C.M. Examination July 2016 : Chief Examiners' Reports

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

The July Chartered Membership and Associate-Membership were moderated through the Online marking system (OMS) introduced in January for the Chartered Membership. The OMS offers a streamlined and efficient moderating cycle which gives the examiners many benefits especially 24 hour secure access to their marking portals. Feedback to candidates is now given on request to candidates of both examinations.

CM 2016 July	Pass	Fail	total	%Pass
Question 1	52	168	220	23.6
Question 2	23	63	86	26.7
Question 3	7	13	20	35
Question 4	7	16	23	30.4
Question 5	14	23	37	37.8
Total	103	283	386	26.7

July 2016	Pass	Fail	Total	%Pass
UK	68	152	220	30.9
International	35	131	166	21.1
Total	103	283	386	26.7

Question 1, New Headquarters Building

The building was divided into two distinct structural zones: the upper square office block and the below-ground car-parking area. The offices were square on plan and had five floors, with Levels 4 & 5 cantilevering progressively in increments of 5.0m to all sides to create a pagoda effect. Column positions to external elevations were specified in the question, while internal columns plus the four required cores were defined by the candidate's chosen car-parking layout. The brief was straightforward and allowed various options for the structural framing, which meant it was not difficult to offer two clearly distinct and viable schemes using either steel or concrete as the construction material.

The office floors worked on a regular 5.0m grid in one direction and a 5.0m or 6.0m grid in the other direction, depending on the chosen car-parking layout. Many candidates achieved this satisfactorily for the lower three floors, proposing a regular steel and composite deck solution or a reinforced concrete slab option. A large majority of candidates had no idea how to deal with the progressively cantilevering floors at Levels 4 and 5. The options put forward suggested a total naivety of structural understanding. There was sufficient depth within the floor and roof zone to propose a simple cantilever. The question allowed 2.0m depth per floor: when taking into account a raised floor and suspended ceiling this would give a structural depth of around 1.5m. Taking the cantilever length of 5.0m and a structural zone of 1.5m this gives a span-to-depth ratio of 3.3, much more generous than the 7.0 which is normally applied. Candidates who proposed this option fared very well. Most candidates who proposed 10.0m cantilever vierendeel girders between levels 4 & 5 demonstrated they had little idea of how to design or detail such an element. Some candidates proposed lattice girders for the cantilevers, but this required diagonal members throughout the floor area of Level 5 rendering it useless as office space and in total contravention of the brief. Some candidates proposed 5.0m deep lattice girders across the roof to cater for a 10.0m cantilever, but the question gave a limiting zone depth of 2.0m. Many candidates showed little conceptual design ability, for example by putting all four cores together in the centre of the building creating travel distances of 30.0-40.0m.

The underground car-parking layout dictated the most suitable column layout and locations for the cores. Most candidates proposed efficient and workable solutions for the 200 parking spaces required by the client. Some, however, demonstrated their lack experience of parking layouts, whilst other made no attempt to provide what was required.

Many candidates proposed to take loads down to the sandstone stratum using various forms of piling for the column foundations. Others chose variations of pad or raft foundations founded on the sand and gravel. The perimeter retaining walls were generally conventional RC retaining walls utilising pad/raft foundations in an open-cut construction technique. Many of the solutions offered tended to expose the inexperience of the candidates in dealing with basement construction. In their choice of foundations, they seemed to lack knowledge of the various options that were available.

The selection of the chosen scheme was, in many instances, was very brief concentrating on concrete versus steel options for the office and with very little comparative analysis for the basement structure and foundations.

Most candidates recognised the key requirements necessary to meet the client's change request, so section 1b) was reasonably well attempted, although the letter in some instance could have been better worded and presented.

Most candidates provided calculations for the simple structural elements, beams, slabs, internal columns, and possibly a simple end bearing pile, which were undertaken efficiently, but not necessarily completely. Candidates, however, tended to ignore the critical elements such as the cantilevers, the overall stability, the retaining wall to the underground car parking area, and the ground slab/foundations. Marks were generally lost because of incomplete or absent calculations rather than because of errors and lack of design knowledge.

Drawings were frequently inconsistent and often incomplete, lacking all the required plans, elevations, and critical sections. Candidates tended to ignore the symmetry of the building to reduce the quantity of plan drawings required, but where it was used the plans were overly complex and confusing. A competent engineer must be able to demonstrate and clearly illustrate their design ideas, but unfortunately many candidates indicated their lack of ability to communicate their proposals through drawings and sketches.

