The Institution of Structural Engineers

Chief Examiner critique – Jan '24

Q1 – Conversion of industrial building to apartments

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Introduction

The Examinations Panel has produced this additional preparation guidance document to show what the Chief Examiner (the person who writes the question) was expecting candidates to consider when answering the question.

The critique does not cover all possible solutions for the question but details the fundamental design challenges and shows examples of how these could have been answered. Candidates are encouraged to consider all potential options as part of their preparation work.

Question Text

Client's Requirements

1. An existing vacant four-storey industrial building is to be converted into residential apartments, see Fig Q1. Two levels of sixteen apartments are to be constructed on each existing floor, providing a total of 128 apartments over eight storeys. The flat roof has a 1m high perimeter parapet.
2. A typical apartment is nominally 4m wide by 7m long with access to a 2m wide corridor. A clear floor to ceiling height of 2.3m is to be provided within the apartments. Each apartment is to have a 2m wide x 2m high window at 1m above finished floor level.
3. The existing building has solid brick external walls 0.45m thick. The perimeter walls have reinforced concrete spread foundations 1.5m wide. The existing north and south elevations have windows 2m high by 2m wide at 1m above each existing floor and a clear horizontal space of 2m between windows.
4. Floors are of precast concrete with structural topping spanning on to steel beams with fire protection, which in turn are supported by steel columns. The type and size of foundations to the columns are unknown.
5. A full height atrium is to be provided with a glazed roof and a glazed external elevation as shown in Figure Q1. The atrium is to incorporate a lift/elevator and staircase for access to all floors. The atrium and the lift/elevator/staircase areas should be clear of structure to allow for following works such as stair and lift/elevator installation.
6. A further internal lift/elevator and staircase to all floors is to be provided at each end of the building as shown in Figure Q1. The existing external staircases at each end of the building have been removed as part of the preparatory work.

Imposed Loading

7. Apartment floors 1.5kN/m^2
   Corridor floors 2.5kN/m^2
   Roof 1.0kN/m^2
   The unfactored imposed load capacity of the existing floors is 6.0kN/m^2.

Site Conditions

8. The site is located on the outskirts of a large city. Basic wind speed at sea level is 46.0m/s on a 3-second gust; the equivalent mean hourly wind speed is 23.0m/s.
9. Ground conditions
   Ground level – 0.3m Fill
   0.3 – 6.0m Dense sandy gravel. N = 50
   Below 6.0m Sandstone, characteristic compressive strength 3500kN/m^2
   No groundwater was recorded in the soil investigation.

Omit from Consideration

10. Stairs and lifts/elevators and atrium glazed roof and glazed elevation secondary steelwork.

SECTION 1 50 marks

a. Prepare a design appraisal with appropriate sketches indicating two distinct, viable and sustainable solutions for the proposed structure including the foundations. Reusing existing structures where required, clearly indicate the functional framing, load transfer, serviceability, and stability aspects of each scheme. Using sustainability as a key criterion, review and critically appraise the schemes, and identify the solution you recommend, giving reasons for your choice. (40 marks)

b. After the scheme design is complete, the Client asks you to suggest ways in which the brief could be altered to reduce material usage whilst maintaining the total number of apartments and an atrium. Write to your client proposing possible changes. As part of any proposals made, explain the effect this may have on the rest of the design. (10 marks)

SECTION 2 — 50 marks

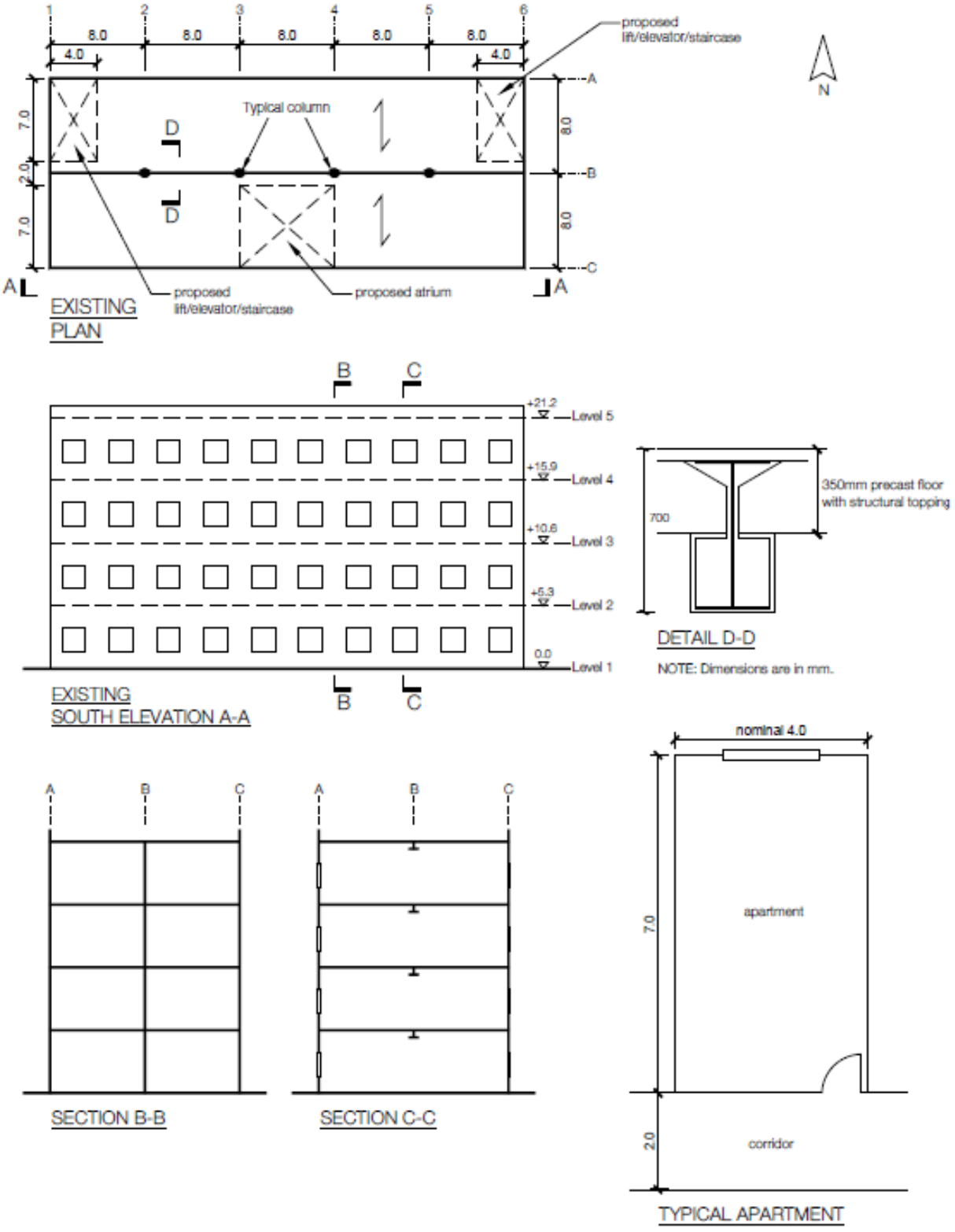
For the solution recommended in Section 1(a):

