Examiners' Report January 2018 – Chartered Membership examination

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 January 2018

Question No.	**Total**	**Pass**	**Pass %**
1	48	12	25.00
2	406	112	27.59
3	26	11	42.31
4	28	8	28.57
5	15	6	40.00
Total	523	149	28.49
	Candidates	**Total passes**	**Pass %**
UK	279	100	35.84
International	244	49	20.08

Q1: Covered Market

The question called for the design of a single-storey building to enclose a market.

There were several possible options for both the geometry and the structural form within the imposed constraints of plan dimensions, roof pitch and column spacing. Most candidates chose steelwork solutions using roof trusses as part of a braced system, portal frames, or a combination of the two. More imaginative proposals included cable-stayed or umbrella-type structures. Foundation proposals were generally either spread foundations on the medium dense sand or piled; the latter often resulting in an uneconomic solution. Few candidates were able to produce two solutions which were distinct, and some seemed to find it difficult to clearly convey their proposals using either suitably descriptive text or adequately annotated sketches.

Most candidates recognized that the length of the building and the temperature range that it was exposed to necessitated consideration of thermal effects. The majority proposed at least one expansion joint; however, many failed to demonstrate how this could be effectively incorporated into their schemes, and in many cases, solutions infringed the minimum column spacing.

Many of the solutions put forward, whilst they were structurally stable, were neither practical nor economically viable; for example, many chose to adopt a duo-pitch roof which, due to the long span and specified roof slope, resulted in an exceptionally deep roof structure. Several candidates placed additional columns and bracing members in the perimeter walls which contravened the minimum column spacing requirement. In some cases, the bracing passed through the external openings.

The scheme appraisal was typically poorly attempted with many candidates simply listing the strengths of one system against the weaknesses of the other, suggesting that one of their schemes was not viable.

The letter was generally well attempted with most candidates understanding the structural design implications. Those who also considered practical issues such as how access could be provided, and the implications of the roof slope gained additional marks.

There was a tendency for candidates to provide calculations for simple non-critical members at the expense of principal members, and stability checks were not often attempted. Some candidates produced good drawings showing clear layouts, main member sizes, bracing elements, sections and critical details; however, others were sketchy and did not include adequate information for estimation purposes. Many failed to include sketches for critical details.

The method statement and construction programme were generally good. Candidates showing an understanding of safe erection and temporary stability gained high marks.

Q2: Science Park Development

A multi-storey building was required, with a large cantilever above the main entrance and with a large internal glazed atrium. The external façade was to be fully-glazed and no columns were permitted internally except around the four service cores and the atrium.

The key challenges were: providing support for the large cantilever, positioning the columns, ensuring the required floor-floor clear heights were achieved, and ensuring lateral stability. Most candidates derived the correct structural depth, but many later ignored this when designing the cantilever supports beams.

The glazing requirements meant that only limited deflections of the support structure could be tolerated and a deflection check, particularly for the cantilever, was necessary.

The preferred options to support the cantilever were diagonal tension members at each level anchored back to the service core or hangers from a deep roof truss incorporated within the 2m-high plant screen. With options such as cantilever beams at each floor or a transfer beam at one floor it was difficult to achieve the low deflection limits within the available structural depth. In all cases the stability of the adjoining core supporting the cantilever was crucial.

The column arrangement needed to respect column-free requirements while giving an economical grid of columns and beams. The preferred option used a 7.5m grid along the longitudinal direction and a 15m grid across the building.

The lateral stability of the structure needed to allow for the atrium and service cores plan openings. Bracings and shear walls were only permitted around the service cores. Shear walls were not allowed around the atrium or cantilever, but feature bracings were allowed. Large floor openings did not significantly impair the floor diaphragm action, provided the bracing system was distributed evenly over the plan of the structure.

The high ground water level affected settlement of shallow foundations, and this needed to be considered.

The letter aimed to test candidates' awareness of the effects of underground water on the basement, the adverse effect on foundation sizes particularly for bracings, the need for an access ramp, and knowledge of practical ways of accommodating these.

Section 1a

The solutions offered included steel braced frames, steel moment frames, and concrete frames with shear walls. Floors were usually concrete composite floors, in situ one- or two-way slabs, or precast slabs. A few candidates made use of CLT construction to minimise the dead load and thereby the beam sizes. A few candidates ignored the cantilever to simplify the question. In selecting two distinct and viable options, a simple change in material was not sufficient to make the solutions distinct.

Many candidates used a large RC transfer beam at level 1 to support the cantilever. This beam was over 1m deep and up to 2m wide, reinforced with up to 5 layers of heavy rebar, clearly an uneconomical and sometimes impractical solution which also infringed the structural depth requirement. Some candidates proposed an intermediate cantilever beam in an attempt to reduce the beam size, but this breached the service core free space and it was not clear how the large bending moment in this beam was transferred to the RC walls. Good candidates checked the adequacy of the supporting service core for uplift, eccentric bearing pressure and cantilever deflections.

