The Institution of Structural Engineers

Examiner Report – January 2024

Chartered Membership Exam – January 2024

Author: Examinations Panel

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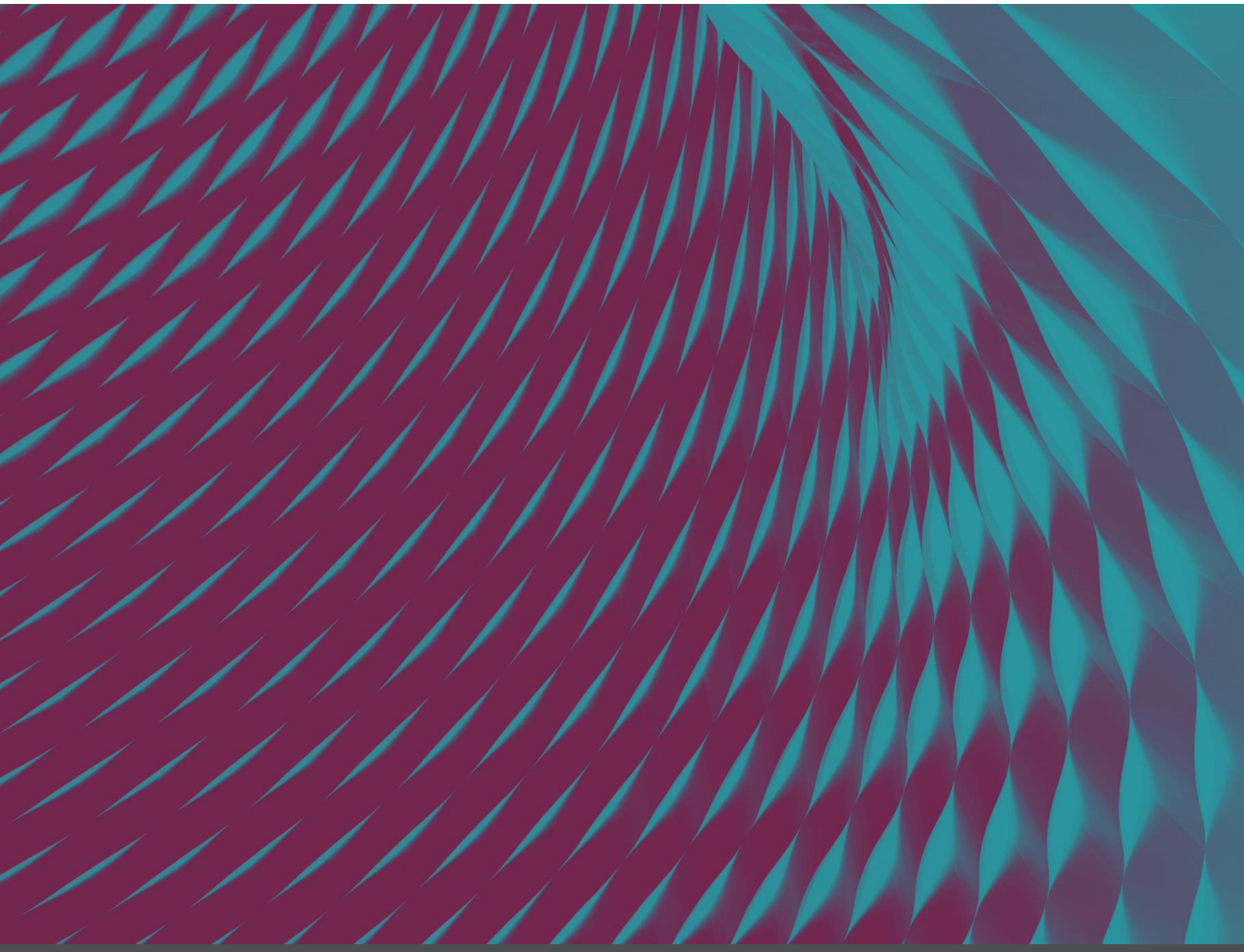

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Notes on the reports

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

Comments from the Examination and PRI 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 make sure that they are aware of their candidate number and the location of the exam in advance of the day. The Institution sends out a reminder prior to the exam to check this information by signing in to the website and looking in the ‘My Exams’ section.

