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What AM Examiners Require - Bob Wilson

The Incorporated Engineer is the title for the person who used to be called a "Designer-Detailer". True to the name this person, back in the 1960's, would design buildings and bridges and manage a complete small contract. The job specification would include the following:

- Solves design problems by combinations of standard procedures, modifications of standard procedures or methods developed in previous assignments.
- Is typically responsible for: design, preparation of plans, layouts and designs with supporting calculations and specifications, checking plans, designs and materials. Advice would be given where problems or unusual features of assignments arose.
- May liaise with construction engineers and suppliers concerning construction and installation.
- Makes recommendations on project or site feasibilities.
- Calculations, specifications, material lists, quantities and cost estimates are not usually checked because they are responsibly self-checked.
- May give guidance to more junior engineers in connection with assigned work. May assign and check the work of draughtsmen or technicians working on a common project.

In the examination, condensed into a single day, every office-based activity is represented:

- Section 1a requires a viable structural solution for the proposed scheme,
- Section 1b requires a description of the implications, upon the scheme in 1a, of a major change in the client's requirements,
- Section 2c requires the preparation of sufficient calculations to establish the form and size of all principal structural elements – including the foundations,
- Section 2d requires the candidate to draw a general arrangement of the scheme that will be suitable for estimating purposes, and also sketch two specific details,
- Section 2e requires a detailed (engineers) method statement for the safe construction of the building.

Section 1 is worth a total of 30 marks and Section 2 a total of 70 marks. Candidates should note that they must "satisfy the examiners" in both sections of the paper. Satisfying the examiners usually means obtaining a minimum of 40% - i.e. 12/30 or 28/70. Furthermore, the overall minimum score must be 40%. Exceptionally, the work is so poorly presented that it is illegible and this may not "satisfy" the examiners on the grounds that this is unprofessional practice.

In the examination the time is very restricted and good time-management is extremely important. A general guide to the amount of time to spend on any part of the answer would be 4 minutes per mark. Hence, the 20 marks allocated to Section 1a suggests 80 minutes of answer time. Respectively, the other sections will be:

Section 1b	10 marks = 40 minutes
Section 2c	30 marks = 120 minutes
Section 2d	30 marks = 120 minutes
Section 2e	10 marks = 40 minutes

It is a demonstrable fact that the candidate needs to answer every part of the question and score 40%, or more, for each part.

Skimping on Section 1b – often called the letter from the comparable part in the CM Examination – or Section 2e, the method statement, is very risky! Too risky for weaker candidates with the consequence that they often fail to score enough!

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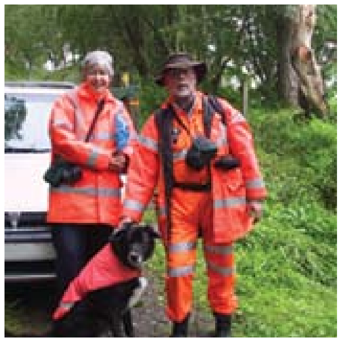

It is worth noting that Section 1a, requiring only one scheme for 20 marks, is exactly half the requirement of Section 1a in the CM Examination! So the same effort needs to be spent on the AM scheme proposal as on one of the CM proposals. However, in AM Section 2 the balance tips the other way. More marks (and consequently more time) are available for calculations and drawings. There is the expectation that both the calculations and drawings will be detailed and specific to the proposal in Section 1a: experience will be demonstrated by focusing on the essential practicalities of each.

Let us try and understand the examiner's expectations, part-by-part:

Section 1a

First of all comes the expectation of a structure that will fulfil the client's requirements and fits into the site limitations. Many schemes will involve a framework which might be in steel, concrete, masonry or timber. Partition walls may be needed and the building must have a weathertight envelope. The framework may have to carry the masonry loads: traditionally this is done by locating a beam under the wall. A floor system needs to be chosen. The whole framework must be stable – using either bracing, shear walls or moment connections.

