The Institution of Structural Engineers

Possible solution to past CM examination question

Question 1 - April 2012

Conference Hall and Exhibition Galleries

by Dr Peter Gardner

Question 1. Conference hall and exhibition galleries

Client's requirements

1. A circular conference hall and three floors of exhibition galleries is to be designed. It is accessed by six circular remote cores, each containing two lifts and a staircase which are joined to the main building by glazed link walkways. See Figure Q1.
2. The area at Level 1 is to be column free and only limited support is permitted to the floors at Level 2 and above. There is no restriction to the number of columns on the perimeter of the hall, except that they shall be at a minimum spacing of 8.0m at Level1.
3. The client requires that 50% of the external wall surface between the access cores to be vertically glazed for natural lighting and the remainder to be clad with composite panels. The access cores are to be clad with composite panels.
4. The roof over the hall shall be of a lightweight structure with aesthetic consideration.
5. The respective floor to floor heights between Level 1 and Level 3 are to be 10.0m with a minimum clear height of 8.0m. The floor to floor height between Level 3 and Level 4 is to be 7.5m with a minimum clear height of 5.0m.

Imposed loading

6. | | |
   |---|---|
   | Roof | 0.6kN/m^2 |
   | Floor Levels 2, 3, & 4 | 5.0kN/m^2 |
   | Floor Level 1 | 25.0kN/m^2 |

   Loadings include an allowance for partitions, finishes, services and ceilings.

Site conditions

7. The site is level and located on the outskirts of a large city. Basic wind speed is 40m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20m/s.
8. Ground conditions – Assume to vary linearly between boreholes.

Borehole 1	Ground level – 2.0m	Made ground
	2.0m – 7.0m	Stiff clay, 100kN/m^2
	Below 7.0m	Rock, allowable bearing pressure 1000kN/m^2
Borehole 2	Ground level – 4.0m	Made ground
	4.0m – 9.0m	Stiff clay, 100kN/m^2
	Below 9.0m	Rock, allowable bearing pressure 1000kN/m^2

   Ground water was encountered at 2.0m below ground level.

Omit from consideration

9. Detail design of staircases and lift shafts, within the cores. The cores themselves are to be designed.

SECTION 1 (50 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)

b. After the design has been completed the client advises that he wishes to hold a sports event in the conference hall and requires terrace seating at Level 2 and four television screens each weighing 5 tonnes hung from the edge of the floor at Level 4. Write a letter to the client outlining how this can be achieved and the implications. (10 Marks)

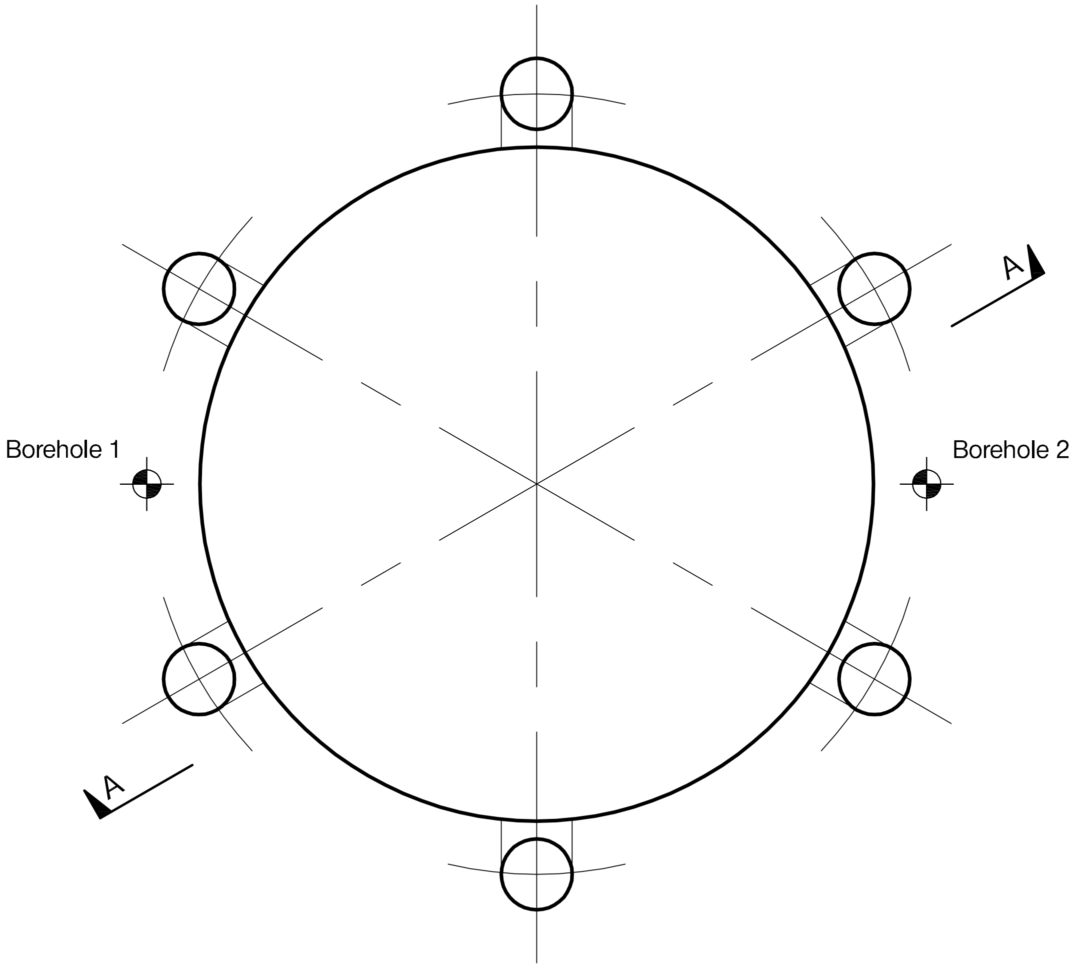
SECTION 2 (50marks)

For the solution recommended in Section 1(a)

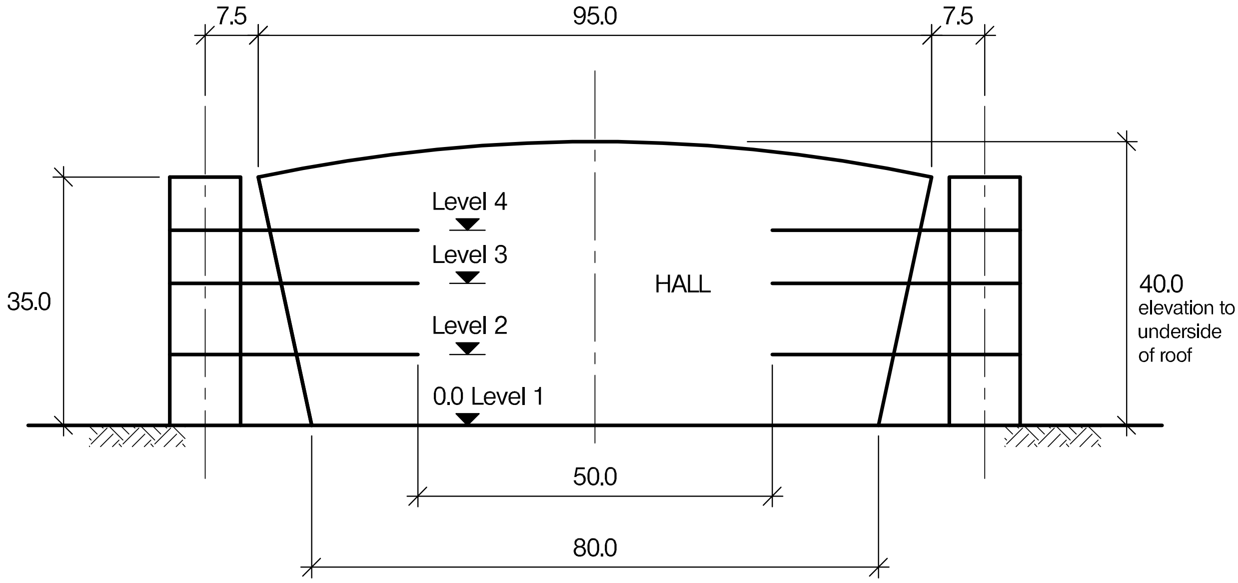
c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)

d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20marks)

e. Prepare a detailed method statement for the safe construction of the building and an outline construction programme. (10 marks)



PLAN



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q1

Conference Hall and Exhibition Galleries

Introduction

This question relates to a large circular conference hall. Despite its size, and circular form the brief is relatively straightforward and thus should allow various options to support the 95m span roof and the associated structural elements.

The brief

- The conference hall is 80m in diameter at ground floor level with sloping sides and a curved roof with a diameter of 95m.
- The whole of level 1 (the ground floor) is to be column free. The columns around the perimeter have a minimum spacing of 8m.
- There are three floors of exhibition galleries each of which are circular in plan. Floor to floor heights between level 1, 2 and 3 are 10m, with a minimum clear height of 8m, and the floor to floor height between level 3 and 4 is 7.5m with a clear height of 5m. This leaves a further 7.5m between level 4 and the underside of the roof at the perimeter (see figure 1).
- There are six circular external cores each containing lifts and a staircase which provide access to the exhibition galleries. They are joined to the main building by glazed link walkways.
- The client requires that 50% of the external wall surface between the access cores is glazed. The remainder and the cores themselves are to be clad with composite panels.
- The main roof over the hall is required to be lightweight, and aesthetics are deemed to be important.
- There is a high load on the ground floor.
- The site is level and is located on the outskirts of a large city.
- The boreholes indicate that there is a significant quantity of made ground, below which is stiff clay, all of which sits on top of rock with a ground bearing pressure of 1000 kN/m^2. There is groundwater at 2m below ground level.

Interpretation of the brief and critical features

The main issues should be fairly obvious.

- There is a large span roof which will necessitate substantial structural members.
- There are three exhibition galleries which cannot be supported on their inner edge by columns going to the ground.
- The six circular cores could help with stability, and may also be helpful with the main structure.
- Although stiff clay is available, a building of this size would best be founded on the rock.

Structural framing

There are various options that could be explored to provide framing for the building, and particularly support for the long span roof. The cores could be used for stability and/or could be utilised as part of the main structural frame. The roof is such a dominant element that it's not practical to see it as a completely separate element from the supporting mechanism (vertical support and stability).

There is theoretically sufficient depth available for the exhibition galleries to be cantilevered from the perimeter, but the brief clearly allows support on the inner edge as long as this doesn't extend to the ground floor. This suggests hangers taken up to the roof, although this will introduce significant additional load on what is a long span structure. These options can be developed in the design, possibly providing two alternative proposals, the most pragmatic of which would be hangers from the roof.

The six circular cores provide an obvious mechanism to provide overall stability, although a number of options for the mainframe (cantilevers, pinned arch or portal frame) would have inherent stability without using the cores. This again provides distinct and viable options that can be discussed in your appraisal.

The ground consists of three very different layers, a top layer of made ground, a substantial layer of stiff clay and underlying rock. This is a large building which is going to generate significant axial load, therefore piling to the rock seems the best solution, however the stiff clay potentially provides an alternative and the deep layer of made ground has implications for the ground floor slab.

This question therefore comes down to providing options for the roof with associated variation in the stability system, support for the exhibition galleries and arrangements for the main foundations and the ground floor slab.

Options for the main roof

The simplest option for the main roof would be a freestanding simply supported roof truss with stability being provided by the cores. Although there are various options, the most logical would either be three long span trusses (but there is the complication of the joint at the centre) or a 3D space frame supported at six points (see figure 3). This may not fully reflect the requirement for a lightweight roof.

An alternative would be a cantilevered roof. Again there are variations on this theme. The cantilever could extend over part of the roof, supporting a separate central roof structure, or it could span right to the centre (see figure 4).

Another alternative would be to extend the cores to provide support for cable stays which would provide intermediate or full support for the roof. This would have the advantage of facilitating a lighter roof structure (see figure 5).

The fourth option would be to construct a portal frame that is integrated into the cores or independent of the cores (the latter option does not take advantage of the natural support mechanism provided by the six circular cores) (see figure 6). Because we have other arrangements that enable us to present two distinct and viable alternatives, my feeling is that this option is not worthy of development.

Stability

All of the options developed above utilise the cores in one form or another. The first option of a freestanding roof would rely on the cores to provide lateral stability whereas the cantilevered structure is integral with the core and therefore is inherently stable.

Exhibition floor support

The obvious mechanism for the exhibition floor support is to provide a limited number of hangers around the inner edge of the floors supported by the roof. Although this increases the load on the roof, it would provide a robust support mechanism for the floor and minimise movement on the outer edge of the floor.

An alternative would be cantilevered floors unsupported at their inner edge but deflection would need to be carefully considered. The most substantial fixity is only available at the six core locations (although moment could also be taken into the intermediate columns). A third option, which isn't prevented by the brief, would be diagonal support. This has the advantage of supporting the inner edge of the floors without adding extra load to the roof, but has the practical disadvantage of occasional inclined structural elements within the exhibition galleries (see figure 2).

Site conditions and foundations

It would probably be possible to found the building on the stiff clay, and this could be investigated as a potential alternative foundation solution, however the principal arrangement would be piles into the rock.

The conference hall would require a suspended ground floor slab which could be supported on piles into the clay or rock.

The letter

The scenario presented in the question is that after the design has been completed the client seeks advice in relation to potential changes connected with holding sporting events in the conference hall. The client wishes to provide terraced seating at level two and four television screens each weighing 5 tonnes which are to be hung from the edge of the floor at level four.

This represents a fairly straightforward change of design which provides a variety of options that can be discussed in your answer. The question implies (but does not state explicitly) that the terraced seating and/or the television screens are temporary and it does not make it clear whether the other levels would be required for concurrent use. This would have some relevance when assessing the additional loads on the roof.

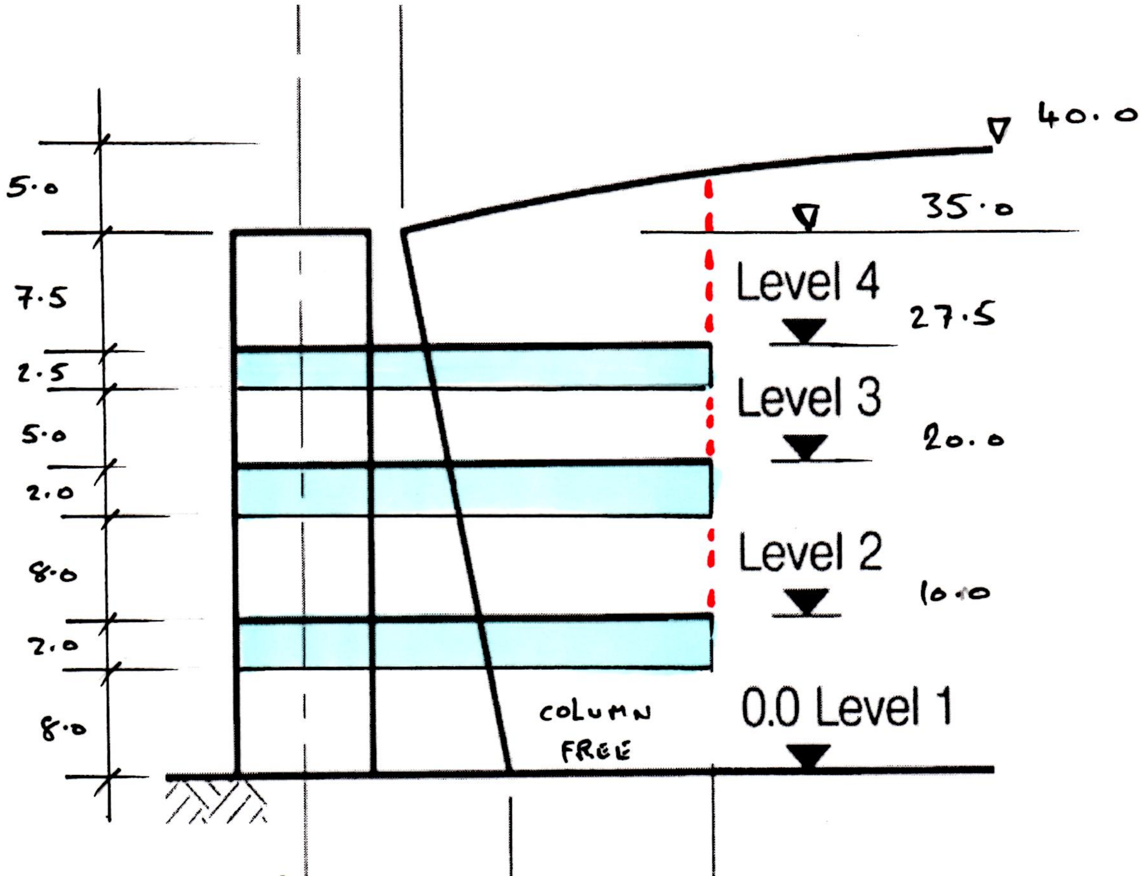
Both the terraced seating and the television screens add additional weight to the support structure and ultimately to the roof. None of this should be difficult to accommodate, but the client needs to be made aware of the extra load and the effect this will have on the existing structure, and especially the long span roof. It would be possible to mitigate the effect of the extra load on the roof by providing temporary props to the ground floor, if this is acceptable to the client. Also, the additional impact of dynamic loads introduced by crowd behaviour at sporting events needs to be brought into your answer.

Summary

This is a large building which is probably outside the day-to-day experience of most candidates sitting the examination. However, these large buildings often lend themselves to very straightforward structural arrangements which are therefore relatively easy to develop into two distinct and viable schemes.

There are four elements discussed in the above appraisal which could be combined to form two very clear distinct and viable schemes, which would be based on the approach taken to provide the long span roof.

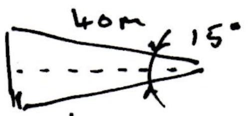
Care would need to be taken to not propose schemes that are too complex to design under examination conditions in the time available, but overall this question should provide a good vehicle for candidates to demonstrate their engineering knowledge, as long as they are not scared off by the scale and geometry of the building.



Check spacing of perimeter columns.

Circumference at level 1 $= \pi D = 251.3\text{m}$

$\frac{\text{Circum}}{6} = 41.9\text{m}$ (say 3 intermediate columns).



∴ spacing = 10.44m

> 8m ∴ ok.

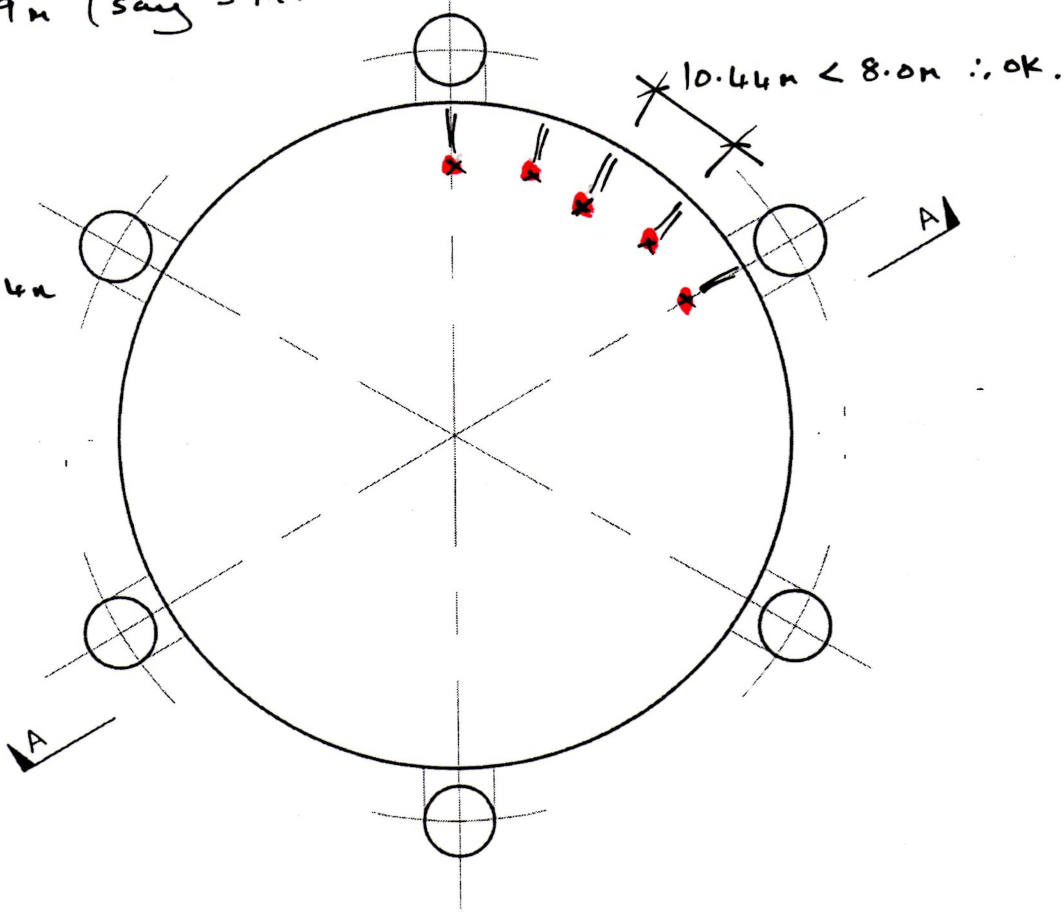
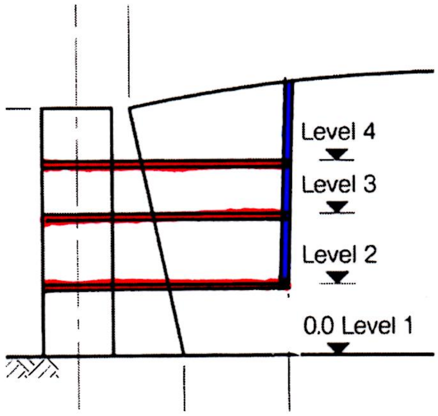
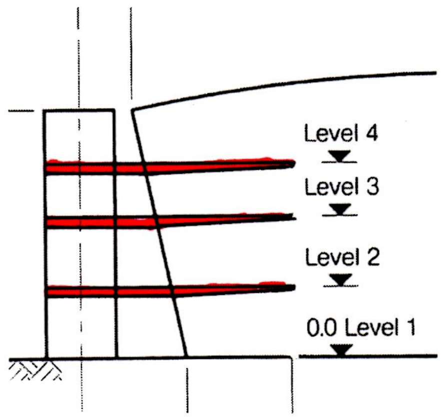


FIGURE Q1-1


Level 4
Level 3
Level 2
0.0 Level 1


Level 4
Level 3
Level 2
0.0 Level 1

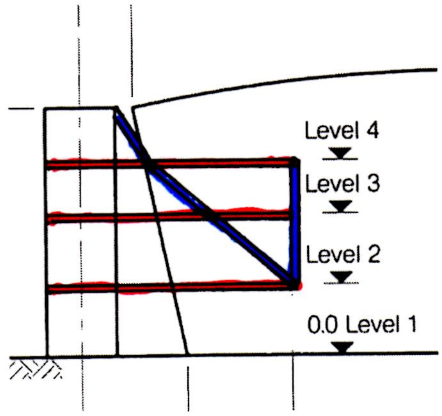
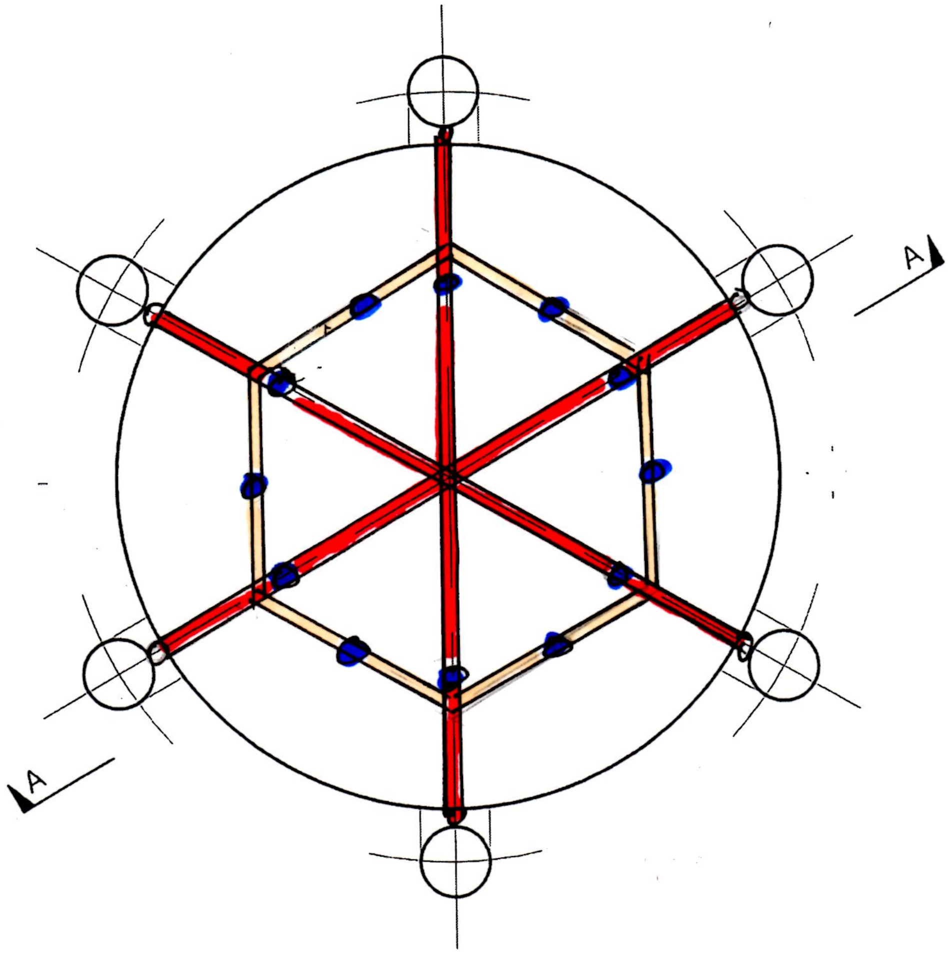
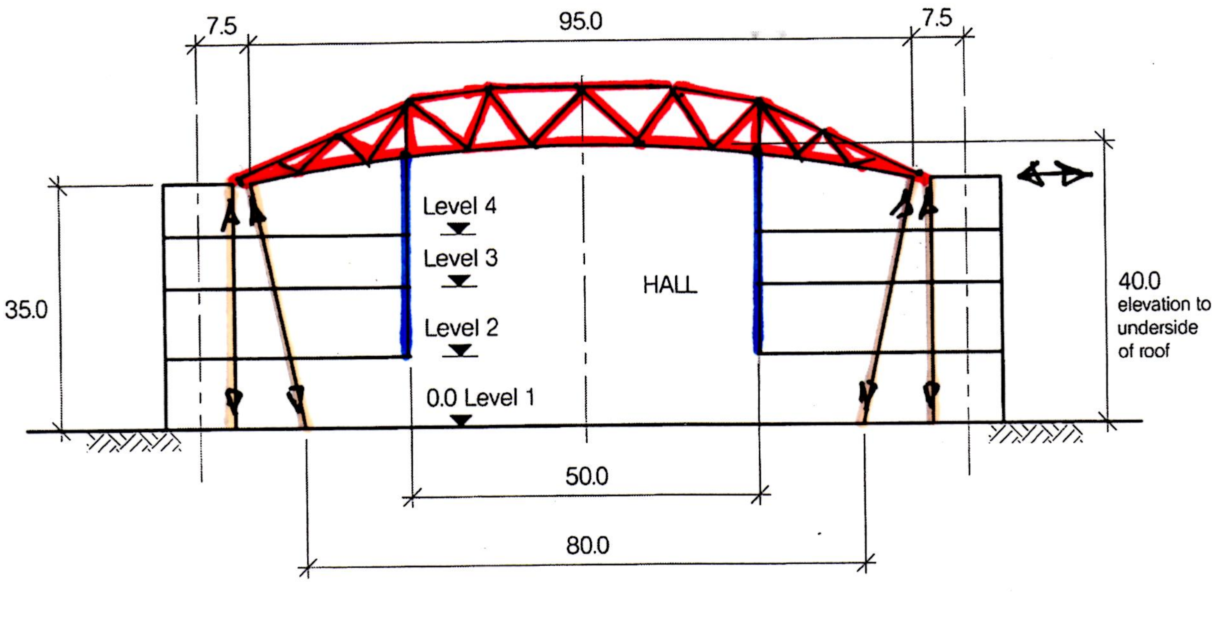

Level 4
Level 3
Level 2
0.0 Level 1

FIGURE Q1 -2



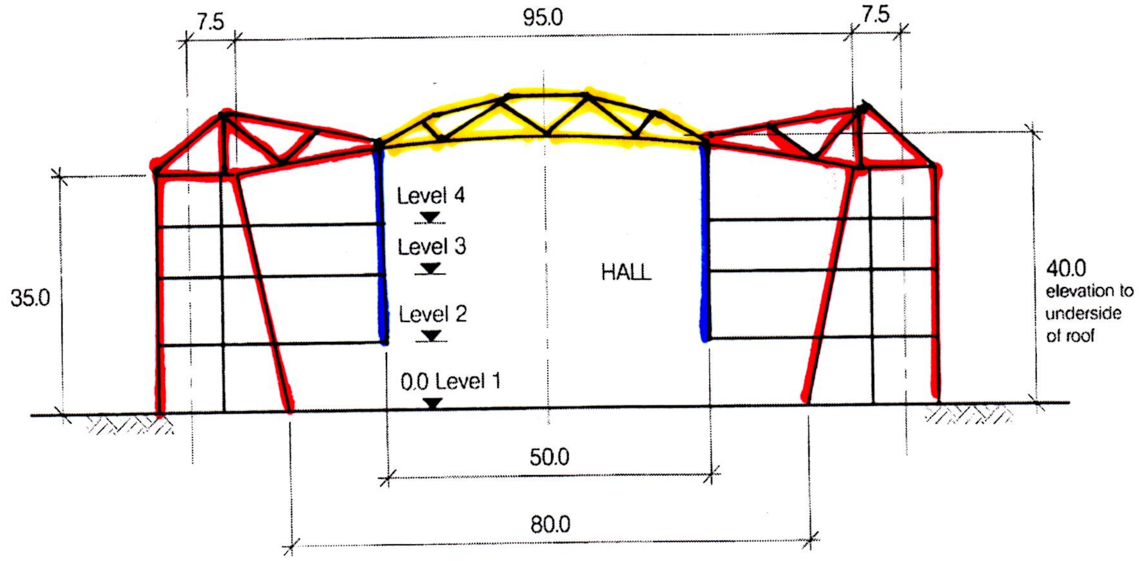
PLAN



SECTION A - A

NOTE: All dimensions are in metres

FIGURE Q1 - 3


7.5
95.0
7.5
Level 4
Level 3
HALL
35.0
40.0
elevation to
underside
of roof
Level 2
0.0 Level 1
50.0
80.0

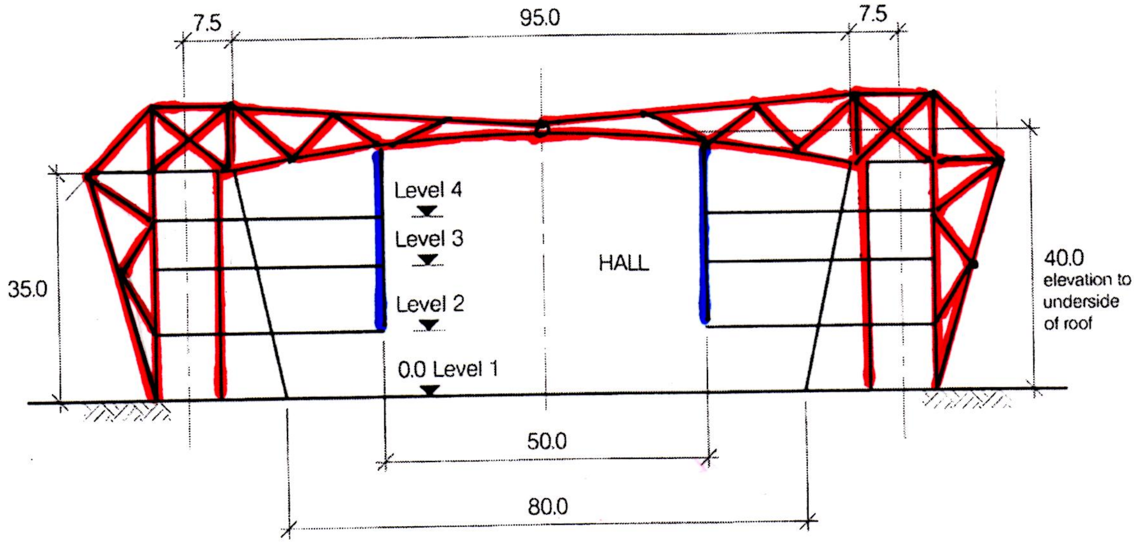
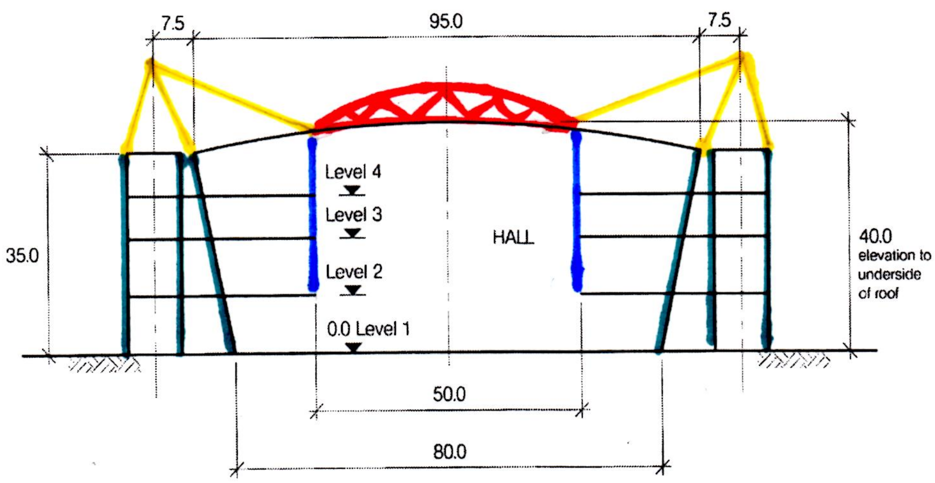
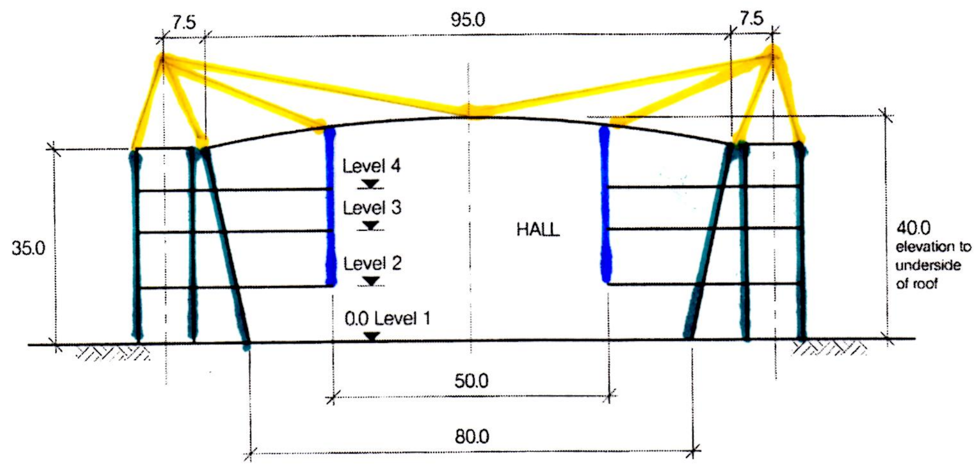

7.5
95.0
7.5
Level 4
Level 3
HALL
35.0
40.0
elevation to
underside
of roof
Level 2
0.0 Level 1
50.0
80.0

FIGURE Q1 - 4.

