Possible solution to past CM examination question

# Question 4 April/ 2007

# Swimming Pool

by Bob Wilson

# Question 4. Swimming Pool

**Client's requirements**

1. A swimming pool with car-parking and a 2-storey basement: see Figure Q4
2. Car-parking is required on levels 2 to 4. Entry and exit to the car-park is via two curved access ramps, integral with services cores, lifts and staircases. The services cores serve all levels including the roof. A swimming pool 50.0m long and 15.0m wide is required on level 1. The pool depth is to vary linearly from 1.5m to 2.5m. Floor-to-floor heights and minimum headroom requirements are shown in Figure Q4. There is no restriction on the roof height.
3. Each parking bay is to be a minimum of 2.5m wide and 4.8m long. 6.0m wide traffic lanes are required on each parking level as shown in Figure Q4. No structure is permitted in any parking bay or traffic lane.
4. A fire resistance of 2 hours is required for all structural elements.

**Imposed Loading**

5.

| | |
|---|---|
| Roof | 1.5kN/m$^2$ |
| Car park floors and ramps | 2.5kN/m$^2$ |
| Level 1 floor and basement floors | 5.0kN/m$^2$ |

**Site Conditions**

6. The site is level and is located in a city centre.
   Basic wind speed is 40 m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20 m/s.
7. Ground conditions:

| | |
|---|---|
| Ground level – 1.0m | Made ground |
| 1.0m – 18.0m | Sand and gravel. N values vary from 10 to 40 |
| Below 18.0m | Rock. Allowable bearing pressure = 1500kN/m$^2$ |

   Groundwater was encountered at 6.0m below ground level

**Omit from consideration**

8. Detailed design of the lifts and staircases.

**SECTION 1** **(50 marks)**

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure including the foundations. 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 completion of your design, it is discovered that groundwater levels are slowly rising and are predicted to reach 1.0m below ground level in the long-term. Write a letter to the client explaining the implications and how your design could be modified to accommodate the rising groundwater. (10 marks)

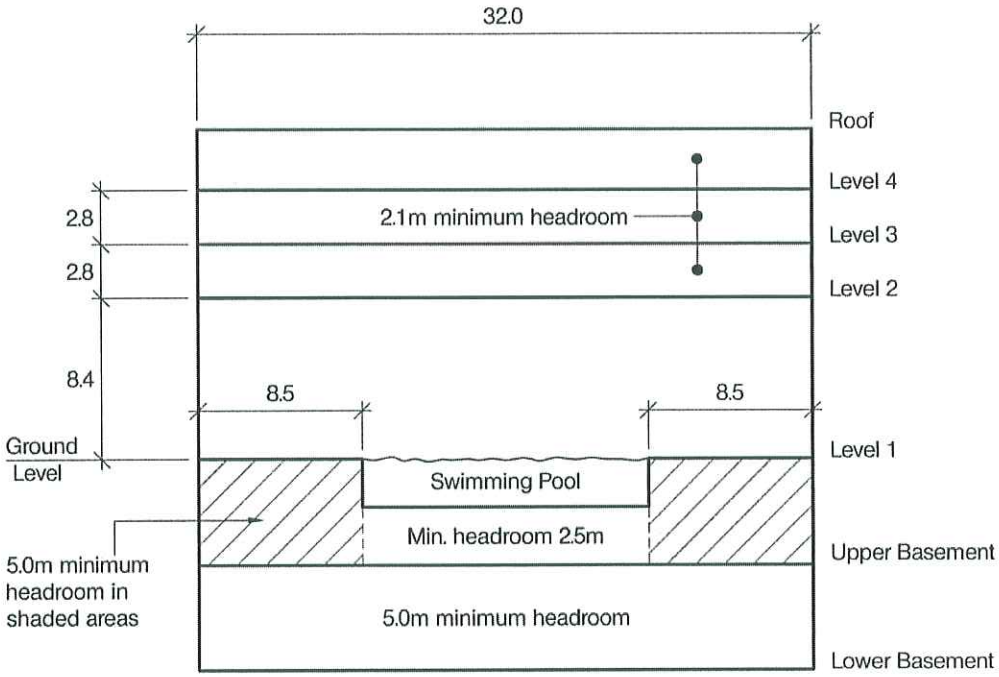
**SECTION 2** **(50 marks)**

For the solution recommended in Section 1(a):

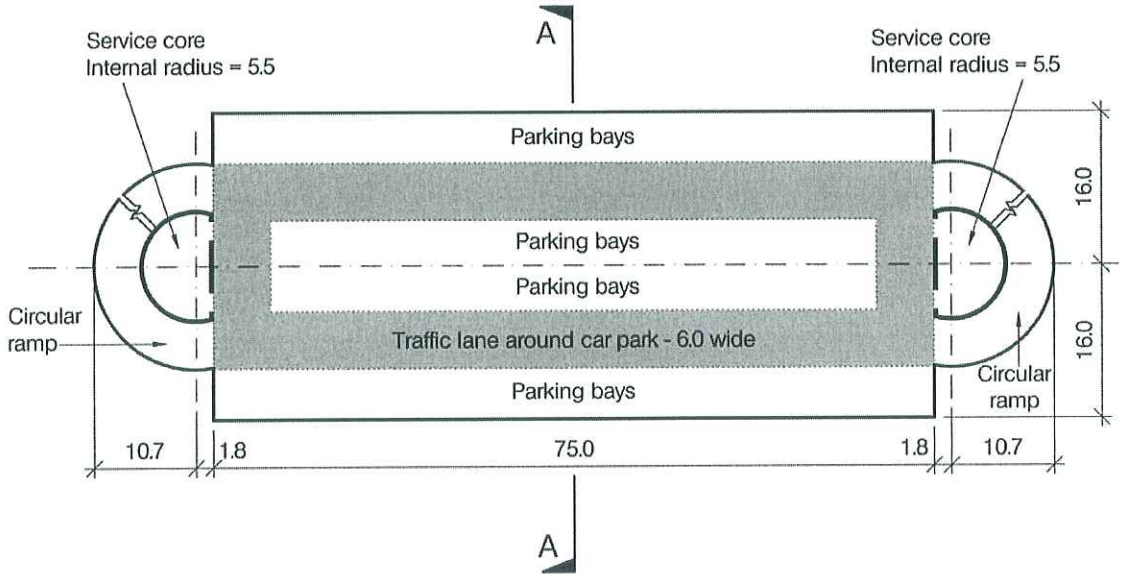
c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)

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)



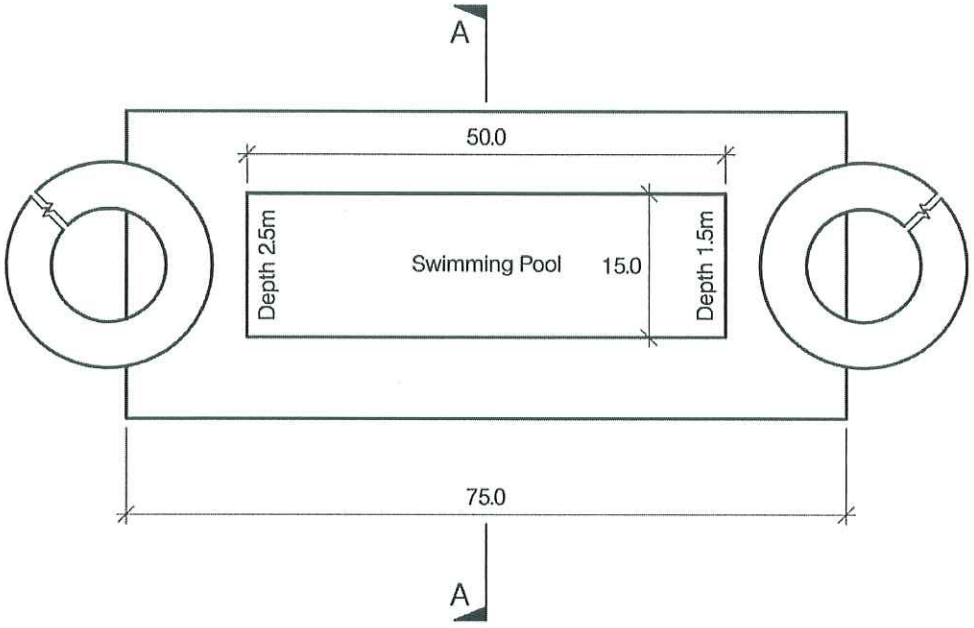

SECTION A-A




TYPICAL FLOOR PLAN OF CAR PARK (LEVELS 2 TO 4)

NOTE: All dimensions are in metres

FIGURE Q4 (Sheet 1 of 2)




PLAN ON LEVEL 1

NOTE: All dimensions are in metres

FIGURE Q4 (Sheet 2 of 2)

# Q4/2007 – SWIMMING POOL

Before marking I like to review the large number of choices presented by this question. This is characteristic of the versatile questions set by this Examiner: answers can be assembled from a wide variety of structural forms and materials, giving candidates with diverse experience the widest scope in their attempt at an answer.

This does not mean to imply that a "Good" answer would need to be, or would have time to be, as comprehensive!

I believe that the key to identifying the two viable alternative solutions required by Section 1a is to have the widest possible knowledge of the different **construction** procedures [as distinct from a facility with different analytical techniques].

So, I have set down a couple of ideas for the pool, the basement, the frame [four ideas], the floors and the wind-stabilising elements. These ideas are not exhaustive and I fully expect to be delighted by another, quite different, answer when I come to mark the scripts.

I have also used a "picture-with-notes" style of presentation. I find that this is an efficient and pragmatic form of communication: I also suppose that it may not suit everyone! It takes some practice to become fluent in this "language". However, it generally avoids ambiguity [often found in wordy presentations] and makes direct contact with the other person in the discussion – in this case the Examiner.

**Remember, we can only mark what you draw and write!** You may have had any number of brilliant ***thoughts*** during the examination, but if you have not written them down they are not available to us! So you **must** get all your ideas down on paper. Only practice and experience will allow you to do so in a professional [neat, tidy and orderly] manner. Mistakes are "painted out" using correction fluid if you are using ink [as I have, because I knew it was going to be printed]. Pencil is a better medium for the examination as it can be rubbed out and does not show your errors.

I have used various colour washes, but then I admit that I am not working against the clock! The ubiquitous Highlighter™ is one source of several colours; however I have used Tombo™ dual-brush-pens that come in 144 brilliant colours and a wide range of Grey tones. I suggest that you select perhaps six from the range to represent water/steel [blue], concrete [grey], soils [yellow and brown] and another two, say, red and green. Colouring is a quick way of defining materials.

As soon as I have set down a couple of sensible ideas for each component of the building [floor, cladding, frame and foundations], I can assemble the two alternative and viable solutions required. As you do this I find that the preferred choice emerges and all you need to do is to keep a note of your thoughts as you go along.

In a real-life situation you discuss the two solutions with your colleagues – especially the QS [and Contractor if you have one aboard at this time]. You will, of course, express your preferences – and this is what you have to do at the tail-end of your answer to

# Q4/2007 – SWIMMING POOL

Section 1a. This is generally called the "Review", but as a Marking Examiner I would be content if the candidate wrote "I prefer this because …" In this manner you can review the Floors, Frame, Foundations and any special features specific to the question.

My approach to this would be "What is the best value for money?" in this question a Bentonite-slurry Diaphragm basement wall is a "good buy" because it can be installed before the dumpling is excavated, retains the sides of the excavation, keeps out most of the groundwater and eventually supports the superstructure. Using top-down basement construction [and a lot of planning!] allows the Contractor to erect the superstructure while at the same time excavating the basement. What other system gives you all this?

Section 1b – "the letter" needs to be addressed in a professional way – not used as an opportunity to make-up time! There are ten marks allocated, and at 4 minutes per mark this allows 40 minutes for a proper answer. Sadly, many candidates regard this as a five-minute respite to write some trite and general remarks about an increase in time, costs and professional fees! This approach does not address the question asked and certainly does not resolve the problems that are posed. Half a page of scribble does not earn 10 marks – at least, not in this examination!

Your Client has asked a question and expects to be led through the answer in a sensible way. You need to express quite complicated engineering concepts related to rising groundwater without being superficial or patronising!

You explain that there will be greater water pressure and how you propose to deal with both the construction and permanent problems raised by the increased pressure. You will also explain that although waterproofing was provided in the original scheme that the waterproofing needs to be extended.

As your remarks are actually going to be read by an experienced engineer – the Marking Examiner – many of the concepts will transmit themselves or be recognised if you incorporate some sketches in your answer and "bullet point" the main issues. The sketches and diagrams can of course be used in "discussions" with other members of the design team and so become a handy way of circulating ideas. The letter is written after the sketches and accompanies them to add brief written explanations. I believe that only in rare cases can this answer be limited to a couple of pages of text.

