The Institution of StructuralEngineers

Examiner Report

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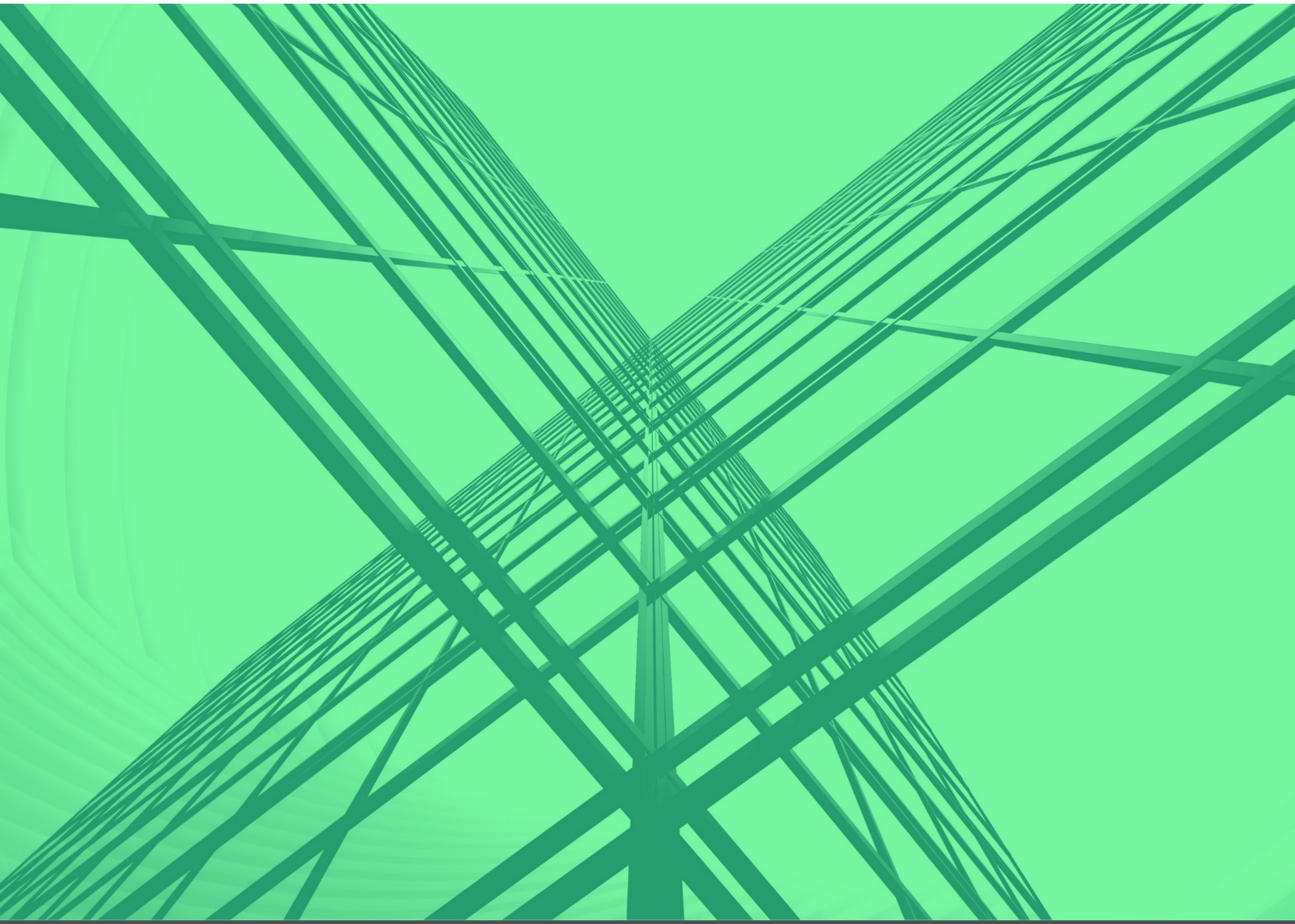

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Notes on the reports

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.

Comments from the Examinations Manager

All candidate exam papers were received back from the exam centres in good time and all scripts and pages were accounted for.