The method statement and programme were reasonably well attempted but often ignored elements such as temporary works, construction sequencing and the stability of the structure in the temporary and permanent conditions. Time constraints seemed to be a problem for many candidates with the attempts at this part of the question being often brief and sketchy. Very few candidates used drawings or sketches to indicate constructional sequencing and possible temporary works.

Question 2, Hospital Extension

This question required a 3-storey extension of a hospital building above an existing physiotherapy gym which was to be kept in operation throughout the construction. The question provided a comprehensive test of a candidate's abilities and offered opportunities for innovative design.

Most candidates proposed two distinct solutions, typically with a transfer structure at Level 2 or a transfer truss with hangers at roof level. Few suggested different stability options between the schemes. Those proposing a transfer beam at Level 2 typically had columns supporting the floors above, spanning the 17m between columns / beams along Gridline 1, a transverse beam along Gridline 3 between the lift / staircase cores and a 5m side span to Gridline 4 with a bridge over the drain. An alternative for some was for 19m span transfer beams with a 3m cantilever over the drain. The spacing of transfer beams varied between about 2m to 6m with various forms of in-situ or composite decks. Of those candidates who proposed transfer structures at Level 2, only a few checked if there was space to fit in the formwork for concrete options, or provide a crash-deck over the top of the gym. Alternative schemes had roof trusses with hangers supporting the floors below, some spanning the full 22m or 19m between the cores. A number of candidates provided transverse roof trusses between the cores to support the trusses. Both reinforced concrete and steel frames were proposed, with stability provided by vertical bracing, portal frame action and /or the lift / stair cores.

The requirement for no columns on grid A/2-3 caused problems for some candidates. While most observed the requirement for "no structure permitted along gridline A/2-3", a minority overlooked that requirement. Some placed new columns along Gridline 3, which would have disrupted the gym operation.

Most candidates demonstrated a fair understanding of ground bearing capacity. Some managed to design ground-bearing foundations on the Firm Clay and at sufficient distance to avoid the existing foundations, but most opted for piled foundations down to rock for both schemes. Too many candidates ignored the need to underpin the existing gymnasium foundations when it was necessary with their chosen scheme, and others proposed sheet piling alongside the existing foundations. The size of piles varied from mini-piles to very large diameter piles, the latter designed mostly with an apparent lack of appreciation of the disturbance installation would cause at this site and the effect on existing strip footings; this was evident in some of the method statements.

Preliminary sizing calculations were included in a number of scripts, some were broad-brush whilst others were too detailed, the latter consequently reducing time for the completion of the other sections of the paper. Some candidates produced detailed drawings of the two options whereas a simple hand-sketch would have been sufficient. Some candidates omitted structural behaviour diagrams: these help the examiners to understand the design logic, and demonstrate a candidate's structural understanding of the proposed scheme.

Scheme comparisons were generally sufficiently well completed, with the majority in tabular form. Scheme selection was often based on individual local practice and experience, rather than selecting the more appropriate structural scheme for the building.

Most letters were somewhat hurried with insufficient relevant points made. Good letters explained the pros and cons of off-site fabrication. Larger offsite elements were described in detail, considering transport, crane sizes, health and safety and logistics, reduced site time and material wastage. The pre-casting of concrete was also addressed, needing advanced procurement and better planning compared to insitu concrete, but with higher quality, less waste, improved health & safety, sustainability, reduced carbon footprint, etc. Very few candidates suggested modular systems where integrated 'boxes' are prepared off-site and assembled / lifted into position similar to precast elements. The few candidates who did propose such modular solutions mentioned the much shorter time on site, but with consideration of design changes, pre-planning and the associated multi-disciplinary integration and procurement lead times and the lack of flexibility for late changes.

Most candidates made good use of tables and were adept at standard design calculations and supporting diagrams. A number made broad assumptions as to loadings and then proceeded with standard beam and column calculations. Only a small proportion of candidates managed to prepare sufficient calculations for all the principal structural members.

Most candidates produced a neat set of drawings though few managed to provide all the information that was required. Some drawings required deduction of what was not shown particularly with combined plans and elevations. Very few candidates produced a section through the building in both planes; but in these cases, the sections assisted greatly in the interpretation of the design.