The Method Statement and Outline Programme – Section 2e – is another area where candidates skimp their answer and effectively throw away marks! Being at the very end of the examination, the last-gasp task, if it is not answered or skimpily answered it is a strong indication that the candidate has not managed their time well – a most unprofessional practice! Avoid creating this impression! Make sure that you allow yourself 40 minutes to address these last two tasks. There will be five marks for each part – the method statement and the programme – although the examiners are given discretion as to how the marks are divided. It should not be difficult for you to pick up 3/5 for both parts – equivalent to 60% for Section 2e and a pass!

# Q4/2007 – SWIMMING POOL

What is wanted in this Method Statement is the Designer's view of how the building will be assembled – the effects of the design on the method of construction and the consequential sequence that must be adopted. In real life these matters are incorporated into the Specification and BoQ and may have significant effect on cost and programme.

The Outline Programme must indicate to the Client and QS where construction time will be spent. Basements take a considerable time to build and usually everything else has to wait until it is finished. Steel superstructure goes up quickly, but then the programme slows down while floors and enclosing cladding are assembled. The building is not weather tight until the roof and cladding have been finished, and may delay the fitting of services and fitting-out the interior of the building. Delays can be caused if large items of plant have to be "built-in". Deadlines may have to be observed if the Client's business is seasonal.

If the answer can indicate that the Candidate has an appreciation of the wider planning process, this will improve the marks. Examples might be: identifying activities on the critical path; specific plant requirements such as heavy lifting equipment for the new crane girders or long trusses; and resource levelling using "Float" available in the non-critical items. Most candidates sketch a Bar Chart but incorporate a large number of activities; this gives them a lot of work cascading the duration times in a sensible manner. Many of the duration times are faulty because they have been blind-guessed. Personally, I believe that the best approach is related to the four quarters that are used to monitor the cost in the form of an S-curve.

Candidates should not become obsessed with the pass mark [40%]. A Pass in the Examination is the final confirmation that you are a competent structural engineer. In an ideal world you would be given time to develop your concepts and provide your Client with a full and exhaustive professional service – viz. a 100% solution! The reality is that you are only given seven hours! Consequently it must be expected that your "service" may be less than 100%.

Would you consider it professional to give 10% or perhaps 15% less service? This would put your examination target at 85%.

Again, if you received only 40% of a full professional service would you be satisfied?

So your objective in the examination should be to pass with a really good mark – 60 to 80% - and not merely scrape through with 42%. A good pass will confirm to both yourself and the rest of the World that you are a competent engineer. In actual fact you will never know what your marks were, but you will know within yourself if you made a good job of it.

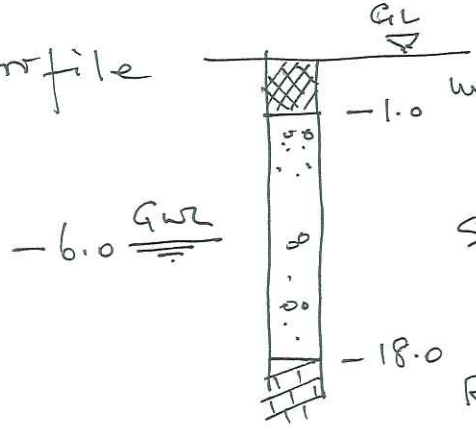
This time I have not attempted the calculations – Section 2c – nor the drawings – Section 2d. Advice is given elsewhere on this CD. I have made a list of the principal elements

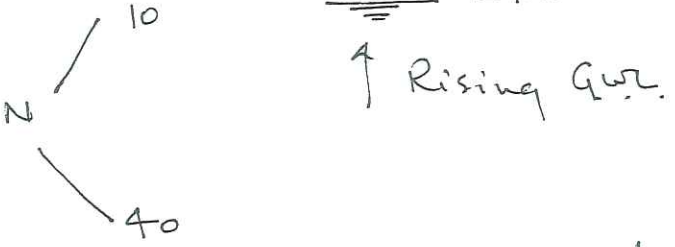
that I would expect to see being calculated. There are 20 marks for the calculations and I have identified four elements – the swimming pool floor, the basement walls [for soil and water pressure], the pool supports and the selected main frame. The allocation of marks would probably be five per element: perhaps two for the loading, one for the moments and shears [the analysis] and two for designing the section to resist the forces on it. Resolved into "working minutes" this is 8 minutes for determining the ***essential*** loading [not every possible load case], 4 minutes for analysing the ***critical*** Bending Moment and 8 minutes for determining [***at the critical section***] the rebar or selecting a steel section ***and drawing a sketch for the detailer!*** There is no time for contemplation! You should have decided the structural model during the work on Section 1a – that is what is meant by the "functional framing, load transfer and stability aspects".

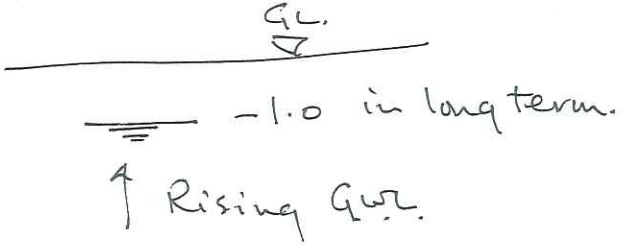
Section 2d – the GA and Details, will need a plan or plans to show the supports for the pool – after all, the question is headed "Swimming Pool" and this goes with a cross section though the basement and upper storeys. A part-elevation may be necessary to show the external column features. The cores and ramps might take up too much time to draw in detail but something must be shown if you are relying on them for overall stability. Cross sections of the main elements will be needed – the transfer beam and the supporting columns; the basement wall and the lower basement slab. Details of the rooftop waterproofing and the finishes to the pool would earn "Brownie Points" and boost your score in this section. Think about this section as a huge field of corn with patches where the corn has grown thicker, and make the best harvest you can from it in a limited time! Candidates with the traditional drawing skills fare best in this part of the question. If your regular work uses CAD drawing this does not prepare you for the examination. You must find time to learn how to draw and letter in the old way: with pencil, setsquare and tee square. Find someone who can teach you the basics and then practice at home. To give you some idea of the effort needed, the old-time apprentice had to fill an A0-size sheet with alphabets drawn by hand before they even started to draw lines! Actually, it can be very satisfying to prepare drawings this old-fashioned way: the way of the craftsman.

## Q. 4. / 2007 SWIMMING POOL

- The question is about a swimming pool 15.0 m wide × 150 m. long. × 2.5 m max depth
- Secondary issues are: Car parking on levels 2 to 4 2.5 kN/m²
  Two curved access ramps with service cores.
  Two basement levels. 5.0 kN/m² Lev 1 + Basements.
- Restrictions are: Parking bays minimum 2.5 m wide and 4.8 m long.
  6.0 m. wide traffic lanes — two on each parking level.
  No structure is permitted in any parking bay or traffic lane.
  Minimum headroom — basements 5.0 m & 2.5 m parking levels 2.1 m
  2 hour fire resistance
- There is no restriction on the roof height. 1.5 kN/m² allows access.
- Soil profile



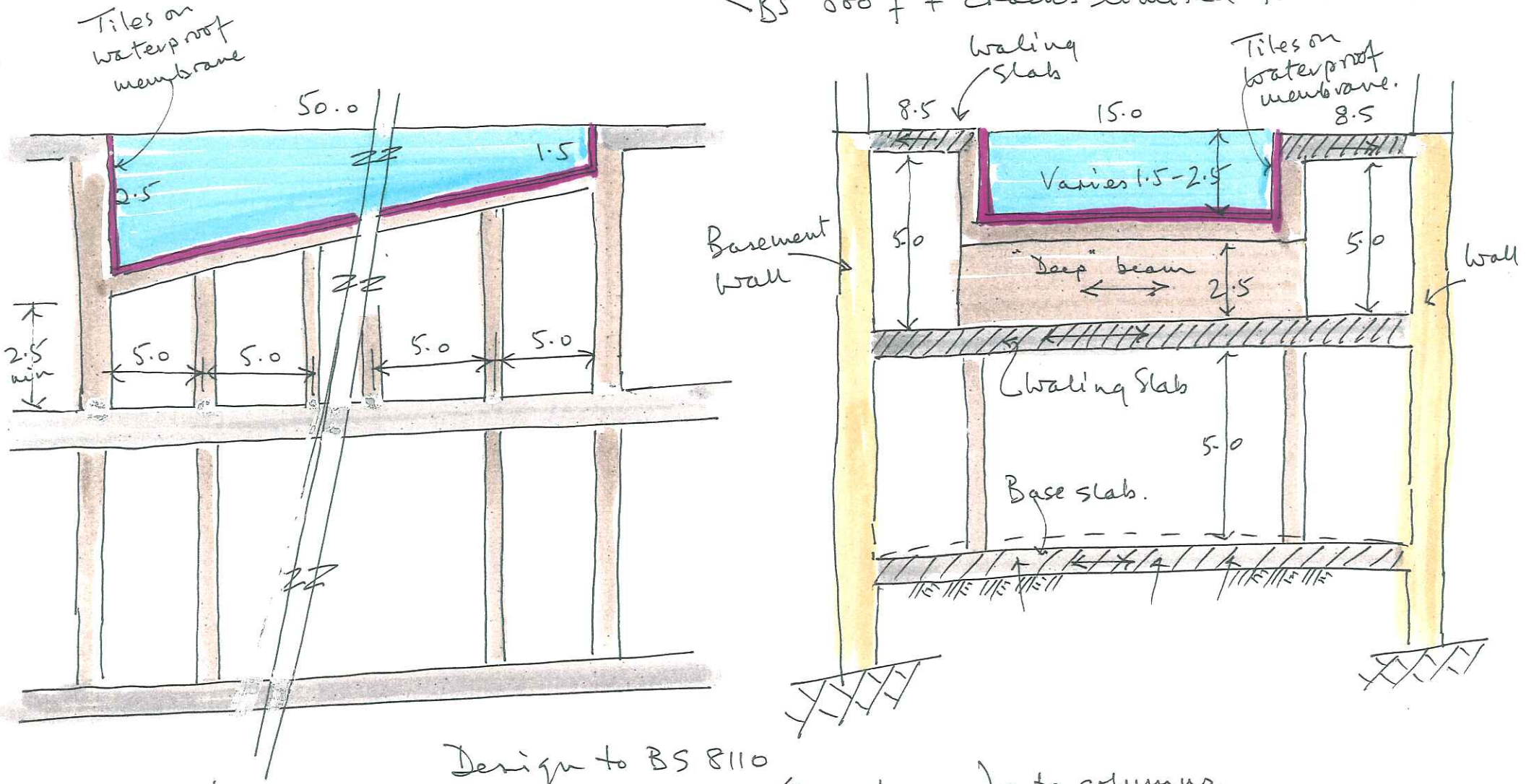




Allowable bearing pressure 1500 kN/m²

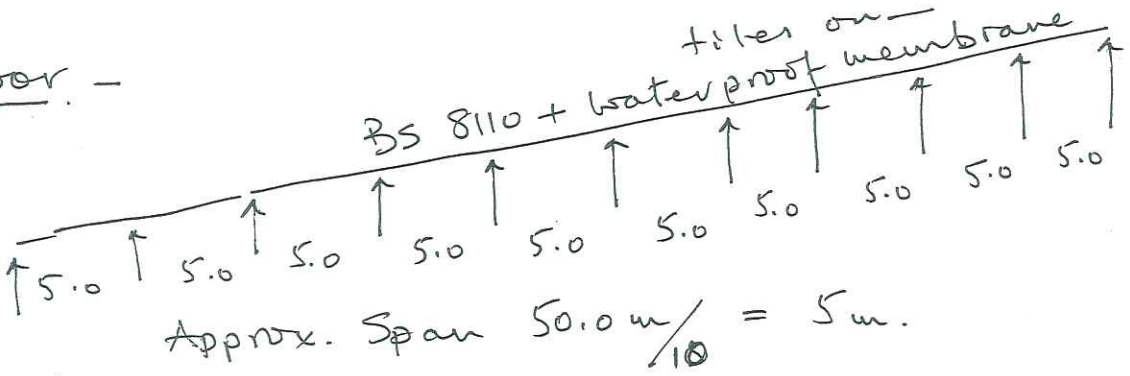
- Swimming pool. — Steel
  — fibreglass
  } purpose made by specialist
  — reinforced Concrete — BS 8110 + lining.
  — BS 8007 + cracks limited to 0.1mm.

Heavy rebar!




Design to BS 8110
Transverse pool supports (Deep beams) onto columns.

