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# Model Answer Q1, 2013:

# Institution of Structural Engineers Chartered Membership Examination

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# FOREWORD

This document has been prepared to assist candidates preparing for the Institution of Structural Engineers chartered membership examination. It forms one of a series of answers, demonstrating steel solutions.

The document was prepared by Ed Yandzio and David Brown of the Steel Construction Institute (SCI), with valuable input from Tom Cosgrove of the British Constructional Steelwork Association (BCSA) and Owen Brooker of Modulus.

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## Contents

# 1 THE QUESTION

A range of past papers is available from the Institution of Structural Engineers at the following url: https://www.istructe.org/membership/examination/papers-etc

The question addressed by this model answer is Question 1 from 2013; it is recommended that the full question is reviewed.

The question requires:

- Development of two distinct and viable schemes
- A recommendation on the scheme to be adopted
- Design calculations for the principle structural elements
- General arrangement plans, sections and elevations
- A method statement
- An outline construction programme
- A letter to the client advising on the implications of the change specified in section 1b

## 1.1 General arrangement

The challenge posed by the question was a factory and adjoining office and storage building, with the overall dimensions shown in Figure 1

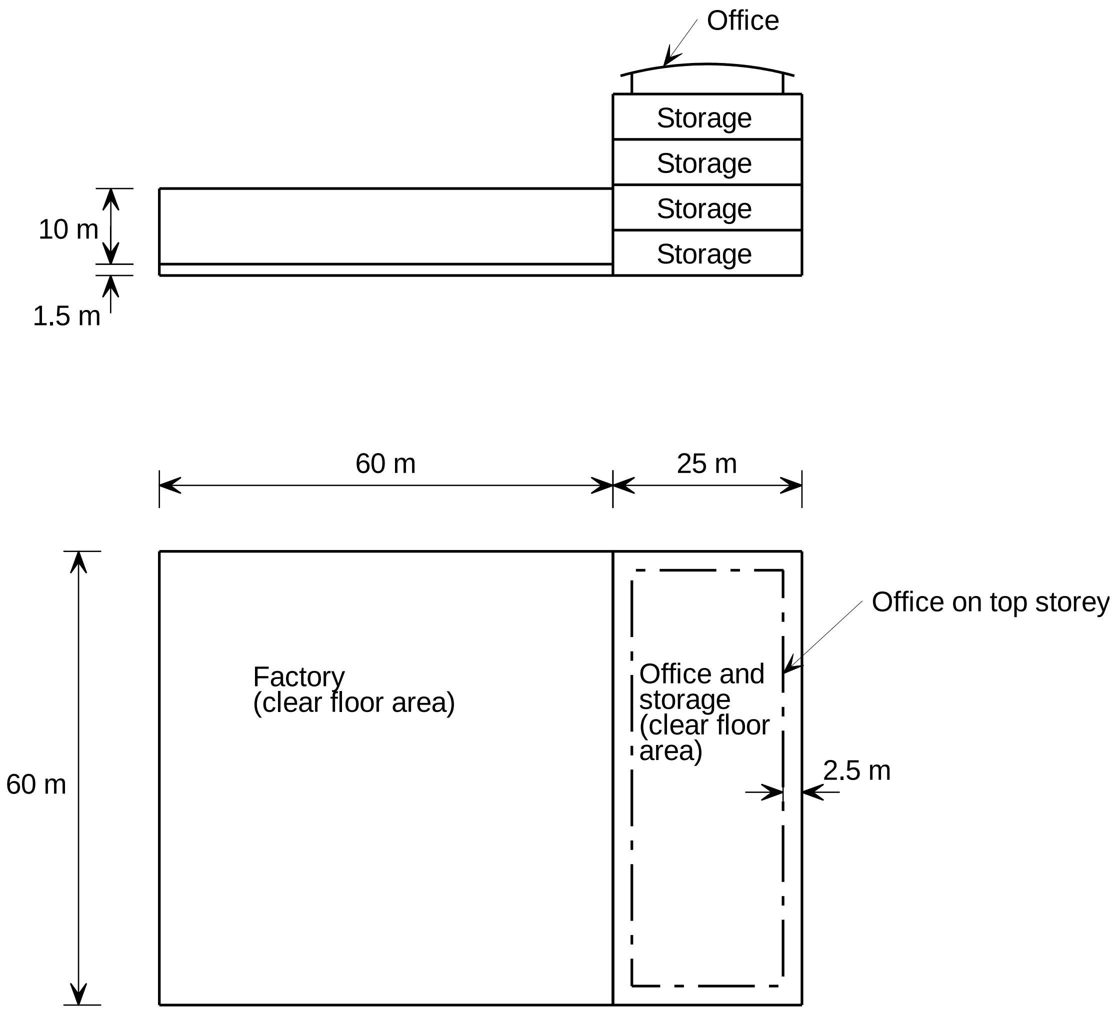


Figure 1 General Arrangement

The factory had to be without internal columns. The clear headroom was to be 10 m, with the floor 1.5 m above ground level. Six equally spaced doors, each 5 m × 5 m were required on the West elevation.

The storage floor areas were also to be without internal columns, with a clear internal floor-to-floor height of 4 m. Two access cores were specified, each 8 m × 4 m on plan.

Both the factory and the storage building were to be clad in composite panels.

The office area was to have a clear internal height of 2.8 m, no internal columns, and clad in glass.

## 1.2 Loading

The following loads were specified:

Roof 1.5 kN/m$^2$

| | |
|---|---|
| Factory floor | 10 kN/m$^2$ |
| Storage floors | 15 kN/m$^2$ |
| Office | 3.5 kN/m$^2$ |

Basic wind speed of 40 m/s based on a 3 second gust, or a mean hourly wind speed of 20 m/s.

## 1.3 Ground conditions

| | |
|---|---|
| Ground level to – 2 m | Made ground |
| 2 m – 5 m | Sand and gravel; N = 15 |
| 5 m – 8 m | Clay; C = 250 kN/m$^2$ |
| Below 8 m | Rock; allowable bearing pressure 1500 kN/m$^2$ |

Ground water at 4 m below ground.

## 1.4 Section 1b modification

The client wishes to install two cranes in the factory area, running East-West, with a central row of columns.

# 2 CALCULATIONS

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CALCULATION SHEET

| Job No. | Sheet 1 of 53 | Rev |
|---|---|---|
| Title | | |
| Subject | | |
| Client | Made by | Date |
| | Checked by | Date |

# SECTION 1(a) – ALTERNATIVE SOLUTIONS

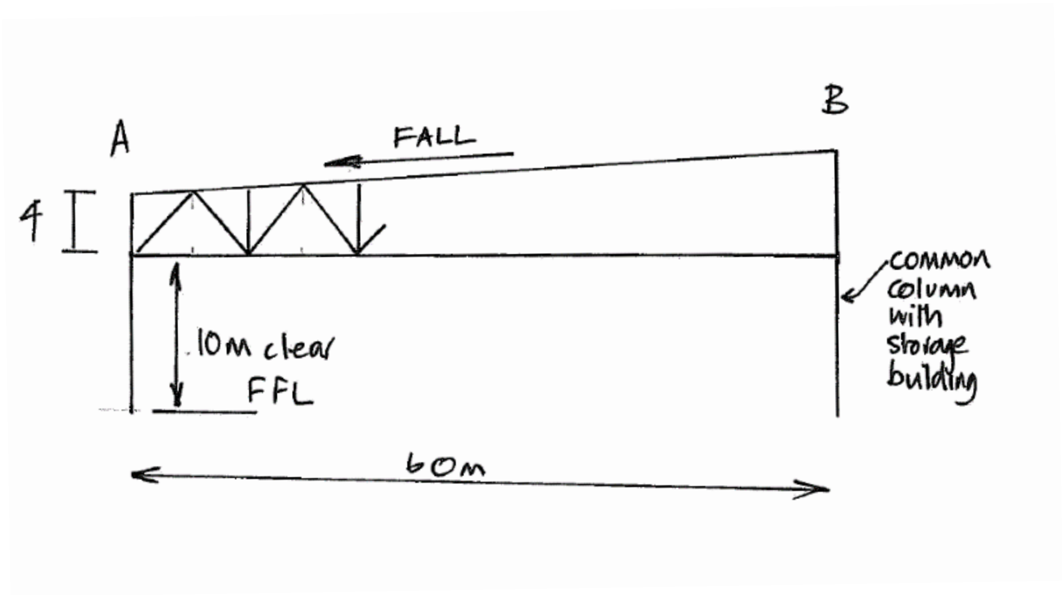
Both schemes are braced steel framed solutions. In both solutions, steel trusses are proposed for the factory area to meet the need for a column free floor area. The storage facility is also a braced frame, with trusses providing the column free space.

## Scheme 1

For the factory, simply-supported long span trusses are provided spanning East-West, at 10 m centres. Stability for the factory structure is provided by horizontal roof bracing and vertical bracing on the elevations. The factory forms a simple braced "box".

### Framing arrangement - factory

60 m span warren truss, so depth = span/15 = 4 m
Fall away from storage building.
Trusses are simply supported at each end, so all stability provided by bracing in roof and vertical bracing in each elevation.




