Part 3 and Associate-Membership examinations, April 1999

The examiners' reports are to be read with reference to the April 1999 question paper available from the Institution at £3.00 for members and £4.00 for non-members.

Part 3 report

This year's examination was attempted by a total of 807 candidates, a slight increase in comparison with last year. Of those candidates, 413 took the examination in the UK while there were 394 candidates abroad. Of those non-UK candidates, 340 took the examination at the Hong Kong centre.

The UK pass-rate was most satisfactory: 205 candidates passed, producing a pass-rate of 49.6%, an increase of 6.1% compared to last year. The pass-rate elsewhere was disappointing: 116 candidates passed, producing a pass-rate of 29.4%. At the Hong Kong centre, 100 candidates passed, producing the same overall pass-rate, 29.4%. The overall pass-rate for the 1999 examination was 39.8%, the best performance since April 1995.

Pass-rate for questions

Question 1 (industrial building) was attempted by 53 candidates, of whom 19 passed, a pass-rate of 35.8%.
Question 2 (storage building extension) was the most popular and was attempted by 244 candidates, of whom 96 passed, a pass-rate of 39.3%.
Question 3 (light urban railway bridge) was attempted by 104 candidates, of whom 41 passed, a pass-rate of 39.4%.
Question 4 (chemical storage reservoir) was attempted by 32 candidates, of whom 12 passed, a pass-rate of 37.5%.
Question 5 (bell-tower) was attempted by 142 candidates, of whom 52 passed, achieving a pass-rate of 36.6%.
Question 6 (public assembly building) was attempted by 222 candidates, of whom 99 passed, achieving the highest pass-rate of 44.6%.
Question 7 was attempted by only 10 candidates, of whom 2 passed, achieving a low pass-rate of 20.0%.

The Examinations Panel members, on behalf of the Institution, continue to review all matters concerning its professional examinations. This includes the implications of SARTOR, 3rd edition, on the content and format of the question papers; maintaining, upholding and improving all aspects of administering the examination cycle; preparation course content; training, guidance and development of marking examiners; instructions and feedback to candidates. The Part 3 Chief Examiners once again highlight the common areas of failure among candidates:

(1) Candidates must answer the set brief, refrain from changing the nature of the question, and provide relevant information with regard to alternative schemes offered.
(2) Candidates must improve general examination technique, time-management (attempting every part of the question), and the lucid expression of their engineering concepts and judgments.
(3) Candidates must improve their standard of drawing, detailing, basic sketches and calculations, while improving their communicating of engineering principles and concepts expressed in letters to clients and method statements.

Question 1

This question concerned a 100m × 60m industrial building to be served by an arrangement of electric overhead travelling (EOT) cranes. A 200Kn. lift was required and six 20m span cranes were available each having a capacity of 100kN.

These were the main constraints around which candidates were asked to plan the arrangement of columns. To make matters a little more interesting ground conditions comprised tapering thickness of variable quality clays overlying sloping bedrock. An observation platform was also required above the cranes over most of the building area and a 20m opening requested in one face of the building.

The question sought to test ability in considering the options available to construct the building and its foundations. On completion of the building the candidates were asked to consider the client's request to achieve a 300kN.lift.

The building superstructure was generally well attempted and most candidates demonstrated the ability to achieve the client's requirements in terms of internal planning. Similarly, the problems of the large opening and observation platform were well tackled.

Fewer candidates appreciated the effects that the ground conditions would have on differential settlement of the building. The standard of drawing (apart from those who had obviously had experience in the steel industry) was poor and few were able to produce information that could even start to be used for estimating purposes.

Disappointingly, the letter to the client telling him how to achieve his 300kN lift was more often a statement requesting extra fees or one saying that it could not be done. Those who gave it a little thought recognised that, with certain limitations, the request was easily accommodated.

Question 2

An existing two-storey steel framed building was to be extended by a further three storeys. The existing building was founded on pads below the water table on uniform competent ground. As part of the project the asbestos cladding on the original building was to be removed and the completed building metal clad. The client's brief stipulated that the building line of the extension had to match that of the existing building. No additional loading could be applied to the existing building; neither could the extension be constructed off any part of it. After the building was designed the client asked for a basement, and candidates were invited to write saying how this might be achieved.

The question sought to test the candidate's ability to design a fairly straightforward building in slightly unusual context. It was expected that columns would be threaded through existing floors (permitted by the question) to support the extension. A suitable method of bracing was also needed.

Generally speaking, the extension was well attempted and most candidates were able to introduce foundations in between existing ones as well as considering the implications of stability. Quite a few, however, tried to simplify the question by introducing columns outside the building line or cut through existing beams to make way for the new structure.

