The Institution of Structural Engineers

Examiners' Report July 2015

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.

The July examination was the second sitting of 2015. The examination paper had seven questions which included the final offshore question and the second glass enclosure question. The CM paper will return to the five question format from January 2016 onwards.

CM July 2015	Pass	Fail	Total	% Pass
Question 1	7	18	25	28
Question 2	83	193	276	30.1
Question 3	9	13	22	41.0
Question 4	9	21	30	30
Question 5	15	32	47	31.9
Question 6	2	2	4	50
Question 7	6	22	28	21.4
Total	131	301	432	30.3

July 2015	Pass	Fail	Total	% Pass
UK	90	173	263	34.2
International	41	128	169	24.2
Total	131	301	432	30.3

Question 1 – New Visitors' Centre

The question required a viewing gallery to be constructed centrally above a 'bottomless' hole with an associated visitors' centre located on the periphery of the hole and entirely contained within Country A, whose border with Country B bisected the hole.

The requirements for the accommodation were specified by floor area, with 200m^2 required for the visitors centre and 30m^2 required for the viewing gallery. How these two spaces were connected together was left entirely free for the candidate to propose, provided that the viewing gallery afforded views down into the hole and that all structure remained entirely within the home nation.

The constraints prevented a simple truss being used to span from one side of the hole to the other, and created what was essentially an equilibrium problem in which cantilever solutions would need to balance the overturning forces in some way. Large cantilevers would require serviceability to be considered in detail. Whilst a detailed dynamic appraisal of the structure's performance was not expected in the solution, candidates who recognised the complexity involved and the benefits of dynamically assessing the structure gained higher marks.

There were no headroom restrictions, which allowed candidates to include mast and cable solutions if they wished, although these were generally handled poorly by candidates who attempted this route. Many candidates simply threaded the inclined cables through the visitors' centre structure to the detriment of the space. A few proposals simply made the platform unusable or even inaccessible because of the inclusion of cables.

Trusses could be used to span across the hole, offset from the centreline, to create an intermediate support. These solutions were acceptable provided that they did not significantly obstruct the views from the gallery. They had the benefit of reducing the span of the cantilever and creating a structure that had the potential to be less susceptible to vibration and deflection.

Pure cantilevers were favoured by many candidates, but only a few took advantage of making the visitors' centre out of a heavier form of construction to act as ballast against the overturning. Indeed, several cantilever solutions neglected to consider simple equilibrium, and overturning of the cantilever was neglected in its entirety by some candidates thus creating potentially dangerous structures.

The creation of holes through the floor of the viewing gallery might or might not cause diaphragm action problems, but did not generally affect the solutions offered.

The ground conditions were specified to be solid rock, thus removing the need to look at local wedge failure or difficulties associated with founding around the perimeter of the hole.

The letter to the client was intended as an opportunity to simplify the structure and potentially remove the equilibrium issues and accessibility issues during construction. The majority of candidates spotted this and presented the client with the option to remain with the current solution if time was critical or, where cost was important, a potentially simpler structural alternative could be generated.

The construction sequence and approach to temporary works was complicated because of the site restrictions, preventing a simple scaffolding solution being presented. Several candidates rose to the challenge here and structures which were safely erected on the ground and jacked into position scored highly where the level of detail was appropriate to show they understood the process well.

When this question was attempted well it was attempted very well indeed. A frequent characteristic of scripts of candidates who failed the question was a lack of sketching, and a lack of a description of the general structural behaviour of their proposed solutions. Very little consideration was given to the equilibrium and serviceability requirements, and all too often some space was unusable because of poor detailing of cable solutions.

Question 2. New city centre office block

This question was typical of city-centre commercial developments where underground parking provision is required. The aim was to test candidates' spatial awareness and their ability to design both superstructure and substructure. Possible structural solutions were relatively straightforward because of the large number of constraints which had to be met. Available structural zones were relatively generous. Key considerations were:

- Merging grids for more open-plan offices and lower level parking.
- Appreciation of the spatial constraints imposed by the brief.

- Waterproof basement construction required, and consideration of buoyancy forces on the lowest basement level floor slab.
- Out-of-balance earth pressures and hydrostatic pressures arising from the sloping site.
- Basement levels buildability.