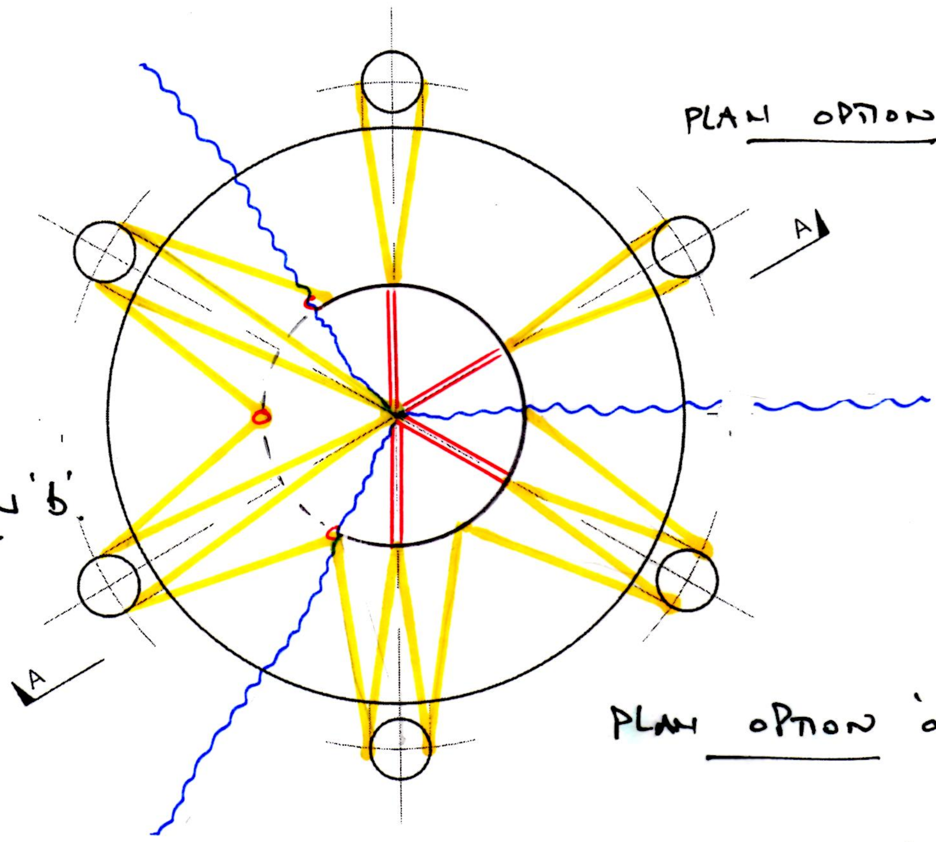


OPTION 'a'



OPTION 'b'

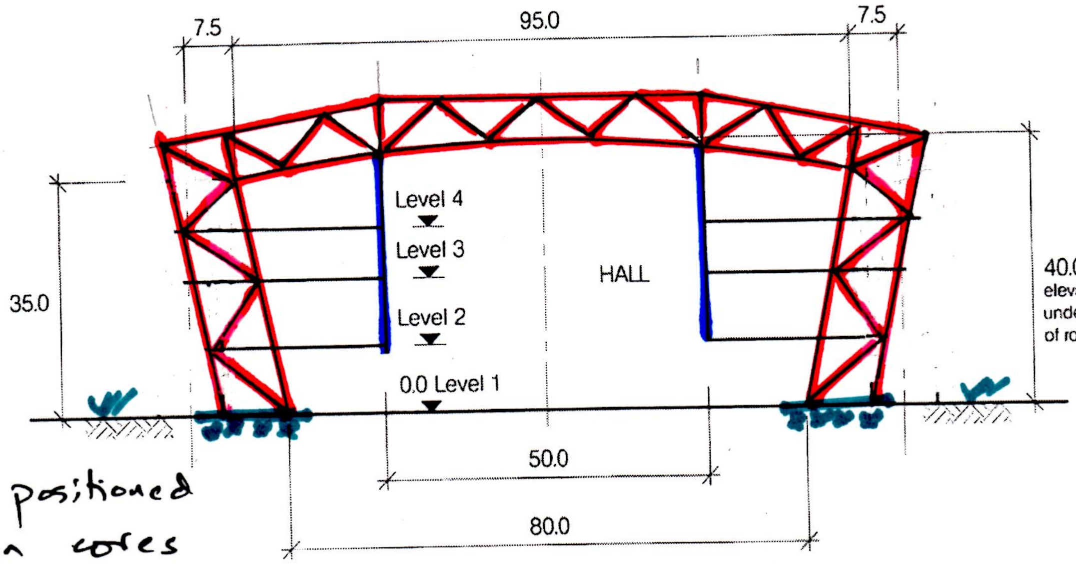
PLAN OPTION 'ai'



PLAN OPTION 'b'

PLAN OPTION 'aii'

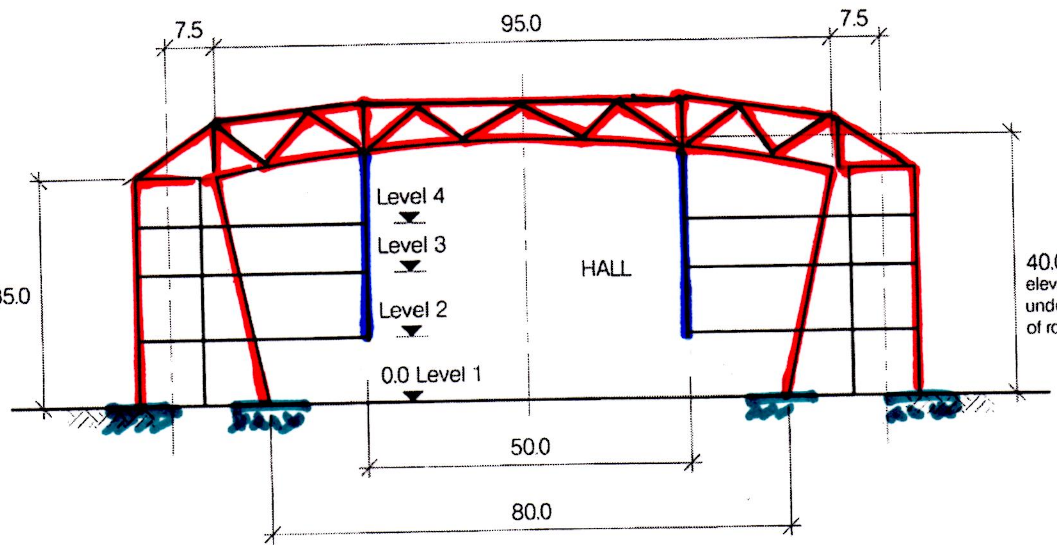
FIGURE Q1-5



Note

Frames positioned between cores to allow sufficient depth of frame.

option 'a'



Note

Using cores as part of overall frame.

option 'b'

FIGURE Q1-6.

The Institution of Structural Engineers

Possible solution to past CM examination question

Question 2 - April 2012

Headquarters Extension

by Dr Peter Gardner

Question 2. Headquarters extension

Client's requirements

1. An existing office building is to be extended to accomodate additional offices and a dining area. See Figure Q2. The exterior of the new building is to be clad with a patent glazing system that requires supports at 2.0m centres vertically and horizontally.
2. The dining area is to be 15m wide and 30m long. The clear height is to be 3m. Only two columns with a maximum size of 1m square are permitted in this area. No other structural members are permitted within this volume or in the free space above the dining area.
3. The office areas are to be 10m wide and 30m long. The clear height is to be 3m. No columns or other structural members are permitted inside the office areas.
4. The building is to be linked by pedestrian bridges at each floor level. No horizontal loads are allowed to be transmitted to the existing building via the bridges. To meet fire regulations, non-structural external stairs will be used.
5. There are no restrictions on the structure outside the building envelope. No bracing or walls are permitted inside the office spaces or within the dining area.

Imposed loading

6. Roof loading 0.5kN/m²
   Floor loading 5.0kN/m²
   Bridge loading 5.0kN/m²

Site conditions

7. The site is located in a coastal location. Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s.
8. Ground conditions:
   Borehole 1 at Level 1

0.0m – 0.5m	Top soil
0.5m – 2.0m	Sand, N=10
2.0m – 5.0m	Gravel, N=30
Below 5.0m	Rock, allowable bearing pressure 500 kN/m²

Borehole 2 at 3m below Level 1

3.0m – 4.0m	Loose clayey sand
4.0m – 7.0m	Gravel, N=30
Below 7.0m	Rock, allowable bearing pressure 500 kN/m²

Ground water was found at 4m depth from ground level.

Omit from consideration

9. Detailed design of link bridges and external stairs.

SECTION 1 (50 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)

b. After your design is complete but before construction has been started, the client requests that the existing building be supported laterally by the new building. Write a letter to the client advising on the impacts of this decision on the new building. (10 marks)

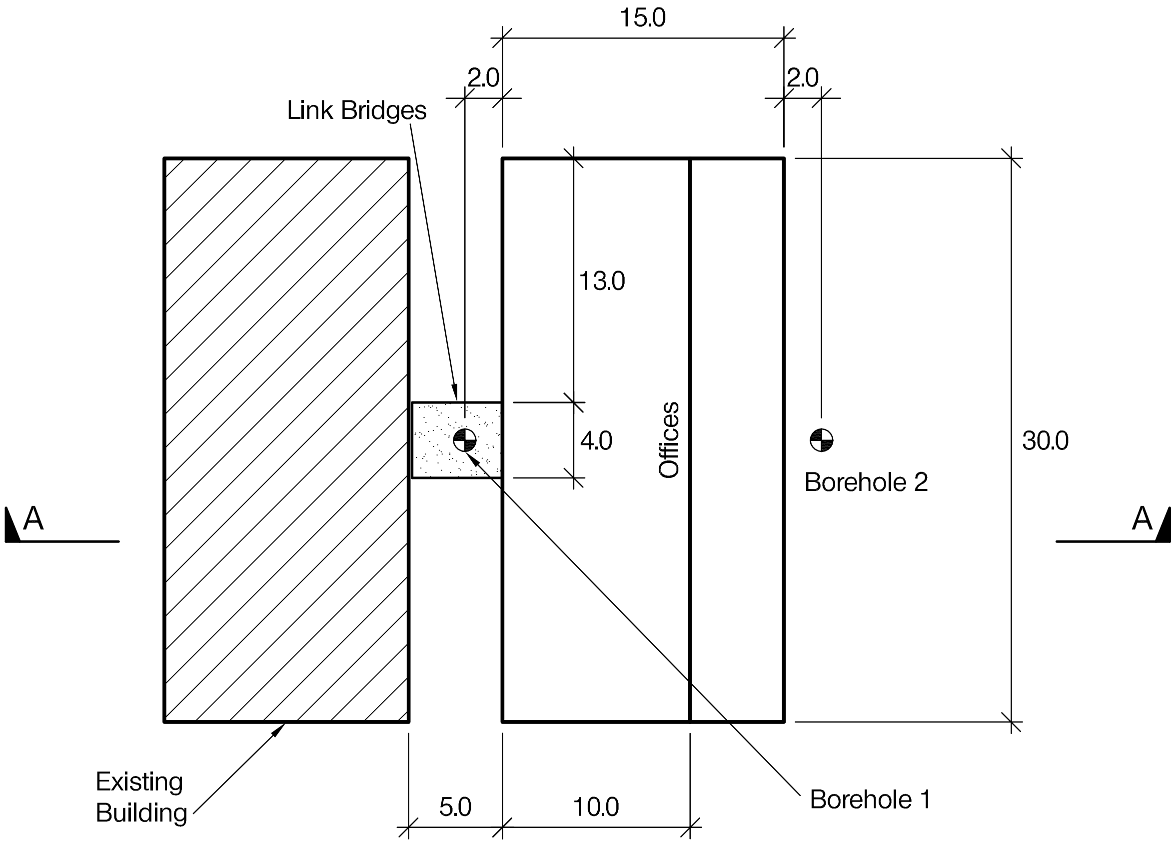
SECTION 2 (50 marks)

For the solution recommended in Section 1(a):

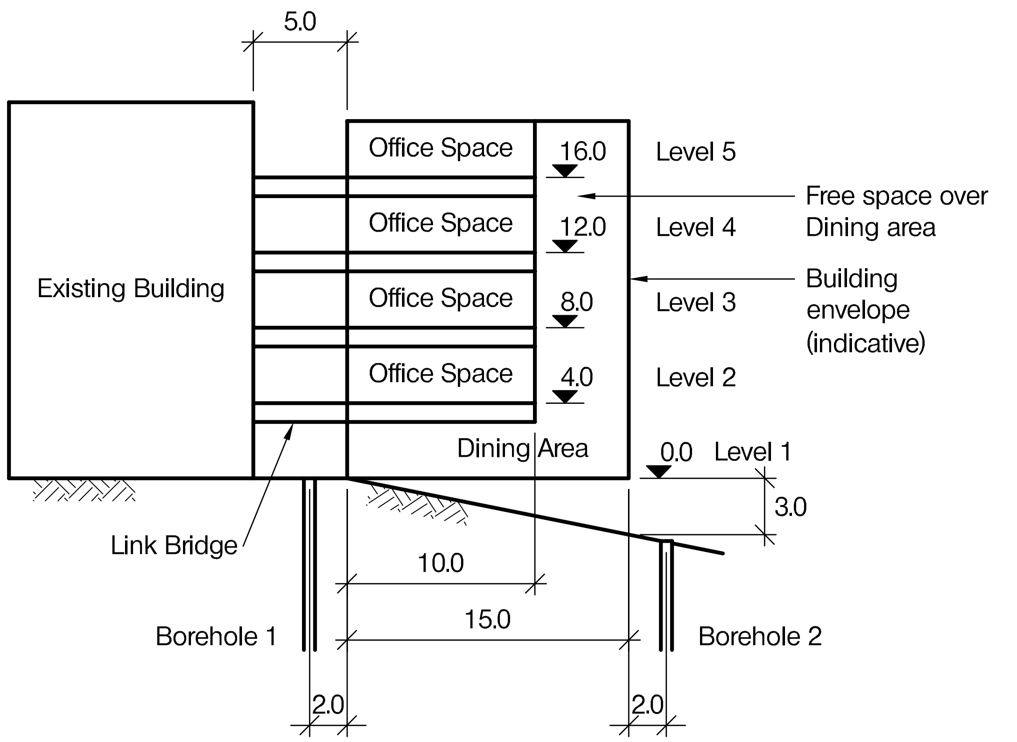
c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)

d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20 marks)

e. Prepare a detailed method statement for the safe construction of the building and an outline construction programme. (10 marks)



PLAN



SECTION A-A

NOTE: All dimensions and levels are in metres

FIGURE Q2

Headquarters Extension

Introduction

This question relates to a five-storey rectangular office building as an extension to an existing construction. It is relatively straightforward but has a few critical features including an open dining area and a large facade of patent glazing, with the whole building sitting over a sloping site.

The brief

A new building, which forms an extension to an existing building, provides additional offices and a dining area.

- The exterior of the new building is to be clad with patent glazing that requires support both vertically and horizontally at 2m centres. This is likely to be a critical feature of your proposal on the eastern elevation (assuming north-south is vertical on the page) as there is a large area of glazing without pre-existing structural support.
- The dining area covers the whole of the ground floor. Only two columns with a maximum size of $1m^2$ are permitted in this area (i.e. only two columns are available to support the offices above). No other structural elements are permitted within the dining area or the open atrium that runs the full height of the building.
- The office area at each level is to be 10m x 30m. No columns or other structural members are permitted in the offices.
- Both the dining area and the offices are to have a clear height of 3m. The floor-to-floor heights are specified, giving a maximum structural depth.
- The buildings are to be linked by pedestrian bridges at each level. However horizontal loads cannot be transmitted via the bridges, so apart from a nominal vertical load from the link bridge, the existing building is structurally irrelevant.
- There are no restrictions on the structure outside the building envelope.
- The site is located in a coastal region and has a significant slope. The building is positioned 3m above existing ground level at its eastern edge. There isn't viable soil in the upper layers but below the loose sand there is gravel overlying rock.

Interpretation of the brief and critical issues

The building itself is a relatively straightforward rectangular office block but does have a few features that form the challenge in this particular question.

There are no restrictions on the structure around the perimeter, other than being aware of the visual impact of structural elements, as the whole building is clad in glazing. However no structural members are permitted inside the office space, nor the atrium, and only two columns are allowed in the dining area.

Each of the usable spaces in the building is required to have a clear height of 3m, with each level having a story height of 4m, effectively allowing 1m for structure, services and finishes. As no specific clear service zones have been specified, it would seem reasonable to use the majority of the space for structural elements (providing openings in the structure for the services as needed). This should be adequate for floor beams in the office area (based on span/depth ratios) but may be insufficient for a long-span transfer structure.

The whole of the eastern elevation is clad in patent glazing, which needs supporting vertically and horizontally at 2m centres, but there are no horizontal restraints at any level (normally provided by the floors). Vertically there will be columns, but probably not at 2m centres. Therefore additional, structural elements will be required to support the glazing.

On the eastern elevation the building is 3m above existing ground level, so some form of support mechanism will be required between level 1 (ground floor) and outside ground level, including transmission of any lateral loads into the foundations.

There is decent gravel across the site, albeit that the strata slopes, however there is underlying rock with an allowable ground bearing pressure of 500 kN/m^2, which would provide an ideal foundation.

Design options

There are effectively four issues that need to be addressed in this question. A mix-and-match from each would form the basis of two very clear "distinct and viable" schemes. These issues are: stability, internal support of the offices, support for the glazing (particularly on the front elevation) and foundations (particularly at the front of the building where the ground floor slab is above ground level). Each of these issues is discussed below.

Principal material and grid layout

Depending on the precise proposal, steel would seem an appropriate material for the main frame and particularly any lattice structures. This would facilitate architecturally pleasing (exposed) bracing. The floors would be constructed of reinforced concrete. Concrete could be used as an alternative material, but offering the same framing arrangement, with one scheme in steel and the other scheme in concrete would not be deemed to be two different schemes. I have chosen a 6m grid as it can be readily subdivided to facilitate the glazing support structure which has a maximum span of 2m.

Office support

As each floor level and clear heights have been specified, it is not practical to have a deep transfer beam at level 2 spanning the full 30m, however with two supporting columns a transfer structure comprising a three span continuous beam would be a feasible option. This could either support additional columns above the level two floor, with shorter span beams at the upper levels, or the same column arrangement at each level, running the two columns right through to the roof. The second option is simpler but requires longer spans for the floors.

Therefore the "obvious" first design option would be to specify two columns in the dining area aligning with the internal edge of the offices above, providing a transfer structure at level two, supporting more conventionally spaced columns on the outer extremity of the offices on levels 2 - 5. See figure Q2 - 1.

As an alternative, a lattice roof structure could span from front to back, with the office columns hung from the roof, meaning that no columns would be required in the dining area, see figures Q2 - 2 and Q2 - 5.   This would give a distinct and viable alternative to this part of the structure.

Support for the patent glazing.

The patent glazing clearly needs some dedicated structural members in addition to any principal columns, as it requires support at 2m centres vertically and horizontally. Because this is such a significant element of the question it would be desirable to provide two alternatives. Although main columns could be supplied at 2m centres it would probably be more practical and cost-effective to provide principal supports at wider centres and then secondary support members spanning between them, see figure Q2 - 7. The columns on the eastern elevation are long (19m) with no intermediate support and therefore no lateral restraint, therefore effective lengths, instability and deflection all need to be carefully considered.

Figures Q2 - 2, 3 & 5 show some options, where this part of the structure could be made a feature. The loads and exact structural purpose of these columns will depend on how they are integrated into the overall structural form (see figures) but each option involves vertical columns supporting the roof, with secondary support spanning horizontally and vertically between them providing support for the glazing system.

An alternative would be to provide horizontal lattice beams as the principal members supporting the glazing. This arrangement would not provide vertical support to the roof, although the roof could be supported from the internal columns and a 5m cantilever truss (see figure Q2 - 4). Because of the relative dimensions of the building (20 m high and 30 m long), this option does not have any particular advantage over vertical supports having the dual function of principal columns holding-up the roof and glazing support, but it is nevertheless a viable alternative and illustrates that you can devise alternatives.

Foundations

The soil profile given in the question is open to some interpretation, however the two relevant elements are the gravel which slopes across the site (and is below the water table), and the rock. This provides us with the opportunity to propose two alternative foundation systems, one utilising pads in the gravel and the second, piles in the rock. We would need to exercise some caution with the pad solution, bearing in mind the gravel slopes and is below groundwater level but it does enable you to offer two different schemes. Once the options and the pros and cons are discussed, I would propose piles into the rock as the preferred scheme.

Because the new building’s ground floor slab is above existing ground level at all but the rear of the building, transferring lateral loads into the ground becomes an issue which certainly should be discussed. One option would be to take all the lateral loads out on the rear foundations, in which case simple axially loaded columns would span between the ground floor slab and the top of the foundations, but it would be desirable to spread the lateral loads across all of the foundations. This could be easily achieved by concrete walls although these may look rather bulky, but the same effect could be achieved by diagonal columns, or raking piles any of which could be made a feature of the building.

Stability

Although the building is clad in glazing, there is no indication that this precludes diagonal bracing. There are many examples where bracing is made an architectural feature, and is deliberately visible behind glass facades. The fact that the building is clad in glass makes deflection a critical issue and therefore a stiff stability system is a desirable feature. Therefore, diagonal bracing in each elevation would seem to be the most desirable option to achieve stability. Concrete shear walls would not be appropriate in this particular situation. An alternative could be moment resisting frames, which could readily be constructed East/West and possibly North/South. Figure Q2 - 5 shows an arrangement where the basic construction consists of large moment resisting frames with the internal offices hung from the frame.

Vertical bracing should be selected as the desirable scheme on the basis of simplicity and critically, restricting deflection in the building. This arrangement of course has the added benefit that it is straightforward to design (an important practical consideration in the examination).

Forming two distinct and viable schemes

Although I have advocated a pick and mix of the various options for each of the main features, this is primarily for the purpose of thinking through the options afforded by the brief which can later be combined into viable structural arrangements. Once this is complete, for the purposes of the exam they should be packaged into two clear schemes (i.e. the analysis of the available options could form part of the initial design appraisal but they must result in "two distinct and viable" [fully worked-up] structural schemes.

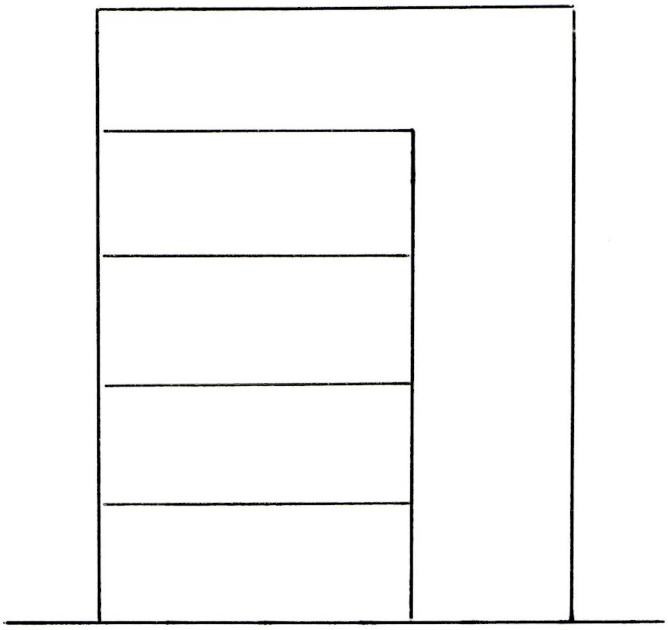
<u>Section 1b - Letter</u>

The scenario presented in section 1b relates to a fundamental issue in relation to the existing building in that the client has requested that the new building provides lateral support for the existing building (presumably via the link bridges). Clearly this would increase the lateral loads carried on the superstructure and foundations of the new building, but this should be easily accommodated by designing for higher loads, assuming the new building has a relatively stiff bracing arrangement. If a more flexible frame has been proposed, the need for resisting additional load would further increase deflection, which would have to be checked very carefully in relation to the glazed cladding. However, the main issue in relation to this proposal is transferring the loads through a single vertical line of link bridges. It would be virtually impossible to resist torsional loads, and therefore part of the solution should involve increasing the number of links by providing additional connections at the North and South intersections.

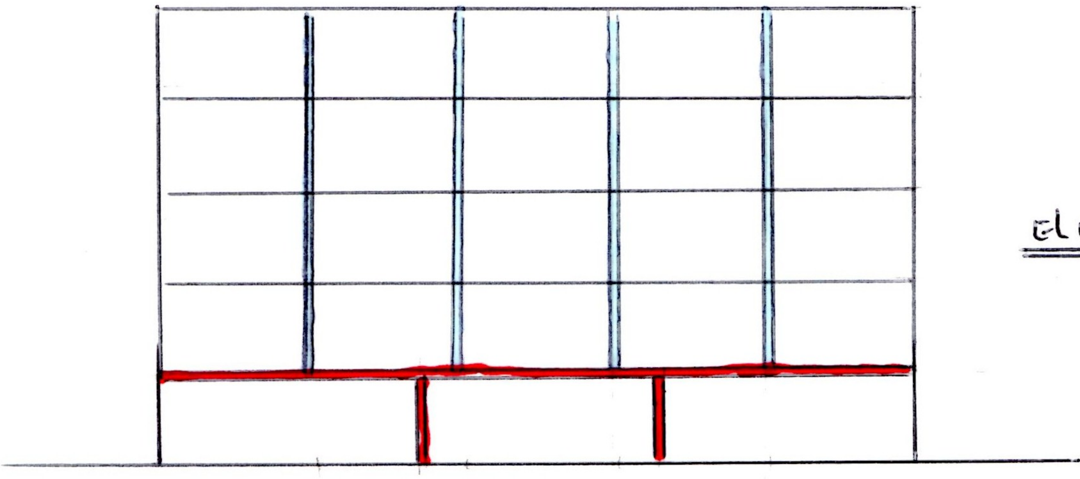
The other issue that is worth considering is the circumstance that has led to this requirement and whether it would be possible to transfer lateral loads out of the existing building without retrofitting strong points into this building. It seems reasonable to assume that the building is currently stable but is subject to some circumstance that requires additional lateral support. This could be inadequacy in the current provision or some change to the existing building that necessitates support from the adjacent new building. If the lateral loads from the existing building are transferred to the new building, it would be relatively easy to strengthen the new building and perfectly possible to provide adequate transfer arrangements, but it could be extremely difficult to collect the lateral loads from the existing building at locations where they could be transferred into the new building. These aspects give another whole dimension that could be discussed in the letter.

Summary

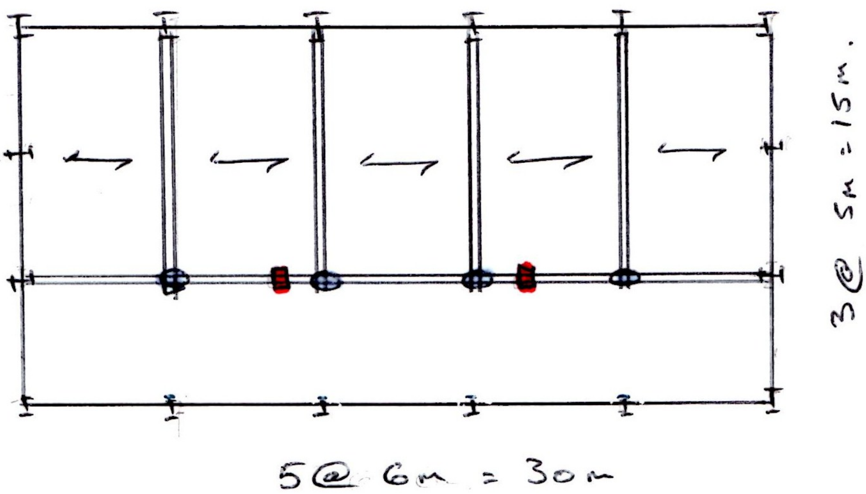
This seems to be a reasonably straightforward question, with some obvious structural challenges. The brief is clear and the combination of supporting the office floors internally (with a limited number of columns), the unsupported glass facade, and the raised building on the East elevation provide a vehicle through which to demonstrate your understanding of structural principles and to develop proposals for viable alternative solutions. By combining these options along with possible alternative stability systems you should be able to provide the "two distinction and viable solutions" required by the question.



SECTION.



ELEVATION



PLAN.

FIGURE Q2 - 1.