The most efficient way of communicating the candidate's proposals is a series of freehand sketches – plans, sections and elevations in good proportion – as spelt-out in the question. If the candidate is not already proficient at freehand sketching it is advised that this skill will greatly enhance communication.

A written description often needs a sketch in order to make clear the candidate's intention which, in effect, is duplication! A more economic use of time is to start with the sketch or plan and add notes as necessary.

Do not limit the answer to some key words or standard phrases. The most common of these are: moment connection, piled foundation, wall or shear wall, diaphragm action and composite floor. These all have several versions or alternative arrangements and distinctions need to be drawn and explained. Marks are available where there is evidence of thoughtfulness and experience.

External cladding and internal walls, whether loadbearing or not, need to fulfil a range of functions including weathertightness, thermal and sound insulation, resistance to lateral actions, and appearance. The scheme design needs to consider these functional requirements: it is not limited to mere structural performance.

The superstructure must have foundations. This may appear so obvious but many answers are lacking. Where there are adjacent buildings underpinning of their foundations is often needed. Details of the strata are always given and the choice of foundation should be justified. A very popular form of foundation is the ubiquitous piling. A quick glance at any text about foundations will show that there are many pile types – driven, bored, augered, etc. and different situations where they should be used. Even the very popular CFA pile has its limitations. The eventual choice of pile must be appropriate to all of the circumstances set in the question. A wrong choice can result in outright failure (because the building is not stable).

The scheme prepared in Section 1a, although not needing to be detailed enough for fabrication in the selected material(s), does need to anticipate construction problems so that sufficient money is put into the budget estimate. Some of the problems that candidates miss are:

- The need for splices in long members, trusses and stanchions,
- The relationships between the column grid, the cladding and the overall dimensions of the site,
- Provision for movement, including deflections in the framework and the jointing of cladding, especially masonry,
- The intersections between beams and columns in the special case where the beams are required to behave continuously or where the assembly is portalised.

All too often these are glossed over and left to others to be sorted out. Where a traditional detail can be applied then a quick sketch will suffice to demonstrate this. Where the problem is more complex then it must be clear that the designer needs to attend to it before proceeding further.

This initial design or concept needs to be dimensioned and have member sizes, directions of span, load paths and stabilizing elements shown. The dimensions need to check out the client's requirements: the member sizes are derived from safe-load tables (e.g. for floors) or span/depth relationships: the directions of span and load paths identify the principal members and allow a credible foundation to be proposed: and of course the structure must be demonstrably stable.

Here it is worth repeating a fundamental principle of all checking or examination marking: "The checker (or examiner) may not assume that the scheme before him/her is correct. The correctness must be demonstrated by the designer submitting the scheme." In the examination the only communication is by sketch or the written word and it is crucial that it is clear and unambiguous.

A take-down of the loads will need to be done at one time or another – the candidate must decide when to do this. When the loading calculations are done in Section 1a they are available for the process of sizing the members and the foundations but a share of the marks (Section 1a – 20 marks), not many, will be used up and cannot be repeated in Section 2c. It may be felt that it is more logical to display these simple calculations in Section 2c and earn a share of the 30 marks available for that part.

In Section 1b the client asks for advice about the implications of a post-design change. The advice must be constructive, comprehensively cover every implication and may be assumed to be given at a time when changes are possible without great expense or effect on the site programme.

As there is never any data that is relevant to either cost or site programme neither of these can be commented upon in more than a superficial way. It is unlikely that many marks are available for these superficial comments!

Many of these post-design changes involve removal of columns and a dramatic increase of slab or beam span. Sometimes a heavy load is added.

It may be difficult to go beyond stating the obvious, but this is the point of this part of the question! Constructive advice will offer a solution – rarely cost-effective as this has already been provided in the original scheme – with member sizes, alternative framing and the changes that will need to be made to the foundations.

If the original scheme incorporates piling it can be cautiously suggested that this may already have been constructed, as is often the case. The advice would be about modifying the arrangements already in-situ. However, it is simpler to assume that a new scheme is still possible.