Planning of the car park layout and circulation was an essential aspect of the question. Consideration of ramps between levels had been omitted.

Many candidates showed poor time management and were unable to complete all parts of the question.

Schemes in section 1(a) could have been tackled in either steel or concrete. Alternative solutions for either should have been distinct e.g. alternative grids, taking account of the essential features of the two materials, and should have been structurally economical. To suit the car-park vehicle circulation requirement, most candidates opted for a transfer structure at level 1. Other possible options included adjusting the spine column grid position to coincide with a car park grid or clear-span offices space. A few candidates were able to propose fresh ideas for their second solution, but those presenting options using the same grids with different materials did not gain high marks.

A concrete solution should include consideration of movement joints. Often those candidates who did note that a movement joint might be required, dismissed it as not necessary without describing how thermal effects would be dealt with.

Because of the roads around the building and the water table, a secant pile retaining wall solution was anticipated, with piled foundations for the frame. A raft foundation, albeit difficult to construct, required differential settlement between the concourse and offices to be considered.

The standard of explanation of load paths, when dealing with the vertical and lateral load transfers, was varied. Out-of-balance earth and hydrostatic pressures were overlooked by some.

Although hydrostatic pressures were recognised in most cases, only some candidates included strategies for dealing with basement slab floatation. The use of ground anchors used to restrain retaining walls against earth pressures was a credible solution.

The letter in section 1(b) required consideration of the problems arising if only half of the building were to be constructed. It was intended to test candidates' recognition of the stability issues of a single core, the need for construction to support floors along the cut line, and the need to extend the retaining wall across the centre of the site. A business format was generally adopted for the letter and some candidates used simple sketches to explain their answer. The issue of stability was recognised by most, but this was not generally clearly explained. The impact of the change on the programme was often not mentioned

It was expected that substantial calculations would be required to justify the structural arrangement, but candidates needed only to identify the critical elements, and restrict other calculations to load determination. Most candidates were able to identify key superstructure elements and design them. Foundations and substructures were less ably approached.

Drawings should be sufficient for cost estimation. There was a wide variation in quality among the scripts. A number of candidates produced sketches rather than scaled drawings with grids. The forecourt structure and parking below was omitted from some drawings. Critical details tended to be generic with boundary interfaces, waterproofing, blinding concrete, and cladding support not illustrated. Many who chose concrete frames mistook critical details to mean standard RC details.

Method Statements should have focused on unusual construction aspects such as building the basement levels. Some overlap of construction activities was expected on programmes. Some candidates had no appreciation of how the building would be constructed even through a deep basement in a city centre is by no means unusual. Method statements tended to be generic with little mention of the specific needs of the scheme. Better candidates included construction sequence sketches. Programmes were generally of an acceptable standard.

Question 3. High-level Road Bridge

The question related to a real-life project involving a conventional bridge.

Three distinct options arose from the feasibility stage of that real-life project, all of which were viable. All three had one common feature: the need to design measures to avoid aerodynamic effects on the spans, greater than 50m in length.

One feasible solution was a precast-concrete box girder in segmental construction with cable-stays, forming an extrados bridge. A second feasible solution was a steel box girder of varying depth, with a concrete deck slab. The third was a five- span bridge with multiple I-girders within a bridge enclosure, additionally supported by thrust arches in three spans to improve the aesthetic appearance. None of the above options found favour with any candidate.

Most candidates proposed a steel composite solution, comprising a reinforced concrete deck slab supported on steel plate girders of constant depth. Unfortunately very few candidates appreciated that such long spans with exposed plate girders would be unlikely to be appropriate for a site with a high wind speed. Few candidates proposed trusses, which could form a possible solution if the required clearances could be met and if the proposed construction method could be achieved in the limited possession times. Some candidates proposed tied arch solutions but without solving the construction constraints.

Few candidates achieved high marks in section 1b. Some started with one solution but concluded with a different one.
Only very few candidates demonstrated their understanding of the consequences of impact load. These depended upon the type of superstructure proposed as well as the span arrangements and bearing articulation arrangements for the particular scheme.
In part 2, with a site in an area of high design wind speed and lots of access restrictions, it was essential to provide calculations which reflected these constraints. Unfortunately, few were able to do so. Candidates showed little skill in the production of drawings and sketches, and their lack of site experience was no doubt responsible for many unrealistic construction programs proposed in section 2e.

