Chartered Membership Exam July 2017 : 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.

Candidates should note that the January and July Chartered Membership examinations are of equal standing and are developed via the same rigorous process.

Results for July 2017

Question No.	Total	Pass	Pass %
1	149	28	18.79
2	151	69	45.70
3	22	5	22.73
4	35	9	25.71
5	89	37	41.57
	446	148	33.18

	Total candidates	Total passes	% Passes
UK	281	103	36.65%
International	165	45	27.27%

Question 1. Steel Fabrication Unit with Offices

The question required the design of an industrial building with offices. The unit was to have a gantry crane, column spacings were restricted, and a transfer structure was needed across the large doors.

Ground conditions were selected so that ground improvement techniques could be used successfully to achieve an economical solution.

Distinct and viable solutions included: portal frames for the factory and beam/column-type structures or portal frames with composite slabs for the office area, braced systems with trusses and simple columns or laced columns. The span direction of the roof could be changed to achieve a variety of different layouts. Many failures can be attributed to contravening the client brief for perimeter column spacing or ignoring the crane. Many candidates made no, or hardly any, reference to the fact that a crane was required. Proposals to suspend the crane from the bottom boom of the roof trusses were not workable. Some candidates struggled to appreciate the ground conditions, failing to recognise the implications of the loose gravel and heavy industrial floor loading which would prohibit the use of a ground-bearing slab without ground improvement.

Part 1(b) required the candidate to think of ways to improve the existing structure to accommodate the increase in crane load. Methods included adding new columns in front of the existing and underpinning the existing foundation, inserting a new line of columns in between the existing with new foundations, or providing a central line of columns to break the span of the crane in half to compensate for the increase in capacity. Most candidates readily recognised the effect of the increased crane load on the existing structure but some unfortunately failed to provide any meaningful solution.

In part 2(c) crane data was provided so that the load from the crane on to the crane girder could be calculated, and then imposed on to the main structure. Calculations would also be required for the bracing, floor beam, column, portal frame or truss, lattice column, foundation and ground floor slab. Few candidates designed the crane beam or added the resulting load onto the main frame and many missed the important stability check.

In part 2(d) a foundation plan, floor plan and roof plan were expected, with a general section showing the crane configuration as well as an elevation showing any bracing. Critical details were likely to include a transfer structure across a large door and the restraint to the crane girder at the support. Some candidates seemed to be confused over what was required to be produced even though the requirements are clearly stated in the question.

In part 2(e) candidates were expected to appreciate the importance of bracing and the erection sequence for this type of building. No construction programme was required, but many candidates nevertheless produced one instead of concentrating on providing viable method statements.

Question 2. Airport Control Tower

The tower could be divided into three distinct structural elements: the elevated control room, the access and supporting shaft, and the foundations. The client required the tower to be aesthetically pleasing in design.
The brief was straightforward and offered various options for the structural framing which meant it was not difficult to offer two distinct and viable schemes using either steel or concrete as the main structural material, or a combination of both. Many candidates however lacked the ability to come up with solutions that were structurally economical and met the brief, with aesthetics usually being totally ignored. Often the solutions proposed were a variation on a single material, usually concrete, and where the two solutions were in concrete and steel, the solution in one of the materials, often steel, lacked structural framing and details.

The elevated control room could be considered as cantilevering off the central access shaft. The control room was circular. The roof element had a minimum projection of 5.5m from the outside of the shaft, and the floor 4.5m. Permutations for the roof and floor included a) cantilever roof and cantilever floor, b) cantilever roof and hung floor, c) cantilever floor and propped roof. Many candidates chose option (a) but produced proposals which were uneconomically large and had little variation in the structural framing for the two optional schemes. Generic statements and descriptions for the functional framing and load transfer were given that often had no relevance to the schemes being proposed. Candidates should note that irrelevant descriptions will be marked down, aside from using valuable time to produce.

Most candidates proposed a concrete circular or square support shaft with little or no consideration being given to the lift shaft and access staircase required within. Although the question stated that the detail design of these element could be omitted their setting-out within the shaft could not be ignored. The options put forward for the wall thickness for the shaft varied from 200mm to approximately 1.0m, the latter preventing access to the control room as the lift and staircase could not be accommodated. Where steel options were put forward they were generally well-presented, but some had incomplete bracing to take the imposed loads to the foundations

The choice of foundations was either a concrete pad/raft bearing on to the sand and gravel strata, or a piled foundation with the piles founding in the sandstone strata, both solutions being acceptable. The detail designs however in many instances lacked vital content as outlined below in Part 2(c).