## Pool floor –




Make "stiff" – reduce sag

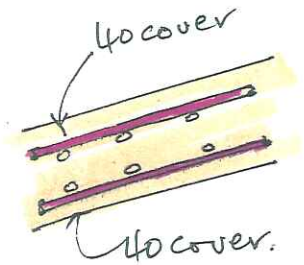
Continuity one-way.

$$d \simeq \frac{5000}{20} = 250$$

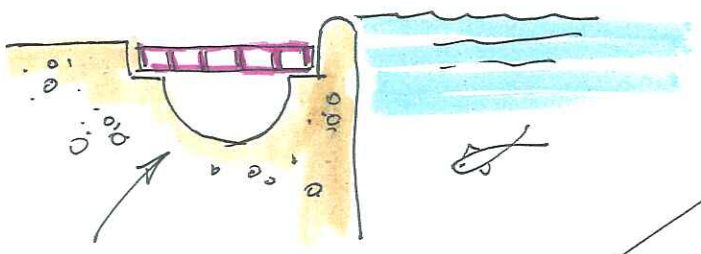
$+ \quad 10 \quad \phi/2$

$+ \quad 40 \quad$ Cover.

$\therefore \; h = 300$ min.



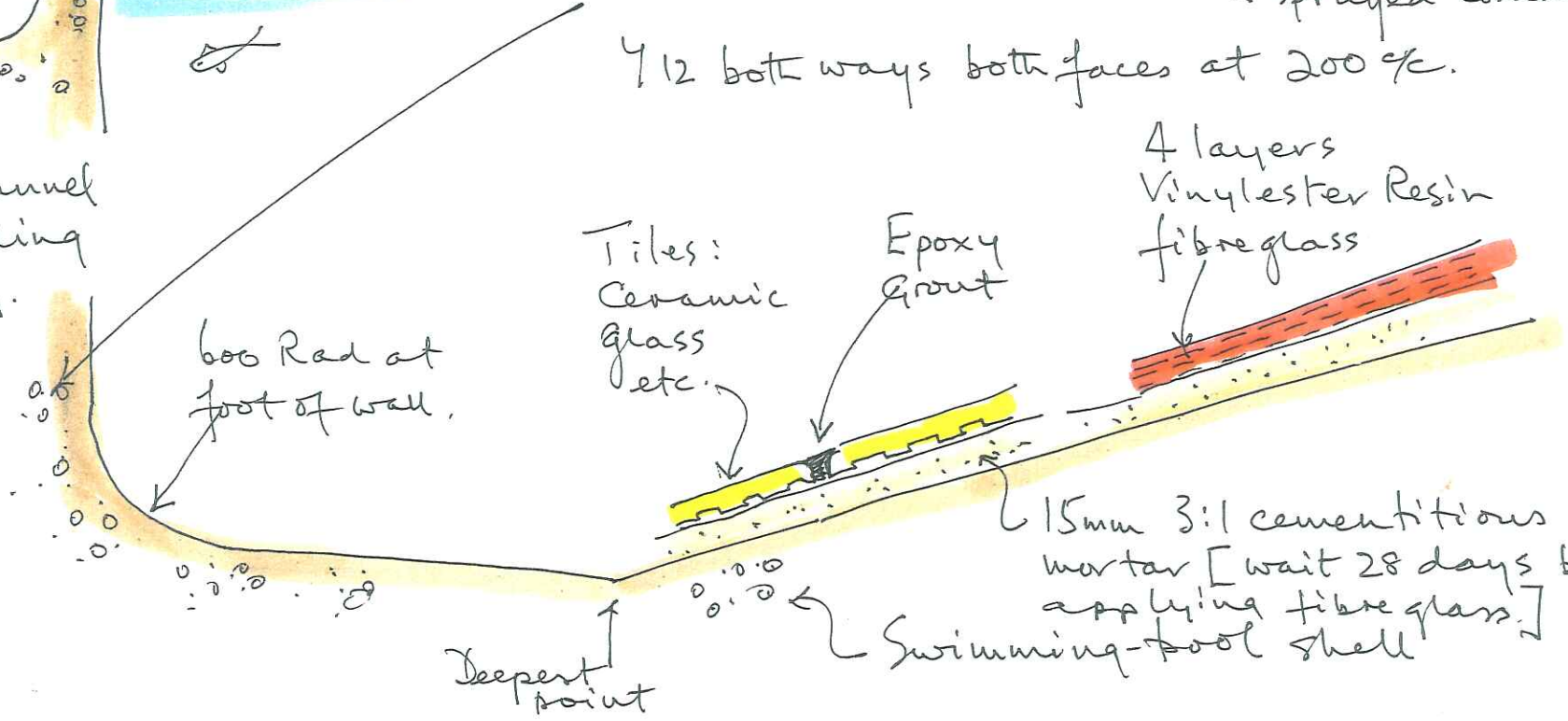

Rebar in both faces and both ways



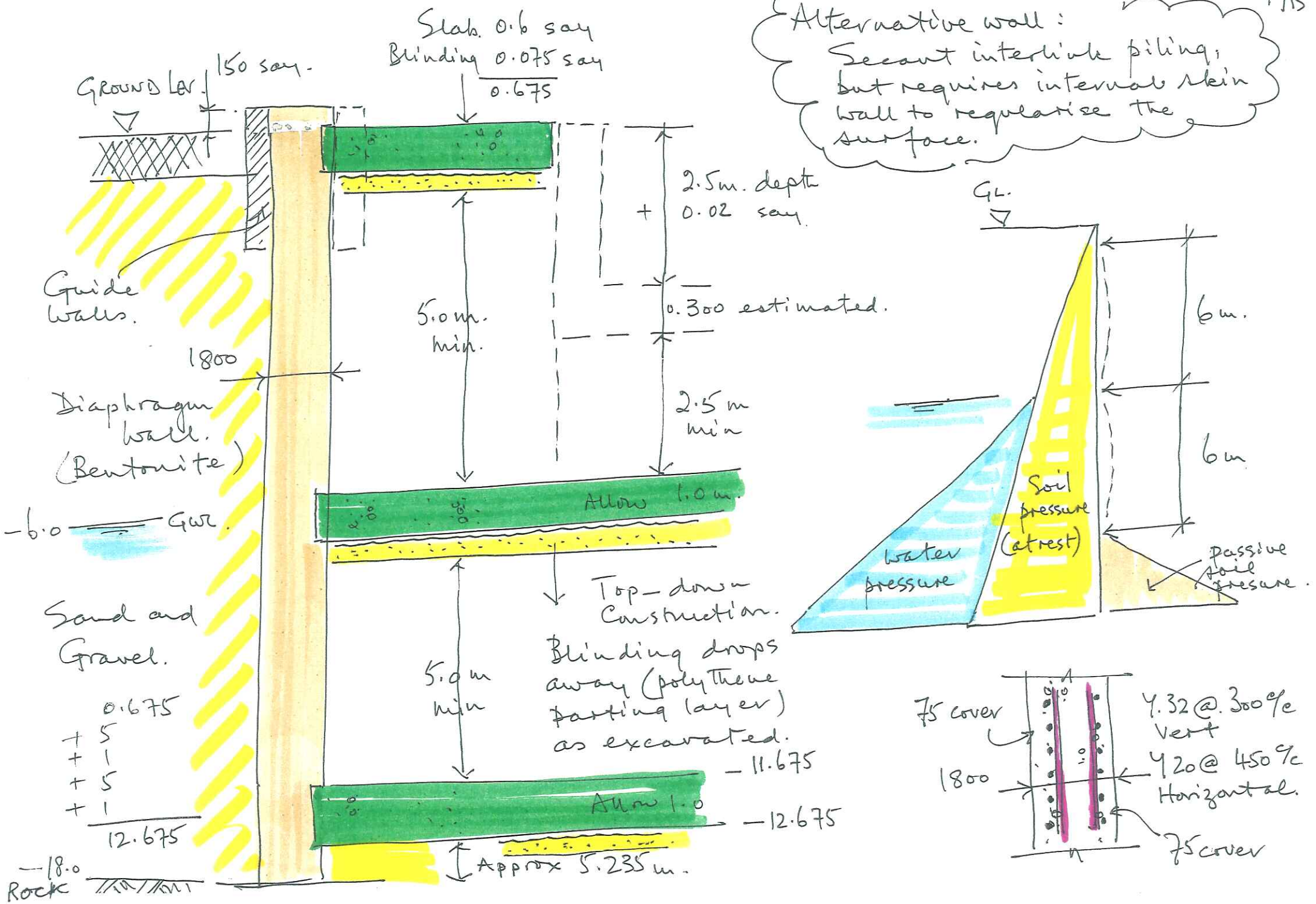
"Zurich" channel in surrounding walkway.

Swimming pool shell — poured concrete / Sprayed concrete

Y12 both ways both faces at 200 c/c.

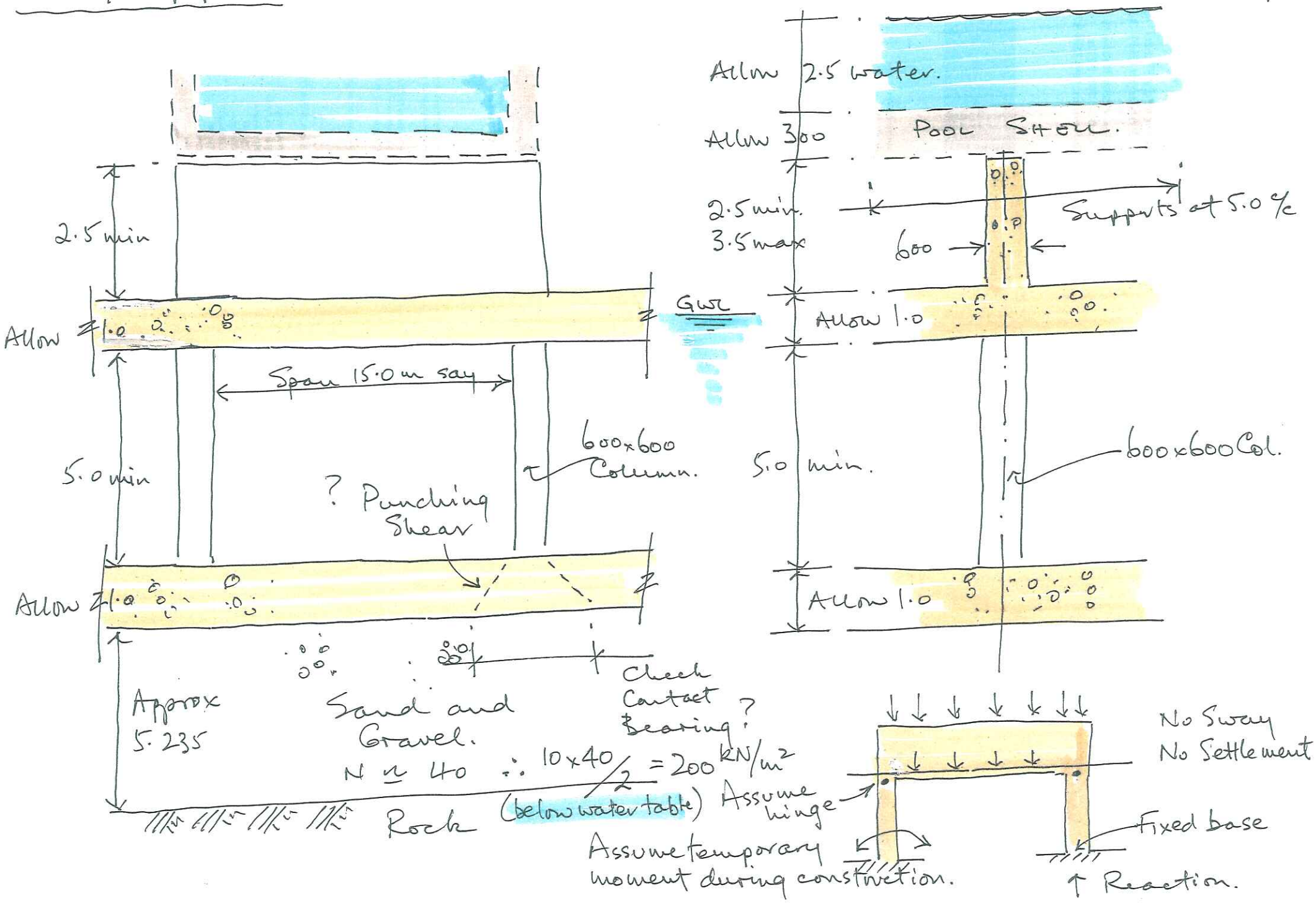


Alternative wall:
Secant interlink piling; but requires internal skin wall to regularise the surface.