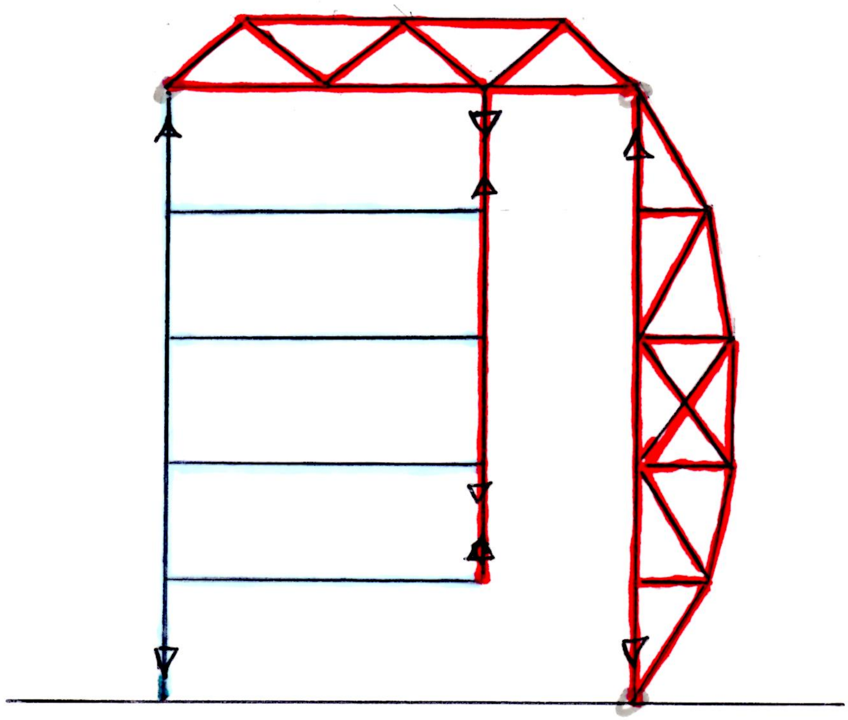


FIGURE Q2 - 2

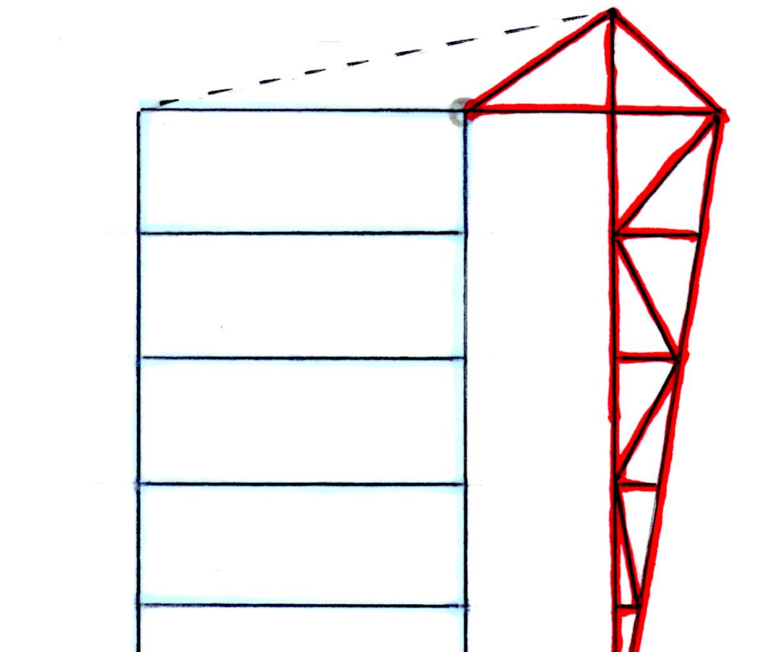


FIGURE Q2 - 3

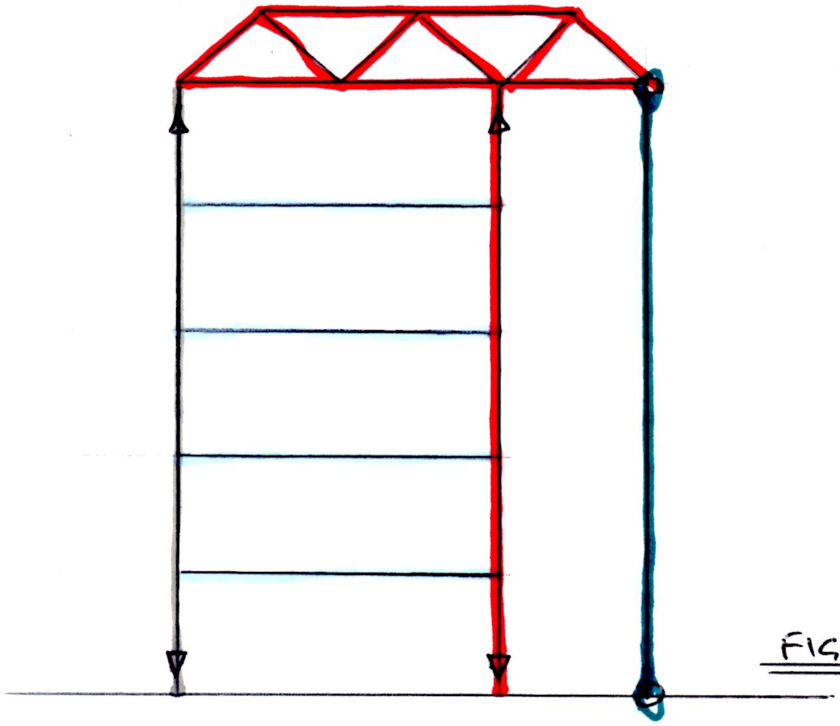
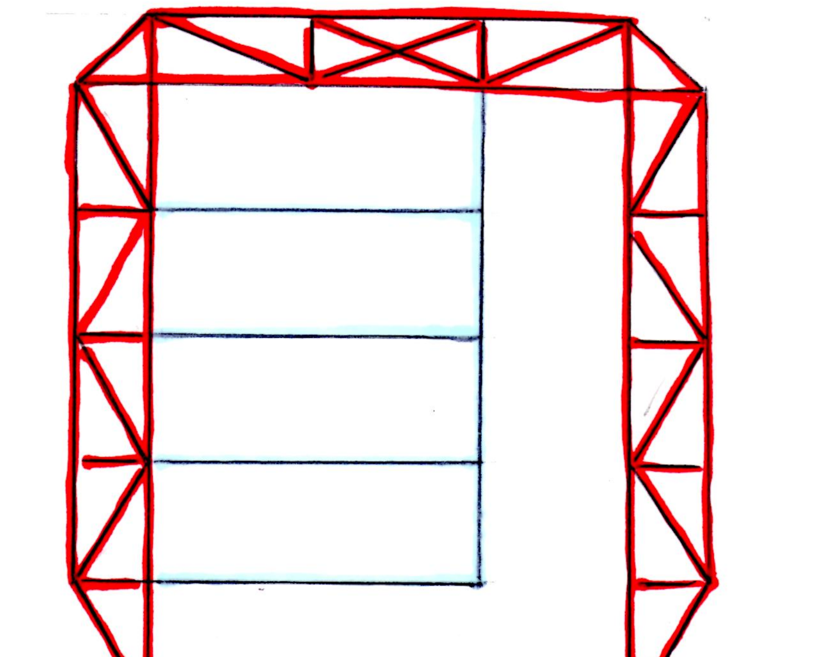


FIGURE Q2-4

ROOF TRUSS SUPPORTED BY INTERNAL COLUMN.

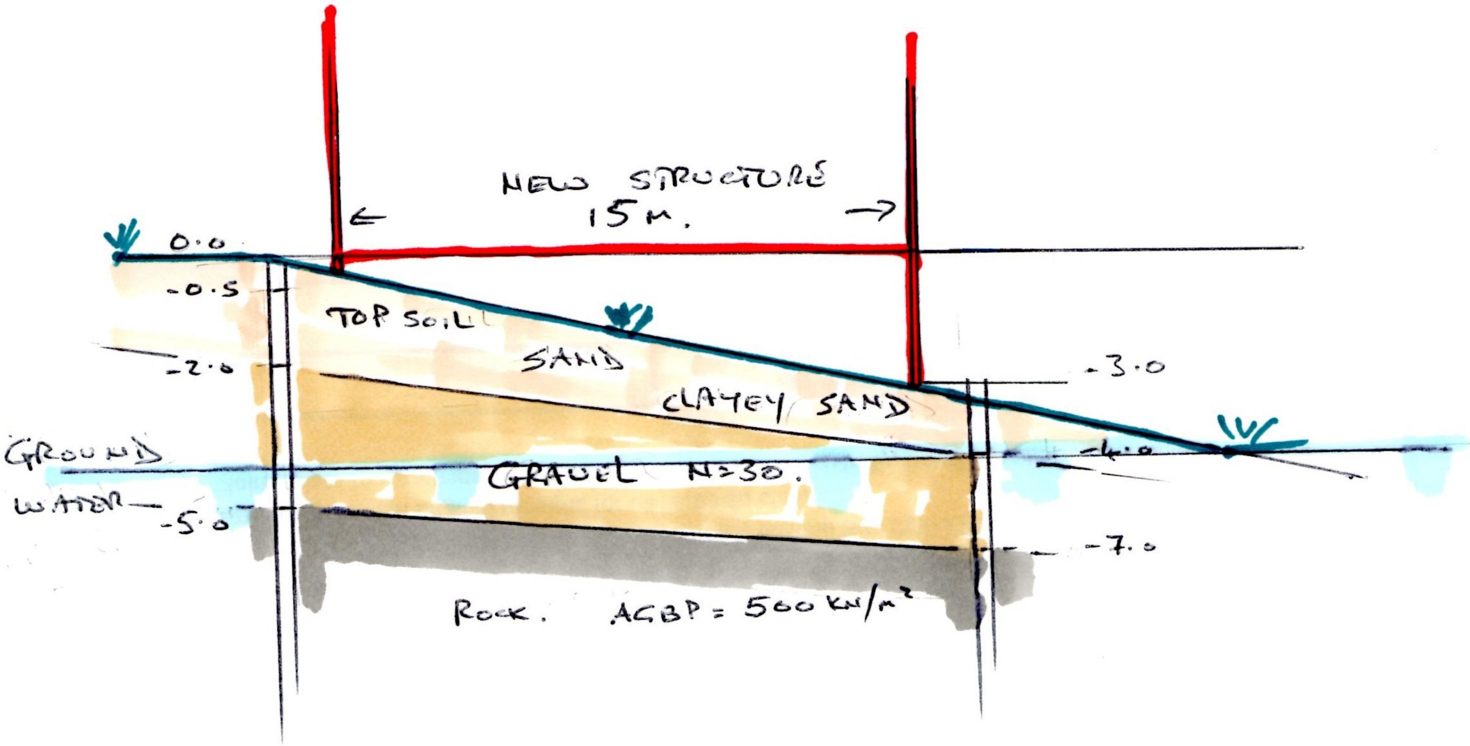
GLAZING COULD SPAN HORIZONTALLY OR VERTICALLY.



MOMENT FRAME.

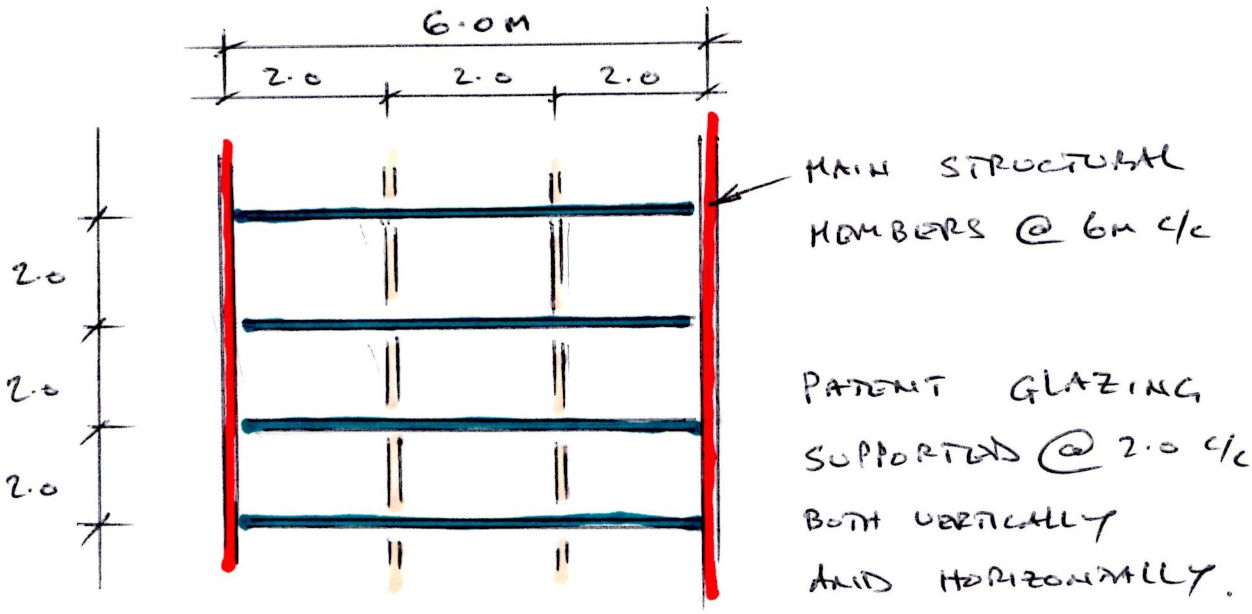
FIGURE Q2-5.

FLOORS HUNG FROM FRAME



SOIL PROFILE.

FIGURE Q2 - 6.



GLAZING SUPPORT.

FIGURE Q2 - 7.

The Institution of Structural Engineers

Possible solution to past CM examination question

Question 4 - April 2012

New Arts School

by Bob Wilson

QUESTION 4 - 2012 NEW ARTS SCHOOL

CAUTIONARY REMARKS!

THIS QUESTION IS OF THE SORT THAT HAS A "NEVER ENDING" ANSWER. IT APPEARS TO BE DECEPTIVELY EASY – A BASEMENT SUPPORTING A CORE AND SUPERSTRUCTURE STANDING ON PILES TO ROCK – VERY STRONG ROCK – WITH SUPERSTRUCTURE EITHER HUNG FROM ROOF TRUSSES OR STANDING ON A LEVEL 2 "STRONG DECK".

IF THE ANSWER IS APPROACHED WITHOUT GRAVITAS OR CONSIDERATION TOO MANY ESSENTIAL FEATURES WILL BE MISSED OR TREATED SUPERFICIALLY E.G. THE GLAZED CLADDING, THE WIND FORCES, THE ROOF, THE WEIGHT OF THE CANTILEVER FLOOR AND THE WATERPROOFING OF THE BASEMENT. SIMPLISTIC APPLICATION OF REINFORCED CONCRETE DESIGN WILL RESULT IN HEAVY AND CONGESTED REINFORCEMENT. THE BUILDING SEQUENCE, FROM EXCAVATING THE BASEMENT TO HOISTING THE ROOF TRUSSES, REQUIRES CLOSE ATTENTION.

HOWEVER, WITH EXPERIENCE, MORE AND MORE PROBLEMS PRESENT THEMSELVES E.G. THE DEFLECTION OF THE CANTILEVER FLOORS SUPPORTING THE GLAZED CLADDING; THE SWAY OF THE TOWER AND VIBRATION OF THE FLOORS; THE TWO-HOUR FIRE RESISTANCE; AND VARIOUS AMBIGUOUS FEATURES OF THE QUESTION SUCH THE $5kN/m^2$ IMPOSED LOAD ON LEVEL 1 EXCLUDING EMERGENCY VEHICLES FROM THE "PLAZA", FLOODING OF THE BASEMENT BY EXCEPTIONAL SEA LEVELS, THE EXTENT [LENGTH] OF THE SEASIDE PROMENADE / DEFENCES, ETC.

IF THE ANSWER IS SUPERFICIAL IT ONLY NEEDS A MISTAKE OR TWO FOR THE MARKS TO BE BELOW THE PASS MARK: IF A DETAILED ANSWER IS ATTEMPTED THE TIME IS TOO SHORT AND UN-ANSWERED PORTIONS OF THE QUESTION, VIZ. THE LETTER AND THE METHOD STATEMENT / PROGRAMME, REDUCE THE MARKS.

I HAVE ATTEMPTED TO "TOUCH" ON MANY OF THE PROBLEMS WHILE KEEPING THE TEXT AS SHORT AS I CAN. SEVERAL FEATURES HAVE NOT BEEN MENTIONED, FOR INSTANCE, THE ROOF AND ROOF BEAMS. THE CONTENTS ARE DIVIDED INTO THREE PORTIONS:

PART 1 - THE GENERAL CONCEPT OF THE SUPERSTRUCTURE

PART 2 - SPECIFICALLY THE BASEMENT AND SEA DEFENCE

AND A DIGEST - USE OF CELLULAR BEAMS.

- I SUGGEST THAT THE CANDIDATE USE THESE TEXTS AS A BROAD "CONCEPTUAL EXPERIENCE", BREAKING OFF TO READ, RESEARCH OR STUDY WHEN TOPICS NEED TO BE DEVELOPED. THE STANDARD OF KNOWLEDGE NEEDS TO BE "PROFESSIONAL", OR "ABILITY" IN TERMS OF THE CORE OBJECTIVES - "PERFORM THE SUBJECT WITHOUT SUPERVISION AND BE COMPETENT TO ADVISE OTHERS".
- PREPARATION FOR THE EXAMINATION WILL INVOLVE DEVELOPING THESE CONCEPTS BY INITIAL SIZING, ASSESSING AND VALUEING, SELECTING AND DEVELOPING [BY CALCULATION AND DETAIL] AND JUDGING BUILDABILITY. ALL THIS NEEDS TO BE COMMUNICATED CLEARLY.
- EACH CANDIDATE MUST PUT TOGETHER THEIR OWN ANSWER IN THE GIVEN TIME.
- WHEN AN ANSWER HAS BEEN ASSEMBLED SIT DOWN IN A CRITICAL MOOD AND EVALUATE WHAT HAS BEEN WRITTEN AND DRAWN - I.E. MARK IT - IN A WAY SIMILAR TO THAT USED IN THE OFFICE AT WORK TO JUDGE IF THE JOB HAS BEEN COMPLETED AND IS GOOD ENOUGH TO LEAVE THE OFFICE - BE SENT TO THE CLIENT, ARCHITECT, CONTRACTOR OR BUILDING CONTROL. THIS IS THE SELF-CRITICAL STANDARD SET BY THE PROFESSIONAL ENGINEER TO HIM- OR HERSELF!
- TRY TO THINK OF THE EXAMINATION AS A PROFESSIONAL PIECE OF WORK - 100% RIGHT! WOULD YOU ISSUE YOUR WORK TO OTHERS IF IT WAS FLAWED AND ONLY 40% CORRECT?

QUESTION 4 – 2012 NEW ARTS SCHOOL – PART 1

THE GENERAL CONCEPT OF THE SUPERSTRUCTURE.

THIS QUESTION HAS A RESEMBLANCE TO Q4–2010 CITYSCAPE DEVELOPMENT IN THAT IT HAS A SUPERSTRUCTURE PERCHED ON A CORE – RATHER LIKE A MUSHROOM! CLEARLY THERE IS A FUNDAMENTAL PROBLEM OF STABILITY – THE BUILDING MUST NOT BLOW OVER; IT MUST NOT TILT OR SWAY; AND THE LARGE OVERHANG MUST NOT DEFLECT UNDULY [FOR PERSONAL COMFORT, OVERALL APPEARANCE, AND STABILITY OF GLAZED CLADDING]

THE BUILDING IS ON THE SEAFRONT AND THE CANDIDATE IS EXPECTED TO REVIEW AND EVALUATE EACH OF THE FACTORS THAT ARE USED IN CALCULATING THE WIND PRESSURE FROM THE WIND SPEED GIVEN UNDER SITE CONDITIONS #5. THE EFFECT OF WIND ON THE UNDERSIDE OF LEVEL 2 SHOULD BE INCLUDED.

[REFERENCE CR #1]

SINCE NO PARTITIONS OR DIVISIONS ARE INDICATED ONE SHOULD ASSUME "OPEN PLAN" WITH AS FEW INTERNAL SUPPORTS AS POSSIBLE. THE CORRIDOR MENTIONED IN CR #2 IS CLEARLY PARTITIONED OFF BUT ONLY 1.5 WIDE AND SO THE PARTITION IS UNLIKELY TO BE OF USE FOR CONCEALING SUPPORTS! IT DOES, HOWEVER, GIVE THE "CLEAR HEIGHT" OF 2.5m. I PERSONALLY DOUBT THAT THE CORRIDOR WOULD BE ACCEPTED AS A MEANS OF ESCAPE IN THE UK!

THE CORE WILL CONTAIN STAIRS, LIFTS, SERVICE SHAFTS AND LANDINGS/LOBBIES. IT WILL NOT BE EMPTY, AS SHOWN ON FIGURE 4 PLAN AND SECTION. IN EFFECT, THERE WILL BE DIAPHRAGMS AND LIFT-SHAFT WALLS: BEING THE ONLY MEANS OF ESCAPE IN CASE OF FIRE FOR A LARGE NUMBER OF STAFF AND STUDENTS IT WILL IN FACT BE A COMPLEX STRUCTURE! THE EXAMINER HAS PROVIDED A SIMPLIFICATION: A FOUR-WALL CORE SHAFT – SEE "OMIT FROM CONSIDERATION #7". THE CANDIDATE MAY BASE HIS/HER CALCULATIONS ON THE DIMENSIONS SHOWN AND ASSUME A WALL THICKNESS.

CR #2 SPELLS-OUT THE CLADDING REQUIREMENT: ONE MAY ASSUME THAT ONLY THE TOP THREE FLOORS ARE CLAD; I.E. THE TERM "FULLY GLAZED" APPLIES TO THE HABITABLE AREAS AND NOT THE FULL 30.0m HEIGHT. TWO REFERENCES APPLY: "STRUCTURAL USE OF GLASS IN BUILDINGS", I STRUCT. E, 1999 AND "STEEL SUPPORTED GLAZING SYSTEMS", SCI PUBLICATION 193

THE SORT OF GLAZED CLADDING THAT HAS TO BE SUPPORTED MIGHT BE SIMILAR TO THAT USED ON THE PROCTOR AND GAMBLE BUILDING AT BROOKLANDS, SURREY — ENGINEERED BY ANTHONY HUNT ASSOCIATES: PRIMARY {MULLIONS} TRUSSES AT 4.05m CRS WITH LAMINATED GLASS {TRANSOMS} PURLINS AT 1.35m. CRS CARRY DOUBLE-GLAZED PLANAR CLADDING COMPRISED OF 12mm THICK, TOUGHENED OUTER LAYER WITH A 16mm AIR GAP AND THEN TWO 6mm PLATE-GLASS SHEETS LAMINATED TOGETHER FORMING THE INNER LAYER.

ALTHOUGH PROBABLY NOT A "FAILURE" POINT, MANY CANDIDATES "FORGET" THE CLADDING OR HAVE TO GUESS. BEING PREPARED MAY WELL EARN VITAL "PASS" POINTS!

BECAUSE THE SUPERSTRUCTURE SELF-WEIGHT ON THE CANTILEVERED OVERHANGING PORTIONS MUST BE MINIMISED, A STRUCTURAL STEEL FRAME WILL SUGGEST ITSELF. BY THE SAME RESTRICTION THE FIREPROOFING MUST NOT CANCEL-OUT ANY BENEFITS. THE 2-HOUR F.R.P. IN CR#3 IS REASONABLY SEVERE. AGAIN, ALTHOUGH NOT A FAILURE POINT, MANY CANDIDATES SKATE AROUND THE FIREPROOFING. IN THIS CASE, BECAUSE FIREPROOFING IS HIGHLIGHTED IN CR#3, OMISSION IS MORE SERIOUS — YOU SHOULD NOT JUST ENCASE EVERYTHING IN CONCRETE! BE PREPARED!

THE CANDIDATE SHOULD NOTE THE IMPOSED LOAD (CR#4) ON LEVEL 1 OF ONLY 5 kN/m². THIS IS THE SAME AS PEDESTRIAN FOOTBRIDGES AND INDICATES THAT THIS IS A PEDESTRIAN AREA, PROBABLY A CAFE AREA, BUT CERTAINLY NOT AN AREA FOR CARS, PARKING OR OTHER HEAVY LOADS. ONE WOULD EXPECT SOME "GRADE SEPARATION" AND EVEN SOME FLOOD PROTECTION, IN CASE OF AN EXCEPTIONAL HIGH TIDE; NOT MENTIONED IN THE QUESTION, SO HERE IS A SEA WITHOUT A TIDE! IF THE CONTRACTOR WISHES TO USE THE AREA DURING THE CONSTRUCTION PHASE IT MUST EITHER BE "PROPPED" OR RE-DESIGNED FOR THE TEMPORARY LOADING. THE FLOORS AT LEVELS 2, 3, 4 AND ROOF MAY BE ASSEMBLED AT GROUND LEVEL [LEVEL 1] AND WINCHED UP INTO POSITION RATHER THAN ASSEMBLED IN-SITU THAT WOULD REQUIRE SUBSTANTIALLY MORE "WORKING AT HEIGHT".

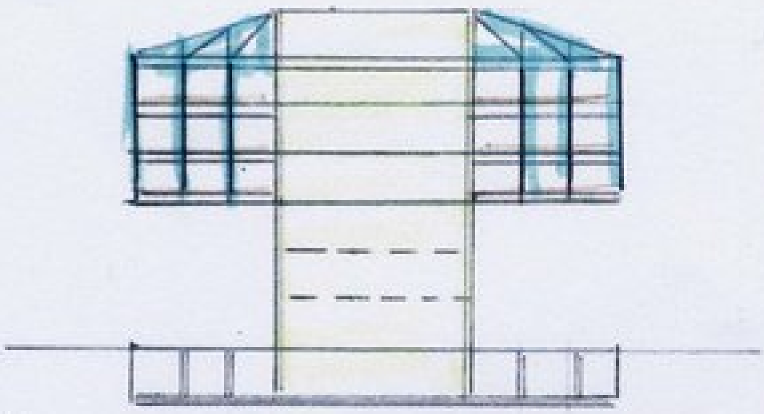
CR#1 STATES THAT THE BASEMENT IS TO BE USED FOR STORAGE. THE CANDIDATE SHOULD BE ABLE TO OFFER ALTERNATIVE WATERPROOFING OPTIONS WITH THE ALTERNATIVE BASEMENT CONSTRUCTION OPTIONS.

IN A FEW PLACES IN THE WORLD LOCAL PRACTICE/CUSTOM CHOOSES A SINGLE FOUNDATION METHOD, [I BELIEVE HONG KONG IS ONE SUCH PLACE], BUT NORMALLY EACH SUPERSTRUCTURE OPTION HAS ITS OWN FOUNDATION. DIFFERENCES IN COLUMN GRIDS, LOADING PATTERNS AND BRACING BEHAVIOUR GENERALLY MEAN THAT IN THE CM EXAMINATION EACH OF THE TWO DISTINCT AND VIABLE SOLUTIONS HAS TO HAVE ITS OWN "TAILORED" FOUNDATION.

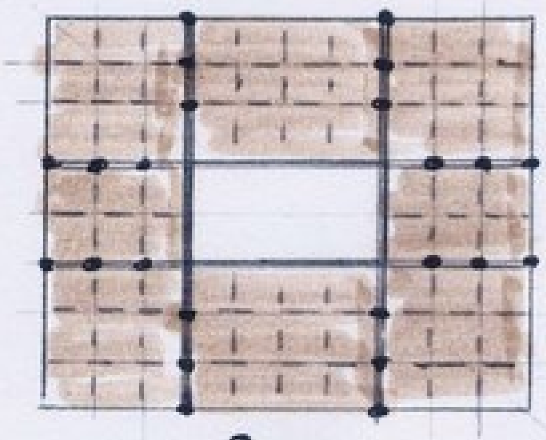
IN Q4/2012 THE CONFIGURATION OF THE CORE AND THE GROUND CONDITIONS MIGHT POSSIBLY BE CONSTRUED BY THE CANDIDATE AS A "HINT" THAT ONLY LARGE-DIAMETER CAISSON PILES TO ROCK ARE NEEDED. THIS WOULD FORM A "TAP-ROOT" TYPE OF FOUNDATION IMMEDIATELY UNDER THE CORE BUT NOT PROVIDE A FOUNDATION FOR THE REST OF THE BASEMENT. IT MUST BE OBVIOUS TO COMPETENT CANDIDATES THAT SECTION 1a MUST PROVIDE TWO COMPLETE — SUPERSTRUCTURE AND FOUNDATION — SOLUTIONS, FROM WHICH ONE SOLUTION [POSSIBLY THE "TAP-ROOT" SOLUTION] IS CHOSEN. BOTH DEEP-SEATED AND SHALLOWER FOUNDATION SOLUTIONS MUST BE EXPLORED! ANY "ONE-ONLY-FOUNDATION-SOLUTION" DOES NOT SATISFY THE REQUIREMENTS OF SECTION 1a AND MAY CAUSE THE CANDIDATE TO "LOSE" MARKS AND ULTIMATELY "FAIL" THE EXAMINATION.

BY LOOKING "HOLISTICALLY" AT THE <u>BASEMENT</u>, THE <u>RETAINING WALLS</u>, THE <u>WATERPROOFING</u> <u>AND</u> THE <u>CORE SUPPORT</u> TWO OPTIONS CAN BE PROPOSED THAT USE THE DENSE SAND AT 12.0 TO 20.0 m DEPTH AND THE STRONG ROCK BELOW 20.0 m. — A SINGLE BASEMENT STRUCTURE COMPRISING A RIGID "BOX" SPREADING THE LOAD INTO THE DENSE SILTY SAND, OR A COMBINED "TAP-ROOT" FOR THE CORE AND SPREAD FOOTINGS FOR A BASEMENT "COLLAR" AROUND THE CORE. THERE MAY BE PROBLEMS WATERPROOFING THIS OPTION.

SECTION 1b PROPOSES A CHANGE TO THE FLOOR-TO-FLOOR DIMENSION THAT APPEARS TO FORGET THE RELATIONSHIP BETWEEN "CLEAR HEIGHT + THICKNESS OF STRUCTURAL ZONE AND SERVICE ZONE" AND THE "F-TO-F DIMENSION". A CLEAR HEIGHT OF 2.2 m WITH A SERVICE ZONE OF 0.3 m LEAVES ONLY 0.5 m FOR STRUCTURE. CLOSE COLUMN CENTRES AND STEEL FRAMING MAY BE NECESSARY!

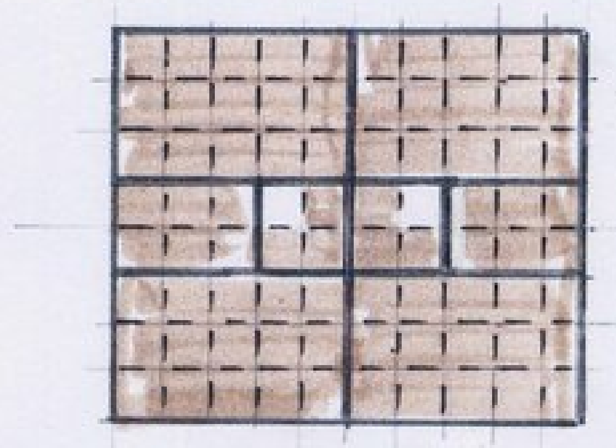


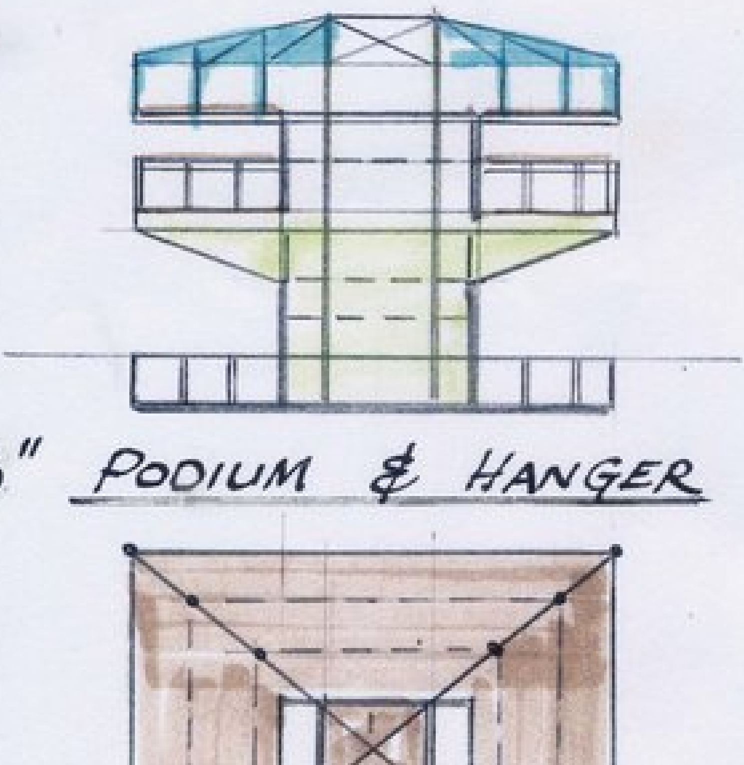
"A" CORE & HUNG FLOORS



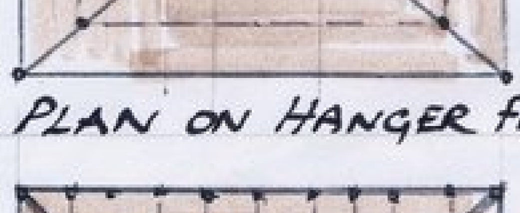
PLAN

"C" HULL-CORE WITH BRACKETS

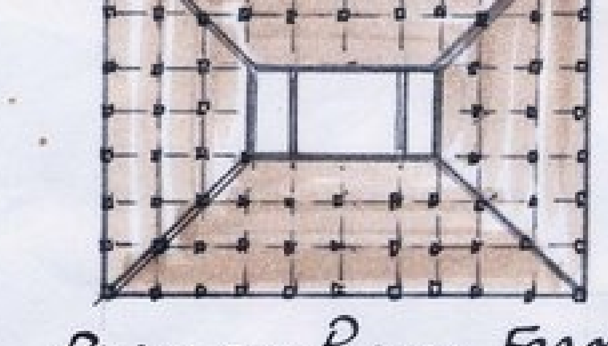




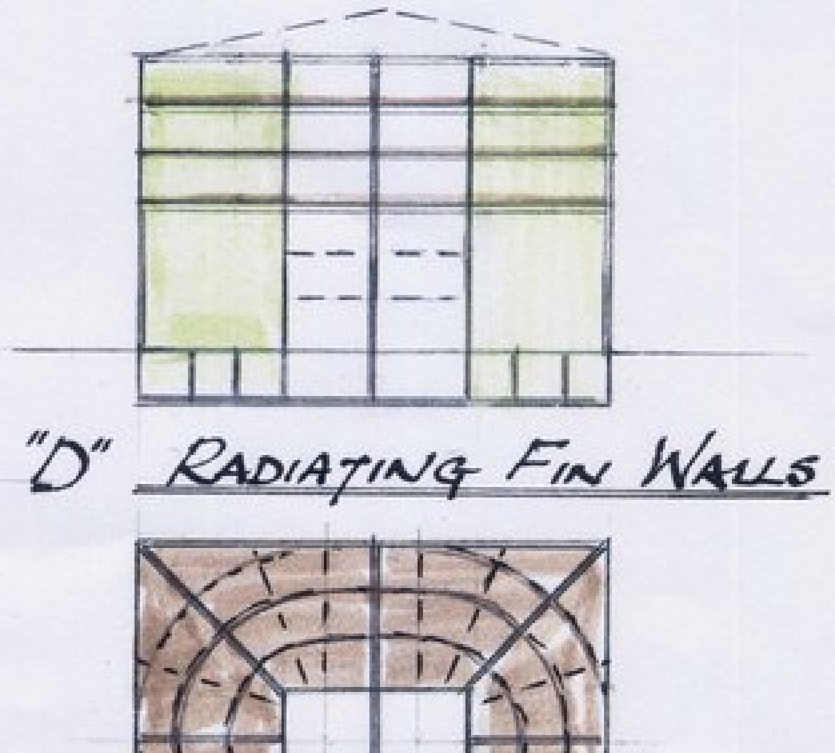
"B" PODIUM & HANGER



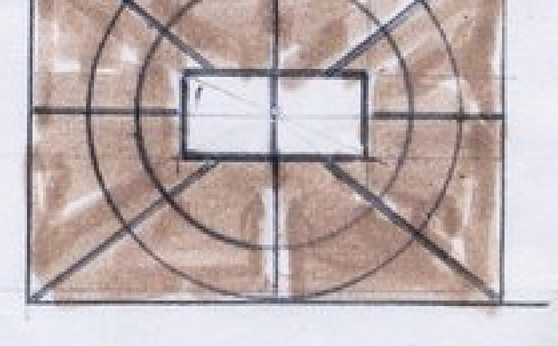
PLAN ON HANGER FRAME



PLAN ON PODIUM FRAME



"D" RADIATING FIN WALLS



R1/(4)

ON PAGE 4 I HAVE ILLUSTRATED FOUR OPTIONS AND A "BOX" BASEMENT. THE BASEMENT IS CELLULAR AND IS MEANT TO BE STIFF AND MONOLITHIC. JUST AS THE UPPER FLOORS CANTILEVER FROM THE CORE SO THE CELLULAR BASEMENT OUTSTANDS FROM THE BASE OF THE CORE TO KEEP IT UPRIGHT.