Where alternative framing is proposed consider how much of the original fabrication can be re-used because, with steelwork, there are often fabrications being made while the early foundation construction is progressing on site. The members that are required at the start of erection are fabricated first!

With the increased span, member sizes become deeper – clashing with headroom requirements. These deeper members can sometimes be raised above floor levels and hidden in walls. Other times it may be necessary to recommend that the overall height of the building is increased. It is important that the client is told the whole story, i.e. the girder size and/or new building height, rather than just the building will be taller.

Perhaps two beams can replace a single one? The implications of this are that the connections at the column will be different and the p.c. floor slabs may not fit.

The proposed solution to the problem must be comprehensive. The candidate needs to demonstrate that all aspects of the problem have been considered, and sketches should be used rather than wordy descriptions.

Section 1b may be answered in the form of a letter – with enclosed sketches, etc. or presented in the form of a proposal – the question is not specific - informal notes are acceptable provided they are neatly presented and describe a viable solution.

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The candidate will probably start Section 2 in the late morning, some 120 minutes into the examination and after completing Section 1. This is unlike the CM Examination where half the available time is spent on Section 1.

Please note that each part of the question has its own allocation of marks. These marks are not "transferable", which means that there will be marks for the relevant plans and other sketches in Section 1 even though rather similar ones may be drawn in Section 2d [the general arrangement and details]. A thoughtful candidate will deduce that the two sections are expected to be significantly different! The same applies to calculations. Marks cannot be awarded twice for the same content. This is why it is important to answer each part of the question as a stand-alone entity with appropriate cross references.

You cannot score marks for non-existent sketches in Section 1a by referring to the general arrangement in Section 2d – and the same for calculations in Section 2c. Both drawing and calculations serve different purposes in the separate sections.

This is why the candidate should progress smoothly through the various parts of the question as these closely follow the natural sequence in design. It is inadvisable to jump about between sections and remember, the examiner cannot transfer marks from one part to another. Treat each part of the question as a separate entity developing different aspects of a common theme.

Section 2 is worth 70 marks and approximately 280 minutes are available for the answer. Divide the time in proportion to the available marks and move-on to the next part of the answer at the end of the allotted time. It is very unlikely that you will produce the necessary standard of answer in less time! Any time stolen from, say, the method statement, and added to, say, the drawing time is also unlikely to improve the total number of marks scored. The universal advice is to keep to the recommended times and move on to the next part of the answer when the time runs out. This is what is meant by the phrase "time management".

Section 2c requires the candidate to prepare sufficient design calculations to establish (or prove) the form and size of all principal structural elements including the foundations. If not already done in Section 1a, establish the gravity loads (dead and imposed) and the wind load (lateral loading). The dead load of floors and walls will come from the sizes already estimated in Section 1a. Remember to apply partial safety factors for the ultimate limit state. Follow the load paths established in Section 1a down to the principal structural elements such as level-2 girders, the columns between level 1 and level 2 and the (piled) foundations.

Now perform appropriate detailed calculations to demonstrate that the estimated sizes of these principal elements (see Part 1a) are adequate.

It is worth considering how the candidate's effort will be rewarded. Section 2c is worth a maximum of 30 marks. The examiner will spread these fairly over all the work that is presented providing none of it repeats what has gone before. So, in principle, there are say, six clusters of five marks to be earned.

- If the loading has not been presented in Section 1a there could be 5 marks for these;
- The question specifically requires the inclusion of calculations for the foundations – another 5 marks;
- The building must be demonstrably stable – 5 marks for this demonstration;
- The roof may have a long, clear span and this portal or truss is clearly a principal structural element – 5 marks for an appropriate design;
- Nearly every question has a "transfer" beam – a principal member – 5 marks for an appropriate design;
- There will always be a critical vertical load-bearing member, column, stanchion or wall whose calculation will earn up to 5 marks.

So – six clusters of five marks = 30 marks!