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

Part 2(c) required the candidate to prepare sufficient calculations to establish the form and size of all principal structural elements. This is therefore where calculations relevant to the chosen scheme should appear, not in Part 1(a). Most candidates provided calculations for the simple structural elements, beams, slabs, and possibly a simple end-bearing pile calculation where appropriate. Calculations were generally undertaken efficiently, but were not always complete as important calculations were sometimes ignored. Design of the cantilever structural elements was often attempted but little or no consideration was given to the support required at the root of the cantilever: the compression on the access shaft or the tie back of the tension forces. The overall stability of the shaft in terms of wind load and in particular the partial imposed live load from one half of the control room roof and floor was often ignored. The same applied to the foundations where vertical loads were considered but in many cases the applied moment from the shaft structure was ignored resulting in inadequate component sizes. Marks were generally lost because calculations were incomplete or absent, rather than because of errors or lack of design knowledge of simple elements.

Drawings in Part 2(d) were often inconsistent and incomplete, lacking all the required plans, sections, and critical details, and therefore did not cover all the elements necessary for estimating purposes. Candidates sometimes used the symmetry of the building to reduce the quantity of plan drawings required, and where this was done plans were reasonably well attempted but often lacked vital information. Simple reinforcement details do not constitute critical details, and candidates often ignored the critical connections between the control room roof and floor to the shaft. A competent engineer must be able to demonstrate and clearly indicate their design ideas, but unfortunately many candidates revealed their lack of ability to communicate their proposals through basic drawings and sketches.

In part 2(e) the method statement and programme elements were reasonably well attempted but often ignored factors 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 attempts at this part of the question being often brief and sketchy. In many cases generic statements were used that were not relevant to the scheme. Very few candidates provided drawings or sketches to indicate constructional sequencing and possible temporary works.

Question 3. Railway Viaduct

The brief called for the design of a railway viaduct spanning over an existing road and an operational railway, at a 30-degrees skew angle. The overall length between abutments had to be calculated by the candidates based on the information provided.

Horizontal and vertical clearances requirements were given allowing candidates to set out the pier locations and hence the options for span arrangements. Clearances were respected, but very few candidates used the constraints as a mean of defining an economical span arrangement. Several candidates used needlessly-long spans to avoid the road-rail interface but ignored the implications on member sizes and construction.

The deck cross section was defined as two tracks with robust kerbs and maintenance walkways on each side. A structural height restriction was specified, and was understood by most candidates. In section 1a, many candidates proposed steel-concrete composite decks and half-through decks. Some proposed decks with span-to-depth ratios which were not suitable for railway bridges, and these lost marks. Examples of acceptable proposals include: a nine-span viaduct with a steel-concrete composite deck made of braced pairs of plate girders; a seven-span viaduct with steel-concrete composite deck made of steel box girder, an eight-span viaduct with prestressed concrete box girder; and a four-span viaduct with half-through truss.

The design of the abutments was excluded from the brief. Nevertheless, no longitudinal forces could be transferred into the end supports, which had to be skewed and set at a specified level. This was well understood by the candidates who mostly avoided longitudinal fixity at the abutments. Solutions that considered the use of shock transmission bearings at several piers to distribute the large longitudinal forces gained additional marks. Configurations using pinned supports at two piers to share the braking and traction loads were also welcomed as long as consideration was also given to the forces from thermal expansion and contraction which would also be restrained.

Ground conditions and the magnitude of the loads indicated the use of piles reaching rock level for the foundations at the longitudinally-fixed pier locations. Spread footings within the dense gravel above water table were considered acceptable for the other supports but taking into account possible differential settlements.

In section 1(b), candidates were asked to assess the effect of increasing clearance to the railway track. Only few candidates demonstrated how to accommodate the changes into their design. When excessive spans had been selected within the previous section, candidates had missed an opportunity to complete the letter appropriately. The letter was expected to cover: an increased span above the railway, necessary revisions to the deck design and structural depth, a revised check for deflection, increased pier loads and redesign requirement, increased bearing loads, additional loading on foundations, potential impact on the construction method, the need for revised general arrangement and detail drawings, delay to the programme due to the redesign, the need for revised approvals, and cost implications.