Many details provided were not considered critical or even sufficient for estimating purposes. Critical details need to be project-specific, such as the interface with the existing foundations, the junction with the main building to all floors, a key connection between a roof or transfer beam with interconnecting members, etc.

The method statement needed to include, for example, protection to the gym (roof and enclosure) so that it remained operational throughout, condition and geometrical surveys of the gym and main building and monitoring pre, during and post construction for any adverse effect and appropriate remedial action. Also required were the sequenced key elements of the proposed scheme, such as installation of the transfer beams or roof trusses and associated temporary and permanent bracings, and health and safety measures for the critical elements. Construction sequences were generally very vague when it came to the difficulty of building over the top of the gym. Many scripts appeared to have been rushed and produced generic method statements only without addressing site-specific aspects. The better scripts were site-specific to their chosen scheme. Bar chart programmes with key activities and associated durations were also generally rushed but a few were sufficiently detailed. Overall construction programme varied from several months to over a year; six months to a year would be a credible duration.

Question 3, Light Railway Bridge

The question was inspired by an existing structure built to carry a light railway together with the station platforms at either side. The question was aimed particularly at structural engineers who deal with bridges in practice, both design and construction. Construction (especially its erection, and managing stakeholders) of such a massive structure over a waterway is a real challenge which was expected to be reflected in the solutions proposed by candidates but very few showed their ability to meet it. The question, both in the text and in Figure 3, contained extensive information as to the client's requirements, which many candidates failed to consider and make use of appropriately.

Various solutions were possible; however, the large truss solution enclosing the entire track and stations was the simplest and most appropriate solution. Many candidates proposed this, but some did not realise the necessity of bracing for compression chords. The question allowed candidates to propose three independent structures as a distinct and viable option but no-one did. Some candidates failed to note that the approach viaducts at either end were to be built by others, hence a 60m single-span bridge supported on these approach viaducts was not a viable option. Most candidates, who proposed 60m-span structures, did not suggest a shared substructure and foundation for the approach viaducts at either end. Many proposed end abutments instead of piers. Some candidates suggested as distinct options steel (plate girders) and concrete (slab) composite bridge superstructure although these were somewhat artificial.

In part 1b) raising the water level in the canal reduced the available depth for superstructure construction. Few candidates managed to calculate the dimensional effect correctly, and even fewer were able to appreciate the consequences. Surprisingly most candidates' proposed alternative solutions were unsatisfactory; rather, they were more interested in demanding extra fees from the client, which was really disappointing.

Few candidates provided sufficient calculations for the substructure, and for the transverse members which were also one of the principal structural elements. Many spent too much time designing slabs.

The quality of the drawings varied but none of the candidates offered details on 'expansion joints for railways' and other critical details such as openings in the deck for the escalators. Most of the candidates' drawings contained insufficient information for pricing.

An important aspect of this question was the construction. Most candidates proposed a project duration of less than a year, which was unrealistic. Many candidates lost marks in this section by ignoring the H&S aspects, especially involved in working over water. No candidates noted provision for liaison with the builder of the approach viaducts.

Question 4, Climbing Wall

The question required the design of a free-standing climbing wall structure, with vertical structure limited to the perimeter wall construction. Candidates were not expected to address the specialist cladding aspects. As expected for such a structure, the geometry was unusual but not overly challenging. There were elements of cantilever and transfer structures, but not significantly difficult to find solutions for.

The structure could be tacked in numerous ways, and the expected common solutions were insitu RC walls for the perimeter with RC slabs, steel beams with precast planks, lightweight steel framing, precast concrete or possibly timber or glulam beams. The substructure was expected to be piled or a raft foundation. The core could be used to provide lateral stability. There were plenty of opportunities for stability structures to be set within the walls, but there was a large opening on one façade and candidates were expected to allow for access to the core.

In Part 1a) many candidates struggled with the geometry and were unable to provide two sensible schemes. Many candidates also struggled to clearly convey their strategy for lateral stability, which is of great concern as this is a fundamental issue to address. As many candidates also seemed to spend too much time on Part 1a), this would suggest that candidates had not fully considered the question before choosing it.

