The Institution of StructuralEngineers

Examiner Report

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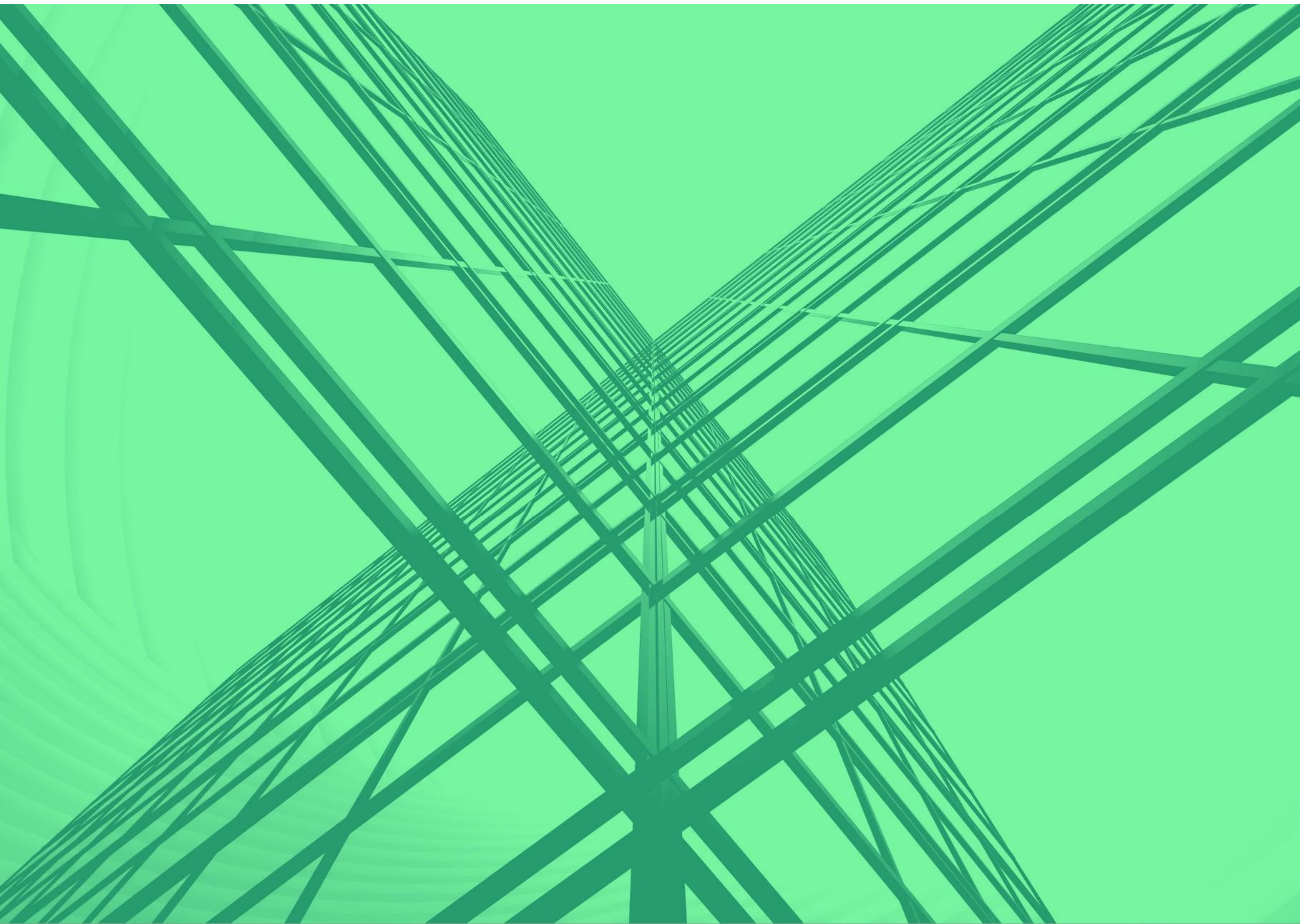

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Notes on the reports

The Examinations Panel on behalf of The Institution of Structural Engineers continues to review all aspects relating to the Chartered Membership and Associate-Membership 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 January and July Chartered Membership examinations 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 not 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.

Please note that this report only contains the observations for Questions 1, 2 and 5.

