Examiners’ report 2012

The Examinations Panel, on behalf of the Institution, continues to review all aspects of the Chartered Membership and Associate Membership examinations and their role in assisting structural engineers to gain Chartered and Incorporated Engineer status within an international professional structural engineering institution.

For the third year running, the Institution has provided personal feedback, in the form of average marks awarded together with individual comments from Marking Examiners, to unsuccessful candidates in order to highlight strengths and weaknesses within their scripts and to assist them in preparing for re-sits the following year. The Examinations Panel has noted an increase in the number of requests for feedback and it continues to be well received by candidates.

The Panel once again highlights the important and perennial advice to all candidates taking the examinations:

- Candidates should attempt to answer all the sections of their chosen question.
- Candidates must identify the key problems in their chosen question that must be solved in order to gain a pass.
- Candidates must communicate their understanding of these key issues and demonstrate how to address them in their chosen solutions.
- Candidates must answer the question set and not modify its requirements.

Chartered Membership Examination 2014

Specialist Question 9

The Panel can confirm that a specialist question based on glass enclosures will be included in the 2014 examination. The topic will run for two consecutive years. The format and level of challenge will be similar to the other questions. A sample question, together with the Examiner's notes, will be published in *The Structural Engineer* early in 2013 and will give structural engineers with specialist knowledge of glass the opportunity to view the format and consider taking the CM examination in the following year. A second specialist topic will be introduced in the same manner in the 2015 question paper, bringing the number of questions to 10.

The Institution of Structural Engineers

Chartered Membership Examination 2012

Overview

Total Candidates:	765
UK candidates:	397
UK pass-rate:	35.3%
Non-UK candidates:	368
Non-UK pass rate:	35.9%
Overall pass-rate:	35.6%

Questions

1. Conference hall and exhibition galleries
2. Headquarters extension
3. Road bridge over river
4. New arts school
5. Mixed use development
6. Refurbishment of an existing office building
7. Subsea package for a new field development
8. An observation platform

Feedback

Question 1: Conference hall and exhibition galleries

This question required a circular conference hall with three internal exhibition gallery floors. The hall consisted of a large clear-span roof supported on raking columns around the perimeter with the gallery floors suspended from the roof structure as the hall was required to be column-free. Six remote cores containing the staircase and lifts were equally spaced around the perimeter of the hall building; these could be designed as individual elements or as part of the overall structural solution to provide stability.

The number of candidates attempting this question was disappointingly low which may be attributed to the daunting combination of the physical size and geometry of the building making it appear more complex that it actually was. The brief however was straightforward and easy to follow and, crucially, offered various options for framing the roof which should have meant it was not difficult to offer two clearly distinct and viable schemes. Most candidates who attempted the question understood the constraints in the brief and dealt with them appropriately.

Knowledge of basic scheme design and structural concepts appeared to be lacking in many scripts. Some candidates struggled to put forward a coherent global structure, with some offering individual elements which did not combine into a sensible overall structural arrangement. Some candidates over-complicated the principal framing arrangement and, where novel solutions were proposed, they were not followed through with sufficient detail to justify their integrity. There were various suitable solutions to deal with the circular plan; they included long-span trusses with a cable supported roof, trussed beams spanning from side to side, or alternatively portalised frames or three-pinned arches. Some candidates suggested an inappropriate mix of these various options.

Irrespective of the building size, a straightforward solution comprised a deep truss arrangement spanning across the building, with the vertical support provided by the inclined columns around the perimeter, and with the lateral stability proved by a combination of the raking columns and the cores. The cores surprisingly were under-utilised, either to provide stability or as part of the structural support to the roof.

Candidates scoring high marks provided calculations for the crucial elements such as the foundations and the overall stability requirements. In too many cases insufficient calculations were provided to establish the form and size of the principal structural elements, with candidates concentrating on the simple elements.

The provision of dimensioned general arrangement plans, sections and details was poor, with many candidates appearing to lack the fundamental ability to prepare drawings and details with sufficient clarity and detail to provide information for estimating purposes. The method statement and programme were, in some cases, well thought-out and although executed in a hurry, were reasonably comprehensive. In other cases they were skeletal to say the least, demonstrating a clear lack of understanding.

