acceptable as distinct solutions in section 1a. Other viable solutions with a longer span over the river included cable stayed decks, through steel truss or tied arch.

Most candidates were able to identify two distinct solutions; however, some load path diagrams were missing and when solutions included piers within the river, the opportunity to discuss the ship impact was sometimes missed. Given the ground conditions, the spans, and the river, piled foundations were expected to be selected by candidates. Additional marks were allocated to candidates mentioning the effects of scour in the design of the foundations within the flood zone. The environmental constraint that was specifically highlighted within the Client's brief was generally overlooked. It was expected for candidates to consider the environmental impact in the scheme's appraisals in terms appropriate use of material, construction methods and maintenance.

The letter requirement in Section 1b was expected to impact most of the solutions with supports located between the river and the railway embankment. This was well addressed in most scripts, and where the selected solution included a longer span without any support in this location it was expected for the candidates to explain how the extended exclusion zone would impact on the construction method and the delivery programme.

For the calculations in Section 2c, candidates were expected to include the sizing of the main deck members, the piers, or the abutments as well as foundations. For supports within the river, candidates were expected to include the effects from ship impact, however this was unfortunately often not considered. There was ample opportunity in this section to state that additional checks would need to be carried out, particularly for large span structures.

In general, the quality of the drawings in Section 2d was disappointing. Candidates should be reminded that drawings are required to be clear and in proportion. Very few candidates provided any critical details of the bridge such as vital connections between the cross girder and the truss members. Details of the splices, expansion joints and parapet connection details were also lacking. Some of the candidates provided few or no notes and drainage details were often missing.

The method statement and construction programme in Section 2e required minimal disruption to the railway line and to respect the fish spawning season for any work in the water. Due to the site constraints, incremental launching or balanced cantilever construction was expected to be identified, with temporary cofferdams for substructure construction. Unfortunately, the fish spawning season was either missed or mis-interpreted by some candidates. The construction programme was generally underestimated.

Question 4: Tall building over tramway

This question tested candidates' knowledge and experience of tall buildings. The key challenge was for candidates to demonstrate an understanding of lateral stability for both superstructure and foundations. Cores were slender and would not provide adequate lateral strength in the weak direction, thus some contribution to lateral strength from the perimeter structure was necessary. There were no constraints on overall height or floor depth. Construction over the live tramway also required consideration.

Candidates should read the question carefully and identify the key challenges before diving in. There are often useful hints in the requirements and constraints, and sometimes failure to read the question thoroughly can lead to candidates missing important points. Some candidates waste time rewriting the question or describing generic load paths. Less than adequate answers are often the result of poor time management; a reasonable exam strategy is to provide some material in answer to every section.

The ability to produce workmanlike hand sketches is a necessary skill for the CM exam and candidates are recommended to attend a sketching course if possible.

Many candidates had difficulty proposing two distinct and viable options. Framing layouts for both options tended to be similar with only materials differing. Differences between schemes could include different materials, grid layout, load paths, foundations, and stability provision. Changing just one of these would not be enough to make a solution distinct and it is expected that at least two should be significantly different to satisfy the requirements of the question. Candidates will not lose marks if they propose an interesting but difficult to analyse structure and a more straightforward structure, then choose the straightforward scheme to develop in Part 2.

A number of candidates did not consider lateral stability in both directions, only dealing with the less onerous gable wind load which was resisted by the stiffer building section. The worst case for lateral stability assessment was in the other direction where a more slender section had to resist a greater wind load. Significant wind loading was not recognised by some due to incorrect wind calculations. The cores alone were too small to provide overall structural stability and a contribution from bracing, a moment frame or an outrigger system in the external façade was necessary.

The impact load included in the question was ignored by some candidates.

Disproportionate collapse was mentioned by some candidates but not really considered in detail.

Interpretation of geotechnical information to inform foundation proposals was generally reasonable. Most candidates opted for piled foundations to the 35m deep strong sandstone. Some candidates chose a reinforced concrete raft founded on the weak sandstone; this was also acceptable, subject to justification.

Most candidates included annotated sketches in describing their schemes; however, load transfer and overall stability often lacked clarity and simple annotated sketches illustrating these systems would have helped.

In Section 1b, increasing the number of floors would increase wind and vertical loads, although residential live loads would be lower. Design and construction programmes and costs would increase. The change of use to the top floors would reduce the threshold of acceptable wind induced vibrations and good candidates could have discussed how building accelerations could be reduced if necessary. A business letter format was generally and correctly used. Most answers identified several the key issues, however few included annotated sketches.