Typical cross section on grid 2 - 6

The two schemes are summarised here. Although detailed calculations are not required at this stage, it is essential to describe, with diagrams:

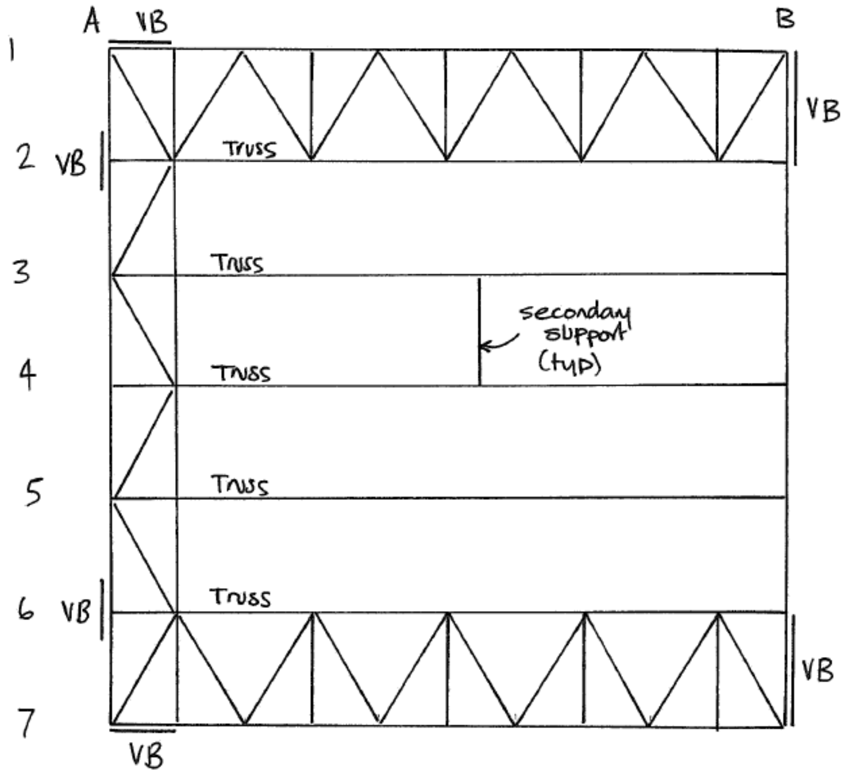
- the functional framing of the structure
- how loads are transferred
- how stability is provided

The immediate observations on the question are:

- two separate structures with a common interface between the factory and storage area (so potential differential settlement)
- the need for clear space in the factory, so the obvious solution is trusses
- the very high loads in storage building combined with long spans across the building
- the relatively low bearing pressure in the clay, so piled foundations are likely

The development of two distinct schemes is a challenge in this question, as the long spans dominate the solution.

The obvious solution for the factory area is trusses. Observing the later requirement to comment on the installation of cranes, a portal frame, though possible, could lead to questions about deflections being inappropriate for crane operations.
60 m span is not a problem for a truss. The trusses have been chosen to span E-W, so that at the interface on Grid B, there is no problem with differential settlement – the trusses are pin-ended on Grid B.
Trusses spaced at 10 m fit well with the requirement for the six delivery doors on the West elevation. The secondary steelwork supporting the cladding will be longer spans (10 m) than usual.
Reversal must be considered, so a necessity to provide restraint to the bottom chord of the truss.
60 m trusses will need to be connected by bolting on site.




Plan view

**Load transfer - Factory**

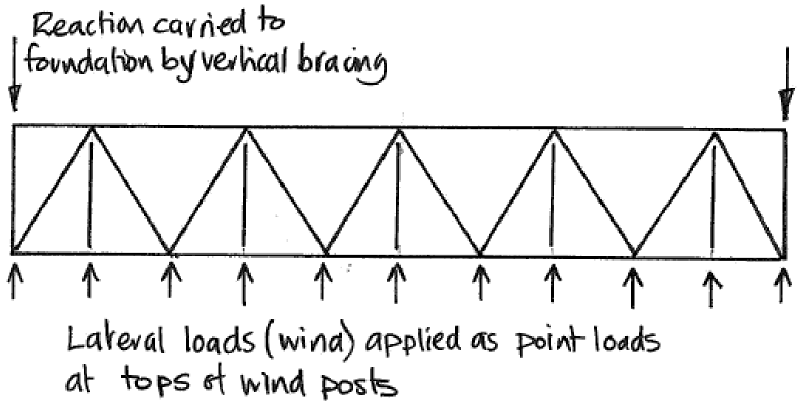
Vertical loads on roof cladding are carried by simply supported secondary steel members to the primary trusses. The trusses are supported by columns at each end, transferring the vertical loads to the foundations.

Lateral loads on grids 1 and 7 are transferred from the side cladding to horizontal rails spanning between vertical columns at 6 m centres. The columns, acting as simply supported members transfer the load to the foundation (at the base) and as point loads onto horizontal trusses in the plane of the roof at roof level.

Trusses in the plane of the roof carry the lateral load to vertical bracing on grids A and B, and thus to the foundations.

To ensure the requirements to describe framing, load transfer and stability are met, a paragraph is identified for each requirement.

Lateral stability in both directions will be by horizontal trusses at roof level and vertical bracing on the elevations – a standard approach




Typical roof bracing grids 6 - 7

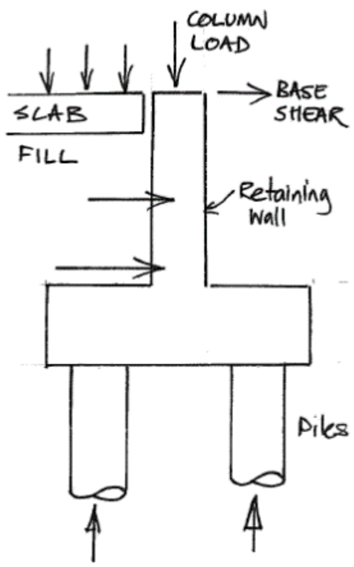
Lateral loads on grid A are transferred from the side cladding to horizontal rails spanning between vertical columns at 6 m centres. The columns transfer the load to the foundation (at the base) and as point loads onto a horizontal truss in the plane of the roof at roof level. The truss carries the loads to grids 1 and 7, where vertical bracing conveys the loads to the foundations.

**Stability - Factory**

The factory area is stabilised in both directions by the horizontal bracing in the plane of the roof and by the vertical bracing.

**Foundations - Factory**

Around the factory, a reinforced concrete retaining wall is proposed to retain fill under a ground floor concrete floor slab. Perimeter columns are supported on the retaining wall, which will be verified for the column loading. A ground bearing floor slab is provided in the factory area.



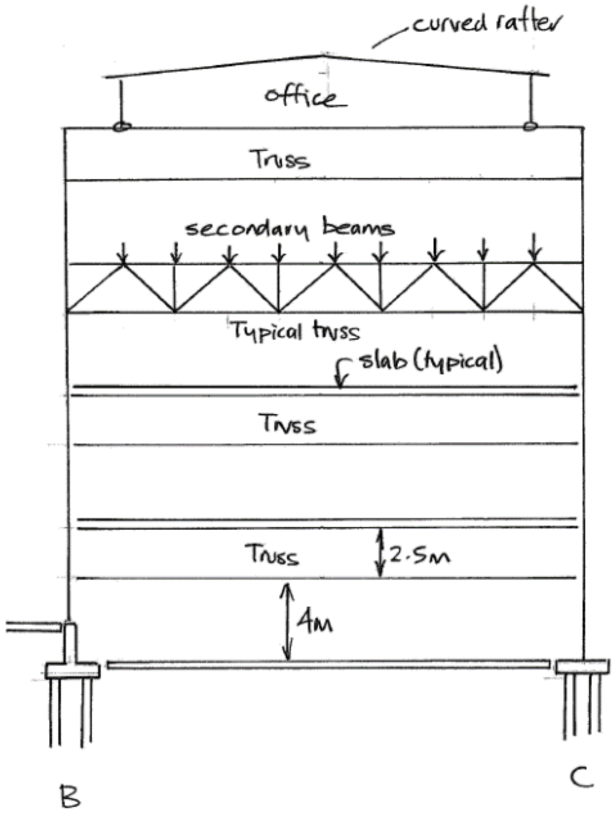

Cross section of retaining wall and column support

The 60 m trusses are unstable in the temporary condition. A braced pair of trusses could be erected initially, and the building constructed from the stable section.

A preliminary investigation indicates that the bearing pressure is low, so a piled foundation is anticipated.

## Framing arrangement - Storage building

The storage / office facility comprises secondary beams spanning 10 m North-South. The secondary beams are supported by substantial trusses at 10 m centres, spanning to perimeter columns on grids B and C.