Chartered Membership exam

The pass rate amongst candidates on their 1st, 2nd, or 3rd attempt was 34.2%.

Question 1: New hotel with apartments

Section 1a

The question required the candidate to consider suitable and alternative forms of structure for a four- storey hotel and apartment building. The proposed building could be split into three distinct areas; the roof, the hotel/apartments and the foundations. The schemes put forward by many candidates ignored the building profile outlined in Figure Q1 with several adding vertical columns to the east and west elevations to make the question easier but non-compliant with the brief. Cantilevers were either ignored or were accompanied by props or hangers, and in some instances vertical stability bracing was included across the outside face of the building or behind glazing with a note for it to be 'decorative'. Many schemes were accompanied by generic, and often irrelevant, statements on the functional framing, load paths and stability that were simply repeated for both options. The question clearly asks for statements to be specific to the schemes being proposed. The proposed designs should also be accompanied by a design appraisal with appropriate sketches. All too often the design appraisal was brief and the structural proposals for all levels were contained only on one small scale plan resulting in incomplete and unclear information. Candidates should appreciate that Section 1a is the nucleus of the examination, attracting a large proportion of the overall marks, so the clear dissemination of their thoughts, particularly in sketch form, is paramount.

The roof was in many instances ignored in both the scheme and final design stage, although it formed a principal part of the structure. Consideration was required as to how to deal with the cantilevered section of the roof and the positioning of the columns required to transfer load to the floor structure at Level 4. Only one internal column was permitted at Level 4. The ideal solution was to have a braced, lightweight lattice type structure supported by a raking column to the west face and a vertical column to the east face which in turn could be supported by the cantilever floor at Level 4 and a vertical internal column on one side of the central corridor. Some candidates proposed a floor-depth Warren truss, completely sterilising the floor zone at Level 4; or a Vierendeel truss arrangement with extra internal columns. Some candidates proposed heavy reinforced concrete beam and slab schemes for both options that were uneconomic with a lack of consideration given to the vertical load transfer required at Level 4.

The options chosen for the main hotel/apartment element were, in most cases, either a braced steel frame structure with composite or pc concrete floors utilising the two cores or internal bracing for stability, or a braced insitu concrete structure with flat slabs using the cores for stability. Whilst these proposals were acceptable, candidates often failed to think the whole design process through and were penalised for failing to observe the restrictions contained within brief in terms of the number, positioning or spacing of columns. External cross-bracing was often sited across glazed areas, or across the faces of the balconies. The cores were taken as a rectangular in plan, ignoring the stair and lift openings, when in reality they were U-shaped and, if used as the sole means of stability, would result in a torsional effect on the structure. The cantilever balconies were often supported by hangers or props, restricting access and circulation. Neither of these types of support were necessary. Two scheme proposals using the same material with just a change in span direction, or grid spacing and span configuration, is not acceptable. Preliminary member sizing was sometimes ignored and when it came to the actual design stage some members were found to be inadequate for the condition under consideration and the constraints contained in the question.

The foundation and Level 1 design was relatively straightforward with a cantilever balcony and a level ground floor slab. A competent bearing stratum was present at 1.4m below the made ground. The ideal solution would have been primary beams, (precast/insitu concrete or steel), supporting either a precast or instu concrete floor slab. The foundations could have been individual reinforced or mass concrete pads, or longitudinal strip footings with the balancing effect of the cantilevered balcony being considered in the design. Whilst most candidates adopted variations of these options, some chose bored piles with pile caps whose underside was located on the competent bearing strata making the piles unnecessary and therefore an uneconomical solution. The bored piles proposed were often grossly oversized. Some candidates propped the cantilever balcony with supports angled back to foundations, often piled in the steep rock face, with no consideration of how this was to be accessed or constructed and with no regard to the weathered rock face outlined in the question.

The comparative analysis of the proposed schemes in the majority of cases was done in a tabular form outlining the respective pros and cons, but often the outcome had already been determined by the lack of viability of one of the schemes.

Section 1b

Section 1b made reference to the building having been in use for a year and asked for the implications of adding a swimming pool on the roof. Candidates were expected to realise that the horizontal structural elements at roof level together with principal vertical elements and foundations needed to be checked for the increased loading and to assess any requirement for strengthening. Also, the cores would need to be extended vertically to provide access. Any alteration and strengthening works would have to be undertaken in a phased manner whilst the hotel was in operation unless a total closure was possible. Too many letters ignored the fact that it was post-construction operation and failed to address the problems of working in an occupied building. Some candidates assumed the pool to be recessed in the roof which would have resulted in no headroom at Level 4. Many candidates did not address all the structural aspects of the change, which was the key requirement of the question, focussing instead on references to programme delays, revised consents and additional fees.