c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. Include approximate A1-A3 carbon calculations for each of your principle elements. (22 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. (8 marks)

Question Figure



NOTE: All dimensions are in metres unless otherwise noted.

FIGURE Q1

Critique

Section 1a – Key challenges

What are the main challenges?

- Comparing the proposed residential loading with the existing industrial one
- Checking the vertical clearances to accommodate an extra floor at each level.
- Use of existing E-W beams and columns versus independent new structure including reduced headroom in corridor
- Structural implication of the atrium and lift/ stair openings on overall and local stability.
- Increased window openings implication on brickwork elevation stability.
- Load path options are restricted by virtue of the apartments' layout.
- To reduce carbon embodiment, one would need to re-use as much as possible.

Preliminary work

It will be necessary to investigate/ survey the existing structure and foundations for geometry, condition and construction details to determine what can be re-used and how it could be integrated with new members and layout.

The clear minimum opening height for a doorway in a new build needs to be 2.0m.

New floors

- From load comparison it is possible for the existing slab, supporting E -W central beam and columns to carry the proposed extra residential floors. Lightweight construction would however be required.
- New partitions: Cold formed steel, timber frame, load-bearing lightweight masonry
- Timber flooring.
- Foundations ground-bearing or mini-piles

Option 1 Re-use of existing steel beam and columns

- New load-bearing partitions N-S at 4m c/c supporting lightweight flooring spanning 4m E–W and new E-W partitions along new corridors.
- Headroom below existing central N-S beam is restricted to 2.0m even though 2.3m clear to soffit to floor above is achieved either side of the central beam. Also, central column in the middle of the new corridor is not prohibited in the brief.
- Vertical loads taken down to new strip foundations (hit and miss sequence) so as not to disturb existing support to slabs and existing foundations.

Option 2 Replacement of existing central beam and columns by new supports

- New braced steel columns at N-S partition locations and lightweight flooring spanning 4m E-W.
- New steelwork support to existing slabs

- Benefit of no height restriction and no columns along the corridors.
- Temporary support to existing slabs prior to removal of existing E-W central beams and columns and installation of new supports
- New mini-piled foundations (less excavation), avoid disturbance to existing foundations.

Option 3 Re-use of existing central beam & columns along north edge of corridor.

- Temporary propping of existing slabs prior to removal of central beam and columns.
- Re-positioning of central beam and columns along edge of corridor on to new foundations (or adding to existing unknown).
- New lightweight partitions and flooring for intermediate floors.
- This is the preferred option subject to suitability for re-use of existing members.

Atrium Lateral support to exposed external elevations.

Option 1 Use new partitions as buttresses with lateral support from the plate action of existing floor slabs and associated foundation. Lateral support to glazed elevation and roof.

Option 2 New braced steelwork lateral support full height and associated foundation and glazed elevation and roof.

Lift/ stair cores

This involves removing existing slab and providing perimeter trim at NE and NW corners of the building. Check on stability and lateral restraint to the external masonry walls.

Option 1 Load-bearing masonry perimeter on new foundations

Option 2 Braced steelwork elevations on new foundations.

Stability

- The existing perimeter walls together with the plate action of the floors provide stability to the building.
- It is proposed not to impose additional loading from the new intermediate floors or to disturb the masonry unnecessarily except for the changes to the existing window openings and the formation of additional ones and for the atrium work.
- Vertical and horizontal restraints are needed to the cut vertical edge at the full-height atrium opening.

