The Institution of Structural Engineers

Examiners' report 2013

Chartered Membership Examination 2013

Associate-Membership Examination 2013

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.

Specialist Question 9 – Chartered Membership question paper

The Panel can confirm once again that a specialist question based on glass enclosures will be featured in the 2014 and 2015 examination papers. The format and level of challenge will be identical to the other questions. A sample question with general information is currently available and can be downloaded from the Institution website.

Chartered Membership Examination 2013

Overview

Total candidates:	725
UK candidates:	387
UK pass rate:	38.2%
Non-UK candidates:	338
Non-UK pass rate:	27.2%
Overall pass rate:	33.1%

Questions

1. New factory, storage and office facilities
2. Sports hall
3. Footbridge over a waterfall
4. Underground car park and garden
5. New school building
6. Mountain rescue centre
7. Pre-assembled unit for terminal expansion project
8. Multi-storey car park in a seismic region

Feedback

Question 1: New factory, storage and office facilities

This question required the candidates to provide two viable alternative schemes from which they would choose their preferred option for a new factory, storage and office facilities. The building was divided into two distinct elements: a 60m clear span factory, and a mixed use heavily-loaded 25m-wide open plan multi-storey block with offices on the top storey inset around the perimeter. Two core areas had to be located within the mixed use area, their location being at the discretion of the candidates. The brief was straightforward and easy to follow, and permitted several possibilities for the structural framing which should have meant it was not difficult to conceive two clearly distinct and viable schemes.

The question was popular, but few candidates appreciated the sheer volume of work required in both parts of the question. Some overcomplicated their structural solution by considering the building as a single entity instead of two parts.

The factory element required a clear span roof structure spanning on to external perimeter columns. Most options offered were a trussed roof or a portal frame, and few variants or novel solutions were proposed. Those candidates that proposed the conventional options answered this part of the question well. Very few candidates considered the required gable door openings and the likely gable frame arrangement. Those candidates who spanned the portal frames on to the storage and office facilities structure often did not consider the resulting increased moment and horizontal loads imposed on the supporting columns within this element.

Surprisingly, very few candidates used the cores to provide overall stability and support to the floors within the storage and office facilities element. Omitting to do so tended to overcomplicate the floor structure, with long spans and bracing introduced around the building perimeter. Most candidates who located the cores on the perimeter of the building ignored the set-back of the office footprint, thus preventing access to this area, and did not consider travel distances for means of escape. Few candidates considered alternative framing options for the upper floor office element, or offered proposals for the transfer support structure. The general descriptions of structural stability and load paths to ground were often poorly outlined.

The implications of the ground conditions, with the effect of the water table lying in the bearing gravel strata, were generally recognised, with piling being the favoured foundation solution. Good candidates recognised the possibility of shallow pad foundations for the factory area as an option. The raised ground floor to the factory was achieved generally by piling or by ground compaction, but few candidates considered the necessary retaining wall element around the perimeter.

In their letters, most candidates recognised the implications of the client’s requirement for a crane as causing increased horizontal and vertical loads and were able to envisage the changes that could be made to the factory roof structure.

In many cases, insufficient calculations were provided. Many candidates focused on the simple superstructure elements of the building: beam and column sizing, but calculation of the overall stability and the system providing it was often omitted. Foundation design, particularly the piled option, was poorly undertaken and in many instances showed a lack of understanding of the technique being proposed.

The provision of general arrangement plans, sections and details was poorly executed. Only a few candidates demonstrated the ability to prepare drawings and details with sufficient clarity and detail to provide information for estimating purposes.

Method statements and programmes were barely acceptable. There was a lack of appreciation of items such as temporary supports to clear-span roofs, and raised floor slabs supported by retaining walls. Good candidates used sketches to illustrate the more involved construction sequences to avoid wordy descriptions, and saved themselves time accordingly.

Question 2: Sports hall

This question required a circular segment building with significantly long spans. The key challenges of the question were: to find a suitable structural arrangement to resist roof loads with clear spans of around 50m in a non-rectangular shape; to take into account an existing basement slab on the site; to ensure that the structure was laterally stable by providing sufficient bracing.

Many candidates produced solutions where the structure followed the curve. Some also proposed schemes with rectangular roofs and these were acceptable solutions. Some candidates proposed roof members curved in plan that were unlikely to be economic. Others proposed very large-span portal frames that were not feasible. For the foundations, some candidates proposed foundations that involved piling through the existing basement slab without considering the possibility of using the slab for shallower foundations.

The letter was designed to test the candidates' understanding of how the imposed vertical and horizontal loads would affect the foundations. Differential settlement was likely to be critical in the second site. Many candidates proposed only to increase the depth of the piles.