Question 2: Headquarters extension

The key challenges of the question were:

a) To find a suitable structural arrangement to resist wind loads on the large front glazed elevation, while excluding some of the normal methods of resisting wind loads e.g. lift cores, or internal columns acting as a Vierendeel truss. Concrete was an acceptable alternative material to steel, but candidates proposing this needed to justify their design clearly. Proposing concrete simply as an alternative material but with the same structural layout as a steel solution was not acceptable, as the concrete design needed to take into account the differences in material properties and was expected to be significantly distinct from a steel solution.

b) As only two columns were permitted inside the building, the office support structure needed to include significant beams at first floor level. Alternatively the office floors could be hung from the roof. Although some candidates proposed Vierendeel trusses, this was not strictly necessary as beams were required to span only 10m and there was no reason that all the loads had to be supported by beams at first floor level.

c) The foundation under the front elevation needed to resist horizontal loads. It was not expected that alternative solutions to piles would be proposed but candidates that did propose viable alternatives were rewarded.

It was appreciated that the question required a significant quantity of calculations to justify the structural arrangement. However candidates needed only to identify the critical elements and restrict other calculations only to load determination. For non-critical elements it was sufficient to select element sizes by inspection without further justification.

Section 1

Three straightforward options were:

(i) first-floor transfer structures
(ii) clear-span lateral roof trusses with hangers to the first floor
(iii) A 10m x 10m office grid avoiding transfer structures

Most schemes chosen were one of these and most credible solutions were in steel. Grossly uneconomical solutions involving longitudinal 30m-span roof trusses or storey-height Vierendeel girders were proposed by a few candidates.

Many candidates overlooked the fact that the front façade required columns (or trusses) to be 20m tall with no lateral restraint, although most candidates did note that the glazed façade would require close control of deflection, which was also usually ignored in the design of the façade columns.

Again, having noted that deflection was an important consideration, moment frames were often proposed as a solution but without demonstrating that lateral deflections could be controlled. The height-to-breadth of the building was such that a moment frame would only work if very stiff connections and members were provided, including the connection at the base of the columns. A few candidates offered a 20m high portal frame with a truss at high level and a pinned base. The intermediate floors had pinned connections to the frame due to hangers being used. Although not strictly a mechanism, the p-delta effect would lead to excessive, or even uncontrollable, lateral deflections.

Almost all candidates ignored the undercroft, and did not consider the lateral loads at ground level. The sloping topography was generally dealt with by fill. Another common approach was to use core walls, located immediately behind the glazing. While structurally sound, it ignored the aesthetic impact on the structure.

Ground conditions were reasonably well considered. The implications of the ground water table on bearing pressures in the gravel were generally recognised. Piling was the favoured solution, but discussions on the types of pile were limited. Some candidates proposed a deep cellar on piles: this would require piling and a deep excavation which is inefficient and would need precautionary measures for the existing building, but this was frequently not mentioned.

Most candidates included sketches and preliminary sizing calculations, but there was generally insufficient description of proposed schemes and a lack of clarity, especially for the alternative scheme that candidates discarded for Part 2.

The letter was designed to test the candidates understanding of how lateral loads would affect the building. A business letter format was generally satisfactorily adopted. Many recognised the implications of the lateral & torsional transfer of wind loads.

Section 2

Too many candidates provided relatively trivial calculations whilst ignoring the stability of the structure. Some noted that deflection could not be checked in the time available, when for particular elements deflection would have been the controlling phenomenon. Candidates tended to focus on superstructure elements and pile designs, where provided, were poor.

Drawings in 2(d) were less than satisfactory, perhaps reflecting a lack of regular direct involvement in drawing production. Sometimes the structural form was not fully conveyed by the drawings and these would therefore be inadequate for costing. Critical details were poor with little comprehension of good detailing practice e.g. blinding concrete below foundations and structure/envelope interfaces.

Method statements and programmes for 2(e) were mostly just acceptable where time permitted. Often the method statement was too simplistic providing mostly generic information on site safety rather than project-specific information. Some candidates did not understand the sequencing for solutions with hangers, and few used sketches to illustrate more involved sequencing.