The atrium roof was often supported by beams or trusses at 5 or 7.5m spacings spanning the shorter 15m transversely. Some candidates chose to span the 30m longitudinally by combining the structure with the roof truss supporting the cantilever section. Some candidates proposed schemes that effectively made the floors unusable because of very deep transfer structures. A lack of experience in sizing structural elements was evident by a number of candidates proposing RC columns of up to 1.2mx1.2m cross section along with RC beams over 1m deep.

Most candidates proposed shallow foundations. Some candidates immediately opted for a pile foundation solution without consideration of the viability of shallow foundations. The suitability of the piling system proposed for water bearing granular ground was not discussed. Generally, pads or rafts were at 2m or 2.5m below ground level to stay above the water table level, or were piled. Pile sizes were generally around 400mm diameter though some candidates proposed very large diameters which could be difficult to justify for such a building. Good scripts recognised the reduction in bearing capacity below the water table. The implications of the organic topsoil layer on the ground floor slab design were often not recognised. Good candidates proposed the removal of the topsoil with granular fill supporting a ground bearing slab or suspended slabs spanning over the topsoil between strip foundations founded on the medium dense gravel. The Level 1 floor slab was generally either ground-bearing or suspended off pile caps or ground beams.

Most candidates correctly concluded that a movement joint in the building was not necessary.

Section 1b

Most candidates appreciated that if the basement soffit were below the water table the building would need to resist flotation, and there would be a need for earth and water retaining walls. A good solution was to provide the temporary perimeter sheet piling or secant piling, required for excavating below the water table, as part of the permanent solution by providing an inner facing and associated waterproofing.

The relationship between the superstructure columns and service cores and a car parking layout and access ramp was not covered well. A transfer slab and beams at Level 1 could be used if the superstructure columns and cores were to remain unchanged. An 8m column spacing would suit a triple 2.5m wide x 5m long parking bays with 6m wide aisles.

Section 2c
Most candidates designed most of the key elements, but some were evidently running out of time. Some spent too much time calculating wind loading in detail where a simplified approach would have been sufficient. Some spent too much time designing a simple beam or slab but omitted a detailed check for overall stability. Most solutions relied solely on the stairs and lift cores to act as the lateral stability elements despite their small sizes compared with the building size. When selecting a 'typical' element to design, candidates are recommended to choose an important one and follow the loads down to the foundations.

Section 2d
The standard of drawings produced was generally good for estimating purposes. Expected critical details would have included, for example, the cantilever section and diagonal tie or supporting roof truss and hanger detail, the atrium roof truss connection on the corbelled column support, an interface between a long-span beam and column, glazing support, etc. Critical details for concrete elements were generally not adequate. They tended to show only reinforcement details without any builders' work context. In many examples 3-5 layers of heavy reinforcement were indicated at the bottom of concrete beams without any workability considerations.

Section 2e
Most candidates struggled to produce a method statement specific to the scheme selected rather than generic. Key aspects should have included: checking the site soil capacity at foundation formation level; using piling mats if piling; taking appropriate measures when piling through ground water; providing slab protection and checking loading from cranes; temporary support to the cantilever; safe lifting of long-span trusses and provision of temporary lateral stability bracing. Programme timescales were mostly ambitious and of less than 12 months duration. A realistic construction period would be 15 – 18 months for a building of this type.

Q3: Canal Bridge over new Shipping Channel

The question was inspired by movable aqueducts, one being the Barton swing aqueduct built in 1893 - a classic example of excellent Structural engineering at the very end of 19th Century - and the other the Falkirk Wheel, an outstanding example of modern structural engineering. The concept of the first could be used to propose a simple solution for this question and the concept of the second could be mentioned to come up with another distinct and viable alternative.

In addition to the above two options, two more conventional solutions are possible using two separate single bascule bridges, or the use of hydraulic lifts to raise a central span within 30m tall guides at the ends. Most candidates proposed either a movable aqueduct in one form or other, or a fixed aqueduct set above the clearance envelope required in the question. Some candidates either tried to fit the question to match a preconceived solution or proposed a structure which might be acceptable for a fixed aqueduct but was inappropriate in moveable form. A swing aqueduct or pairs of bascules could be acceptable if the proposal satisfied clients requirements and at the same time was practical. Solutions involving high-level fixed aqueducts were acceptable if the proposal also included the details of the proposed approach structure to the fixed aqueduct.

Calculations addressed the two structural situations arising when the bridge was (i) at rest, and (ii) on the move. The stability and safety of the proposed structure needs to be demonstrated in this section. Candidates proposing high-level aqueducts did manage to make the superstructure design relatively easy but made the substructure design harder.

Drawings were of indifferent quality. They needed to show how the bridge moved, and this made them more complex than usual. The production of drawings highlights the need for certain essential elements such as the bascule, bearing arrangements for the structure to move, locks for the structure when it is stationary etc. Overall it was a good effort from successful candidates.