Cross section of storage building

## Load transfer – Storage building

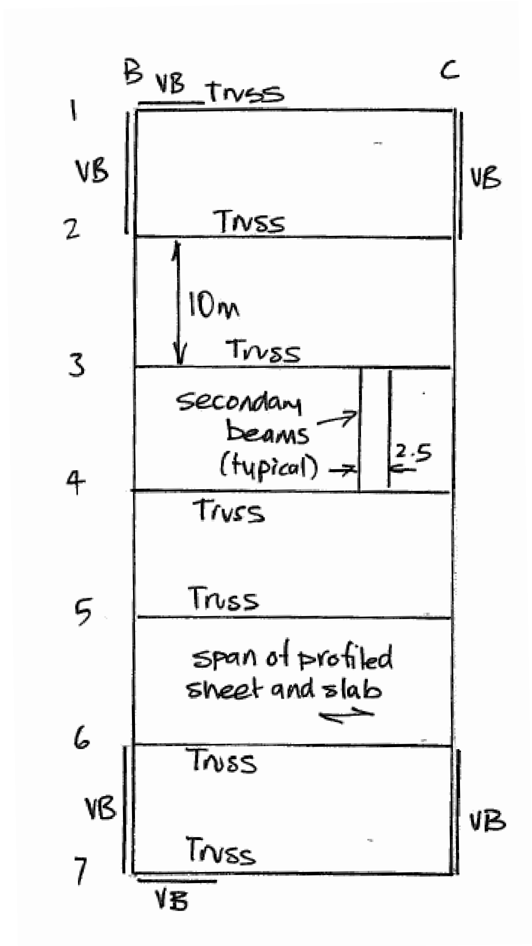
Vertical loads are transferred from the floor slab to the secondary beams spanning North-South at 2.5 m centres. The secondary beams are supported by trusses spanning East-West. The simply supported trusses transfer the vertical loads to the columns on the elevations, and thus to the foundations.

Lateral loads are transferred from the cladding to horizontal rails spanning to the columns on the elevations. The columns span between floors. The concrete floors are diaphragms which transfer the lateral loads to the vertical bracing systems on each elevation.

The storage loads are huge, and the requirement for the clear span of 25 m leads immediately to trusses – of very heavy construction. The foundations for this building will be a challenge.  10 m spacing suits the factory trusses – 5 m spacing would reduce the loads on each truss and column, and mean smaller foundations, so this is a viable alternative

The secondary beam spacing of 2.5 m is low but the imposed load is very high.  Composite beams could be utilised, but these are too difficult to design in the exam, so in the detail calculations, non-composite but fully restrained beams are proposed.

The two access cores are clearly available to be used as bracing to provide stability. The cores must be inset within the perimeter, else they would clash with the office on the top storey, so are not immediately ideal. Conventional bracing on the perimeter is easy to design




Typical floor plan – storage building

## Stability – Storage building

Stability is provided by the diaphragm of the concrete floor, and vertical bracing on each elevation. The building forms a braced box. The large vertical loads will mean that frame stability is very significant – a conservative approach will be taken to ensure second-order effects are not significant.

Temporary bracing will be required in each floor, until the floor has been cast and acts as a diaphragm.

## Foundations – Storage building

Piled foundations are provided to support the columns. On grid B, the column and foundations carry the load from the storage building and the factory area.

A ground bearing floor slab is provided at the lowest level.

## Office

The office on the uppermost storey is a simple portal frame, spanning East-West, with portalised vertical bracing (PB) in the North-South elevations and roof bracing at both the ends of the structure.

Vertical loads are carried by cladding to secondary steel members (at typically 1.8 m centres) which span 10 m onto the curved rafters.

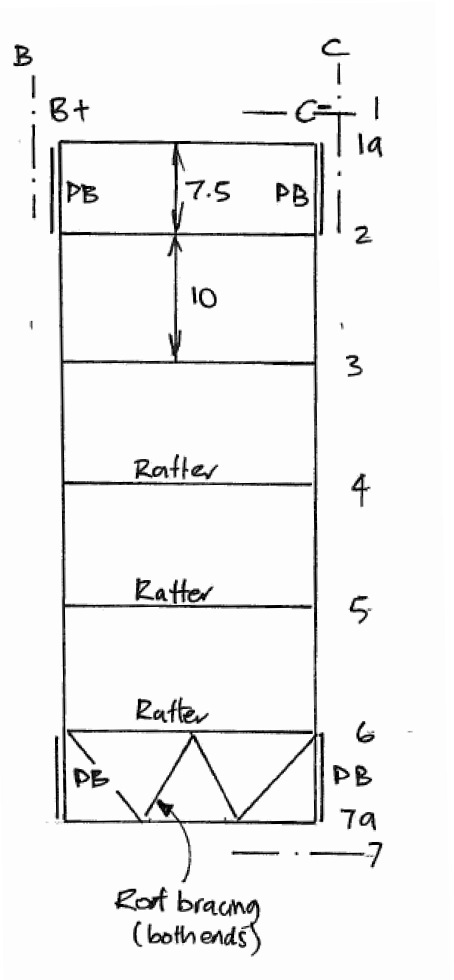
The vertical loads are carried by the columns, through nominally pinned bases.

Stability is always noted as being critical in the examiner's comments – so a full description with annotated sketches is recommended.

Helpful to identify issues that arise during construction

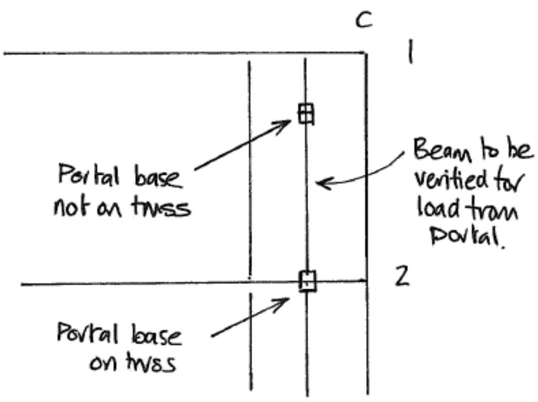
Certain to need piled foundations here as the loads are so large

The office on the top storey is almost an irrelevance compared to the storage loads. The brief says it is clad in glass, so presumably the idea of vertical bracing is not welcome. A simple portal frame (with a curved rafter) is proposed. Longitudinally, bracing will be avoided by portalised bracing in one bay. The portal is conventional.




Plan on office building

The bases on grids 1a and 7a are not located on a principal truss, so the secondary beams at those locations will be verified to carry the (relatively small) vertical load to the two adjacent trusses.



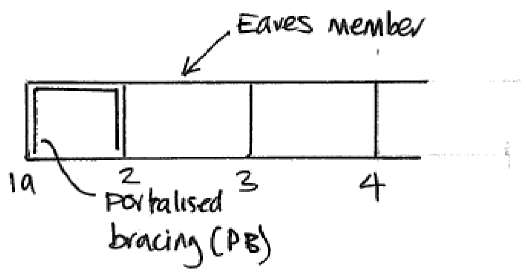

Arrangement to support corner of the office building

The vertical loads are small.

## Load transfer – office structure

Lateral loads are transferred through the continuous portal frame to the nominally pinned bases. Moment resisting connections will be designed at the eaves to ensure continuity. The lateral loads are transferred through the floor slab diaphragm to the vertical bracing on grids 1 and 7, and thence to the foundations.

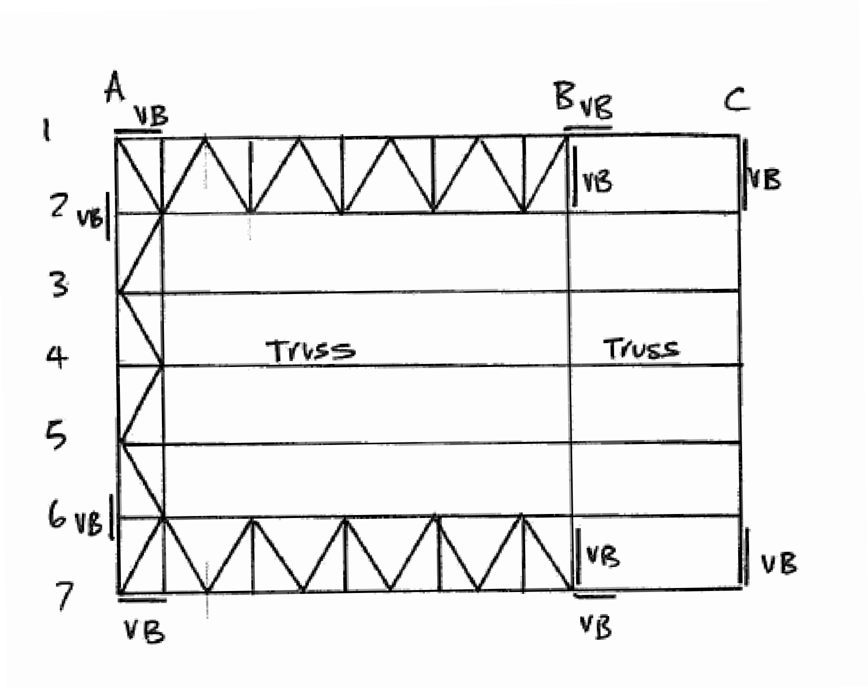
Longitudinal loads on the office building, are transferred by gable posts on grids 1 and 7a to the floor diaphragm (at the base) and to bracing in the plane of the roof. The roof bracing conveys the loads to the eaves. In both end bays (1a to 2 and 6 to 7a), a rigid jointed portal is provided on grids B+ and C- to transfer the longitudinal loads to the base level. The floor diaphragm transfers these loads to the vertical bracing on grids B and C, and thus to the foundations.