New windows

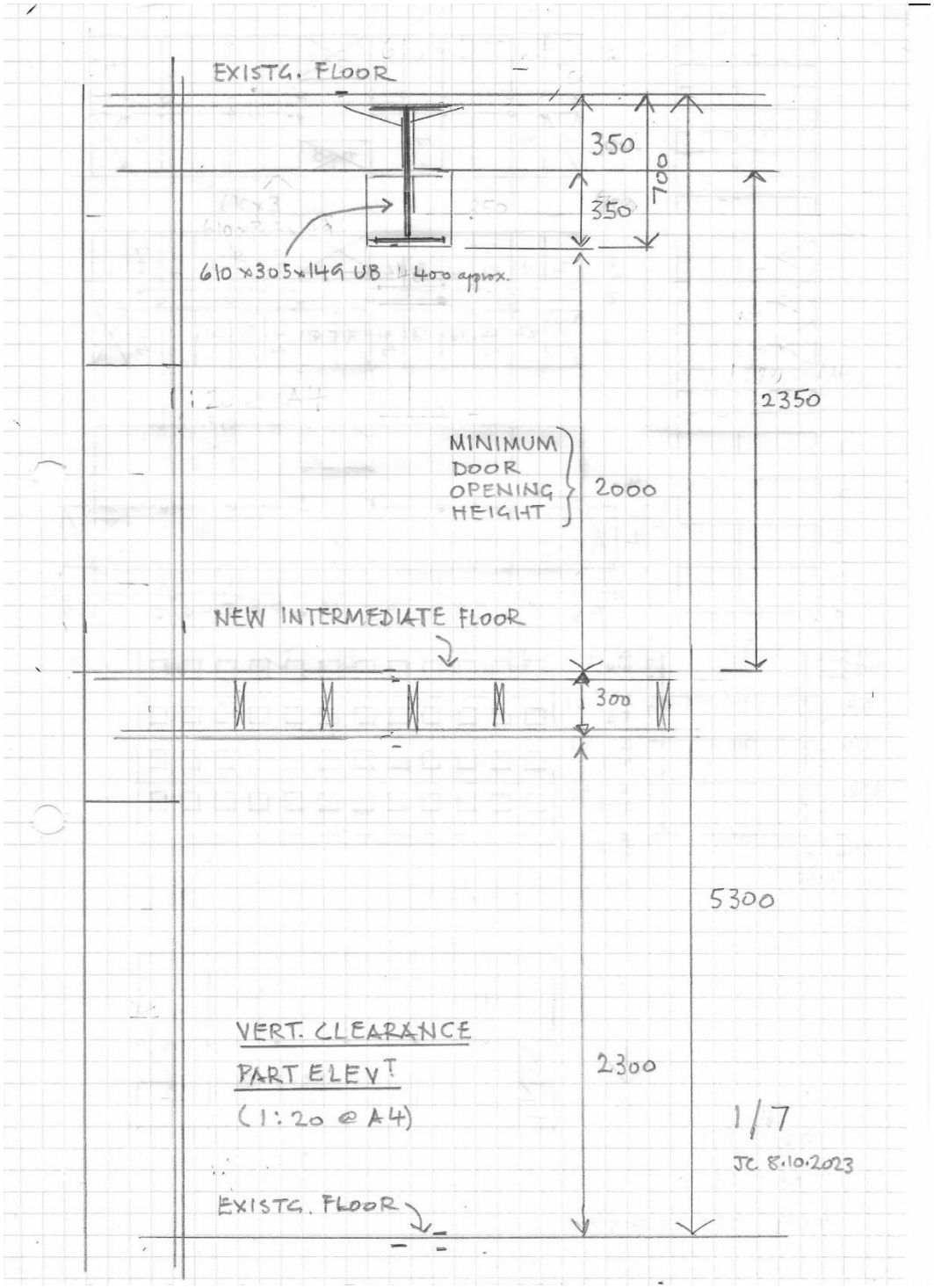
There are clearly an increased number of new openings for the new apartments for which existing tall openings will need to be modified to suit and new openings above formed. Recognition of implications on stability of the external brick elevations and of any temporary supports.

