The Institution of StructuralEngineers

Examiner Report – July 2023

Chartered Membership Exam – July 2023

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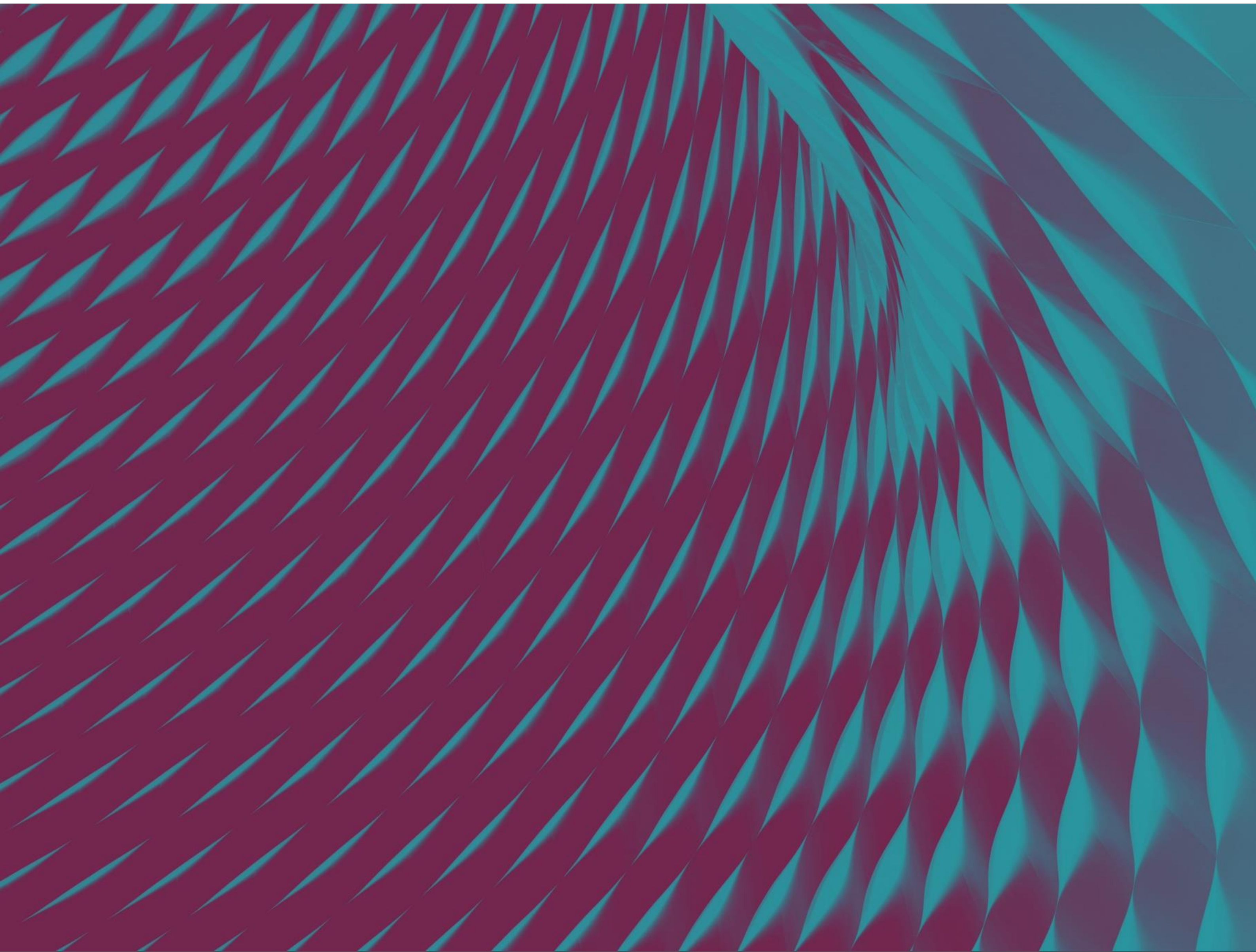

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Notes on the reports

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

Comments from the Examination and PRI Manager

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

Candidates continue to leave page numbers blank on scripts which results in Marking Examiners not always being able to follow an answer script logically. Candidates are reminded that the final 5-10 minutes of the exam should be used to ensure that their papers are in order and ready for collection at the end by the invigilators.