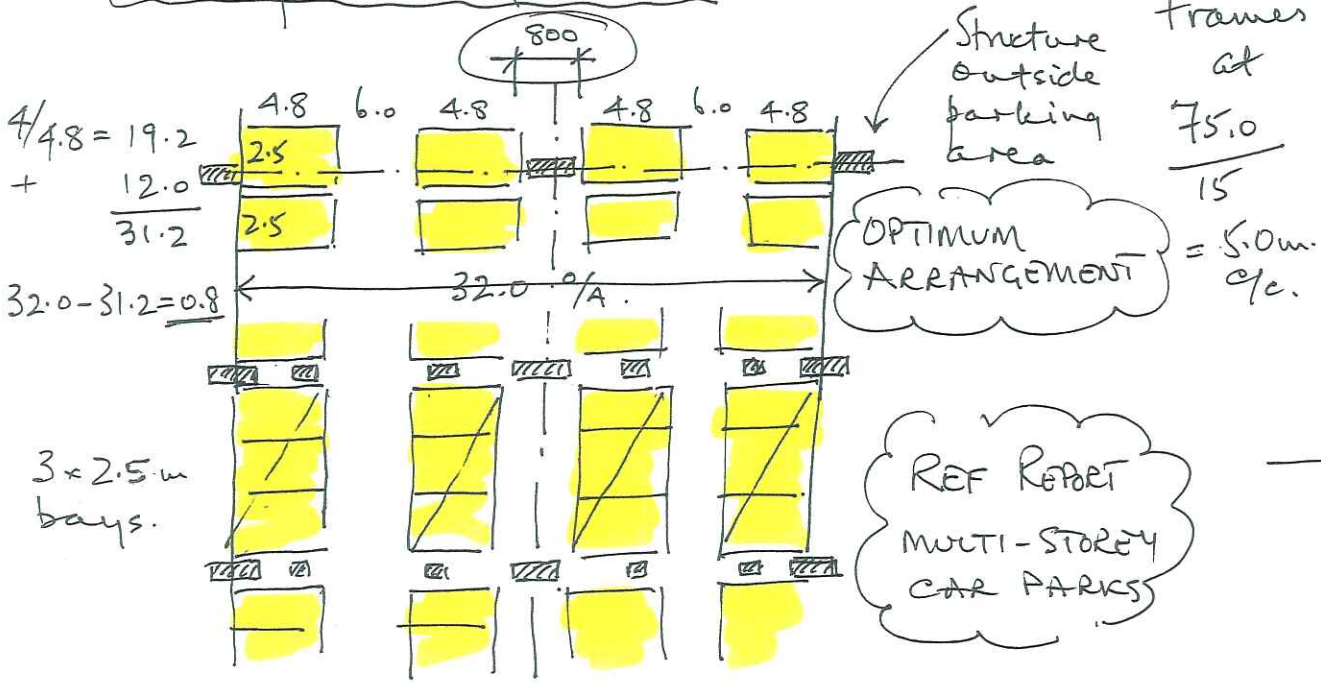


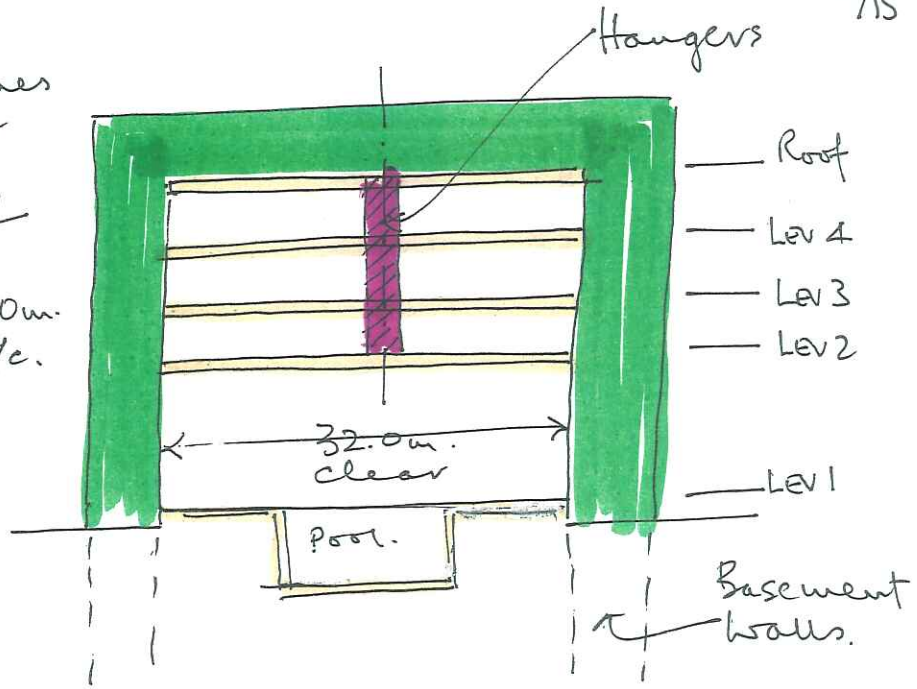
# Pool Supports

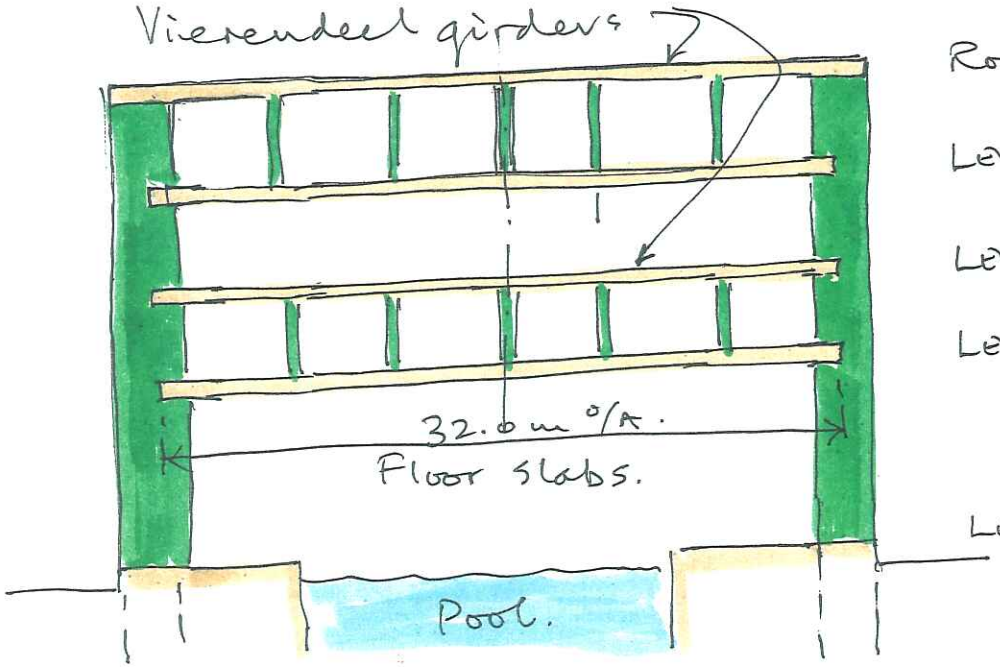




# Car parking levels.

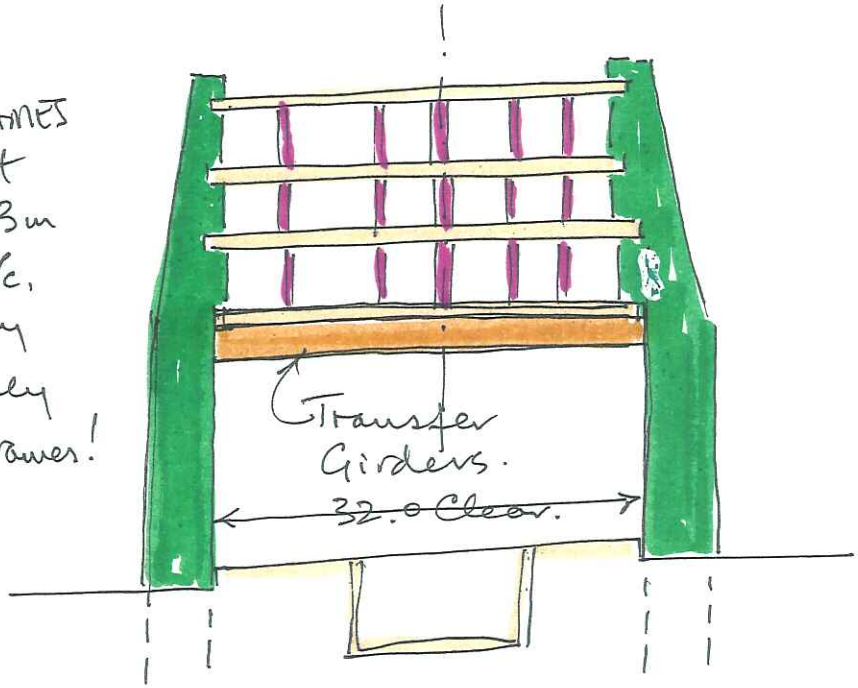


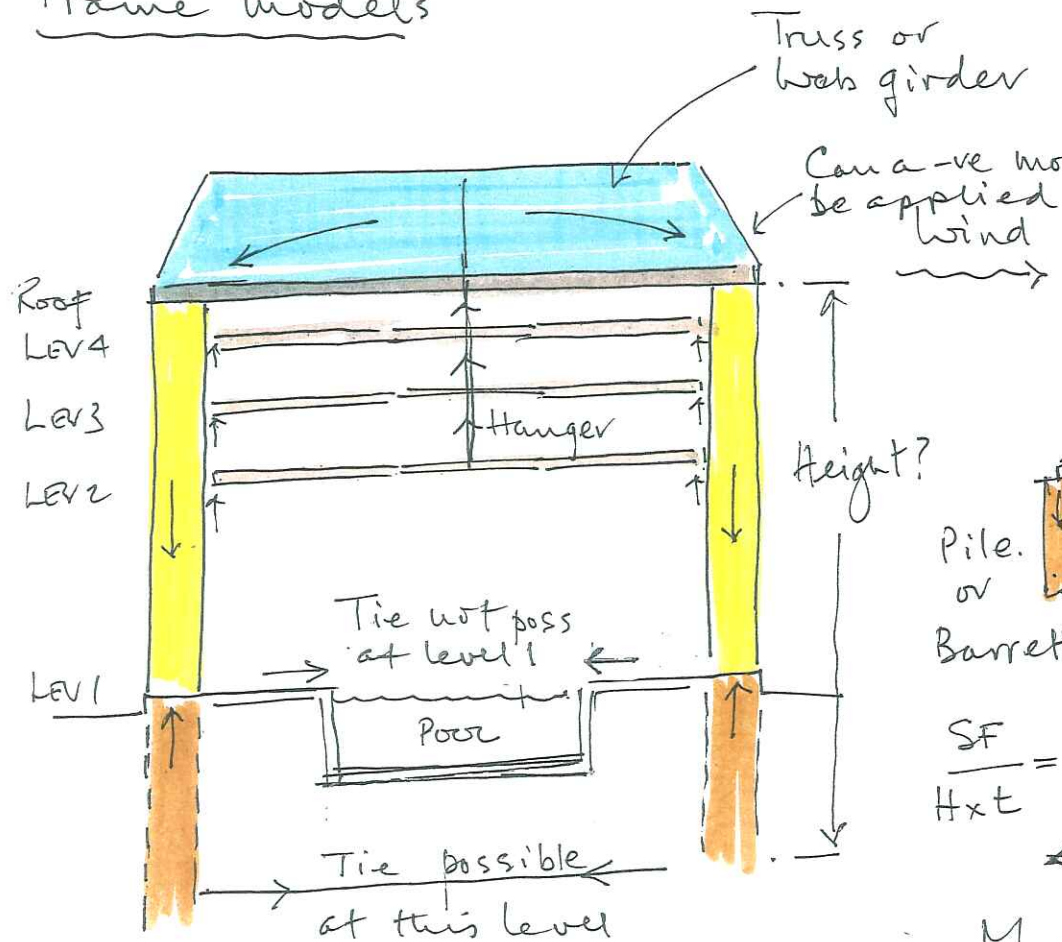



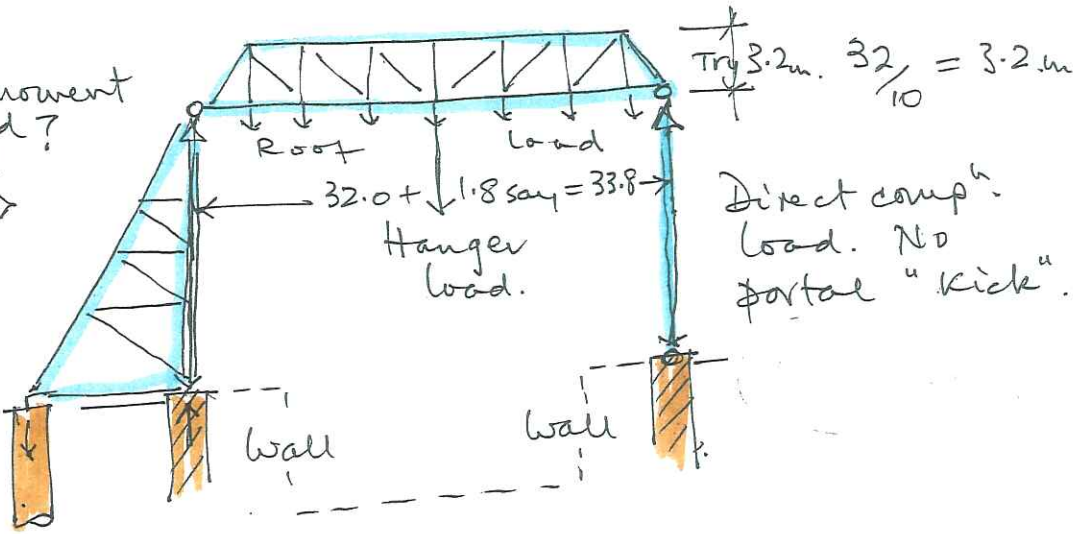

Roof.
Lev 4
Lev 3
Lev 2
Lev 1.

