The Institution of StructuralEngineers

Critiqued Answer Script

Question 2 – February 2023 Chartered Membership Exam

Author: Jon Bird

Introduction

The following document has been produced by the Examinations Panel as part of the continual effort to provide candidates with as much material as possible to help with preparations for the exam.

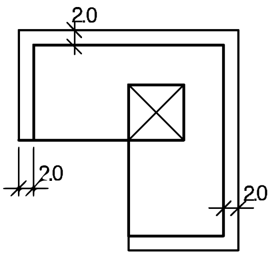
The fully critiqued answer script contained within the document is intended to show candidates a general idea of how their answers should be structured. It is not intended to be used as a 'model' answer and it should not be replicated in part or full as an answer to any future questions.

The critique features comments by Jon Bird, the Chief Examiner for the question, that show where marks were gained and where the candidate could have improved their answer to secure higher marks. The actual marks awarded are not shown in this document.

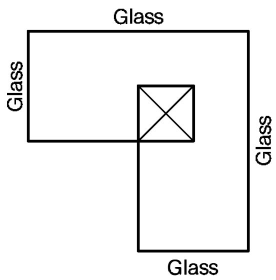
This answer has been taken from the February 2023 Chartered Member Exam. Candidates preparing for January 2024 onwards should note the changes to the exam as detailed in the Exam Preparation Guidance document for further examples. Candidates are advised to continue to engage with their Regional Group with exam preparation activities. They should also download and review all other guidance material supplied by the Institution, which is available on the website.

Michael Lewis

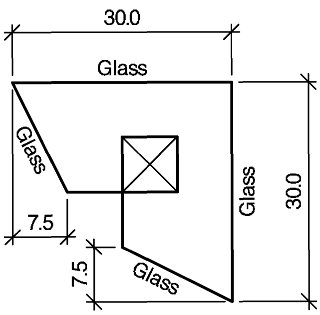
Examination and PRI Manager



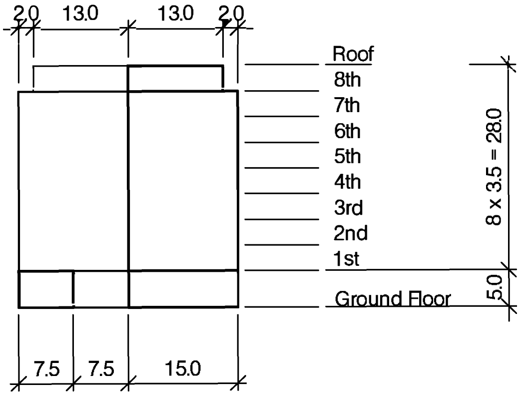
8th FLOOR TO ROOF



1st to 7th FLOOR



GROUND FLOOR



ELEVATION

NOTE: All dimensions are in metres

FIGURE Q2

Q2. Office Building

Client's requirements

1. An 8-storey office block is to be constructed. See Figure Q2.
2. All elevations are to be glazed. No bracing is permitted in glazed facades
3. Minimum column spacing is 6m. Only 2 internal columns are permitted at ground floor level. No columns are permitted outside the perimeter of the building
4. The first floor is to be 5m above the ground floor level. Other floors are to have a 3.5m floor to floor height.
5. On the 8th floor the façade is to be set back 2m from the lower floors. See Figure Q2.

Imposed loading

6.	Roof	4 KN/m^2
7.	Floors	10 kN/m^2 on ground floor and 4kN/m^2 on other floors

Site conditions

8. The site is in the centre of a large city. Basic wind speed is 40.0m/s based on a 3 second gust; the equivalent mean hourly wind speed is 20.0m/s.
9. The ground conditions are as follows:

Ground level – 5m	Heavily contaminated made ground N=2
-5m –to -10m	Firm clay C=50kN/m^2
Below -10m	Mudstone C= 150 kN/m^2

No water was discovered.

Omit from consideration

10. Design of the lifts/elevators and stairs.

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, serviceability, and stability aspects of each scheme. Review and critically appraise the schemes, and identify the solution you recommend, giving reasons for your choice.
(40 marks)

b) After the scheme is complete, the client advises you that they wish to add an additional storey. Write a letter to the client explaining the implications on your design and the construction.
(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 drawings, which may include 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 works and an outline construction programme to include consideration of any temporary works that may be required
(10 marks)

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IStructE examination answer booklet

Candidate details

Date: 0 8 0 2 2 0 2 3

Question: 2

Candidate number: [redacted]

Number of A4 lined paper sides used: 31

Candidate initials: [redacted]

Number of A3 graph paper sides used: 2

1. All answers are to be given on the A3 and A4 paper provided. This includes all rough working and preparatory sketches.
2. The number of sides of A3 and A4 paper used during the examination should be recorded at the top of this cover sheet. You should record your initials above in block capitals. All papers should be secured to this front cover sheet with the treasury tag provided.
3. Your full candidate number should be written in the section above and the last five digits of your candidate number on each answer sheet. A3 graph paper will be moved to the back of the pack for scanning – please number these D1, D2 etc. so that the whole answer pack remains in number order.
4. Your answer sheets and question paper, unless previously given up, will be collected by the invigilator at the end of the examination. Question papers may not be taken out of the examination room.
5. You may not bring any wireless-capable electronic devices into the examination room.
6. If you are found using a mobile phone at any time during the exam, including lunch time, the matter will be reported to the Examination Panel with the recommendation that you are disqualified from the examination.

Martin Powell

Chief Executive

A reminder on codes of practice

Any design code or standard may be used to answer the questions in the paper as long as the codes or standards used are clearly stated and reference to those codes or standards is consistent throughout.

Candidate number: [redacted]

setting out requirements is an effective way to organise thoughts, and show the examiners that you are considering the key aspects of the question

1a

Office Building

The client would like a new 8 storey office block within a city centre.

key client requirements and other structural observations

- all elevations are to be glazed - assume all 4 glazed
  - ↳ no bracing is permitted in the glazed facades
  - ↳ minimise deflections
- 7.5m triangular setback at ground floor
  - ↳ cantilever structure required since no external columns are permitted
- minimum column spacing = 6m c/c
  - ↳ only 2 internal columns permitted at ground floor
- central core - assume 7.5 x 7.5m since no dimensions shown
  - ↳ since no external bracing is allowed core must be used for stability
  - ↳ H = 33m, H/7 = 4.7m min bracing required each direction
  - ↳ consider openings for access into core
- 8th floor has 2m set back
  - ↳ additional transfer structure may be required
- assume 2H fire resistance since H > 30m

Robustness - office > 4 but < 15 storeys so class 2B

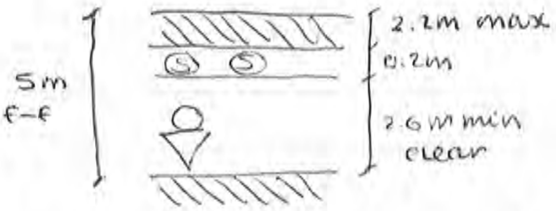
∴ to reduce the risk of progressive collapse horizontal + vertical ties to be detailed

Candidate number: [redacted]

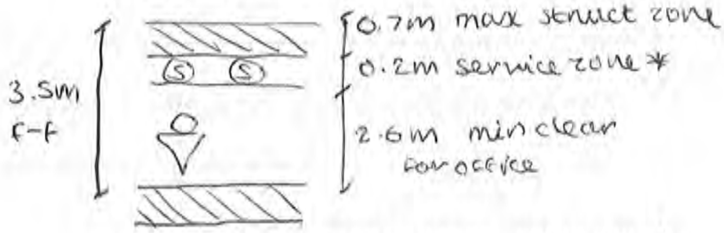
The use of sketches here is an effective way of showing your thought process to the examiners. Contaminated land recognised as an issue and discussed.

Structural Depths

Ground floor



Level 1+



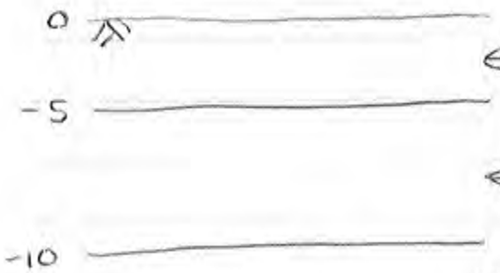
* could be coordinated with steel beam penetrations if needed

- imposed loads do not allow for services/partitions therefore:

SDL = suspended services 0.25kPa, ceiling 0.05kPa, partitions 1kPa, finishes 0.35 = 1.85kPa

Ground Conditions

(ABP = allowable bearing pressure)



← heavily contaminated made ground
N = 2, ABP = 10N = 20kPa

← firm clay c = 50kPa
ABP = 2Cu = 100kPa

← mudstone c = 150kPa
ABP = 300kPa

- No groundwater encountered

heavily contaminated ground → ~~[illegible]~~

↳ assessment would be undertaken to determine specific contaminants and associated risk

↳ remediation could be ↗ assumed

- excavate + reconstruct clean fill material
- blending with clean material to reduce concentration
  ↳ difficult to implement + consider adjacent sites?
- physical treatment
- isolation - sheet pile around site to prevent contaminants moving

Candidate number:

Scheme 1

Scheme 1 uses a concrete framed structure braced using RC shear walls founded on piled foundations

The building uses a 7.5 x 7.5m grid.