The calculation of loads and load transfer in section 2(c) was generally well attempted. Longitudinal and transverse loads from the deck were transferred to the pier bases correctly by most candidates. However, the critical stress levels in the key elements were not covered sufficiently. The design of the foundations was also neglected by a few candidates. Although detailed calculations covering the deck deflections and end rotations under traffic actions were not expected, a simple mention of them would have gained an additional mark since these are critical design criteria for railway bridges.

Drawings were generally well attempted but candidates who failed to provide sufficient clarity in plans, elevations and cross-sections were marked down. Drawings with insufficient notes were also marked down.

The quality of method statements varied considerably. Most candidates only referred to generic Health and Safety aspects without addressing the site-specific issues set out in the brief such as problems of working adjacent to live traffic and an operational railway, as well as the key construction activities and the temporary works requirements. A few candidates mentioned track monitoring, which attracted bonus points. The quality of construction programmes varied substantially. It was expected that candidates would identify the need for track closures within their construction programme.

Question 4. Supermarket Deck.

Candidates were asked to provide a large suspended deck to carry a new supermarket above a former railway yard. The slopes on the two sides of the former railway yard were unstable and the northern slope needed to be realigned to accommodate the new building. The southern slope was some 13.5 m high. Clearly, no excavation or vibratory construction could be undertaken safely below either of these slopes until they had been stabilised. This work would need to be undertaken before the site could be developed.

Because of the intention to park heavy goods vehicles under the new deck and the 13.5m floor-to-floor high columns, the column grid needed to be chosen carefully, having in mind the appropriate turning areas and clearances, the proposed supermarket grid of 6.0m x 6.0m, and the culvert under the former railway yard. Two distinct arrangements should have been considered. Just using different materials such as steel or concrete would not be acceptable, since one grillage of beams is very like another. However, if one grillage were to span the length of the building and the other transversely across the building, and different materials were used; there is a good chance that the behaviour of each option would be sufficiently distinct. Further differences may be engineered if continuity could be employed to reduce deflections. If composite construction or the use of precast concrete flooring could be used the differences are multiplied.

The footprint was to be large, 104.0 x 86.0m, and many textbooks advise that this needs a movement joint or joints. Can it be designed without any? In order to provide two options the candidate could decide to have a joint in one option and not in the other. Any arguments would need to be supported by considering the effects on the superstructure, the provision of stabilisation of one or two blocks and an explanation of how the movement could be accommodated or resisted if the joint were not included. Prevention of fire burning through from the parking zone into the supermarket above must also be considered. The deck slab could be a continuous slab spanning in one direction, either transversely or longitudinally, with a movement joint or joints dividing the area. The slab would span between continuous beams, themselves either spanning longitudinally or transversely. If the main beams spanned transversely then the movement joint could be accommodated between a pair of these beams. If the main beams spanned longitudinally then the movement joint would have to cross them.

Foundations for the columns, retaining walls and even shear walls were required. Piling will cause vibrations, but instead ground strengthening or ground treatment could be provided by Pali Radice, (reference Thorburn and Littlejohn [Editors] "Underpinning and Retention; Chapter 4, 'Pali radice' structures"). These techniques can also be used in stabilising the sides of the former yard. With the voids filled the foundations under the columns can be cast as a mat or reinforced raft. If the raft is cast on the 136.5 level then there should be no need to excavate or cart excavated material to a tip. There is ample headroom under the supermarket deck, and the approach area to the east of the supermarket can be built up to allow entry to the lorry-parking basement.

The existing masonry bridge runs along one side of the site and this structure may need shoring and underpinning. Although the detail may be omitted the Candidate should acknowledge the facts. The interface between the new construction and the existing roadway and footpath would need some design attention because there is a difference in level between the new supermarket and the existing pavement beside the road.

Part 1(b) required openings at the four corners of the deck. The letter was expected to advise the Client in a positive way, including a sketch (or "enclosure", since it is a letter) describing how the openings could be made, and what the implications would be including the effect of a basement fire. The service routing would need to be enclosed in a similar way to a staircase, effectively forming cores at each corner. Issues of possible access between the basement to the sales floor via these cores, and their possible use to stabilise the building should be considered.

Very few of these matters were mentioned in the scripts. The result was that the proposed options were not 'complete' as they should be.