Candidates should ensure that all pages of their exam script have the candidate number on them, and they should also ensure that the pages are numbered in a logical and consistent way. In addition, several candidates included their full name on the cover sheet. Candidates are reminded that in order to preserve the anonymity of the marking process they should only put their initials (e.g. JS and not John Smith) on the front page and not their full name.

Chartered Membership exam

Question No.	Candidates	Pass	Pass %
1	38	18	47.4
2	116	56	48.3
3	28	5	17.9
4	364	99	27.2
5	68	21	30.9
Total	614	199	32.4

Worldwide	Candidates	Pass	Pass %
UK	359	130	36.2
International	255	69	27.1

Sat preparation course	Candidates	Pass	Pass %
Yes	220	82	37.3
No	394	117	29.7

Question 1: New stadium stand

Section 1a

The question required candidates to consider suitable types of structure for a new stadium stand. There were constraints to the question which required candidates to consider stability, suitable spacing and location of columns and how to deal with the long-span column-free roof.

Few candidates undertook an introductory appraisal of the brief to identify the main engineering challenges. The question offered scope for distinct options using different grids, e.g. 6m vs. 9m, and different materials, e.g. steel vs. concrete, using the same conceptual design. Some candidates struggled to produce two distinct and viable options. A simple change in material alone was commonly proposed but was not enough to make the solutions distinct. A few candidates ignored some of the structural constraints and proposed grids less than the specified 5m minimum. Others introduced braced internal bays within the main floor plate or columns within the 15m clear span concourses, contravening the brief requirement to avoid obstructions within main concourses.

The building was 108m long, but the need for movement joints was rarely considered, particularly for concrete frames where recommended movement joint spacing is approx. 50m. In most scripts preliminary sizes using engineering judgement or rules of thumb, e.g. span to depth ratio were not included.

For the roof, good candidates proposed either a trussed or cable-supported roof structure. Those attempting cable-stayed structures needed to consider potential wind uplift conditions where the roof would undergo reversal of loads. Few appreciated the resulting out-of-balance horizontal component of cable loads where the back span was shorter than the free spanning length, omitting consideration of this in their overall stability model. Columns were not permitted to the end elevations of the roof, and candidates were marked down if columns extended above the terrace area to the end elevations. Good candidates considered the slope of the roof to allow for drainage.

The raking nature of the terrace support structure meant that stability across the stadium was easily provided using the triangulation of the terraces as props or ties. Rigid frames across the hospitality box, braced bays in end bays, or concrete cores were all suitable means of ensuring stability. In the long direction of the stadium, braced bays to the rear elevation, rigid frames internally or concrete cores around the stairs were all viable options. Good candidates identified the torsional wind forces induced if concrete cores or braced bays to the rear only were utilised, because of the offset in the centre of stiffness relative to the applied wind loading. Longitudinal wind load torsional effects tended not to be fully considered in stability models, when positioning stiff vertical stability elements. Candidates simply elected to introduce bracing or shear walls along main longitudinal grids.

Framing for the stadium could be either of concrete, steel or a mixture of the two. Some candidates struggled to understand the question as to where columns were not permitted in the concourse area. Section A-A of the sketch indicates heavy black dividing lines where assumed wall lines are located. Columns were permitted on these lines but not within the open spaces between. Good candidates identified the roof supports on the two internal wall lines, using a coupling arrangement between the front and rear columns to support the roof. Some candidates extended the roof structure to the rear, external to the rear wall line and in line with the access core. This was unnecessary and candidates were marked down for this. Candidates who used cable-stayed structures also needed to consider how the rear cables which anchored the roof down would interact with the stair cores. Some candidates showed cables through the core which would be unacceptable, and marks were deducted for this. To reduce load on the transfer structure, the better candidates proposed the stadium roof as a free-spanning cantilever from the Level 4 hospitality rear elevation. The sensitivity of long-span members to deflection and vibration was frequently not identified.

The ground conditions for the site were good. Better candidates proposed economical foundations using shallow pads either on mass fill or on areas where ground improvement techniques were used in the upper soils. Piled and raft foundations were both feasible but were likely to be uneconomical compared to pad foundations. Good candidates took into account the uplift on the rear foundations caused by the cantilever effect of the roof. Weaker candidates simply proposed piled foundations without considering other alternatives.