Proprietary precast or composite floor slabs, using safe-load tables cannot be considered to be principal structural elements. Similarly, wind posts, uplift tie-downs at roof level and secondary beams will not make-up the score if the critical members have not been tackled! This is not to

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say that they don’t need calculations, but not at this time or in this part of the examination.

It can be seen that the marks are hard-earned. There is not sufficient time to perform detailed or proof calculations, as would be done in the office; nor are the software programmes available. The calculations presented in the examination need to be deeply selective and focused on the weakest elements. The following are worth considering:

- Load combinations that produce the most severe effects on the member being considered;

- Loading caused by temperature effects;

- Beneficial load reductions;

- Use of the ground conditions included in the question for estimating safe or allowable bearing pressures under foundations and the capacity of piles;

- The effects of lateral load on the superstructure creating a push-pull effect on foundations;

- Where the design relies on moment connections, sway frames or shear walls these need sufficient calculations to demonstrate that they provide the necessary stability.

- Calculations may be required to demonstrate that stability has not been compromised by flotation, differential settlement or gantry-crane-like moving loads.

- The amount of calculation for the roof will vary and the candidate must judge carefully the effort needed to score the limited number of marks available. A trussed-rafter roof over a domestic building could be simply selected from a supplier’s list (if included among the candidate’s data sheets). Few marks will be awarded and the candidate should re-examine the question because the problem may not be this simple! It may be more appropriate to have a steel truss supporting purlins and timber rafters.

- The larger industrial trusses will often be parallel-chord style of the Warren or Pratt forms. The critical members are the struts (because they tend to buckle) and these should receive attention from the candidate.

- A common proposal in Section 1a is the “Vierendeel” or rigid-jointed girder-truss. Although by no means beyond the capability of most candidates, given time, in the examination it is necessary to restrict the calculations to the bare essentials. The forces in the members are arrived at from a simplifying consideration of the shear which is shared at mid-panel by the top and bottom chords (hinges are inserted at the mid-point of each member making up the panel). The conditions of equilibrium need to be satisfied. The calculation needs to include the moment resistance of the rigid joints. The axial forces maximise at mid-span and the bending moments maximise at the supports – as you might expect!

- If the scheme proposed in Section 1a involves portal frames a similar restriction needs to be imposed in order to fit the available time. Design aids are available for estimating the bending moments at the portal knees, apex and feet. It is important to quote your reference when using design aids. Again, the calculations need to include the moment resistance of the rigid joints. Any rafter splices may need a calculation too.

- Transfer beams or girders may simply span over a large space like a ballroom, or may carry a masonry façade over an opening with point loads from the façade columns (that are curtailed at level 2). They may be crane-rail girders along the sides of a workshop. They may be a reinforced-concrete beam buried deep within a building that carries a hefty column load over a car-park ramp. In any event they will need some serious calculations that are beyond “guesstimating” the overall size of the member. The spans are often over 10.0m which takes them outside the simple limits of BS8110. Shear, deflection and local stability become significant issues. The candidate needs to cut quickly to a critical Limit state and perform appropriate calculations.

- Do not defer a decision by indicating that these matters will be dealt with during the detailed-design stage! The matter at issue here is that a budget estimate is about to be prepared and the structure cannot be undersized. The designer must demonstrate that all the elements of structure are fit for purpose, especially the principal structural elements.

- No design will be complete without a vertical load-bearing member – a column (reinforced concrete design), a stanchion (steelwork), a post (timber), a portal leg or a wall (concrete or masonry). These elements lie along the load path between the beam ends and the foundations. They may be axially loaded (without moment), uni-axially or bi-axially bent (moments applied). At this early stage in the design these members are usually designed as axially loaded but the section is enhanced to provide surplus strength that can be used to resist bending. Consequently it is not always necessary to perform a full analysis that will provide bending moments – the leg of a portal frame is an obvious exception.

- The temptation to bulk up the section – as a precaution must be resisted because this would not be a viable solution (Chamber's Dictionary: of such a kind that it has a prospect of success; practicable). Grossly oversized members will be uneconomic and wasteful of floor space, and consequently will be rejected by the client.