FRAMES at 8.3m c/c. Say nearly 9 frames!

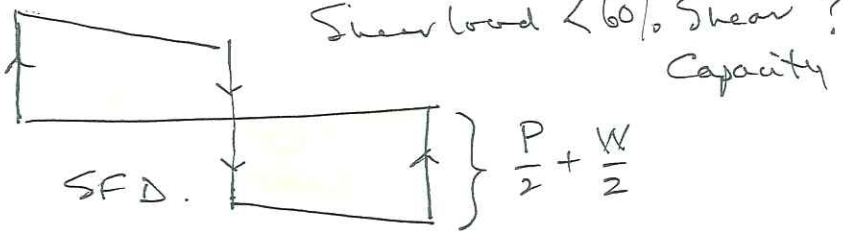


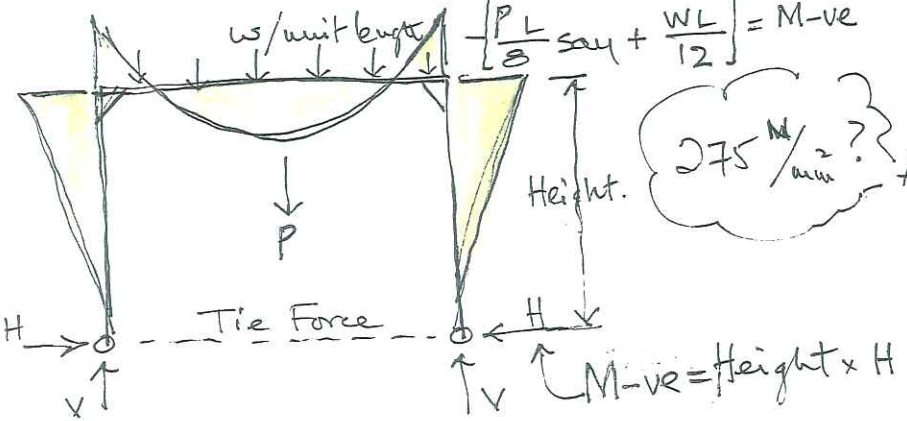
# Frame models




$\frac{SF}{Hxt} = \frac{\text{actual shear}}{\text{shear area}} \leq 0.6 p_y$



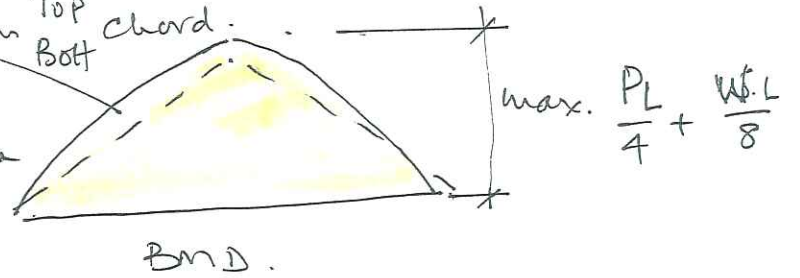

275 N/mm² ?

$\frac{M}{\text{Depth}} = \text{Force in Top Bolt chard.}$

$\frac{H}{\text{Force}} = \text{Area}$

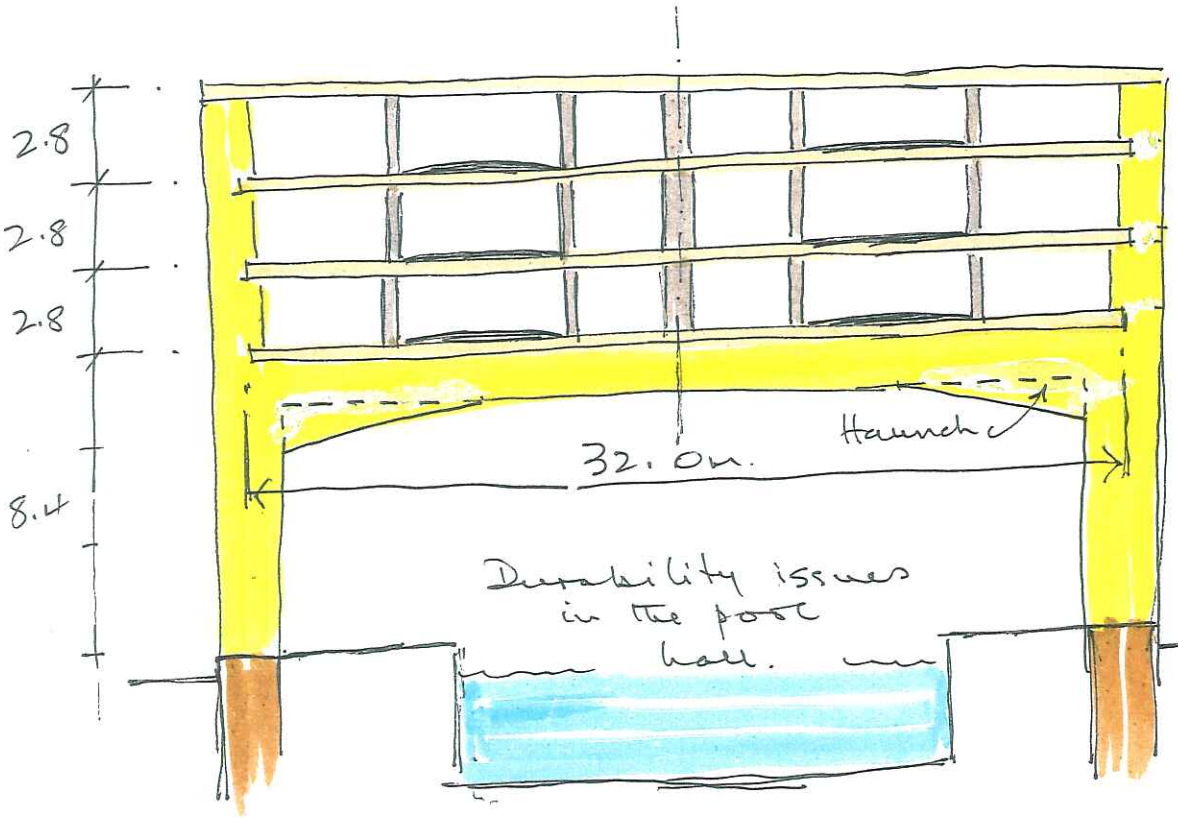
$\frac{\text{Force}}{\text{Allowable stress}}$

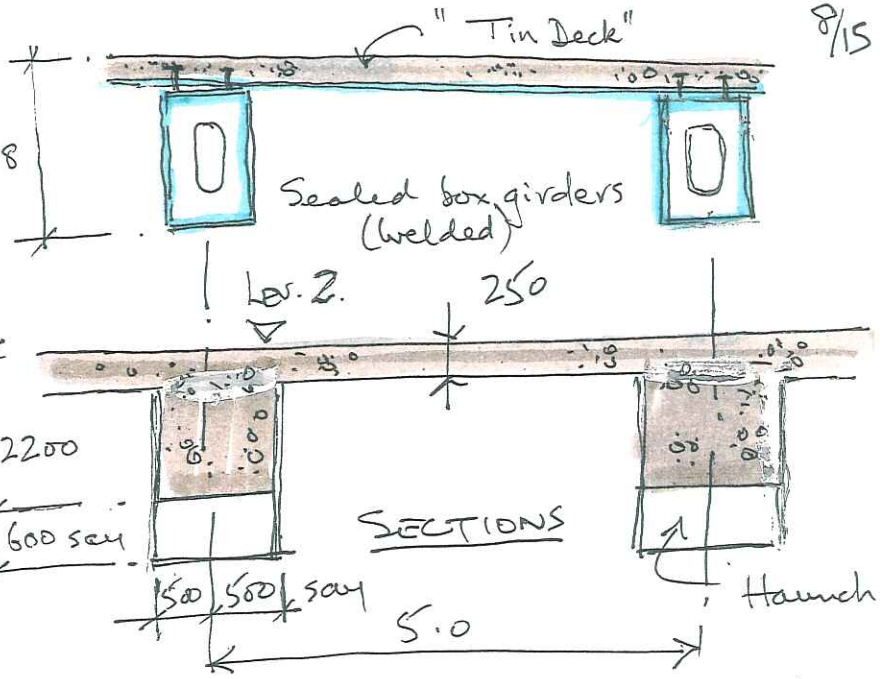
$I \approx a \cdot \bar{y}^2$

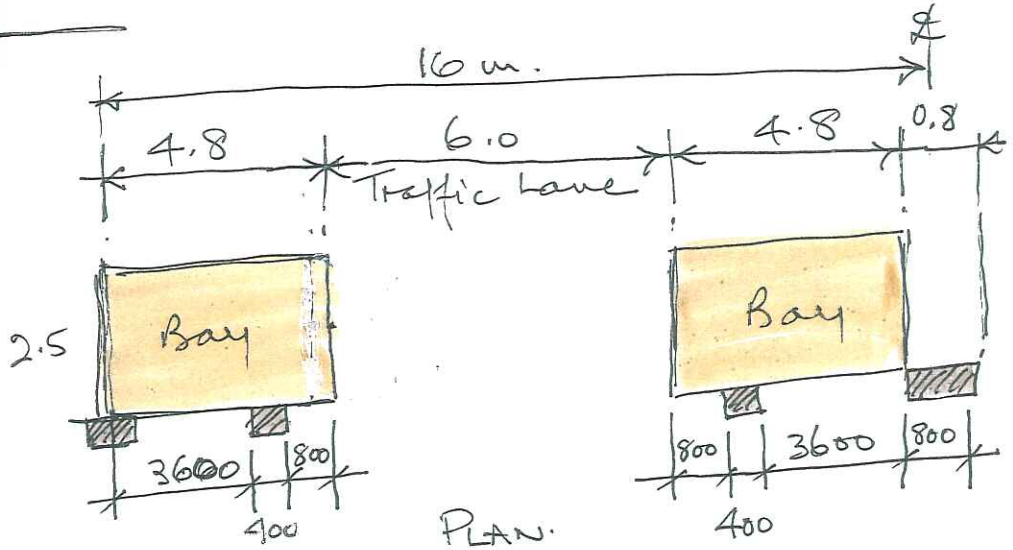


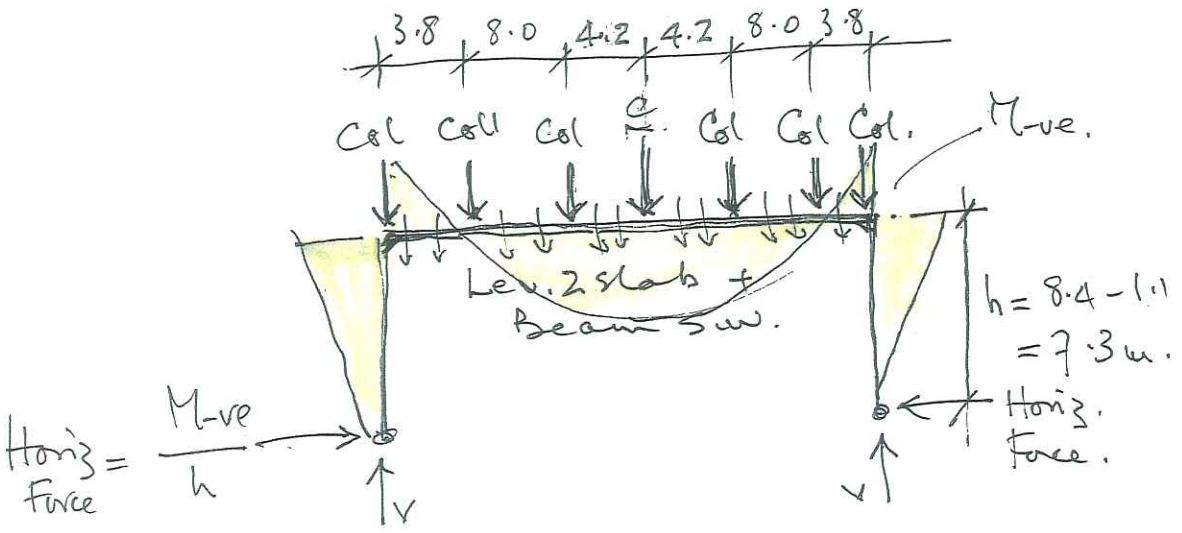

$E = 205 \text{ kN/mm}^2 = 205 \times 10^3 \text{ N/mm}^2$

$\text{deflection} \equiv \frac{PL^3}{48EI} + \frac{5WL^3}{384EI.} \not> \frac{\text{Span}}{360}$