Candidates are reminded that the use of any paper that has not been provided by the Institution is prohibited. Tracing paper and sketching paper can be taken into the exam however anything written on these pages will not be marked and can cause a significant loss of marks.

A general observation from examiners is that many candidates continue to adopt a formulaic approach in their responses to Part 1b and Part 2e, using 'standard' wording and sketches possibly taken from an exam preparation course. Candidates should note that examiners are looking for bespoke solutions which address the specific requirements of the brief and marks will not be awarded for generic answers.

The Examinations Panel have created and made available a preparation guidance document that all candidates are encouraged to download and use as part of the revision, as well as taking a copy in to the exam for any last-minute reminders.

Please note that there is no report at present for Q5. This may be included in a later version of this report.

Question 1 – Medical centre building

The question required the design of a five-storey building with two rectangular wings at 120 degrees connected by a central triangular area and with one storey below ground.

The key challenges were requirements for movement joints, column arrangement (taking account of column spacing restrictions), large span beams, floor set-back at level 3 and lateral stability considering large glazing panels in one elevation.

The building is angled in plan with an overall length in excess of 120m; therefore, movement joints are necessary to avoid thermal and, in the case of concrete structures, shrinkage movement due to the length of the building. The most natural positions for these joints are at intersections of the rectangular wings and the triangular area. There are several possible grids but the column spacing at level 3 needs to take into account the requirement for a 5m setback and candidates were expected to provide transfer beams to deal with this.

The floor construction can be in the form of composite floor, two-way RC slab, or precast slab with reinforced concrete topping. The floor construction must be adequately robust to transfer the lateral loads to stability points in diaphragm action and the total thickness of the floor slab, beam, and ceiling finishes should not exceed the specified structural zone. In the case of a precast floor construction, a minimum of 100mm thick insitu reinforced concrete topping is required to provide the diaphragm action.

The lateral stability of the wings can be provided by core walls, perimeter walls (ideally using a series of short walls between glazing panels to satisfy the percentage glazing requirement) or moment frames in both directions. The stability of triangular area can be provided by shear walls.

Foundations can be isolated pads on the dense sand. Piled foundations extending into the dense sand is a possible but uneconomical solution. A raft solution is also likely to be uneconomical where wide column spacings have been used. Columns either side of movement joints must be separated to allow differential movement to take place; however, this does not need to continue through the foundations. Foundations to shear walls need to be designed to resist the overturning moment due to the lateral wind loads. Ground water is at 10m below the ground level and is not considered to be an issue for pads bearing onto the dense sand.

The letter requires candidates to address the addition of a plantroom to the roof. This will increase the overall height of the building and will also increase the roof load which, depending on the plantroom's location, could generate larger loads on the transfer beams and may require an increase in the structural zone increasing the height still further. An increased building height means larger wind loads and a heavier roof load results in larger notional horizontal loads, both of which could affect the lateral stability of the structure and the column/foundation sizes.

Section 1a

Generally, candidates did not recognise the importance of the movement joints in the structure. A small number of candidates provided a single movement joint at the centre of the triangular area with double columns obstructing the main entrance and resulting in an impractical solution.

Many candidates proposed impractical or uneconomic column grids, and some used fewer than the permitted 8no. internal columns which led to larger spans and heavier structures than necessary. A number of candidates used 5m or even 7m long cantilever beams as primary methods of support without checking the adequacy of the back spans or columns supporting them and without considering the resultant excessive deflections and the effect on the supported glazing. A significant number of candidates included columns 5m off the southern elevation in an attempt to remove the need for a transfer structure at level 3. This was contrary to the rule on internal spacing, which stated that a minimum of 7m should be observed except at the two cores.

Most candidates failed to provide two distinctly different solutions in terms of the stability system and load transfer. A change from concrete to steel with no change to the stability philosophy and a similar column grid is not distinctly different. The second option was often steel and almost always included unfeasibly large spans. The reasons for scheme choice were consistently inadequate; many candidates used the argument that steel was too complicated for local labour. The quality of the sketches in the majority of scripts was below standard, often providing incomplete information and with generic load transfer diagrams. Few candidates mentioned that, as a medical building, vibration could potentially be an issue.