Question 4 – Below ground pumping chamber

The question required a buried chamber, of shape and depth to be chosen by the candidate, and should have been straightforward for candidates with any experience of underground or retaining structures.

Two key aspects that needed to be dealt with were the level of the water table, and how the chamber could be safely constructed.

Lots of solutions resembled what can only be described as buildings in the ground, with candidates seeking to skirt around the need for retaining structures. The requirement for a minimum chamber volume meant that some long-span roof structures were inevitable, but some candidates went to extreme lengths to make the chamber as shallow as possible which resulted in very long-span roofs that were generally bridged by steel trusses. The requirement for fire protection was often not taken into account when steelwork was proposed.

Straightforward distinct and viable alternative schemes were square/rectangular or circular chambers which worked differently in the ways they resisted the necessary loadings. A few candidates proposed these simple solutions.

Most candidates appreciated the need to dewater during construction but few really outlined how the construction was going to take place. Some explained this would be by a 'specialist', which dodges the question. Likewise, some stated that the design of the sheet pile, secant or diaphragm walls would be done by a specialist, but the exam requires such fundamental matters to be addressed and not bypassed. Feasibility calculations in section 1a were expected to be simple to establish key sizes, and candidates were not expected to spend time in section 1 duplicating the detailed calculations required in Part 2.

The letter required consideration of the higher water table. This had three effects: greater uplift, higher pressures and more difficult construction. Most appreciated the first, but many did not explain the other considerations and so did not gain high marks. One candidate designed for the high water table from the start, which was marked down as being uneconomic.

The calculations provided were limited and often too simplistic. Many candidates listed the calculations that were needed, but then did not perform them or undertook only the easy parts. The number of elements requiring calculations was limited, therefore a high quality was expected for each of them. Too many candidates ignored the retaining structure and concentrated on more familiar spanning elements. The lack of ability to calculate the pressures on the walls for their design seemed to demonstrate that most candidates had no experience of designing real structures of this type. Whether the lateral earth pressure coefficient should be taken as active or at-rest was considered only by a few.

As with the calculations, there were few elements to draw and therefore a higher standard was expected. Unfortunately the overall standard of drawing was very poor. Critical details were not well done and sometimes were not included at all or comprised only reinforcement details. Marks were given to the different parts of section 2(d) as stated in the question: plans, elevations/sections and critical details. Candidates providing drawings addressing each requirement gained higher marks.

The method statement needed to explain the temporary works needed to allow construction to be achieved. Most candidates appreciated this, but were unable to provide enough detail to demonstrate that they knew how such a structure could be built safely. Time pressures meant that some candidates failed to attempt this part of the question.

Question 5. Fire fighter training building.

This question called for a relatively small building with a simple layout. Key constraints included no obstructions at ground floor, possible flooding, fire, buoyancy, and a required lifting beam.

Most candidates overlooked some or all of these items. Alternative schemes were generally very similar, most proposing a change of material using steel or concrete. Very few looked at the possibility of a masonry structure which was a distinct and viable option for this type and size of building.

A number of candidates proposed using the same framing for both solutions, one with internal isolated columns and the other without, then concluded that the solution without internal columns was preferable for providing a larger column-free space. Indeed, a column-free internal space (i.e. between the walls of the ground-floor training area) should be considered essential in such a small training area even though this was not specifically mentioned in the question, and it was expected that candidates would appreciate that solutions with internal isolated columns were impractical.

The majority of candidates failed to present a practical solution for the lifting beam. Some provided RC beams cantilevering from the roof structure, and some of those proposing steel beams did not allow for the beam to continue inside the building.

The stability of the upper floors, which on one side relied on a transfer beam, was not recognised as a potential problem by almost all candidates.

Few proposed solutions for flooding were practical. In resisting the buoyancy of the pit a number of candidates attempted to use unrealistically thick walls and floors instead of using the self-weight of the structure.

Letters generally demonstrated understanding of the key issues but failed to give simple solutions and typically were not written in standard business format.

