The Institution of Structural Engineers

# Examiners' Report January 2015

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

This was the first Chartered Membership examination held in January for over 40 years, initiating the Institution's intention to offer an opportunity to take the CM exam twice a year.

The table below outlines the performance of candidates per question.

| CM January 2015 | Pass | Fail | Total | % Pass |
|---|---|---|---|---|
| Question 1 | 31 | 133 | 164 | 18.9 |
| Question 2 | 3 | 7 | 10 | 30 |
| Question 3 | 3 | 7 | 10 | 30 |
| Question 4 | 20 | 66 | 86 | 23.3 |
| Question 5 | 7 | 13 | 20 | 35 |
| Total | 64 | 226 | 290 | 22.1 |

| Jan 2015 | Pass | Fail | Total | % Pass |
|---|---|---|---|---|
| UK | 28 | 64 | 92 | 30.4 |
| International | 36 | 162 | 198 | 18.1 |
| Total | 64 | 226 | 290 | 22.1 |

## Question 1 - New Hotel and Conference Facility

The building comprised two different structural arrangements: the upper floors laid out in a regular crucifix, accommodating the four wings of bedrooms centred around the main lift and staircase core, and the lower two floors in a square, containing the reception, dining area, and underground conference facility.

The bedroom floors required a structural layout to meet the constraints of the 6.0m long x 4.0m wide bedroom layout with a requirement that the external columns should be at centres no closer than 4.0m, the internal columns ideally conforming to the same constraint. Many candidates either ignored or did not understand this requirement. It was clear from the question that the 4.0m column dimension represented the width of each bedroom so only multiplies of this width, i.e. 4.0m, 8.0m, 12.0m etc. would be satisfactory otherwise the columns would not coincide with the division walls to the bedrooms and would therefore conflict with the window and door openings. Candidates proposing alternative spacing at e.g. 4.5m or 6.4m were therefore penalised.

At the end of each bedroom wing there was a storage room and staircase. This offered the opportunity to provide stability to the ends of the wings, but was ignored by many candidates.

The public rooms on Level 1 and the underground area on Level -1 were to be open- plan with restricted numbers of columns. This constraint required a transition structure at Level 2. While most candidates proposed a viable solution, fewer were able to propose viable alternatives. Some suggestions were grossly over-designed, and some candidates introduced intermediate columns to reduce the critical 27.0m span, thus ignoring the client's brief.

Most candidates chose to take loads down to the rock stratum using various forms of piling for the perimeter retaining walls and the column foundations; however, the dense silty sand was suitable for conventional RC retaining walls and pad/raft foundations formed with open-cut construction. Some solutions exposed candidates' inexperience in designing basements and their foundations.

The selection of the chosen scheme was often brief and focused on concrete and steel alternatives. Adopting identical structural schemes and just changing the material is not acceptable unless the characteristics and constraints of the different materials are taken into account. Better schemes included variations in the load paths and in the systems of stability.

The letter to the client was reasonably well attempted, although presentation could have been improved by some. Most candidates recognised the key elements required to meet the client's change request.

Most candidates provided calculations for the simple structural elements: beams, slabs, internal columns, and possibly a simple end-bearing pile. Candidates did tend to ignore critical elements such as the transition structure, the overall stability, the retaining wall to the conference area, and the ground slab or foundations. Marks were lost because of incomplete or absent calculations rather than errors and lack of design knowledge.

Drawings were often inconsistent and incomplete, lacking all the required plans, elevations, and critical sections, and therefore did not provide sufficient information needed for estimating purposes. 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 complex and confusing. A competent engineer must be able to demonstrate and communicate their design ideas, but unfortunately many candidates indicated their lack of ability in drawing.

The method statement and programme elements were mostly well attempted but some ignored temporary works, construction sequencing and the stability of the structure in the temporary and permanent condition. Time constraints seemed to cause problems for many candidates. Very few candidates used sketches to indicate constructional sequencing and potential temporary works.