Foundation solutions were generally raft, piled, or pad foundations. A pad foundation solution was the most economical approach considering that there was no constraint on the projection of foundations beyond the building footprint. A number of candidates opted for a raft solution not appreciating the spans/loads involved and amount of reinforcement and concrete required.

Section 1b

The letter presentation was generally reasonable. Most candidates recognised the impacts of the proposed relocation of the plant room; however, a significant number omitted to discuss the effect on the foundations and the stability due to the building height increase and very few provided design suggestions to address these impacts.

Section 2c

Calculations consistently lacked clear narrative; element design was adequate but the understanding of how the structure functioned and how loads were derived was not well demonstrated. Most candidates suggested that frame action contributed to the stability, but none included any resulting moments in the calculations. In a number of cases calculations for transfer beams were missing, or candidates struggled with the magnitude of the loads generated and encountered issues with the design. In designing the columns, the bending moments (nominal bending moment or bending moment from a framing or cantilever action) were generally missing.

Candidates generally over-simplified the design of beams by assuming simply supported beams or cantilevers with no back spans. This led to under-designing elements due to the lack of consideration given to bending moments over continuous supports. Serviceability was also not sufficiently considered, which is problematic when proposing cantilever beams as part of the primary structure.

Several candidates concentrated on the overall stability such as overturning, sliding and uplift of the structure instead of the lateral stability. Calculations for the stability were often incomplete or inadequate. The load transfer between the floor diaphragm and shear walls adjacent to a floor void was appreciated by very few candidates.

Foundation calculations tended to focus on the foundation rather than the ground. A raft was a common design even though this was inappropriate for good ground and widely spaced point loads. When the raft calculations showed very low bearing pressure candidates did not think to use pads instead which would have saved a considerable amount of material. Piles were often specified which were not an economic solution for the ground conditions. Retaining walls were generally secant piled walls.

Section 2d

Drawings were very mixed in terms of quality; most candidates presented a reasonable floor plan, typically using a split plan for presentation efficiency. More often than not details were limited to RC details and did little to describe the key interfaces in the question. Details continue to be an issue, with too many either reproducing stock details or providing details deemed not critical.

Section 2e

As is common with this section, most candidates provided generic method statements that did not deal with the unique aspects of the scheme they had designed; however, some candidates did manage to address the construction of cantilevering elements and temporary instability related issues. Few candidates discussed crane positions or possible phasing as a consequence of the building having two wings and movement joints. The Gantt charts were generally less than satisfactory and rarely showed correct overlap of activities. The construction duration was generally underestimated by most candidates.

Question 2 – Airport secondary fire station building

Introduction

The main challenges in this question were the long span roof over the fire engine area and the heights and varying roof slopes of the single-storey building.

Section 1a

There were many feasible framing layouts and material choices to give two distinct, viable and sustainable schemes and it was therefore possible to have distinct differences on framing, stability, foundations and load paths. Viable options were:

- A two span portal frame east to west for the east and west wings with a separate single span portal for the southern part of the west wing.
- Separate single span portals for the east and west wings due to their different roof heights separated by a north to south movement joint.
- A braced structure using the internal partitions in the west wing to reduce the span of its roof members with a separate single span for the taller east wing spanning either east to west or north to south.

A braced structure is more rigid than a portal one and better suited for such a building in an exposed location.

Materials for the frame could be steel, concrete or timber. Masonry could also be used for partitions. Stability frames or flat panels could be provided at various partition and/or elevation locations thereby providing different load paths.

Due to the good ground conditions, foundations for this single-storey building could be ground-bearing strip footings with local thickening or pads and many candidates recognised this. Long-span options required heavier foundations due to the increased reactions compared to short spans. Piled foundations could be difficult to justify and a raft foundation for the east wing might not be appropriate given the large column spacings.

Generally, the substructures were poorly designed compared with the superstructures. The design of the ground floor slab was often ignored, or just noted as ground-bearing without any mention of the jointing arrangement in the slab, make-up under the slab etc. In some instances, the script stated trench fill founded on the clay rather than on the competent sand and gravel, resulting in digging through running sand which would have required dewatering measures. A number of scripts suggested piled foundations, which was unnecessary, and one script noted that a piled raft would be a suitable solution. Where deeper pad foundations were used, there was no comment on the pressure bulb under the pad and no consideration of whether the pressure under the foundation exceeded the safe bearing capacity of the ground at the water table level.