Section 2c

The calculations that were attempted were generally carried out to an acceptable standard, but many failed to include all the principal elements. It appears that some candidates do not understand what constitutes a principal structural element as too often only simple beam, slab and column calculations were attempted with no consideration given to cantilevers, transfer structures, raking columns or overall stability provision. Where pile designs were attempted they were often grossly oversized. The provision of simple calculations only attracts low marks; the expectation is for candidates to attempt around four or five principal structural elements as a minimum but this is a rarity. There was also a tendency for some candidates to carry out an overall building overturning and sliding check, assuming the building to behave as a rigid block on grade. This is not a suitable check for a building of this nature and does not substitute for the stability check. Along with the above comments time management appeared to an issue with candidates attempting this part of the question.

Section 2d

The standard of preparation of general arrangement drawings from candidates was mixed. Split plans were widely used, accompanied by a building section which was often not completed. When preparing split level plans they should be clear, not over-complicated, and produced to a reasonable scale. Where several levels need to be shown in order to provide the necessary information, they should not be crammed onto one plan but contained on several. Good candidates produced clear, neat, fully dimensioned drawings that identified member sizes, critical details, sections and provisional reinforcement estimates where applicable. The question states the information is for estimating purposes so clear dimensions and member sizes are a minimum requirement, but unfortunately they were not always provided. Critical details were rarely attempted; however those produced were generally to a good standard. The production of reinforcement details for a pile cap or a simple beam is not considered a critical detail. Time management was again an issue as many candidates did not complete the work they had started.

Section 2e

The method statements and programs were mixed in their success. Many candidates produced generic method statements and did not focus on the specific challenges of the question such as constructing the cantilever balconies at Level 1. It is difficult to award marks to candidates who just list tasks without consideration of construction sequencing. The better candidates produced clear concise method statements which considered the whole construction process including erection sequencing and propping requirements. The programs were similar to the method statements with good candidates establishing programmes which considered the sequencing of the construction as outlined in the method statement. Poor programme attempts again listed generic activities with little detail as to how time scales were derived. Construction times varied considerably from 20 weeks to 120 weeks indicating a lack of understanding of construction processes and timing. Some candidates made no attempt to produce a programme, presumably through poor time management.

Conclusion

Good candidates had a good understanding of how to develop a design concept and were able to come up with two distinct and viable schemes. Many poorer candidates could only produce what was basically a single concept with just a change of floor material or variation in grid centres to differentiate between their two schemes. Unfortunately too many candidates tried to simplify or ignore the client's brief requirements so that their solutions did not reflect the required profile outlined in Fig Q1; these were marked down as non-compliant. Candidates must understand that the client's brief comprises both the text and the drawing accompanying each question.

Where concrete schemes were proposed they were often uneconomic with members greatly oversized and not fully thought through in terms of the brief. The preparation of calculations to establish the form and size of the principal structural elements was often ignored in favour of simple structural elements that could be established by using design guides. The design of the stability core for the braced structure was often ignored or the profile incorrectly identified. Critical details were often ignored in favour of simple pile cap/column bases or unnecessary reinforcement details of simple elements. The method statement and programme were often generic and not specific to the scheme proposed. Time management is always a problem and again many candidates found this an issue.

Candidates should take time to read the 'Exam Guidance and Instruction' booklet which is issued to all candidates as it contains helpful information in relation to each section of the examination.

Question 2: Headquarters building

Section 1a

The question involves a multi-storey open-plan office building with a basement. Challenges include the change in orientation of the alternate floors and associated cantilevers, and poor ground conditions with the basement below the water table and within a soft clay layer over part of its area. Ground conditions are such that ground-bearing or piled foundations are feasible. The brief does not rule out internal columns but sensible spacing is required to suit open-plan offices; the space within the atrium should be column-free as it is reserved for lifts and stairs. External columns are not allowed and maximum floor to ceiling height is required.