Part elevation of office building

## Stability – office building

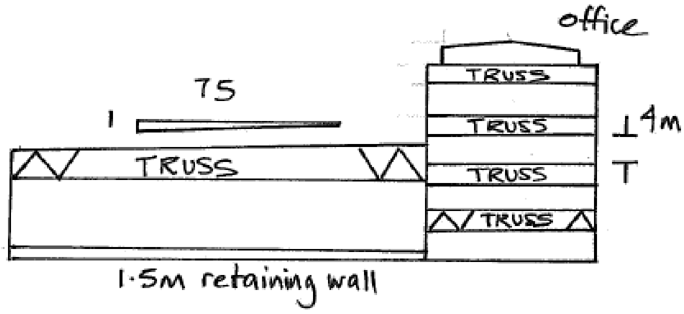
Laterally, the office structure is a continuous frame and needs no in-plane bracing. Longitudinally, stability is provided by the portalised bracing at each ends of the structure.



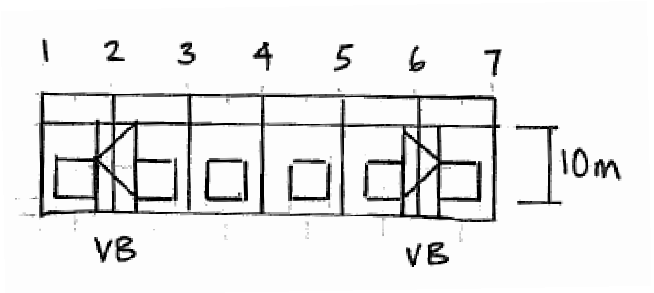

Scheme 1 – plan of main steelwork

Because the office is wide and low, there is significant base shear. On most grids, the portals sit on the trusses, so there is a tie between portal legs. For the very end portal frame, there is no tie. It could be assumed that the concrete floor slab will carry this load, or a tie provided. For the end frame the loads (and base shear) are small.

This arrangement to recognise the glass cladding



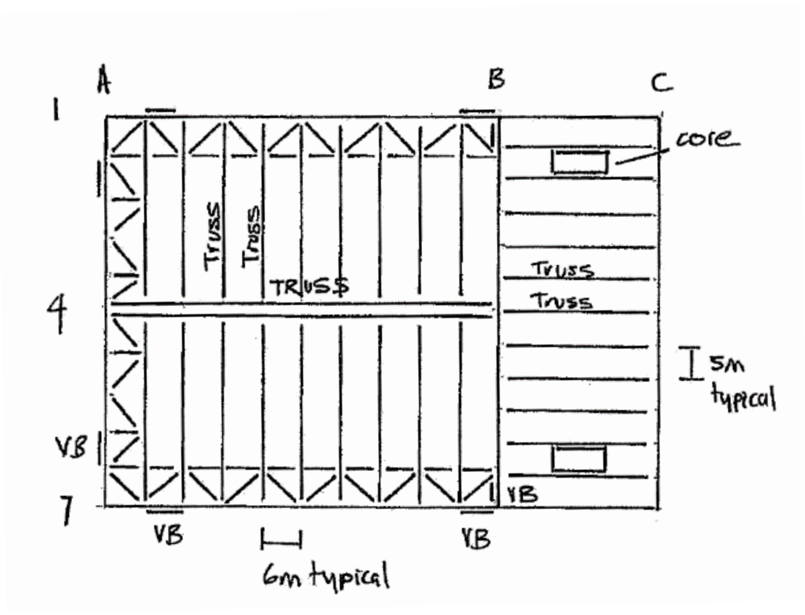

Scheme 1 – typical cross section




Scheme 1 – elevation on loading bay doors

## Scheme 2

For the factory, a central 'spine' truss (of a box form, to provide stability in the part-erected state), spans East-West on grid 4. Secondary trusses at 6 m centres span 30 m North-South from the spine truss to the elevations on grids 1 and 7. Stability for the factory area is provided by roof bracing and vertical bracing on the elevations. A ground bearing floor slab is provided throughout the factory area. For the storage building, trusses spanning East-West are provided at 5 m centres, with the two cores providing structural stability.




Scheme 2 - plan

Vertical bracing on the west elevation would normally be between primary columns – but these are at 10 m centres, so relatively wide, and the doors preclude that arrangement. Bracing stacks 5 m wide fit between the doors, so can be proposed. An alternative detail could have the columns on grids 2 and 6 transferred onto the columns forming the bracing system – so two columns instead of 3, but this is a minor detail

It is not easy to imagine a thoroughly different scheme for the factory – long spans are needed, so trusses are required. A central spine truss is the option proposed, as the secondary trusses have a much smaller span (30 m), and in this scheme are spaced at 5 m, so are considerably lighter. There are more trusses, however, so the economics probably still favours scheme 1.

Halving the bay size means that the foundation loads are also halved.

The central spine truss is in the form of a box, so it is stable within itself, and easier to erect than the primary trusses in scheme 1.

## Framing arrangement - Factory

Spine truss spans 60 m, so depth 4 m throughout. As the truss is key to the scheme and is heavily loaded, preliminary calculations follow to show the solution is viable.

### Roof loading

Say 0.30 kN/m$^2$ permanent

Say 0.15 kN/m$^2$ services

1.5 kN/m$^2$ variable (from brief)

ULS loading = 1.35(0.3+0.15) + 1.5(1.5) = 2.86 kN/m$^2$

Loaded width on spine truss = 30 m, so 85.8 kN/m

Midspan bending moment = 85.8 x 602/8 = 38610 kNm

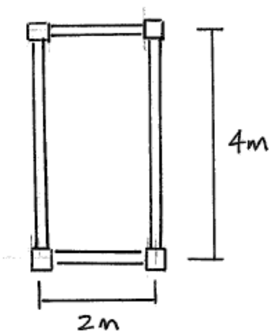
Force in each chord (twin truss), 4 m deep = 38610/(2 x 4) = 4825 kN

350 x 350 x 12.5 $N_{bRd}$ = 5330 kN, so main chords OK

End reaction on each truss = 85.8 x 60 / 4 = 1287 kN

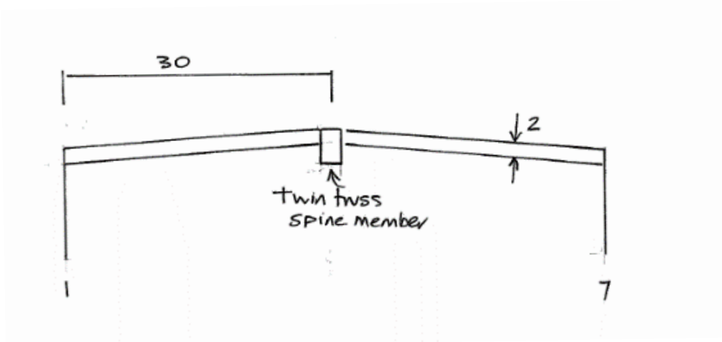
1287 equates to 1820 kN in a diagonal. 250 x 250 SHS OK

Preliminary calculations show that the spine truss is viable. Spine truss is box profile, 4 m deep by 2 m wide.




cross section of spine truss

Secondary trusses at 6 m centres span from grids 1 and 7 to the spine truss on grid 4. Depth = span / 15 = 2 m




Scheme 2 – cross section through factory area

Preliminary calculations only needed if the proposal is unusual in some way

This calculation is simply to verify if a reasonable truss can be envisaged

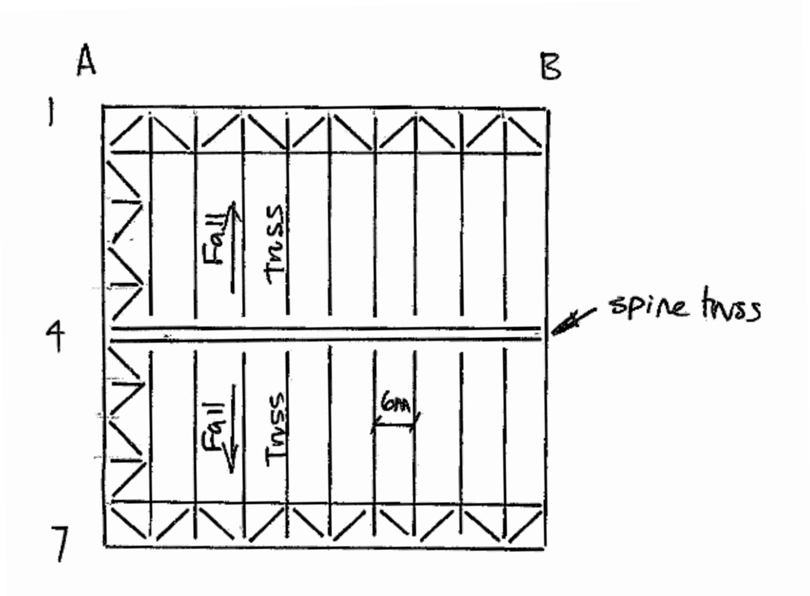
The reduced loading on the elevations means that a pad footing for both the columns and the retaining wall is viable

**Load transfer - factory**

Vertical loads on roof cladding are carried by conventional cold rolled purlins (at typically 1.8 m centres), spanning 6 m to the secondary trusses. The secondary trusses convey the vertical loads to the columns on grids 1 and 7, (and thus to the foundations) and to the spine truss on grid 4. The spine truss spans from grid A to B, and is supported on columns, transferring the vertical loads to the foundations

Lateral loads on elevations 1 and 7 are transferred to the columns by conventional cold formed side rails (at typical centres of 2m). The columns span between the base and the roof level. At roof level, trusses in the plane of the roof transfer lateral loads to vertical bracing on grids A and B, and thus to the foundations.