Section 1b

A business letter format was generally adopted. Most letters were acceptable, identifying design, programme and cost implications. Better scripts included annotated sketches. Most candidates correctly identified that adding another level of terrace would increase the weight of the structure and attract more wind loading. Good candidates identified that there may be planning restrictions on increasing the height of the stadium and that a column supporting the roof at the front of the hospitality box would become visible. This visible column contravened the client's requirements and would require the roof to be re-designed: this should have been highlighted. The poorer scripts proposed to continue the internal roof support columns to the underside of a raised roof, contravening the brief requirement that the roof should be free spanning with no columns.

Section 2c

For this question it was essential for candidates to consider the design of the roof. In general, the quality of the calculations was just acceptable, albeit most candidates opted for more straightforward elements, ignoring roof and the vertical stability systems, concourse and raking beams and foundations. Design guides were frequently used to size members, but calculations are expected in this section and such practice was marked down. Good candidates designed the primary roof elements, considering wind and uplift effects. Other critical elements which required design were the columns, terrace beams, concourse beams, foundations and stability systems.

Good candidates attempted all of the above. Some candidates did not attempt stability calculations and so lost marks. Some candidates carried out an overall building over-turning check, assuming the building behaved as a rigid block, but this was not a suitable stability check for a flexible structure like this. Deflection checks for long span beams and roof structures were sometimes omitted. Introductory Loading Schedules commonly used in calculation packages were not generally included and cladding loads were often omitted from designs. Less adequate answers were normally the result of poor time management.

Section 2d

The preparation of general arrangement drawings from candidates was mixed. Split plans were widely used, accompanied by an overall building section and details. Good candidates produced clear, neat drawings that identified principal member sizes, critical details, sections, elevations and dimensions. Some candidates produced general arrangement drawings that did not identify member sizes or reinforcement provisions. The question states that the drawings are for estimating purposes and so member sizes and reinforcement estimates are essential, and marks were lost for not identifying them. This was often the result of poor time management. The drawing of critical details varied in quality. Critical details appeared to be an after-thought for some candidates where simple elements of the structure were identified as a token or generic offering e.g. base plates etc. Good candidates identified the trickier elements such as the connection of the precast terrace elements to their supporting beams, the raking beam connection to columns, and the connection of the roof truss to the columns. Less adequate answers were normally the result of poor time management.

Section 2e

The method statement and programme were mixed in their success. Quite a few candidates produced very generic method statements and did not focus on the specific challenges of the erection and construction of the stadium stand. Suggested programmes were mostly in the same ballpark as the 6 – 9 months structure and 12 – 15 months overall estimated by the chief examiner. Good candidates thought about the construction sequence of the frame, including how the roof could be transported in segments, pre-erected on the ground and then lifted in place. Better scripts included detailed descriptions, with in some cases sketches depicting abnormal construction sequences. Poor attempts simply listed generic tasks which would be applicable to almost any project, and it is difficult to award marks for this. The programme was similar to the method statement in most scripts. Good candidates established programmes which considered the sequencing of the construction as outlined within the method statement. Poor programme attempts again listed generic activities with little detail as to how time scales were arrived at. Some programmes depicted a simple building structure only. Programme bars for M&E, fit-out and finishes, should ideally be included to demonstrate a candidate's appreciation of the overall building process. Less adequate answers were often the result of poor time management.

Overall

Candidates who attempted this question appeared to fall into two categories: those who understood basic structural concepts that could be applied to a stadium stand structure, and those whose structural concept knowledge was limited. The two viable and distinct structural solutions were often presented as a single concept with just a change of material, and often the solutions were not fully thought through. The question asked for the form and size of the principal structural elements, not simple beams and columns, and candidates were required to justify the elements chosen by the use of calculations not design guides. Critical details were often ignored in favour of unimportant details such as a simple bolted connection, or a column base, which are unacceptable unless they are critical to the design of the structure. The method statements and programmes were often generic and not specific to the project which is unacceptable, as they must relate to the actual structure and its construction. Time management is always a problem and this question was no different for many candidates.