Most calculations were untidy and difficult to read. Candidates risk losing marks if their scripts cannot be understood by the examiners. A few spent too long in over-elaborate calculations of some elements while ignoring other principal elements. Calculations for the lifting beam typically omitted a deflection check, which is usually a governing item for such elements.

Drawings often lacked key information such as principal dimensions and details. In some cases they were prepared without even using a ruler. Details of the relationship between foundations, columns and cladding were sometimes impractical.

The method statements often missed key items such as deep excavation and flooding impact. Programmes were too basic with randomly selected construction durations for various items.

Question 6. Glazed entrance to civic building

This was a question aimed at candidates working with façades. While the requirements included the support structure and foundations, the examiners were also looking for evidence of experience and competence in supporting a glass façade. This was an unusual question, as the façade designer is generally relying on a structure by others to provide the support for their glazing; however, the exam requires a demonstration of competence as a Chartered Structural Engineer, not just as a glass façade Engineer, so the wider elements were included. The support structure, being more conventional, appeared to attract more attention from candidates.

Section 1a required a detailed appreciation of the problem. Because of the unusual geometry of the structure and the focus on the glass façade, candidates had to take a pragmatic view regarding movement. The structure in the question was a very large and high canopy and did not provide support to anything except the glass cladding that covered it. This caused problems of lateral movement, and the amount that would be deemed acceptable, on which no code of practice would provide guidance. It was this aspect of the question that undermined candidates' attempts at answering it, with some ignoring it completely.

Another aspect of the question that caused some confusion was the provision of a 10m-wide zone either side of the canopy for bracing. This was largely ignored by most candidates, but its use would have made their proposed schemes a great deal simpler and even in some cases viable.

Part 1b was understood, though not well answered. Some candidates added details about the structure and the environment it was placed within that were never stated in the question itself.

For some candidates their choice of scheme made section 2(c) difficult. Some candidates failed to identify the principal elements and properly design them for all the load effects required. Loads were not fully worked up and the possibility of uplift from wind on the canopy was ignored. Poor layout of the calculations made some difficult to follow.

Most candidates drew their designs in section 2(d), though often omitting much detailed information. The examiners look for sufficient information to estimate costs. The omission of foundations and other elements, and deficient dimensioning, all fail to gain high marks.

Performance in section 2(e) depended on the exam time remaining. What was sought included the method of erection of the new gable, including setting the various components and especially the glass, then demolition of the existing gable.

Q7 Flare structure

The question required a flare structure consisting of a horizontal bridge and vertical tower structure, tied back to an existing platform. It combined aspects of bridge design and jacket design, and required careful selection of the key elements to be designed, rather than attempting to design every item and inevitably running out of time.

Most candidates offered variations of triangular and rectangular bridges, with tower structures that were 4-legged jackets with X and K bracing patterns. Second options included vierendeel towers, caisson or STAR platforms, or monopiles. Some candidates sketched both schemes neatly to scale but with very little narrative. Comparisons between schemes were often standard pre-prepared tables. Demonstration of stability during temporary conditions was a common difficulty. Unsafe structures automatically failed, although such failings were usually accompanied by other weaknesses.

The letter was expected to demonstrate knowledge of how operational and accidental ship impact forces could be accommodated in the tower structure. Most candidates were unable to do so. Some proposed major impact frames be installed, and some suggested that the impacting vessel would absorb most energy, neither of which met the requirement of the question. Impact resistance is a common feature of jacket design and well-prepared candidates should have been aware of basic industry norms and regulations.

Calculations had to be carefully selected in order to demonstrate competence in identification and design of key elements. Most candidates were able to design the bridge, but several spent too much time designing trivial items such as walkway gratings and secondary beams. The tower structure, frequently a 4–leg jacket, proved problematic. This is where most of the design effort should have gone, since the bridge was relatively simple and could have been designed very quickly by approximate methods for top and bottom chords, and worst-loaded bracing. Several candidates elected to design the jacket solely by L/R and D/T ratios, taken from industry design guides, and did not demonstrate how vertical and horizontal wind wave loading would be safely transferred down through a braced frame into the foundations. The essence of the examination is to demonstrate competence in structural engineering analysis and design, which justifies scheme selection, and leads on to drawings capable of being accurate cost estimation.

The drawings, details and method statement were generally adequately performed by successful candidates.

