The Institution of Structural Engineers

Examiners' report 2014

Chartered Membership Examination 2014

Associate-Membership Examination 2014

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.

Personal feedback to failing candidates

The Institution continues to provide personal feedback in the form of the average marks awarded and key examiner comments to those candidates who request it. This is in order to assist in identifying strengths and weaknesses within their scripts.

Bi-annual Chartered Membership Examinations

Chartered Membership Examinations are now held twice-yearly. In 2015 the dates are Friday 9 January and Friday 10 July. The Associate-Membership Examination will continue to be held once a year at the same time as the July CM exam.

The Institution of Structural Engineers

Chartered Membership Examination 2014

Overview

Total candidates:	709
UK candidates:	383
UK pass rate:	42.0%
Non-UK candidates:	326
Non-UK pass rate:	27.2%
Overall pass rate:	35.4%

Questions

1. New university building
2. Garage for snow ploughs
3. Vehicle crossing for waterway
4. Library building
5. Cliff-top house
6. Health centre
7. Offshore wind farm substructure
8. Multi-storey hotel

Feedback

Question 1: New university building

A new university building was required, set into a hillside, and with a sloping facade. The building was broadly regular in plan but was divided into two main elements: a single-storey portion containing three lecture theatres, and a four-storey portion containing study/office facilities. A two-storey retaining wall was needed at the junction between the two elements. An atrium void with stairs and lifts was required in the study/office facility.

The study/office element had two features that needed to be addressed: the two-storey retaining wall and the sloping front elevation. For the retaining wall, feasible options included a bored piled wall, or sheet piling which could be installed prior to the removal of the surplus soil and propped by the new construction during erection. In all cases it was necessary to show how the 10m-high retained face was to be propped in both the temporary and permanent conditions.

For the front elevation, many candidates proposed a vertical column with varying lengths of cantilevers on the respective floors, but typically ignored the load introduced because of deflection etc. on to the glazing mullions which are normally designed as tension members. Setting a vertical column at Level 1 placed it about 5.0m from the front elevation. Some candidates provided a second row of columns between the front elevation and the core, but in clear contravention of the brief. Sloping columns were both acceptable and efficient, but some candidates were confused by the sloping front elevation suggesting it introduced tension into the floor not compression. Good candidates defined the system of load transfer and suggested alternative stability solutions as part of their schemes.

Options for the study/office superstructure included a braced structure depending on the candidate's preference for the use of the core area, or placing bracing on the perimeter walls, or an unbraced structure using a moment frame. Floors could be precast concrete slabs, or composite floor construction on a simple beam and column arrangement.

The lecture theatres required a clear-span roof structure spanning on to external perimeter columns or the internal dividing walls between the theatres. Good candidates took into account the height and stability of the walls where they were load-bearing. The roof options chosen were predominantly lattice trusses.

Part 1(b) asked candidates to explain how to add an additional floor over the entire building. Good candidates considered factors such as sound transmission and vibration over the lecture theatres, as well as dealing with the increased load the proposed new floor would impose.

Most candidates efficiently provided calculations for the simple structural elements: beams, slabs, internal columns and in some cases a simple end-bearing pile calculation. Good candidates also considered the critical elements such as the stability, retaining wall, raking column and ground slab/foundations.

Candidates providing the required plans, elevations, and critical sections with sufficient dimensions scored high marks. Where expansion joints were introduced between the two elements of the building, separate stability for the two elements was ignored by many.

The method statement and programme tended to comprise just a list of operations with no logical sequence or explanation to indicate how the building was to be constructed, bearing in mind it was a sloping sight with two distinct structures. Very few candidates used sketches to indicate constructional sequencing and possible temporary works.

A large number of candidates who attempted this question lacked time management skills and underestimated the work content required in both Sections 1 and 2 of the question, and were unable to propose two distinct and viable solutions. Just changing materials but using the same structural principles was not acceptable.

Question 2: Garage for snow ploughs

This question required a simple rectangular single-storey building to house four snow ploughs. Ground conditions changed across the site, with solid rock at the high end and deep gravel at the low end. Before the structure could be designed, the space required for the four snow ploughs and their relative orientation needed to be established, ensuring access to the road. Different shapes and sizes of building were possible, which could have been used to provide distinct structural solutions, and this opportunity was taken up by good candidates. Some proposed two buildings with different footprints, while some produced different structural arrangements for a single layout. A significant number filled the whole site with an unnecessarily large building without realising that long spans and high loads would result in overly large structure. Some proposed curious schemes such as portal frames spanning the long direction or very deep plate girders. Others produced more logical variants based on lattice girders. A few suggested more imaginative solutions but often they were not backed up with a rationale of their pros and cons.