Question 2: Exhibition hall for steam preservation centre

A moderately-large-span single-storey building was required. It was relatively simple without many constraints, thus allowing candidates freedom to propose an interesting structural form for at least one of their schemes. The client requirement no. 4 in the question hints at this. Candidates gained marks if they proposed a complex but interesting structure as one scheme and a straightforward structure as the other, then chose the straightforward scheme to develop in part 2.

Key design issues were the 18m clear span with high headroom, the high line load on each rail, the retaining wall, the lateral and longitudinal stability systems required in the absence of cores, and the large glazed end walls.

Candidates sometimes missed aspects of the brief. There are often useful hints given in the question requirements (and omission of constraints) thus it is advisable to read the question carefully and make short notes against each requirement before starting an answer. An example in this question was that some candidates applied the rail load to a complete track rather than each rail, i.e. halving the required load.

Section 1a

Some possible schemes for the roof structure and its support were:

- Steel trusses spanning across the 18m span and stabilised from the perimeter.
- Trusses across the full 30m width with light interior columns carrying vertical load only.
- Transverse 18m span portals, but these would need quite intrusive columns.
- Longitudinal primary structures on interior columns with secondary beams at close centres spanning 18m, which could be steel or precast.
- Arches or a barrel vault spanning from the top of the retaining wall to the ground outside the east wall.
- A space frame.
- An external cable-stayed structure, with robust corrosion protection.

Bracing needed to be place in the perimeter, and portal action could also be used for stability.

Glazed end walls could have primary vertical steel posts, trusses or cable trusses spanning between ground level and the roof structure with horizontal secondary beams.

The ground floor could be a ground-bearing slab on medium dense sand integrated with thickening under the tracks and main columns, or individual pads for slab and columns generally and strips under the track founded on the dense sand at 3m depth. The retaining wall could be cantilevered from the ground slab.

Most answers respected the spatial requirements although some placed truss elements within it, thus violating the brief. Few created space frames that spanned over the space, despite it being a valid solution.

Proper consideration of lateral stability was a significant issue and led to failure in some cases. Perhaps due to the lack of a stair core or vertical wall, this resulted in many candidates only providing a lateral stability system in one direction, and many neglecting to include plan bracing, thus leading to instability.

Foundations were often significantly over-designed, but in many cases ignored the 50kN/m line load on each rail of the train tracks.

Section 1b

The letter presented a problem with an existing drain that could be addressed in various ways. The most obvious was to bridge over the drain, and candidates who recognised that the spread of load from the foundations should not affect the drain gained marks. Cantilevering foundations over the drain, again with compressible material to avoid loading the soil above the drain, was also viable.

Some candidates proposed moving the building slightly to the south, this was acceptable but if it was the only suggestion it did not gain many marks. The track would still need to span over the drain.

Some candidates struggled with developing sensible solutions for the letter and few considered the impact that construction work would have on the existing drain, by failing to mention the need to survey and monitor it.

Section 2c

Calculations were often weak with few considering serviceability for horizontal deflection of the structure, which in many cases was the governing factor in their design.

Candidates also spent a lot of time on one component at the expense of other elements, forcing them to rush and make errors in the process.

Section 2d

Reasonably neat hand sketches were acceptable for details and illustrations of the scheme. Measured scale drawings are expected for the GA plans and sections.

Drawing quality in scripts was variable with some being barely legible and others showing well detailed plans and sections. Plans sometimes lacked enough dimensions and details did not cover interfaces with the external envelope of the building.

The examiners consider that the ability to communicate structural concepts with hand sketches and simple drawings remains an essential skill. and this part of the exam tests that ability.

Section 2e

Method statements were generally quite sparse in detail with some being little more than a series of bullet points. Very few candidates gave sufficient detail about how the structure was to be erected; instead there was a tendency to list actions which could apply to any building rather than to the candidate's scheme. This final part of the exam is often poorly attempted because of time pressure. Candidates should consider making notes for this section as they develop their scheme.

Programmes generally lacked sufficient detail as they did not reflect what was described in the method statement.

Marks were gained if difficulties with the transportation of long items or provision of splices were mentioned.