Typical floor construction is concrete flat slabs 230mm thick.

To span the setback at ground floor, 2.2m deep transfer beams are used

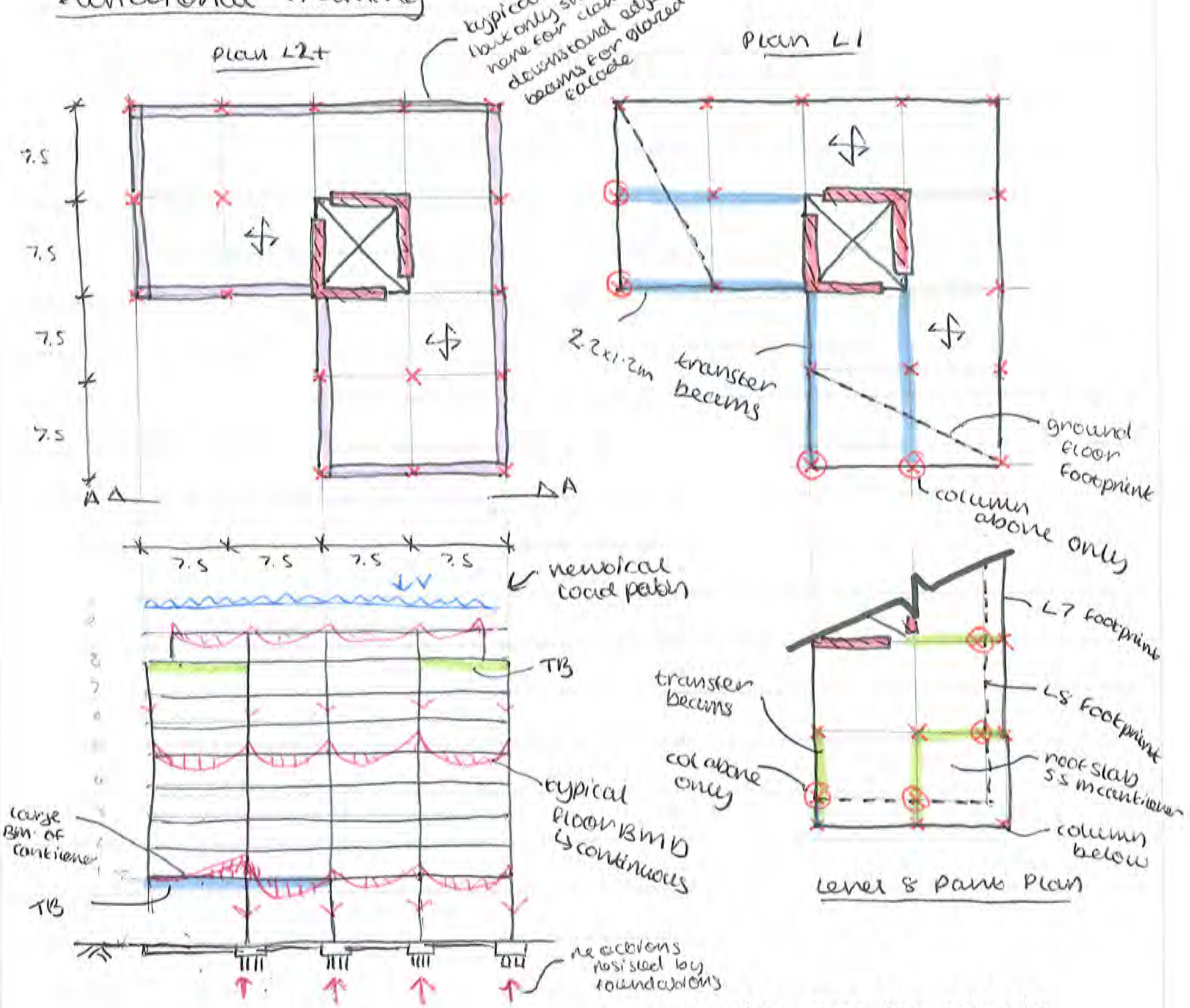
Minimum dimensions have been selected to achieve the 2H fire rating

Simple clear summary introduction - this is enough for examiner to know what to expect in following pages

Candidate number: [redacted]

Effective and clear sketches. Use of colour and key helps to keep sketches clear and simple to understand. Key transfer structures shown.

Functional Framing



Elevation A-A

see following pages for column, foundation and L1 TB sizing

Preliminary Sizing:

RC flat slab without drops, span = 7.5m, S/d = 33 → d = 0.227m
↳ min for 2H fire = 125mm so use 230mm

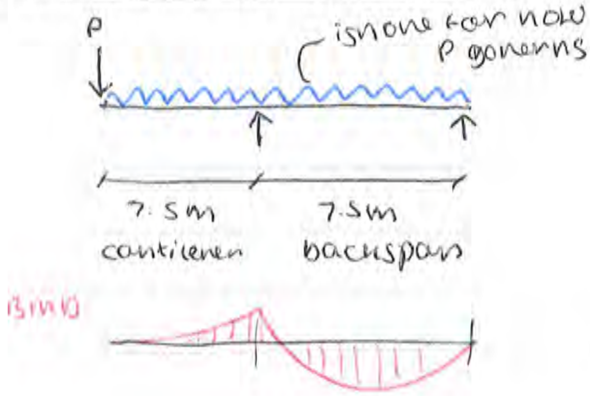
300mm thick RC shear wall - openings assumed for access

RC continuous edge beams to limit glazing movements
span = 7.5m, S/d = 15 ∴ d = 0.5m

Level 8 transfer beams - only carrying 1 floor
700mm structural depth = S/d = 10.7 so OK - detail check later

Candidate number: [redacted]

Level 1 Transfer Beam → Try 2.2m deep (→ working hard so S/d not suitable)



$d = 2100$ mm $b = 950$

P = 8 floors DL = $0.23 \times 25 = 5.75$ kPa

IL = 4 kPa

SDL = 1.85 kPa

Trib area = $7.5 \times 3.5 = 26\ m^2$

$\therefore P = 8 \times (1.35 \times (5.75 + 1.85) + 1.5 \times 4) \times 26$

$= 3382$ kN → very big → C40/50 conc

$M = PL = 3382 \times 7.5 = 25365$ kNm

$$K = \frac{M}{bd^2 f_{cu}} = \frac{25365 \times 10^6}{950 \times 2100^2 \times 40} = 0.151 < 0.168 \therefore \text{no compression rebar}$$

$z = 0.85d$

$$A_{s,req} = \frac{M}{0.87 f_y z} = \frac{25365 \times 10^6}{0.87 \times 500 \times 0.85 \times 2100} = 32667\ mm^2$$

2 layers = $16333\ mm^2$ per layer

max 11 B40 for 950 width → only $13823\ mm^2$

$\therefore$ make 1200mm wide

conclusion working hard but feasible

↳ detailed shear and deflection checks

to be carried out in detail design

= 2.2 x 1.2m beam

Sizing calculations for key members is important, and candidate has correctly recognised that a span/depth check would not be sufficient for this member.

Candidate number: [redacted]

LTD → internal column 7.5×7.5= 56 m² trib area

level	#	A	DL	SDL	IL	SLS TL	ULS TL	
R	1	56	5.75	0.85	4	594	836	
1-8	8	56	5.75	1.85	4	5197	7285	
G	1	56	5.75	1.35	10	986	1415	8121 kN
						6777 kN		

- assume suspended ground floor as upper levels
- no partitions at roof and no ceilings at G
- EC load factors 1.35 DL + 1.5 IL for ULS

✗ columns use 8121 kN ULS → 2% rebar so use 620×620 mm square

foundations - for bearing onto firm clay (assume fill replaced) area required $= \sqrt{\frac{6777}{100\text{ kPa}}} = 8.23$ m square

therefore > 7.5 m grid → use piled foundations

Assume 4 pile caps → 1694 kN per pile
(edge foundations to be 2 pile caps)
approx 900Ø piles 30 m long

~~transfer~~

Candidate number: [redacted]

vertical load path

- see elevation A-A on previous page

vertical loads from gravitational effects are supported on 2 way spanning flat slabs