OPTION "A" IS ONE OF TWO "STANDARD" ANSWERS AND WAS POPULAR IN THE EXAMINATION. THE CELLULAR BASEMENT AND ENCLOSING RETAINING WALLS SPREAD THE GRAVITY LOADS AND WIND MOMENTS INTO THE SOIL. THE CORE — FOUR WALLS ONLY — PROJECTS STIFFLY FROM ITS BASE UP TO ROOF LEVEL. FOUR STEEL TRUSSES [INTERSECTING AT THE FOUR CORNERS OF THE CORE] ARE ASSEMBLED TO FORM THE ROOF AND TO PROVIDE SUPPORT FOR AN ARRAY OF HANGERS TO THE FLOORS BELOW. THE CORE IS STIFFENED BY INTERMEDIATE DIAPHRAGM FLOORS AT 5.0M STAGES. PRECAST CONCRETE STAIRCASES ARE INCORPORATED BETWEEN THESE LANDINGS AND PROVIDE ACCESS TO THE WORKING AREAS AND ADDITIONAL STIFFENING TO THE CORE WALLS. THE 5.0M DISTANCES BETWEEN FLOORS/LANDINGS WILL MEAN THAT THE STAIRS WILL BE FORMED FROM SEVERAL FLIGHTS BECAUSE OF THE REGULATION LIMITS ON THE NUMBER OF STEPS IN A CONTINUOUS FLIGHT.

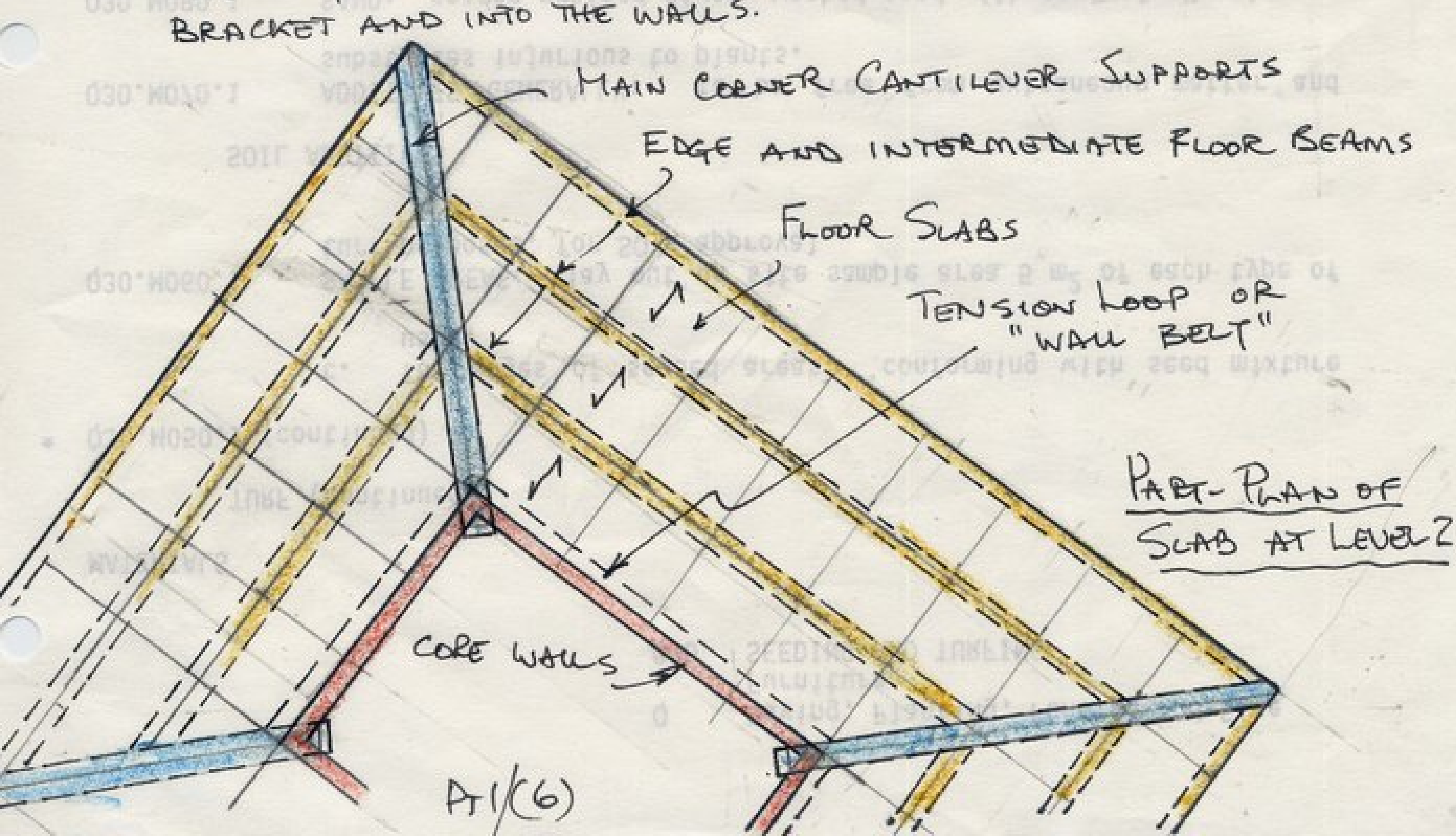
THE SUSPENDED FLOORS WILL BE ASSEMBLED AT LEVEL 1 FROM PRE-FABRICATED CELLULAR STEEL BEAMS AND PROFILED STEEL SHEET TOPPED WITH CONCRETE [TIN-DECK COMPOSITE CONSTRUCTION] AND LIFTED [LIFT-SLAB TECHNIQUE] TO LEVEL STARTING WITH LEVEL 4; THEN LEVELS 3 AND 2. THE HANGER LOADS [AND EXTENSIONS] WILL BE "TUNED" AND THE ENCLOSING GLASS CLADDING WILL BE ATTACHED. THE ROOF WILL BE CLAD AT THIS TIME TOO.

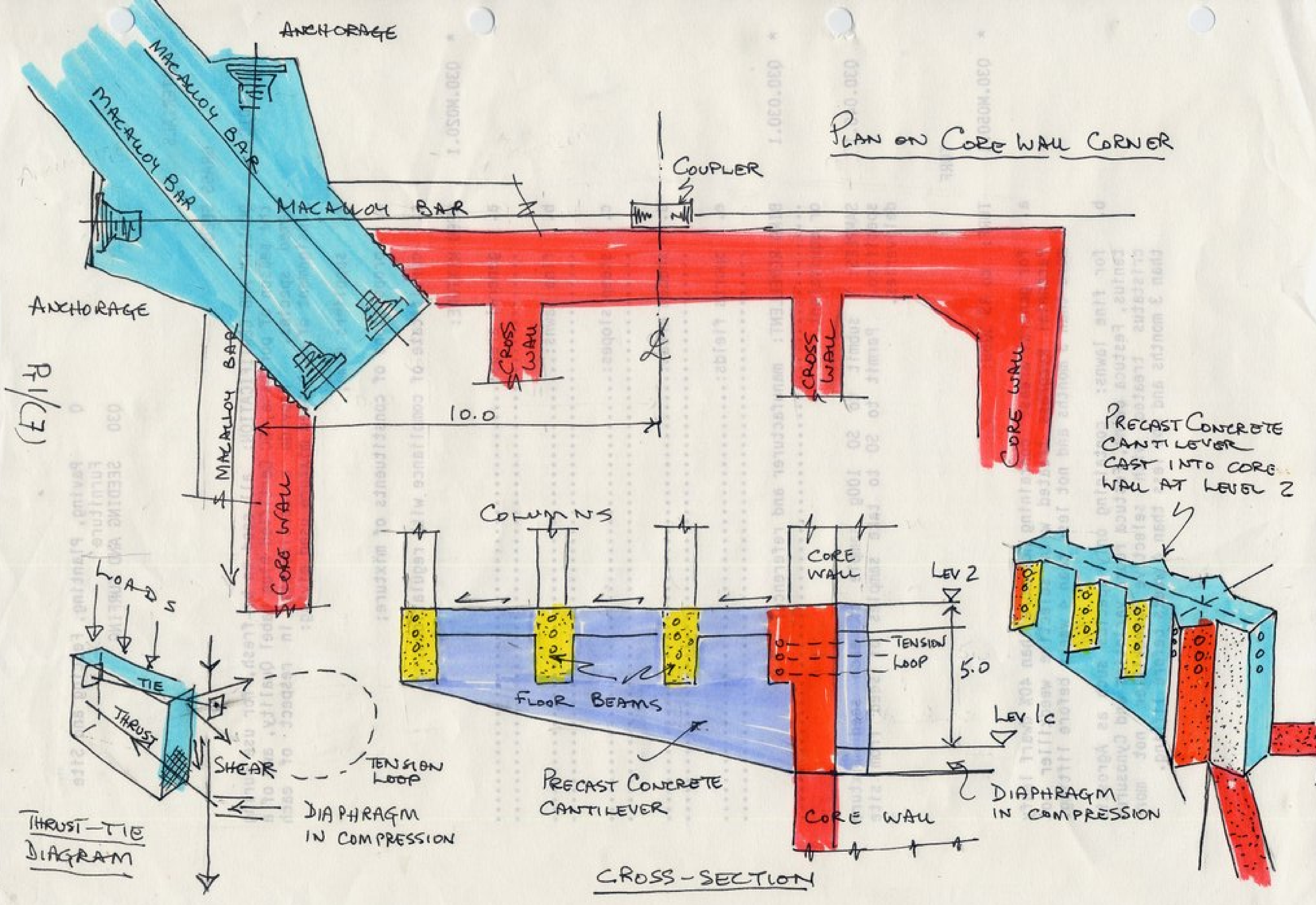
THE UNDERSIDE OF EACH FLOOR WILL NOT BE COVERED [NO CEILINGS] TO SAVE WEIGHT. THE STEEL FRAMING AND SERVICES WILL BE LEFT EXPOSED. THE SERVICES WILL BE THREADED THROUGH THE CELLULAR STRUCTURE. FIRE RESISTANCE WILL BE INCORPORATED IN THE DESIGN [USE THE TWO PROGRAMMES AVAILABLE FROM "WESTOK" IN YOUR LAPTOP. THIS DESIGN WILL NOT BE MARKED BUT WILL ALLOW YOU TO SIZE THE SECTIONS AND MEET THE FIRE RESISTANCE REQUIREMENTS]. IF YOU DO NOT WANT TO USE THE MORE SOPHISTICATED CELLULAR SECTIONS TRY USING THE LIMITED RANGE OF CASTELLATED SECTIONS LISTED IN SECTION BOOKS. YOU WILL NEED TO PROVIDE YOUR OWN FIRE PROTECTION DETAILS — SEE BOOKLETS BY BRITISH STEEL AND THE FORMER CORUS GROUP, ASFP/SCI YELLOW BOOK. SPRINKLERS REDUCE FRP BY 30 MINS.

OPTION "B" IS THE ALTERNATIVE "STANDARD" ANSWER AND WAS ALSO POPULAR IN THE EXAMINATION: BUT CANDIDATES WHO USED IT WITH REINFORCED CONCRETE SECTIONS ENDED UP WITH IMPOSSIBLY CONGESTED REINFORCEMENT AND DIFFICULT IN-SITU CONSTRUCTION. THE VERSION SHOWN AT "B" DIVIDES THE LOAD BETWEEN A CANTILEVER "PODIUM" AT LEVEL 2 AND A ROOFTOP HANGING FRAME. LEVEL 3 FRAMING IS SUPPORTED ON COLUMNS OFF THE PODIUM: LEVEL 4 FRAMING IS HUNG FROM THE HANGING FRAME.

WITH THIS OPTION THE PRINCIPAL SUPPORTING GIRDERS ARE ARRANGED ALONG THE DIAGONALS. THE TWO ROOF TRUSSES INTERSECT OVER THE CORE AND SUPPORT TWELVE HANGERS. THE LONG-WALLS OF THE CORE ARE STIFFENED BY TWO CROSS WALLS FORMING FOUR BEARING POINTS [SEE THE UPPER PLAN OF TWO]. THE FOUR DEEP CANTILEVER BRACKETS AT LEVEL 2 ARE SUPPORTED OFF THE END WALLS OF THE CORE. THE FOUR WALLS OF THE CORE HERE PERFORM TWO FUNCTIONS SIMULTANEOUSLY: A WALL-LIKE FUNCTION CARRYING GRAVITY LOADS TO THE FOUNDATIONS, AND A TYING FUNCTION LIKE A BELT PROVIDING A BALANCE FOR THE CANTILEVERS, [SEE THE LOWER OF THE TWO PLANS].

THE COLUMN GRID [LEVELS 2 AND 3] PROVIDES A 5.0m SLAB SPAN. THE ROOT-DEPTH OF THE CANTILEVER BRACKET IS ALSO 5.0m — A STOREY HEIGHT — AND GIVES A SPAN/DEPTH RATIO OF SLIGHTLY OVER 3.0. THE COMPRESSIVE REACTION IS PROVIDED BY AN INTERMEDIATE SLAB OR DIAPHRAGM WITHIN THE CORE. THE TENSILE REACTION IS PROVIDED BY THE "WALL BELT" AT LEVEL 2. THE TENSION IN THE BELT WOULD BE PROVIDED BY HIGH-STRENGTH-STEEL MACALLOY REINFORCEMENT BUILT INTO THE TOP LAYERS OF EACH BRACKET AND INTO THE WALLS.





PLAN ON CORE WALL CORNER
ANCHORAGE
MACALLOY BAR
MACALLOY BAR
MACALLOY BAR
ANCHORAGE
COUPLER
MACALLOY BAR
CROSS WALL
CROSS WALL
CORE WALL
CORE WALL
10.0
PRECAST CONCRETE CANTILEVER CAST INTO CORE WALL AT LEVEL 2
COLUMNS
CORE WALL
LEV 2
TENSION LOOP
5.0
LEV 1C
FLOOR BEAMS
PRECAST CONCRETE CANTILEVER
CORE WALL
DIAPHRAGM IN COMPRESSION
CROSS-SECTION
LOADS
TIE
THRUST
SHEAR
TENSION LOOP
DIAPHRAGM IN COMPRESSION
THRUST-TIE DIAGRAM
Pt 1/(7)

LOADS:

TAKE FULL AREA [50.0 x 40.0 = 200 m²] BECAUSE STAIRS & LIFTS ETC FILL THE CORE.

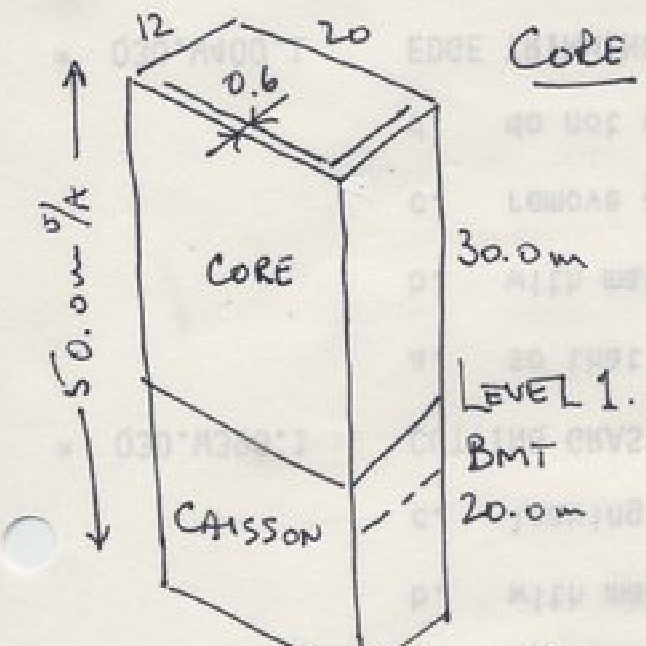
IMPOSED LOADS: ROOF 2.0
FLOORS 3x 5.0
L1 SLAB 5.0
BMT. SLAB 5.0

CONSIDER THE FOLLOWING LOAD COMBINATIONS:

(i) DEAD LOAD + CLADDING + FULL IMPOSED + LATERAL WIND.

(ii) DEAD LOAD + CLADDING LESS GW UPLIFT + WIND + UPLIFT ON LEV. 2.
[CONSIDER EFFECT OF WIND APPLIED TO DIAGONAL]

(iii) DEAD LOAD + CLADDING + IMPOSED ON ONE SIDE OF BUILDING + LATERAL WIND.



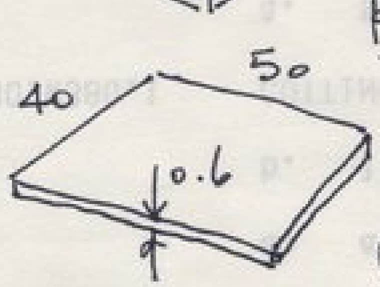
CORE

PERIMETER : 20 + 20 + 12 + 12 = 64 m.

SOLID AREA : 64 m x 0.6 = 38.4 m²

CONC. VOL : 38.4 x 50 = 1920 m³

WEIGHT : 1920 x 25 kN/m³ = **48 000 kN**



FLOOR

CONC. VOL : 50 x 40 x 0.6 = 1200 m³

WEIGHT : 1200 x 25 kN/m³ = 30 000 kN

AND INCLUDES LANDINGS IN CORE

ROOF + 3 FLOORS : 30 000 x 4 = 120 000 kN

L1 + BMT + CAISSON PLUG : 3/20x12x0.6 x 25 = 10 800 kN

= 130 800 kN
48 000
178 800
54 000
232 800 kN.

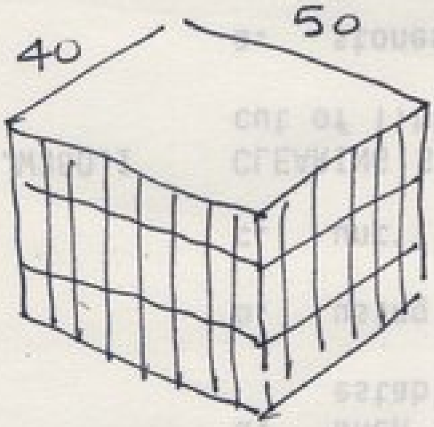
IMPOSED: 1 x 40 x 50 x 2.0 = 4000
5 x 40 x 50 x 5.0 = 50000
54000 kN

ASSUME ALL-UP WEIGHT = 250 000 kN

A1/(8)

CHECK THAT ALL-UP WEIGHT INCLUDES AN ALLOWANCE FOR THE CLADDING.

$$\begin{array}{r} 250\,000 \\ -\ 232\,800 \\ \hline 17\,200 \text{ kN.} \end{array}$$



GLASS: [SEE PAGE 2]

12 mm thk OUTER

12 mm thk INNER [LAMINATED]

24 mm thk @ 26 kN/m^3

PERIMETER = $2/(40+50) = 180\text{ m} \times 15\text{ m} = 2700\text{ m}^2$

& AREA

VOLUME $= 2700 \times 0.024 = 64.8\text{ m}^3$

WEIGHT $= 65 \times 26 = 1690$ kN

+ 50% – ALLOW FOR FRAMES = 2535 kN ≪ 17200

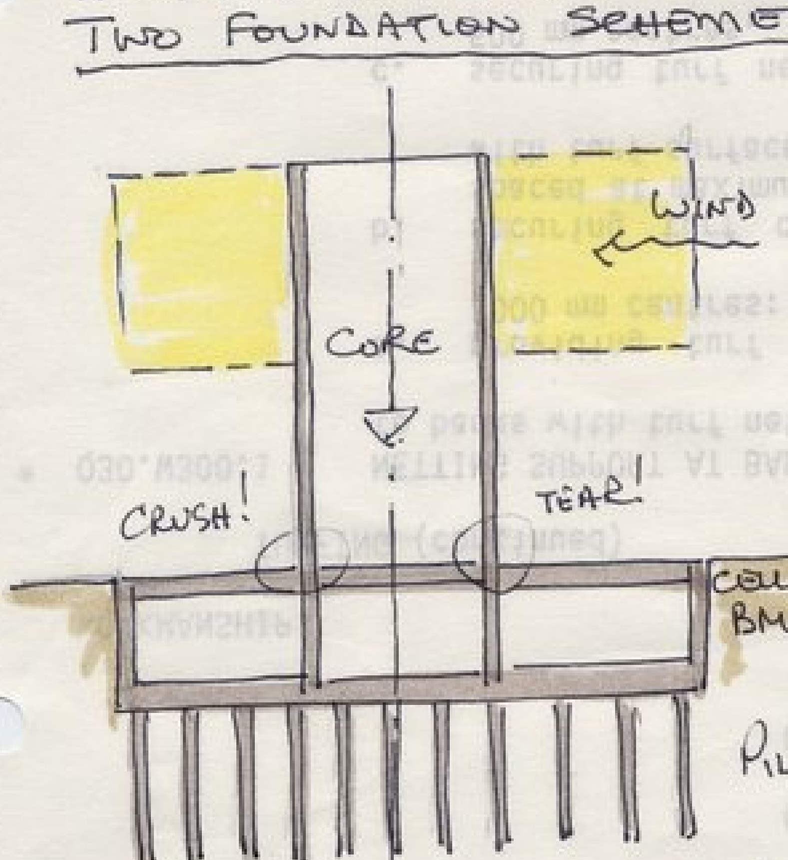
CHECK: ALL-UP AREA = $6 \times 40 \times 50 = 12\,000\text{ m}^2$

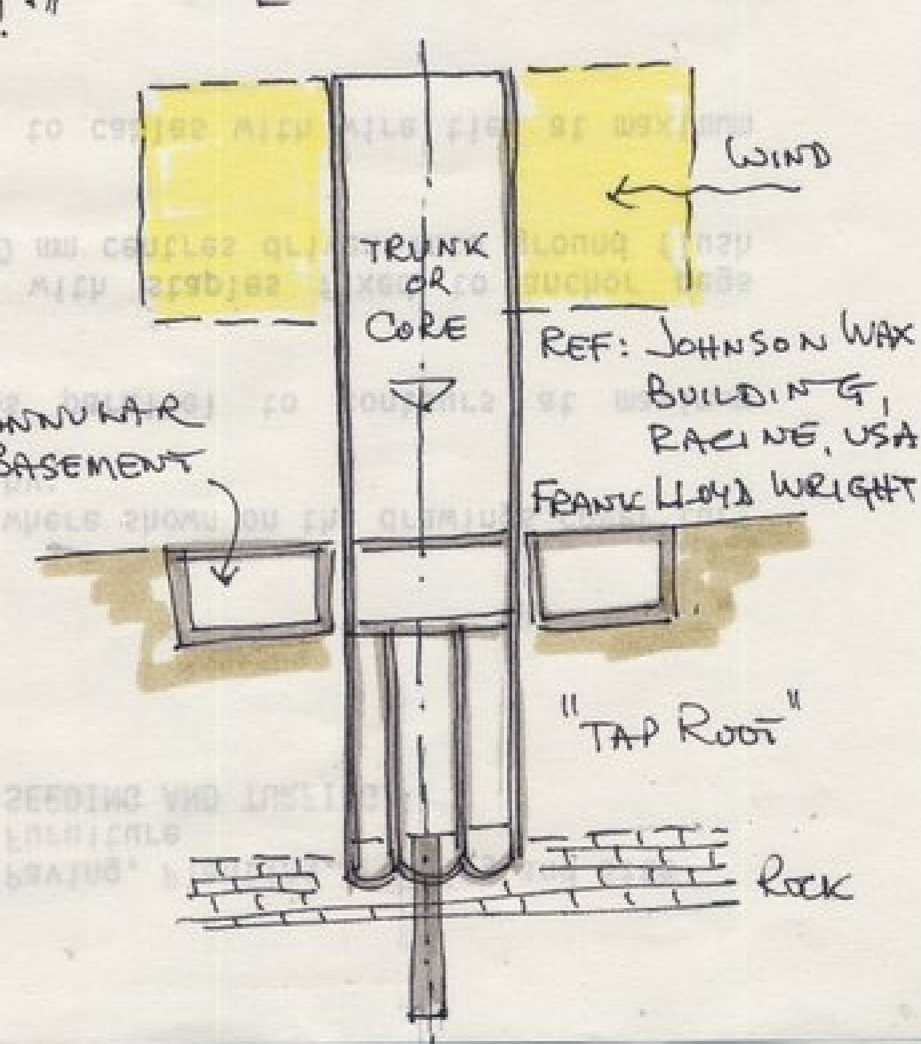
ALL-UP LOAD = $\frac{250\,000}{12\,000} = 20.83$

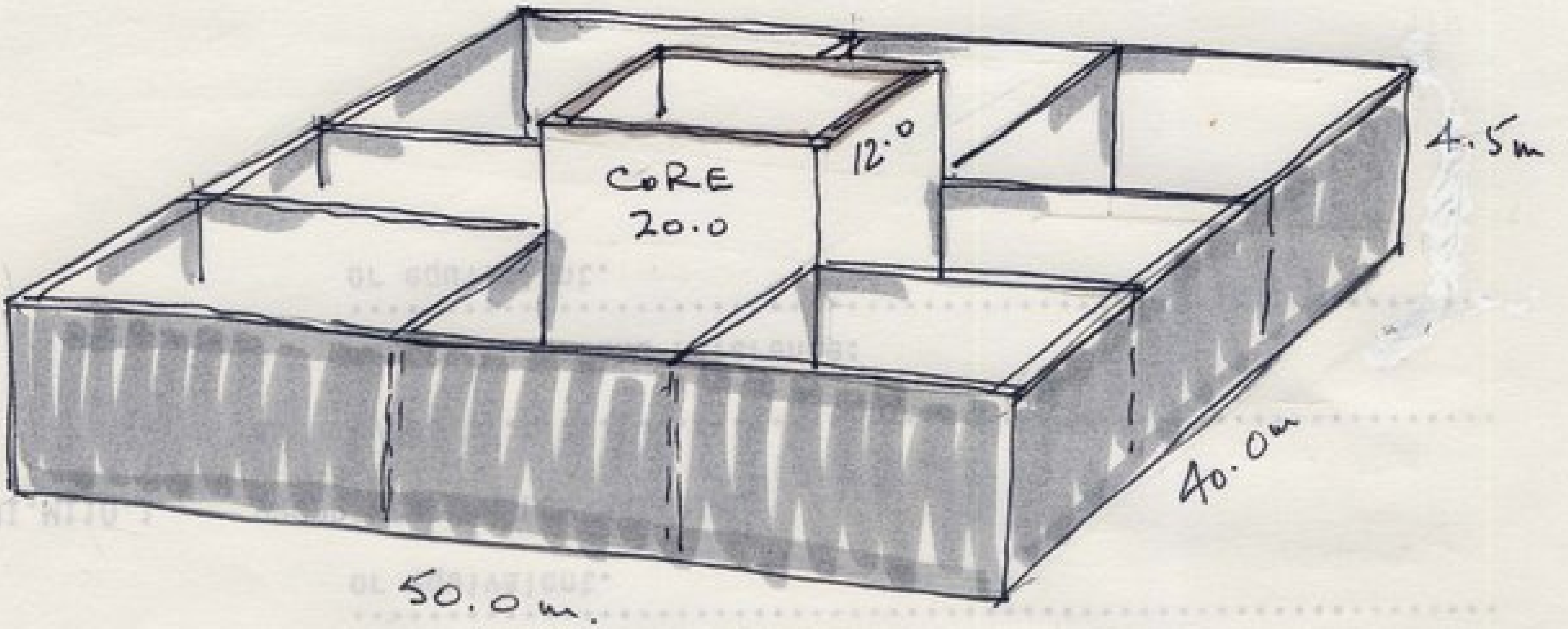
PROBABLY ON THE HIGH [SAFE] SIDE – [REF F. COBB]

"AN AMPLE SUFFICIENCY OF LOAD!"

TWO FOUNDATION SCHEMES:







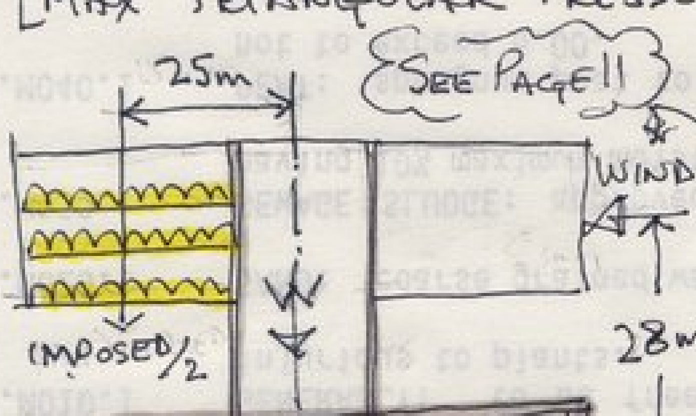
BASIC CELLULAR RAFT — MAY BE STIFFENED BY FORMING MORE CELLS — MAY BE GROUND-BEARING OR SUPPORTED ON A "GROUP" OF PILES TO ROCK OR INTO SILTY SAND.