## Question 2 - Facilities for road toll barrier

The question included numerous detailed design criteria that on first sight might be regarded as restrictive, but in reality liberated candidates to develop ideas within well-defined limits. The structure formed an item of highways infrastructure, probably rarely encountered by building structures engineers. The above factors might explain why so few candidates chose this question.

While most candidates identified the design criteria, many did not understand the impact they would have on the design of the structure. The redundancy and overall lateral stability of the structure were given scant regard, as the 20m-high cantilevering canopy structure became the focus of candidates' attention. This led in some cases to unstable structures and thus automatic failure. The lack of attention to robustness was also of concern.

In the letter, some candidates perceived the change requested by the client as extreme, which perhaps led them to make proposals which went outside the design brief on the basis that a precedent had been set by the client.

Many design calculations presented were not comprehensive and ignored critical elements; some contained errors. None covered the longitudinal stability of the structure, and only a few included the columns to the control room tower or the roof support structures. The lack of ability to prioritise the design of critical elements was of concern: the examiners wish to see that candidates understand which elements are most important and can design them. Most candidates noted the varying soil conditions and presented sub-structure solutions appropriate for the conditions. Some highlighted the need for tension piles.

The method statements varied widely in quality with most acknowledging the need for sequenced and modular construction, with modules having independent stability, as the canopy was constructed across the highway. Programmes were generally poor, with many making estimates of operation durations based on little understanding of the construction and site access limitations. Some just listed the tasks in a sequence of works with durations but without logical links between them, such as with a rudimentary Gant chart. The drawings were generally clear but not comprehensive enough. Many candidates produced drawing elevations only in the short direction.

## Question 3 - Temporary pedestrian bridge

The question was written so that standard steel and composite bridge solutions would not be appropriate for the problem given, and it was hoped that candidates would be able to 'think outside the box'. A fundamental aspect to the problem was that temporary reusable bridge structures should be provided. One straightforward method of achieving this was to use pontoons to support temporary decking, so that there would be little to demolish on removal of the bridge.

Although the question asked candidates to propose two solutions for a temporary bridge structure, use of a truss superstructure was probably inevitable. To make solutions sufficiently distinct from each other, it was necessary to propose two truss bridge superstructures whose supporting arrangements differed significantly so that the load paths were different.

The question encouraged candidates to propose solutions using the principle of a cantilever bridge, which has the advantage of determinacy such that analyses can be quickly and accurately undertaken, useful in the exam situation. Unfortunately, very few candidates were able to propose appropriate solutions to this particular problem. The majority of candidates did not understand and adhere to the limitation in allowable loading on the existing jetty. The suggestion of a cable-stayed bridge for a temporary structure was unrealistic, especially where the site had so many other constraints.

In the letter, the further reduction of the load-bearing capacity of existing jetty could easily be dealt with if the proposed scheme was based on a cantilever bridge. Unfortunately very few candidates demonstrated knowledge of this concept in their design appraisal, and the majority of candidates found the change was leading them towards an impossible bridge structure.

Candidates proposing appropriate solutions found that a significantly reduced quantity of calculations was needed. Most candidates did not demonstrate that the loads applied to the existing jetty were within the permitted limit.

The quality of drawings was disappointing, when the ability to draw should be considered as fundamental to an Engineer’s capabilities and essential to aid communications.

Most method statements lacked consideration of Health and Safety measures needed for the safe construction of a bridge structure over 30m depth of water and provision for its future safe demolition. Some of the candidates showed lack of site experience by proposing unrealistically-long construction programmes.

## Question 4 - Mixed-use apartment block

The question required a nine-storey structure over a single-storey basement. The building was rectangular in plan but stepped in elevation. A major road abutted one elevation, and this elevation was sloping outwards over the height of the building. There was a four-storey car showroom on the ground floor adjacent to the main road, and columns were limited along the façade of the showroom. Restrictions on columns were imposed by the requirements of the apartments and car park below.

The main issues to be dealt with were the high water table causing uplift and construction issues, the eccentric cores and the stepped building, and the transfer of loads to the car showroom structure.

Columns could be placed anywhere on façade and corridor lines, and this allowed distinct solutions on different grids with a variety of materials and construction methods. Solutions were expected to include reinforced concrete flat-slab construction, post-tensioned slabs, composite steel-framed structures, and possibly precast concrete structures for the upper floors.