Candidates continue to leave page numbers blank on scripts which results in Marking Examiners not always being able to follow an answer script logically. Candidates are reminded that the final 5-10 minutes of the exam should be used to ensure that their papers are in order and ready for collection at the end by the invigilators.

A general observation from examiners is that many candidates continue to adopt a formulaic approach in their responses to Section 1B and 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.

The Examinations Panel have created and made available a preparation guidance document that all candidates are encouraged to download and use as part of the revision, as well as taking a copy in to the exam for any last-minute reminders. Particular focus should be on the recent changes to the requirements, such as the sustainability elements and the fact that a programme of works is no longer needed to be produced in Section 2E.

Please note that there is no report at present for Q3. This may be included in a later version of this report.

Question 1 – Conversion of industrial building to apartments

The main challenges to converting the industrial building to residential apartments are: comparing the proposed residential loading with the existing industrial one, checking the vertical clearances to accommodate the intermediate floors and the downstand beam in the corridor, re-use of the steel beams and columns versus independent new structural members, the structural implications of the atrium and lift/stair openings and additional windows on overall and local stability, and maximising re-use of the existing structure to reduce carbon embodiment.

In light of the climate emergency and sustainability, the essence of the brief was to re-use as much of the existing structure as possible to minimise the need for new materials; however some candidates proposed new-build schemes, completely replacing the slabs, beams, columns and their foundations. The majority of candidates proposed re-using existing elements to varying degrees.

Section 1a

Preliminary work would include investigating/ surveying the existing structure and foundations for geometry, condition and construction details to determine what could be re-used and how it could be integrated with new members and new layout. All re-use is subject to existing construction details and condition as well as temporary propping as required.

From a load comparison, the existing concrete slabs, central steel beams and columns were capable of carrying the proposed additional residential floors assuming that lightweight construction in the form of timber or cold-formed steelwork was provided, (though for sustainability timber is the preferred option). Where heavier flooring such as concrete was used, then new supports could be provided extending through pockets in the existing concrete slabs down to new foundations.

Alternative load paths were possible for distinct options. The existing perimeter brick walls together with the plate action of the floors provide overall stability for both the existing and proposed conversion building. Partitions between apartments could be load-bearing with the new intermediate floors spanning 4m east to west with an overall depth of up to 300mm to provide the 2.3m headroom.
In the corridor the 2.3m clearance is possible except at the underside of the central beam where it reduces to 2.0m and the existing columns make the corridor awkward, but not impossible, to use. Some candidates replaced the central beam by shallower ones but retained the existing columns. Other candidates replaced both the central beam and columns by new ones along the new corridor partition elevations. An alternative, and more efficient, solution chosen by some candidates was to relocate the central beams and columns along just one of the corridor walls. Where new columns are used along the external perimeter walls, these need to avoid loading the existing perimeter foundations. Where the new columns are located on the edge of the existing spread foundations, the additional and eccentric loading needs to be checked. In practice, unless a full and detailed knowledge of the existing foundations is known, they are best left undisturbed and independent.

The formation of the opening for the full-height atrium requires temporary works for the new lateral support to the exposed edges of the south external brick elevation and horizontal load transfer at the respective floor slabs. Removal of concrete floor slabs and support to cut edges would also be required. The need for some primary structure to support the atrium glazed roof and provide stability to the 20m high glazed slot was not always well dealt with.
The formation of new floor openings at the north-east and north-west corners of the building for the new lift/stairs also requires temporary works prior to installation of new lateral supports to the brick elevations at each floor level.

The new layout and size of windows involves reducing the size of existing ones and the formation of new ones above. That too requires temporary works and careful sequencing.

Due to the good ground conditions, spread footings or mini-piles would be appropriate. The use of large diameter piles and heavy equipment would be difficult to justify and accommodate due to the restricted headroom.

Many candidates provided two distinct schemes with varied framing options and supporting description and sketches; however, some candidates provided options which were too similar. Some scripts were lengthy with too much detail provided at the expense of later sections.

Section 1b

Possible alterations to the brief are to provide external lift/ staircases as previously, to provide an external atrium which would minimise the need for removal of slabs and provision of new support members whilst also providing additional floor space, and reducing the plan area and/or height of the atrium. A few candidates came up with some of the above changes to the brief but most dealt with changes to their schemes instead.