$N = \left(\frac{35 + 60}{2} \right) = 47.5$ — ASSUME 50

EQUIVALENT SAFE BEARING CAPACITY = 500 kN/m²
AT A DEPTH OF 15.0m SO THAT SETTLEMENT [SAY 25mm]
PROMOTES/MOBILIZES SKIN FRICTION AS WELL AS END
BEARING [ROCK AT −20.0m]

ALL-UP WEIGHT [ASSUMED] $= \frac{250\,000 \text{ kN}}{40 \times 50 \text{ m}^2} = 125 \text{ kN/m}^2$

[MAX TRIANGULAR PRESSURE = 2 × 125 = 250 < 500]



DL. CORE + FLOORS	178 800
& WIND CLADDING	2 847
HALF × IMPOSED	27 000
W =	208 647

OTM = 1260 × 28 = 35280
27000 × 25 = 675000
710280 kNm

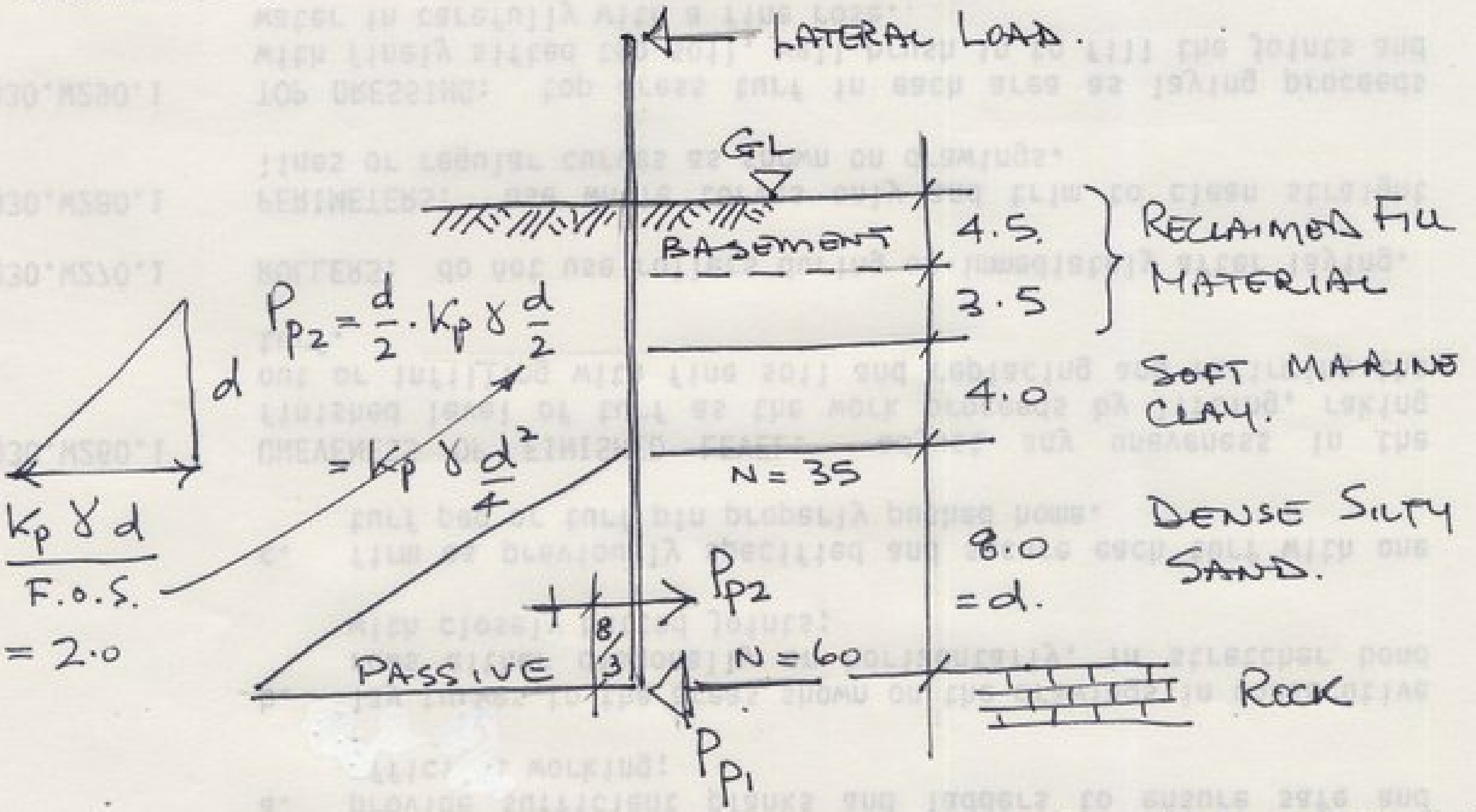
$f_b = \frac{208647}{40 \times 50} \pm \frac{710280 \times 6}{50 \times 40 \times 40} = 157 \text{ kN/m}^2 < 500 \text{ kN/m}^2$

(104) ± (53)

NO TENSION!

"ANCHORED TAP-ROOT" FOUNDATION WITH ANNULAR BASEMENT

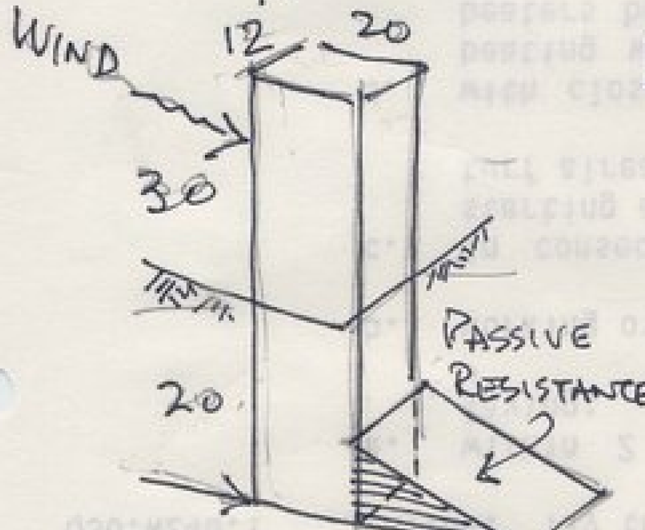
AFTER JOHNSON WAX BUILDING, RACINE, WISCONSIN, USA, BY FRANK LLOYD WRIGHT – ARCHITECT.



$$P_{p2} = \frac{d}{2} \cdot K_p \gamma \frac{d}{2} = K_p \gamma \frac{d^2}{4}$$

DISTRIBUTION ASSUMED FOR DESIGN — <u>ALL PER METRE WIDTH!</u>

NOTE P_{p1} ASSUMED TO ACT AT TOP OF ROCK STRATUM.



LET $K_p = 3$

$\gamma = 18 \; kN/m^3$ } ALL PER M WIDTH.

$d = 8.0 \; m$

PASSIVE RESISTANCE $P_{p2} = 3.0 \times 18 \times 8 \times \frac{8}{4} \; /m.$

$= 864 \; kN/m \times 12 \; m$ SAY $= \underline{10\,368 \; kN}$

WIND: APPROX $1.2 \; kN/m^2 \times 50 \times 15 = 900 \; kN$

$+ \; 1.2 \; kN/m^2 \times 20 \times 15 = 360 \; kN$

$\underline{1260 \; kN. < 10\,368 \; kN}$

OVERTURNING: $1260 \times 50 = 63000 \; kN \, m.$

RESTORING : $10\,368 \times \frac{8}{3} = 27\,648 \; kN \, m.$ <u>UNSATISFACTORY!</u>

ΣH = OK. ΣM NOT SATISFACTORY! TOWER BLOWS OVER!

$\Sigma V = \frac{250\,000}{12 \times 20} = 1042 \; kN/m^2 < 5000$ ALLOWED ∴ OK

OPTIONS 'C' AND 'D' WOULD PROBABLY NOT BE ACCEPTED BECAUSE THEY BOTH CONFLICT WITH CR#2 — "NO COLUMNS ARE PERMITTED OUTSIDE OF THE CORE AT LEVEL 1."

IN THE EXAMINATION YOU DO NOT HAVE TIME TO ARGUE THAT A WALL — "A PERPENDICULAR SURFACE FORMING AN ENCLOSURE OR BARRIER" — IS NOT A COLUMN ["A SUPPORT FOR SOME PART OF A BUILDING"] AND THAT IN OUR CLIMATE, THE UK, AN ENCLOSURE WILL BE ESSENTIAL TO MAKE LEVEL 1 USEABLE; OR THAT CR#2 GOES ON TO SUGGEST FULL OR PART GLAZING FOR ALL FOUR ELEVATIONS. ONE MUST RECOGNISE THAT THE EXAMINER WANTS AN "OVERHANG" AT LEVEL 2 THAT EXCLUDES ANY SUPPORTS.

HOWEVER, SOME CANDIDATES MIGHT BE BOLD ENOUGH TO SUGGEST A LARGE, ANNULAR ATRIUM — IN WHICH CASE OPTIONS 'C' AND 'D' ARE VIABLE OPTIONS. OPTION C ALLOWS THE FLOORS AND ROOF TO SPAN BETWEEN THE CORE AND AN ENCLOSING WALL OR "HULL". CLEARLY, THE SLENDERNESS OF THE HULL IS A BIG PROBLEM AND MIGHT BE SOLVED USING A DIA-GRID WALL THAT FORMS A HUGE TUBE. ALTERNATIVELY, A SYSTEM OF FLYING SHORES THAT WOULD "PROP" THE VERTICAL MULLIONS FROM THE CORE COULD BE CONSIDERED. THESE WOULD PROVIDE SUPPORT FOR LIGHTING TO LEVEL 1 THAT WOULD EXTEND THE USE OF LEVEL 1 IN WINTER EVENINGS.

NOTE: THE INTERNATIONAL STATUS OF THIS EXAMINATION EXCLUDES SPECIFIC PERPETUAL FINE WEATHER AND DAYLIGHT!

OPTION 'D' SUPPORTS THE FLOORS AND ROOF OFF EIGHT 'FIN' WALLS THAT RADIATE FROM THE CORE. WITHIN THE ART SCHOOL THESE COULD BE PERFORATED [I.E. DOORS AND ARCHWAYS] BUT WOULD PROVIDE HANGING SPACE AND DIVIDE STUDIOS. WITHIN THE ATRIUM SPACE THE FIN WALLS COULD BE TEXTURED, SCULPTED OR PIERCED. THE LOWER PARTS OF THE WALL, IN THE PUBLIC AREAS, COULD PROVIDE SPACE FOR WALL-HUNG EXHIBITS AND DIVIDE THE ATRIUM INTO SEPARATE, LETABLE, CONFERENCE OR STUDIO/EXHIBITION SPACES.

OPTION 'C' HAS "BRACKETS" THAT ARE SIMILAR TO THE FINS IN "D", BUT PROVIDE CONVENTIONAL RECTANGULAR "ROOMS". BOTH "FINS" AND "BRACKETS" ARE USED IN THE BASEMENT TO FORM THE CELLS IN THE CELLULAR STIFFENING OF THE BASEMENT PLATE.

WITH BOTH OPTIONS 'C' AND 'D' THE DISTRIBUTION OF THE LOADS SHOULD BE MORE UNIFORM AND THE PERIMETER RETAINING WALL WILL BE LESS SUSCEPTIBLE TO OVERTURNING.

AS EVER – AS SOON AS I PUT DOWN MY PEN – A FLOOD OF IDEAS SWEPT OVER ME! HAD I SAID ANYTHING ABOUT?

In the examination write a list and then tick off any that you have had time to enlarge upon!

- ✓ ROOF COVERING
- ✓ ROOF DRAINAGE
- ✓ ROOF TRUSS AND CARCASING / SECONDARY MEMBERS
- ✓ BEARINGS BETWEEN THE CORE AND THE TRUSS
- HANGERS AND CONNECTIONS TO THE CORE
- CONSTRUCTION OF THE CORE: –
  - (i) STEEL FRAME
  - (ii) CONCRETE SHAFT
- FIRE PROOFING

AND THEN SUNDRY MATTERS THAT SHOULD – IN A COMMERCIAL SITUATION, BUT PERHAPS NOT IN AN EXAMINATION – HAVE BEEN SORTED OUT AND NOT LEFT TO THE STRUCTURAL ENGINEER:

If time permits indicate WHERE and HOW you would deal with these matters

- \+ PLANT ROOMS (WHERE AND HOW BIG)
- \+ LIFTS (PASSENGER, FIREMAN, GOODS, HOW MANY)
- \+ TOILETS AND WASHING AREAS (ART MATERIALS)
- \+ WATER SUPPLY AND DISPOSAL (SUPPLY TANK)
- \+ DISPOSAL OF WASTE FROM STUDIOS (PAINT, PLASTER STONE, FABRICS AND METAL).

HAVING "FORGOTTEN" THESE MATTERS IN THE HASTE TO "GET OUT" A COUPLE OF SCHEMES AND "GET DOWN" TO THE BASEMENT AND FOUNDATIONS SHOULD ONE SHRUG ONE'S SHOULDERS AND FINISH?

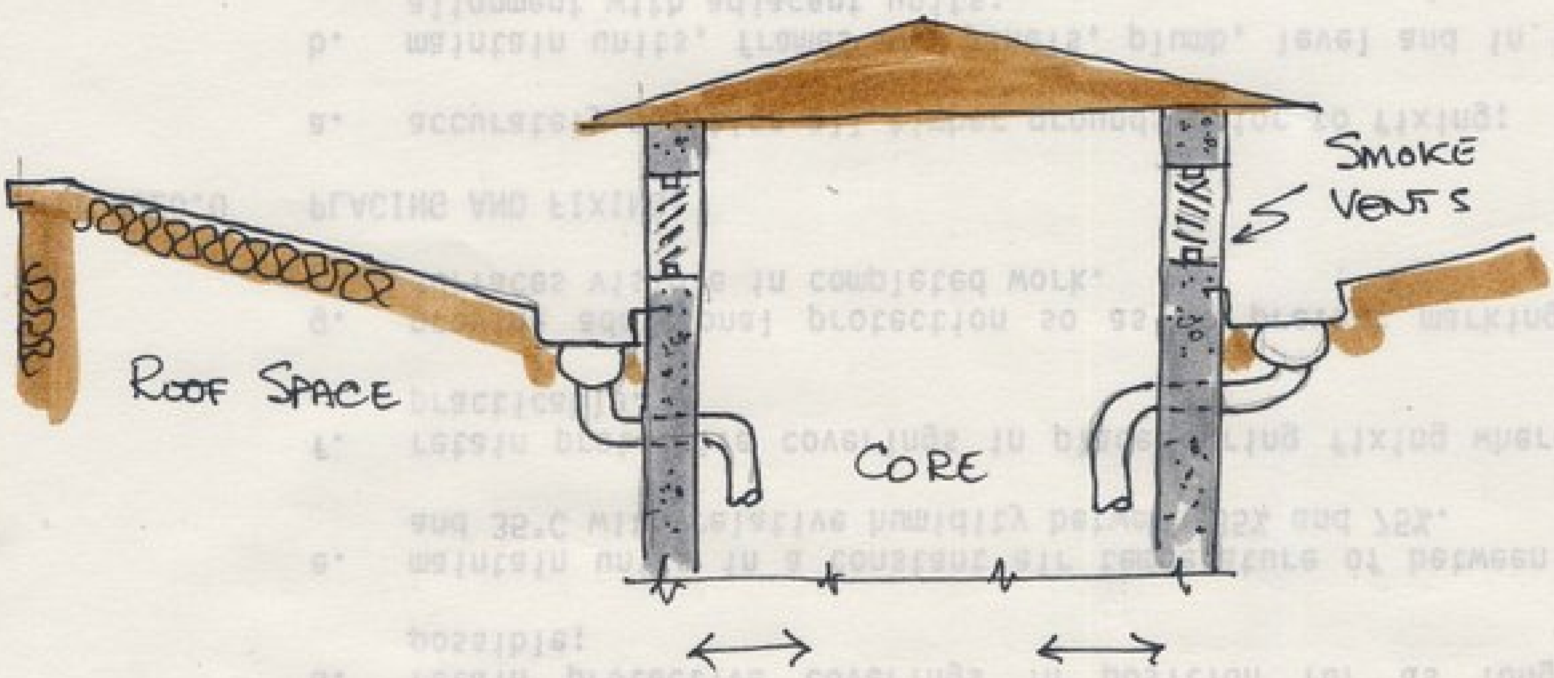
PLEASE REMEMBER IT IS EASIER TO DEDUCT A MARK FOR SOMETHING THAT IS NOT THERE, BUT SHOULD BE, THAN TO GIVE THAT SAME MARK FOR A HALF-EXPRESSED IDEA OR A "HALF-RIGHT" SKETCH OR CALCULATION — AND THIS EXAMINATION DOES NOT USE FRACTIONAL MARKING!

CAN YOU "SWEEP-UP" THESE MATTERS IN A FEW WORDS OR A SKETCH OR TWO?

LET US TRY:

ROOF COVERING: • PROPRIETARY PROFILED SHEETING.

ROOF DRAINAGE: • RAINWATER DISPOSAL PIPES HAVE TO GO DOWN THE CORE, INTO THE BASEMENT AND THEN AWAY INTO A STORM DRAIN — A "SEPARATE" SYSTEM OF DRAINAGE.

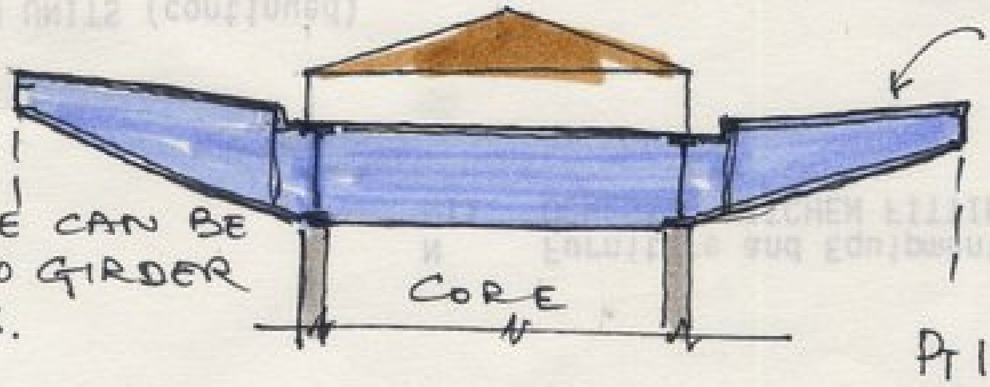


SERVICE DUCTS IN EACH CORNER

THE VOLUME OF RAINWATER IS LIKELY TO BE LARGE. RWPs WILL BE 150mm DIAMETER, OR LARGER, WILL FILL WITH WATER AND HAVE CONSIDERABLE WEIGHT. THE RWPs MUST BE SUPPORTED TO PREVENT BREAKAGE AND INTERNAL FLOODING!

ROOF TRUSS, ETC: • THE SHAPE SHOWN ON PAGE 4 IS LOGICAL BUT CONTRADICTS THE DRAINAGE PROPOSAL ABOVE. FIGURE Q4 — THE EXAMINATION QUESTION, SHOWS A FLAT ROOF. NOTHING IS MENTIONED IN THE QUESTION SO ONE MAY PRESUME THAT FIG Q4 IS DIAGRAMATIC ONLY. CERTAINLY THERE IS NO STRUCTURAL REASON [AESTHETIC PERHAPS!] WHY THE TRUSS SHOULD NOT BE PARALLEL CHORD OR A PARALLEL FLANGE DEEP GIRDER. WITH AN EFFORT ONE CAN INVERT THE ROOF THUS:

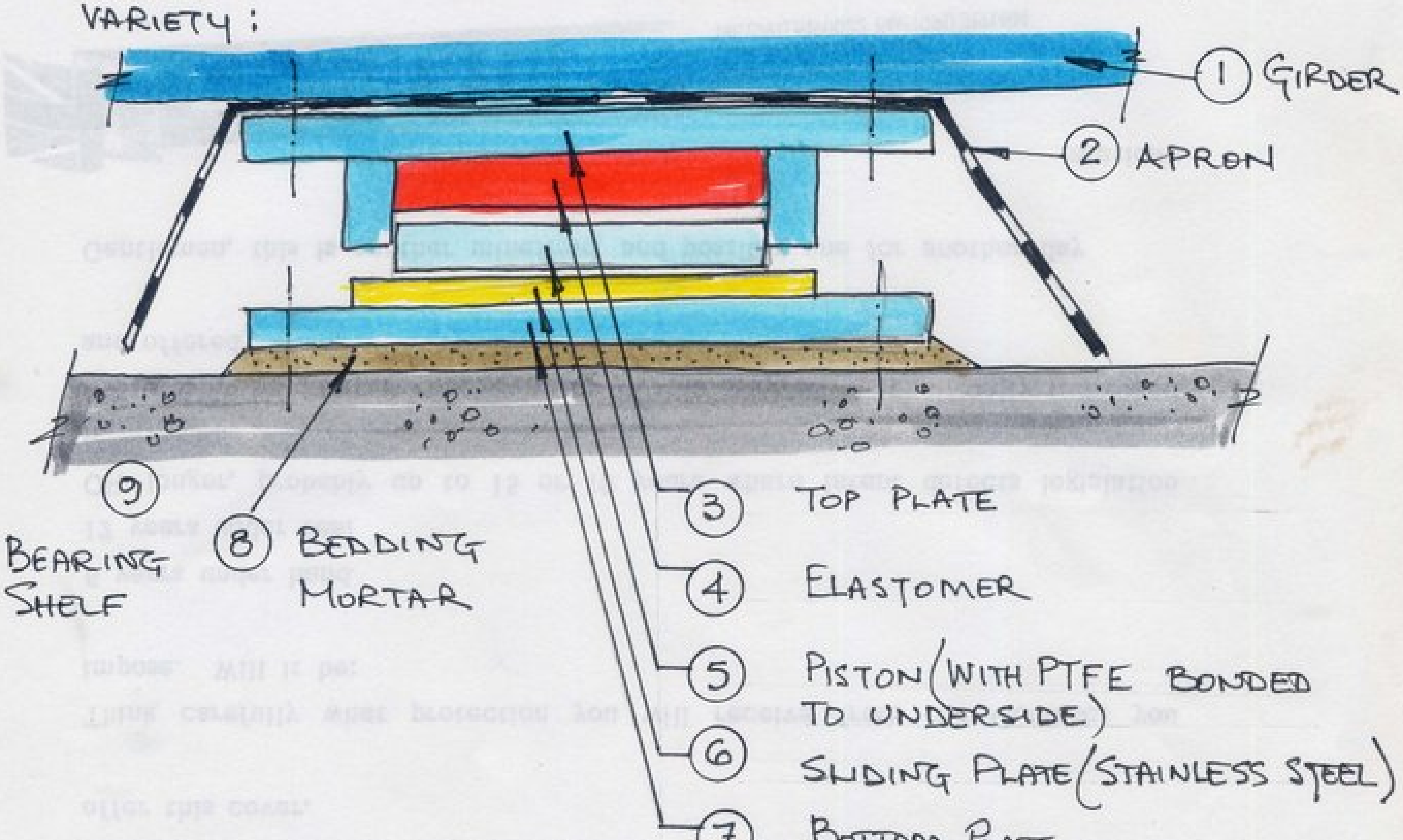
FRAME WITH RAFTERS AND PURLINS



THIS SHAPE CAN BE APPLIED TO GIRDER OR TRUSS.

THE MAIN ROOF MEMBERS WILL BE TRANSPORTED IN SHORTER SECTIONS AND ASSEMBLED USING HSFG BOLTS AND PRE-DRILLED PLATES ON SITE FOR LIFTING TO THE TOP OF THE BUILDING USING A HIGH-CAPACITY CRANE BROUGHT ONTO SITE FOR THE PURPOSE. THE CRANE MAY NEED TO STAND ON THE SURROUNDING "PLAZA" SLAB, AND THIS MAY NEED TO BE PROPPED OR STRENGTHENED TO REDUCE THE "OUTREACH", THE COST TO BE BORNE BY THE CONTRACTOR.

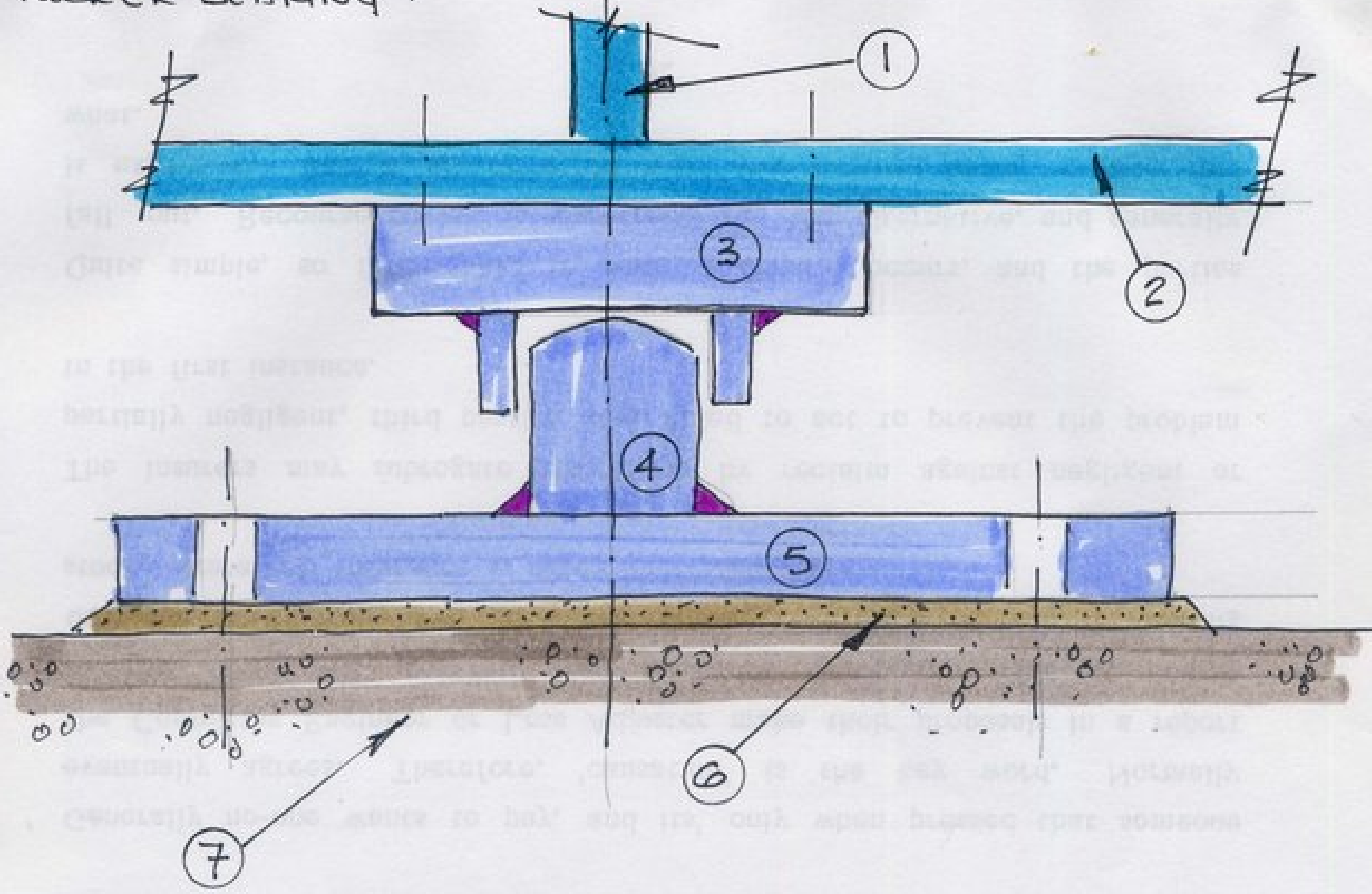
THE SUPPORT BEARINGS SHALL BE OF THE SLIDING-POT VARIETY:



THE ECCENTRICITY OF THE LOAD CAN BE AVOIDED BY HAVING THE ELASTOMER ABOVE THE SLIDING PLATE. THE SLIDING PLATE IS PROTECTED FROM ACCUMULATING DUST AND DEBRIS BY BEING SHROUDED IN A "SKIRT" OR "APRON".

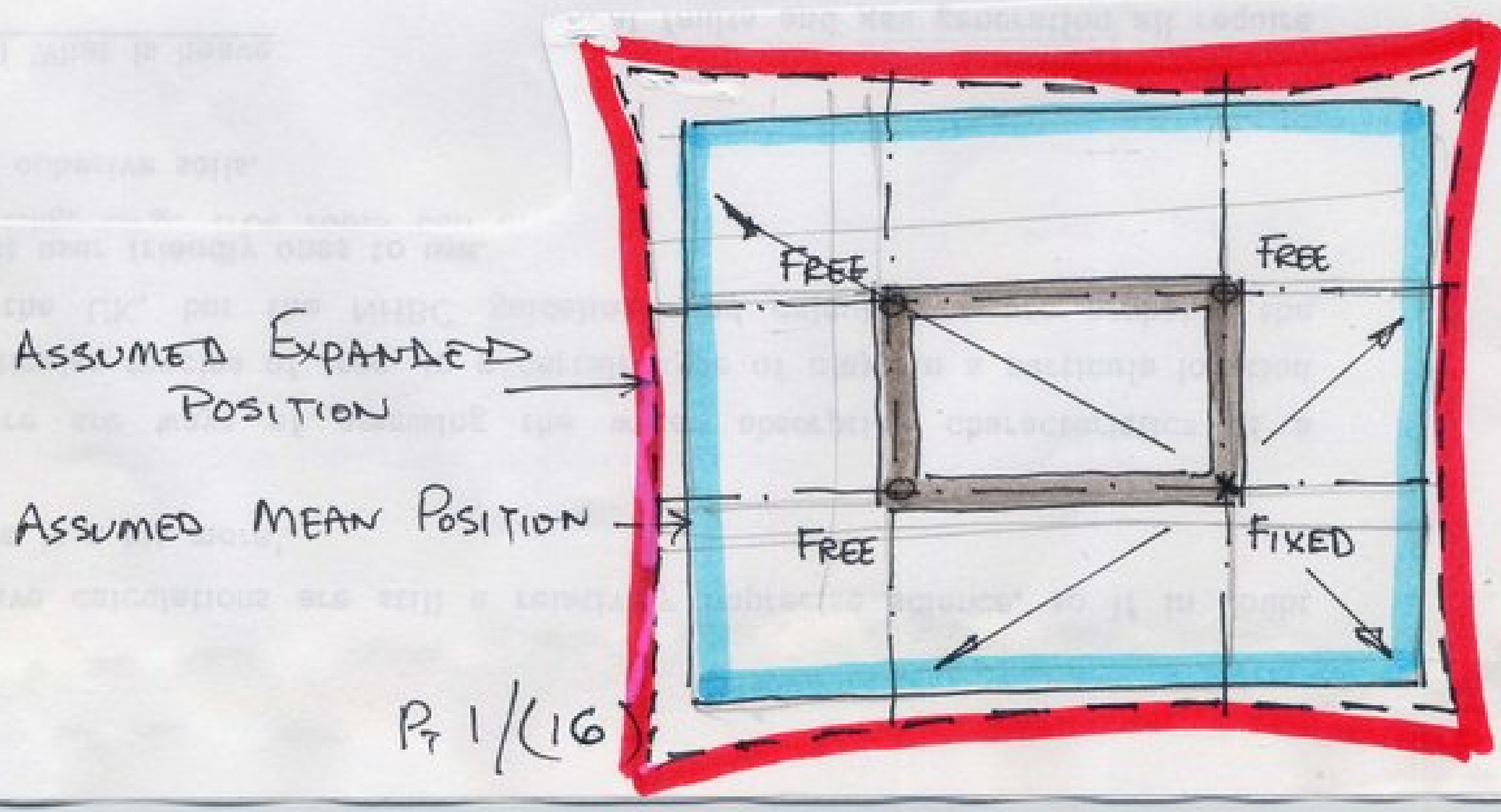
THIS ASSEMBLY WOULD BE A "FREE" BEARING. IT MUST BE RETAINED IN POSITION [I.E. NOT "WALK-OFF"] USING STEEL "KEEP-STRIPS" ATTACHED TO THE BEARING SHELF. THE MOVEMENT IS RESTRICTED TO ABOUT 40 mm FROM THE MEAN POSITION. ALL BEARINGS <u>MUST</u> BE REPLACEABLE. [SEE STEEL DESIGNERS' MANUAL 6TH EDITION 2003]

THE "FIXED" BEARING WILL BE A FABRICATED LINEAR ROCKER BEARING:



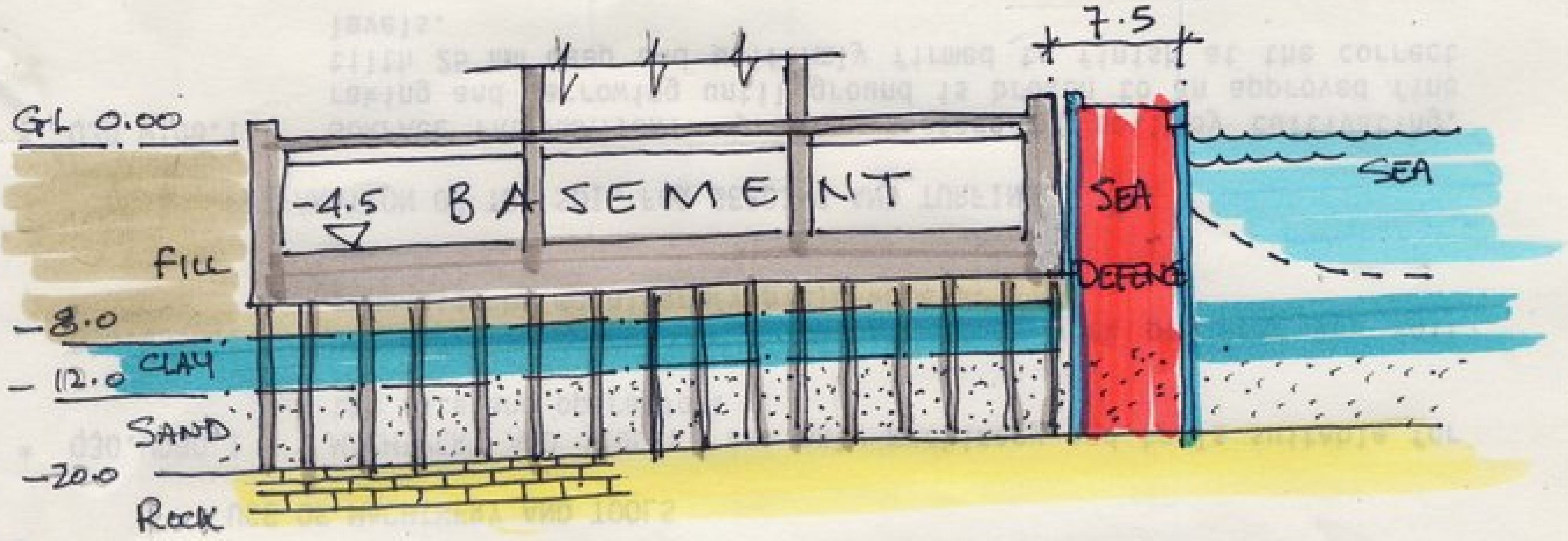
1 - WEB STIFFENER, 2 - WELDED PLATE GIRDER OR TRUSS
3 - "KEEP" ASSEMBLY 4 - "PINTLE" WITH ROUNDED ROCKER SURFACE
5 - BASE PLATE AND H.D. BOLTS 6 - BEDDING MORTAR
7 - BEARING SHELF.