Wind loads were high and needed to be assessed. The dominant openings created by the large doors in combination with high horizontal loads from the snow gave rise to significant lateral loads of which few candidates took sufficient account. The effect of differing foundation conditions, particularly at the access road end of the site where there was 4m of gravel, and the potential need to provide retaining walls, needed to be considered.

The letter asked candidates to advice on the implications of a reduced construction period. A pleasing proportion of the letters were written in an appropriate grammatical style; however, many limited their advice to the obvious, such as; "we will need to work longer and harder", or "we will need to spread the construction over two seasons". Few candidates linked their advice specifically to the scheme they had proposed, and few appreciated that the ground works were likely to be more of an issue than the superstructure. A few realised that buildings that did not occupy the whole site offered the opportunity to store components on-site.

Most candidates also failed to take account of the 7.0 meter member length limit. Generally insufficient information was indicated on the general arrangement to enable a quantity surveyor to estimate the cost of the works and consequently candidates were marked down.

Question 3: Vehicle crossing for waterway

The question was inspired by the Veluwemeer aqueduct in the Eastern Netherlands, which is located on the N302 road near the small town of Harderwijk. It required a road to cross a waterway, and was worded carefully so as not to exclude an aqueduct solution with the road passing under the waterway, but disappointingly, no candidate offered such a solution. Many candidates proposed two composite solutions with concrete slabs supported by steel plate girders or pre-tensioned precast Y or U girders keeping the rest or the structure identical. These may have been viable but were not sufficiently distinct to score high marks.

A few candidates proposed lifting bridges, but were unable to demonstrate sufficient understanding of the basic geometry of such moving structures with the required clearances. Some candidates proposed a bascule bridge, but without appreciating the need to provide balancing kentledge, with the increase in total weight then needing to be supported. Many candidates did not consider the possibility of scour under their proposed foundations caused by water movement between the lake and the tidal river.

The letter required consideration of a greater range of water levels. Many candidates proposed solutions contravening the height limitation imposed by planning requirements, and very few addressed the effects of both rising and falling water levels.

The quality of drawings was uninspiring, and leads to doubt as to whether candidates understand what they are trying to communicate in their drawings. Good candidates produced brief but appropriate calculations which were satisfactory and sufficient.

The construction methodology for this particular project could well differ from standard bridge construction, but most candidates produced standard points in Part 2e. The health and safety constraints of working near or over water should have been inherent in method statements but were mentioned by only a minority of candidates.

Question 4: Library building

The question required a 3-storey building with a large-span roof over a central atrium and a method of supporting the substantial height of retained ground along one side. It was essential that this support was present during the temporary construction stage as well as in the permanent situation.

The question did not define a site boundary, but being in a ‘city centre’ it was expected that candidates would appreciate there would be limited space in which to form a suitable retaining structure. Satisfactory options included the use of steel sheet piling, or contiguous or secant piles. Open-cut solutions were less appropriate given the space constraints. It was expected that at-rest earth pressures would be used in the design. Good candidates were able to describe the safe transfer of lateral loads to the foundations, but those unable to demonstrate load transfer and stability lost marks. It was acceptable to propose a retaining wall structurally separate from the building, but good candidates presented integral solutions where the retaining wall gained support from the building frame. Candidates who offered identical schemes differing only in the use of steel or concrete frames did not gain high marks, whereas those distinguishing their schemes by changing load paths or stability systems scored well.

The internal floors around the atrium had either cantilevered or suspended sections of floor to avoid placing columns in the zones required to be clear. Candidates gaining high marks described (a) floors cantilevered with an 8m backspan and (b) floors hung from roof trusses. Extra marks were gained when candidates justified their choice by explaining that hung floors made for more difficult construction. A truss system was generally proposed for the roof. Candidates who appreciated that lateral earth pressures were much greater than wind loads avoided pointless calculations.

Section 1b required candidates to consider the addition of a basement. The key issues to be dealt with were the increased vertical and lateral loads, uplift, the need for waterproofing, and the methods of construction to be used.

Good candidates were able to produce calculations for the retaining walls as well as for the key elements of the building.

Drawings were generally of a satisfactory standard, but some candidates struggled to identify critical details relevant to their chosen solution, and produced standard RC details instead which gained few marks. Well-chosen critical details included: connections between the foundations, ground floor and superstructure to the retaining wall; drained cavities to retaining walls; and (where required) connections of steel roof trusses to the remainder of the superstructure.