The superstructure could be in concrete or steelwork or a combination of both. An obvious and practical scheme would have columns at the intersection of the alternate floor orientations and around the atrium. Floors with a square orientation could have 10m span main beams with or without secondary beams and slabs, or internal columns could be added at 5m centres which would result in shallower beams and increased clear height but with more structural members and additional construction costs. Alternatives could include longer main beams spanning diagonally without secondary beams. Hanging the multi-storey structure from the roof would result in heavy localised foundation loads and deflection difficulties for the glazed elevations; such an option is unlikely to be economical. If cranked cantilever beams are used allowance should be made for torsion at the perimeter columns. Alternatively a simply supported edge beam off short cantilevers from the columns could be adopted.

Stability could be provided via vertical bracing at the atrium allowing for access to the respective floors. Another option would be for sway frames around the perimeter or across the atrium. Lateral deflection restrictions should considered due to the glazed elevations. A reinforced concrete monolithic frame would provide the required stability but a heavier structure.

The basement perimeter wall could be a reinforced concrete cantilever retaining wall propped at Level 1 and by the basement slab at Level -1. An alternative could be a secant piled perimeter, which could be propped in the permanent condition by the floors. In view of the unrestricted open space, the obvious construction method would be to batter back the ground and backfill once the Level 1 slab has propped the retaining wall. Temporary sheet piling would therefore not be economical or necessary.

Options for the foundations include ground-bearing or piled foundations. The reduced soil capacity below the water table needs to be allowed for. The use of large diameter piles might be difficult to justify for such a building and soil properties.

A number of candidates interpreted the constraint of no external columns to mean no perimeter columns and this resulted in them trying to design large cantilevers longer than the back-span which struggled to satisfy the deflection restrictions of the glazed elevations. Several candidates found it difficult to come up with two distinct schemes or failed to present a coherent script to describe their schemes, particularly the second one. A few candidates produced one scheme in concrete and an alternative in steel with similar layouts so that the schemes were not distinct. Some scripts proposed radial beams from the corners of the atrium without addressing the difficulty of detailing and building such a complex junction; such a layout was unnecessary as a square orientation would be simpler and more practical.

Stability was generally provided by vertical bracing, sway frames or monolithic frames. Many candidates indicated solid atrium cores or vertical bracing without allowing openings for access and some proposed very slender cantilever atrium walls which would not satisfy deflection restrictions. A small number of candidates proposed vertical bracing with internal columns within the office floors which would restrict available space and was not appropriate for office use. A number of candidates addressed the global stability of the whole building rather than stability of key structural members such as bracing or sway frames.

Proposed foundations included ground-bearing and piled. Several candidates provided ground-bearing slabs which were not thick enough to withstand the hydrostatic uplift. Pilecaps with large diameter piles were also proposed which would be difficult to justify for such a building and ground conditions.

Basement walls were cantilevered rc walls, (propped or unpropped), secant piled or sheet piled.

Outline calculations were generally absent or poorly done, resulting in piled foundations by default. Reduction in soil capacity below the water table and hydrostatic uplift was also only allowed for by a few candidates.

Section 1b

All candidates recognised the increased loading resulting from placing the plant room on the roof. The better scripts identified that the increase in both foundation load and lateral wind load on the building would be small and considered the location of the plant room to minimise visual impact and the implication on services and access. Many candidates struggled to write a coherent and presentable letter and many focussed on non-structural aspects such as fees and planning.

Section 2c

Many candidates spent too long on non-critical elements as well as on wind loading and simple slabs. The majority also prepared calculations for only a few key elements. The standard of calculations also varied from over-simplistic to too detailed. The better candidates made good use of section tables.

Section 2d

Only a minority produced sufficient plans and sections to demonstrate their selected scheme. Many used combined plans which were incomplete and did not give sufficient information, and far too many scripts included time-consuming non-critical rc details at the expense of conveying their scheme. The better scripts were of a professional standard and a number produced typical floor plans to include both orientations, basement and foundations as well as a sectional elevation.

Section 2e

The majority of method statements and programmes were generic indicating a lack of adequate construction experience and/or misunderstanding of what is required. A few included sketches.