It was expected that this question would require a substantial quantity of calculations to justify the structural arrangement; however, candidates needed only to identify the critical elements and restrict other calculations to simple load determination. Once the critical elements had been designed, it was satisfactory to choose non-critical element sizes by inspection. Good candidates found time and had the ability to assess vibration in the seating elements.

Many candidates produced a good set of drawings and details.

Some candidates had run out of time before reaching part 2(e). Those who did attempt it frequently suggested unrealistic programmes in their project plans.

Question 3: Footbridge over a waterfall

This question required a footbridge to be constructed over a waterfall, with constraints on the positions at which supports could be placed. The number of possible solutions for this question was limited, hence it was a straightforward question for confident candidates to attempt. A lightweight bridge, curved in plan, was required. It was envisaged that a non-moving bridge similar to the Gateshead Millennium Bridge at Newcastle, UK, could be aesthetically appropriate for this site. However considering the constraints as well as the functional requirements a bridge C-shaped in plan suited the situation better. Although a majority of candidates tried that approach, few were able to make it simple and suitable for the site.

Taking into account the constraints at the site, a minimum amount of construction activity was desirable, so the use of cantilevered steel beams at least 5m long fixed by rock anchors at locations set back from the cliff was preferable to deep rock cuttings to create massive concrete foundations resisting overturning of a huge cantilever. The same consideration would rule against options such as cable-supported bridges, in-situ concrete bridges etc. Simply-supported bridges were also inappropriate. The fixed supports at either bank required lightweight superstructure, which was proposed only by a minority of candidates.

The load capacity of the central rocky outcrop was limited to 250kN so that candidates who were familiar with the analysis of beams curved in plan would appreciate it would not be possible to use the outcrop for intermediate support. Unfortunately, very few candidates demonstrated understanding of this form of structure.

Very few candidates provided adequate and appropriate calculations for their structure. Few candidates were able to make accurate calculations of the effect of torsion due to curvature and the loads on the intermediate support. A beam curved in plan needs three simple supports to be a determinate structure, but this was not appreciated by some.

Those candidates who provided clear general arrangement drawings with elevations and sections demonstrated their understanding of the structural behaviour and gained high marks. Some did not appreciate that their proposed bridge was supported on but not connected to the banks at either side.

The site presented an unusually high level of potential hazards during construction, and it was expected that candidates would place a high priority on health and safety aspects such as maximising prefabrication off-site and keeping on-site activity to a minimum. Unfortunately this was not apparent for the majority in their proposed method statements.

Question 4: Underground car park and garden

The question required an underground 3-storey car-park with a landscaped garden above, at a site with a high water table.

A vital part of the design was to counteract the large flotation forces caused by ground water during both the construction stage and the on completion. During the construction stage dewatering might be used to reduce the uplift force, but once completed the uplift force needed to be counterbalanced by the dead weight of the structure. If the total dead weight was insufficient to hold down the building, permanent anchors or tension piles were needed. The flotation effect caused different problems depending on whether top-down or bottom-up methods of construction were adopted: with the bottom-up method the dead weight of the partially-completed structure continually changed whereas the flotation forces remained essentially constant. Some candidates failed to understand the need for stability checks during construction.

Most candidates were able to provide two distinct schemes, but not all the schemes proposed were viable. In many cases, the dead weight of the structure was not sufficient to resist the flotation forces.

Some candidates had the insight to see the advantage of using top-down construction, which solved some of the problems due to uplift during construction. This method also helped to limit the deformation of the surrounding ground during construction.

Most candidates proposed temporary works in the form of diaphragm walls or sheet pile cofferdams. It was acceptable to use diaphragm walls as the permanent basement walls; however, many candidates failed to consider how to deal with seepages through the joints of diaphragm wall panels or waterproofing of the underground structure.

Dewatering was adopted by many candidates for the construction of the underground structure but some candidates did not consider the large ground settlements this would cause outside the site.

The design of the basement slabs was a major problem for many candidates. In many cases, the basement slab was not properly designed to resist the large flotation forces.

Many candidates failed to provide clear and acceptable framing plans, sections and details for the car park. They failed to give critical details for the construction of the underground car park. Examples of critical details were: methods of water proofing; details for permanent anchors etc.

Question 5: New school building

The question required a three-storey school building, sinuous in plan, with a single-storey sports hall.

Many candidates assumed that the requirement for a column-free space in the classrooms and across the atrium allowed hangers and walls to be used instead. This was unreasonable: a client, who did not want a column in the way would certainly not want a wall.

Most candidates proposed steel or concrete schemes, and some suggested load-bearing masonry. The question permitted different building materials and construction types, which could have added to the distinctness of alternative schemes, but when comparing schemes many candidates tended just to list generic steel versus concrete factors which could have applied to any project. Some candidates did produce very good arguments specific to their scheme and they scored high marks.