The good scripts produced distinct schemes with variation of the options; however, many candidates could offer only minor variations and insufficient changes to vertical and lateral load paths. Candidates' ability to produce two distinct solutions remains the biggest challenge; this also applies to the general concept of lateral stability. Candidates who proposed load bearing masonry tended to overlook the stability aspects of the large wall panels with respect to buttressing and wind post requirements as well as the need for movement joints. Some schemes used concrete roofs resulting in heavy column and foundation loads. Where steel trusses were used, many candidates did not comment on the need for bottom chord bracing required against wind uplift.

Some candidates produced schemes that were difficult to understand with small, unclear sketch layouts with legends that were hard to follow and, in some instances, did not match the sketch plans.

Scheme comparison varied from basic tabulated to quite detailed; however, for some, local practice was an important factor rather than the technical superiority of the alternative.

Section 1b

Candidates recognised the increased vertical loading on the structure and foundations due to the extra floor as well as the increased wind loading resulting from the greater building height. Some good scripts also suggested a location and size for the first floor and associated access. However, several scripts failed to consider how stability was affected by the modifications for the additional floor. Many scripts discussed non-structural aspects, such as extra fees and planning costing candidates valuable exam time.

Section 2c

The calculations generally indicated that candidates had a good understanding of element design. The standard of calculations varied from over-simplistic to too detailed. The better scripts focussed on key members which were then easy to identify in section 2d. Many candidates did not select sufficient key members and instead used simple elements, while some struggled for time, designing too few elements to gain sufficient marks.

There were scripts that calculated the overturning and sliding stability of the whole building which by inspection of its size and weight was unlikely to overturn or slide. Instead, what was required was the design of the structural members that provide the stability. Calculations often ignored wind uplift and dominant openings.

Section 2d

Plans for foundation, ground floor and roof levels as well as sectional elevation(s) were required to convey the selected scheme for quantification. Critical details such as the junction between the east and west wings, plan bracing at a corner connection, members at an opening, etc. would also be appropriate.

The standard of drawings varied widely and was generally not very good. Very few produced a comprehensive suite of drawings and key details for their selected scheme. Some candidates omitted critical details and others just showed non-critical reinforced concrete details.

Section 2e

Method statements could have included the following:

- Constraints of working in a live airport, access, plant movements and height restrictions

- Checking ground conditions and services
- Foundation construction
- Long span members' erection and connections
- Temporary stability
- Starting at cores & sequencing
- Ongoing check of as-built loading & geometry

Method statement and construction programme remains a weak point for most candidates with some just providing a list of operations. Buildability is an essential part of the brief. Good scripts coherently included many of the main construction activities and credible programmes with critical paths in some instances. Some candidates also discussed ground preparation for construction of the substructures, and temporary bracing for steel columns / members during erection. In several scripts it was unclear if solutions were conceived with a clear understanding of safe construction, buildability and timeframe.

Overall

This building is one that most structural design offices would be expected to cope with relatively easily. It is therefore disappointing that so many candidates struggled to produce two distinct schemes and follow through their selected scheme with sufficient calculations and drawings.

It would appear that for many candidates, better time management could have helped as some produced scripts that were too detailed in parts at the expense of critical coverage. Nevertheless, many candidates produced acceptable schemes to pass the examination.

Question 3 – Water pipe and access road bridge

The brief called for a 50m span bridge carrying a 5m carriageway road with a 1.2m wide pedestrian footway at one level and a 3m internal diameter carrier pipe full of water 12m below the road. The structure crosses a natural gorge with steep rock slopes. The top of the gorge is 38m above road level and the bottom of the gorge contains a river with no construction permitted below water level. The brief provided the usual uniformly distributed imposed loadings for road traffic, footpath, and maintenance as well as the self-weight of the steel carrier pipe. The weight of the water inside the pipe had to be calculated by the candidates. Maintenance walkways with pedestrian handrails were required along either side of the pipe.

The bridge is in a mountainous region with restricted access due to the presence of existing tunnels on each side of the gorge limiting the sizes of components for delivery to the site.