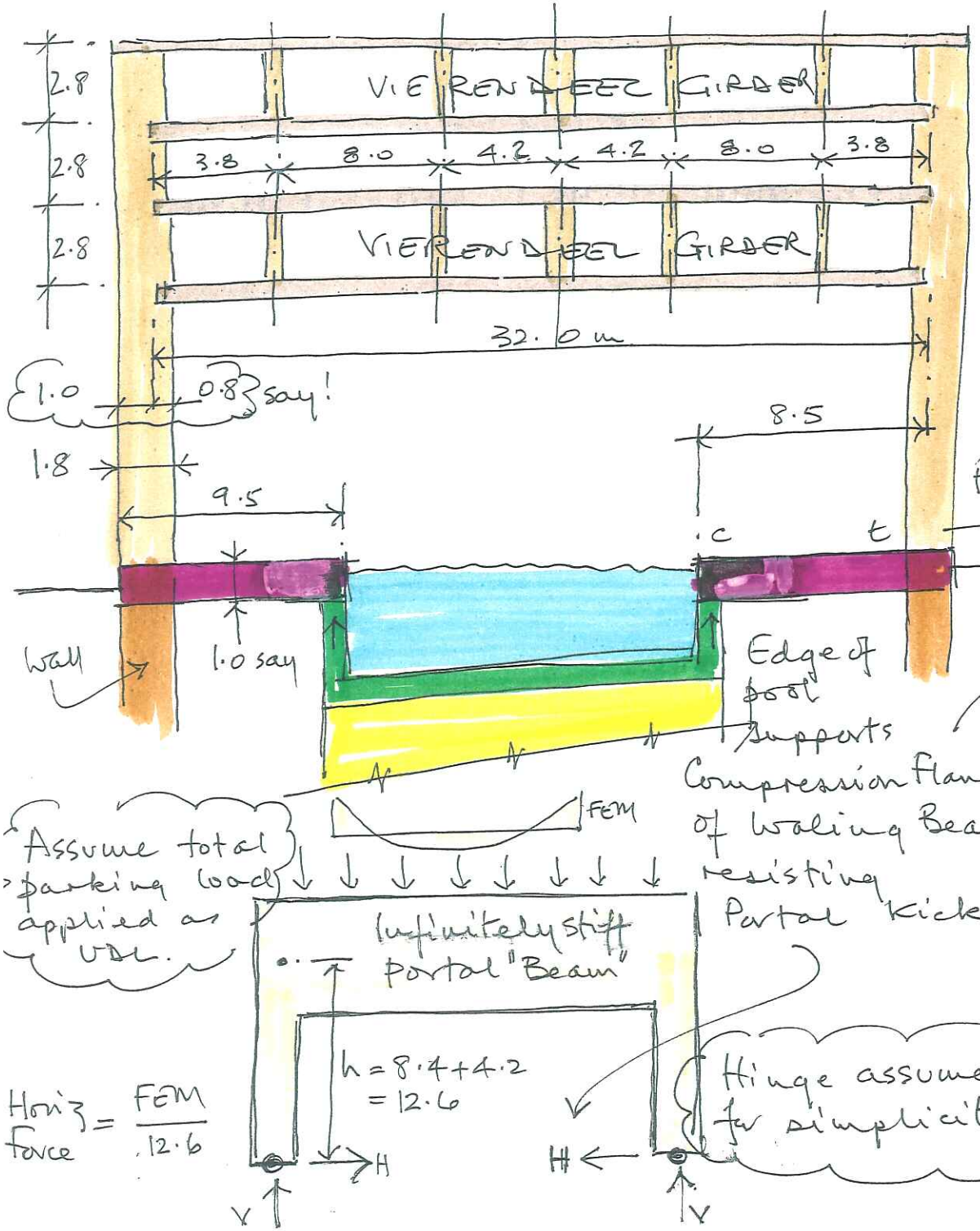


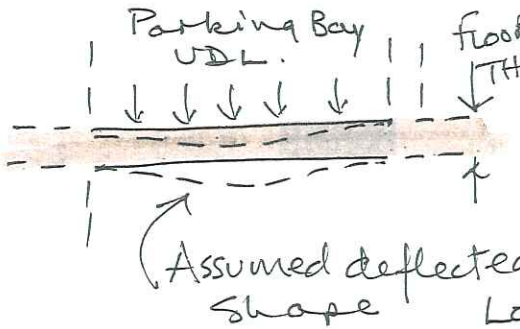



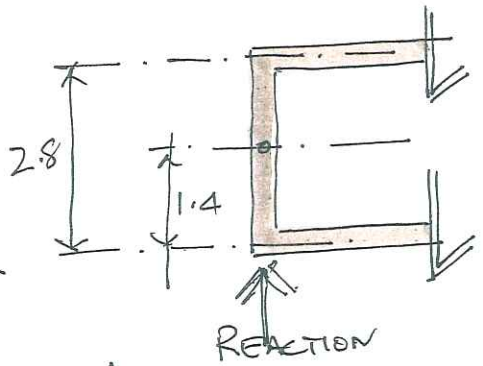




Ref: Design recommendations for Multi-storey and Underground car parks. [Fig 4.2]

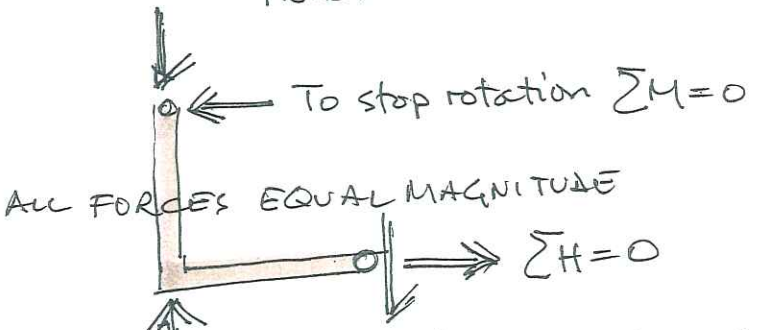


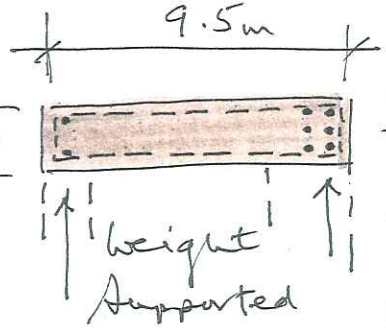

## LOCAL BENDING




VIERENDEEL BEHAVIOUR




Hence
$\Sigma V = 0$ (Step 1)
$\Sigma M = 0$ (Step 2)
$\Sigma H = 0$ (Step 3)