Question 3: Bridge for light rail transit system

The brief called for a light rail bridge over a wide road at skew of 15 degrees and at 5% gradient. The brief restricted the positions of permanent supports directing the most straightforward solution towards a simply-supported span of approximately 72m. The brief gave candidates the opportunity to develop a variety of solutions in Section 1a and to exercise creative expression based on their engineering knowledge. The available structural depth was limited by the set rail level and the clearance above the existing road. The live loads specified for the light rail system were of similar magnitude to highway structures, but because of the rail operating requirements it was anticipated that a relatively stiff structural arrangement would be needed. Thus it was expected that proposals would include braced steel through-truss girder solutions or arch options (tied-arch or network arch) with steel-concrete composite decks. This was recognised by most candidates.

Section 1a

The ground conditions indicated rock at shallow depth, but some candidates proposed piling without considering the competent stratum. Only a few candidates realised the stability issues with steep embankments particularly when the ground would be disturbed during the construction of the sub-structure. Some candidates omitted any explanation of how the bridge might be constructed when describing their options in Section 1a. The appraisal of scheme options was often unclear, and in selecting the preferred option there was an obvious bias towards the perceived “easier for the exam” solution.

Section1b

The alignment had to change to accommodate a curvature with 150m plan radius. From this change, it was expected to see candidates identifying the torsional effects, the centrifugal loads and the potential uplifts at bearings with their impact on the substructure. Many candidates identified the implications on the design, but some candidates failed to recognise the implications on construction in terms of programme and cost.

Section 2c

It was expected that the calculations would include sizing of main transverse members as well as main girders, with some consideration of lateral torsional buckling and transverse wind effects due to the non-negligible span. Many candidates spent a lot of time producing very detailed calculations for one member or calculating non-critical loads, and thereby ran out of time to include calculations for all the main elements including the foundations. It was expected that one abutment would be sized-up with consideration of earth pressures and the effects from the bridge articulation arrangement. Some candidates positioned the axle load at mid-span to calculate their worst bending effects but did not move it near the support to calculate the maximum shear. Some candidates ignored the axle load completely. It was disappointing to see some calculations not matching the final drawings, with no explanation of differences.

Section 2d

In general, the arrangement drawings were disappointing. Some candidates failed to provide basic information such as dimensions, levels, material specifications, information about bearings and articulation.

Section 2e

Candidates were expected to demonstrate how to minimise the traffic disruption during construction. Many candidates proposed structures to be erected by crane or by launching, which was acceptable, but they failed to demonstrate how to minimise disruption to the highways traffic. The method statements were generally found to be light on Health and Safety aspects and missing identification of main temporary works requirements. Most candidates presented an adequate construction programme.

Question 4: Multi-storey hotel

This question required the design of a multi-storey hotel with 3 wings at right angles on a ground floor podium. A top storey penthouse restaurant was included in one wing cantilevering by 5m from the main facade. The external façade was required to be free of any bracing or shear walls. The penthouse however was permitted to have external but not internal bracing. The column spacing was limited to a minimum of 9m below the podium.

The room size requirements were stated which gave column spacing options above the podium of 3.5m, 7m, or 10.5m longitudinally and 7m or 9m across the wings. This arrangement did not align with the 9m minimum column spacing below the podium and therefore transfer beams were required at the podium level to support columns above. Nevertheless, in order to maintain effective lateral stability, some of the columns, in particular in braced-bays or shear walls, must be kept continuous over the full height. The determination of a satisfactory column layout was among the main challenges in this question.

In order to maximise the use of the allowable structural zone, main beams were better positioned within the crosswalls. The floor construction could be in the form of a composite slab or PC slab. For a PC slab solution a slim floor construction was more appropriate to minimize the floor depth.

External cladding was not specified and any reasonable lightweight solution giving a robust, fire-resistant performance was acceptable.

The ground was dense sand at 2.5m bgl and ground water at 20m bgl. The deep ground water would not influence the design. Both shallow and deep foundations were feasible.

The letter was aimed to test the candidate's awareness of the effects of extra loads on podium roof, columns and foundations, and water-proofing issues related to the podium roof.