↓

these loads are transferred through bending and shear to the slabs column strips

↓

columns act in compression to transfer loads to foundations

↓

piles provide friction and end bearing to transfer loads to ground

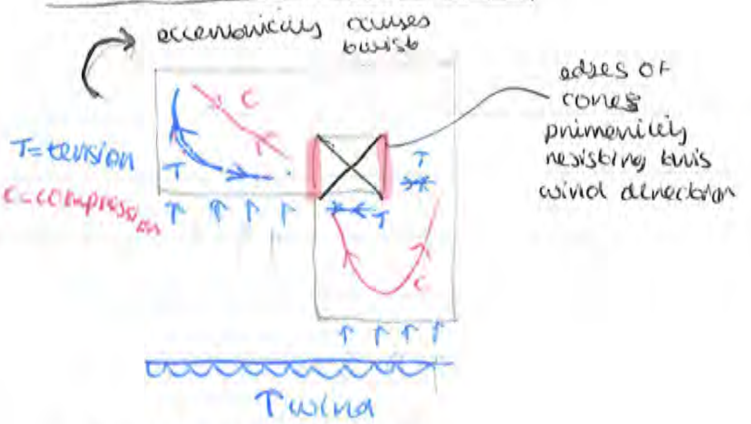
At transfer locations, deeper transfer beams take the loads to the columns through bending and shear

Simple and clear description, referring back to a clear sketch

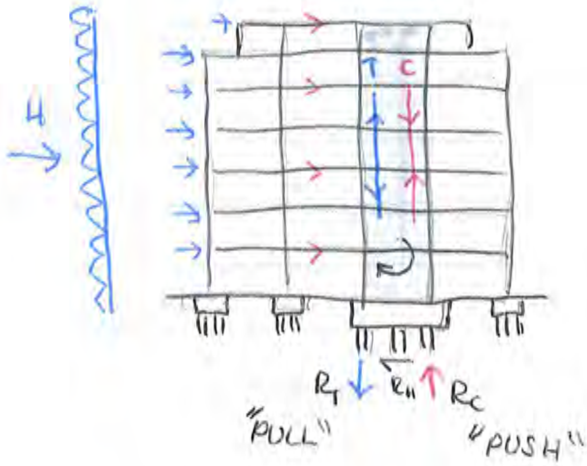
Again the candidate has used a clear and simple description with clear sketches.

Candidate number: [redacted]

Horizontal load path



Diaphragm action of floor plate



horizontal loads arising from wind + geometric imperfections are distributed to the floor levels by the cladding

↓

significant in plane stiffness of floor plate distributes to stiff core walls by diaphragm action

↓

floorplate resolves the eccentricity from the building geometry

↓

horizontal forces at each floor resolved by the core walls which act as vertical cantilevers ~~[illegible]~~ resisted at the base as push pull action by the foundation

↓

piles transfer resulting forces to the ground

Candidate number: [redacted]

Scheme 2

scheme 2 uses a steel framed structure braced using steel braced bays founded on piled foundations

The grid is 7.5 x 15m.

Typical floor construction is 130mm composite slabs supported on secondary beams at typically 2.5m c/c, which span onto primary beams.

To span the 7.5m setback at ground floor a steel cantilevering transfer truss is used.

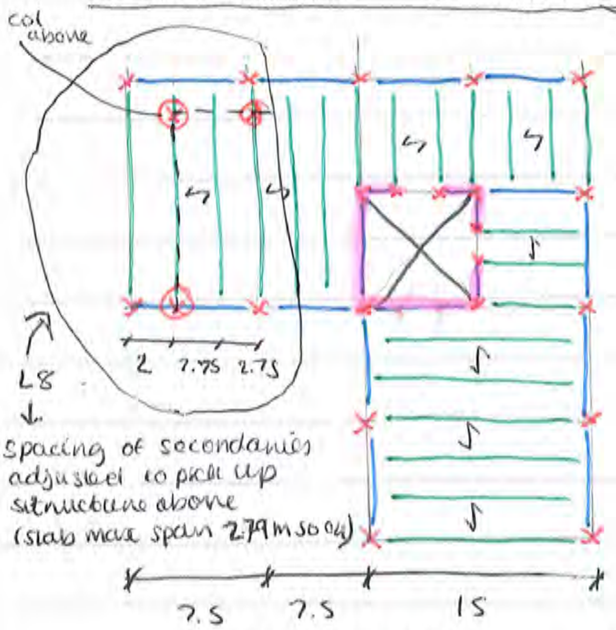
Fire protection will be provided by intumescent paint, the slabs have been sized based on the 2th fire rating.

Simple clear description again.
Looking at distinctness:
Frame - distinct framing, but could maybe add comments along lines of "clear spans give more flexibility for future use changes".
Could also maybe discuss any alternatives considered for locations of transfer structure.
Foundations - not distinct for the 2 schemes. It is acceptable to have piled solutions to both schemes, as long as alternatives are discussed and ruled out as unviable. This discussion has not been done by this candidate.

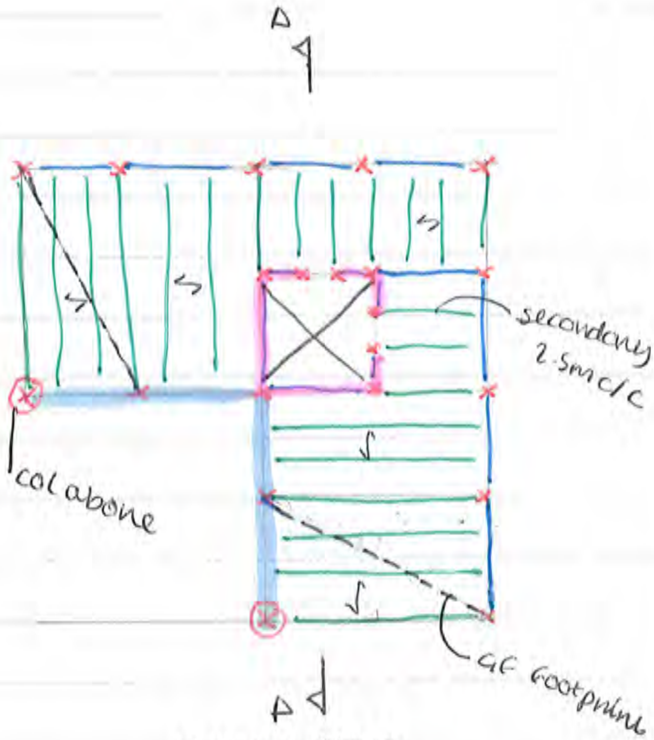
Candidate number: [redacted]

Candidate recognised an issue with their scheme on upper floor and dealt with this clearly

Functional framing

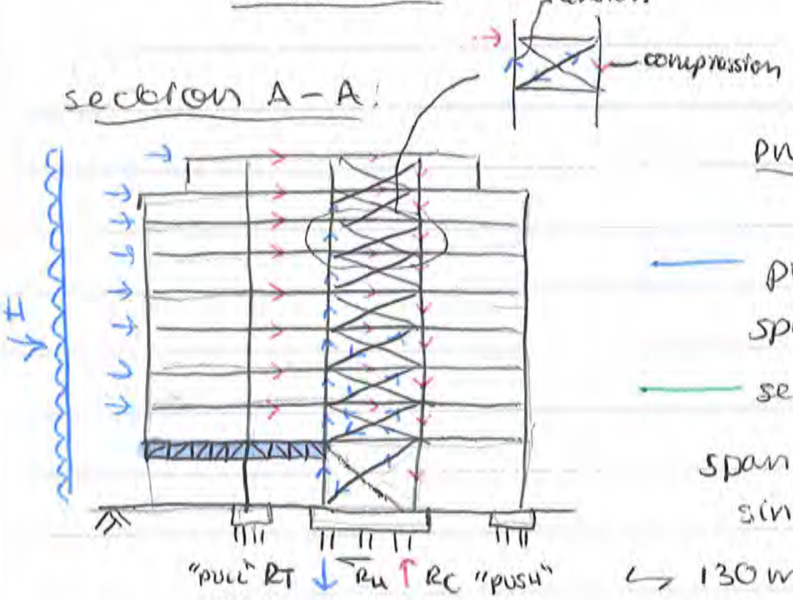


Level 2+ Plan



Level 1 Plan

Section A – A:



Preliminary sizing

primary beam 700mm deep
span = 7.5m max, S/d = 11 so OK

secondary beam, 700mm deep
span = 15m max, S/d = 21 so OK
since composite

↳ 130mm Comflor 51 slab (1mm gauge) max 2.5m span typically

9 storeys total so UC354

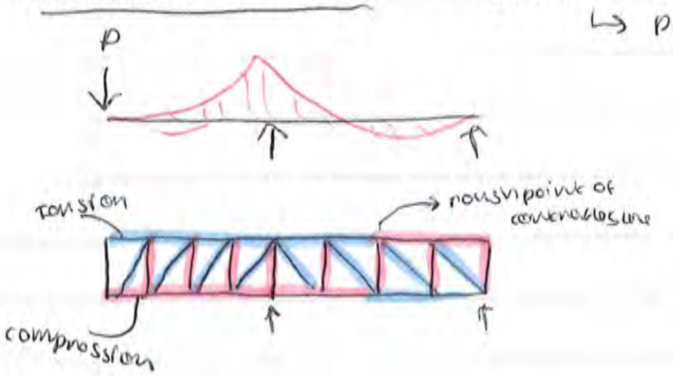
braced steel bays
2x2.5m openings for access / lifts

transfer truss
2m deep carrying floors above – see next page

• set back roof structure aligns with L8 structure – beams designed to take point loads – stiffeners may be needed at PL locations