- Very large members may develop in the effort to provide the change that the client wants in Section 1b. These might be used to discredit the proposal.

Section 2d requires the candidate to prepare a general arrangement drawing (for estimating purposes) and to illustrate two specific details. In the examination the candidate is provided with a number of A3-sized graph sheets – the pages have a metric grid of lines on both sides, and it is expected that both sides of the sheet will be used.

The candidate must bring all other drawing equipment. Because of the blue-coloured grid already on the page, lines drawn with a hard lead do not show very well. It is prudent to practice drawing with soft leads such as 2B or even 4B. An A3-size drawing board with integral straight edge should be considered: the alternative is a rolling straight edge with the paper held down on the desk top with adhesive tape. None of this is quite like normal office practice, but that is CAD-based these days and unavailable in the examination.

A successful development used by some candidates is to trace over some of the underlying pencil work with a pen and black ink. This can be done freehand if you have a steady hand. Another good technique is to use highlighter coloured pens instead of plain hatching. Different colours can be used to represent concrete, steel, soil, etc.

In principle it is possible to assemble the sheets into a "mosaic" of A1-size. In practice, on a small desk, this does not work!

The basic expectation (in the examination) is that a scale drawing showing a plan, cross-section and elevation, together with general notes, is prepared to a professional standard. The standard is one that the office would require before a public issue of the drawing.

A typical plan will show the outline of the building, the structural grid and dimensions and the principal framing. Different parts of the plan may show the framing at different levels though this has to be done judiciously to avoid a confusing tangle of lines! A clearer communication may be made by drawing a typical floor plan and adding part-plans at pile-cap and roof levels.

Steelwork framing plans and reinforcement plans are not appropriate on their own as the quantity surveyor is not supplied with all the information needed to prepare a budget estimate. These "specialist" plans are directed towards the steelwork fabricator or reinforcement supplier. An exception would be the typical reinforcement in a floor panel, the associated bar schedules and the derived weights of the various bar sizes.

The full general arrangement drawing will show concrete casings to stanchions and beams, supports for cladding, cavity walls enclosing bracing, structural screeds, over-site concrete, construction and movement joints, basement and roof waterproofing and many other details that need to be included in the price. The general notes should specify the materials.

The cross-section is a very necessary part of the general arrangement drawing. It shows the various levels (relative to ground or datum level), other vertical dimensions, floor thicknesses, beam depths and the clear height of rooms. It will show the relationship of the cladding to the main frame, partition walls (and their supports), stairwells, roof construction (and drainage), suspended ground floors, basements, pile caps and ground beams.

Elevations may be needed to show transfer beams over large openings, details of façade jointing, shear walls, sway frames or bracing. Where columns or slab edges are exposed at the façade, atrium glazing or similar features of the faces of the building are required, appropriate elevations are a must.

A distinctive feature of all AM questions is that two specific details are asked for in Section 2d. It would be reasonable to expect 5 marks for each of these (which is equivalent to 20 minutes work). The details will relate to that particular question and require a demonstration of knowledge of building construction. Typically they require (i) a detail of the junction between the main structure and the foundations, and (ii) the junction between the cladding and the roof. A key feature is resistance to the penetration of the elements. Traditional details are acceptable providing that they are adapted to the question. If the figure accompanying the question shows an eaves overhang of 0.5m it would be wrong to provide a detail with a lesser overhang!

These details need to be practical and buildable. They may be drawn freehand, in good proportion and both details might be expected to fit on one side of A4 paper. The two details are usually incorporated into the general arrangement drawing.

Because of the difference between the four questions offered within an examination paper, the details will range over domestic, industrial and civil engineering construction technology, and the candidate should not be limited by the examples given above.