Where method statements were specific to the designed solution and actually described how to undertake a particular operation, especially where illustrated with diagrams, candidates scored high marks. Programmes were generally acceptable although many suggested construction periods too short for a building of this size and complexity.

Question 5: Cliff-top house

This question required a 5-storey house to be built at the top of a cliff. Very few candidates tackled it although it was fairly straightforward.

Not many candidates appreciated that wind needed to be considered given the building's height and its position perched at the top of the cliff. Several candidates did not provide a description and design of the lateral stability system within the frame.

There was no mention of stairs or lifts in the question, but obviously some means of vertical access needed to be considered. Stairs could be located outside the building as a stair core, or within the building but not used for stability. Most candidates ignored the means of getting from one floor to another. Some form of access should have been shown on the plans, and the floor openings should have been allowed for in the design.

The stability of the building could have been achieved by means of a small stair core, but more simply by relying on the thickness of the external walls together with the circular shape. The stability of the roof structure should have been considered as views minimally interrupted by structure were required in all directions, so the roof supports should have been kept to a minimum.

Materials could have been *insitu* or precast concrete, masonry, steel or timber. Candidates were expected to should consider the constraints on delivering large elements to the site.

A number of candidates proposed columns in the small pool. Although doing so did not lead to automatic failure, it would hardly be acceptable to the client within a pool that was 3.5m diameter. Such solutions were marked down.

The cantilevers at the balconies and for the top storey seemed to cause candidates some difficulties. No candidate suggested using external columns, although their use was not prohibited by the brief and would have provided a viable and distinct structural solution.

The letter required candidates to consider the effect of adding a storey. The implication of increased height generating additional wind load was understood by some of the candidates, but the letter presentation let many down.

Calculations offered were limited and often too simplistic. Most candidates listed the calculations that were needed but then produced hardly any of them, or undertook only the easy parts. As with the calculations, the overall standard of drawings was very poor. Critical details were not well done and were in some cases not included at all, or only reinforcement details were provided.

It was apparent that many candidates ran out of time before getting to the method statement, and those that attempted it did the bare minimum. This section should have been a source of easy marks as all the issues to be considered were clear in the question: the cliff, the constrained access, excavation in rock, and a cantilevering structure at height. It was of concern that candidates were unable to see the obvious in this regard. Some timescales were proposed which were clearly too short or too long.

Question 6: Health centre

A small two-storey health centre was required, with equipment on the roof. Ground conditions included an upper layer of highly plastic clay, and the close proximity of a mature tree required the building to be protected against heave when the tree was removed. A long-span cantilever was required above the front entrance.

A variety of structural solutions was feasible, including load-bearing masonry, a steel frame with precast concrete or composite slabs, *insitu* or precast concrete, and timber.

Most candidates opted for columns at 4m or 6m centres with braced or portal frames. However, very few ensured that the positions of external columns and bracing were co-ordinated with the window openings. Good candidates were able to describe a coherent stability strategy: weaker responses included proposing bracing mixed with stiff framing, or generalised proposals relying on the cores as stiff points. Foundations were mostly either piled or ground-bearing pads or strips. A significant number of candidates failed to deal with the potential for clay heave resulting from removal of the tree. Those that addressed the issue correctly provided deep foundations, compressible board and a locally suspended slab. Good candidates provided a coherent plant support structure consistent with the lower levels, integrated with the cantilever columns for the high façade, and with adjacent areas framed in a lightweight structure over the training and atrium areas. The offset timber cladding was not addressed in many cases. Good candidates gained marks when they gave some description and simple sketch cross-sections to clarify their proposals.

The letter required candidates to advise the client on the implications of infilling the atrium with a new floor at Level 2. The floor was to be constructed whilst keeping the health centre fully operational. Most candidates correctly highlighted the increased loading from the extra floor and the need to keep the centre operational; however, the temporary works to create an alternative entrance were not well addressed. Assessment of the capacity of existing members was mentioned as a way of accommodating the extra loading. Localised breaking-out was described to connect the new floor to the perimeter structure. Some candidates suggested a completely free-standing structure within the atrium, to be constructed from lightweight steel and timber. Although letters continue to be very poorly written, many were positive over how to construct the new floor but failed to appreciate the extent of disruption to the health centre.