Candidate number: [redacted]

Transfer truss – ignore UDL from floor load for now
↳ PL governs



slab ↓ steelwork ↓

P = 8 floors $DL = 0.13 \times 25 + 1 = 4.25$

$SDL = 1.85$

$IL = 4$

Trib area $= 7.5 \times 3.5 = 26\,m^2$

$P = 8 \times 26 \times (1.35 \times (4.25 + 1.85) + 1.5 \times 4)$

$= \underline{2960\,kN}$

$M = PL = 7.5 \times 2960$

$= \underline{22207\,kNm}$

say 2m deep truss

Top/Bottom chord $N_{ed} = M/h = \frac{22207}{2} = 11103\,kN$

$A = \frac{N \times 1.15}{f_y} = \frac{11103 \times 1.15}{0.355} = 35967\,mm^2$

↳ $359\,cm^2$

∴ $\boxed{UC\ 356 \times 406 \times 287} = 366\,cm^2$

∴ feasible – full checks to be done in detail design

Foundations

LTD - typical edge col

Level	#	A	DL	SDL	IL	SLS TL
R	1	56	4.25	0.85	4	509
1-8	8	56	4.25	1.85	4	4525
G	1	56	5.75	1.35	10	958
						5992 kN

• ground floor as scheme 1 = 5.75 kPa DL underestimated loads provide spare capacity

for bearing $\sqrt{\frac{5992}{100}} = 7.74 > 7.5m$ so

piles needed * contaminated fill replaced

4 pile caps - 1498 kN/pile

so 900 Ø piles 25 m long

ground slab = suspended → replaced fill = low bearing capacity

15 m span → 2 way continuous slab

S/d = 39

d = 15/39 = 0.38 m

↳ use 400 thick

Candidate number: [redacted]

Horizontal load path

- see section A-A

horizontal loads from wind + EHFs distributed to floors by cladding

↓

significant floorplate stiffness distributes to braced bay by diaphragm action (similar to pt 1)

↓

resulting bracing forces transferred to foundations by push pull action in the column pair.
and resisted by piles

 ← simple steel connections

Vertical load path → see transfer truss page also

vertical loads from gravitational effects are supported on 1 way spanning composite slabs

↓

slabs span onto secondary beams which acts compositely with the slab

↓

secondaries span onto primarys which take loads in bending and shear to supporting columns

↓

columns act in compression to take loads to foundations

↓

piles friction + end bearing to soil

Candidate number: [redacted]

scheme comparison

key considerations for the building
- city centre site - likely limited storage / access
  ↳ limited working hours due to noise
- glazed facade - aesthetics and column spacing key
- efficient structure

(+) = more desirable (−) = less desirable

	scheme 1 concrete	☆ scheme 2 steel ☆
foundations	heavy due to conc sw (−)	piled - but less so (+) quicker and cheaper
buildability	many wet trades, (−) H&S - slow on site due to construction and striking times (−) faster delivery to site (+)	long lead in + deliveries of long sections may be difficult (−) fast to erect on site - less disruption to neighbours, (+) better quality on site (+)
service integration	thin flat slab construction (+) expand to explain advantage of clear zone	services can travel through penetrations but must be coordinated (−)
aesthetics	thick concrete columns (−)	No internal columns - greater flexibility (+) "fashionable" exposed steel possible (+)
material efficiency	heavy structure - 7.5m concrete transfer pushing limits of concrete ∴ inefficient (−)	lighterweight structure - steel transfer truss lightweight solution ∴ efficient (+)

PTO →

Candidate number: [redacted]

	1 conc	2 steel
Future flexibility	less easy to adapt once built −	easier to extend/ deconstruct once built ↳ better future proofing +
Fire / Acoustics / vibration	inherent +	assessment needed + cost of provision −

Both schemes fulfil the clients brief, however considering the above, scheme 2 (steel) has been chosen since it best fits the clients key requirements. The more efficient structure will be quicker to construct on the city centre site, and ~~more~~ the lighter foundations have less impact on the contaminated ground. There are no internal columns so the use of the space would be much more appealing to the client.

Other issues that could be considered:
Sustainability
Propping/pre-camber long spans?
Discussion on differences of the key transfers

Candidate number: [redacted] / Part 1b

CC: ARCHITECT, QS, MEP, MAIN CONTRACTOR

Engineer LTD
Address

Client LTD
Address

8th February 2023

Dear Client,

RE: OFFICE BUILDING

Thank you for your correspondance concerning adding another storey to the building. This would increase the lettable floor area to the office in the prime city centre location so we can see why you are keen to consider this option. Since we are at the stage where the scheme is complete but the project has not started on site, this change is possible however it raises the structural concerns below:

① We assume the additional floor will increase the height of the building, to avoid compromising the clear floor heights currently provided. The vertical loads will therefore increase due to the weight of this additional floor. The foundations and columns will need to be re-checked for these new loads and their size may increase. The L1 transfer truss will now be taking an extra floor so would need to increase in depth. Alternatively, if the requirement of no external bracing could be relaxed, the L1-2 floor height could be used for this truss, increasing the clear height at ground floor. Aesthetically pleasing sections could be chosen here to retain the intended aesthetic facade

Candidate number: [redacted]

(2) Due to the increased height of the building, the building will see a greater wind load. These increased lateral loads will mean the braced stability system will need to be re-checked and ~~&~~ the sections may increase in size. The foundations will also need to be checked for this increased lateral load

we reccomend any revisions to the design are submitted to the project quantity surveyor to assess the estimated cost of this change, for example cladding and column splice costs will have now increased since there are more.

we also suggest that the main contractor is contacted to assess the impact on the draft construction programme, the project would now take marginally longer on site because of the increased amount to construct.

Furthermore the additional floor will need to be assessed by the MEP engineer. service provision may need to increase which could affect the riser layouts. If the risers or plant space is insufficient, increasing could result in loss of diaphragm action due to increased voids or increased loads due to greater plant space. Also, the increased height should be verified by the planning council.

we look forward to hearing from you, please get in touch if you have any further questions.

Yours sincerely

engineer

Comprehensive and well thought out letter. The candidate addresses the key structural issues, but also mentions other possible effects, such as impact on riser sizes.

Candidate number: [redacted]

2c Calculations

The calculations shown in this section are in accordance with eurocode (EC) guidance as listed below

① Design standards and sources of reference

BS EN 1991 – EC1 – Actions on structures
" 2 – EC2 – Design of concrete structures
" 3 – EC3 – Design of steel structures
" 7 – EC7 – Geotechnical Design

② Loading

DL = 3.125 kPa composite slab + 1 kPa for steelwork
SDL = 1.85 kPa (see part 1)
IL = Ground 10kPa, elsewhere 4kPa
wind = see next page

③ Performance requirements

movement – total deflection = span/250
glazed areas = span/500
building sway = H/500

durability – external cover = 75mm
– 50 year design life
– internal steelwork = C1 (very low risk) ∴ I1 or I2 paint
– external " = C3 (medium risk) ∴ E1 paint

Fire – all steelwork to be intumescent painted to achieve 2H fire rating

Candidate number: [redacted]

(4) materials

- all concrete C30/37 UNO
- all steelwork S355 UNO
- all rebar grade 500B

(5) calculation schedule - key elements

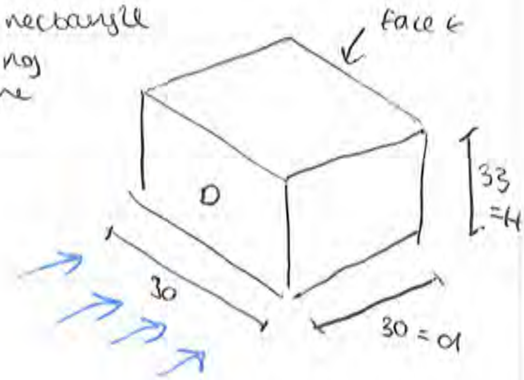
- [x] bracing system
- [x] transfer truss
- [x] secondary beam
- [x] column
- [x] foundation

all other elements sized using engineering judgement

Candidate number: [redacted]

wind load calculation

enclosing rectangle of building
- conservative



Basic wind speed

$V_b = c_{dir} \times c_{season} \times c_{alt} \times V_{b0}$

$= 1 \times 1 \times 1 \times 1.06 \times$ mean hourly

all directions — permanent struct — altitude = 0 so tends to 1

$V_b = 1.06 \times 20 = 21.2 m/s$

Basic pressure $= q_b = \frac{1}{2} \rho V_b^2 = \frac{1}{2} \times 1.226 \times 21.2^2 = 0.276 kPa$

Peak velocity pressure $= q_p = c_o(z)\, c_e(z)\, c_{pr}\, q_b$

orography not relevant — NA.7 > 100m from shore — conservatively ignore town obstructions