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Question 3: Road bridge over river

The question called for the design of a road bridge carrying a dual two-lane carriageway with cycle track and footpaths over a river in open countryside. Earth embankments for the new bridge at both sides of the river had been constructed some years ago. This kind of situation is quite common in many countries as highway networks are constructed in stages in accordance with long-term highway development programmes.

Although the bridge deck was skew on plan at 30 degrees to the river and there were constraints on the supporting column positions and construction over the river, there were a variety of feasible solutions for the longitudinal structural layout, including simply-supported beams or continuous beams/trusses on vertical supports; even cantilever and suspended span forms were possible. The deck could be in the form of beam-and-slab, twin-box or steel truss with cross beams. Precast concrete or steel beams were possible and could be lifted by a crane at night when the marine traffic was closed. The supporting structure was simple as the deck could rest on cross-beams which would then be supported by columns. The simple footings should be supported by end-bearing piles. Most candidates proposed 3-span solutions with beam-and-slab deck construction that was sensible and is normally adopted in practice. A solution using precast concrete segments installed by a launching girder was possible but a rather expensive option.

A small number of candidates mentioned skew effects but hardly any discussed the implications of skew and included them in their calculations. The skew effects were generally ignored in subsequent design. Many candidates proposed a cable-stayed bridge as one of their options but only a small minority demonstrated understanding of the elastic support provided by the cables that had been the common weak point of similar proposals in previous exams.

For steel truss options, most candidates did not visualize the difficulties associated with the erection of the central span, approximately 80m long and 24m wide, heavy, and near transmission lines.

Most candidates tackled section 1(a) adequately. The deck configuration was quite simple and many similar examples would be found in the design office.

Responses to the client on the change of environment were generally satisfactory. As is often seen, candidates lost easy marks by failing to use a formal letter presentation.

In section 2(c) calculations should be consistent with the scheme adopted and its method of construction, but some offered were not relevant to the proposed method of construction; for example, for steel/concrete composite construction, calculations would be completely different according to whether it was propped or unpropped. Many candidates chose to use trusses and only considered axial forces in the top and bottom chords. The effective length of the top chord was occasionally checked but none of the candidates considered the local bending effects on the bottom chord from the cross girders and deck slab. Horizontal loads, particularly the traffic and wind loads, were not considered by most candidates even through the question specifically asked for their inclusion.

The examiners were looking for plans, sections and elevations with sufficient details, with dimensions of the bridge structure for estimating purposes. Some candidates omitted drawing or drew only a very simple schematic plan, thus losing a significant number of marks.

As usual, most candidates seemed to have left section 2(e) until the very last moment because of poor time management. Hence the method statements were simply lists of activities, and the key issue of how to achieve safe construction over water and near the transmission lines was totally ignored.

Question 4: New arts school

The question required a three-storey building suspended around a central core, with a basement. The question was straightforward and there were limited options for different load-paths; however, the question was particularly unforgiving for those candidates who were unable to provide engineering solutions to meet the challenge.

The common solutions were (i) large-span cantilever steel trusses at roof level, and (ii) concrete cantilever transfer beams at level 2. Others offered included cantilever beams at all levels, steel trusses at level 2, and multi-storey Vierendeel trusses in both steel and concrete. Cores were generally of concrete.

When choosing concrete solutions, very few candidates undertook a satisfactory span/depth check on the long-span cantilever beams.

The junction between the cantilevers and the core walls were critical, and it was necessary to check and design for the large bending moments at these positions. In many cases the connection details provided were wholly inadequate to resist the bending moments, and the structure was not stable. Good candidates either brought the cantilever beams across the core and used the cantilevers on the opposite side as a balance (and appreciated that the layout had to be carefully thought out so that the beams would not obstruct the installation of the lifts) or thickened the core walls locally to support the large bending moments. Some candidates who correctly proposed primary cantilevers from the core with secondary cantilevers off the primary ones to support the corners, often failed to appreciate the need for back-spans for the secondary cantilevers.

Most candidates chose foundation solutions bearing into the rock, but a factor of safety was needed on the stated bearing pressure which some did not include. The project called for a deep basement near the sea, requiring a check on the stability of the building against both wind and floatation.

In the letter, most candidates satisfactorily identified the structural issues involved with adding a deeper basement, but some would have gained more marks if their presentation had been better.