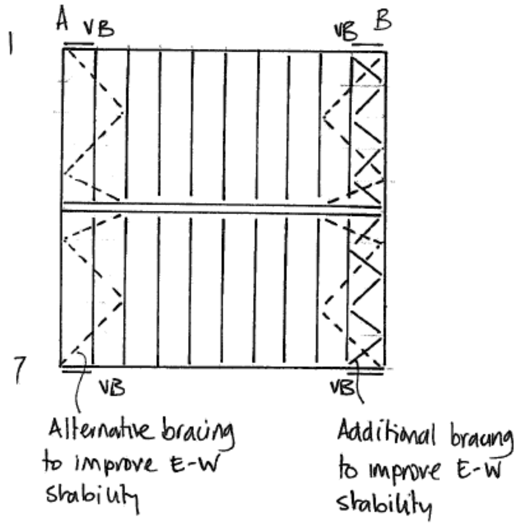
Lateral loads on Grid A are similarly transferred to a truss in the plane of the roof, and to the foundations via vertical bracing on grids 1 and 7.




Scheme 2 – plan of factory area

**Stability - factory**

The supports to the primary truss are critical in the factory area. In the north-south direction, stability is provided by vertical bracing on grids A and B. In the east-west direction, stability is provided somewhat indirectly by the roof bracing adjacent to grid A. The deflection of this truss is critical in providing stability in the east-west direction, and would need careful assessment. If necessary, a second roof truss could be introduced adjacent to grid B, with associated vertical bracing on grids 1 and 7. Finally, the stiffness of the bracing system could be increased by doubling the "depth" of the wind bracing from one bay to two bays.




Scheme 2 – alternatives to improve East-West stability

## Foundations - factory

Around the factory, a reinforced concrete retaining wall is proposed to retain fill under a ground floor concrete floor slab. Perimeter columns are supported on the retaining wall.

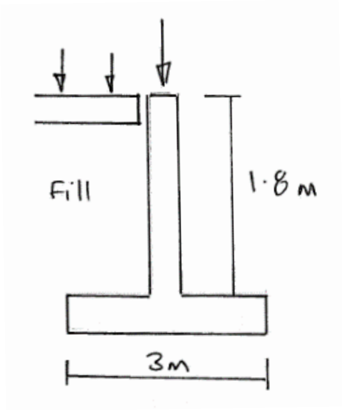
The retaining wall is supported on a pad footing.

Preliminary calculations for pad footing.
SLS axial load from column = 2.86 x 15 x 6 / 1.45 = 177 kN
Assume a retaining wall 250 mm thick and a 3 m wide base, 300 thick.
Self weight of wall = 30 kN/m
Overturning moment approximately 25 kNm/m

Assess a length of base 4 m long
Total vertical load = 177 + 4 x 30 = 300 kN or 75 kN/m

M/N = 25/75 = 0.33m
D/6 = 3/6 = 0.5m, > 0.33, OK
max pressure = 75/3 + 25 x 6/32 = 41.6 kN/m$^2$

Allowable for N = 15 is approximately 125 kN/m$^2$
Preliminary calculations indicate a pad footing to the retaining wall will suffice.




Typical cross section of retaining wall and column support

There appears to be no reasonable alternative to a low retaining wall.

In Scheme 2, one of the distinctive differences is that piles are not necessary round the factory area. These preliminary calculations are to establish if a simple pad foundation is feasible.

See Brooker, Figure 3.12

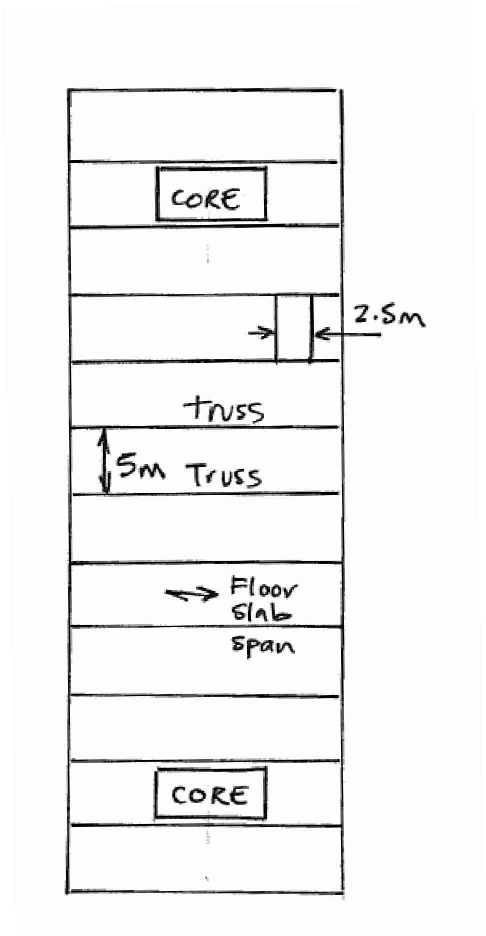
Foundations for the spine truss may be pad foundation.
Vertical load is 1287 kN or 1287/1.45 = 887 kN (SLS value)
This would need a pad foundation 887/125 = 7m$^2$, so 3 m x 3 m is OK

### Storage building

The storage / office facility comprises secondary beams spanning 5 m North-South. The secondary beams support a composite slab spanning east-west between secondary beams. The secondary beams are supported by trusses at 5 m centres, spanning to perimeter columns. The cores are used to resist lateral loads and to provide stability to the structure. A ground bearing floor slab is provided at ground level.

### Framing arrangement – storage building

The storage / office facility comprises secondary beams spanning 5 m North-South. The secondary beams are supported by substantial trusses at 5 m centres, spanning to perimeter columns on grids B and C.




Scheme 2 – typical flor plan in storage building

### Load transfer – storage building

Vertical loads are transferred from the floor slab to the secondary beams spanning N-S at 2.5 m centres. The secondary beams are supported by trusses spanning East-West. The simply supported trusses transfer the vertical loads to the columns on the elevations, and thus to the foundations.

The spacing of the trusses has been reduced, meaning smaller secondary beams, smaller trusses and columns, and lower foundation loads.

Lateral loads are transferred from the cladding to horizontal rails spanning to the columns on the elevations. The columns span between floors. The concrete floors are diaphragms which transfer the lateral loads to the cores at each end of the building.

### Stability – storage building

Stability is provided by the diaphragm of the concrete floor, and the cores at each end of the building. The large vertical loads will mean that frame stability is very significant and the core will need careful assessment. The core could be concrete, or a steel frame with diagonal bracing.

Temporary bracing will be needed in each floor, until the floor slabs are completed.

### Foundations – storage building

The vertical loads in the columns are high, so piled foundations will be required. The cores carry all the lateral forces and provide stability, so substantial piled foundations will be required. Piles to the cores will be subject to tension, (and must be designed for this load case) as the vertical load is carried by the columns on grids B and C, not the cores.

The interface on Grid B (see diagrams) needs careful detailing to allow some articulation between the secondary roof steelwork (purlins) on the factory at the junction with the storage facility, due to the anticipated deflection of the factory roof trusses and to allow for differential settlement between the two parts of the building.

### Differential movement between building areas

As the factory and storage buildings have dissimilar loading and quite dissimilar foundations, differential settlement is expected. A construction joint will be detailed on Grid B to accommodate this movement.

### Office building

The form of the office building on the uppermost storey is identical to that in Scheme 1 The office is a simple portal frame, spanning East-West, with portalised vertical bracing in the North-South elevations and roof bracing at the ends of the structure.

## Scheme selection

Scheme 1 has been selected as the preferred option.

In the factory area, the central spine box truss proposed in Scheme 2 adds complexity and expense, compared to Scheme 1. The increased numbers of trusses in Scheme 2 add fabrication cost, offset by reduced costs in the foundations due to the simple pad footings. Although the secondary steelwork spanning between trusses spaced at 10 m (Scheme 1) will be larger than that in Scheme 2, the members are simple and do not increase the fabrication effort.

It would probably be a mistake to ignore the cores, thoughtfully provided by the compiler of the question

Point made to recognise the challenge of erecting this scheme

There will be substantial overturning moments on the cores, so uplift is anticipated

The junction on grid B needs comment because of the deflection of the trusses, and also because of the potential for differential settlement. In fact, all foundations will be piled to rock, so there should be negligible differential settlement.

Differential movement might be anticipated as a result of different foundation solutions, or changing ground conditions across a site

The portal frame proposed in scheme 1 remains a realistic solution (or the only realistic solution)

Reasons for the selection of a scheme should address structure, cost, programme, function, safety, aesthetics, if necessary.

Here, the primary reasons for the choice are simplicity (so economy), since there is less fabrication effort. The penalty of increased loads on the foundations is likely to be offset by the savings in superstructure costs.