The single-storey sports hall was covered well by many candidates, but some did not give much attention to the design of this part of the question. In particular, several candidates proposed a portal frame for the sports hall, but did not take it through to the design of the columns. For the classroom block, some candidates who produced schemes which relied on moment frames for stability designed all of their primary beams and columns as simply-supported without mentioning that they should be designed for a bending moment.

Some candidates appeared to lack experience in the appropriate sizing of columns. A low-rise building does not require columns sized for a 20-storey building. Several candidates proposed columns sized at 1m x 1m, and when calculations proved that the capacity was an order of magnitude larger than required for the loads, the candidate did not consider making the columns smaller. For this question a 300mm square column would have been sufficient. Candidates will lose marks for gross over-design.

Most candidates provided at least one movement joint, normally between the sports hall and the classroom block, although some also had one along the length of the block. There was not enough discussion about the need for and the locations of movement joints.

Little thought was given to the location of the bridges across the atrium in the classroom block which could have provided a stability link between the two sides of the building.
The letter was generally well written with most of the points addressed, but handwriting was sometimes difficult to decipher.

Method statements were often attempted well in describing the stages of construction but not on the provisions necessary to achieve safe construction. Some candidates made no mention of the sports hall in the method statement. In some cases, and possibly caused by pressure of time, little thought went into the outline construction programme, e.g. some made no mention of the construction of the sports hall, and few considered adjusting the timing of construction of the two buildings for most efficient working.

Question 6: Mountain rescue centre

This question required the candidates to design a two storey structure above a basement garage. A restriction on height and a high water table meant that the basement would be constructed below the water level. Site constraints meant that some form of temporary support would be necessary to some elevations but it would be possible to construct other elevations in open cut.

The question required candidates to recognise the difficulty of construction below the water table and also appreciate the relatively small scale nature of the works. Loads were generally light and there should have been no necessity to heavily-engineer the proposed structure.

A variety of solutions proposed included steel portal frames for the superstructure with concrete for the basement, timber frames, or load bearing masonry. Some included over-complicated curved beams to achieve the curved elevations, which were uneconomic as a simple facetted structure would suffice. Some layouts proposed for the single row of columns in the basement were impractical for manoeuvring of vehicles. The majority of candidates recognised that transfer structures were needed to support the superstructure above the basement and relatively long spans were necessary for the Level 1 slab.

Many candidates opted for piled foundations, often of unrealistically large diameters. In practice, careful consideration of the loads would have allowed a small increase in basement floor slab thickness to resist the upthrust from the groundwater with no requirement for piling of suspended slab. Many candidates failed to address dewatering or temporary support close to the site boundary.

As in previous years, a large number of candidates provided standard answers to describe stability and load paths. It is essential that these elements are bespoke to the structure required by the question. Candidates lose marks for quoting irrelevant material.

Overall the majority of candidates grasped the requirements of the brief, although it appeared that a significant number wasted considerable time in resolving layouts for parking bays rather than concentrating on structural solutions.

In their letters, most candidates appreciated that the removal of columns and accommodating additional loading from the helipad would increase the depth of Level 1 members and thus increase the overall depth of the basement structure. This had a knock-on effect of increasing the buoyancy of the building. Some candidates also recognised that there would also be an increase in excavation and disposal of material and associated environmental aspects. A few suggested relocating the helipad away from the basement thereby avoiding any change to the structure. The standard and clarity of letters varied but generally would not be of a standard acceptable in a design office.

Calculations ranged from very detailed but repetitive designs, to over-simplified rule-of-thumb methods of design for key elements. It is important that candidates recognise which members are key and provide fully detailed calculations inclusive of bending, shear and deflection. Having designed a typical element there is no need to provide repetitive calculations for similar members. In general, where foundation designs were included candidates took account of the reduced bearing capacity below the water table.

Many scripts included drawings that were scrappy, hard to interpret and would not be acceptable in professional life. Candidates should appreciate that drawings need to be neat and readable. Some papers failed to provide a range of details.

Method statements were somewhat generic. Candidates should make them bespoke to the structure they are designing. Where bespoke method statements were provided candidates identified the need for propping near the top of temporary sheet piling prior to completion of the excavation and sequenced the superstructure to erect the braced bays first. Many programmes were sparse and generic, varying from 25 weeks to over a year. A programme of approximately 48-56 weeks was considered optimal. Many candidates appeared to rush this section of the paper.

Question 7: Pre-assembled unit for terminal expansion project

The question concerned the design of an onshore based Pre-Assembled Unit (PAU). This is a very common form of structure in petrochemical and offshore engineering, and should have been a straightforward test of basic structural engineering knowledge. The PAU was to be constructed in a North European yard, and transported to a UK coastal terminal, hence all normal module load cases were to be considered. Foundation design was excluded, thus considerably simplifying the question.