THE ROOF STRUCTURE WILL EXPAND/CONTRACT ABOUT THE "FIXED" BEARING:



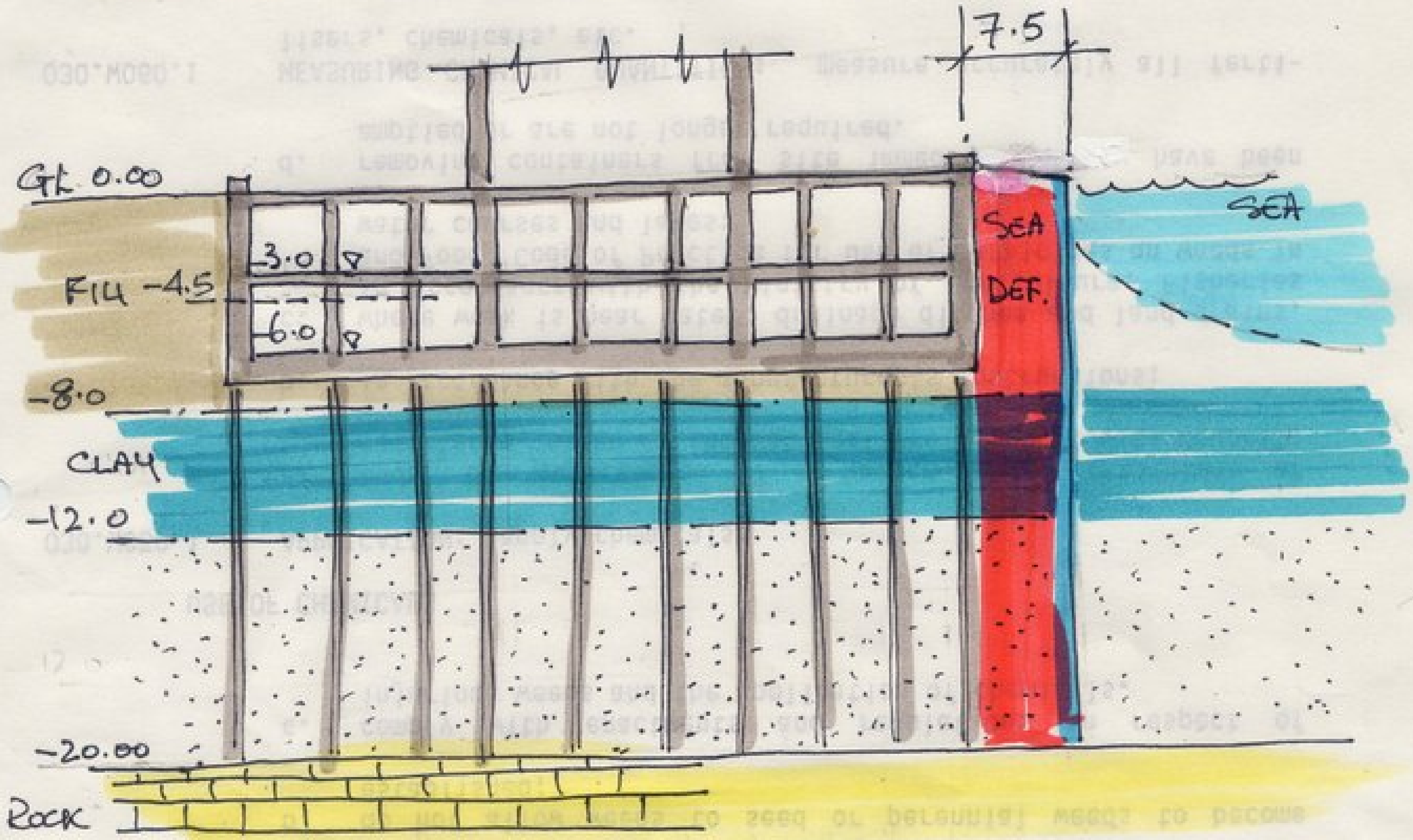
QUESTION 4 - 2012 NEW ARTS SCHOOL - PART 2

SPECIFICALLY THE BASEMENT AND SEA DEFENCE.



MAIN QUESTION

LONG SPANS POSSIBLE WITH DEEP STRUCTURAL ZONE - DOWNSTAND BEAMS / NO COLUMNS

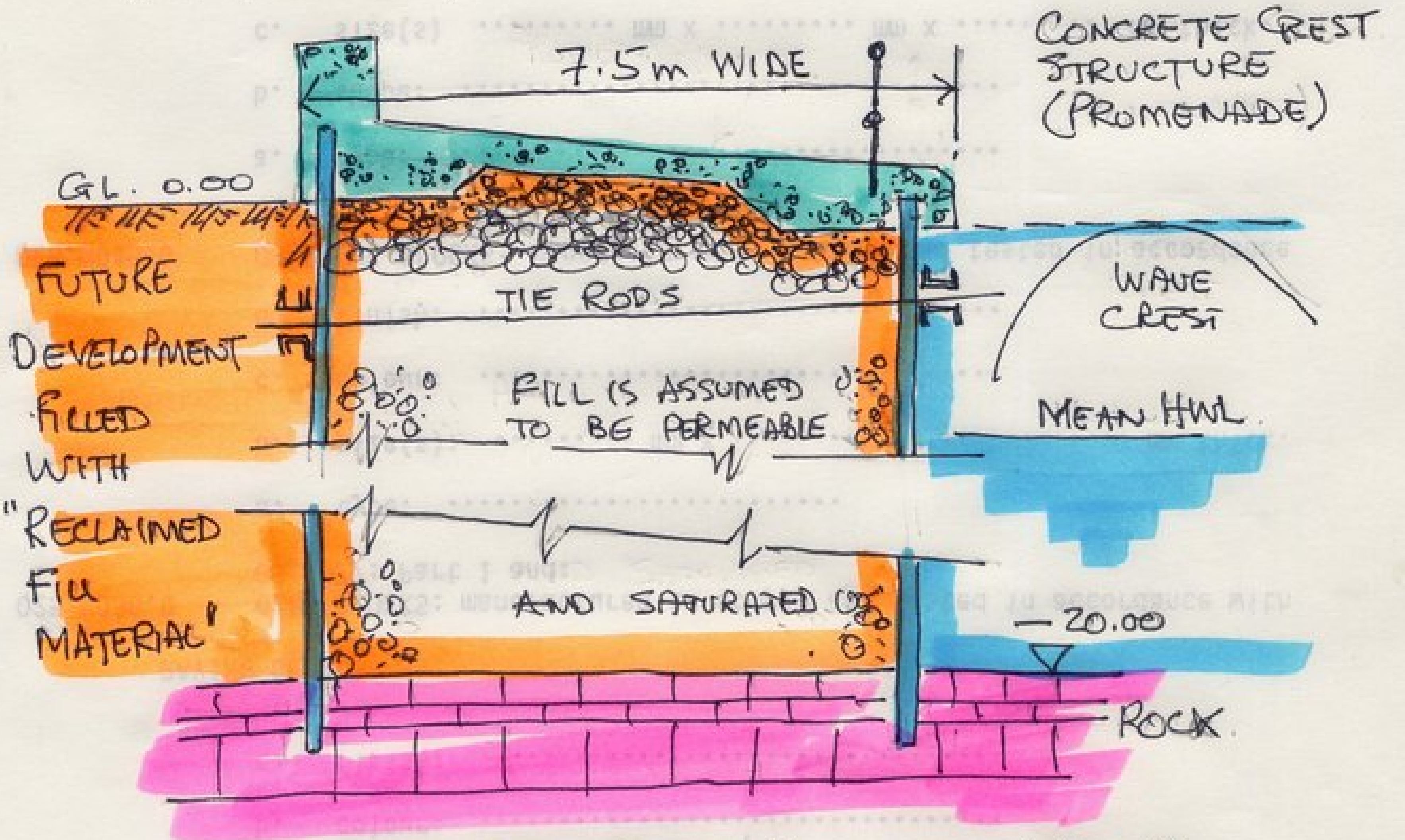


REFERENCE SECTION 1b

IN ORDER TO MINIMISE THE STRUCTURAL ZONE THE SLAB SPANS NEED TO BE SHORT AND THIS REQUIRES A CLOSE COLUMN GRID - SAY 5.0m: ALLOWING A FLAT SLAB TO BE USED - NO DOWNSTAND BEAMS OR COLUMN HEADS.

THE "FILL" IS DESCRIBED AS "RECLAIMED FILL MATERIAL" SO IS PROBABLY HYDRAULIC FILL SUCKED UP BY DREDGING AND WOULD HAVE NEEDED CONTAINING AS THE SURPLUS WATER DRAINED AWAY. THE MATERIAL WILL BE REASONABLY COMPACT.

THE QUAY WALL / SEA DEFENCE WILL BE ASSUMED TO BE A DOUBLE-SKIN SHEET PILED CONSTRUCTION FOR SIMPLICITY. THE TWO SKINS WILL BE TIED TOGETHER, THUS EXCLUDING "TIE-RODS-AND-DEADMAN-ANCHORS", AND WILL EXTEND WELL BEYOND THE LIMITS OF THE PRESENT DEVELOPMENT.



DOUBLE-SKIN STEEL-SHEET-PILED QUAY WALL OR SEA DEFENCE

BECAUSE NO MENTION HAS BEEN MADE OF STORM FLOODING IN THE QUESTION IT WILL BE ASSUMED THAT POSSIBLE FLOODING OF THE BASEMENT MAY BE OMITTED FROM CONSIDERATION.

LEVEL 1 SHOULD BE RAISED AT LEAST 1.0m ABOVE GROUND LEVEL WITH ACCESS BY STEPS OR RAMPS. THIS WOULD ALSO PREVENT VEHICULAR ACCESS, PERMITTING THE IMPOSED LOADING TO BE 5 kN/m² [CLIENT'S REQUIREMENT #4] RATHER THAN 10kN/m². ALL VENTS TO THE BASEMENT, PLANT ETC. TO PROJECT ABOVE THIS LEVEL

SEEING THE BUILDING SITE PROTECTED FROM THE SEA IN THIS WAY ALLOWS US TO CONCENTRATE ON THE PROBLEMS DIRECTLY ASSOCIATED WITH THE PROPOSED BASEMENT. WHERE POSSIBLE THE CANDIDATE SHOULD ANSWER SECTION 1A BY OFFERING TWO DISTINCT AND VIABLE SOLUTIONS.

HOWEVER, IN PART 1 OF THIS ANSWER, TWO OPTIONS HAVE BEEN DISCUSSED FOR THE FOUNDATIONS AND THE CANDIDATE MAY FEEL THAT PROPOSING TWO ADDITIONAL BASEMENT SOLUTIONS WILL BE TOO TIME CONSUMING. <u>THE QUESTION'S ANSWER WOULD NOT BE COMPLETE WITHOUT ATTENTION TO ONE VIABLE SOLUTION.</u>

AT LEAST ONE OPTION MUST BE SUGGESTED FOR THE FOLLOWING:

(i) A METHOD FOR EXCAVATING THE BASEMENT VOID

(ii) A METHOD FOR TEMPORARILY / PERMANENTLY, OR BOTH, SUPPORTING THE SIDES OF THE EXCAVATION

(iii) MAKING THE BASEMENT SUITABLE AS A STORAGE SPACE [SEE CR #1] — I.E WATERPROOFING / VAPOUR PROOFING AND/OR DRAINAGE.

(iv) A METHOD FOR SUPPORTING THE SLAB AT LEVEL 1 WITH AN IMPOSED LOAD OF 5.0 kN/m^2 [SEE CR #4]

(v) A METHOD OF DISTRIBUTING THE WIND MOMENT FROM THE CORE

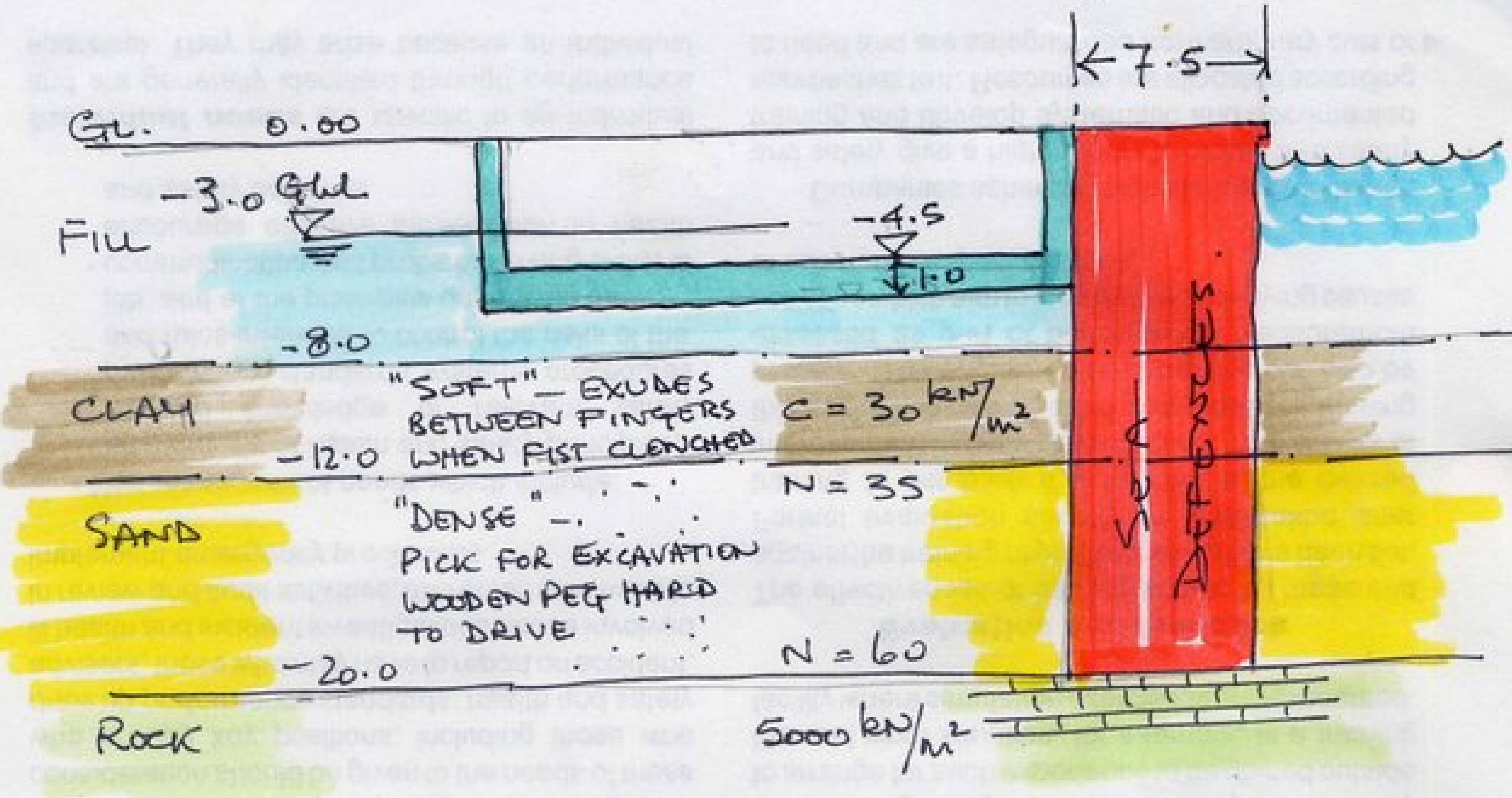
(vi) A METHOD OF DISTRIBUTING THE LOADS INTO THE PILES BELOW THE BASEMENT [SEE PAGE 9 OF PART 1]

(vii) THE SELECTION OF PILE TYPE, THE PILE GRID, AND THE SAFE LOADING ON EACH PILE.

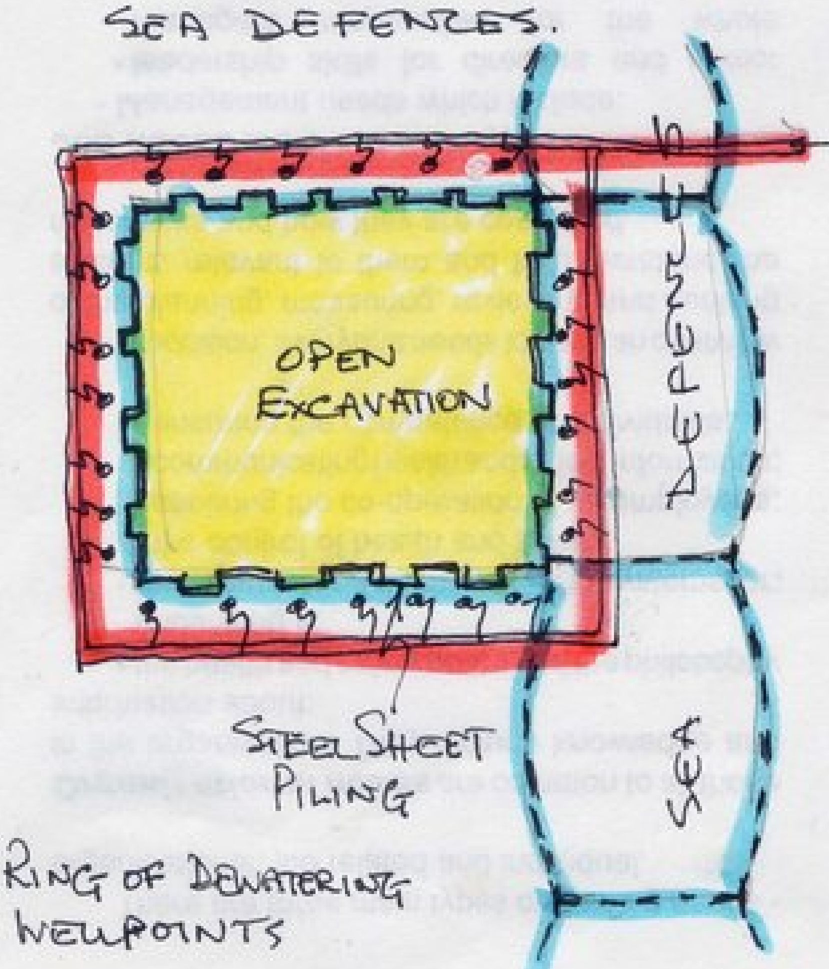
LOOKING FORWARD TO SECTIONS 2c, 2d AND 2e THE CANDIDATE MUST BE ABLE TO DO SOME MEANINGFUL CALCULATIONS, DRAW A CONVINCING GENERAL ARRANGEMENT AND WARN/ADVISE THE QUANTITY SURVEYOR/CLIENT ON THE SPECIAL NATURE AND/OR FEATURES OF THE BASEMENT CONSTRUCTION THAT WILL AFFECT THE COST, E.G. THE DEWATERING AND DURABLE CONCRETE.

SECTION 1B RELATES TO THE BASEMENT [SEE PART II, PAGE 1]. THE FIRST FOUR ITEMS IN THE LIST ABOVE NEED TO BE RE-VISITED AND REVIEWED. DO <u>NOT</u> MERELY REMARK THAT "IT WILL COST MORE, TAKE LONGER TO BUILD AND THAT THE CONSULTANT'S FEE WILL BE LARGER"! ALL TRUE PROBABLY, BUT THE CANDIDATE NEEDS TO BE EXPLICIT.

CONSIDER BASEMENT LEVELS:



GROUNDWATER OBVIOUSLY FLOWS THROUGH THE "FILL" AND WITH THE SEA NEARBY THERE IS CLEARLY AN INEXHAUSTIBLE QUANTITY! DE-WATERING WITH WELLPOINTS OR DEEP WELLS DOES NOT APPEAR TO BE VIABLE. FOR AN "OPEN" EXCAVATION IT SEEMS BEST TO SURROUND THE EXCAVATION AREA WITH A STEEL SHEET-PILE COFFERDAM EITHER CONNECTED TO THE SEA DEFENCES OR WITH ONE SIDE OF THE COFFERDAM INSIDE THE SEA DEFENCES.



FIG(i)

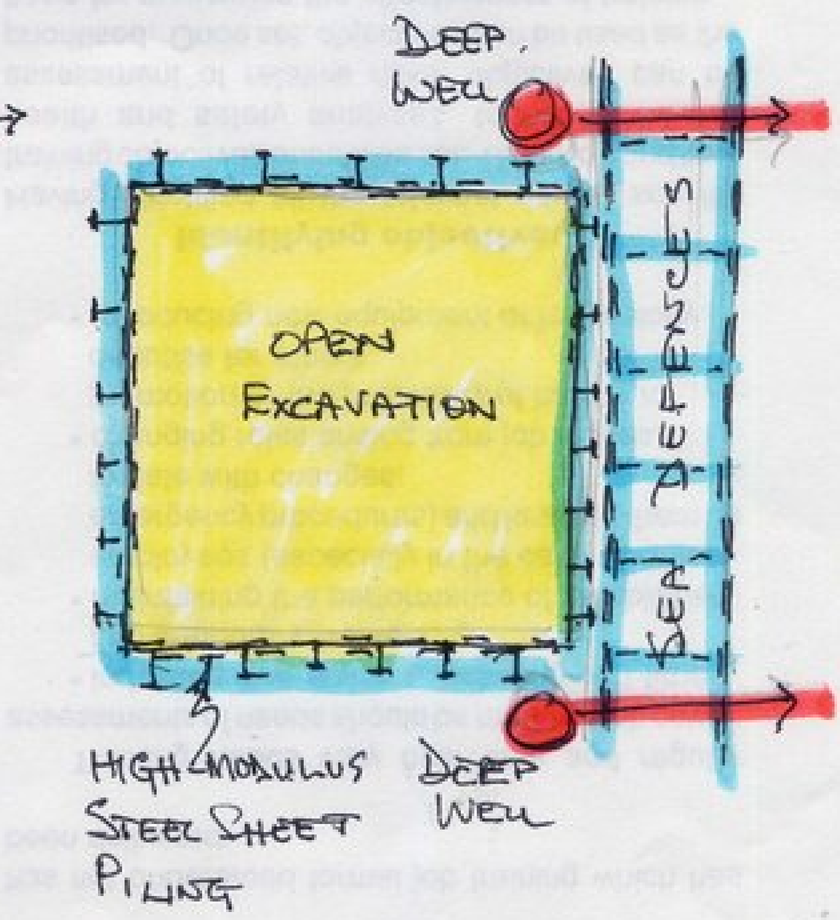
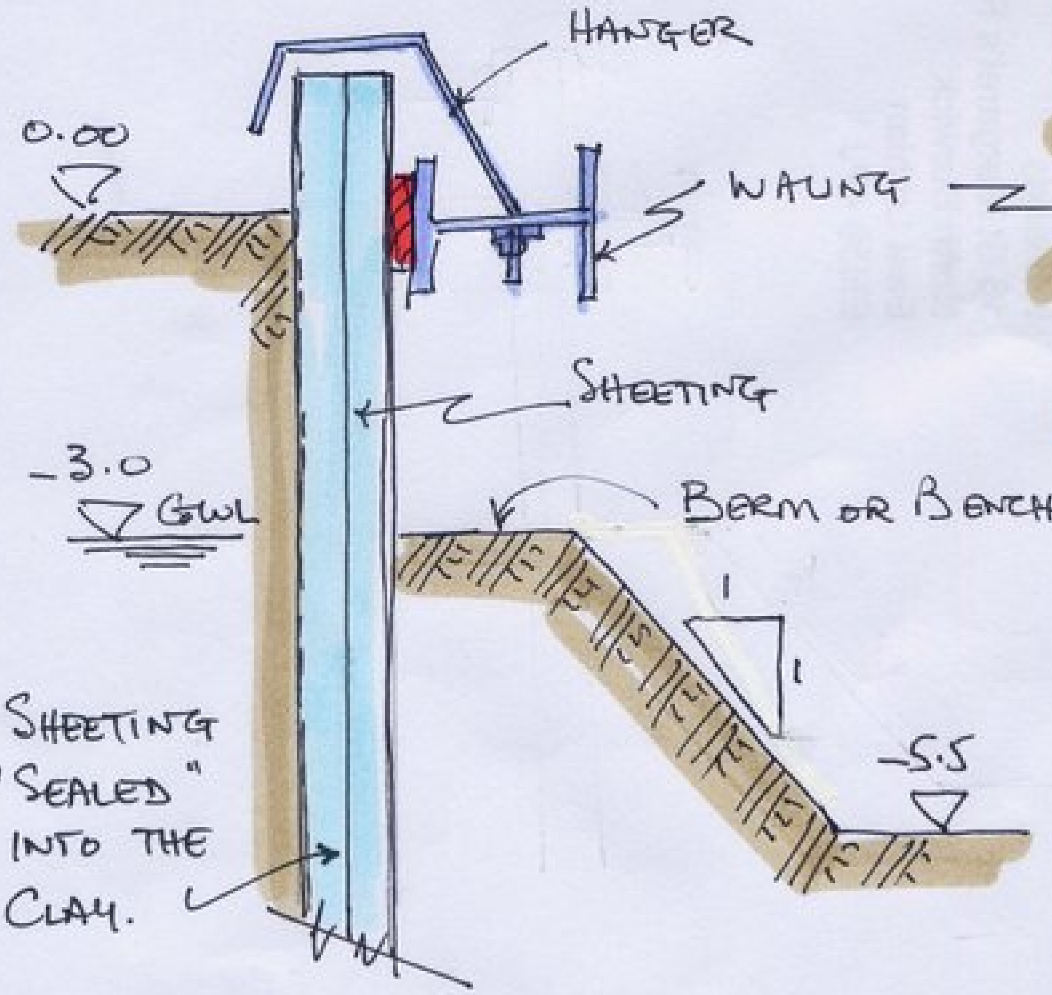
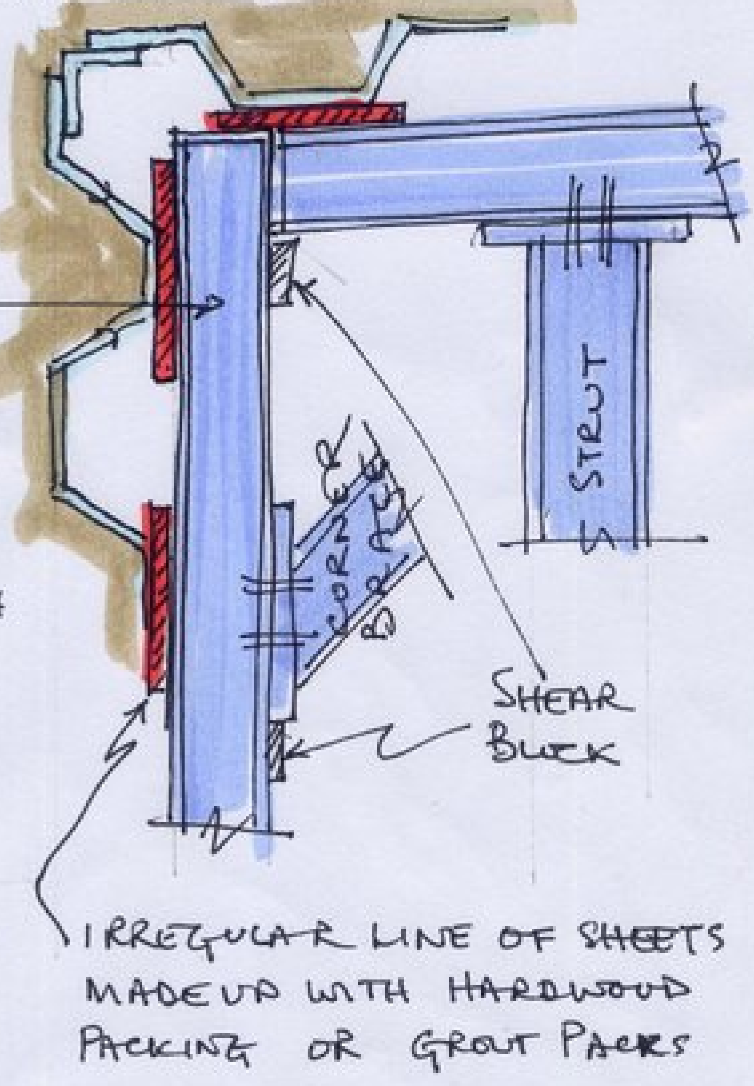


FIG (ii)

IN FIG (i) I HAVE SHOWN ONE WALL OF ONE OF THE SEA DEFENCE CELLS REPLACED BY THE ART SCHOOL'S BASEMENT COFFERDAM. THIS WILL GIVE THE FULL BASEMENT AREA INDICATED ON THE QUESTION'S PLAN. IN FIG (ii) THE SEA DEFENCES WILL NEED TO BE NARROWER TO ALLOW THE COFFERDAM TO BE CONSTRUCTED "INSIDE" THEM.

THE COFFERDAM IN FIG (i) IS COMPOSED OF INTERLOCKING SHEET PILES [EITHER 'Z' OR 'U' SECTION] SUPPORTED INTERNALLY BY STEEL WALING FRAMES USING DIAGONAL CORNER BRACING HUNG FROM THE TOP OF THE COFERDAM WALL. THE EXCAVATED DEPTH WOULD BE ACHIEVED IN TWO STAGES: DOWN TO GWL AT -3.0 M WITH THE SHEETING SUPPORTED BY A TOP FRAME, AND BELOW WATER LEVEL BY A "BENCH" OR "BERM" LEFT BY THE EXCAVATION. LATER, IN STAGE TWO, THE BERM IS CUT AWAY IN SHORT SECTIONS TO ALLOW THE PERMANENT RETAINING WALL TO BE CONSTRUCTED. THE SHEETING IS THEN PROPPED OFF THE PERMANENT WORKS TO ALLOW THE NEXT SECTION OF BERM TO BE CUT AWAY.

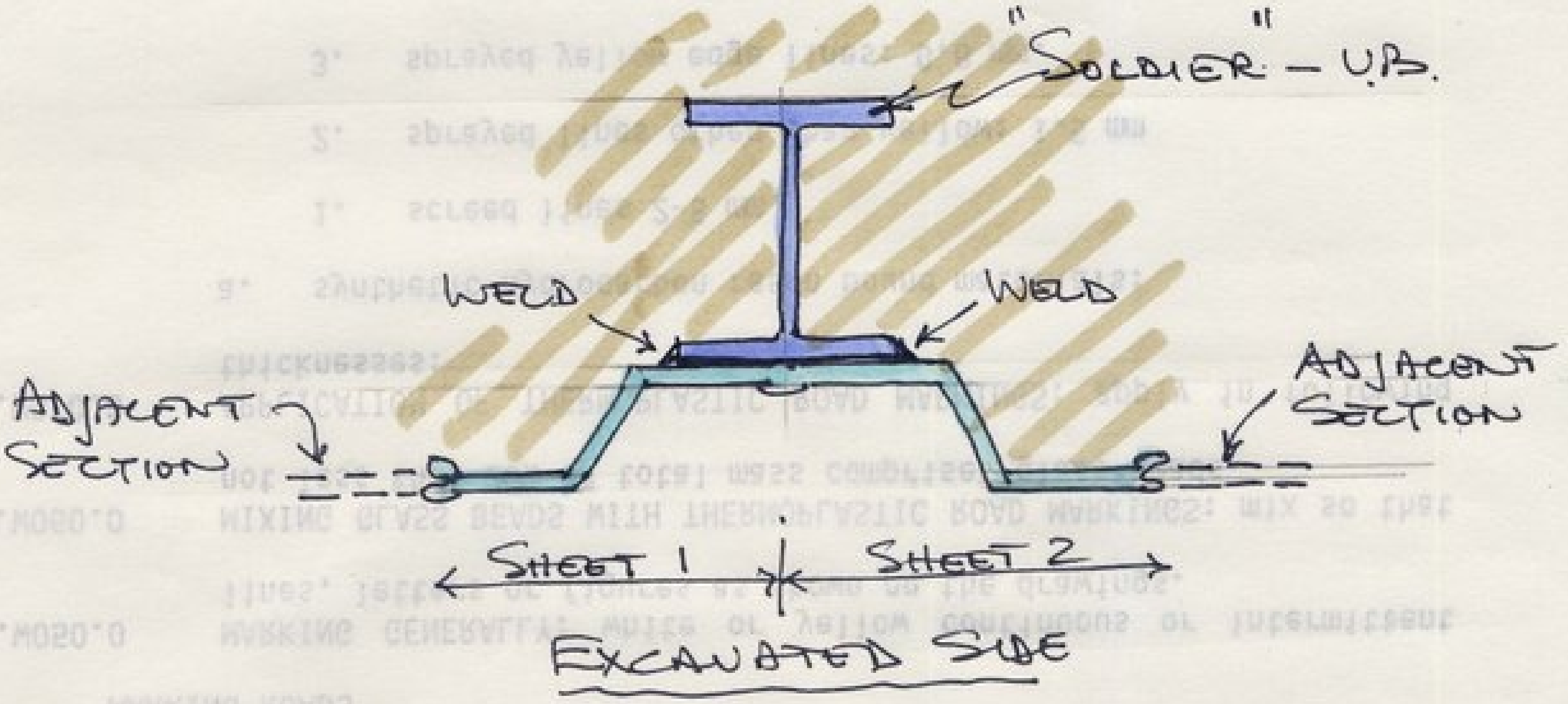




REFERENCES: 1. CIRIA "DESIGN AND CONSTRUCTION OF SHEET PILED COFFERDAMS" THOMAS TELFORD 1993 [SPECIAL PUBLICATION 95].