Fully-detailed calculations were required for all key members including masonry, the superstructure frame, the beam over the seminar room, the foundations, the roof structure, and the cantilever structure. Most candidates made good use of capacity tables and included deflection and reinforced concrete calculations, although a minority relied on preliminary calculations from Section 1a. A higher level of detail in calculations is required for Part 2c, with full checks on deflection, shear, vibration etc. Where load-bearing masonry was proposed, full calculations for vertical and lateral loads were required. Calculations varied from too detailed but limited, not covering sufficient key elements, to very preliminary based only on span-to-depth ratios. Foundation design was generally rushed, and some candidates lost marks by designing large-diameter piles that were unnecessary and uneconomical.

Drawings were expected to show foundations in plan, a typical floor plan, the roof plan, and a cross-section of the building. Critical details included support to the cantilever, foundation details, details of heave protection, and details of the interface between the timber façade and the main building. Very few candidates provided all the required views. While a number were of a professional standard with sufficient information for costing purposes, the majority were poorly presented and scrappy, and would not be acceptable in practice. Combining plans of several levels might seem efficient but did not give a clear picture of the scheme, leaving the examiners having to guess at what was intended particularly where there was also a lack of elevations & sections. The atrium entrance cantilever and roof plant screen were generally not well covered, and many details were generic and not crucial to the stability of the building.

Good candidates identified key structural issues for the safe erection of the structure, mentioning sequencing and temporary bracing particularly for construction of the cantilever. A number of scripts paid too much attention to peripheral issues such site fencing. Programme durations varied from less than six months to over a year, 12 months being realistic for this type of structure and location.

Question 7: Offshore wind farm substructure

Candidates were required to design a steel substructure to support a wind turbine, to be installed in 35m of water. Among the reasons for failure were: an apparent lack of knowledge and experience in the design of offshore substructures; omission of wave load calculations; and illegible handwriting which left the examiners unable to assess the script.

Candidates' proposed solutions included 4-leg jackets, monotowers, Vierendeels, tripods, monopile structures, braced frameworks and guyed towers. Jackets, tripods and monotowers were especially suited to the question and candidates who proposed these received high marks. A Vierendeel was not a good structural solution because of dynamic effects caused by wind and wave loadings, and it appeared that in some cases candidates who proposed Vierendeels had come armed with a 'jacket-and-Vierendeel' option to be applied to any substructure question, whether suitable or not. Candidates who proposed monopiles could not demonstrate that these would be viable at 35m water depth and were marked down.

The letter asked Candidates to consider the implications of adopting a concrete gravity-based substructure solution. Of the unsatisfactory letters, some failed to recognise the fundamental changes in the design, construction and installation of the substructure, especially the change in foundations., and a few wrote unprofessional letters that favoured the original steel solution and did not address the Client's request.

Candidates were expected to present sufficient calculations to establish the form and sizing of the principal structural elements including the piled foundations. Only a minority attained adequate marks. Some presented poor-quality calculations or did leave sufficient time to complete the content required by the question. Calculation of wave loading was a fundamental requirement, and in many cases was not determined in a rational and clearly-understandable manner. Calculated values of base shear and overturning moment varied alarmingly between scripts.

Candidates were required to draw their proposed structural arrangements. Some lost marks because of a lack of information such as key dimensions on their arrangement drawings. Many did not have sufficient information to show the piles or the transition piece between the substructure and the turbine generator unit.

The method statement required candidates to describe the sequential steps involved during the transportation and installation of the substructure and TGU. Good candidates provided sufficient information, especially regarding installation of the turbine and blades. A few wasted valuable time by including construction or loadout activities with no gain in marks as these activities did not form part of the question.

Question 8: Multi-storey hotel

The question required a 6-storey hotel to be constructed in an area of high seismicity. The building was to be star-shaped in plan with three identical wings and a central core. A key challenge was avoiding or minimising torsional irregularity because of the eccentricity between the centre of mass and the centre of rigidity, caused in turn by the discontinuous shape of the building. This meant it was best to have identical lateral load resisting systems in all three wings.

The building also had vertical irregularity because of ground-floor setbacks at gable ends which could lead to stiffness-soft storey irregularity. Therefore, the lateral stability elements such as bracing, shear wall, etc, needed to be kept away from the end setbacks in order to prevent attracting significant seismic forces to these areas. The building included a transfer structure, covered by certain requirements in seismic codes such as increases in design forces by over-strength factors.

Possible solutions could use a 10m grid along the longitudinal perimeter, and one line of internal columns with one column missing to give 15m clearance. However, above ground-floor level, an additional column supported on a transfer beam could be introduced to economise on the beam spans. The centre of gravity of the building as a whole passed through the centre of the core. Therefore, a lateral force-resisting system was needed, to have a centre of rigidity as close to the core centre as possible to minimise the torsional effects. The lateral resistant system could have been vertical bracings or shear walls, moment frames or a combination of these two systems. Floor

could have been of composite concrete construction on metal decking or a precast flooring system overlain with a reinforced concrete structural topping.
The gable end walls were discontinuous due to the ground-floor setbacks, so the gable end columns should be kept exposed below the first floor level. They were required to be aesthetically acceptable: options included inclined columns, inverse v-shaped double columns, etc. The two-hour fire rating could be achieved utilising an intumescent paint.