The construction method plays an important role in a project such as this. Since the canal could be closed, construction becomes much easier. The shipping channel could be excavated late in the programme and top-down construction is possible. Construction near or above water could be avoided if planned carefully. However, very few candidates could envisage that: few used the shipping channel for erection purposes.

Q4: Water Tank

The client required a 9,000m^3 water tank. Candidates had a free choice of structural framework, but an economic design was essential. Tank supports could either be rigid or pinned open frame, but a stability check was essential to resist wind load. Because of poor ground conditions and a high water table, shallow foundations were not suitable without any ground improvement, and piled foundations were expected.

Many candidates were able to propose distinct and viable schemes, but most found it difficult to draw neat annotated sketches for illustrating the layouts and framing of the water tank and depicting the vertical and lateral load transfers. Around half of the candidates proposed circular and square/rectangular tanks to alter load transfer methods and/or change materials between schemes to make them distinct and viable. Only very few candidates were able to review and critically appraise their schemes in the identification of the recommended scheme for further development.

Most candidates overlooked the weak subsoil and shallow water table and proposed unsuitable shallow foundations within the sand and gravel layer underlying the top-soil. Few candidates were aware of the need for soil improvement when adopting raft foundations. Many candidates did not carry our sufficient concept design calculations for sizing the main elements and producing overall stability checks. Many candidates were not able to explain the vertical and lateral load paths satisfactorily for the proposed schemes. In the case of circular tanks, candidates had demonstrated their understanding of the horizontal hoop tension created by the hydrostatic pressure in the tank wall, but only very few candidates had clearly depicted the concurrent occurrence of vertical bending and horizontal hoop tension in the tank wall.

With the addition of the tank roof, two issues arose; the additional weight, and the need to stiffen the top edge of the tank wall. Most candidates were able to identify the structural implications of incorporating a roof over the water tank., but only a few were able to clearly convey their ideas in words and sketches.

Most candidates were able to carry out sufficient detailed calculations for designing key structural elements, but many did not check the stability of the structure in their calculations. Only very few candidates demonstrated an understanding of serviceability limit state requirements: concrete crack-width limits and design for water-tightness.

Many candidates did not produce sufficient drawings for estimation purposes. Ccritical details were often insufficient and poorly drawn. Only a few candidates did well in producing neat and clear drawings.

Most candidates produced a satisfactory method statement depicting the sequence of construction of the water tank and the related construction programme associated with it. A few candidates either did not attempt to answer this subsection or did so poorly and were clearly short of time.

Q5: Disaster Relief Field Hospital

The client required a modular disaster-relief field hospital with a short lifespan.

Candidates were given no guidance on the state of the environment and had to make their own judgement on the availability of plant, labour and materials. In a disaster situation these would all be adversely affected, yet many candidates responded to the question as though conditions were normal. There were very few constraints, complications were few, and there was plenty of opportunity for both practical and creative solutions.

Critical constraints were stated for weight and volume to ensure the hospital structure would fit in a standard shipping container. It was surprising how many candidates either failed to recognise or ignored the clear constraints of weight and volume. For a question that was otherwise straightforward, it was essential that these factors be given due consideration.

Very few candidates used the container itself as part of the structural solution, with others assuming its use was only for shipping: a wasted opportunity. Some candidates proposed precast concrete elements, which are naturally heavy: a more sensible solution was to ship cement and use demolition rubble available on site to mix in situ concrete.

Solutions ranged from timber 'flat pack' proposals to steel frames with portal or simple frame construction with wards arranged side-by-side or in a cruciform layout. Very few candidates addressed the temperature range, which required considerable thought into insulation. Steel solutions used hot rolled steel where a lighter and more appropriate solution for a small-scale building was cold rolled steel.

The letter required an explanation of how the wards could be erected by unskilled labour without mechanical plant. The standard of letter writing continues to give cause for concern with many responses being little more than notes/bullet points. Most letters responded by addressing how heavy members would be lifted and reiterated which elements were already capable of being erected by hand.

The scale and simplicity of the structure meant that there was limited scope for calculations and the level of detail, therefore, was expected to be more in-depth and include accurate analysis, WL/8 was insufficient. Portal frames required deflection checks and braced frames required the design of bracing. The wind loading was high, and therefore full stability checks were required with due consideration given to stability against overturning and the potential re-use of demolition rubble as ballast.

Drawings ranged widely from scrappy freehand sketches to well-presented general arrangements. Most candidates concentrated on GA's and sketches lacked detail. Few candidates provided an adequate level of detail on their drawings for estimating purposes. No candidate sketched out in any detail how the materials could fit in the container to demonstrate that the structure could be safely stowed, but marks were not deducted for this.

Many candidates did not include a method statement for dismantling, or simply stated it was the reverse of erection without addressing how concrete foundations and slabs would be dealt with. An acceptable solution would have been to dismantle the superstructure and leave the slab and foundations. A number of scripts included a programme, which was not asked for, but gained no marks and wasted time, suggesting the question had not been read properly.