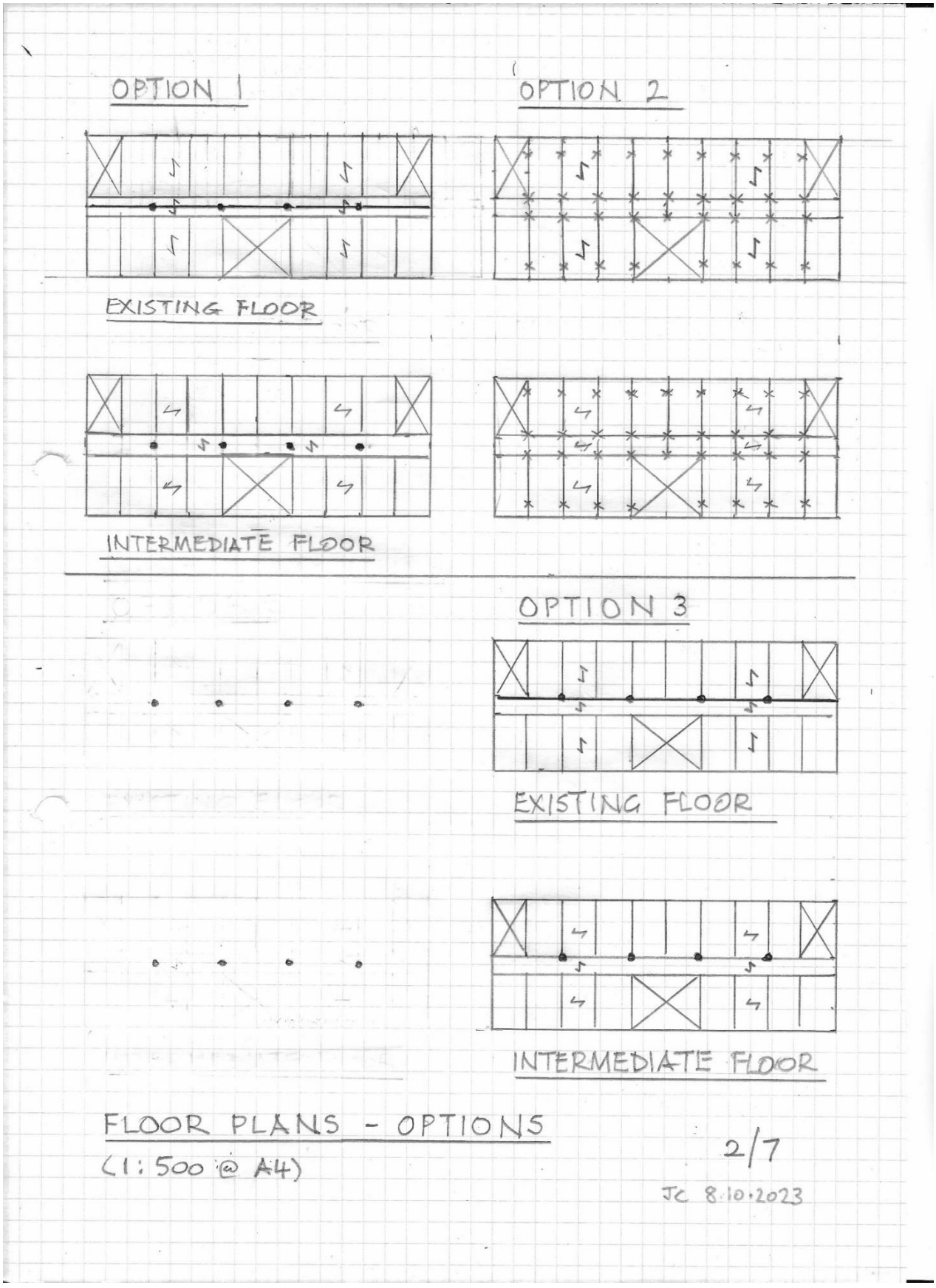
Foundations

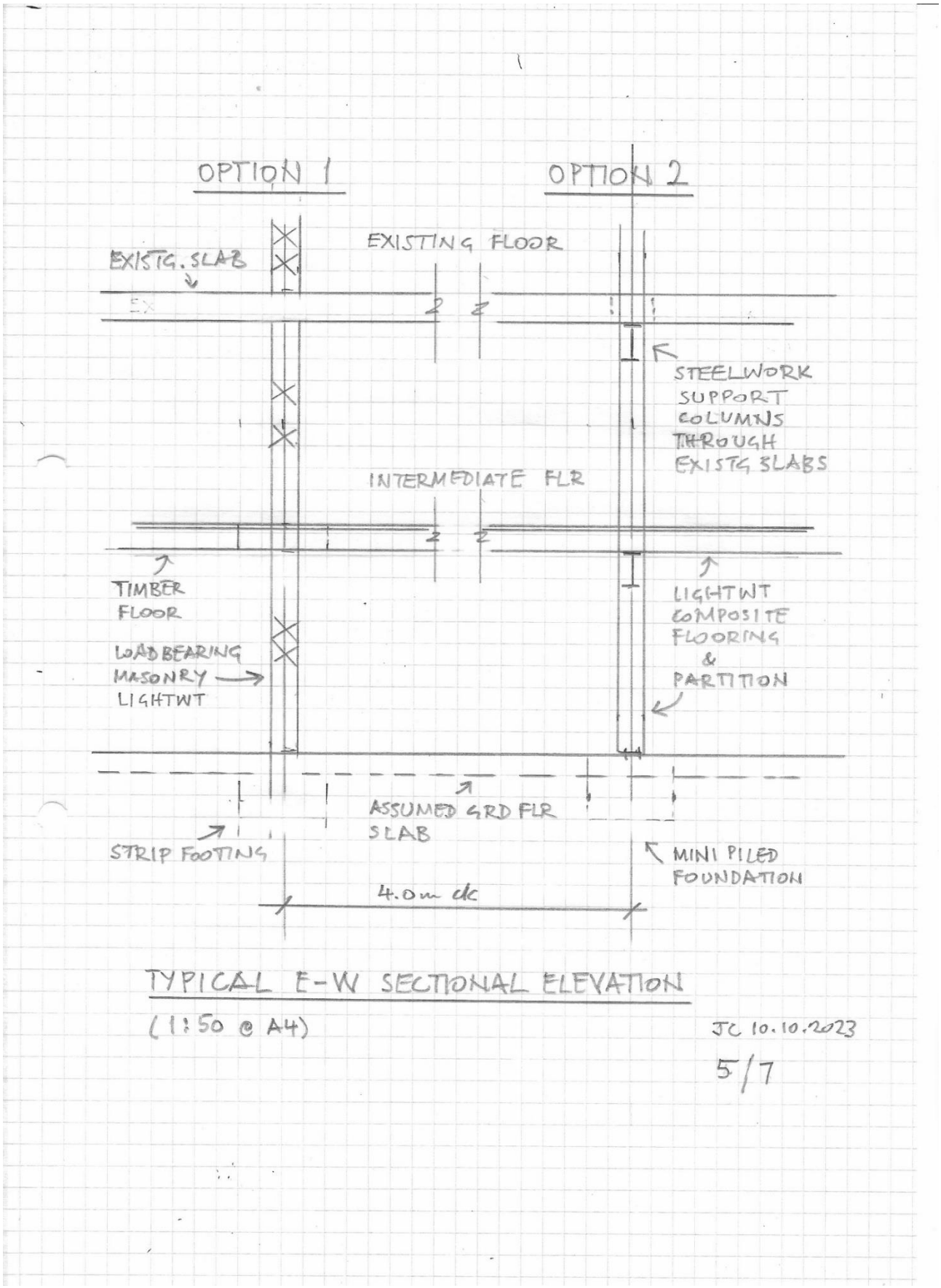
Due to the good ground conditions and restricted headroom, the use of large diameter piles and heavy equipment would be difficult to accommodate or feasible. Other factors include protection of existing and unknown foundations.