For lateral stability of the structure it was expected that the two cores would be used, with an approximate calculation sufficient to apportion loads between them. An alternative would have been to supplement this with frame action elsewhere in the structure.

Most candidates chose piles for the substructure, but good candidates realised that they could spread loads through the gravels and use a raft. Dewatering sandy gravels should have been spotted as a problem, and should have formed part of the thinking for the construction methodology. The basement walls were expected to be permanent steel sheet piles, or secant piled walls. Because of the water levels the structure would require waterproofing details.

Most candidates appreciated the constraints of the car park and apartments above, and managed to position columns accordingly. In some cases large square columns were proposed but these were unsuitable as parking spaces and apartment floor area would be lost. Thin rectangular columns would have been more suitable. Candidates are encouraged to consider how their proposed solution takes into account the use of the finished building.

On the front elevation some candidates included five columns along Grid 1 in the car showroom. This clearly contravened the brief. Candidates are reminded to read the question carefully.

Too many candidates struggled to come with a sensible distinct second solution, resorting to either the same grids as for the first solution, or coming up with an uneconomical solution such as clear spans of 16m, or proposing roof trusses with hangers supporting floors below.

The substructure was generally dealt with poorly, with a lack of understanding being apparent. Basement structures often feature in the CM Examination, and a well- prepared candidate should know how basements are constructed safely, and how to select methods to suit ground conditions. Some candidates proposed very large diameter end-bearing piles, rather than using skin friction. Good candidates realised that skin friction could also help to resist uplift. Unfortunately too many candidates barely addressed the substructure, possibly in the mistaken belief that the Examiners would not notice. Candidates also generally failed to discuss how their solutions would be safely constructed.

In part 1(b) the letter required the candidate to address two issues: the change of grid resulting from the supermarket, and the deeper basement. Candidates were able to accommodate the inclusion of the supermarket: if they had previously avoided using a transfer structure, it offered a suitable option to be proposed in the letter. The deeper basement made uplift more significant, along with creating construction issues. Too many candidates dodged this part of the question by ignoring it. More ingeniously, some candidates proposed raising the entire building so that the basement level remained unchanged. This was not the intention of the question, but did not contravene any requirements, but candidates would need to consider other issues such as planning constraints and access in order to make this a workable possibility. Candidates should not seek to avoid the challenges of the question: as a general rule, if a way is found to make a question easier, it is likely that a mistake has been made.

Calculations were generally poor, with few candidates producing sufficient. In particular, calculations omitted lateral stability, the feature columns to the car showroom, the basement walls and foundations. These are all evidently critical elements of the structure and candidates should ensure that they cover all of the critical elements.

Drawings were also generally poor, with many candidates unable to identify or draw critical details. The general arrangement and long-section drawings should be sufficient to describe the building fully, but many candidates produced insufficient drawings to do this. As a general rule, candidates are unlikely to pass if they produce less drawings than the Examiners have provided to describe the question.

The main issues in the method statement that candidates were expected to deal with were basement construction in high ground water, formwork to the car showroom and propping for the transfer structure. Candidates are expected to show that they know how more complicated items can be built safely. Candidates should also ensure that they leave time to answer this section.

## Question 5 - Conversion of industrial Building to apartments

The question required candidates to consider the conversion of an industrial building into residential apartments This required structural design on a relatively small scale, keeping construction lightweight to avoid exceeding the allowable imposed load and maintaining shallow construction depths to permit construction of two floors of apartments on each level of existing floors. Calculating existing versus proposed loadings on existing columns appeared challenging for a number of candidates. Another challenge was the assessment of existing perimeter spread foundations which indicated bearing pressures in excess of those derived from the soil properties given. This apparently confused some candidates who then provided new perimeter foundations for the new floors and underpinned the existing foundations. It should have been possible to continue to use the existing columns and perimeter walls for the additional floors and the reduced proposed imposed loadings, but the proposed floors and partitions would need to be of lightweight construction.