Section 1a

The question and the site constraints gave limited choices of structural forms and methods of construction. Steel trusses, whether two independent trusses for the upper and lower tunnels or a single deep truss with two deck levels were the obvious choices, with arch bridges, in their various forms, considered by many candidates. The difficulty, however, was in their method of construction, particularly in relation to the limitations on maximum length and sizes of the components due to the access restrictions. Access from the existing tunnels was possible, subject to considering the internal dimensions of the tunnels as part of the construction method. Given the many site constraints, the consideration of buildability was therefore critical from the early part of the exam.

Most candidates included an introductory review of the brief, identifying key constraints and options explored before moving into scheme appraisal. Many of the scripts included two distinct options; however, the descriptions regarding load path, structural framing, structural behaviour, stability, construction method and maintenance aspects were not sufficiently covered by some candidates. Some scripts proposed bridge decks of length more than the required span length leading to excessive rock cutting and associated risks for undermining the existing tunnels. In other cases, the deck length proposed was insufficient to cover the gap.

The structure needed to have sufficient stiffness to minimise deflection of the carrier pipe under the effects of imposed live loads. Within the scheme proposals of section 1a, candidates were expected to consider this criterion. For rigid structures such as a deep truss or well-proportioned arch bridge, the constraint was deemed to be met; however, for flexible structures such as cable suspended bridges, the deflection of the deck can be significant, and the candidates were expected to consider this. Some candidates proposed that the lower deck carrying the water pipe should be hung 12m from the upper structure without provision of any plan bracing. This was not considered acceptable as the lower water pipe would swing significantly transversely under wind loads. Some preliminary sizing using engineering judgement or span to depth ratio was generally included within Section 1a.

The existing ground condition was competent rock with high allowable bearing pressures except within the zones of tunnel portals. The limiting ground bearing pressure at the tunnel portal zones implied that the main support of the bridge should be located below the lower tunnel and above the high-water level. However, many candidates proposed main support within the tunnel portal zone without assessing if the allowable bearing pressure would be exceeded.

The scheme comparisons and recommendation were generally very generic with no specific arguments on the form of structure and method of construction being proposed. Comparisons of scheme for embodied carbon was considered by only a few candidates and reference to Whole Life Cost was also missed out by most candidates.

Section 1b

In section 1b, the Client advised the presence of a newly identified fault line at the top of the rock face within 15m of the right bank. The question asked for an explanation of the design and construction implications and any necessary modifications. Although the question did not provide further details of the fault line, it suggested that the area would not be suitable for heavy construction plant. The candidates were therefore expected to review their design and method of construction to avoid the need for heavy construction plant in that area. Given the site constraints, the top banks provided the main access for cranes and installation of components. The exclusion zone would thus require the cranes to be set-back by a further 15m. As the question also stated some constraints in the access to the site, it is unlikely that specifying larger cranes would be the right approach; thus, this new constraint would also have an impact on the detail design as some structural elements may require additional sub-divisions introducing new splices and reducing the weight of components. This would also have an impact on the construction programme. Many candidates simply proposed to lengthen the bridge to span over the fault line whilst maintaining the need to deploy heavy construction plants in the area. Very few scripts included annotated sketches which complemented their text. Candidates generally lost significant marks in this section.

Section 2c

The calculations for section 2c were generally not sufficiently developed to justify the dimensions of key structural elements. Calculations were required for the superstructure, substructures and foundations and many candidates failed to cover all the main and essential structural elements. Although wind parameters were provided in the brief, candidates should be reminded that if the proposed structure is not expected to be wind load critical for the sizing of main structural members, a simple assessment or a statement could be included in their script to explain why wind load can be ignored.

It was expected that the candidates should carry out a calculation on the foundation loads to ensure that they are within the allowable bearing pressures stated within the client's brief. The question also gave specific requirements on the deflection requirement for the water pipe. For rigid structures such as an arch bridge or a deep truss, it was considered acceptable to provide a statement explaining why the deflection would not be critical. Calculations were however expected for candidates choosing beam type or flexible decks.

Candidates should also be reminded that the design of bridge structures can be governed by the method of construction with some of the most critical load cases occurring during construction rather than during the in-service condition. For instance, incremental launching method was a popular choice for this question, but most candidates failed to identify the effects induced during launching and their implications on the sizing of the main structural elements. This resulted in some structures being unstable or unsafe during the construction stage.