In section 2(c), the calculations required would include a column, its base design, the continuous slab and supporting beams and a check on stability. Stability may be provided by shear walls or a special structure that acts like a 'core'. A concrete structure could be engineered in such a way that stability was provided by 'frame action' through the rigid joints, but care and attention would be needed where the column bars were spliced to the beam bars at the top of the tall columns; perhaps couplings would solve the problem. The culvert under the building will need maintenance and should not be covered over completely. Perhaps a culvert corridor where vehicles were excluded completely would be an answer, with the main columns arranged beside the corridor using an 'A'-frame arrangement. This would be effective in the longitudinal direction but perhaps less so in the transverse direction. With the lateral wind forces taken care of, the perimeter would not need to provide support and could be unclad. Only the eastern facade would be fully loaded by wind forces, the other facades being sheltered below the supermarket deck level. An architectural feature might be the enclosing of the basement inside a brick diaphragm wall. The wall would support the deck edges and be post-tensioned. The wall would wrap around the parking areas with smooth curves at the corners, or even have a vertically-corrugated footprint: a wavy perimeter to assist the wall to be stable.

In section 2(d) it was expected that candidates would provide a plan of a typical bay of the deck and possibly the reinforcement in the deck, together with a couple of similar bays of the basement plan, one for the typical foundation raft under a column and the other for the strip foundations along the edge of the culvert. Critical details for the slope stabilization could be shown. A critical detail of the column connection at the supermarket level would be interesting and would explain the column splice.

The method statement would need to address the basic delivery and storage of the materials and possibly the taking-away of spoil from the excavations. The programme would need to highlight the stabilization at the start of the work on site and the ground strengthening, the protection of the culvert and the masonry bridge: the casting of the columns using 'tremmies' or 'trunking': and the pumping of the concrete into the deck and the finishing and possibly thermal curing of the deck.

Question 5. Protection for Ancient Building

This question required candidates to design solutions to protect a small fragile ancient building with a 2m clearance zone required around it; however, matters were complicated as an area above adjacent underground caverns overlapped the clearance zone. The protective envelope was required to maintain the building's visibility, indicating large areas of glazing would be needed to all sides.

Most candidates departed from the brief which required only the building to be protected, opting instead to include the no-foundation zone within the structure. This simplified the question significantly and those choosing this route had to demonstrate why the increase in size of structure would result in a better solution.

As the ancient building was fragile, it was expected that proposals for temporary works and construction methods would be detailed to show how damage to the building would be avoided. However, very few candidates provided adequate evidence to demonstrate that their solutions considered construction and temporary works such as craneage, transport of long-span trusses or providing working areas away from the caverns.

Whilst most candidates avoided foundations in the zone of the caverns and supported the adjacent façade by hanging glazing from the roof, very few candidates addressed how the glazing would be supported laterally at ground level.

Most schemes proposed were industrial-looking frames comprising UC columns and UC trusses which were in stark contrast and overly industrial for the proposed structure they were enclosing. Most candidates did, however, use wire or tension rods as bracing to facilitate unobstructed views of the buildings. A few candidates proposed insitu concrete frames, which were impractical to build over the ancient building, and no consideration was given to the installation or removal of formwork for these solutions.

Foundations were reasonably straightforward with pad foundations the most appropriate solution. However, many candidates sized a foundation based solely on the applied load and decided that a 400mm square pad foundation was suitable, not realising that this was totally impractical to construct. Some candidates also failed to recognise the need to resist uplift forces in braced bays.

Most candidates made a reasonable attempt at providing calculations and covered the key elements. Most provided some form of introduction to their calculations, but a number failed to explain how loads were built up or to provide a list of design codes used. Few candidates clearly stated what they were designing, opting to describe, for example a 'floor beam' or 'truss' without identifying it or linking it to a grid line or direction. Few provided a section at the conclusion of their calculations to illustrate, say, the reinforcement in a concrete beam or column, which would be considered good practice.

The quality of method statements varied, with a number of candidates opting to provide a generic statement that could be applied to any building. There was also a tendency to focus on site set-up activities instead of the actual construction sequence. This question required consideration of issues such as the positioning of cranes in relation to the building and caverns, protection of the building, limiting vibration during foundation excavation, and temporary stability during erection of the frame, and was on the whole poorly attempted.