The spine truss proposed in Scheme 2 is relatively straightforward to erect, as a box truss is stable in the temporary condition. Substantial temporary bracing will be needed in the East-West direction until the roof bracing and vertical bracing are completed. The 60 m trusses proposed in Scheme 1 are unstable during erection without temporary bracing, so making erection more complex.

In the storage building, the decrease in primary truss spacing serves to decrease the foundation loads, which may decrease foundation cost, although more foundations are required. However, the axial loads are considerable in both schemes, and it is concluded that the saving will not be significant. Of greater significance is the reduced number of trusses in Scheme 1, which is of considerable economic benefit.

The difference in stability systems is not significant, as temporary bracing will be needed in each floor plane until the floor slabs are cast and act as a diaphragm.

The cores will themselves require very substantial piled foundations to accommodate the significant overturning moments, which are not offset by the permanent loads of the floors, which are carried by the external columns.

Scheme 2 requires the erection of more elements, so would result in a longer erection programme.

The primary reason for selecting Scheme 1 is the reduced fabrication effort in the trusses – both in the factory and the storage buildings. It is considered that the increased foundation costs associated with Scheme 1 are more than offset by the reduced fabrication costs.

## SECTION 2 – DESIGN CALCULATIONS

(for scheme 1)

Preliminary design completed in accordance with EN 1993-1-1

Design combinations of actions determined in accordance with expression 6.10 of BS EN 1990

All steelwork is S355

### Factory Area

### Primary Truss

Each primary truss is 60 m span, at 10 m centres.

Form of truss is a Warren truss with intermediate vertical members.

Depth of truss = span/15 = 60/15 = 4.0 m

Assume a 1:75 fall for the roof, hence deep end = 4+60/75 = 4.8 m

### Roof loading

Say 0.30 kN/m$^2$ permanent

Say 0.15 kN/m$^2$ services

1.5 kN/m$^2$ variable (from brief)

ULS loading = 1.35(0.3+0.15) + 1.5(1.5) = 2.86 kN/m$^2$

Noted that temporary stability needs to be considered in scheme 1 – to be covered in the erection method statement later

Noting issues during construction.

The additional complexity of 6.10a and 6.10b is not worthwhile at this stage

In the UK, S275 is no longer generally available.

Only the main chords and the most heavily loaded internal (at the supports) will be selected. The force in the chord is simply the mid-span bending moment, divided by the distance between the chords. The force in the end diagonal is the resolved force based on the end reaction

Certain that a factory will need some services, such as lighting

This value from the brief

UDL on truss = 2.86 x 10 = 28.6 kN/m

Midspan bending moment =28.6 x $60^2/8$ = 12870 kNm

Force in truss chords = 12870/4.0 = 3218 kN

Buckling length in both axis = 4 m (secondary verticals required)

From Blue Book (All hollow sections to be hot finished)

Note that on grids 2 and 6, the chord members also carry load from the horizontal wind girder; this will be included later and a revised section selected.

Use 260 x 260 x 10 SHS; $N_{b,Rd}$ = 3230 kN, > 3218 kN, OK

End shear = 28.6 x 60/2 = 858 kN

Length of diagonal at deeper end = $\sqrt{4.8^2 + 4.0^2}$ = 6.25 m

Resolving, force in end diagonal = 1213 kN

Use 200 x 200 x 10 SHS; Nb,Rd = 1430 kN on 7 m, > 1213 kN, OK

**Column on West Elevation**

Length of column to foundation = 10.0 + 2.0 (say) = 12.0 m

Axial load =858 kN

As there is some moment, (not calculated at this stage) limit resistance in axial compression to utilisation of 0.85 rather than 1.0

Therefore design for 858/0.85 = 1009 kN

No major axis restraint so $L_{ey}$ = 12m

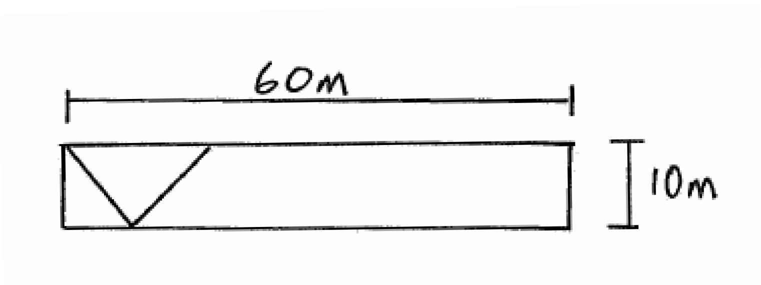
Minor axis restraint at 7m (above 5 m doors) so $L_{ez}$ = 7m

Use 254 UC 73 S355

$N_{bzRd}$ = 1140 kN on 7 m, > 1009 kN, OK

$N_{byRd}$ = 1240 kN on 12 m, > 1009 kN, OK

**Roof bracing to factory area**




Plan view of roof bracing

**Columns (wind posts) on North and South elevations**

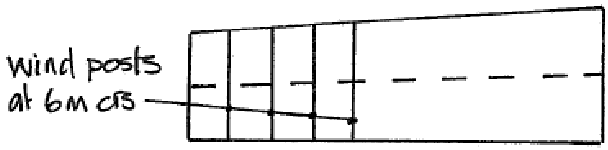
Note the use of secondary vertical members – else the buckling length in plane would be 8 m

The sections have been chosen so that the two members are close in size. This is deliberate to increase the resistance of the joints. A note pointing out that all truss joints would need to be verified would be helpful

Always, some moment, but only a simple allowance made here

Always beware openings which mean that restraints are not possible. Assumed that a restraint is possible above the door level, at 5 m, meaning the remaining length is 7 m.

Plan view, showing the form of the wind truss. As noted earlier, the chords of the wind truss are also chords of the primary trusses, so the loads need to be combined.




Elevation on grid 7

Height of wind post = 2 m (say) + 10 m + 4.4 m = 16.4 m

Either major axis bending resistance is critical, or lateral torsional buckling between side rails at (say) 2m vertical centres.

Assume wind load of 1.1 kN/m$^2$

ULS wind load = 1.1 x 1.5 = 1.65 kN/m$^2$

UDL load on post at 6 m centres = 1.65 x 6 = 9.9 kN/m

Maximum moment = 9.9 x 16.4$^2$/8 = 333 kNm

Use 406 x 178 x 54;

$M_b$ on 2m = 334 kNm, $M_{c,y,Rd}$ = 375 kNm, > 333 kNm, OK

**Roof wind girder (in plane of roof)**

The roof girder between grids 6 and 7 (and 1 and 2) are loaded from the tops of the wind posts on the elevations. It is assumed that this load is equivalent to a UDL applied to the chord of the wind girder. The UDL arises from half the loaded area (the other half direct to the foundations).

UDL Wind load = 1.65 x 16.4/2 = 13.5 kN/m

Midspan bending moment =13.5 x 60$^2$/8 = 6075 kNm

Force in chords = 6075/10 = 608 kN

Chord members on grids 1 an 7 (6 m length):

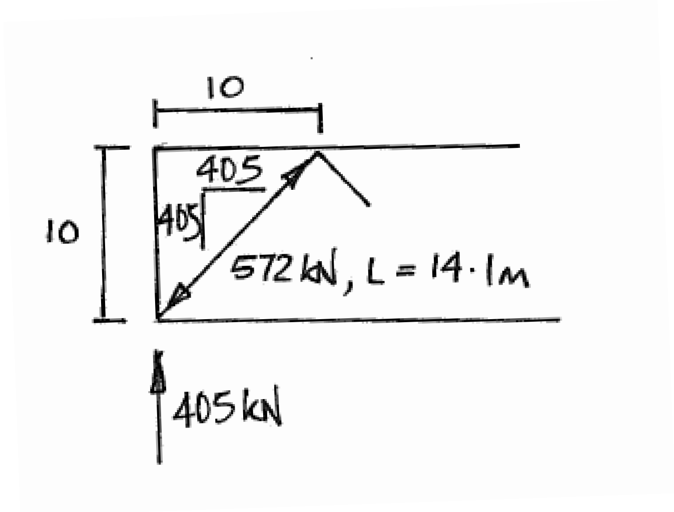
Use 150 x 150 x 8 SHS; $N_{bRd}$ = 696 kN on 6 m, > 608 kN, OK

End reaction in wind girder = 13.5 x 60/2 = 405 kN

Resolving, force in end diagonal = 572 kN

Length of diagonal = 14.1 m

Because the wind posts span from ground to the roof, half the load on the elevation is carried to the foundations by the wind posts. The lateral load on the wind girder is based on this assumption




End of roof bracing

Use 250 x 250 x 8 SHS; $N_{bRd}$ = 695 kN, > 572 kN, OK

**Chords on grids 2 and 6**

Total force in chord = 3218 + 607 = 3825 kN

Use 300 x 300 x 12.5; $N_{bRd}$ = 4740 kN on 4m, > 3825 kN, OK

**Secondary roof steelwork (supporting cladding)**

Span = 10 m; spacing 2 m

UDL on member = 2.86 x 2 = 5.72 kN/m

Maximum bending moment = 5.72 x$10^2$/8 = 71.5 kNm

Provide SHS, for unrestrained resistance in an uplift condition.