Section 2d

Drawings in section 2d were generally poorly presented and more in the form of rough illustrations rather than clear sketches showing plans, elevations, sections, details, and notes. There was a general lack of key dimensions, as required for estimating purposes. Many candidates prepared drawings that did not correspond to the information presented in their scheming or calculations with contradictory information in terms of span arrangement, articulations, dimensions and even foundation types. For the critical details, most candidates simply presented typical generic details rather than details specific to the site condition or to the structures they had proposed. Given the constraints at the zones of the tunnel portal, it was expected that the scripts would include a longitudinal section and an elevation at the abutments showing the interface arrangement between proposed abutment and tunnels, and indicating how undermining the existing foundation of the tunnels was to be avoided. The sketch of the abutment should also demonstrate how the bearings and expansion joints can be accessed during future inspections and replacements.

For compliance with site access restrictions, it was expected to see the proposed splice locations for delivery and erection in any structural steelwork solution.

Drawing notes were generally covered sufficiently with regard to main material grades and, finishes; however, this section should also include structure-specific information; for example, if a cable supported structure is being proposed, it is expected that notes relating to the tension components will be included.

Section 2e

The method statement in Part 2e asked for a description of the safe construction of the works and consideration of any temporary works required. Generally, the proposed method statements were presented in the form of a sequence of headline activities in very broad terms, which were then repeated in the construction programme. The use of simple diagrams identifying the most critical construction activities, the type of plant and/or temporary works required, and any safety measures considered were expected to be included. Unfortunately, not many candidates were able to provide this information. Where candidates recommended a bridge launch it was generally forgotten that the launch would occur at a higher level and thus would also need an additional stage for deck lowering onto the final level.

The construction programme was covered by most candidates with generally acceptable overall construction periods except for a couple of candidates who had significantly underestimated the number of months required to build their bridge proposal.

Question 4 – Distillery and museum

Section 1a

This was a reasonably straightforward question but there were still aspects that needed careful consideration, and these were not always dealt with adequately by candidates.

- Some candidates contravened the brief by providing a flat roof rather than the pitched roof specified.
- Many candidates did not provide suitable foundations for the structure, particularly missing the need to consider the heavy loading beneath the vats and the potential for differential settlement.
- Little mention was made of the ground floor slab.
- Little consideration was given by candidates to maximising the economy of the scheme.

Some candidates seemed to spend too long on this section and ended up rushing other parts of the paper, failing to get sufficient marks as a result. Despite this, Section 1 a) was often poorly attempted, with many candidates struggling to articulate the full functional framing and stability with sufficient clarity.

Section 1b

The letter required candidates to consider an increased clearance over the vats. This was not considered a difficult change, but some candidates still struggled to explain the structural implication of raising the roof or did recognise this as a solution at all.

The presentation quality was considered by the examiners to be poor, with only a few candidates writing a letter to a standard that could be sent out to a client.

Section 2c

The quality of the calculations was variable. Most candidates were able to identify the key elements, but many did not have time to design all of them. A stability calculation was generally attempted. Examiners felt that candidates appeared to lack practice in producing hand calculations, whilst many relied on guidance documents to select sizes without showing calculations.

Section 2d

Candidates were expected to provide plans for the key levels of the building and a section. Many candidates did not produce adequate drawings for estimation purposes. In many instances the section was incomplete, inadequate, or not drawn. Limited critical details were drawn and those prepared were poorly presented by most candidates. Examiners found that few candidates were able to draw legible and meaningful general arrangement plans, section, and critical details, possibly as a result of the prevalence of CAD in most practices.

Section 2e

Some candidates did not attempt this section. Others were not able to score adequate marks due to incomplete method statements which did not entirely cover the construction sequences of both the museum and distillery. Many candidates' construction programme showed shorter or much longer time frames than required.

Examination Statistics

The following section provides some general statistics to provide an overview of candidate performance during the exam. A total of 417 candidates attempted the exam.

Pass rates by question

Question	Pass rate
1: Medical centre building	18.77%
2: Airport secondary fire station building	45.10%
3: Water pipe and access road bridge	5.88%
4: Distillery and museum	34.21%
5: Grandstand new roof	100.00%
Total	23.26%

Pass rates by exam attempt

Exam attempt	Pass rate
1st Attempt	54.64%
2nd Attempt	12.37%
3rd Attempt	13.40%
4th Attempt +	19.59%

This table does not include the total number of candidates in each attempt number, only those that passed.