Associate Membership Examination July 2017

Results for July 2017

Question No.	Total	Pass	Pass %
1	2	1	50%
2	2	2	100%
3	0	0	0
4	3	3	100%
	7	6	86%

	Total candidates	Total passes	% Passes
UK	6	6	100%
International	1	0	0

The following provides candidate feedback on the examination. Of the four questions only three were attempted. Question 3, the Bridge Question, was not attempted by any candidates.

Question 1. New Hotel

The building consisted of a 6-storey development, the upper 4 floors, Levels 3 to 6, being bedrooms where the candidates had to set out the client's requirement of 20 bedrooms per floor located along a 3.0m central corridor where only one row of columns was permitted. Level 2 was an area of conference and meeting rooms that were required to be column-free, and Level 1 was the reception area containing restaurants and lounges etc. where only one row of columns was permitted at specified centres. Level 1 also projected out beyond the face of the building.

The candidates that attempted this question managed to achieve the required setting out of the bedrooms with ten either side of the centrally-placed core area. However, where the core was not placed on the building centreline this produced torsion in the structure. The overall scheme was better presented as a structural steel option with composite or precast concrete floors, and with the appropriate transition beams at Level 3 and Level 2. The transitions at these floors were generally recognised and most candidates ensured columns were not placed in the column-free area. Where concrete schemes were proposed they were heavy and uneconomical.

The client change requirement of an additional level of bedrooms was reasonably covered with the increased loading on foundations, vertical structure and stability etc. considered.

The calculations were reasonably well executed with the candidates recognising the principal structural elements, but the roof structure tended to be ignored along with in some instances the foundations and ground slab. Simple pad foundations should not have presented a problem to the candidates.

The general arrangement plans, sections and details were of a good standard and the specific details well presented. The method statements were generally brief but contained most of the key operations

The candidates who attempted this question produced schemes of a reasonable quality but some of the client's requirements were ignored.

Question 2. Boatyard Maintenance Shed

The maintenance shed was adjacent to a slipway and was a rectangular building with a clear span of 24.0m and a travelling crane running along the length of the building. A mezzanine floor was required at one end for office purposes. High wind loading had to be accommodated.

The structural schemes for the shed were presented as steel options utilising either portal frames or trussed rafters and columns with stability being provided by diagonal bracing in the long direction. The large door opening proved a problem for some candidates in terms of frame stability and the internal wind pressure due to the dominant opening.

The high water table was not always recognised, but in general the high superimposed ground floor loading led the candidates to adopt a suspended ground slab with pad foundations bearing onto the rock strata.

The client change requirement was reasonably well answered by most candidates who recognised the need to bund the building against the increased water level. The calculations were reasonably well presented with the candidates recognising the principal structural elements. The quality of the general arrangement plans, sections and details was good demonstrating the experience of the candidates. Again the method statements were brief but contained most of the critical operations required for the construction.

Question 4. Theatre Building

This was a simple rectangular building consisting of an auditorium with a stage and a cantilever balcony at one end, plus a separate open-plan concourse area.

The structural schemes chosen by candidates were steel frames spanning the 15.0m clear internal theatre width either using portal frames, or trussed rafters with columns in the external cladding. Stability was provided by bracing to the roof and within the external side and end walls. The cantilever balcony was generally supported by a clear span truss/ lattice beam spanning across the width of the building supporting secondary steel beams with precast concrete floors. The ground conditions comprised loose fill with a depth of 2.5m above stiff clay which meant that a suspended ground slab solution was required – this was recommended by most candidates. The foundations were either deep reinforced pads, or a piled solution which was the most popular option.

The client change requiring the balcony to be raked generated several solutions, some providing an additional raking beam above the main horizontal beams, whilst others raked the whole of the floor on to the main truss /lattice beam.

Most candidates recognised the principal structural elements and provided competent calculations. The general arrangement plans, sections and details were very well presented and provided sufficient information for estimating purposes. Once again the method statements were brief but contained sufficient information to demonstrate knowledge of the construction process required.

General Comments

Candidates should allow sufficient time to read the question thoroughly to ensure that all the client's requirements are noted, particularly relating to column-free areas and minimum head heights etc. which are often forgotten when developing the structural scheme.

Although generally the calculations were well presented, assumptions and references should be noted along with any additional checks that may be required. Method statements tend to suffer from time constraints but candidates must remember that the method statement is an important part of the overall question. The statement needs to include sufficiently detailed information about items such as erection sequence, use of cranes, temporary works and in particular temporary stability.