Section 2c

Calculations were varied, with some being too detailed at the expense of coverage. Others demonstrated good use of sections tables. The better scripts clearly identified the principal members that were included in 2d. Carbon calculation was generally well done.

Section 2d

The quality of sketch drawings was disappointing. The expectation was to see a typical floor plan for existing and for intermediate floors and at foundation level, a typical east to west sectional elevation through apartments, and a plan and section for lateral support of brickwork at atrium and lift/ stair openings. Critical details could include, for example, new floor to existing structure, atrium lateral support connection to existing structure, window openings, etc.

Section 2e

Method statements were generally generic rather than specific, and many appear to have been rushed. Some appear not to have read the question or the exam guidance and provided programmes for which no marks were allocated. Method statements were expected to give consideration to existing structural condition and construction details, checking ground conditions to verify design assumptions, temporary propping and opening-up, central beam and columns if replaced or relocated, construction sequence for new floors, stability of walls to atrium and lift/ stair openings when floors were removed locally, protection of existing foundations for construction of new ones, and maintaining stability when reducing the size of existing windows and for forming the new openings.

Conclusion: This question was one which candidates from most design offices should be able to tackle without difficulty. It is disappointing, that despite the helpful guidance on the Institution's website and the various courses, so many candidates still struggle to clearly convey their scheme.

Question 2 – Defence facility

This question involved the design of a defence facility comprising a single basement level with five floors above it. The site is easily accessible and is situated on the outskirts of a city. The building has several unique functional requirements and the question challenged candidates to demonstrate their capability in the design of large column-free spaces and basements.

Appropriate solutions included reinforced concrete and steel frames, post-tensioned floor systems and hybrid systems involving both concrete and steel. The majority of candidates proposed one scheme using concrete and one using structural steel as the dominant materials; however, the sketches provided to illustrate schemes often lacked clarity. Many candidates failed to deal with the limitations relating to the positioning of columns, shear walls and bracing. A few candidates proposed unnecessary cantilevers in order to change the column grids at different levels. Some steel schemes included 24m span beams with no consideration of deflection, while some used 24m span trusses which resulted in the overall allowable building height being exceeded. The better candidates dealt with the column spacing requirements by providing suitable transfer structures at Level 2 or Level 5.

Foundations solutions provided included both shallow and deep foundation systems; however, some candidates did not adequately address the structural implications of building them below a basement. Several steel schemes utilised piled foundation systems when a shallow foundation system with soil improvement of the medium dense sand strata would have been a better solution.

Candidates should note that both schemes in Section 1a should be given equal consideration in order to obtain good marks.

The majority of candidates failed to give consideration to sustainability when reviewing and critically appraising their schemes.

In Section 1b, communication with the client often ignored the prime objective of reducing material usage. Many overlooked the functional requirement of the shooting range and proposed internal columns to avoid transfer structures. A few candidates sensibly proposed to relocate the shooting range above the office floor to avoid the need for transfer structures. Many candidates wisely proposed to reduce the glazing areas of the façade.

Most candidates were able to identify the principal elements for producing detailed calculations, although some ignored the lateral stability elements. A1-A3 carbon calculations as required in the new format of the examination were generally well done.

Many candidates took advantage of the building symmetry and presented their drawings in split plans to illustrate the disposition of the structure, but the quality of the drawings was often poor and not sufficient for estimation purposes. A few candidates misinterpreted the question and provided a full floor for mechanical plant which was not required. Often, the critical details drawn did not adequately illustrate the more complex elements of the structure.

Good candidates were able to produce a satisfactory method statement. A very few candidates overlooked the new format of the exam and produced an outline construction programme unnecessarily. Some of the method statements provided demonstrated a lack of experience in dealing with temporary works and construction of long span structures. Good candidates interpreted the ground strata correctly and proposed battering loose sand in the excavation to reduce the extent of earth retention required during the temporary construction stage.

Some candidates lost marks by omitting to answer one or two sub-sections of the questions due to poor time management.

Question 4 – Private leisure facility

The question required candidates to design a 10m high private leisure facility. Its most prominent feature is the sloping external facade that the structure's form should follow, rather than leaving it to the cladding to provide this geometry. This would lead to eccentric loads being applied to the vertical support elements of the structure. There is also an internal single storey structure to accommodate changing rooms with a lounge and bar area provided on its roof. The focal point of the building is a swimming pool that is 3m deep at its lowest level.