Example solutions are as follows:

- Steel/concrete frame structures with bracings/shear walls in both directions (in core areas or within the cross walls and corridor walls). A composite slab, PC slab, or insitu slab can be used for floor construction. Special attention to the diaphragm action of the floor construction is imperative.
- Steel/concrete moment frame solutions in transverse direction with bracings/shear wall in the longitudinal direction. Again, the floor diaphragm action needs to be thoroughly examined.
- A braced concrete structure between the base and podium level with a transfer structural system at the podium roof to support braced steel frames above this level.
- Same as the above solution but with the use of a modular structure above the podium for side wings only.

Section 1a

Most candidates came up with a column layout meeting the client requirements, although some opted to use a line of columns at the middle of corridors between the rooms which was not acceptable. However, a significant consideration was missing from most scripts, in that almost all columns above the podium were assumed to be discontinuous, i.e. columns at 3.5m/7m intervals supporting the wings all sitting on transfer beams at the podium roof level. No thought was given as to how lateral loads and their associated overturning moments on these columns would be transferred to the foundation.

Some candidates provided two distinct transfer systems by placing transfer beams at podium roof level for one scheme and placing a thick-plate transfer system at the top floor for the other scheme. The latter may be a possible solution provided it can be shown that there is an adequate lateral-load transfer system to transmit the loads to foundation. Nevertheless, a quick cost comparison of the two systems may still point to this solution being inappropriate.

In general, candidates appeared to have difficulty in developing a second distinct solution. The first scheme was usually discussed reasonably well but when it came to the second scheme, they seemed to be trying to find a different version of their first scheme (with almost identical load paths) without enough discussion/initial sizing.

The two distinct solutions were required to have significantly different structural systems, such as different means of lateral stability or different vertical load carrying systems and different foundation systems, etc. Changing from a braced steel frame to a braced concrete frame with an otherwise similar arrangement was not be considered a second distinct solution.

Time management also appeared to be a main hurdle. Feasibility calculations sometimes were not done and sometimes were overdone. Presentation, if improved, can bring more marks.

The choice of foundation appeared to be based on choosing between standard deep or shallow foundations without enough discussion of why and how the solution had been reached.

Section 1b

Most candidates recognised the impact of extra loads on columns and foundation but failed to offer clear solutions and advice on the impact on the design and construction. Lack of good grammar in writing technical reports in order to put the message across appears to be still a major issue.

Section 2c

Calculations generally covered simple elements such as slabs, secondary and main beams, and columns. A large number of candidates failed to produce sufficient calculations for transfer beams, lateral load resisting systems down to the foundation, the penthouse cantilever, and the basement retaining wall, all important key items in this question.

When designing columns, generally the effects of bending moments generated through framing action or notional horizontal load were missing.

The need for serviceability checks was often missed by candidates. This in particular is of immense importance when checking transfer beams or the impact of frames swaying on columns (P-delta effects).

Section 2d

Many candidates produced drawings which lacked sufficient information to allow preparation of a cost estimate. Most were only able to produce a handful of plans, some which missed dimensions, and did not provide clear foundation layouts or sections. Building sections and elevations generally were poorly presented or missing, and critical details provided were generally inadequate or erroneous. For example, RC beams as big as 2.5m wide x 1.6m deep were presented with inadequate and incomplete reinforcement details.

Drawings should ideally be to scale, if that is not possible for any reason then they should be in proportion.

Some candidates used different pen colours, line types with the aids of notes and highlights to show schemes and drawings clearly, which was helpful in clarifying their thinking.

Section 2e

Many candidates did not identify the critical paths in their programmes and only provided a list of activities. A number of scripts did not depict clear sequences - mobilization, enabling works, temporary works / erection and permanent works for safe construction in the method statement, though most were able to provide typical construction sequences. Unfortunately, many of the scripts appear to run out of time at this section and only presented incoherent programmes, thus losing valuable marks. Candidates commonly produce a statement and programme which are too general, and lack specific discussion of the proposed structural solution. Programmes frequently underestimated the time taken to complete a building ready for occupation once the structure is complete.