One scheme was anticipated to be a structure braced in both directions, of standard construction, keeping the central area clear. Details offered included pad-eyes located to take a lift beam, load-out trailers under level 1 beams, and sea transportation forces resisted by vertical bracing systems. How different should scheme 2 have been? Most attempts varied the bracing in one or both directions, while a few attempted a portal frame solution in one direction.

The letter introduced the concept of an explosion pressure of 0.3 bar being retrospectively applied to the PAU design. It was expected that a sketch and some quick order-of-magnitude calculations would be required, along with a professionally-written letter, to show understanding of the basic concepts.

The calculations and drawings were usually dealt with adequately. At least one beam, one column, and one bracing for the in-place condition was required. The question stated that open-grating does not offer lateral restraint to floor beams, which avoided ambiguity. An estimate of wind forces was necessary, in order to design the vertical bracing systems. Some sketches for lift, loadout and sea transportation conditions were required, preferably showing the critical aspects affected by each.

Question 8: Multi-storey car park in a seismic region

This question was for a multi-storey car park with large spans and few internal columns in a seismic region. The key challenges were: sway under lateral seismic loads in a structure with a limited number of columns and large spans in the transverse (narrower) direction; significant plan irregularity due to external circulation ramps located only on one side of the building; height limits requiring an appropriate method of framing and construction to optimise the clear height; requirements for diaphragm action of the floor slab with large holes for stair/lift cores; and foundations on a significant natural slope with issues such as short columns and slope stability.

Viable solutions could use a 7.5m grid along the longitudinal perimeter with 16m internal spans. Lift/stair shafts were positioned symmetrically in order to avoid torsion and such that the fire regulation requirements were also satisfied. The two access ramps were located only to one side of the building creating significant floor irregularity resulting in complexities due to large torsions. It was advisable for more simplicity to separate the main building and access ramps structurally by introducing separation gaps between the building and ramps, which meant that the ramp structures needed to be self-supporting both vertically and laterally. However, since the detailed design of ramps was excluded from the question, only an explanation was needed of ways to achieve stability.

Half the building towards the rear road required a 2-storey cut into the ground and therefore needed retaining walls on the rear and gable ends to the level of the rear road. The retaining wall could be isolated from the main structure to simplify the design, or alternatively be combined with the main structure in which case the seismic forces generated by the weight of the soil behind the walls should have been considered in the design.

Floor construction could be in the form of 100mm-thick PC units overlaid with 100 to 125mm thick structural topping. The roof was a lightweight flat construction with high parapets, therefore snow drift needed to be considered for purlin design.

It was advisable for the structure to be a framed one, with or without bracings/shear walls. Bracings and shear walls needed to be located in service cores and perimeter elevations. The latter needed to be left exposed from the inside. The floor diaphragm action was a key issue in distributing the shear forces to bracings/shear walls. The requirements for chords and the load path around the large floor openings in core areas plus cantilever action of the floor beyond the cores were amongst the challenging issues.

For a framed structure solution the main challenges were the storey drift, P-Δ effects, and significant moment connections between beams and columns. The structure of the ramps could be in the form of a separate braced frame or a 3D framed structure. The foundation could be in RC pads bedded into the rock for braced frame solution or a piled foundation for moment frame solution with required base fixity.

The letter was intended to measure the candidate’s appreciation of the soft storey configuration principle and its effects on seismic behaviour and seismic loading of the structure.

Most candidates recognised the need for separation of access ramps from the main building and proposed two schemes, one with bracing and one with moment frames in the transverse direction. However, the majority failed to explain clearly the advantages of their selected scheme and gave weak generic comparisons between the two schemes. A number of candidates spent a lot of time clarifying the requirements of the question and their assumptions unnecessarily. Some candidates failed to propose initial structural sizes to justify compliance with the brief. The effects of ground conditions on the design of retaining walls and foundation selection were not fully appreciated or discussed by some candidates.

Most candidates recognised the implications of the client change requirement in their letters but generally failed to offer a solution. It is very important to present the client with a workable and economical solution(s) for his/her desired change(s).

Some candidates spent much time calculating the seismic forces but not enough on calculating various elements. Calculations generally addressed the seismic deflection check but did not fully cover all the main elements.

Drawings were generally poor, particularly in detailing the main connections, edge columns, shear wall/floor slab junction, floor slab adjacent lift/well openings, etc.

Most candidates generally attempted the method statement by giving an outline list of activities and allocating some time against them in the Programme. The key stages with related construction issues, the sequence of the work considering all factors influencing the construction work and any related temporary enabling or stability work were generally missing.