The client's request to introduce a basement would have led, in some cases, to the undermining of the existing building foundations (even though founded lower than the requested basement), or a 'swimming pool' with many failing to recognise the implications of groundwater.

Drawing work was of a low standard and few candidates produced a set of drawings that could be of use for estimating purposes. Of extreme concern was one candidate who used a set of transparent stick-on standard notes and crossed out most of them as not being applicable to the project.

Generally, the standard of competence, apart from the mere ability to design structures, continues to be of concern. Few candidates can draw even basic sketches and a large percentage appear never to have been subjected to any other than routine design office work. Many blame computers for this but the reality is that many seem to have little decision-making experience or responsibility for running projects.

Similarly, too few have the ability to tackle unforeseen problems and have been conditioned to do the minimum when extra work beckons. Adequately prepared candidates can pass first time and at a young age. Employers must start again to take more responsibility in training their successors. Sponsors should similarly take responsibility in satisfying themselves that their candidate is competent. The Institution must take a lead, otherwise Chief Examiners reports are not going to change.

Question 3

The question required candidates to design a bridge to carry a light urban railway over an impounded dock basin. The following are key features of this question.

The specified clearance envelopes together with other geometric constraints dictated that fairly large spans of around 85m would be required. The depths available between rail level and the clearance envelope would lead to some form of through or half-through girder bridge, although other forms of structure such as arches would also be feasible. Designs for the main spans in both steel and concrete should be feasible.

The brief allowed the dock to be closed during construction so it would be acceptable to propose *in situ* concrete construction with falsework supported on piles. Imposed loading from the railway included significant horizontal loads due to traction and braking. Some form of piled foundation would be required adjacent to the existing quay walls to eliminate the application of vertical or horizontal loading to the walls. Construction of a pier within the dock basis would require careful consideration of construction methods. A requirement to span an access road on each side of the dock basin presented a further constraint on span arrangements.

The question was intended to offer candidates the opportunity to design a substantial heavy civil engineering structure and tackle a number of challenging construction-related problems. It was also hoped that the question would not unduly restrict candidates in developing interesting and practical designs.

A reasonable range of structural solutions was considered as options for the main spans. These included through and half-through steel trusses and plate girders, arches in both steel and concrete and cable-stayed structures. Most candidates chose to go forward with and develop a through steel truss or plate girder design. Some chose to incorporate the access roads within the main spans. Whilst this would not normally be economical, it provided a solution to the problem of foundation loading on the existing dock walls.

Most candidates appreciated the requirement not to impose load on the existing dock wall and generally proposed piled foundations. Removal of the wall was not looked on favourably.

A number of candidates chose to restrain the main spans at the pier in the dock basin and by this means were able to eliminate the effects of traction and braking loads on the foundations adjacent to the walls. The design of the pier within the dock basin did not generally attract much attention from candidates.

The following comments relate specifically to each part of the question.

In Part 1a, the examiners were disappointed that some candidates did not offer two distinct solutions where there is a reasonable range of options which would meet the client's requirements. Many paid insufficient attention to load transfer and stability. These are key areas where candidates could have demonstrated their understanding of the behaviour of the structures they are proposing.

Question 4

Candidates were required to design a large storage reservoir for a water-based chemical. Only the required volume was stated, with a limit on height above ground-level but with no constraints on the maximum depth of the structure. Candidates were asked to reach an appropriate compromise between a shallow reservoir with large footprint, for which the land purchased would have been expensive, and a deeper reservoir with small footprint but with the increasing costs of deep excavations. There was a wide choice of options for alternative schemes for the structure.

To answer this question successfully it was necessary to assess and deal with the uplift applied to the structure from displaced groundwater. A majority of candidates appreciated this need.

Most candidates were able to deal with the routine technical processes of designing reinforced concrete walls, columns and slabs, and calculations and drawings were generally tackled adequately.

However, candidates were less comfortable arriving at solutions to the more open-ended questions of choice described above. It was encouraging to note that most candidates were aware of the nature of problems caused by contaminated sites, although very few were prepared to think sufficiently laterally to recommend that the client should choose a different site for the project.

Question 5

A bell-tower was required, with the essence of the question being the need to deal with the high horizontal loads generated by bell-ringing.

Sadly, a primary cause of examination failure was the inability of many candidates to realise that the bell loads were significant, and they caused a much greater overturning moment on the building than the wind loading.

To emphasise the point further, part 1b of the question required candidates to consider the effects of a single additional bell which, if incorporated, would have more than doubled the horizontal load and the overturning moment.