Some candidates quoted element sizes by reference to external documents or by guessing at the size without justification. Candidates need to provide sufficient proof of adequacy of their proposed structure.

Drawings often omitted sections and elevations. Good candidates presented a coherent set of labeled plans, sections and critical details. Some candidates attempted to combine all plans into a single multiple plan with sections not to scale and without critical details, and these lost marks.

Many candidates put forward reasonable method statements, but some missed important matters such as dewatering.

Question 5: Mixed use development

The question called for a fairly straightforward building with two important structural issues to be resolved in the design. Most candidates realised that a transfer structure was required over the open space at ground floor for the art gallery, but surprisingly few realised that the out-of-balance earth pressures on the two storey basement required some thought. The whole basement area was often treated as an after-thought rather than as a key part of the question.

Most candidates prepared a reasonable first scheme for the transfer structure, with most opting for the main element either at first floor level or up in the roof. Assorted beams, girders and trusses were generally well sized, but the Vierendeel girders that some candidates chose were often poorly proportioned in terms of panel aspect ratio, as well as being an unusual choice for hand calculation when a truss in the plant room seemed more sensible. Second schemes for the building itself were generally reasonable too, with alternative foundation schemes generally demonstrated using either pad foundations or a raft. A small number of candidates suggested the use of bored piling for the vertical loads, which was highly inappropriate because of the rock close to the lower basement level.

Several candidates offered a cantilever retaining wall around the lowered area, but did not consider the differential movement between the top of the retaining wall and the structure of the building; for example, in several cases columns were supported on the top of the cantilever retaining wall. Many ignored the out-of-balance horizontal loads from the earth pressures on to the building, assuming that the wind loads were the only horizontal loads to be considered.

The letter asked for the structural implications of removing the lightwell from the two shorter sides of the building. This actually allowed the earth pressures to be propped by the slabs, but comparatively few candidates saw that the change was beneficial for the structural design of the retaining wall. Presentation was poor and only a few of the letters would have been acceptable in practice.

The calculations were usually very limited and often too simplistic. A lot of candidates listed the calculations that were needed and then produced hardly any of them or did only the easy parts.

The key element of the transfer structure was not dealt with very well at all. For the transfer beam spanning over the gallery, many did not take any real account of the deflection. Some concrete beam designs proposed ridiculous amounts or arrangements of reinforcement for the beam size chosen, and it was clear that these candidates had no real experience in the design of these types of members in reinforced concrete. Likewise the Vierendeel structures were not well considered.

Foundations were dealt with very simplistically and the retaining wall solutions were not really considered by a number of candidates.

The drawings were generally of poor quality and did not cover the range expected. The details provided were frequently reinforcement details rather than details giving information about important structural areas, for example the transfer-structure-to-column arrangement or the connection of the slab to the retaining wall.

Many candidates failed to complete the method statement and programme, and several seemed to produce generic method statements rather than site-specific method statements.

Question 6: Refurbishment of an existing office building

This question required candidates to consider how to cover a courtyard within a two storey office building with an aesthetically pleasing roof. Openings were also required to be created within the existing concrete flat slab floors above the reception area. Details of the existing building foundations were unknown but there were signs of differential settlement. There were conditions, which included a reduction of the original design imposed load and that the courtyard should be kept as column-free as possible. The sub-soils were peaty to 2.0m, then firm clay becoming firmer with depth.

There was difficult access for plant, but the works were relatively small-scale with light loads, and there should have been no necessity to heavily engineer the proposed structure.

Candidates produced a variety of solutions for part 1(a). Predominant among these were portal frames with the columns close to the courtyard perimeter. Many had solutions which depended wholly or in part on support on the existing building. The solutions included frames which bridged the building entirely – hardly complying with the 'economy' requirement.

Most of the proposed roof structures were in steel, though timber was proposed by some. Over half the candidates prepared solutions that made no reference to the 'aesthetically pleasing' requirement of the brief. The 1.0m gap on the perimeter was universally allowed for. By and large the forms and structures offered were of conventional construction, but with little innovation. Some solutions involved glazing, mostly in the form of roof-lights but without explaining what these were.