The method statement could have included the following:

- Check of ground conditions for extent of soft clay layer and ground water.
- Testing ground bearing capacity to verify design assumptions.
- Checking extent of dewatering requirement.
- Checking for services as on the outskirts of a large town.
- Location of crane and reach to suit construction method.
- Temporary sheet piling or preferably batter back as cheaper and quicker.
- If piled foundations install at Level 1 with cut-off at basement level; casing through ground water.
- Construction of basement foundations including services followed by perimeter walls but backfilling after Level 1 ground floor is constructed to act as prop and concrete strength reached.

- Sway frame construction floor by floor or vertical braced bays followed by main, secondary and slab construction.
- Cantilever sections with temporary props until strength achieved.
- Curtain walling.
- Ongoing check of as-built dimensions (slab thicknesses) and verticality to ensure self-weight and eccentricities do not exceed design assumptions. Checking of cumulative dead loading versus any ground settlement.

A bar chart programme showing key activities with sensible overlaps, lead-ins and durations was produced by a few candidates. Overall structural construction periods of around 15 to 18 months were generally indicated which is feasible depending on the type of construction.

Conclusion

This was a question that candidates in most design offices would be expected to deal with adequately. It was relatively straightforward except for the different alternate floor orientation and ground conditions. Many candidates struggled to provide two viable solutions or had difficulty conveying their schemes and the client letter. The standard of calculations and drawings was generally poor. The method statement and programme were also not well addressed which may be partly due to time management and partly due to lack of construction experience. Too much time was spent on generic text and details rather than providing information specific to the client’s brief.

Question 5: Pipe rack

Section 1a

The client required two sets of pipe racks to support two decks of pipes with mechanical equipment, cable trays and a walkway over existing access roads in an industrial processing plant and subject to a cyclonic wind condition.

Many candidates had difficulty proposing two distinct and viable options. Frame layouts for both options tended to be similar with stability provided by either braced or moment frames. Two different truss types were not considered distinct framing schemes. Acceptable differences between schemes could include different materials, grid layout, load paths, foundations, and stability provision etc. but 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.

Most candidates opted for shallow foundations in the near surface sands and gravel, although some proposed piled solutions to 10m rock depth which would be costly and require heavy plant to be brought to site.

Most candidates included annotated sketches to describe their schemes, however proposals for load transfer and overall stability often lacked clarity and simple annotated sketches illustrating these systems would have helped. Interpretation of geotechnical information to inform foundation proposals was reasonable and some preliminary sizing using engineering judgement or rule of thumb, e.g. span to depth ratio, was generally included. Significant wind loading was not recognised by some candidates and consideration of the implications of an unclad structure on wind loading was generally ignored. Contraventions of the brief tended to relate to the infringement of the soffit of the 6.5m level pipe rack within the 6-metre clearance required above the roadway. This was treated as a mark down rather than a failure point.

Section 1b

In order to minimise site work by fabricating the entire structure in the workshop modularisation is required. The weight and size of the modular components are key to the logistic considerations with the final installation requiring suitable splice joints. Some candidates did not appear to appreciate the difference between modularisation and stick build construction. Some scripts included annotated sketches which complemented their text.

Section 2c

In general the quality of the calculations was just acceptable, albeit most candidates opted to design the more straightforward elements. Typically the calculations did not flow very well; the results from the design of an element should flow into the design of the next element. The inappropriate use of design guides to size members was common. The design calculations should be prepared in accordance with any current recognized national codes of practice. Introductory loading schedules commonly used in calculation packages were not generally included. Sensitivity of long span elements, i.e. consideration of deflection and natural frequency was not considered in some cases and lateral load resisting systems were also often ignored. Very few candidates attempted to design a steelwork connection, and typically details drawn were inadequate. Bearing in mind this was a steelwork question this was disappointing.

Section 2d

Overall, the draughting quality of drawings & details was poor. Most candidates produced drawing content just adequate for budget costings. Despite the rack layout being symmetrical, few used split plans or overall sections. Critical details submitted were generally sketchy with limited builders work context. Appropriate details to clarify critical areas were required; these would include such details as connections between trusses and supporting frames, pipe rack deck to perimeter structure connections and connections between vertical structure and foundations.

Section 2e

Most scripts included a method statement and bar chart programme demonstrating a general appreciation of the construction sequence. The better scripts included detailed descriptions, in some cases with sketches depicting unusual construction sequences. Many candidates when discussing construction methodology raised some good health and safety issues, such as hoarding off site, and scanning for below ground services prior to excavation.