In Part 1b), the client asked for a letter explaining how the design could be amended to allow the structure to be dismantled and moved at a later date. This was intended to allow candidates to demonstrate knowledge of building techniques by coming up with ideas that were lighter, fixed together in elements, and transportable. Whilst those choosing steel-framed solutions might have thought that they could tackle this easily, they still needed to show understanding of how the frame could be dismantled safely.

In Part 2c), calculations were expected for the following key items: an element each of vertical and inclined structure, any transfer structure, a typical floor slab/beam, lateral stability provisions, foundations, and bridge walkway link. Too many candidates listed the calculations they intended to do and then failed to do them, presumably due to time constraints.

In Part 2d), candidates failed to consider what drawings were required to describe the structure. As a bare minimum, the candidates should look at how many drawings are required in the examination paper to describe the question. When candidates produce less than this, it causes concern. Critical details could include transfer structure details and connections, bridge connections, balcony connections, and inclined structure details.

Part 2e was not covered well by most candidates, again presumably due to time constraints. The primary issue that candidates should have been addressing was the temporary stability during construction.

Question 5, Residential property in woodland setting

This question required a relatively-small domestic-style building, constrained by planning, location, foundation, aesthetics, and durability requirements.

The solution demanded a piled foundation, but piles could be bored, augured or driven. Whichever was used, they had to resist lateral loads, as the piles were the only way to stabilise the superstructure.

For stability of the superstructure which "floated" above the ground, a means was required of transferring the lateral loads to the piles. This could be columns between the piles with the underside of the ground floor being rigidly attached to the top of the piles, or bored/driven piles continued up to the underside of the ground floor. Here, aesthetics and durability were an important consideration on the choice of materials.

The ground floor could be one of the following constructions:

1. Beam and block floor – needs a supporting beam over the columns/piles.
2. Metal decking – requires steelwork and has visual and durability implications.
3. Precast concrete slabs – requires a crane and probably edge beams.
4. In-situ concrete slab – requires soil compaction/preparation.
5. Timber floor –requires consideration for fixings into column/piles, and has durability implications.

The front elevation was completely glazed and so a rigid frame was needed. The first floor could simply be a timber floor on to masonry or timber stud walls.

The roof should either have had a ridge beam, or be tied with a rod system or with timber collars. The ridge beam could be glulam, a flitch beam or steel. Any ties would be exposed so should be aesthetically pleasing.

The letter offered the candidates the opportunity to significantly simplify the foundations. Shallow foundations would become feasible and probably the most cost effective option. A good method of dealing with the small area of protected roots could be achieved by using one of these methods: a single pile, a small pad, a ground beam, or cantilevers over the protected area. In all cases ground must be carefully excavated to expose tree roots in the protected area.

While candidates generally recognised the problems meeting the foundation requirements, they appeared to be less familiar with domestic structures of this type and of possible ways to ensure the stability of the structure through the piles. Few candidates used braced support steel frames up to level 1 and some relied on the piles cantilevering up to level 1, but generally the solutions did not provide a robust and at the same time aesthetically-pleasing approach.

Proposals for the superstructure included CLT panels, timber framing, and masonry supported on a steel frame or RC ground floor. Floors generally were of timber, though a few RC ground floors were utilised as well. A number of candidates used steel structural frames, some quite heavy, which did not seem the best approach for this type of dwelling, certainly not on cost grounds. Many candidates failed to provide load transfer diagrams as requested.

The particular issue of supporting the perimeter cantilever balcony was generally recognised, although many candidates did not appreciate that the corner of the balcony required some consideration because the cantilever was quite long.

Supporting the roof structure was well handled by some, but lack of experience with such structures was noticeable with a few.

The letter was generally satisfactory and most candidates changed their solution from piles to strip foundations with a cantilevered corner. However, few economic solutions were proposed. Some decided that the relaxation in the planning requirements was going to make the foundations more expensive.

Calculations were generally not inspiring. Many covered most of the structure, but none covered all the elements sufficiently. Wind loads were often poorly realised, and there was little effort to show how notional horizontal forces would be computed or resisted.

As is often the case, the drawing work was affected by the time left, and suffered as a result with a number of key details missing or not attempted.

The method statements were generally poor, often being a list of operations without explaining how the operation would be undertaken. The sloping site and elevated building gave candidates plenty of opportunity to discuss construction methods, but few were able to demonstrate this.