Part of the existing structure was to be removed to create an atrium and this required careful consideration of how to support the existing masonry wall against lateral wind loads. Historic settlement was evident to the structure locally to one corner which would require investigation.

A variety of structural solutions was possible including load-bearing masonry, a steel frame with timber or precast floors, or a cold-rolled steel structure. Most candidates opted for a solution in masonry or steel build off the existing floors, which were checked to ensure the existing imposed load was not exceeded. Some candidates provided a complete new steel structure off new foundations. This was an acceptable solution but in many cased the new foundations were excessive in size.

One complication was the depth of the existing central beam which reduced the height within the central corridor to an unacceptably-low clearance. The majority of candidates recognised that the existing UB was too deep for the required 2.3m height clearance. A number replaced the beam with a pair of shallower UCs on to the existing columns (and associated foundations). Other candidates replaced both the columns and the deep beam by new columns along the proposed corridor partitions.

Creation of the atrium was generally handled well with the majority of candidates giving consideration to the lateral stability of the existing masonry wall, although few alternatives were offered in the second scheme. A number of candidates correctly recognised the consequent conflict between the infill floors, the new balconies and the existing windows. Some proposed precast floors but provided no explanation on how the planks would be installed. Few scripts addressed the design options for the balconies; however, most gave consideration to cold bridging indicating that many candidates have experience in general building issues.

The existing perimeter walls and plate action from the existing floors could continue to provide overall stability, but the atrium void and external elevation needed to be stabilised by horizontal supports at floor levels and by the vertical end elevations. Stability was generally adequately addressed. Some used the braced frames of the new construction to provide stability in view of the many partitions and longitudinal corridor.

The letter in part 1(b) required candidates to advise the client on any investigative work required. The majority of scripts addressed a number of the key issues. It was evident from a few scripts that they appeared to have had experience of such investigations but the majority of scripts only mentioned a few items.
Key issues to be covered in the letter were:

- Archive search of building and maintenance records
- Exposing and assessing existing foundations to both columns and external perimeter walls.
- Opening up beams, columns and connections for construction details, condition and capacity assessment.
- Existing slabs construction details, condition and capacity assessment.
- Perimeter brickwork: construction details, condition and capacity assessment.
- Ground conditions: borehole(s) and trial excavations because of the peat lenses and apparent low C value of the stiff clay.
- Existence of any trees or vegetation in the vicinity which might affect the foundations.
- Presence of drains and underground services: drain testing for any leakage, condition and construction details. Any services such as gas, water, electricity, telecoms which could influence foundation and superstructure work.

The general standard of letter writing continued to be poor with very few reaching a standard that would be acceptable in professional practice.

Fully detailed calculations in part 2(c) were expected for all key members including masonry support, superstructure for apartments, balcony design, remedial foundation design, and support to glazing. Calculations varied from too detailed, thereby not covering sufficient key elements, to very broad-brush based on span to depth ratios. Many scripts included design checks for beams in bending only and failed to complete the calculation by checking shear and deflection. Where the implications of the atrium were recognised calculations for additional restraints and wind posts were generally well handled. Where new foundations were provided these were often excessive in size and should have indicated to the candidates that the solution was not practical or economical.

In part 2(d), drawings were expected to include a typical floor plan, details of masonry lateral support, a cross-section through the apartments, details of foundation remedial works, a cantilever balcony detail, fixings of lateral support to masonry, and wall-to-floor details of apartments. In practice very few scripts provided all the required views, the majority falling short. While a number were of a professional standard with sufficient information for costing purposes the majority were poorly presented and scrappy and would not be acceptable in practice. The nature of the question required a number of details which a significant number of scripts failed to address and only provided plans at floor and foundation level.

In part 2(e), method statements were generic rather than specific to the brief. The better scripts identified key structural issues for the safe erection of the structure mentioning key sequencing and temporary bracing particularly for construction of the atrium. Very few candidates recommended undertaking remedial works to the foundation prior to construction of the apartments. Programmes varied from simplistic activities to detailed ones; a number incorporating services and fit-out. Duration varied from less than 6 months to over a year; 12 months being realistic for this type of structure and location.