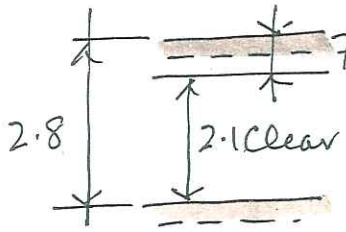



→H = Portal Kick

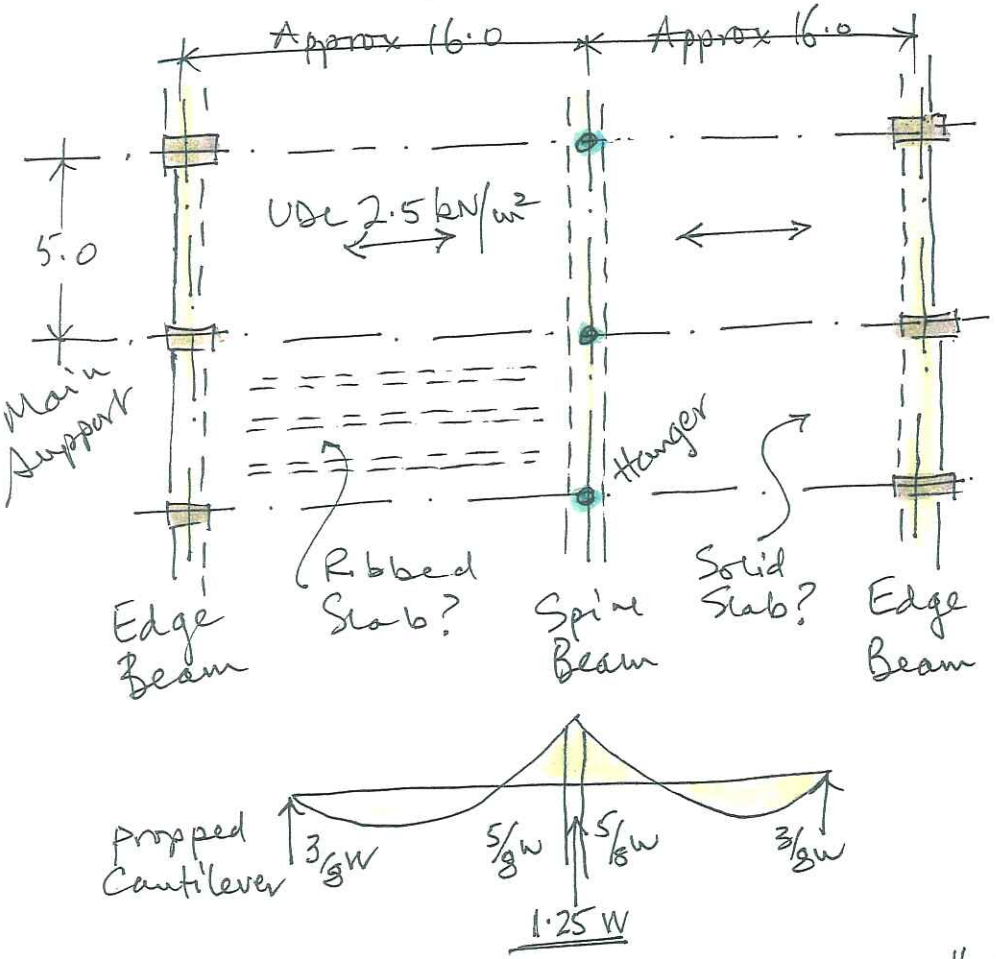
Span approx 55.0m

## WALING BEAM

# Parking-floor Slabs



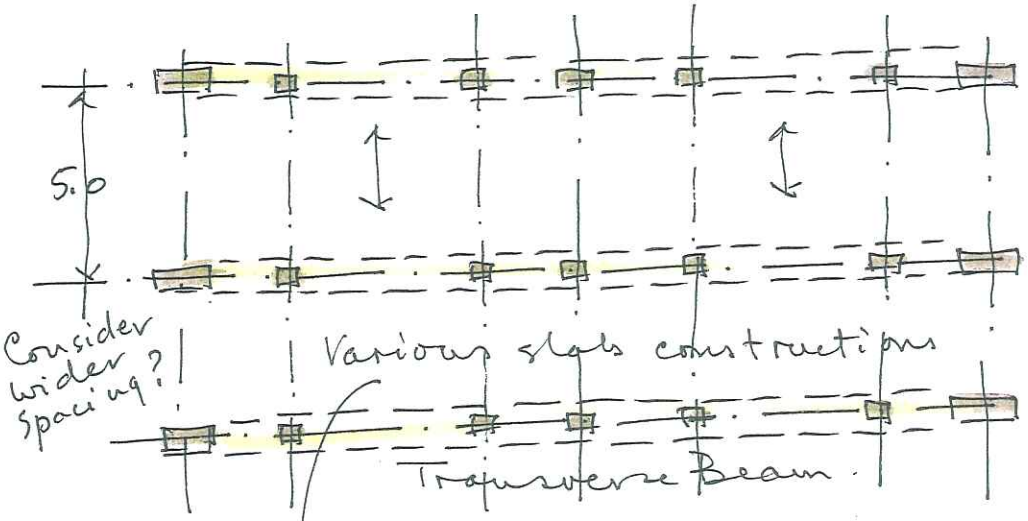

## Transverse spanning —

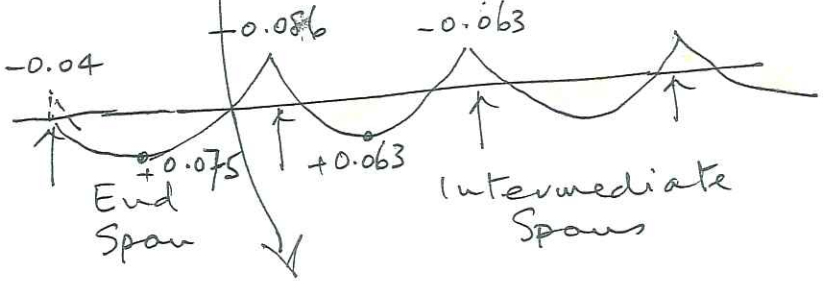






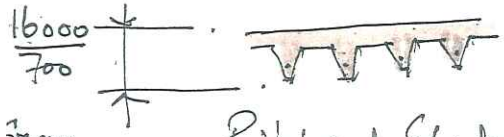
## Longitudinal spanning —

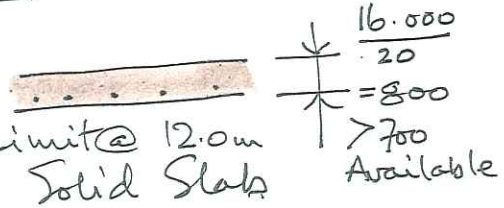


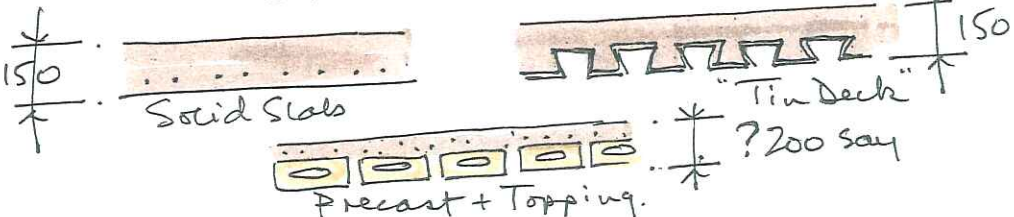




BS 8110
Pt 1 : 1997
Table 3.12

Check 2hr. Fire resistance



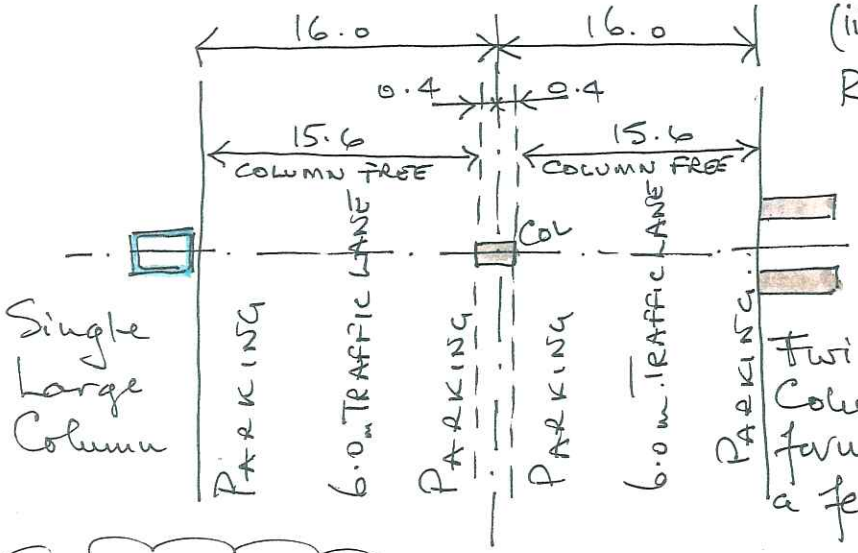




? Formwork ??

Reference: Concrete Buildings - Scheme Design Manual

# Main Supports.




Single Large Column

Twin Columns forming a feature.

## Core

(i) Slip formed

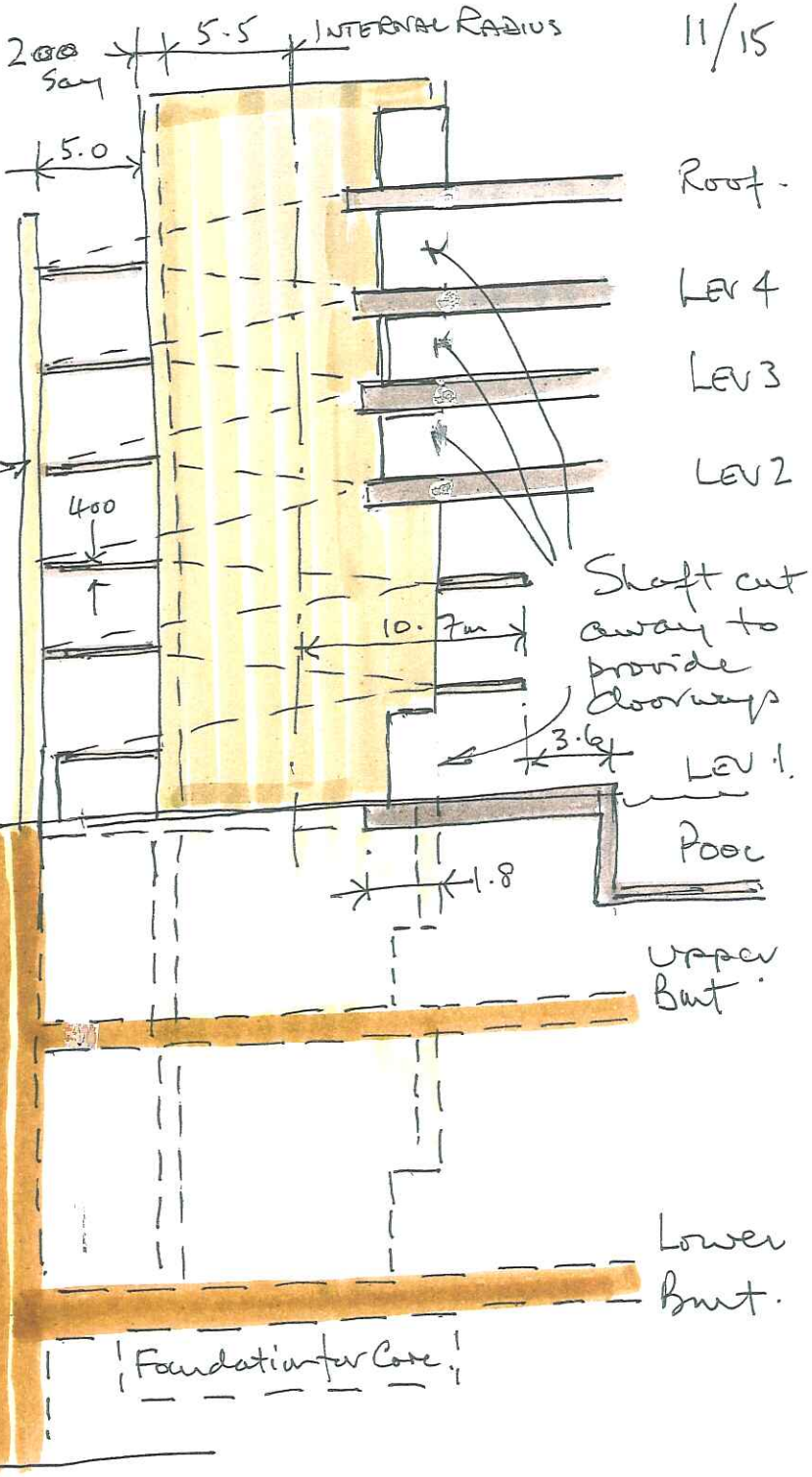
(ii) Jump formed

Ramp added after.

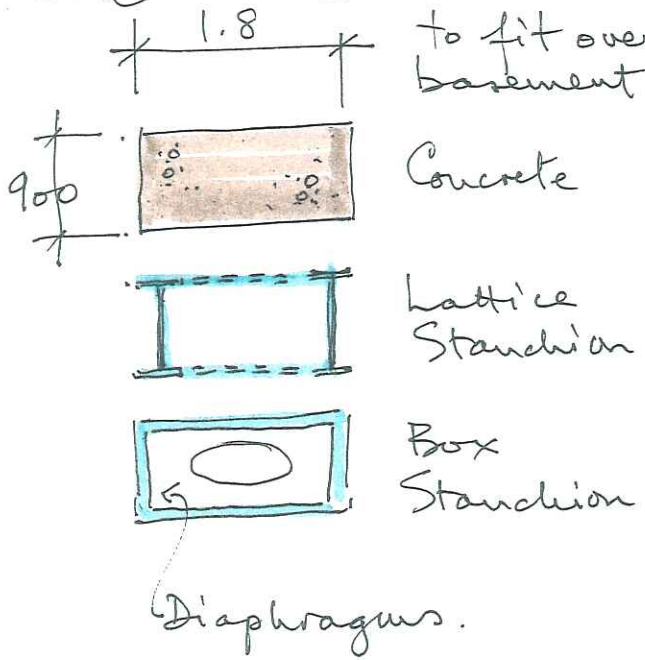
Slim feature columns

Count: $\frac{5000}{7} = 714$

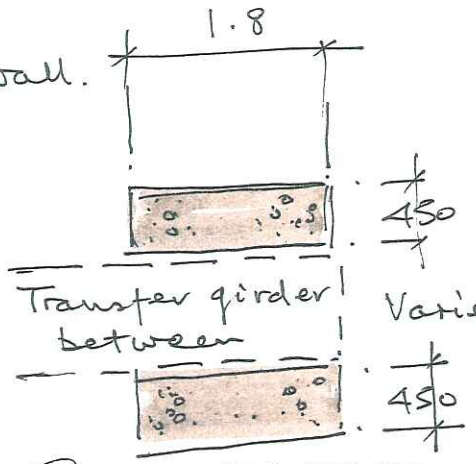
Prop. Count: $\frac{5000}{12\,\text{say}} = 400$




Wind onto Service Cores.




to fit over basement wall.

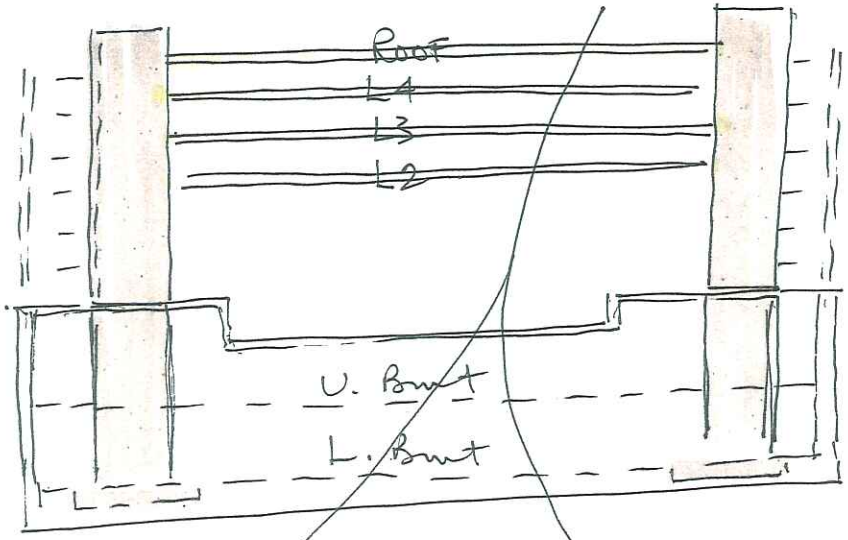



Probably able to resist longitudinal wind forces.

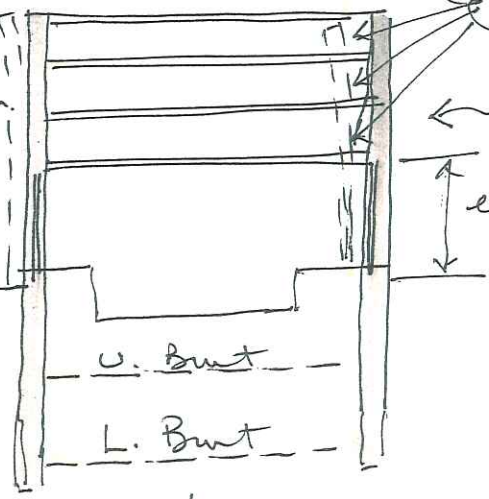
# Wind stability

Approximate treatment on each axis. Real behaviour much more complex.

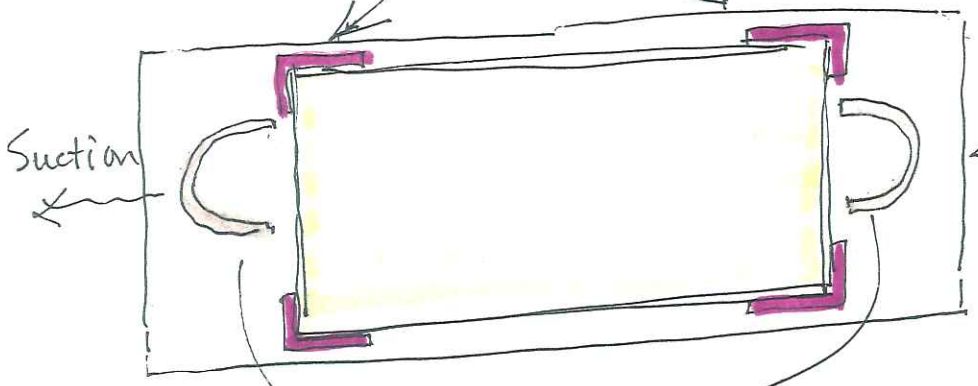
Alternative could use L-shaped shear walls.