It was disappointing to find many candidates accepting the additional bell with equanimity and being more concerned about obtaining planning permission and additional design fees, while failing to appreciate that their designed schemes would have collapsed had the extra bell been installed.

Successful candidates made proper allowance for the loads caused by the bells. Most used piled foundations and offered alternative schemes based on reinforced concrete walls, beams and columns, steel braced frames or, in a very few cases, a 'traditional' masonry design.

Candidates offering what appeared to be pre-prepared answers based on irrelevant differences between beam-and-slab and flat-slab floors did not gain high marks.

Candidates who wish to become Chartered Engineers must demonstrate their ability to cope with the unexpected. They should understand that they will win no marks for repeating information already in the question or for offering information that does not relate to the question, but they will gain substantial marks for showing that they have understood the problems that have to be overcome and for proposing satisfactory solutions.

Question 6

This question was a new-build project of a relatively simple nature: a 24m × 29 m, split-level, public assembly building, on a sloping site. The ground conditions were also relatively simple: clay over sandstone.

The size and open-plan format of the building required framing (most easily in steel), although other solutions utilising, for example, diaphragm brickwork walls were advanced.

The simplest solutions adopted portal frames from front to rear. Across the centre, between the upper and lower halls, transverse stability requirements needed the inclusion of elements such as vertical framing or cross-bracing in the roof to take wind forces on the side gables back to the front/rear walls. For conventional masonry cavity walls, wind-posts were required for the gable elevations.

The substructure of the central wall and the gable flank walls needed to be retaining, at least in part. The more economic solutions had a void under the upper hall, with the central wall retaining for only half the height of the lower storey. Overall sliding of the retaining structure needed to be addressed, by solutions such as a key into the sandstone.

The lower floor was most likely to be of ground-bearing reinforced concrete. The upper floor was most likely to have been suspended, being concrete (or less likely steel) framed. The cantilever balconies potentially dictated the form and direction of span of the upper hall floor.

Foundations were most beneficially taken down to sandstone rock, as the front part of the lower hall was just cut into the sandstone. Any reliance on foundations part in clay and part in sandstone would be likely to result in differential settlement. The store room under the upper hall required reconfiguration of the retaining wall, to go around the front of the store room. Being cut into sandstone and requiring a reconfiguration of retaining walls, it would be a relatively expensive provision of additional space.

In too many cases, the candidates' appreciation of geotechnics and foundation design was poor, with a significant number adopting piled solutions for this low-rise and lightly loaded building founded on sandstone. Most candidates failed to address sufficient facets of the structural design and detailing of what is a relatively straightforward building design.

This may be because these candidates had been diverted from the other steel and concrete questions. In many cases, there was a misunderstanding of the brief and also many found difficulty in arriving at two distinct solutions, an example of which was opting for variations in direction of span of the same types of material and structural form.

There was concern over how a significant number of candidates disregarded the provision of basic lateral stability. Of those who had considered it, too many failed to address how the deflections of various frames would affect the brittle nature of the brickwork cladding. In many cases, there was no mention of wind posts and the external brickwork cavity walls would have failed.

Many letters were poor, considering that the points to make were simple in engineering terms. Rather, candidates concentrated on matters such as additional fees and late instructions, rather than, for example, the cost of excavating into rock. Preparatory notes would have helped candidates address the main issues before commencing the letter itself.

The standard of presentation of calculations and drawings was generally poor. In many cases, design calculations for portal frames for the roof structure were skimped and the design of cantilever retaining walls failed to address overturning and sliding stability. There was a tendency to show structural sizes on drawings which were not justified elsewhere in the scripts. The details of how building components fit together and how cladding, etc., is attached to the main structure was poorly addressed in a significant number of scripts.

The sketches showed that many candidates did not appreciate aspects of retaining wall stability and showed unsafe handrail detailing. Candidates' answers to Section f, where included, generally gave construction sequences, rather than detailed method statement; in these, safety was poorly addressed.

In conclusion, candidates should realise that examiners are looking for simple, sound structural designs, with due regard for function, aesthetics, economy and safety. Clear and comprehensive well-annotated drawings gain marks and give a good initial impression to Marking Examiners that the candidate has understood the brief and produced a viable structural solution.

Question 7

The question required candidates to design a quarters module (building) for an offshore oil production platform. Key aspects to be considered in the design are as follows.

The support locations are asymmetric to the plan outline and centre of gravity. In-place forces and loads are therefore higher near the supports zone gridline 5 to 6. This effect is exacerbated by the requirement in the letter to add 8m to the east end.