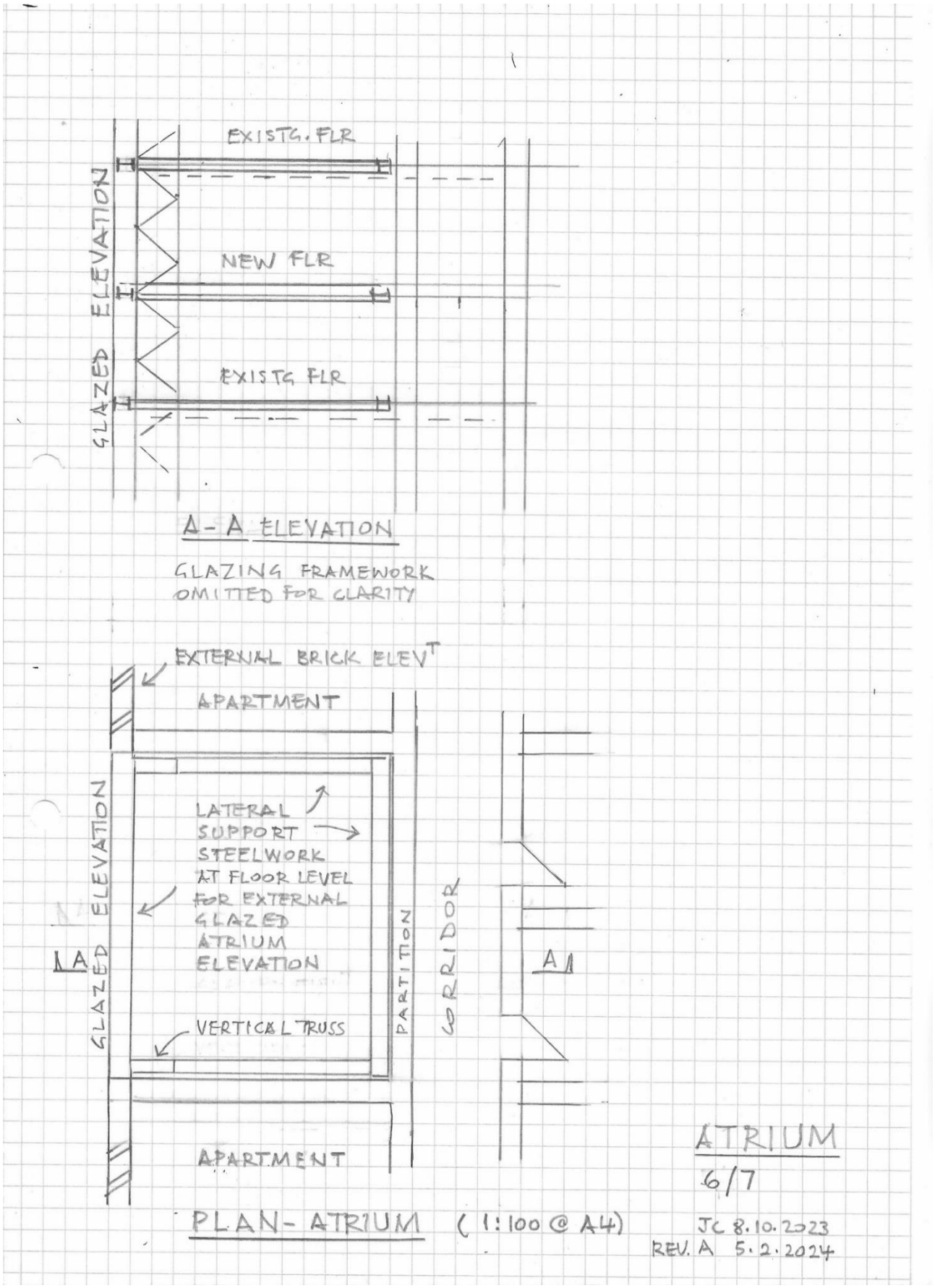
It is envisaged that spread footings or minipiles would be appropriate.