Perimeter columns were close to the existing structure and generally in the same grids as the existing columns, leading to problems with interference at the foundation level. Some resolved this, but many ignored the problem.

Very few candidates checked the loads and compared these with what could be carried on the existing building, because of the now reduced imposed loads. In reality the reduction in imposed load would allow a considerable increase in column loads of the existing structure without increasing the foundation load. A few candidates stated that the movement in the building precluded any additional loads, which was not the case.

Most opted for piled solutions within the courtyard, though many selected types of unnecessarily large diameter piles that could not be installed because of the practical difficulty of access for the rig. A few looked to underpin the existing building. Careful balancing of the reduced imposed loads, together with an appropriate column layout would have avoided the need for any work to existing foundations

The opening in the floor slab was handled in the most part as just that, with added structure to counteract the perceived loss in strength. Few recognised a flat slab and adjusted their opening to avoid the beam strips, and only one or two realised that the reduction in imposed loading and the type of construction meant that properly positioned holes might mean that no strengthening was required.

Part 1(b) produced widely-varying responses. Many put the required additional floor area at 1st floor level; some kept part of the light-well aspect and had a smaller area on each of two levels. Some put the area above the existing roof level. Some realised that the area could be at ground floor level and made things much easier for themselves.

Part 2(c) was generally poorly carried out. Few managed to prepare calculations justifying all aspects of their chosen structure. Loads were rarely properly laid out and computed. Some elements of the structures were, by some, sized and designed to tables without properly explaining what was involved. Calculations for foundations were limited, and no real assessment was made of the effect on the existing footings.
A few candidates managed to cover all the basic elements, but most were struggling and some managed hardly any calculations. The time available should be enough to prepare analyses with basic bending, shear and deflection calculations for all the main elements. Candidates need to be familiar with hand calculations and avoid reliance on computers.

Part 2(d) was rushed by most, with two or even three part-plans per layout. A few candidates managed to show enough information for someone to take off quantities, but most just did not get it all down.

Details were, by and large, inadequate or over-simplified. Details could have been provided for the eaves, foundations, and opening-up of the slab, as well as general items such as beam/column connections.

Part 2(e) was skimped by most. There were many statements about health and safety, but little on matters that related how to properly and safely construct the structure. A number were quite prepared to crane their piling rig into the courtyard, but clearly had no comprehension of the size of rig required for the piles proposed or the magnitude of crane this would necessitate. Breaking out the floor was not well described by most, though many recognised the need for temporary support for the cut slab section.

Programmes varied, but nearly all were over-optimistic. A realistic period would be around 20 weeks.

The question was straightforward and should have been well within the capability of a Chartered Engineer. However, candidates appear not to do enough real design in their working lives to gather the experience and instinct that an engineer needs to resolve structural problems quickly and effectively. The good candidates had this, but most gave the impression they were not able to use innovation to resolve problems that fall outside a standard framed solution.

Question 7: Subsea package for a new field development

Candidates were required to design a new subsea package to be installed on the seabed in 100m of water. The package was to accommodate incoming flowlines, an export pipeline and a manifold unit. The manifold had to be provided with protection from dropped objects and a clear access corridor was required on the west side of the subsea package. Subsea structures are often at risk of snagging by fishing gear so a 1,000kN omni-directional snagging load was included in the design criteria.

The subsea package was to be installed by an installation vessel having a crane with no heave compensation mechanism, this being a critical aspect of the brief as it increases the installation loads experienced by the structure as it is lowered through the water. Similarly, the omni-directional snag loads have a significant effect on the structure and piled foundation. These specific installation and in-place design considerations were fundamental to the package design and their adequate consideration essential to a successful design solution.

In part 1(a), candidates generally selected alternatives from trussed, portal or plated (box girder) forms. Candidates are reminded that two distinct and viable solutions are required to gain sufficient marks to pass this part of the paper. Candidates must fully explain the functional framing and include appropriate sketches to illustrate load transfer of both structural systems.

This year, many candidates lost marks due to insufficient attention given to their alternative solution. Candidates are expected to critically assess both structural arrangements and provide justification for their preferred solution. Marks were awarded to solutions that considered in-place conditions, including snagging, and relevant temporary conditions, loadout, transportation and installation, as these conditions influence the framing and member sizing of the subsea package.