$\therefore q_p = 1 \times 3.1 \times 1 \times 0.276 = 0.823 kPa$

Net pressure coefficients

$H/d = 1.1$ — $c_{pe,10}$ face D = 0.8 (windward pressure) — $c_{pe,10}$ face E = -0.5 (leeward suction)

$\therefore$ Net pressure $= (0.8 - -0.5) \times 0.823$

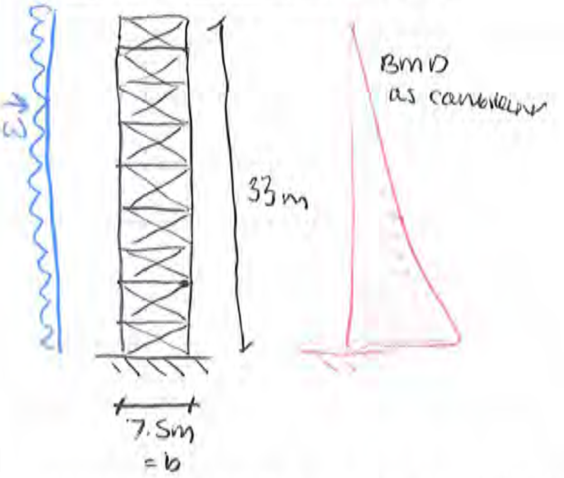
$= 1.0699 kPa$

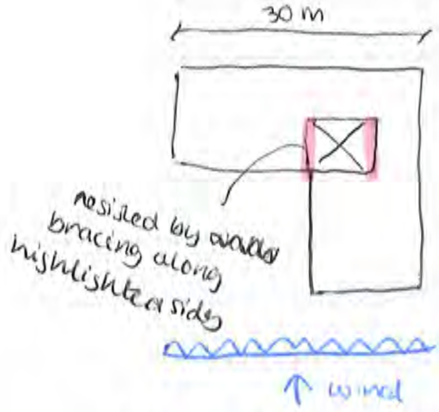
$\therefore$ $\boxed{\text{use } 1.1 kPa}$

since this calculation is conservative, assume this value accounts for EHF due to geometric imperfections

Candidate number: [redacted]

Steel Braced Bay



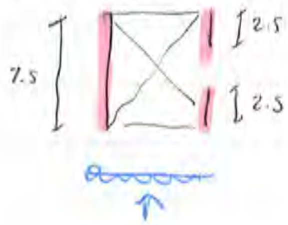


Since building is square on plan - only 1 direction checked - other direction ok by inspection since same length of bracing provided

critical case = max overturning

$\boxed{1.0DL + 1.5\,WIND}$ i.e. no LL contribution

actual core layout:



Assume wind is split between the 3 braced bays proportionally, 7.5m bay:

$$\omega = 1.1 \times 30 \times \frac{7.5}{7.5+7.5+2.5} = \underline{19.8\ kN/m}$$

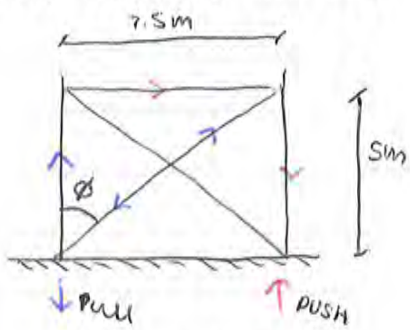
$$\text{max overturning} = \frac{\omega h^2}{2} = \frac{19.8 \times 33^2}{2} = \underline{10781\ kNm}$$

$$\text{Push / Pull} = M/b = 10781/7.5 = \underline{1437kN} \rightarrow \text{check columns for this}$$

$$\text{Base shear} = V = \omega h = 19.8 \times 33 = \underline{653\ kN}$$

$$\text{Bracing Axial Force} = \frac{V}{\sin\phi} = \frac{653}{\sin 56} = \underline{788\ kN} = f_b$$

$$A_{s,req}\ (ULS) = \frac{1.5 f_b}{f_y/1.15} = \frac{1.5 \times 778}{0.355/1.15} = \underline{3780\ mm^2}$$



Ground Floor

$$\phi = \tan^{-1}(7.5/5) = 56°$$

therefore use $\boxed{40 \times 100mm \text{ flat plate}}$

PTO for deflection

Candidate number: [redacted]

Braced Bay Deflection

$$\delta = \frac{\omega \times L \times L^3}{8EI}$$

$E = 205$ ~~xxx~~ kN/mm^2 ↗ 356 x 406 x 287 UC

$$I = \frac{A_{col} \times d^2}{2} = \frac{366 \times 10^2 \times 7500^2}{2}$$

$$= 1.03 \times 10^{12} \ mm^4$$

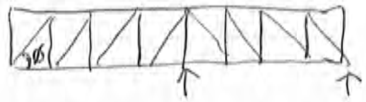
$$= \frac{19.8 \times 33 \times 33000^3}{8 \times 205 \times 1.03 \times 10^{12}}$$

$$= 13.9 mm$$

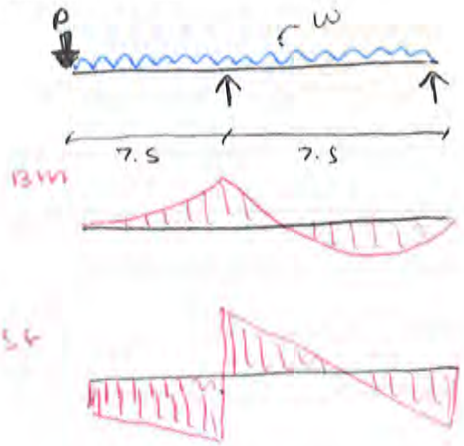
$\delta_{lim} = H/500 = 33000/500 = 66$ mm so OK

Acceptable, but should consider eccentricity effect to increase forces in braced bay.

Candidate number: [redacted]



Transfer Truss



from part 1 P = 2960 kN (ULS)

$$w = 7.5 \times [1.35 \times (4.125 + 1.85) + 1.5 \times 4]$$

$$= 105 \text{ kN/m} \quad (ULS)$$

$$M_{max} = \underset{\text{from P}}{PL} + \underset{\text{from w}}{\frac{wL^2}{2}}$$

$$= 2960 \times 7.5 + \frac{105 \times 7.5^2}{2}$$

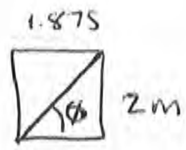
$$\cancel{25153 kN}$$

$$\underline{M = 25153 \text{ kNm}}$$

$$V = P + wL$$

$$V = 2960 + 105 \times 7.5$$

$$= \underline{2971 \text{ kN}}$$



Diagonals - end bays max shear

$$F_t = \frac{V}{\sin \phi} = \frac{2971}{\sin 47} = 4062 \text{ kN}$$

$$\phi = \tan^{-1}\left(\frac{2}{1.875}\right) = 47°$$

$$A_{req} = \frac{4062 \times 1.15}{0.355} \div 100 = 131 \text{ cm}^2$$

↳ $\boxed{254 \times 254 \times 107 UC}$ = 136 cm²

Top / Bottom chord

$$N_{ed} = M/_H = 12577 \text{ kN}, \quad A_s = \frac{12577 \times 1.15}{0.355} \div 100 = 407 \text{ cm}^2$$

↳ $\boxed{356 \times 406 \times 340 UC}$ = 433 cm²

mention restraints to bottom chord

Deflection

$$\delta = \frac{wL^4}{8EI} + \frac{PL^3}{3EI}$$

$E = 205$ kN/mm²

$$I = \frac{A_c d^2}{2} = \frac{433 \times 10^2 \times 2000^2}{2}$$

$$= 8.66 \times 10^{10} \text{ mm}^4$$

$$\delta = \left(\frac{105 \times 7.5 \times 7500^3}{8 \times 205 \times 8.66 \times 10^{10}} + \frac{2960 \times 7500^3}{3 \times 205 \times 8.66 \times 10^{10}}\right) \div 1.4 \text{ for SLS}$$

$$= 25.8 / 1.4 = 18.4 \text{ mm}$$

$$\delta_{lim} = \frac{7500}{500} = 15 \text{ mm}$$

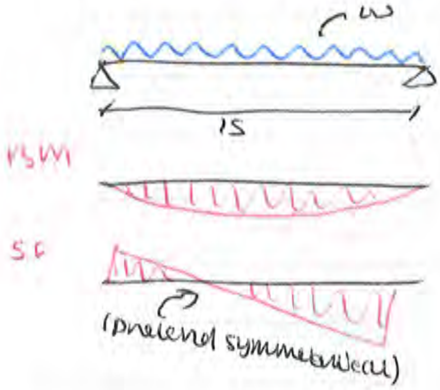
∴ NOT OK SO PRECAMBER DL

Candidate number: [redacted]