Reasonable calculations for wind load, vertical loads and lateral stability including stability of the building as a whole against overturning were required. Element calculations were expected for a selection of principal structural elements such as the rooftop zone structure, perimeter columns, cores, typical floors, and foundations (either piles and pilecaps or raft) and the lateral load resisting system.

In general, the quality of the calculations was just acceptable; most candidates opted to design more straightforward elements and lateral load resisting systems were sometimes ignored. Sensitivity of long span elements to deflection & natural frequency were often not considered.

Design guides were sometimes used to size members. Whilst this is acceptable in Section 1a the design calculations should be prepared in accordance with any current recognised national codes of practice.

The draughting quality of drawings and details was often poor. Unruled drawings should be approximately to scale in order to show correct proportions. Most candidates produced drawings which were just adequate for budget costings. Split plans were commonly used, accompanied by an overall building section. If split plans are used they need to be clear.

Dimensioned plans and sections were required as a minimum. The plans needed to include the roof, upper floors, substructure and foundations. All member sizes should be included for estimating purposes even if not calculated.

Appropriate details to clarify critical areas were required; these would include such details as beam to core wall connection, roof enclosure, perimeter structure to cladding interface, support frame joints, main column to foundation details. Good details are helpful in showing a candidate’s engineering experience.

The method statement should have considered the means of installing the foundations below the tramway, including a method for protection of the tramway at all times. The need to maintain stability of the superstructure during construction should also have been addressed. Candidates who focused on site specific matters for the method statement were likely to gain more marks than those providing stock answers. The better scripts included detailed descriptions with sketches depicting unusual construction sequences. Programmes were mostly in the 24-36 months range.

Question 5: Forestry lookout station

The question was kept as open as possible with a very simple brief to provide an elevated platform within a forest that needed to be readily demountable. The simplicity of the brief meant that no sketch was required with the question.

It was pleasing to see a mixture of free standing and guyed towers offered as solutions, both in steel and in timber. There were some very good solutions but sadly the construction aspects were not handled as well. The good solutions recognised the need to keep the structure light and to be designed so that they were simple to erect and dismantle. The weaker ones were far too bulky and relied upon substantial erection equipment which would have been difficult to use in such a remote site, resulting in a number of failed scripts. It is vitally important that designers understand how structures are built so that they are able to produce safe and economic structures.

The dominant load effect was overturning: those candidates who used a guyed system of cables generally demonstrated a good knowledge of structural behaviour and ended up with a light system. Those who went with free standing structures inevitably had a heavier design but there was significant variation in the overall tonnage of material. The better scripts used a narrower face width of the tower at the top and flared the legs out at the base by using outriggers to substantially reduce the foundation loads.

There was also significant variation in the treatment of the foundations. Bearing in mind that the key parameter was dismantling and transport of the tower, some candidates used very heavy cast in place foundations. The better solutions used screw piles and outriggers and guys to arrive at very effective solutions. One candidate proposed using ballast bags to resist overturning with the bags filled with soil from the forest floor that was replaced in-situ after demobilisation. This saved hugely on transporting the tower.

There were several opportunities for candidates to demonstrate their understanding of structures and design briefs. One was that there were essentially two load cases; a service load case and a survival case. The tower needed to be sufficiently stable in service when it was occupied. Clearly a tall flexible structure might present some challenges for the comfort of the users but few candidates recognised the need to consider deflections or acknowledge that vibration could be a problem.

It was pleasing to see that there were some very good papers produced for an unusual but relatively straightforward structure.

Examination Statistics

The following section provides some general statistics to provide an overview of candidate performance during the exam. A total of 407 candidates attempted the exam.

Pass rates by question

Question	Pass rate
1: Residential building with basement car park	27.66%
2: Airport Main Terminal	21.88%
3: Crossing over river and railway line	9.09%
4: Tall building over tramway	30.00%
5: Forestry lookout station	35.71%
Total	26.54%

Pass rates by exam attempt

Exam attempt	Pass rate
1st Attempt	44.44%
2nd Attempt	25.93%
3rd Attempt	10.19%
4th Attempt +	19.44%

This table does not include the total number of candidates in each attempt number, only those that passed.

Chartered Membership Online Preparation Course

Since the launch of the online preparation course, hundreds of candidates have benefitted from the learning opportunities around the world. Up-to and including the September 2021 exam, 42.92% of candidates that have purchased the course have subsequently passed the exam.