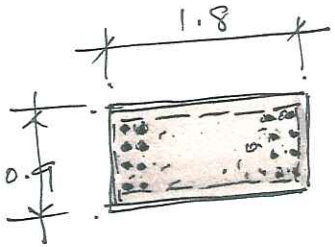



Circular Base
See Faber + Mead
"Reinforced Concrete"
p. 427 – Fig 13.9
"Pressure distribution under eccentrically loaded circular base"




For simplicity:
Assume wind moment taken on column section(s) as a cantilever



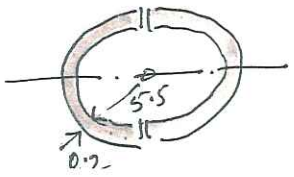




@ 5.0m c/c.

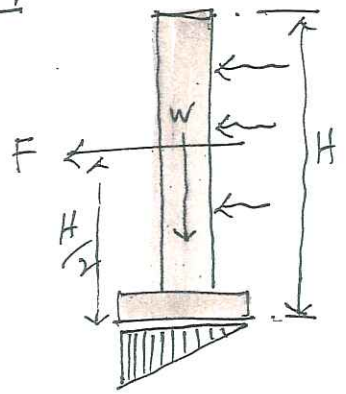
and combine with "portal" moments as appropriate.

Reinforce symmetrically.

Equivalent to:



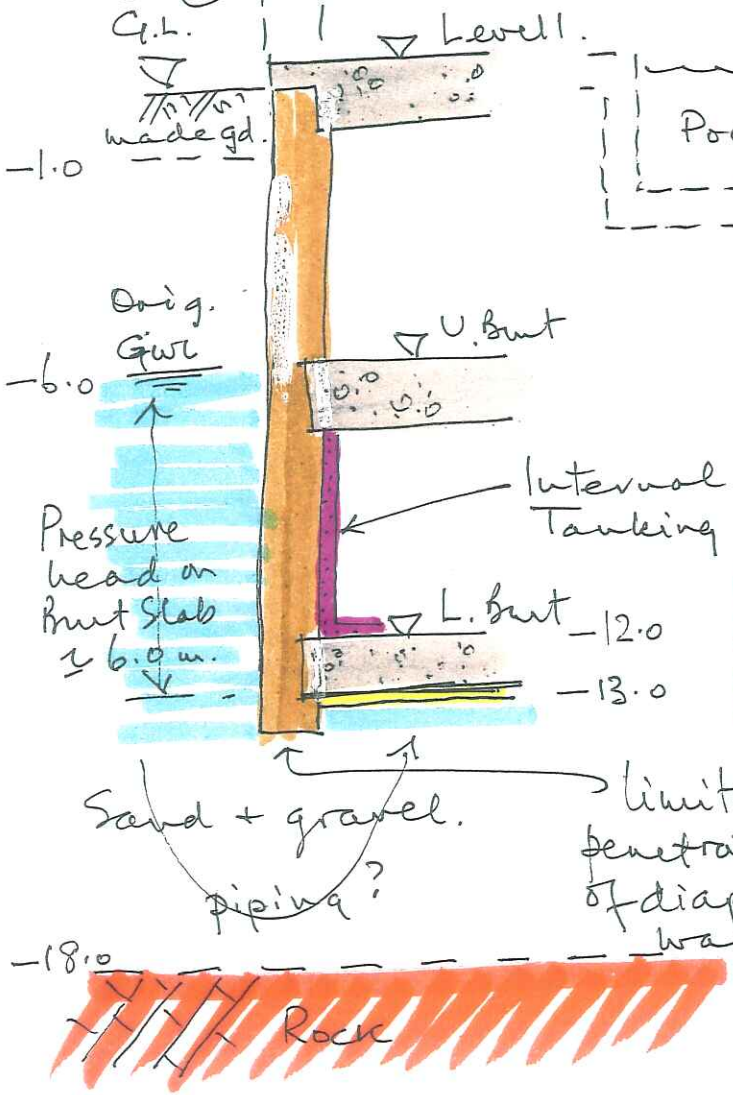

Single core

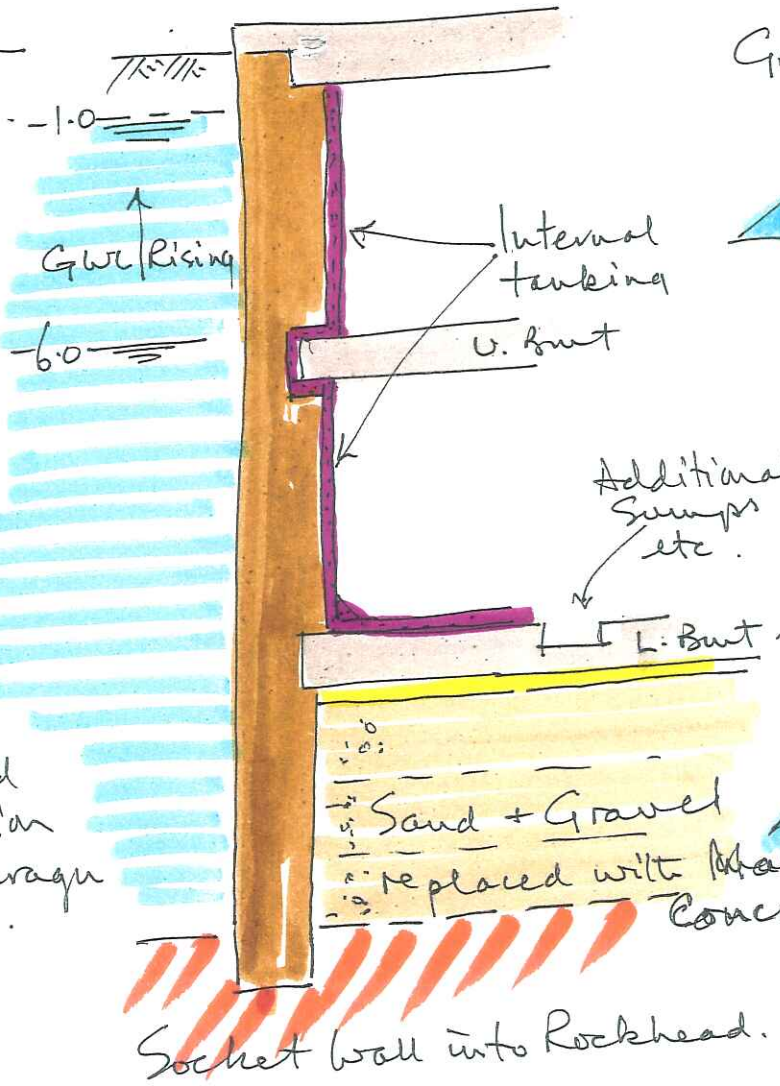


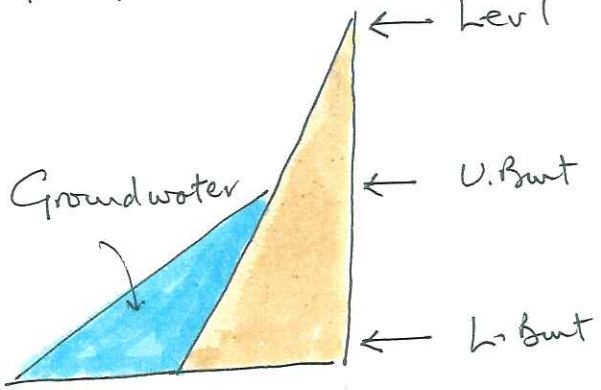
Letter

Issues: (i) Uplift increase unless cut-off used.
(ii) Lateral pressure on wall increases.
(iii) More elaborate water proofing needed.

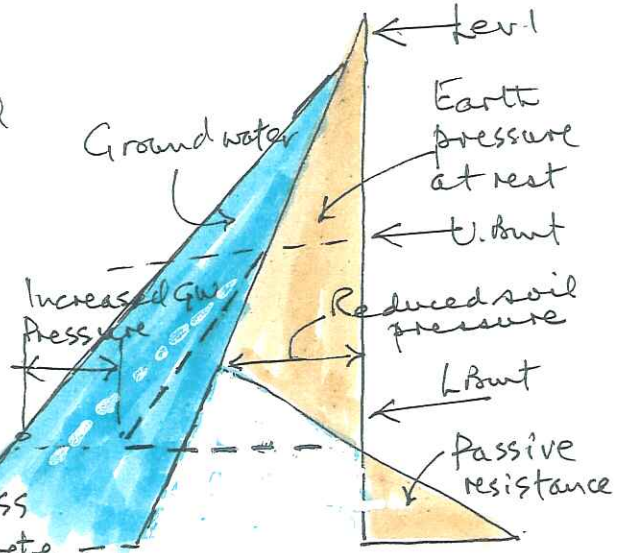
{Weight of superstructure not included in calculation of uplift stability.}




Original estimate




Increased estimate if GWL. rises.

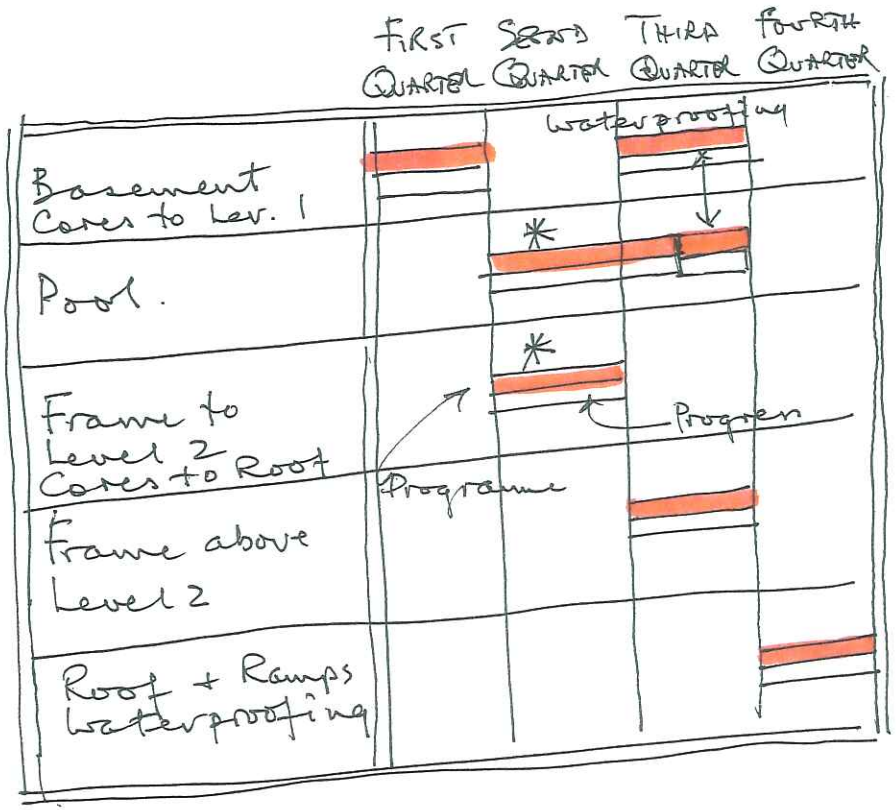
# Method Statement & Programme

(A) Top-down basement/assumed with external diaphragm walls. Level 1 slab, U. Bmt + L Bmt act as struts

Danger of piping under external wall — install wellpoints OUTSIDE and control water until L. Basement slab has been constructed.

(B) Swimming pool has been designed as an R.C. structure with internal waterproof membrane — i.e. concrete shell is not watertight!

(C) The superstructure frame has been designed as a "Portal Frame". Neither the columns nor the transverse beam can be considered to be stable until the parking level slab at Level 2 is in place and can be load bearing. Above this level the construction is "traditional" insitu concrete using falsework + formwork. Minimum concrete strengths are required at various stages.




Matters to be resolved:

- Critical path
- Seasonal construction
- Resource levelling.
- Cash flow.
- Safety if working over the pool *

# Principal design elements

From page 3 — swimming pool floor (assume walls similar)

From page 4 — basement walls for soil + water pressure.

From page 5 — pool supports, check punching shear and contact bearing.

From page 6 — main frame — either — transfer girder + cols
— portal frame
— Vierendeel girders.

(See also pp. 7-9 incl)