Secondary Beam → 2.5m c/c

- assume full lateral restraints from slab

Try UB 686x254x170



Loading DL = 3.125 kPa
SDL = 1.85 kPa
IL = 4 kPa

Σ SLS = 8.975 kPa = 22.4 kN/m
Σ ULS = 12.7 kPa = 31.8 kN/m

max BM = $\frac{wL^2}{8} = \frac{31.8 \times 15^2}{8} = 894$ kNm

- composite behaviour allows for 1.4 times increase on steel section capacity

Bending $M_{Rd} = 1.4 \times W_{pl} \times f_y = 1.4 \times 5630 \times 10^3 \times 355 \div 1 \times 10^6$
$= 2789$ kNm ∴ OK 32% utilised

Shear $V_{Rd} = 0.577\, A_v\, f_{yd} = 0.577\, b_w h \times 355$
$= 0.577 \times 14.5 \times 692.9 \times 355 \div 1 \times 10^3$
$= 2058$ kN

$V_{Ed} = \frac{wL}{2} = \frac{31.8 \times 15}{2} = 239$ kN ∴ OK 12% utilised

Deflection

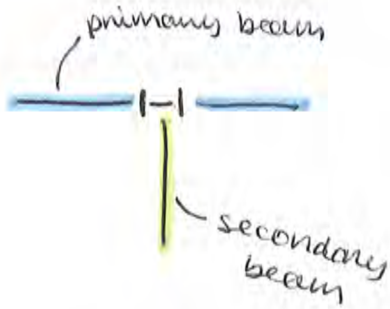
$\delta = \frac{5wL^4}{384EI} = \frac{5 \times 22.4 \times 15 \times 15000^3}{384 \times 205 \times 170000 \times 10^4}$
$= 42.4$ mm

δ_{lim} = span/250 = 60mm
∴ OK even ignoring composite action

~~All utilisation~~

Candidate number: [redacted]

<u>Column</u> Try $\boxed{356 \times 406 \times 287\,UC}$



Out of balance moments from secondary end shear (primary balance)

see part 1

$$N_{ed} = (509 + 4525) \times 1.4 = \underline{7048\ kN}\ \ ULS$$

$$M_{yy} = 0$$

$$M_{zz} = 239\,kN \times \left(\frac{399}{2} + 100\right) \div 1000 = 72\ kNm$$

end shear

B

100mm eccentricity from face of col

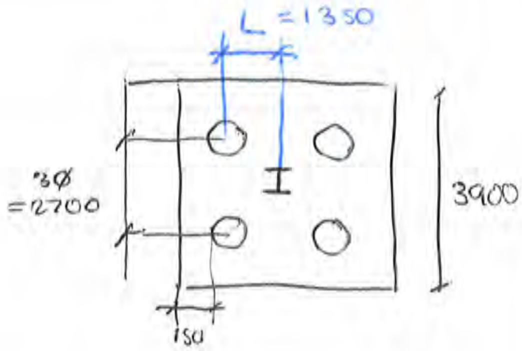
worst case Buckling length = 5m

$$\frac{N}{N_{brd}} + \frac{M_{yy}}{M_{brd}} + \frac{1.5\,M_{zz}}{W_{z}f_{y}} \leq 1$$

$$\frac{7048}{9719} + 0 + \frac{1.5 \times 72}{1017}$$

$$0.725 + 0 + 0.106 = 0.831 < 1 \therefore OK$$

Candidate number: [redacted]



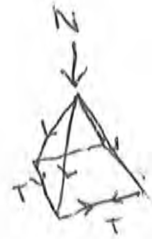
Foundation

4 pile cap - 25m long 900Ø piles

Depth = 2.3Ø to limit punching

= 2.2m

∴ d = 2200 - 75mm cover → say 2100 mm



Using strut + tie truss analogy

Tension force between piles

$$T = \frac{NL}{4d}$$

N = 5992 kN from part 1

$$\therefore T = \frac{5992 \times 1350}{4 \times 2100} = 963 \text{ kN}$$

$$A_{s,req} = \frac{963 \times 10^3}{0.87 \times 500} = 2214 \text{ mm}^2$$

∴ $\boxed{\text{Provide B25 @ 200}}$ = 2454 mm² each direction

Punching

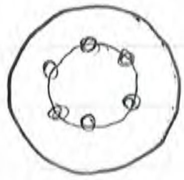
at col face $v = \frac{N}{u_0 d} = \frac{5992 \times 10^3}{[2(356+406)] \times 2100} = 1.87 \text{ N/mm}^2$

$v_{rd,c}$ = 3.64 N/mm² so OK

· d from col face is outside pile cap ∴ punching OK

Candidate number: [redacted]

Pile Design



- Assume no moment
- N_{ed} = 1498 kN / pile (part 1)

$$\frac{N_{ed}}{h^2 f_{ck}} = \frac{1498\times10^3}{900^2 \times 30} = 0.062$$

Therefore use min steel $0.4\% \rightarrow 2544\,mm^2$

$= \underline{6B25}$

Soil capacity not checked

Candidate number: [redacted]

2e

METHOD STATEMENT

① PRELIMINARIES

- clear site and erect perimeter hoarding
- carry out further site investigation to identify type, extent and concentration of contaminants within the ground
  - ↳ also identify any below ground services or obstructions - city centre site so likely
- redirect underground services if necessary + install temp services to site
- induct staff - site specific risk assessment highlighting key H&S areas (e.g. contaminated land + transfer structures)
- develop traffic management + delivery strategy
  - ↳ city centre site so may need single lane closure ~~for~~
  - ↳ splices in elements > 12m long to allow normal vehicle without an escort

② OFF SITE CONSTRUCTION

- order steel = 12 week lead time + HD bolts
- reinforcement = 6 week lead time but can begin coordination of detail drawings

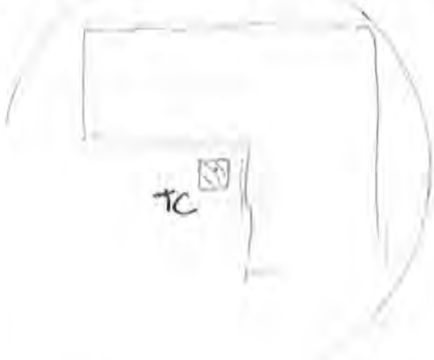
③ SUBSTRUCTURE

- contaminated land to be removed and suitable disposed of
- replaced with compacted fill
- level site and set out piles - construct piles

Replacing this volume of material is expensive. Is it required? Alternatives should be considered.

Candidate number: [redacted]

- cut off piles at connect level ensuring sufficient projection into pile caps
- install any below ground drainage
- excavate pile caps, trim sides, blind base
- construct rebar + place in excavations
  ↳ locate HD bolts for baseplates
- prepare crane base



Tower crane placed external to building with ~20m reach prevents having to leave a bay of slab within building vacant

- concrete cast to underside of ground slab
  ↳ ground slab rebar layed
  ↳ ground floor + tops of pile caps cast as one

④ STABILITY SYSTEM

- erection of steel to start in a braced bay in order to be self supporting
- this stable and self supporting bay can then be used to support subsequently erected steel
- temporary stability to be maintained throughout construction

⑤ SUPERSTRUCTURE – continue erecting steel frame

- safe access to and from working areas to always be provided
- Transfer truss – temporary propping must be provided until fully constructed inc. backspan

Good to make key stability items during construction clear

Candidate number: [redacted]

- composite decking – consider orientation and volume of material being stored to prevent overloading
- install edge protection
- maximum amount of protective steel paint applied in workshop to be made good only after erection damage has been inspected
- install shear studs

(6) <u>SLABS</u>
- lay reinforcement onto decking
- ensure all cast in cladding brackets and reinforcement are installed
- pour concrete
  ↳ ensure any areas where temp propping is identified are propped
- appropriate finishes to slab to be applied