Associate-Membership Examination July 2016: Chief Examiner Reports

Nineteen candidates sat the 2016 Associate Membership (AM) examination on Friday 8 July. This is a slightly less than last year - 25 in 2015. Twelve candidates passed the examination, a pass rate of 63%. This is similar to last year, when the pass rate was 60%. The AM pass rate remains consistently higher than that for the Chartered Membership examination.

In the AM examination, candidates were asked to answer one of four questions. Only two of the four questions were attempted (Question 1 and Question 2), so the feedback relates to candidates' performance in these two questions only.

QUESTION 1

This question called for the design of a showroom and office development. This is in line with the principle that Question 1 in the AM examination is a typical commercial or residential building comprising a routine frame structure that can be designed to be constructed in either concrete or steel.

Generally those candidates above the 'pass' mark did well. Most designs were in structural steelwork, but a few designs were in reinforced concrete. Candidates recognised the significance of the ground conditions and correctly opted for piled foundations, linking pile caps with ground beams supporting a suspended ground slab. Most chose bored piles, noting that this would minimise vibration affects to the existing buildings beside the site boundary. There were variations in the proposed perimeter column grid from 6 to 9 metre spacing with only one instance of the optimum spacing of 6.5 metres. Some candidates then did not check for the minimum 4.5 metre spacing required for the internal columns particularly near the stairs shafts.

Section 1a
Low marks were scored where the design appraisal lacked appropriate sketches; functional framing was not clearly shown or not understood; or insufficient consideration given to the stability aspects of the design. Most of the candidates gave good reasons for their chosen solution.

Section 1b
In some cases there were good explanations of the effects the client's proposed design change. Other solutions were unrealistic - particularly the 'transfer beams' needed at Level 2, resulting in excessive beam spans or the necessity to increase the overall building height.

Section 2c
Generally the design calculations were poor and sketchy, with some key elements omitted from the design calculations. This could have been due to poor time management by candidates.

Section 2d
General arrangement plans, sections and elevations were either well drawn, so easy to use for estimating purposes, or very poor, lacking detail and missing important dimensions. Similarly, the two details (i) and (ii) were either well done or very poor. The misunderstanding of the 2 metre set-back at Level 2 appeared to have been a contributory factor to low marks given for detail (i).

Section 2e
Again, method statements were was either clearly set out, including particular mention of a 'condition' survey 'before' and 'after' of the existing buildings on the site boundary, or just a list of site activities was given. In at least one instance this section was not attempted, probably due to lack of time. As feedback, candidates are reminded that marks can be gained quickly by ensuring that this final section is given appropriate attention.

QUESTION 2

This question called for the design of a distribution warehouse. This is in line with the principle that Question 2 in the AM examination is a typical larger span building of portal or similar construction eg industrial building, leisure centre, swimming pool that could be constructed in either concrete or steel.

Section 1a
Most candidates produced viable scheme with reasonably clear sketches. However some presentations were brief with neat sketches, although some had no sketches. In general candidates focused on the main frames, vertical bracing and horizontal bracing for the roof. Some candidates either did not show in cross-section or mention the importance of the haunch and the apex connections of the main frames. Some candidates provided no discussions on the ground floor construction, removal of top soil and vegetation, presence of groundwater, types of piles and presence of the stream.

Section 1b
In Section 1b most candidates were able to propose and discuss possible options to use the stream to generate electricity and the implications on the foundations, ground beams, etc.

Section 2c
Most candidates produced calculations to cover the essential elements eg the main roof frames, including wind loads, vertical and horizontal bracing, ground beams, culvert, etc. However most also did not produce calculations for the suspended ground floor slabs.

Section 2d
Most candidates produced dimensioned layout plans of main frames and roof structural members including horizontal bracing on the roof plane. The bays for vertical bracing were usually marked on

the roof plan as well. However, the layout plans for the ground floor and foundations were mostly brief, sketchy or even omitted altogether. The culvert details were often shown as an isolated reinforced concrete box without showing the relationship with the adjacent ground floor, columns and foundations.

Section 2e

Most candidates attempted the method statement without great difficulties but the content and performance varied considerably, possibly reflecting the candidates' site experience. One candidate made no attempt at this section, probably due to poor time management. As mentioned above, marks can be gained quickly by ensuring that this final section is given appropriate attention.