No internal bracing was permitted in the lowest level. This means sideways forces (in-place blast and wind, temporary transportation roll forces) need consideration of how to react them from the chosen supports.

The module was required to be installed by a heavy lift crane vessel, and no lift frames/beams were permitted. The roof therefore has to resist the horizontal component of the lift sling force. The upper three levels had constraints on floor beam size to allow services to be run. Consideration of beam depth and use of castellated or solid webs was required.

The question required candidates to consider the various load cases, in particular transportation from building location to offshore platform site, heavy crane vessel lift, and when in-place. The more onerous case then needed to be selected for each of the main structural elements.

In order to provide an economic and efficient structure, concepts were expected, taking into account the key aspects. For example, options may include:

- a steel trussed solution or external structural steel cladding acting as a 'stressed skin'
- transportation forces reacted by external braces form cargo barge deck up to level 2 to avoid high bending in columns from level 1 to level 2
- horizontal component of lift sling forces taken by roof plate diaphragm action between lift points
- use of best member type for force and location, e.g. tubular braces, UC or tubular columns, truss and deck beams, UBs
- no heavy plate girders were envisaged to be needed
- joint details that are structurally efficient and also economic to build eg. minimal fillet weld in preference to full penetration welds.

Question 7 in Part 3 has a topic from the offshore oil and gas production industry. It is insufficient for candidates working in this industry, who attempt this question, to rely on knowledge of current methods for aspects such as load-out onto transport barge and heavy lift operation.

It is a requirement to demonstrate capability in structural engineering primarily, and emphasis on aspects such as load transfer and efficient design is needed for this question in line with the other Part 3 questions.

Associate-Membership report

The number of candidates for the written examination was 45, which included one non-UK candidate. Although candidate numbers increased slightly compared to last year, they remain under 50. It was in 1990 when numbers were last above 100. Almost half the candidates (44.4%) attempted the steelwork question, whilst 26.6% chose the concrete question and general question. One candidate attempted the bridge question, which had been included for the first time.

In general, candidates gained higher marks in Part A than in Part B. It is important that candidates realise that they must satisfy the examiners in both parts of the question and that they should allocate the appropriate time during the examination.

Those candidates who attempted the steel question and failed, showed a weakness in the basic design elements. Those who attempted the concrete question and failed, showed an overall weakness in satisfying the examiners that they were competent in reinforced concrete design and detailing.

In the general question, many candidates started off on the wrong 'design' path and were too inexperienced to know this. Their realisation, in nearly all cases, came at the end of their allotted time for the question.

Structural steelwork

This concerned the design of a cantilever stanchion and lattice roof truss construction with an independent travelling crane.

In Part A, the candidates were required to design the main roof lattice truss, a stanchion, a gable post, the wind bracing members in roof end bay and to prepare detailed drawings.

In Part B, the candidates were also tested on foundation details, bill of quantities, and a method statement to show the sequence for extending the building by two bays after the initial construction had been completed.

Generally the question was answered competently by those candidates who passed, although the quality of drawings and calculations ranged from good to just adequate in order to achieve a pass.

Reinforced concrete

This required candidates to design a proposed car park basement for a new office building with the loads for the framed structure above being given in the question.

Part A asked for the design of the slabs, beams for the suspended slab element, also the column and foundation base design.

Part B required specification clauses for 'finishing' the basement slab surface, details of falsework and formwork; also the writing of a letter recommending actions necessary when some of the concrete to the basement columns and suspended slabs failed to comply with the cube strengths required. Generally the design calculations and drawing details were satisfactorily presented, but several candidates omitted some of the question items, particularly in Part B, due to lack of time.

General construction

This question related to the design of a swimming pool with ancillary rooms.

Part A asked for the design of various elements, including the masonry wall between portal frames, the laminated timber posts to the full- height glazed elevation, the steel portal over the pool area, and details of one of the swimming pool concrete walls.

Part B dealt with the specification for the waterproof membrane to the pool and the paint protection system for the steelwork, and a method statement for the sequence of operations.

The question was a good test of a candidate's skills in all the common structural materials.

Bridge construction

This question was for the design of a footbridge crossing a dual-carriageway road between the first floors of two buildings. The bridge was to be supported by each of the buildings on either side of the road and by a central pier in the central reservation.

The bridge deck comprised a pair of steel sections, together with an *in-situ* concrete deck which was to be designed to act compositely with the steelwork. The bridge beams were to be designed to be continuous over the central support pier.

Associate-Membership oral examination

During the year, one candidate from outside the UK was examined at the Institution headquarters, and was successful.