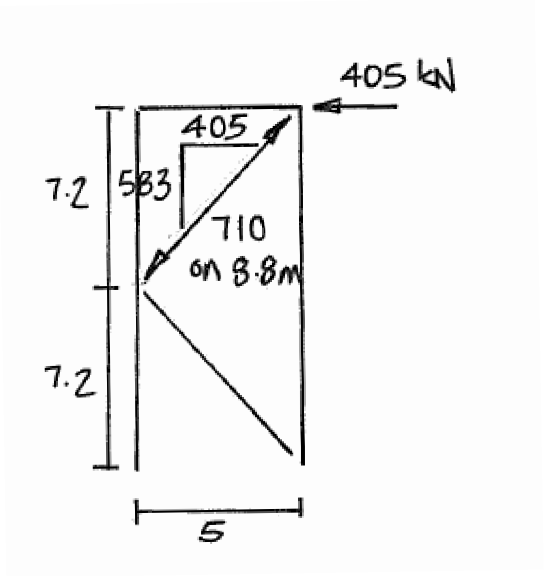
Use 150 x 150 x 8 RHS $M_{cRd}$ = 84.1 kNm, > 71.5 kNm, OK

**Vertical bracing on Grid lines A and B**

Point load at top of bracing
(end reaction from wind girder) = 405 kN

This is going back to the primary truss design, and increasing the design load, because it also carries load from the wind girder

Simply supported members. Designed for gravity loading, but recognising that uplift will happen (all the loading doors), a SHS has been chosen, so there are no concerns about LTB with an unrestrained bottom flange. It has been implicitly assumed here that the gravity loading is larger than the uplift case, which has not been assessed.




Typical vertical bracing arrangement

Axial force in 8.8 m member = 710 kN

Use 219 x10 CHS $N_{bRd}$ = 784 kN on 9 m, > 710 kN, OK

Adopt similar bracing arrangement on Grids B, 1 and 2.

Because factory is certain to experience uplift, bottom chord will experience compression. The bottom chords of the trusses will be restrained at intervals by ties (114 x 3.6 CHS) running North-South between the primary wind girders.

## Storage building

### Office structure on upper storey

The office structure will be designed as pinned base portal. In the longitudinal direction (North-South), portalised bracing will be provided on the elevations (as the cladding is glass)

### Loading on office roof

Permanent = 0.3 kN/m$^2$

Services = 0.15 kN/m$^2$

Variable = 1.5 kN/m$^2$

ULS loading = 1.35(0.3+0.15) + 1.5(1.5) = 2.86 kN/m$^2$

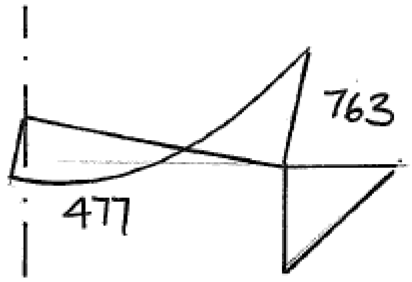
ULS load on one frame at 10 m centres = 2.86 x10 = 28.6 kN/m

Eaves bending moment = wL2/15 (say) = 28.6 x 202/15 = 762.7 kNm

No frame stability calculations for the factory, as the roof is very lightly loaded. Frame stability issues will be important in the storage building

The key design moments are at the eaves (for column design) and near the apex (for rafter design). Simplistically, a rafter is like a fixed-ended beam, (except its not fixed). $wl^2/12$ is too onerous, so $wl^2/15$ is more realistic. Near the apex, $wl^2/24$ is a reasonable first guess.

Midspan bending moment = wL2/24 (say) = 28.6 x 202/24 = 477 kNm




Column buckling length = 3 m

Triangular bending moment, so $C_1$ = 1.77

Use 533 x 210 x 92;

$M_b$ = 838 kNm on 3 m with $C_1$ = 1.77, > 762 kNm, OK

Rafter buckling length = 2 m (say) between purlins, with $C_1$ = 1.0

Use 406 x 178 x 74;

$M_b$ = 485 kNm on 2 m with $C_1$ = 1.0, > 477 kNm, OK

Vertical reaction at column base = 28.6 x 20/2 = 286 kN

**Beams on upper storey supporting the office**

**Loading**

Permanent = 3.5 kN/m$^2$ (assumed slab on profiled steel decking)

Variable 5 kN/m$^2$

ULS loading = 1.35(3.5) + 1.5(5.0) = 13.73 kN/m$^2$

Beam UDL = 13.73 x 2.5 = 34.3 kN/m

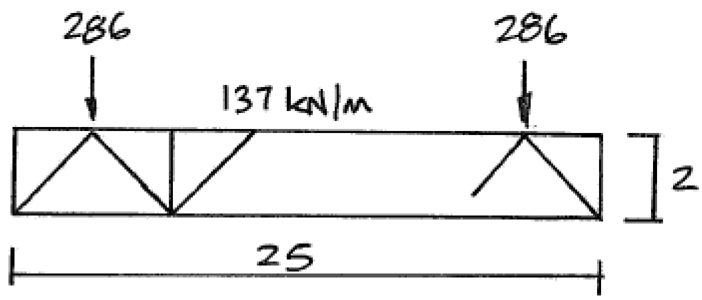
Midspan moment = 34.3 x 10$^2$/8 = 428 kNm

Assume  non-composite slab but fully restrained beam

Use 406 x 178 x 67 ($M_{cy,Rd}$ = 478 kNm)

**Truss supporting top storey and office**

Assume truss depth = 2.0 m



$C_1$ = 1.77 for a triangular bending moment diagram

The BMD is approximately uniform in the sagging zone, so $C_1$ = 1

These beams span between the trusses at 10 m centres. Designed as non-composite, but fully restrained

The trusses are highly loaded – substantial members are anticipated

UDL on truss = 13.73 x 10 = 137.3 kN/m

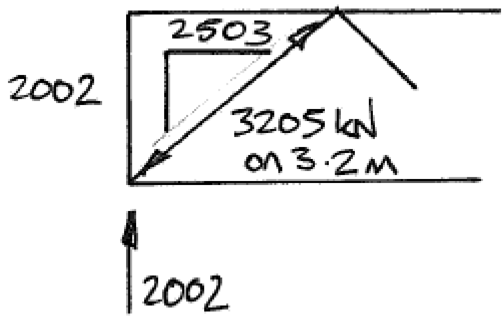
Midspan bending moment = 137.3 x 252/8 + 286 x 2.5
= 11442 kNm

(Note point loads from office contribute little to bending moment)

Force in chords = 11442/2.0 = 5720 kN

Use 305 UC 158; $N_{bzRd}$ =5880 kN on 3 m, > 5720 kN, OK

End reaction = 137.3 x 25/2 + 286 = 2002 kN




Resolving, axial force in end diagonal = 3205 kN on a 3.2m long diagonal

Choose 254 UC 107; $N_{bzRd}$ = 3440 kN on 3.5 m, > 3205 kN, OK

**Storage floors – secondary beams**

Assume beam span = 10 m, at 2.5m centres

Assume floor slab to be 200 mm deep concrete slab on profiled steel decking, (say) 3.6 kN/m$^2$

Allow self weight = 0.5 kN/m$^2$

Beams will be designed non-composite, but fully restrained

ULS Load = 1.35(3.6 +0.5) + 1.5(1.5) = 28 kN/m$^2$

UDL on beam = 28 x 2.5 = 70 kN/m

Max bending moment = 70 x 10$^2$/8 = 875 kNm

Use 533 x 210 x 101 $M_{cy,Rd}$ = 901 kNm, > 875 kNm, OK

SLS variable load = 15.0 x 2.5 = 37.5 kN/m

$$\text{Deflection} = \frac{5 \times 37.5 \times 10000^4}{384 \times 210000 \times 61500 \times 10^4} = 38 \text{ mm}$$

Allowable deflection = span/360 = 10000/360 = 27 mm

However, the composite action will reduce deflection by approximately 33% to (say) 25 mm, OK

**Storage floors - primary trusses**

Span = 25 m

Assume a 2.5 m deep truss

This value has been calculated by interpolation within the table

Relatively deep slab, recognising that the imposed load is very high

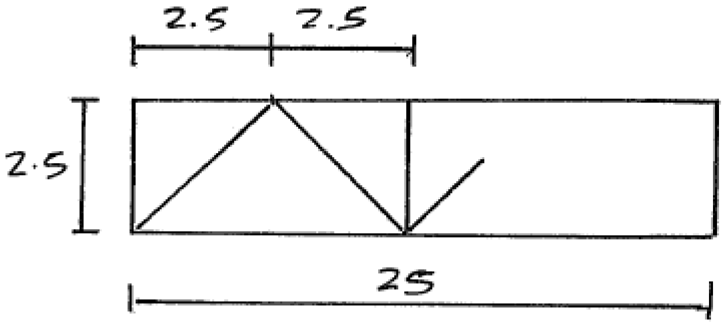
A reasonable assessment of the beneficial effects of composite action

With a storage load of 15 $kN/m^2$, very substantial members anticipated.