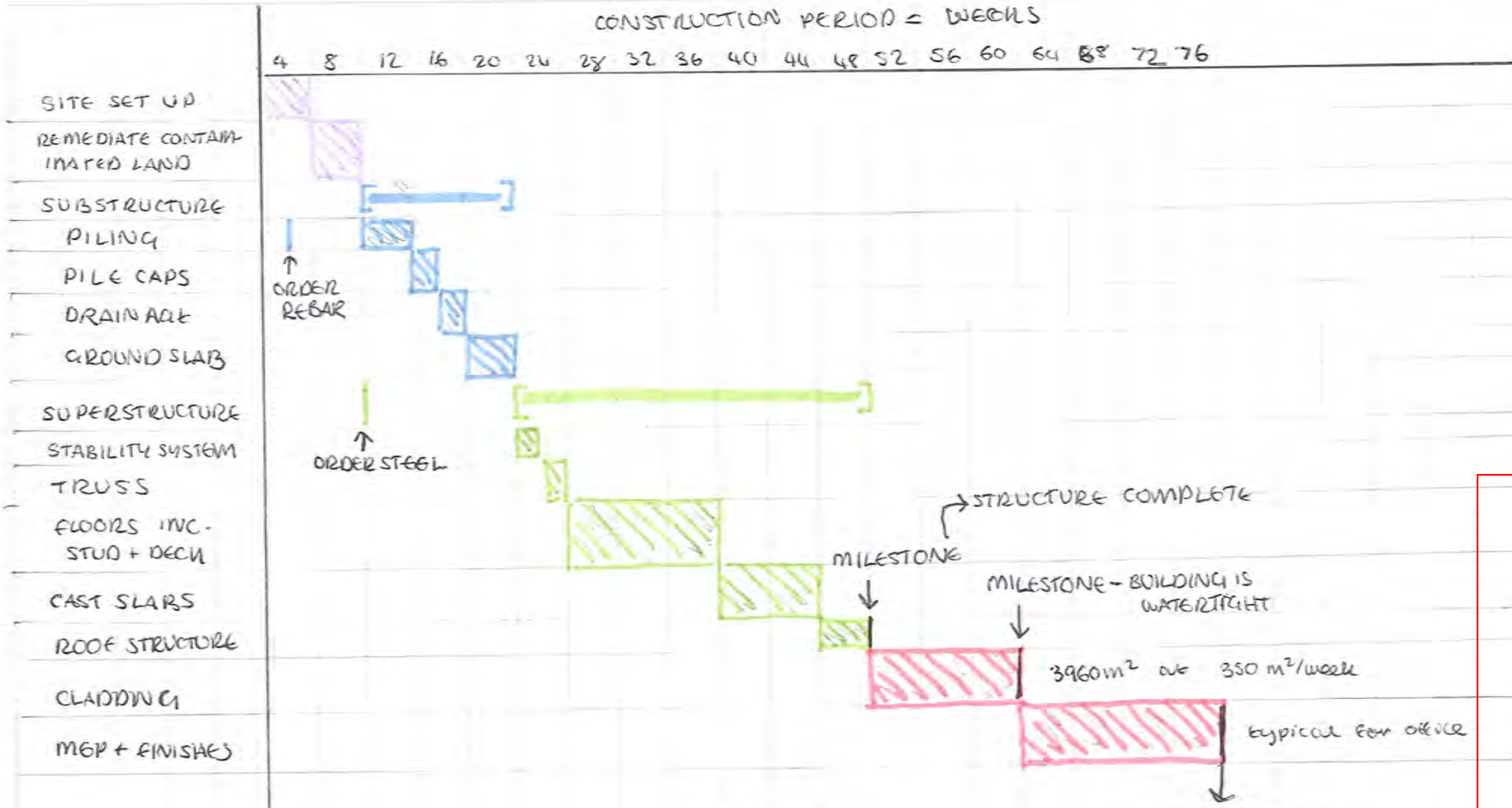
(7) <u>ROOF</u> – as floors plus membrane

(8) <u>CLADDING</u>

(9) <u>MEP</u> + <u>finishes</u> → handover to client
- start when 3 floors of frame have been completed for non-sensitive items
  ↳ once cladding complete (watertight building) comissioning + installation of services finished

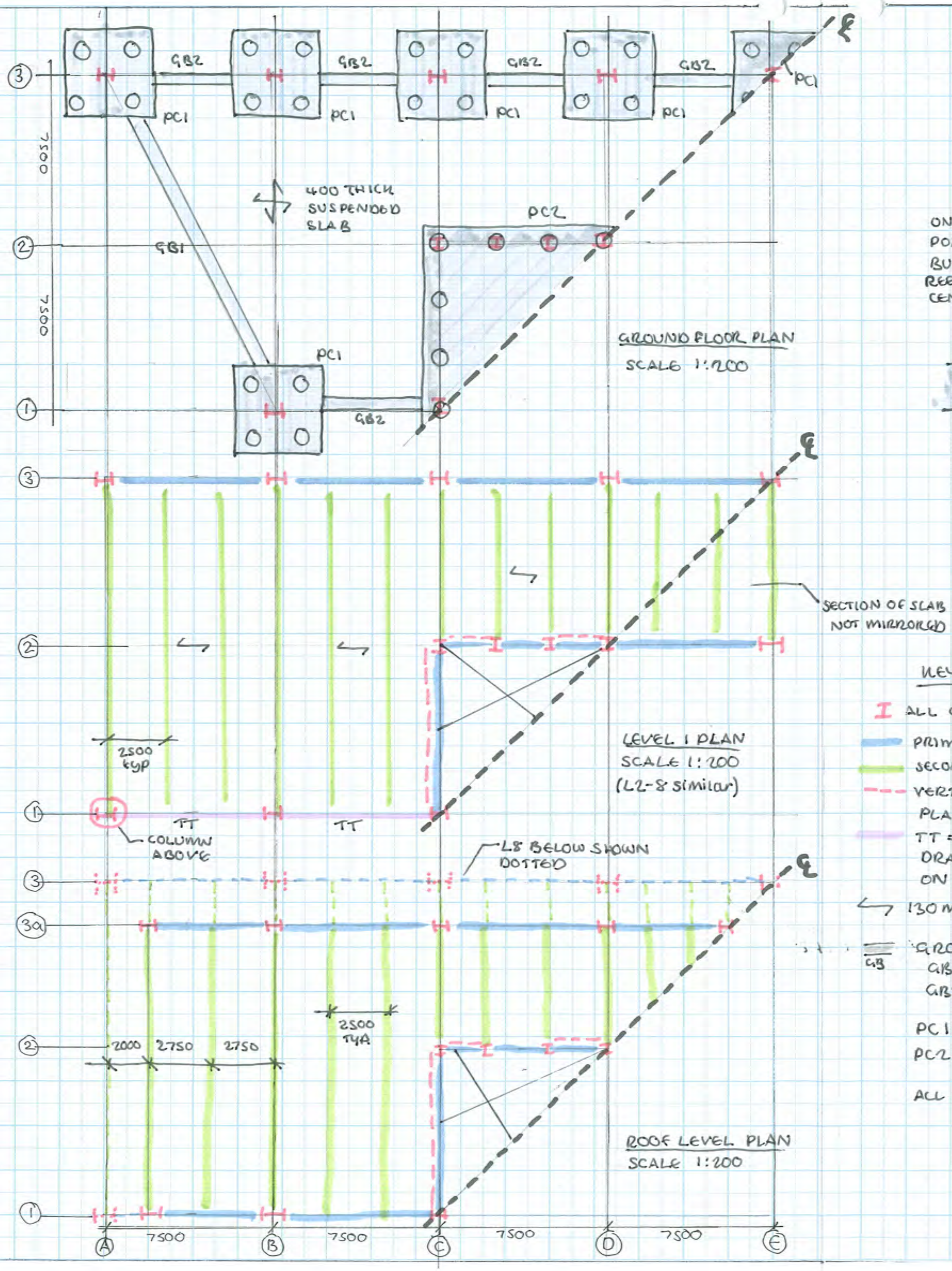
Candidate number: [redacted]

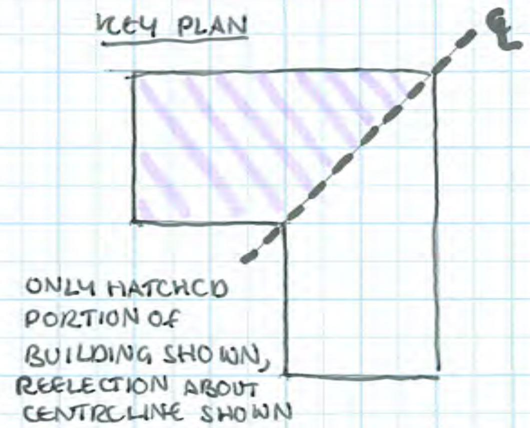
Good clear programme. Mentions key order dates

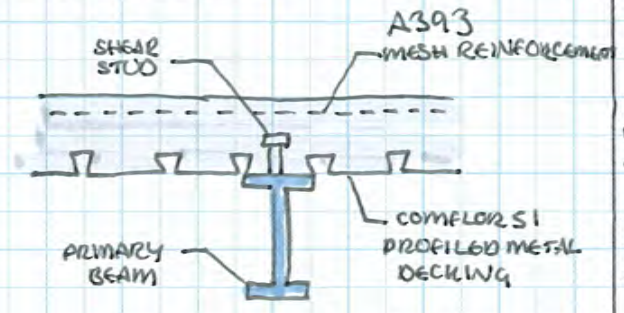


∴ 76 week
(19 month) total (typical office 15-18 months)

$(30 \times 30 - 15^2) \times 9$ floors = 6075m² total







TYPICAL COMPOSITE SLAB SECTION (NTS)

KEY

- ALL COLUMNS UC 356x406x287
- PRIMARY BEAM UB 686x254x170
- SECONDARY BEAM UB 686x254x170
- VERTICAL X BRACING 40x100 FLAT PLATE
- TT = TRANSFER TRUSS - SEE DETAIL ON DRAWING D2. TYPICAL PRIMARY BEAM ON L2+
- 130 mm COMFLOR 51 COMPOSITE SLAB
- GB GROUND BEAMS
  - GB1 = 500 w x 1000 dp
  - GB2 = 350 w x 500 dp