The external cladding consists of glass curtain walling, and the roof material is an insulated composite sheeting which does not offer any form of diaphragm across the roof. The test for the candidates includes design of the enclosing clear-span structure and its stability, the water-retaining swimming pool, the internal single storey area with its lounge and bar facilities above and the foundations.

As the building element consists of a reasonable amount of design work for the candidates the foundations have been kept simple. The soil bearing strata are consistent across the site with sand and gravel with an N value of 10 (100kPa), which would permit the use of isolated RC pads, mass concrete pads, trench fill, or strip foundations to be adopted. The ground slab around the pool could be ground bearing, providing compacted fill is defined and used and the same applies to the single storey internal area.

The structure presents several possible options:
a) Portal frame with raking columns
b) Three-pinned arch with raking columns
c) Raking columns and a clear span lattice truss

The material options:
d) Steel frame with lightweight steel purlin roof construction
e) RC frame with lightweight steel purlin roof construction*.
f) Timber framed structure with timber purlins

*The concrete frame option, although possible for the defined span, is not felt to be a practical solution due to size, sustainability, and physical handling etc.

The Internal Structural options:
a) Load bearing masonry walls with steel cross beams supporting a timber, beam and block, or a precast concrete floor

b) Steel frame with light weight stud partitions

The watertight swimming pool options:
a) Sprayed concrete shell (Gunite)
b) In-situ reinforced concrete walls and base slab
c) Reinforced concrete block walls and concrete base slab. Watertight finish required to block walls

Section 1a

Candidates tended towards a steel-frame based design, that was typically portalised in one direction. Some did not have the structure follow the form of the building which undermined the principle of the question, i.e., how structural engineers address unique geometric forms and the way in which they affect the design of the primary elements. The schemes were typically either portal frame or long span truss with moment connections at the end. Few adopted a 3-pinned arch, which was the ideal form of structure for the purposes of the exam as it is statically determinate and therefore possible to analyse by hand. Some candidates chose to have a long-span structure across the greater dimension of the building, which led to inefficient designs that were not appropriate. With respect to lateral stability, most schemes seemed to only provide any restraint in one direction and had insufficient plan bracing within the roof. The lack of bracing in the roof would have resulted in an unstable structure due to racking action across the building.

Due to the lightweight nature of the roof structure, there is a risk of reversal due to negative wind pressure. Few candidates considered this as an issue and therefore did not allow for it in their schemes. The choice of material was somewhat traditional, with very few candidates recommending the use of timber frame elements. This would have been optimum considering the humid environment the swimming pool would generate. Similarly, the internal changing room was usually a steel framed structure, whereas a load bearing masonry wall would have also been acceptable, yet no candidates considered this.

Foundations were either ground bearing on the sand/gravel substrate or in some cases piled. The latter was deemed to be excessive for a building of this size and candidates were marked down for considering it as a viable form of foundation.

Section 1b

The January 2024 membership exam paper was the first to address the need for candidates to objectively review the proposed development described in the question with respect to its embodied energy cost. Most candidates found this difficult to do as they are typically trained not to question or challenge a brief described in the exam paper. Those that did understand the amount of latitude they were being afforded provided some sound proposals that included changing the form of the building to vertical sides, thus removing the eccentricity on the support frame and therefore reducing the size of the primary vertical elements. Few, however, considered changing the overall size of the building, which would have been a viable suggestion. Candidates need to understand that this is the only time in the exam that they can challenge the client's brief itself on the understanding that they are seeking to provide the same building, but in a more efficient form with respect to embodied energy costs.

Section 2c

The level of detail and rigour applied to calculations was generally acceptable, with primary elements being designed and lateral stability being given sufficient consideration; however, no candidates considered the design of connections within the frames and where long span elements prevailed in the proposed scheme, deflection of these elements and how they would have affected the cladding of the structure was often not sufficiently addressed. Many candidates ran out of time in this section, which is problematic as it serves as a demonstration that their chosen scheme is viable. Carbon calculations were generally sufficient, with some candidates isolating them from the rest of the output. Finally, there is a heavy reliance on the use of design guide text, which is acceptable in Section 1 of the exam, but should not be referred to in Section 2. This is especially true for steel elements, most of which would be laterally restrained therefore the use of such texts should not be needed.