The letter in part 1(b) asked candidates to look at the implications of extending the east side of the subsea package by 2m to incorporate an increase in the size of the flowline tie-in porch. Marks were awarded to candidates who recognised an increase in weight, installation hydrodynamic loads and the implications of loss of symmetry on the loadings, which affected the lifting arrangement and piled foundation. Candidates are encouraged to produce simple sketches to illustrate the influence of the issues raised and their structural resolution, while maintaining the formality of a letter.

For part 2(c), candidates presented calculations that did not adequately cover the stated design criteria. In particular, installation loads were poorly derived despite the specified limitation of the installation vessel crane, and in some cases snagging loads were not properly considered. Candidates are reminded that the magnitude of critical loadings will govern the member sizing of the main structural and foundation elements, and these loadings should be determined in a rational and clearly understandable manner. Candidates should allocate sufficient time to consider design of the critical details such as lift points and member connections. Candidates are also encouraged to reconcile their initial dead load estimate with a final designed weight to confirm their calculations remain valid. The dead weight versus buoyancy and inertial and drag loads is a significant input to determining crane hook loads.

In part 2(d), candidates are reminded of the importance of good quality sketches, drawn to scale, to clarify their design submissions and to provide the detailing necessary to support a viable arrangement. For a subsea package, the critical detailing comprises the connections of the piles, lift points and member end connection details especially where welder access is limited. Single-line diagrams are not as useful, as joint eccentricities are not apparent and sensible design proportions cannot be verified by simple visual checks.

In the method statement in part 2(e) it was unnecessary to include aspects of the construction and loadout as these did not form part of the question: some candidates devoted valuable time to these subjects with no gain in marks. Important procedures in this instance would be continued weather forecasting and monitoring, during both transportation and particularly installation, lifting, subsea rigging retrieval, subsea package levelling and piling. Candidates are encouraged to produce simple sketches to illustrate all significant transportation and installation activities.

Question 8: An observation platform

The question required the candidates to design a tall observation tower in a zone of high seismicity. The footprint of the tower was small but space was provided on the site for a larger base to the tower, which also allowed the candidates to explore the use of guy cables to support the structure laterally. Candidates who chose to use guys were required to make some consideration of system flexibility and the partial rigidity of the base. The large observation deck was specified as being a column-free space requiring the candidates to consider how the roof loads could be carried down through the glazed observation deck. Apart from these the question was generally unconstrained and allowed candidates free rein with structural support systems.

Conceptually, structures such as the Blackpool tower or Heathrow control tower are the most obvious example of successful solutions to the problem. The structure-free space in the observation platform suggested the floor and roof needed external support systems such as cantilevers or some other form of suspension from cores. Sufficient mullions were required to support glazing but these should be around 2-3m apart. Use of mullions to prop roof beams would be acceptable. Both the roof and the floor would need diaphragms to distribute lateral loads and some simple system was required to transfer lateral loads down from the roof.

The service building could be considered a secondary item as the point of interest is the tower, and any open-framed form would be acceptable.

The method statement needed to suggest some sort of self-building system such as slip-form concrete cores or jack-up steel cores if the tower was not a lattice/frame. Delivery of materials should have been considered for the city centre location. Work space should not have been an issue.

Only three candidates attempted the question. All papers were generally a little too brief on defining the second option for the structure with a very similar foundation system used for both heavier, all-concrete solutions and lighter weight, steel framing options. As a result, all foundation systems were on the heavy side and would have resulted in some costly structures.

The other consistent point across the three papers was that the calculations were all a little short on detail with too much effort being placed on the roof beams and not enough on the primary elements. In a top-down design this is not surprising, as the weight of components is required for the permanent load effects on elements of the structure below. It is recommended that candidates identify the important elements first (particularly the critical stability elements) and cut out unnecessary detail on secondary vertical load-carrying elements. With only three scripts it was not possible to draw out other trends.

The response to the client letter showed some variety in the quality of answers from the candidates. Clearly the client’s request was a possibility and would require an improved floor/roof support system but the challenge of the letter was to maintain stability with a non-concentric stability system. If a lattice/framed support structure was selected which did not rely upon a lift core the request became a floor support rearrangement challenge only.