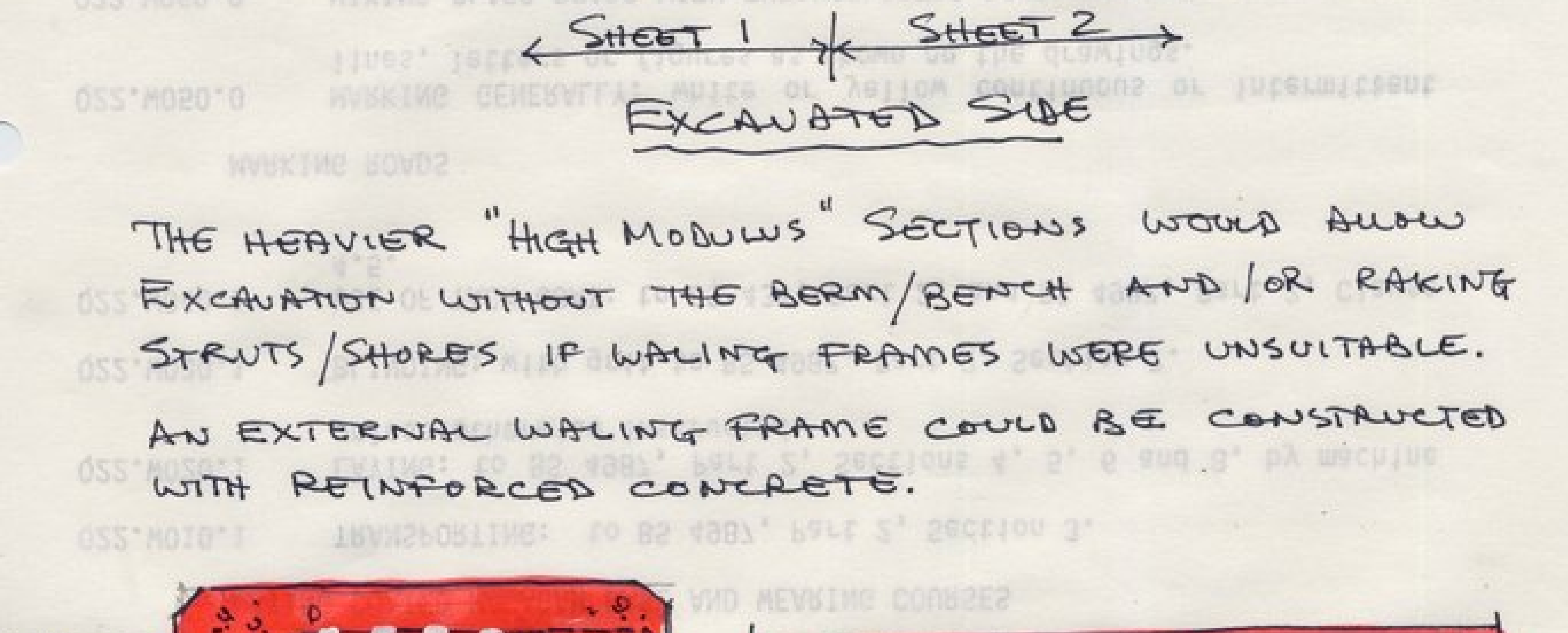
2. "DEEP EXCAVATIONS", MALCOLM PULLER, PUB. THOMAS TELFORD 2003, ISBN 0-7277-3150-5

THE COFFERDAM IN FIG (ii) WOULD USE "HIGH-MODULUS" SHEETING COMPRISING STEEL SHEET PILE SECTIONS REINFORCED WITH STEEL BEAMS



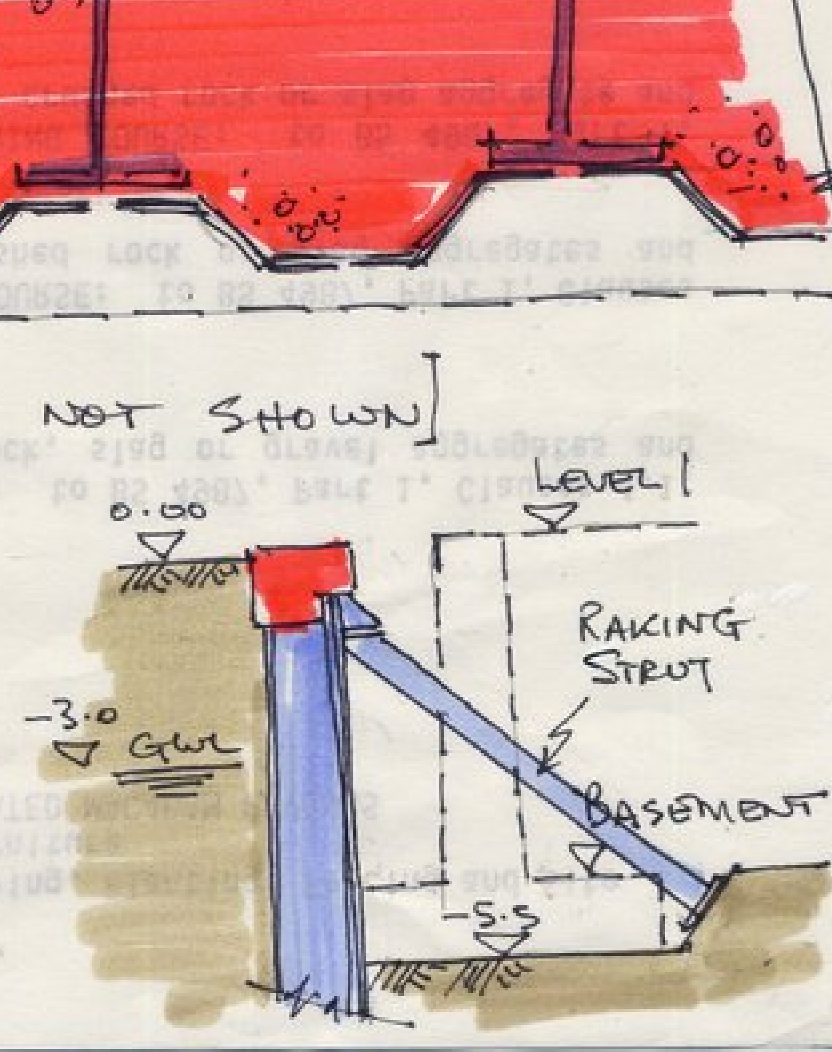
THE HEAVIER "HIGH MODULUS" SECTIONS WOULD ALLOW EXCAVATION WITHOUT THE BERM/BENCH AND/OR RAKING STRUTS/SHORES IF WALING FRAMES WERE UNSUITABLE.

AN EXTERNAL WALING FRAME COULD BE CONSTRUCTED WITH REINFORCED CONCRETE.



[REINFORCEMENT NOT SHOWN]

UNDER THE CDM REGULATIONS (DESIGN AND MANAGEMENT) 1994 THE DESIGNERS DUTIES AND RESPONSABILITIES INCLUDE THE CONSIDERATION OF METHODS OF SAFE WORKING WHERE RISKS CANNOT BE ELIMINATED.



AN ALTERNATIVE PROPOSAL WOULD BE TO CONSTRUCT THE PERMANENT WORKS IN A WAY THAT WOULD ALLOW THEM TO PROVIDE SUPPORT TO THE SIDES OF THE EXCAVATION. TWO METHODS SUGGEST THEMSELVES: A REINFORCED CONCRETE DIAPHRAGM WALL CONSTRUCTED USING BENTONITE SLURRY [A SLURRY-TRENCH WALL], OR INTERLOCKING REINFORCED CONCRETE PILING [SECANT PILE WALL].

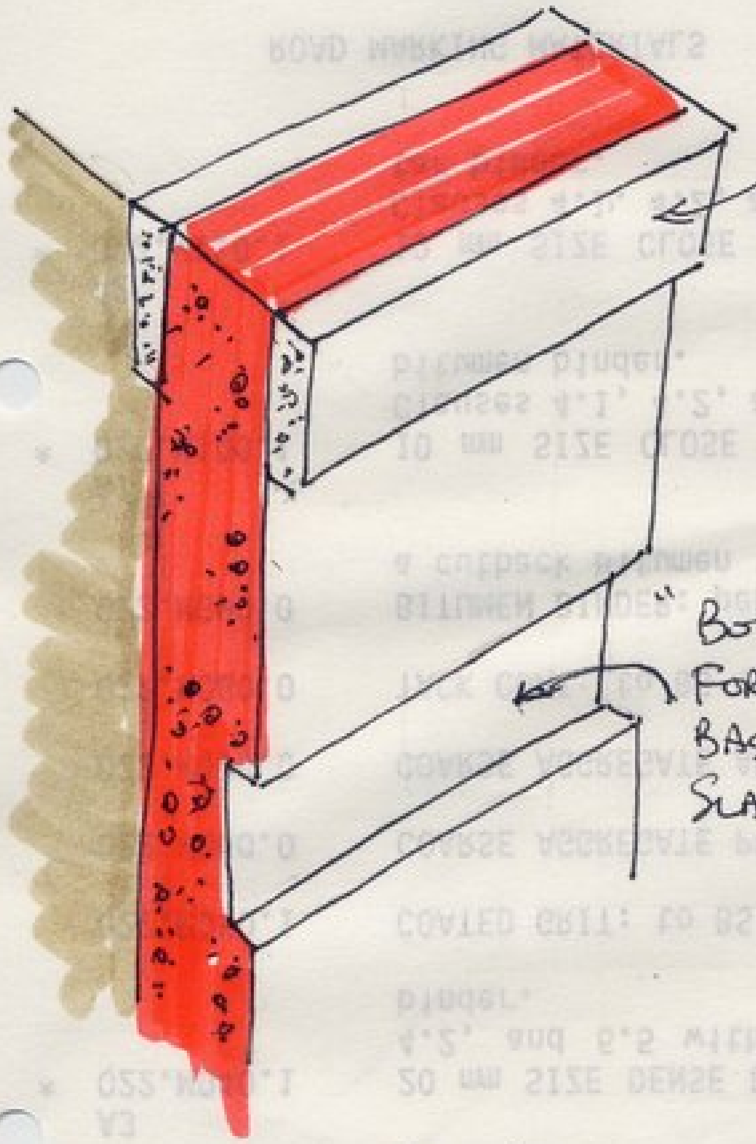


FIG (iii)

SLURRY-TRENCH WALL

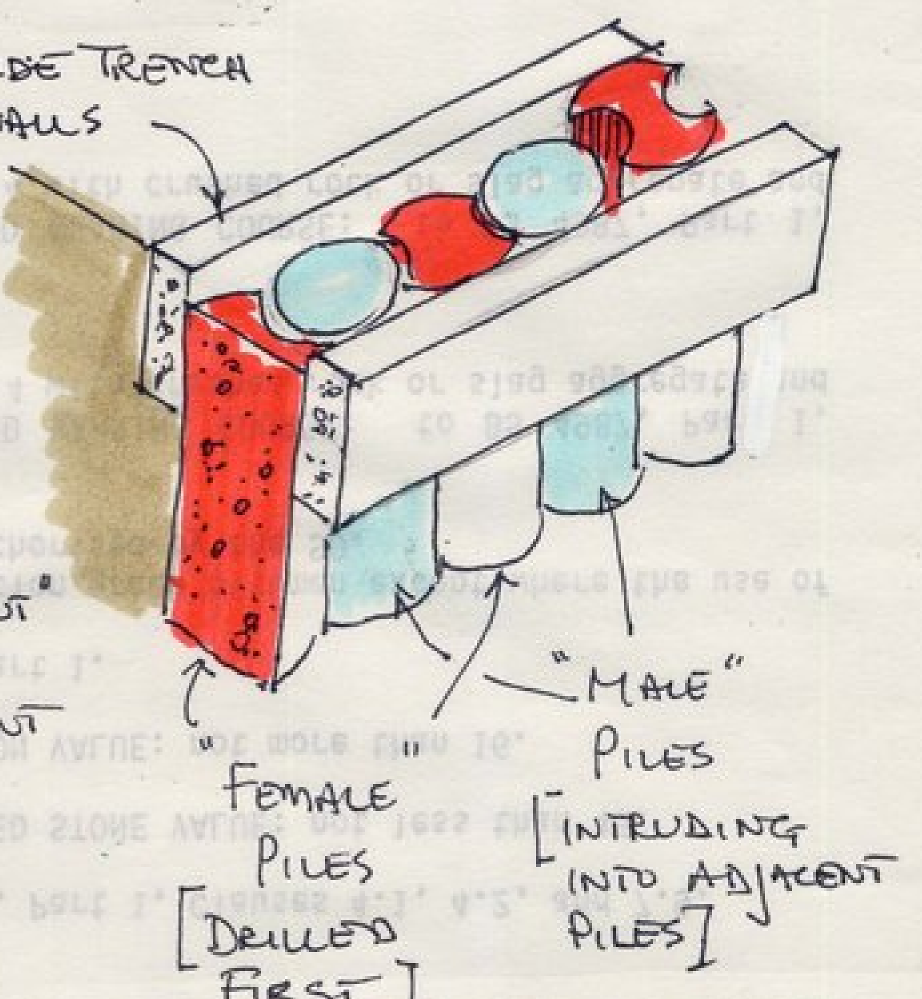


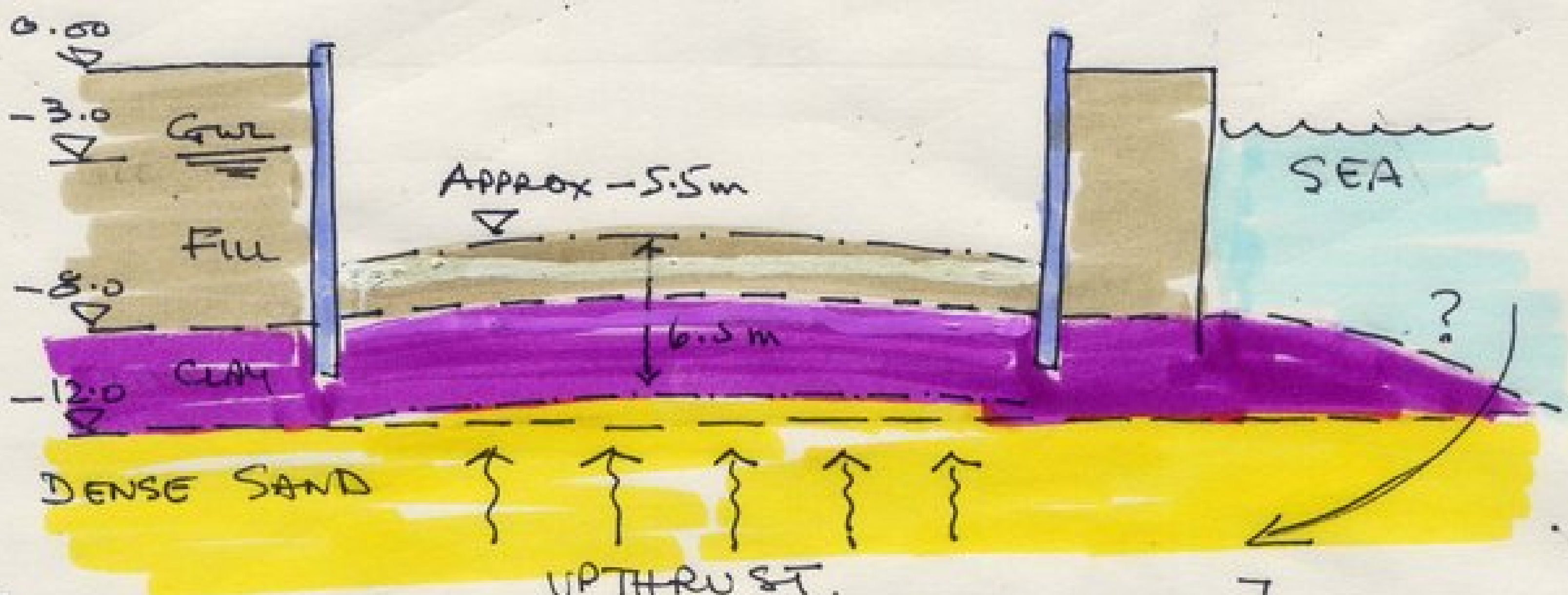
FIG (iv)

SECANT-INTERLINK PILE WALL.

THE USE OF POLYMER-MODIFIED BENTONITIC SLURRY WILL PROBABLY BE NECESSARY BECAUSE THE GROUND/FILL AND THE GROUNDWATER WILL BE SALINE [PROXIMITY TO THE SEA].

NEITHER OF THESE PROPOSALS CAN BE EXTERNALLY WATERPROOFED. THE SECANT WALL WILL NEED TO BE LINED IF IT IS TO BE EXPOSED. A CONCRETE [LINING] WALL CAN BE CLEANED AND SCABBLED [TO PROVIDE A KEY] AND RENDERED WITH WATERPROOF MORTAR [E.G. SKIKA]. IF LEAKS DEVELOP THE RENDER CAN BE REPAIRED; SOMETHING THAT CANNOT BE DONE TO EXTERNAL WATERPROOF MEMBRANES.

THE SHEET-PILED OR SECANT-PILE COFFERDAM WALLS ARE USUALLY SUFFICIENT TO CONTROL GROUNDWATER IF THE COFFERDAM WALLS ARE DRIVEN AND SEALED INTO A CLAY LAYER SUCH AS FOUND HERE [SEE PAGE 4]. HOWEVER, THE PLUG OF CLAY IN THE BOTTOM OF THE EXCAVATION MAY BE PUSHED UP BY THE UPTHRUST FROM UNRELIEVED POREWATER PRESSURE IN THE CONFINED SAND AQUIFER [PRESUMED]. IT SHOULD BE PRESUMED THAT THE DENSE SAND LAYER BELOW −12.0m IS SATURATED AND THEREFORE A "CONFINED AQUIFER".



[REF: CIRIA C515 "GROUNDWATER CONTROL", 2000.]

OVERBURDEN PRESSURE FROM BASE OF EXCAVATION $= 20.0\ \text{kN/m}^3 \times 6.5\text{m} = 130\ \text{kN/m}^2$.

HYDRAULIC UPTHRUST $= 10.0\ \text{kN/m}^3 \times 12.0\text{m} = 120\ \text{kN/m}^2$

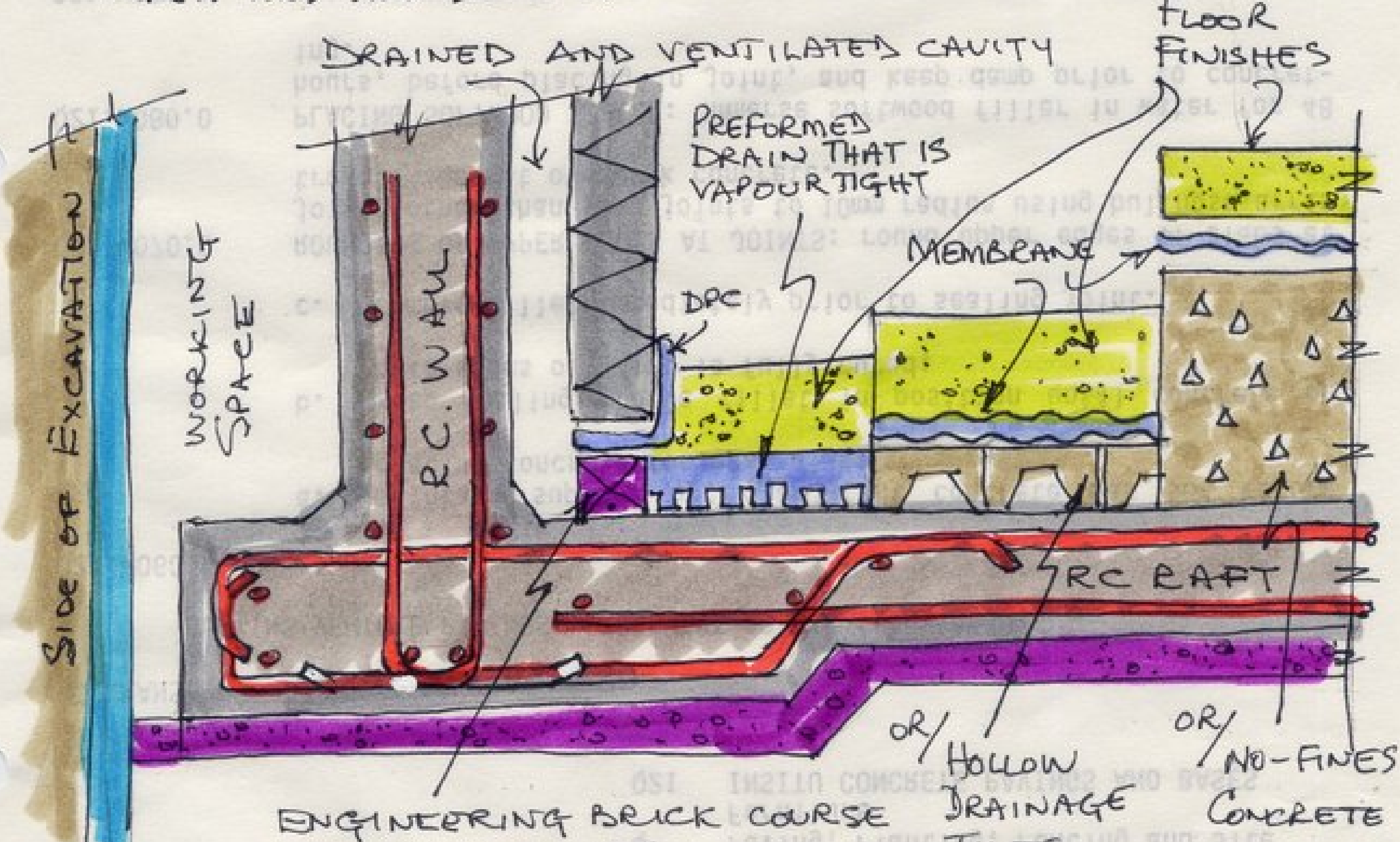
$$F.O.S = \frac{130}{120} = 1.08 \ll 1.3\ [F.O.S]$$

THEREFORE IT SEEMS PROBABLE THAT BASE FAILURE WILL HAPPEN. THE USE OF PILES [SEE PAGE 1] WILL REDUCE THE RISK TWO WAYS: BY HOLDING THE CLAY STRATUM DOWN AND BY PUNCTURING THE CONFINED AQUIFER THUS REDUCING THE PORE WATER PRESSURES.

THUS IT CAN BE SEEN THAT WATER IS LIKELY TO SEEP INTO THE EXCAVATION FROM BELOW EVEN THOUGH THE COFFERDAM WALLS ARE SEALED INTO THE CLAY LAYER. THIS EXPLAINS WHY I HAVE INDICATED DEWATERING [SEE PAGE 4]. DRAWING GROUND WATER AWAY FROM THE EXCAVATION IS THE SAFEST WAY TO PROTECT AN OPEN EXCAVATION. THE WELL-POINTS AND/OR DEEP WELLS SHOULD REDUCE THE PORE PRESSURE IN THE DENSE SAND

CLEARLY THERE ARE TWO WAYS OF WATERPROOFING THIS BASEMENT: EXTERNAL OR INTERNAL WATERPROOFING. HOWEVER, MERE WATERPROOFING AS FOR A RESERVOIR IS NOT SUFFICIENT. CR #1 SPECIFIES THAT THE SPACE IS TO BE USED FOR "STORAGE". CIRIA REPORT NUMBER 139 – "WATER-RESISTING BASEMENTS", 1995 CLASSIFIES THE INTERNAL ENVIRONMENT INTO FOUR GRADES AND THREE PROTECTION TYPES. COMBINATIONS OF PROTECTION TYPES ARE FREQUENTLY USED, E.G. "DRAINED PROTECTION INCLUDING A VAPOUR BARRIER – TYPE CA", AND IF THE SPECIFICATION [OR THE DETAILS] IS MUDDLED THE EXAMINER WILL CERTAINLY MARK DOWN QUITE SEVERELY. THE STANDARD REQUIRED IS "PROFESSIONAL": DISTINCTLY DIFFERENT FROM 'BASIC COLLEGE KNOWLEDGE.'

IN THIS QUESTION – A NEW ARTS SCHOOL – BASEMENT STORAGE WILL REQUIRE A CONTROLLED ENVIRONMENT – RELATIVE HUMIDITY 50%; TEMPERATURE 18–22°C AND A TOTALLY DRY ENVIRONMENT FOR ART STORAGE; THIS IS GRADE 4 (SPECIAL) – REFER TO CIRIA REPORT 139. DAMPNESS AND WETNESS ARE CONTROLLED BY PROTECTION TYPE CA – A DRAINED CAVITY WALL AND FLOOR COMBINED WITH VAPOUR BARRIERS. THE CLIENT MAY WANT TO LIMIT THE CONTROLLED ENVIRONMENT TO A PARTICULAR BASEMENT AREA, BUT IN THIS QUESTION ONE MUST ASSUME THAT THE WHOLE BASEMENT AREA HAS THE SAME GRADE.



NOW, WITH DETAILS, THERE MAY BE SOME REGIONAL VARIATIONS BUT THE BASIC PRINCIPLES CANNOT BE COMPROMISED. CHECK THE FOLLOWING:

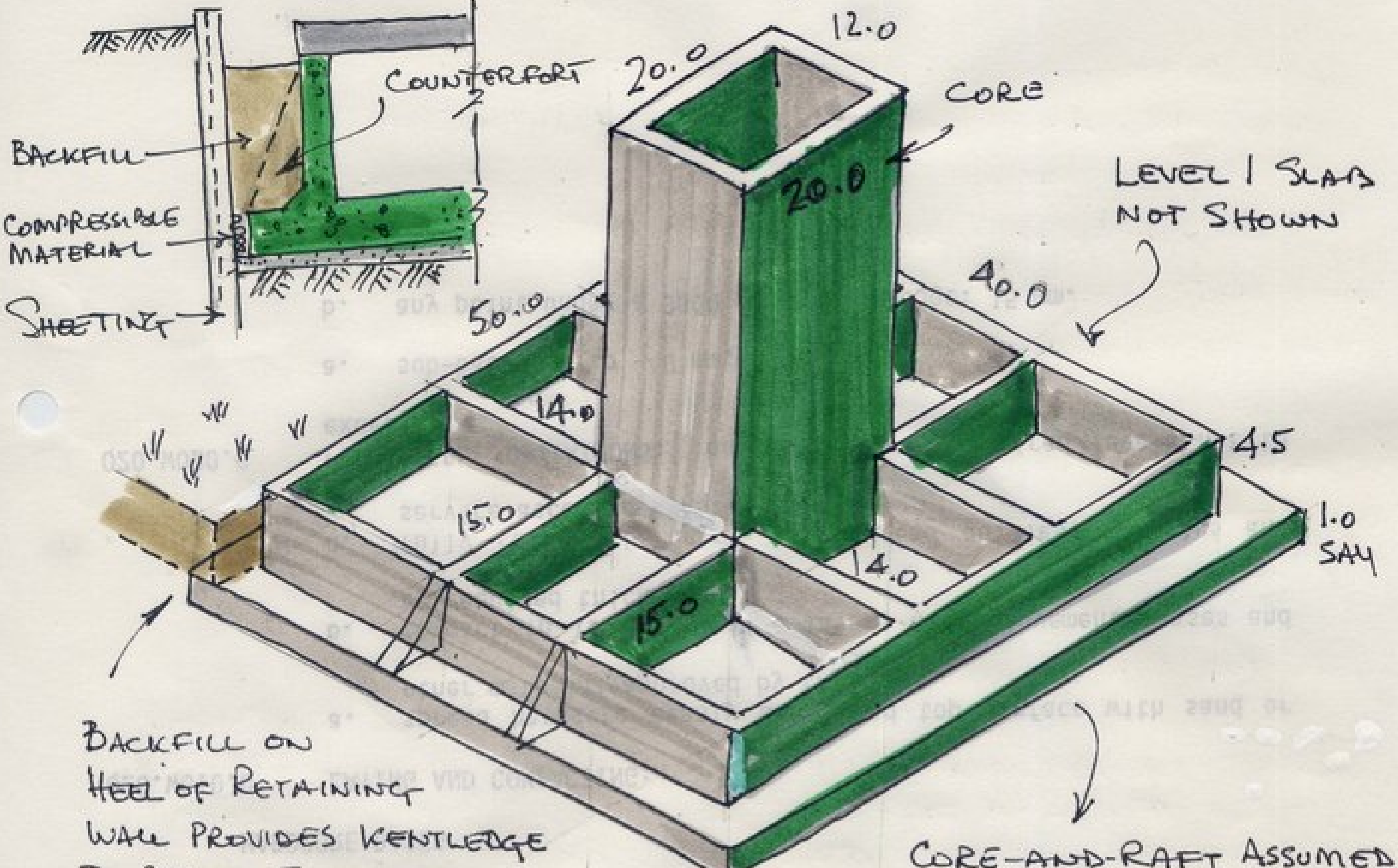
1. WATER PENETRATING THE OUTER STRUCTURAL WALL IS INTERCEPTED BY AN UN-BRIDGED, DRAINED AND VENTILATED CAVITY.
2. THE VERTICAL CAVITY IS DIRECTLY CONNECTED TO A HORIZONTAL CAVITY UNDER THE FLOOR. THE FLOOR IS LAID TO FALLS SO THAT ANY WATER COLLECTED EITHER FROM THE OUTER WALL OR PENETRATING THE FOUNDATION RAFT IS DRAINED TO A SUMP FROM WHICH IT IS PUMPED AWAY BY AUTOMATIC SUBMERGED PUMPS
3. VENTILATION IS ACHIEVED BY CREATING A SMALL POSITIVE PRESSURE WITHIN THE STORAGE CHAMBER(S) SO THAT THE ESCAPING AIR CARRIES WATER VAPOUR UP THE CAVITY AND AWAY FROM THE STORAGE CHAMBER(S).

THE CANDIDATE IS RESPONSIBLE FOR ENSURING THAT HIS/HER PROPOSAL FUNCTIONS CORRECTLY AND IS BUILDABLE. AS AN EXAMPLE OF BUILDABILITY, THE REINFORCEMENT SHOWN EMBEDDED IN THE STRUCTURAL FLOOR/RAFT AND WALL MUST BE CAPABLE OF BEING ASSEMBLED WITH THE SPECIFIED COVERS. CHECK THE FOLLOWING:

4. LACING BARS RUNNING ALONG THE WALL ARE ON THE OUTSIDE OF THE MAIN REBAR
5. HAIRPIN BARS ARE USED SPARINGLY BECAUSE, SHOULD THEY BE BENT TOO WIDE, WILL NOT FIT INTO THE NARROW FLOOR OR WALL.
6. LARGE-DIAMETER REBARS ARE HEAVY TO HANDLE, ESPECIALLY IN WALLS, AND NEED LONG LAP LENGTHS. USE SMALL-DIAMETER BARS AT CLOSER SPACING AND CONTROL EARLY-AGE CRACKING TOO!
7. REDUCE CONGESTION AT STARTER BARS AND LAPS BY STAGGERING LAPS OR USING CONNECTORS.