Section 2d

The drawings produced by candidates were generally reasonably comprehensive, with most candidates providing long form cross sections through the building's structure. Annotation was fair, with many failing to add dimensions, thus making it difficult to measure from, which is what is required for these drawings. Many candidates did not provide sufficient details, such as roof cladding, facade supports, and connections between primary elements. The overall quality of drawings was poor, with some resorting to free-hand sketching making them difficult to read. Many candidates ran out of time during the creation of the drawings, which led to low marks in this section.

Section 2e

This is the first time that only the method statement was required. A reliance on a candidates' knowledge of frame construction to a relatively tall building with no intermediate floor was put to the challenge. The temporary stability of the superstructure as well as how the swimming pool would be formed was rarely considered, with most candidates simply providing a generic set of actions. Some candidates even provided a programme, which is no longer required and therefore consumed valuable time. Similar to Sections 2c, and d, candidates often ran out of time when attempting this part of the exam.

Question 5 – Community centre building

The question presented site specific issues with an adjacent highway and nearby railway. Many candidates gave these insufficient or no consideration whether from a buildability or temporary works perspective.

The earth retaining solution might best have involved a solution that incorporated temporary support into the permanent works, yet many candidates selected a separate temporary works solution.

Piled foundations generally were not required, other than perhaps secant piles or sheet piles for the highway retaining structure. In a number of instances very deep raft foundations were proposed as a foundation solution, which were considerably over-engineered for such a small-scale building.

A singe core alone was unlikely to succeed as providing structural stability; the core could be backed up by bracing in the lower portion of the building and portal bracing in the upper portion. Some candidates did not provide stability systems that were distinctly different for the two schemes.

In the lower portion of the building a 6m x 6m grid of internal columns would have been acceptable but many candidates did not use this and instead opted for greater than necessary spans for the heavily loaded green roof. In other cases, the 6m rule in the question was often disregarded with internal columns at less than 6m spacing.

The upper portion of the building included lightweight imposed load and requested slim cantilevers so deserved to be lightweight construction. Often candidates used a concrete roof here which did not seem appropriate. Some candidates offered deep trusses which did not really satisfy the slim cantilever requirement, nor were trusses really needed for the spans involved.

Consideration of carbon footprint was not included by all candidates.

Most candidates correctly understood that Section 1b asked for suggestions for a change to the brief. Perhaps the most obvious was to consider repositioning the building a little further from the highway to reduce the earth retaining challenge while not going too close to the railway. Similarly, there was potential to reduce the below ground extents of the building by moving it parallel to the highway. Beyond this, there were

a number of options to minimise material usage, for example suggesting reductions in roof loading, reducing glazing extents, changing column spacing, etc.

In Section 2c most candidates dealt well with designing basic elements as might be expected. For a relatively low-rise building wind loading could have been assumed on judgment leaving more time to deal with more important aspects. Often too much time was spent on retaining walls and not enough on the stability systems. Most, but not all, candidates included some carbon assessment.

Section 2d is an important part of the question and often well done but some candidates appeared to dedicate insufficient time to this section. A great deal of the candidate's judgement and experience can be communicated to the examiner by well-annotated sketch drawings which should be sufficient for costing the project. As this was a small-scale building, there was an expectation of at least one building section to clearly describe the split-level form of the building. Similarly, focus should have been given to critical details of question-specific challenges, e.g. the roof cantilever and the retaining wall interface to the main building.

Often a somewhat generic construction sequence was presented with not a great deal of consideration to temporary works requirements. Sometimes the adjacent highway and the nearby railway were not mentioned although these would have been significant factors. Cladding the 2m cantilever feature, which projects on plan to within 1m of the edge of the highway would be a major health and safety challenge as would other aspects of the build on the face near the highway, but this was almost universally not mentioned.

Examination Statistics

The following section provides some general statistics to provide an overview of candidate performance during the exam. A total of 388 candidates attempted the exam.

Pass rates by question

Question	Pass rate
1: Conversion of industrial building to apartments	33.34%
2: Defence facility	27.78%
3: New railway bridge	35.29%
4: Private leisure facility	26.32%
5: Community centre building	25.69%
Total	27.84%

Pass rates by exam attempt

Exam attempt	Pass rate
1st Attempt	42.59%
2nd Attempt	25%
3rd Attempt	17.59%
4th Attempt +	14.81%

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