PC1 = 3900 w x 3900 L x 2200 dp
PC2 = 8700 w x 8700 L x 2200 dp

ALL PILES 900 Ø 25 m LONG

NOTES

- ALL DIMENSIONS IN mm UNO
- ALL REINFORCED CONCRETE TO COMPLY WITH LATEST NSCS
- ALL STEEL TO COMPLY WITH LATEST NSSS
- CONCRETE TO BE GRADE C30/37
- 75mm BLINDING, C16/20, TO ALL CONCRETE IN CONTACT WITH GROUND
- REINFORCEMENT GRADE 500B
- STRUCTURAL STEEL GRADE S355
- BOLTS GRADE 8.8. MINIMUM 2 BOLTS PER CONNECTION
- ALL WELDS 6mm FW MIN
- FIRE RESISTANCE IS 2H. ALL STEEL TO RECIEVE INTUMESCENT PAINT TO ACHIEVE THIS
- COVER TO REBAR = 75mm to EXTERNAL FACES, 30mm INTERNAL
- FOR DURABILITY ALL INTERNAL STEEL-WORK TO RECIEVE I1 or I2 PAINT, EXTERNAL = E1
- SHEAR STUDS TO BE 19mm DIA 100mm LONG HEADED STUDS
- REFER TO DETAILS ON D2

REBAR RATES kg steel / m^3 concrete

- GROUND FLOOR SLAB = 80
- PILE CAPS = 120
- PILES = 60

Clear and well thought out drawings.
Notes clear.

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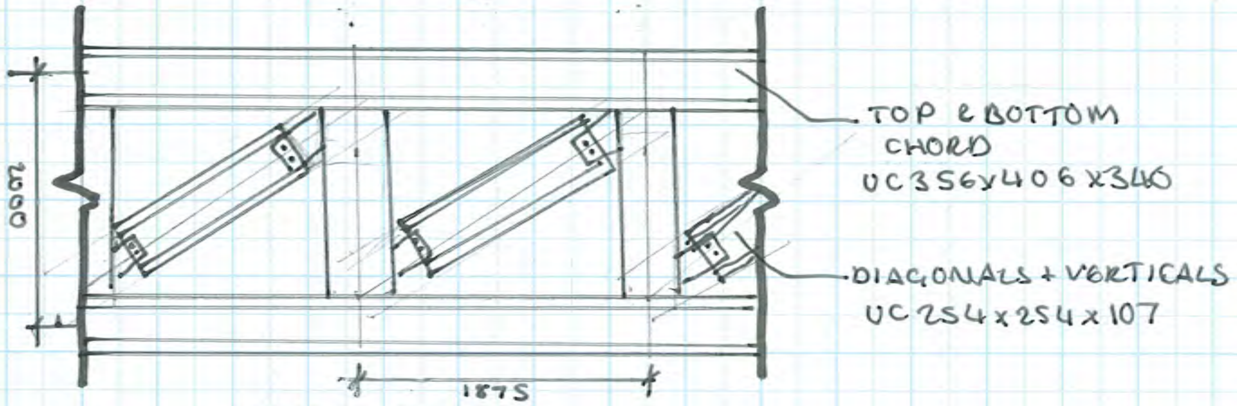
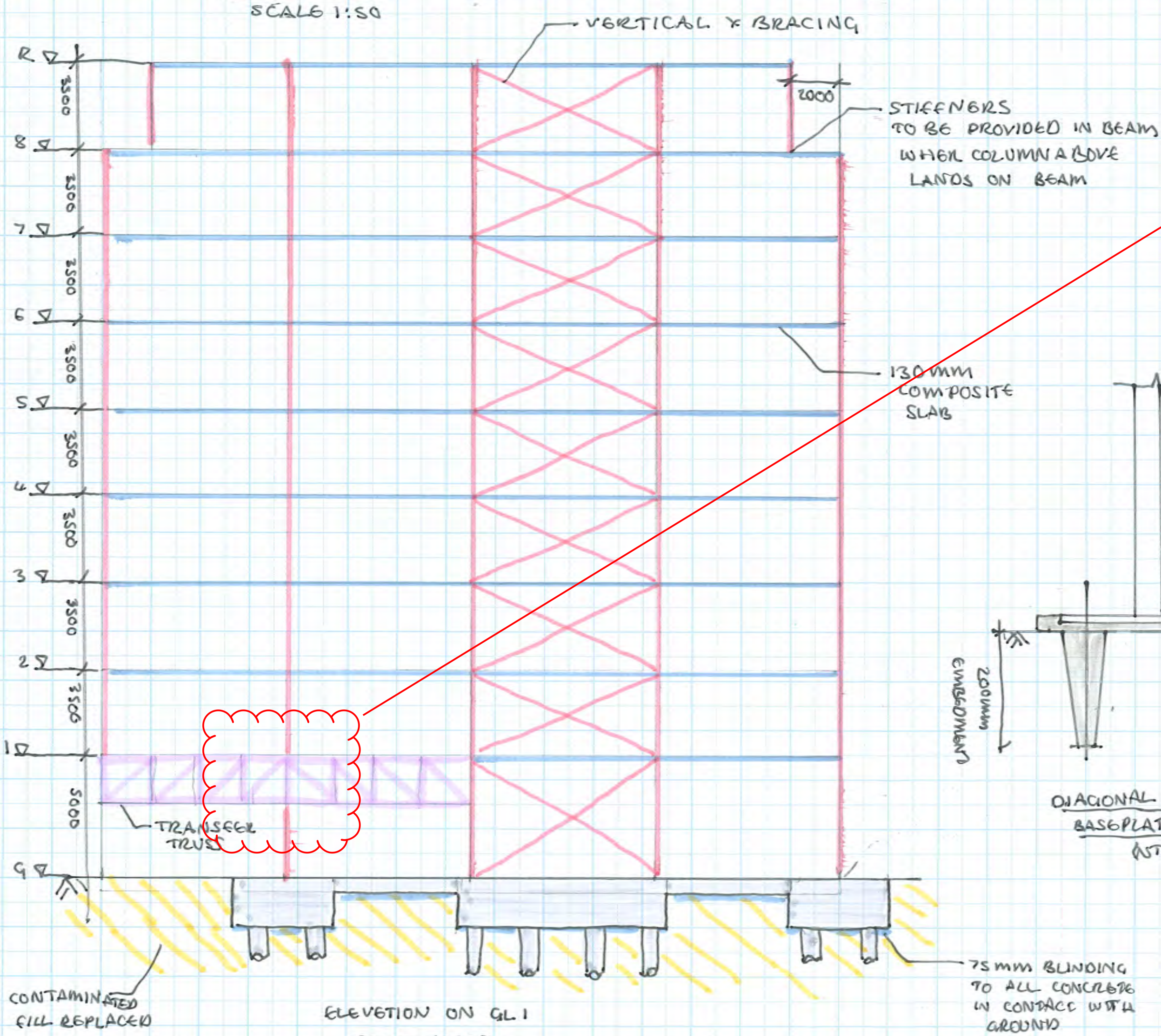
Examination question No. Q2

Candidate No. [redacted]

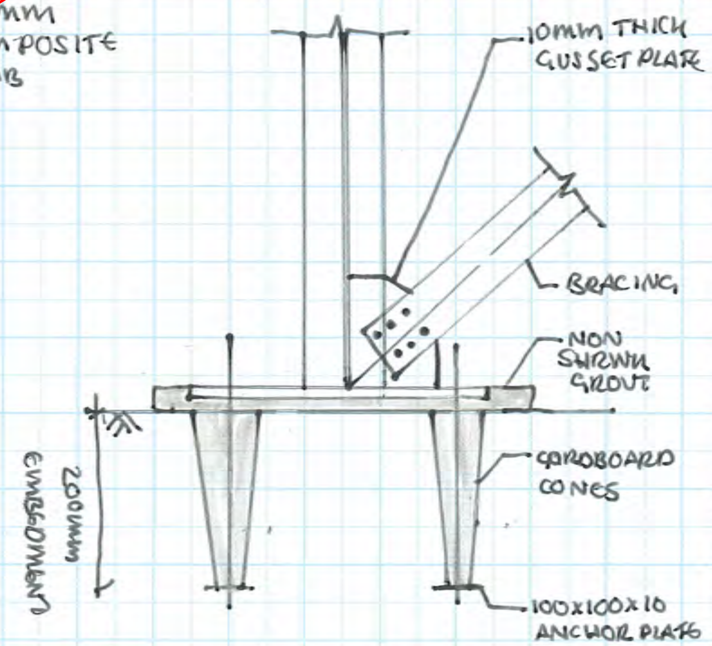
Sheet D1



TRUSS DETAIL
SCALE 1:50



ELEVATION ON GL 1
SCALE 1:200



DIAGONAL BRACING AND BASEPLATE DETAIL
(NTS)

NOTES

- REFER TO DRAWING 01 FOR DETAILS

This detail should be drawn as a critical detail

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Examination question No. Q2

Candidate No. [redacted]

Sheet 02