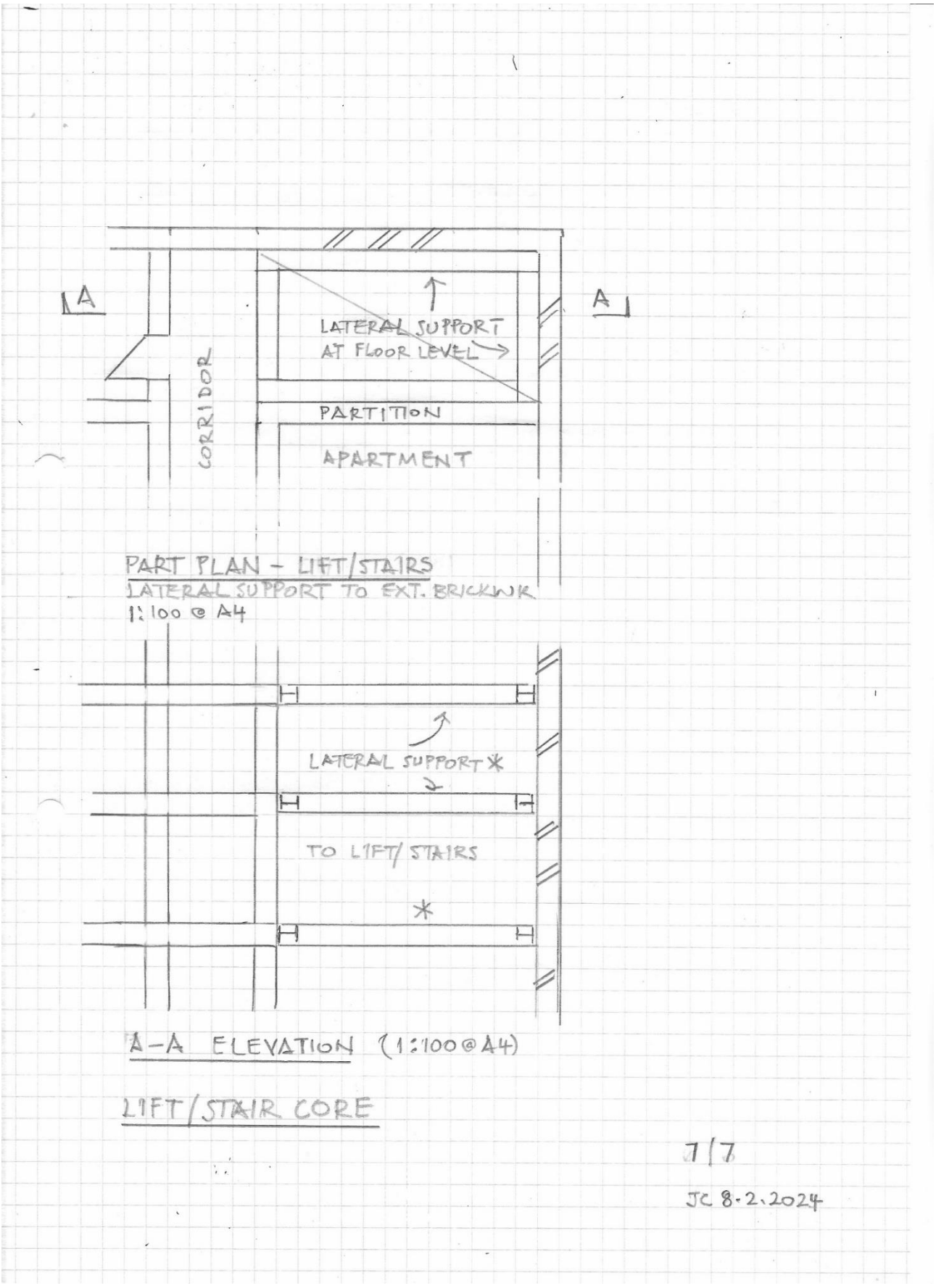
Sketches

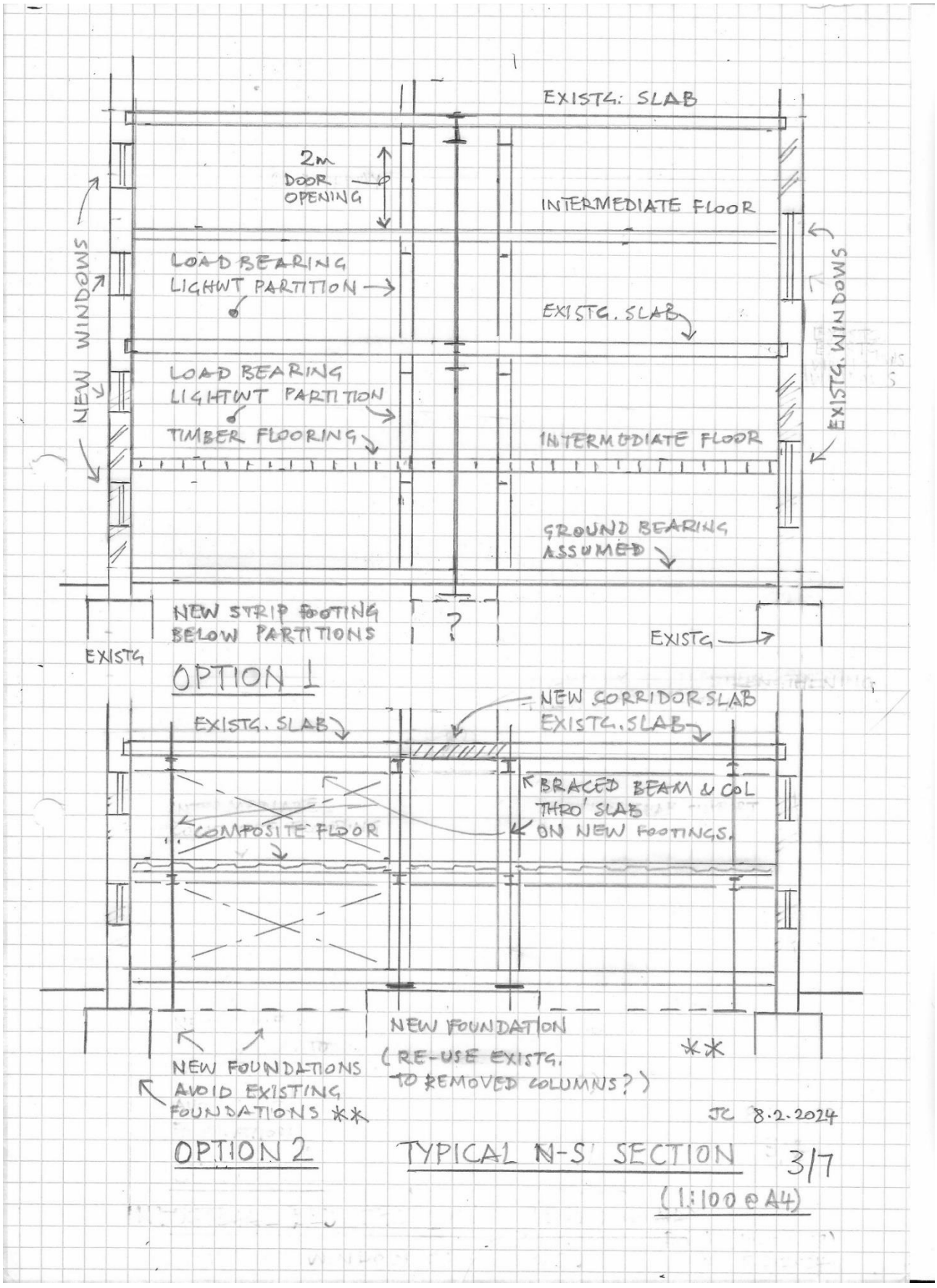


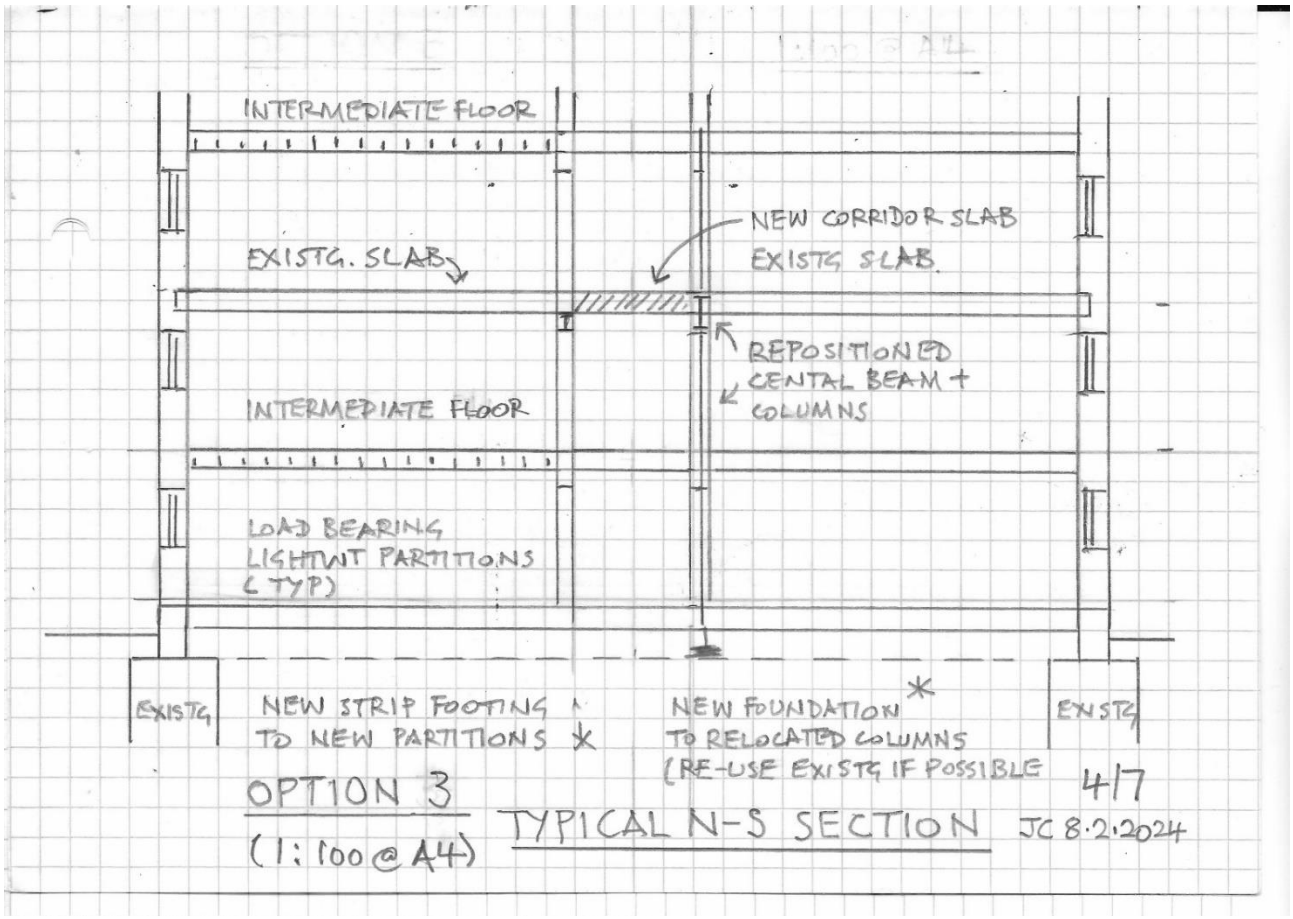

OPTION 1
OPTION 2
EXISTING FLOOR
INTERMEDIATE FLOOR
OPTION 3
EXISTING FLOOR
INTERMEDIATE FLOOR
FLOOR PLANS - OPTIONS
(1:500 @ A4)
2/7
JC 8.10.2023


OPTION 1
OPTION 2
EXISTG. SLAB
EXISTING FLOOR
STEELWORK SUPPORT COLUMNS THROUGH EXISTG SLABS
INTERMEDIATE FLR
TIMBER FLOOR
LOADBEARING MASONRY LIGHTWT
LIGHTWT COMPOSITE FLOORING & PARTITION
ASSUMED GRD FLR SLAB
STRIP FOOTING
MINI PILED FOUNDATION
4.0m c/c
TYPICAL E-W SECTIONAL ELEVATION
(1:50 @ A4)
JC 10.10.2023
5/7


EXISTG. FLR
NEW FLR
EXISTG FLR
GLAZED ELEVATION
A-A ELEVATION
GLAZING FRAMEWORK OMITTED FOR CLARITY
EXTERNAL BRICK ELEV^T
APARTMENT
LATERAL SUPPORT STEELWORK AT FLOOR LEVEL FOR EXTERNAL GLAZED ATRIUM ELEVATION
VERTICAL TRUSS
GLAZED ELEVATION
PARTITION
CORRIDOR
A
A
APARTMENT
PLAN- ATRIUM (1:100 @ A4)
ATRIUM
6/7
JC 8.10.2023
REV. A 5.2.2024


A
A
LATERAL SUPPORT AT FLOOR LEVEL
CORRIDOR
PARTITION
APARTMENT
PART PLAN – LIFT/STAIRS
LATERAL SUPPORT TO EXT. BRICKWK
1:100 @ A4
LATERAL SUPPORT *
TO LIFT/STAIRS
*
A–A ELEVATION (1:100@A4)