Foundations preferably needed to be deep because of the presence of shallow ground water and relatively soft top-soil, but shallow foundations could be acceptable if the effect of buoyancy was considered. If a moment-frame system was adopted then the base fixity needed to be assured to minimise the storey drift. For a moment-frame structure solution the main challenges were the storey drift, P-Δ effects, and significant moment connections between beams and columns.

In Part 1a schemes were competently presented by most candidates, although provision of information was patchy by some leading to loss of marks. The discussion of scheme options was plentiful but presentation and ordering of thoughts could have been improved.

The letter was intended to assess the candidate's appreciation of the torsion and its effects on seismic behaviour and seismic loading of the structure. Letters were generally satisfactory with most candidates able to identify the problem and offer a solution. Some letters were too generalised and marks were lost if the location and possible size of replacement walls was not described.

Calculations were generally competent, with reasonable simplifications to the analysis made, particularly when they were justified by a reasoned argument but which was not always forthcoming. Interpretation of codes was generally faultless.
Drawings were of varying quality and were often roughly done, rarely meeting the necessary standard for a general arrangement. Most were adequate for information transfer purposes. The details were often somewhat trivial, as only a few showed what could be considered to be critical.

The method statements and programmes were disappointing. A method statement should include a safe procedure to construct the structure, such as the sequence of operations and necessary temporary works etc, not just a list of construction activities, often featuring only a single entry for the erection of the structure.

Question 9: Glass façade and canopy

The question was aimed at Engineers specialising in façades. While the problem included consideration of the support structure and foundations, the Examiners were also looking for a demonstration of competence in supporting a glass façade. This is an unusual situation, since the façade designer is generally relying on a structure by others to provide the support for their work; however, the exam requires a demonstration of competence as a Chartered Structural Engineer, not just as a glass façade Engineer, so the wider structural elements were included.

Part 1a, as usual, required detailed understanding. The question stated that the new facade was to replace an existing gable. The crucial point, which was not properly understood by some of the candidates, was the new gable-end façade's relationship with the existing structure. Some assumed the old gable end remained in place, thus allowing them to install props from this non-existent structure to the proposed new installation but consequently losing marks. A further misunderstanding appeared with the scope of the works, with the infill side elevations being required by the question but not being detailed or even expressly being ignored by some candidates.

Two solutions were sought: while some possible ones may have been seen as too complex to design in an exam, offering a good practical solution to take forward and a more esoteric solution to demonstrate knowledge would have impressed the Examiners. Trusses, including bowstring, are often used for long spans, but there was a dearth of them here. The perimeter support frame and foundations were straightforward and relatively easy to describe.

The letter required candidates to assess the effect of 6.0m depth of made ground discovered under the gable. The problem was understood, though sparsely answered by some. A simple solution to the problem should be identified.

For some candidates, their choice of scheme made the calculations difficult. The wind load was the primary load normal to the façade, and lack of proper analysis of this was marked down. Candidates generally spent more time designing the main frame than supporting the glass. They also did not properly resolve the support for the canopy or provide any design for the side glazing, which would incorporate the props to the existing structure. Glass support was varied, but most candidates looked to some form of steel fin. These are not an efficient use of material and add considerable weight to the whole. Most importantly they interrupt the view. The use of trusses, tension rods and suchlike would have been preferable.

The perimeter support frame received much attention. It was required to be stable in the plane of the glass, but was propped by the existing structure. This was not properly understood by all the candidates.

Most candidates were able to draw their designs, although omitting much detailed information. The omission of foundations and other structural elements, and deficient dimensioning, all lost marks.

The method statement required a description of the erection of the new gable, including a method for setting in place the various components especially the glass, then demolition of the existing gable.

The fact that this was a glass façade question, with all that it entailed, was not well appreciated. It was the Examiners' impression that few, if any, of the candidates had any real experience in façade design: although many details were appropriate, they could have come from experience on projects where a façade was incorporated. For those seeking to use the question as a trial paper for a future exam attempt, it is suggested that 'Cribbs Causeway' be searched for on-line. While this project was not the design on which the question was based, the photo that will appear gives a good example of what was looked for in an answer.