There are three components to the answer to Section 2d:

- The general arrangement drawing,
- Detail (i),
- Detail(ii),

And each will have a proportion of the marks – which are not transferable! In other words, if details (i) and (ii) are not offered by the candidate these marks are lost – they are not available for rewarding a more elaborate general arrangement. Good examination technique will be to work on each component for the appropriate time and thus score a maximum mark.

Section 2e, the final part of the question, may be written after Section 1 if preferred – while the initial concept is still fresh in the mind. Alternatively it may be answered last, allowing the candidate to include contributions from the preceding stages. Some candidates keep notes of the relevant ideas they have while doing the other parts of the answer, and then arrange and expand these in this final part.

The candidate should not confuse this method statement and identification of hazards with similarly-named documents traditionally prepared by the building contractor. The purpose of this (engineer's) method statement and risk evaluation is to assist the architect, quantity surveyor and Client to evaluate the cost of special (specific to this job) construction activities and also the cost of providing the necessary safe practice.

Examples of matters to be discussed in the method statement might include:

- Piled foundations: restrictions on pile driving, casings needed in silty or sandy water-bearing soils, the use of bentonite slurry, the allowable tolerance in pile position, disposal of excavated soil, cutting-down pile heads, etc.
- Suspended ground floor: the construction of the under-floor space, permanent formwork, allowable loading.
- Ground floors on grade: backfill and over site concrete, moisture and gas barriers, jointing, finishing.
- Substructure: basements, underpinning adjacent buildings and roads, upholding the sides of excavations, control of groundwater, preventing fines being extracted during dewatering, disposal of excavated soil, waterproofing.

- Superstructure: temporary and permanent elements providing stability, delivery and erection of [large] transfer girders and roof trusses, securing HSFG bolts, decking-out with precast concrete or composite tin deck profiled sheeting, roofing over, cladding and need for scaffolding where there is brick or masonry facing.
- Health and safety risk evaluation respective to the engineering design – examples:

1. Pile positions outside the permitted tolerance can cause excessive bending in the pile.
2. Collapse of adjacent (existing) gable walls because they were not underpinned.
3. Collapse of public footpath and road because sheet piling retaining the sides of an excavation was not stiff enough.
4. Collapse of scaffolding because it was not securely tied-back to the main structure.
5. Collapse of a steel frame over the weekend because of lack of adequate temporary bracing. The candidate learns from reported accidents and will adapt them, as appropriate, to the answer. The designer has a responsibility at law to specify a safe construction or mitigate the danger if there is no safer alternative. The candidate must demonstrate their awareness of this design-stage responsibility.

The candidate must decide on the format of the method statement. A list is too brief and a number of paragraphs of script in essay form are not reader friendly. A simple division of the page into two – the left-hand column used for sub-title or sketch to identify the risk, and the right-hand column used for warning notes and precautions to be taken, is probably all that is needed.

With reference to Q1/2009 – New shops the ground conditions consist of 3.0m of made ground or fill over sand and gravel, with a GWL at -3.5m. This could be sketched and noted in the left-hand column.

The right-hand column might contain the following:
"The made ground or fill needs investigation (trial pits). Is it an in-filled basement? What materials have been used? Are they compact? Are they hazardous? Can the proposed CFA piling drill through?"

And *"Will ground-water control be needed?" The waterlogged sand and gravel will need support if excavated.*

Something like this should earn some marks and would not take very long to write. Obviously, if time allows, more of the same sort will earn more marks!

In 2009 the number of questions was reduced to four. Unlike the CM examination the questions are not tuned to a particular material. Hence Question 1 – 2009 might have had a steel, concrete or masonry main frame. The specification of timber rafters in the roof is not necessarily a hint that timber should be used in the roof! Question 3 is perhaps tuned towards the candidate familiar with "civil engineering", though this may be more a matter of scale rather than complexity.

A prudent candidate will be prepared to answer any of the questions – only one question should be attempted – and should not waste time looking for the steel question. The selection of the subject of the question is more appropriate. Has the candidate designed something similar recently (or in the past)? A candidate with a wide experience of different types and uses of buildings will be the best equipped to sit the examination.