LIFT/STAIR CORE
7/7
JC 8.2.2024


EXISTG. SLAB
2M DOOR OPENING
INTERMEDIATE FLOOR
LOAD BEARING LIGHWT PARTITION
EXISTG. SLAB
NEW WINDOWS
LOAD BEARING LIGHTWT PARTITION
TIMBER FLOORING
INTERMEDIATE FLOOR
EXISTG. WINDOWS
GROUND BEARING ASSUMED
NEW STRIP FOOTING BELOW PARTITIONS
?
EXISTG
EXISTG
OPTION 1
NEW CORRIDOR SLAB
EXISTG. SLAB
EXISTG. SLAB
BRACED BEAM & COL THRO' SLAB ON NEW FOOTINGS.
COMPOSITE FLOOR
NEW FOUNDATION (RE-USE EXISTG. TO REMOVED COLUMNS?)
**
NEW FOUNDATIONS AVOID EXISTING FOUNDATIONS **
JC 8.2.2024
OPTION 2
TYPICAL N-S SECTION
3/7
(1:100 @ A4)



Section 1b – changes to the brief for reduction in material usage options

- External lift/ staircases as previously noted
- External atrium
- Benefit of additional usable floor space and reduced risk of opening-up and reducing waste
- Modular construction to reduce waste and construction time.

Section 2c – calculations

What calculations are you expecting candidates to perform for principal elements?

- Loadings and vertical clearances
- Superstructure for apartments and central corridor
- Foundations
- Stability
- Lateral support for atrium and lift/stair openings

Section 2d - drawings

What do you expect candidates to detail here? What plans/part plans, sections, elevations are crucial to the scheme design?

- Typical floor plan for existing and intermediate floors
- Typical E-W section through apartments
- Typical N-S section through apartments (bonus marks)
- Lateral support of brickwork at atrium, plan and elevation
- Lateral support of brickwork at lift/ stair openings (bonus marks)
- Critical details: 3no: Atrium to brickwork connection, new floor to existing structure, new floor typical detail.

Section 2e – method statement

What are the key aspects of the construction process candidates need to include?

- Existing structural condition and construction details,
- temporary propping and opening-up works,
- construction sequence of new floors,
- stability of walls to atrium and lift/ stairs openings when floors removed,
- central beam and column if replaced or repositioned,
- protection of existing foundations for the construction of new ones,
- maintaining stability when blocking existing window openings and forming new ones for new apartment locations.