Associate-Membership examination

AM July 2015	Pass	Fail	Total	% Pass
Question 1	11	2	13	84.6
Question 2	0	0	0	0
Question 3	2	1	3	66.6
Question 4	2	7	9	22.2
Total	15	10	25	60

In the AM examination, candidates were asked to answer one of four questions. Only three of the four questions were attempted (Q1, Q3 and Q4), so the feedback on each section below relates to the candidates' performance in these three questions only. Also provided are the key features of these three questions.

Section 1a The examiners emphasise the need for candidates to give a clear appraisal of the functional framing; of how the overall stability of the structure could be maintained; that the drawings were poorly presented and in some cases lacked essential details for estimating purposes.

In each question there is a fundamental requirement to ‘indicate clearly the functional framing, load transfer and stability aspects of the scheme’. Functional framing and load transfer are probably most effectively described through diagrams, so candidates are encouraged to consider techniques for showing these aspects of design. The examiners noted that functional framing and load transfer diagrams were either omitted or were unclear. Descriptions of stability were often confused or unclear. Diagrams can also help in this regard.

Section 1b This section introduces a specific, usually client-driven, issue that involves fresh structural engineering challenges. It is important that candidates recognise the challenges and deal with the structural engineering implications. The examiners noted that the majority of candidates correctly identified the structural issues raised, but their letters lacked providing firm advice to the client. Ideally candidates should demonstrate a good understanding of the issue, identify several options to meet the engineering challenges and give clear recommendations to the client.

Section 2c Most candidates produced satisfactory calculations. The examiners noted that some candidates incorporated insufficient calculations to establish the form and size of all principal structural elements, including foundations. Candidates should consider how their proposed solution is sub-divided into principal structural elements.

Section 2d Some candidates did not include sufficient information to show the dimensions, layout and disposition of structural elements for estimating purposes. The examiners often noted that there was insufficient information for a quantity surveyor to estimate the cost of the works. It is recommended that candidates consider the design information that is typically provided for a conceptual design cost estimate. Including sufficient views (plans, elevations and sections) will help ensure that enough information is provided.

Section 2e The marks for this section were generally poor, even for candidates with good overall pass marks. The principal reason for this appears to be candidates leaving insufficient time for this section at the end of the exam. Candidates are reminded that marks can be gained quickly by ensuring that this final section is given appropriate attention.

Question 1 This question related to a single-storey warehouse, with a showroom at one end which had two further storeys for offices above the showroom. The showroom was set below the floor level of the warehouse because of the topography of the site. The brief was quite specific regarding the internal and external column arrangements. Two delivery door openings were required – a minor inconsistency regarding the location of these delivery doors was stated; however, all the candidates addressed this in their response to the question. The examiners marked the question on the quality of the structural engineering and not on this inconsistency. For a relatively straightforward structural design, most candidates answered the question well and the solutions were generally acceptable.

Question 3 This question related to a ballroom extension with an elevated promenade for an existing hotel. The brief was very specific. The positions of the twenty-two columns were indicated on the plan; however, the position of two columns only could be repositioned by the designer. The east and west sides of the hall were to be glazed. The 13.5m high existing brick wall of the hotel could not support any further load. The maximum structural depth of the ballroom roof was to be restricted to 1.3m. Generally candidates had difficulty in explaining the functional framing for their solution. As a result, candidates limited their calculations to beam designs with no consideration of stability framing. Drawings were poorly presented, in some instances lacking elevations, sections and essential detail.

Question 4 This question related to a single storey Coach Reception building which was to be open-plan, but having cantilever roof projections. The design brief called for the interior of the building to be free of obstructions: attractive in appearance with visible structural elements carefully designed. Because of the extensive glazing being used, the lateral deflections of the structure were limited to height/500, and vertical deflections of the roof structure were limited to span/300. Site investigations noted loose fill material to a depth of 6.0m and significant water ingress at 1.0m below ground level. Again candidates had difficulty explaining the functional framing, or how the overall stability of the structure could be maintained for their solution. Some candidates failed to work within the design restrictions imposed for lateral and vertical deflections. Piling was chosen for the foundations; however, in several instances, the piling calculations were lacking. Drawings were generally poor in presentation and content. Generally the Method statements were fairly limited in content.