Question 5: Sailing academy

This question required candidates to design a sailing academy comprising a yacht inspection area with associated two- storey elements to include offices, cafe, function and training rooms together with a small race control room at roof level. The function room extended partly over the inspection area and the cafe had an open terrace above the Level 0 rooms. Built on the coast, the structure required a large door facing the sea to facilitate launching of yachts. There was no restriction of columns in the ancillary areas, but the inspection area needed to be column-free and also have a roof that allowed light into the hall. Shallow ground conditions above -6.0m were poor but were suitable for ground improvement. Below that level was a band of silty clay then competent sandstone at -9.5m.

Section 1a

A variety of structural solutions were possible including load-bearing masonry, a steel frame with metal deck flooring, timber or precast floors. Most candidates chose a solution in masonry or steel with a few opting for reinforced concrete or a mixture of materials. Most candidates chose piles for the substructure with pile caps. A few candidates opted to use a suspended slab on piles. Although the shallow ground was suitable for improvement only a limited number of scripts proposed this together with a ground-bearing slab. Very few candidates identified that a dominant opening for wind loading was present although some did note the possibility of reverse wind load to the underside of the members located over the scrutineering/inspection hall. While detailed design of the doors was not required, candidates were expected to recognise that the lateral support to the doors would be a primary structural element. Solutions to supporting the function room above the inspection hall included a cantilever structure, a deep truss between the floor and roof, or a shallower truss at roof level with hangers to support the floor. All were viable but required detailed calculations for this key part of the frame. Many candidates failed to include supporting 'rule of thumb' calculations to justify their schemes. Better scripts included clear sketches to assist explanation of the schemes, and these are particularly helpful when describing load transfer and stability; however, candidates providing standard answers to explain stability and load transfer gained few marks.

Section 1b

The letter asked candidates to write to their client after the primary structure had been completed explaining the implications of the maximum high tide rising to 1.0m above Level 0 during storms likely to occur every two years as a result of global warming. Some candidates did not read the question and recommended raising the whole building to be above the high tide which would not be possible given that the structure was complete, and consequently gained very few marks. Solutions offered included: flood gates at doors; allowing the inspection area to flood while raising the level of mechanical and electrical services; the creation of a bund with flood barrier around the building. Given the high floor-to-floor height, some candidates suggested inclusion of a new floor above the high tide in the ancillary areas with steps down to the inspection hall. A key issue of the high tide would be buoyancy of the ground floor slab which was not addressed by many candidates. The standard of letter writing continues to be very poor. Candidates are expected to write a clear, professional response that addresses the issues in the question and avoids standard answers.

Section 2c

Most candidates provided calculations for the simple structural elements: beams, slabs, internal columns and truss members. However, calculations were often oversimplified without cross-reference to codes of practice or published tables. In Part 2c more detailed scheme calculations are required to justify member sizes including deflection and shear for beams where appropriate, and moments induced by connection eccentricity in the case of columns. The majority of candidates also considered the lateral stability of the structure, providing calculations for bracing or shear walls. Some candidates however, presented no calculations for stability with some suggesting that the mass of the structure was enough to cater for lateral wind loading. Candidates provided basic calculations for piles but often neglected to consider the design of the pile cap.

Many candidates typically ignored the layout of the building or failed to identify the loadings applied to the critical elements within the scrutineering/inspection hall area of the building such as the roof member under reverse loading and door support beam. Marks were lost because of this.

Section 2d

The presentation of drawings was of a reasonable standard; however, the level of detail was often insufficient. Many candidates failed to include plans at each level and often omitted elevations and sections. Candidates often provided standard 'general notes' which had no relevance to the particular issues of this question such as corrosion protection in a coastal environment.

Critical details chosen were mostly limited to one or two simple junctions showing the structure only. Better scripts provided clear details that showed the structure in its interface with other elements such as insulation and cladding indicating a more comprehensive understanding of building construction.

Section 2e

Many candidates provided stock answers for the method statement without addressing the specific issues of the question such as working near water or fluctuating tide level. Method statements were often satisfactorily detailed at the early stages of surveys and excavation but then referred to common construction practices for the upper levels.

An overall programme of around 18 months was considered reasonable for the project.

Most candidates provided programmes ranging from 6-10 months, which was far too short, indicating a lack of experience and understanding of building construction.