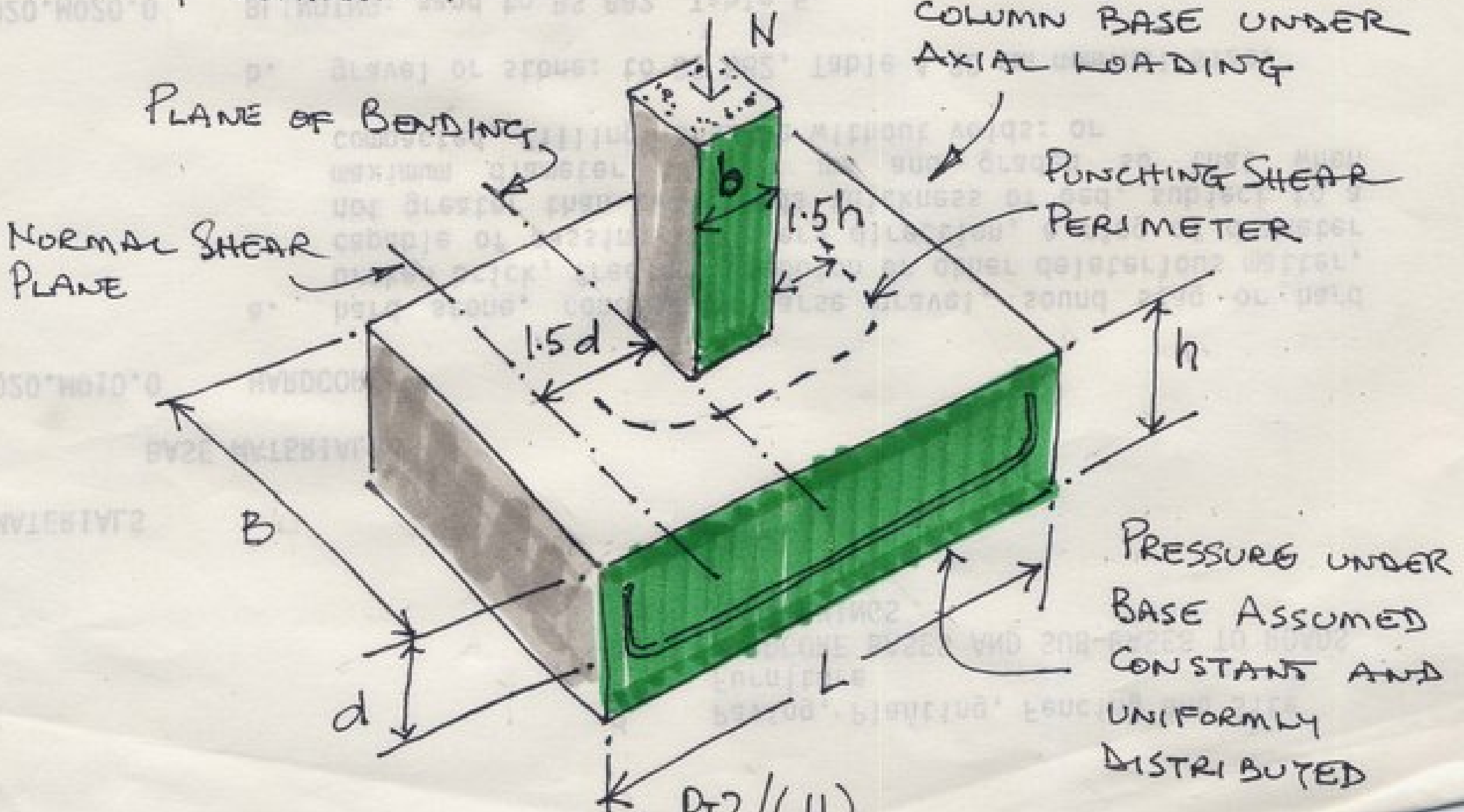
POOR BUILDABILITY WILL BE MARKED DOWN WHEREVER IT IS FOUND!

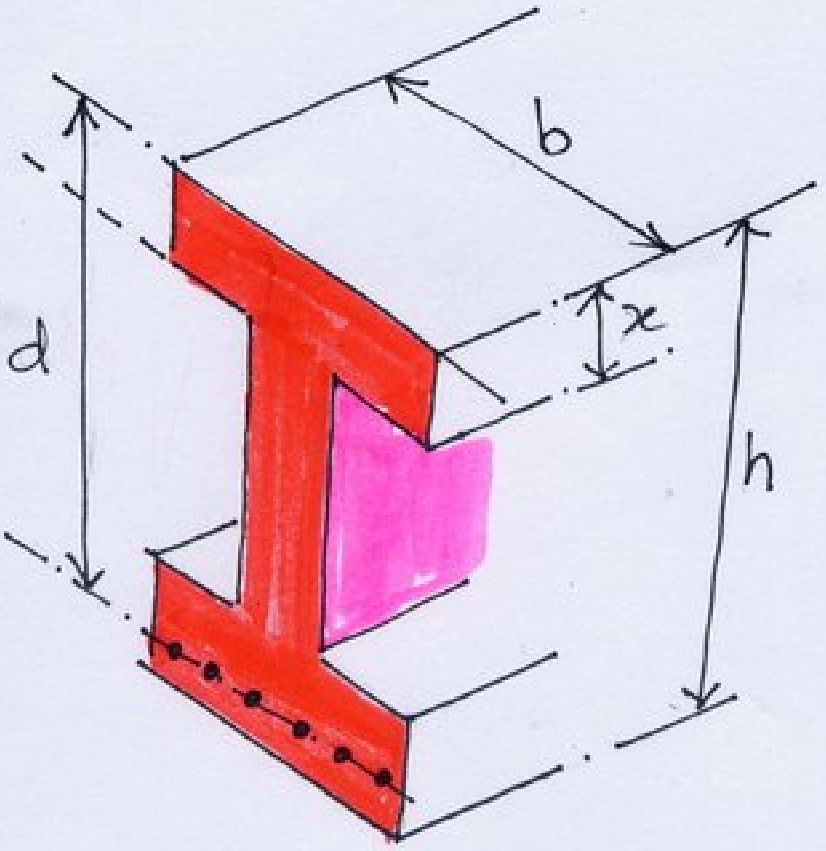
THE BASEMENT COMPRISES A FLOOR RAFT THAT MAY ALSO BE A PILECAP; A PERIMETER WALL — VERY OFTEN A VERTICAL CANTILEVER; A GROUND-FLOOR OR LEVEL 1 SLAB, WHICH IN THIS CASE CARRIES AN IMPOSED LOAD OF 5 kN/m² [CR # 4]; AND WALLS/COLUMNS.



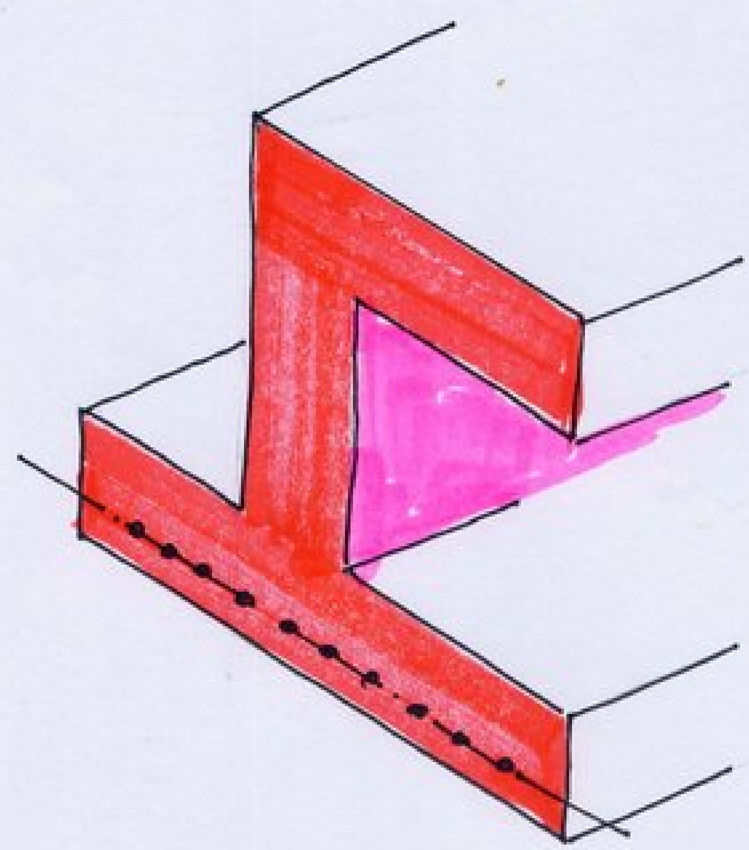
BACKFILL ON HEEL OF RETAINING WALL PROVIDES KENTLEDGE TO RESIST FLOTATION. COUNTERFORTS ALLOW SECTIONS TO BE BUILT SEPARATELY.

CORE-AND-RAFT ASSUMED TO BE SIMILAR [FOR DESIGN PURPOSES] TO AN ISOLATED COLUMN BASE UNDER AXIAL LOADING





CROSS-SECTION OF MAIN CANTILEVER RIBS PROJECTING FROM CORE.

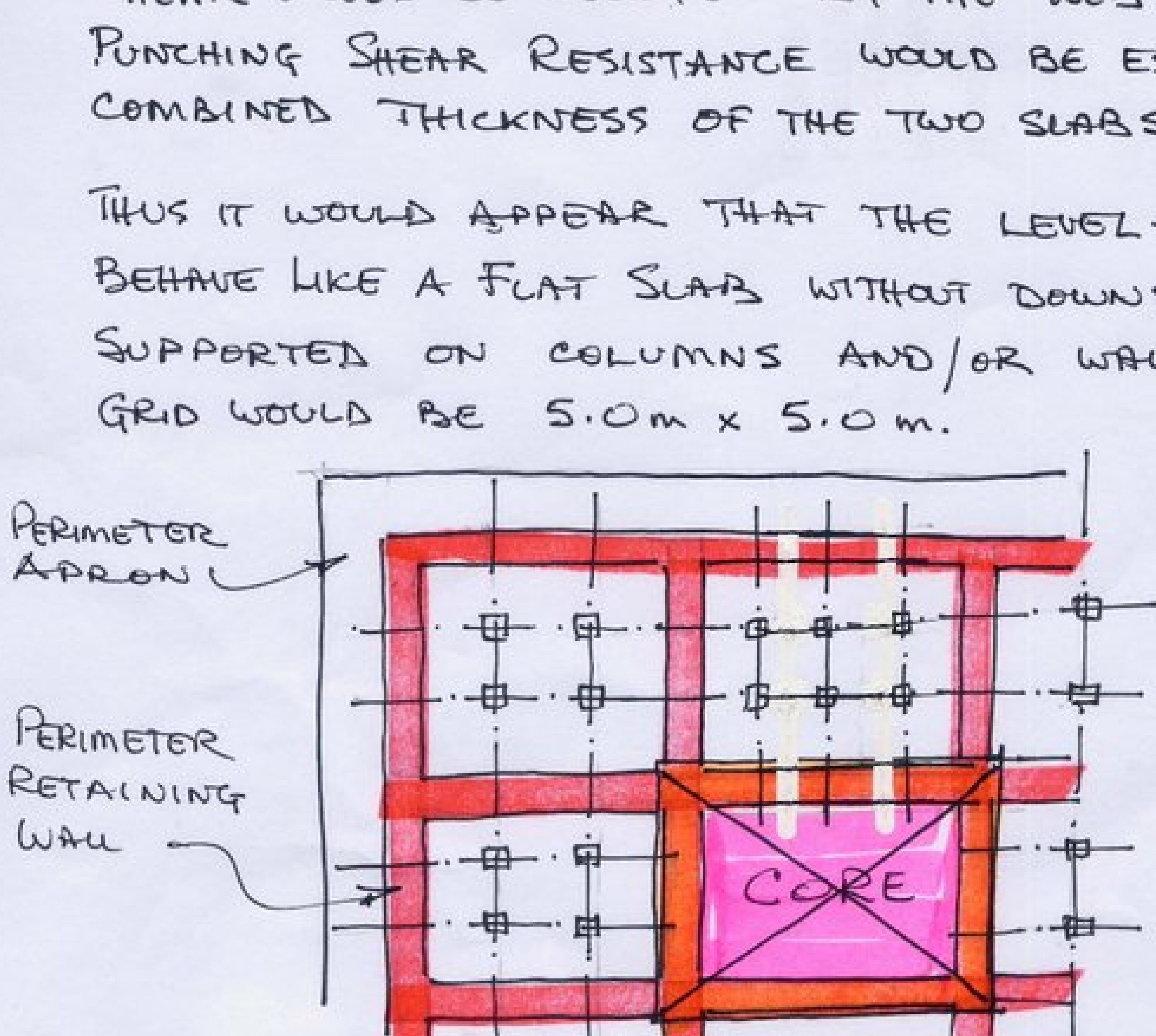


CROSS-SECTION OF COMBINED RETAINING WALL AND RIB.

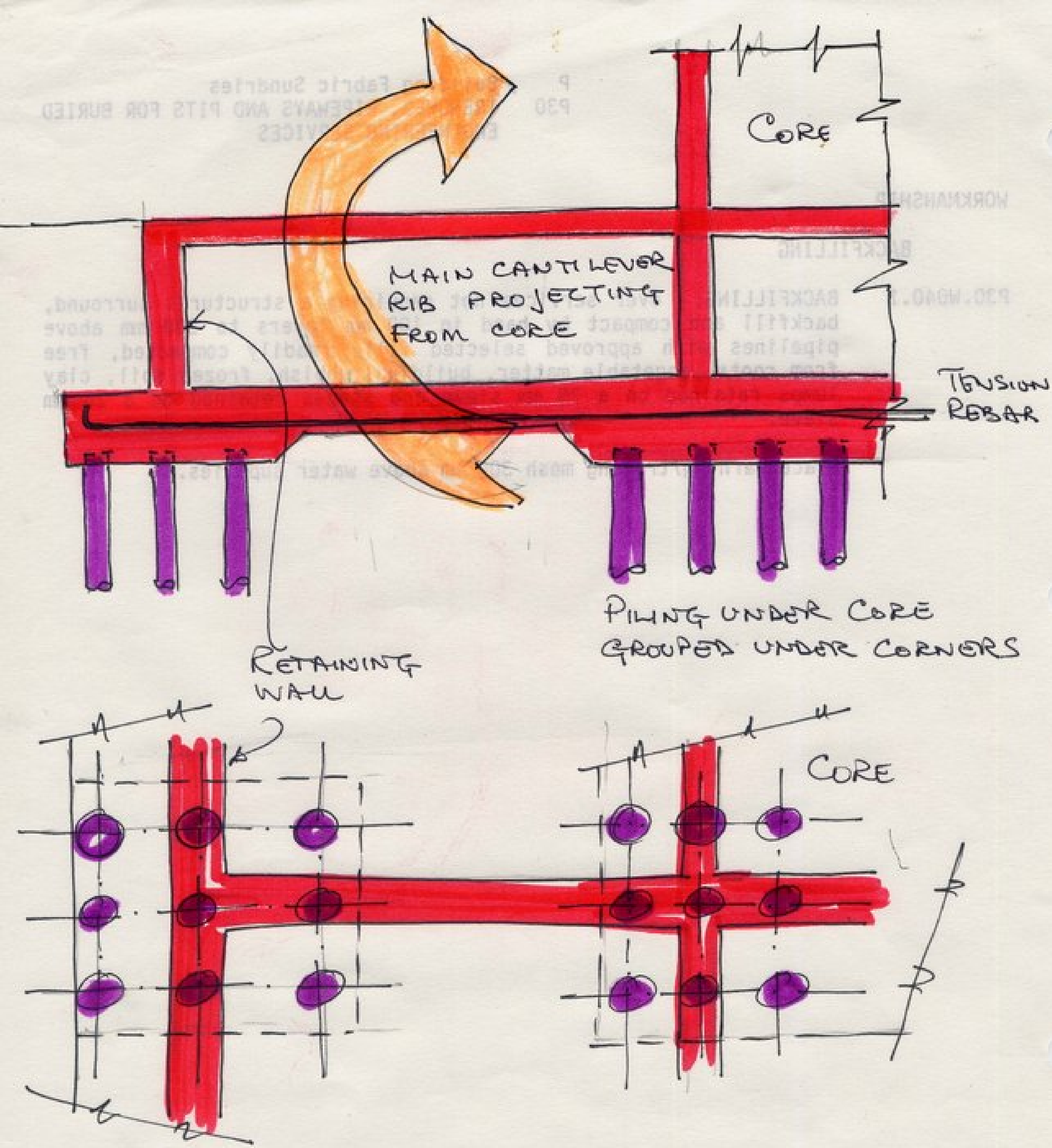
ADDITIONAL RIBS MAY BE NECESSARY BETWEEN THE MAIN RIBS AND THE RETAINING WALL

SHEAR WOULD BE RESISTED BY THE 'WEB' OR WALL ELEMENT PUNCHING SHEAR RESISTANCE WOULD BE ESTIMATED ON THE COMBINED THICKNESS OF THE TWO SLABS.

THUS IT WOULD APPEAR THAT THE LEVEL-ONE SLAB SHOULD BEHAVE LIKE A FLAT SLAB WITHOUT DOWNSTAND BEAMS AND SUPPORTED ON COLUMNS AND/OR WALLS. THE COLUMN GRID WOULD BE 5.0m x 5.0m.



GENERAL ARRANGEMENT OF THE BASEMENT



GROUPS OF PILES WOULD BE STRATEGICALLY LOCATED TO PROVIDE CLEARLY DEFINED REACTIONARY FORCES THAT WOULD BE TRANSMITTED TO THE ROCK STRATUM AT -20.0 m. THUS RELIEVING THE HIGHLY COMPRESSIBLE MARINE CLAYS AT BETWEEN -8.0 m AND -12.0 m. THESE CLAYS WOULD CONSOLIDATE UNDER THE "UNIFORM" GENERAL LOADING AND APPLY NEGATIVE FRICTION OR "DRAG DOWN" TO THE PILE SHAFT UNLESS THE SHAFT WAS SLEEVED THROUGH THE CLAY. SMALL GROUPS OF NINE PILES WOULD BEHAVE AS NINE SEPARATE PILES, WHEREAS A BASEMENT-SIZED GROUP WOULD BE SUBJECT TO A GROUP REDUCTION

IF THE PILES ARE "END BEARING" ON ROCK THERE WILL BE LITTLE SETTLEMENT OR MOVEMENT THAT COULD MOBILIZE SKIN FRICTION ON THE PILES. CONSEQUENTLY, THE CAPACITY OF EACH PILE WILL LARGELY BE DECIDED BY ITS CROSS-SECTIONAL AREA AND THE STRENGTH OF THE CONCRETE OR STEEL USED.

CANDIDATES ARE ADVISED TO BE FAMILIAR WITH SEVERAL PILING SYSTEMS, RANGING FROM MINI-PILES, THROUGH THE ORTHODOX OR TRADITIONAL SYSTEMS TO THE LARGE-DIAMETER CAISSON PILES WITH UNDER-REAM ENLARGEMENT.

IN THIS CASE THE CANDIDATE MIGHT EXPLORE 500 TO 600 DIAMETER BORED OR DRIVEN PILES: AND COMPARE WITH LARGE-DIAMETER BORED/CAISSON PILES.

DIAMETER	SERVICE LOAD (PILE INTEGRITY ONLY) kN
600	2000
900	4000
1350	8000
2100	15 000

THE BASE DIAMETER - UNDERREAM - IS USUALLY 2x DIAMETER OR SLIGHTLY BIGGER.

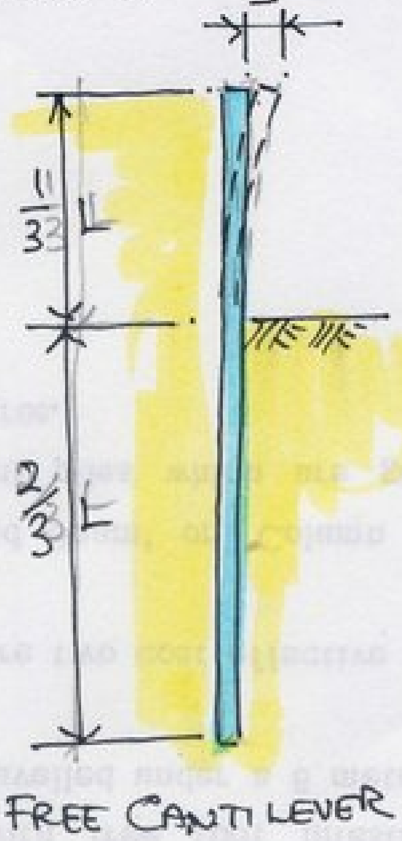
DIAMETER	BASE DIAMETER	
600	1500	DEPENDING
900	2400	ON THE
1350	3300	EQUIPMENT
2100	4500	

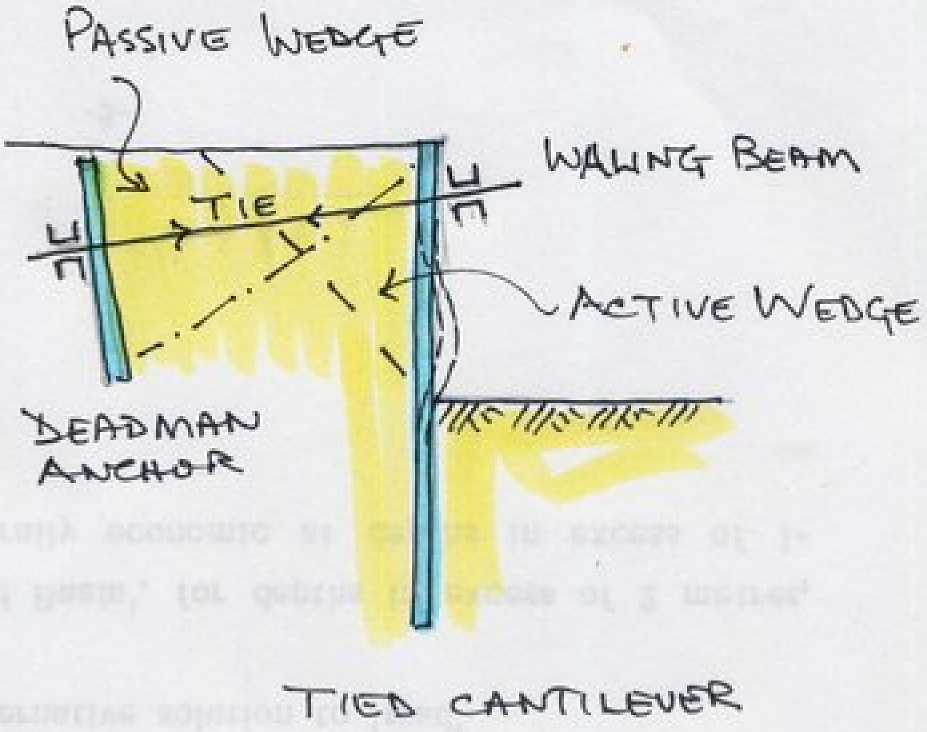
WHERE THE DRILLED SHAFT FLOODS WITH WATER ALL CONCRETE MUST BE PLACED BY TREMIE — DITTO WHERE BENTONITE SLURRY IS USED TO SUPPORT THE EARTH SIDES AS IN THE SAND STRATA IN THIS CASE.

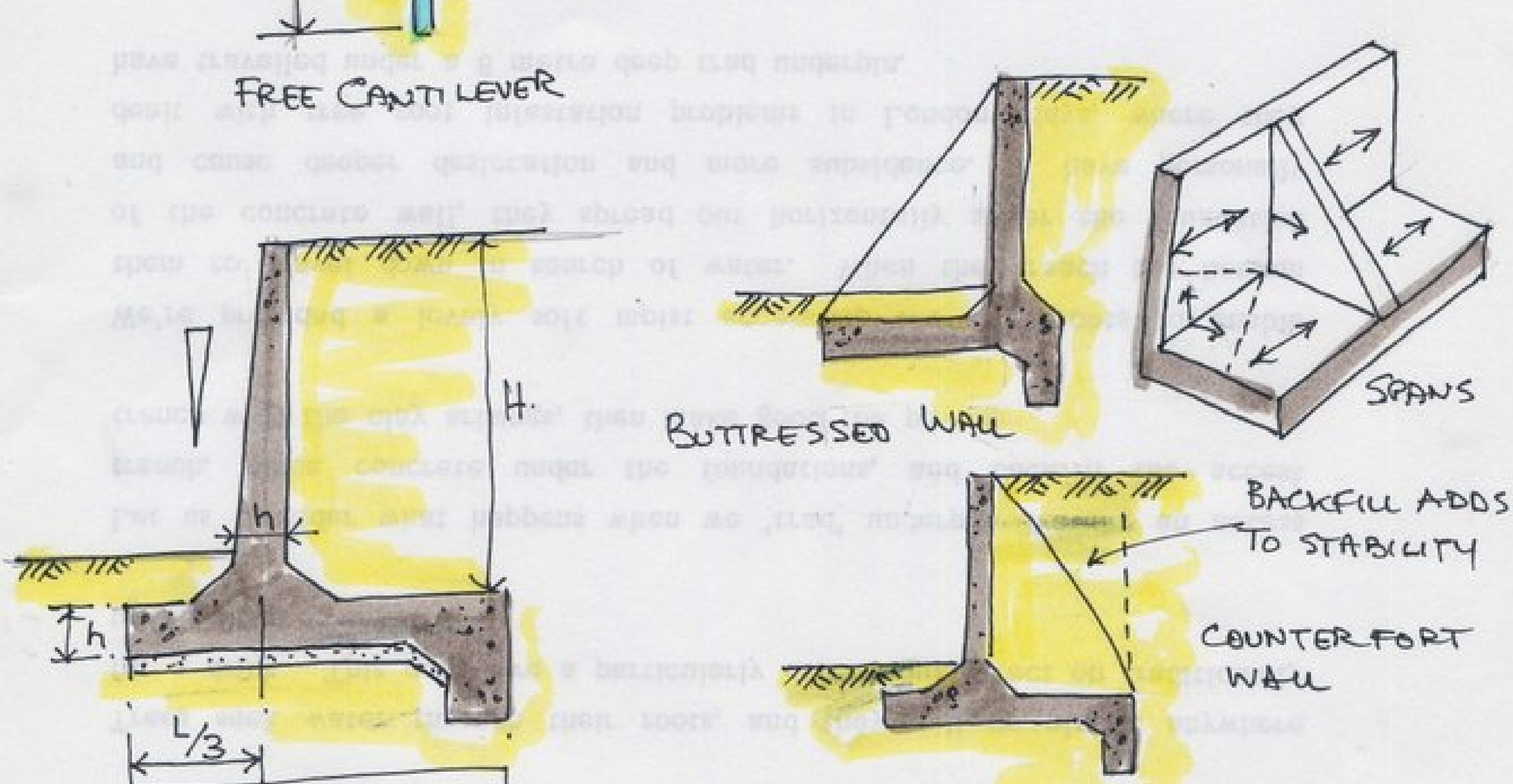
A CASING WOULD PROBABLY be USED THROUGH THE 8.0 m OF RECLAIMED FILL MATERIAL AND MUST BE DRIVEN AHEAD OF THE DRILLING BUCKET TO PREVENT COLLAPSE — SEE CIRIA REPORT PG2 - "REVIEW OF PROBLEMS ASSOCIATED WITH THE CONSTRUCTION OF CAST-IN-PLACE CONCRETE PILES" 1977. THE REPORT MAY APPEAR DATED BUT THE PROBLEMS STILL OCCUR DESPITE IMPROVEMENTS IN TECHNIQUE AND EQUIPMENT. PG2/(14)

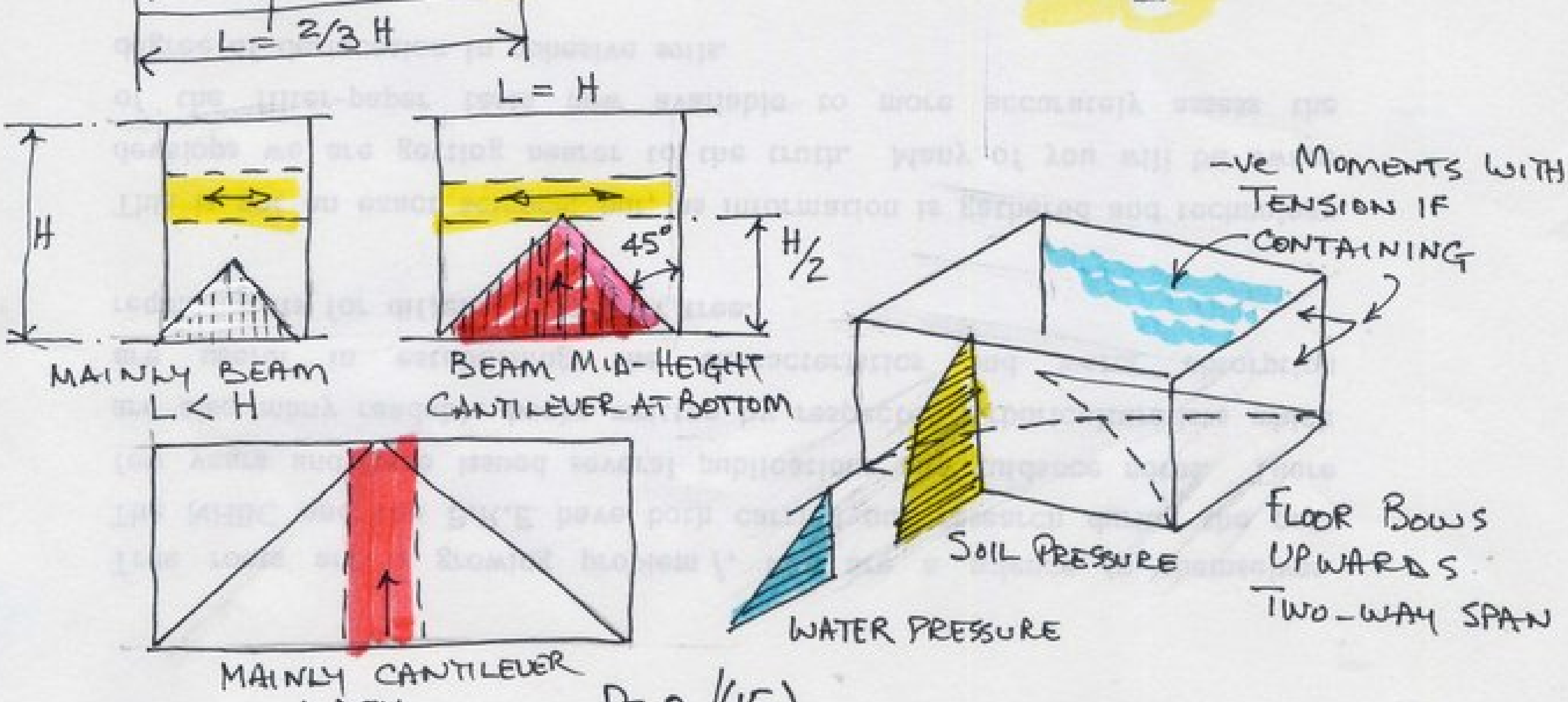
Retaining Walls: Behaviour and Design.

Cantilever









QUESTION 4 - 2012 NEW ARTS SCHOOL

POST SCRIPT!

YOU WILL NOT BE SATISFIED WITH YOUR ANSWER BECAUSE IT IS A "NEVER ENDING" ONE! IN THE EXAMINATION YOU NEED TO ANSWER THOSE PARTS WHERE YOUR EXPERIENCE SHOWS THROUGH. YOU ONLY ANSWER FOR AS LONG AS YOUR PROGRAMME ALLOWS YOU TO, AND YOU PRESENT IT AS NEATLY AS YOU CAN. BECAUSE YOU HAVE PRACTISED YOU KNOW TO "COVER THE QUESTION" — ANSWER WHAT IT ASKS AND ATTEMPT ALL PARTS. IF THERE IS SOME SPARE TIME AT THE END CONSIDER "SWEEPING-UP" AS I HAVE DONE ON PAGES 13, 14, 15 AND 16 OF PART 1.

TRY MARKING YOURSELF ON THE CONCEPT PART - SECTION 1A.

DIVIDE THE 40 MARKS THUS:

15 FOR OPTION OR SCHEME A
15 FOR OPTION OR SCHEME B
10 FOR IDENTIFYING THE SOLUTION YOU RECOMMEND AND THE REASONS FOR YOUR CHOICE.

YOU MUST SCORE 16/40 FOR A "PASS".

HOW WILL YOU DISTRIBUTE YOUR 15 MARKS FOR EACH SCHEME? PERHAPS YOU WILL MAKE A LIST OF THE MAIN ELEMENTS? ROOF, FLOORS, CORE, SLAB AT LEVEL 1, BASEMENT/FOUNDATION, AND BASEMENT WALLS — I.E. 6 — AND GIVE 2 MARKS FOR EACH = 12 AND MAKE-UP THE '15' WITH 3 MARKS FOR PRESENTATION, SIZING AND ACCURACY.

THIS WAY YOU CAN EASILY SEE HOW MUCH WORK HAS TO BE DONE BEFORE YOU ARE AWARDED JUST ONE MARK!

- REJECT SCHEMES THAT ARE NOT DISTINCTLY DIFFERENT OR ARE NOT VIABLE.
- MARK-DOWN UNFINISHED SCHEMES, FAULTY BUILDING OR INCORRECT CALCULATIONS WITH IMPROBABLE OUTCOMES.
- MARK-DOWN POOR PRESENTATION BECAUSE PROFESSIONAL ENGINEERS CANNOT OFFER SUCH WORK TO THE CLIENT

DID YOU FIND IT HARD TO SCORE 40%-PLUS? WERE YOU HELD BACK BY A POOR KNOWLEDGE OF BUILDING TECHNOLOGY?