Load on truss = 28 x 10 = 280 kN/m

Mid span bending moment = 280 x $25^2$/8 = 21875 kNm

Mid span chord force = 21875/2.5 = 8750 kN

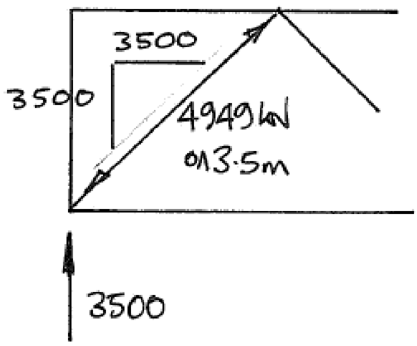



Buckling length = 2.5 m

Use 305 UC 240; $N_{bzRd}$ =9050 kN on 3m, > 8750 kN, OK

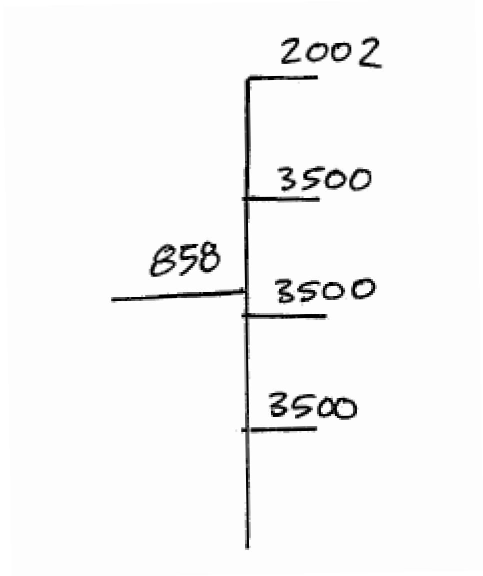
End shear 280 x 25/2 = 3500 kN

Resolving, force on end diagonal = 4949 kN on 3.5 m




Use 303 UC 158; $N_{bzRd}$ =5720 kN on 4 m, > 4949 kN, OK

Column design on Grid B




Columns on Grid B support the storage building trusses and the trusses over the factory area.

Reaction from East-West factory truss = 858 kN

Forces from the trusses in the storage building

= 3 x 3500 + 2002 = 12502 kN

Total load at base = 12502 + 858 = 13360 kN

Buckling lengths of columns are:

$L_{ey}$ = 6.5 m (4 m clear storey height + 2.5 m truss)

$L_{ez}$ = 2.0 m (between side rails)

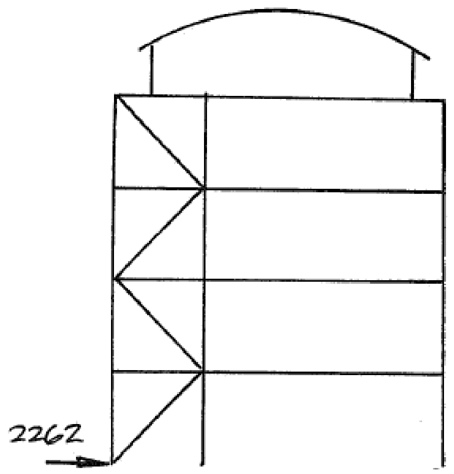
Use 356 x 406 x 393 UC;

$N_{bzRd}$ = 16400 on 2 m, > 12952 kN, OK

$N_{byRd}$ = 15200 kN on 6m, > 12952 kN, OK

Only the column on grid B (being the most heavily loaded) has been designed. In some structures, it would be beneficial to take account of the reduction in axial load allowed for several storeys. However, as this is a storage building, and the load is likely to be less than transient, it seems unwise to appeal to that reduction factor

Vertical bracing in Storage building




Vertical bracing will be designed for the more onerous of the wind load or a NHF equal to 2.5% of the factored vertical load. The value of 2.5% will ensure that the frame is not sway sensitive. The wind load will be (conservatively) calculated for the larger elevation.

Assumed wind load (ULS) = 1.5 x 25 x 60 x 1.1 = 2250 kN

or 1125 kN base shear at each end of the building.

Based on the column forces of 12502 and 13360, the total vertical load (ULS)

= 12502 x 7 + 13360 x 7 = 181034 kN

Base shear at each end, taking 2.5% as a NHF

= 0.5 x 181034 x 2.5/100 = 2262 kN

As the NHF is larger, the bracing will be designed on this basis

Resolving, the force in the lowest diagonal = 3200 kN

Use 305 UC 198; $N_{bzRd}$ = 3440 kN on 8 m, > 3200 kN, OK

(the bracing members could be reduced higher up the building)

Foundation and floor slab design

Factory area floor slab

Assumption is that the made ground is removed, and replaced with appropriate granular sub-base material.

Based on BCA technical note 11, a 300 mm slab in C40 concrete will be appropriate for the design loading of 10 kN/m$^2$. Slip membrane and construction joints to be provided. Slab to be reinforced with steel fibres and additional steel mesh.

There is no way that a proper assessment of second-order effects can be completed in the exam. A conservative approach has therefore been adopted – if the NHF are 2.5%, and the bracing designed for this as a minimum, then it may be assumed that the second order effects are small enough to be ignored. In such a heavily loaded building, second order effects are important and should not be overlooked

The total NHF has been calculated based on the total base reaction – and then divided into the two bracing systems.

Perhaps soil improvement could have been specified. Candidates clearly need a good understanding of soil conditions, foundations, and how the examination questions are formulated.

This (old) BCA guide covers industrial floors.

## Factory area retaining wall and column support foundation design

Excluding columns on Grid B, columns are to be supported on a low retaining wall used to retain the 1.5 m granular fill and factory floor.

Axial load (Sheet 29) = 858 kN

Additional force from the wind loading (Sheet **Error! Bookmark not defined.**)

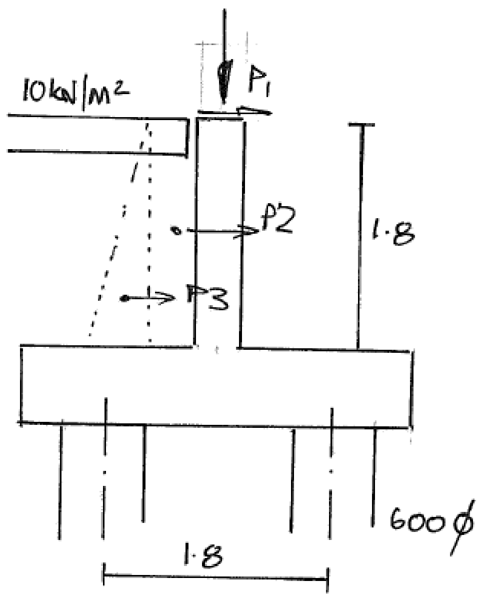
= 405 x 14.4/5 = 1166 kN

The wind load is in combination with the vertical loads, so $\psi_0$ = 0.5 applied to the contribution from the bracing system.

Total reaction = 858 + 0.5 x 1166 = 1441 kN

Shear from wind (Sheet 31) = 9.9 x 16.4/2 = 81 kN

Retaining wall arrangement thus:




Stem thickness 1800/10 but say 300 mm (for 254 UC)

Base thickness, say 600 mm.

Concrete: C30; reinforcement 500 N/mm$^2$

For the fill behind the wall, assume the coefficient of active pressure to be 0.3 and the density to be 20 kN/m$^3$.

If the column load is distributed to the base at 45°, length of retaining wall carrying the column load = 2 x 1.8 + 0.25 = 3.85 m

Lateral load on retaining wall (per m)

Shear: P1 = 81/3.85 = 21 kN/m

Imposed floor load: P2 = 1.5 x 0.3 x 10 x 1.8 = 8.1 kN/m

Fill: P3 = 1.35 x 20 x 1.8 x 0.3 x 1.8/2 = 13.1 kN/m

In this instance, the water level is below the base of the retaining wall/pile cap.  In many questions, the water level will have an impact on the foundation scheme

The wind is a secondary variable action, so its contribution is reduced.

For concrete design, foundation design and helpful guidance on soils, the guide *Concrete Buildings Scheme Design Manual* by Owen Brooker is invaluable. The guide was prepare to assist candidates in the ISE examination.

Note the reasonable assumptions made about the fill. A reference work on soil mechanics will assist in determining these values.

This is basic retaining wall loading – from the superimposed load and from the fill.

Moment at base

21 x 1.8 + 8.1 x 1.8/2 + 13.1 x 1.8 x 1/3 = 53 kNm/m

Assume main bars at 50 mm from face, so $d$ = 300 – 50 = 250

$$k = \frac{M_{Ed}}{f_{cu} d^2} = \frac{53 \times 10^6}{30 \times 1000 \times 250^2} = 0.028$$

then $z = d\left(0.5 + \sqrt{0.25 \quad k/0.9}\right)$

$$z = 250\left(0.5 + \sqrt{0.25 \quad 0.028/0.9}\right) = 242 \text{ mm}$$

$$A_s = \frac{M_{Ed}}{0.87 f_y z} = \frac{53 \times 10^6}{0.87 \times 500 \times 242} = 503 \text{ mm}^2\text{/m}$$

Use H16 at 200 crs (1010 mm$^2$/m)

Shear: $V_{Ed}/d$ = (21 + 8.1 + 13.1) x 103 /(250 x 1000) = 0.19 N/mm$^2$

this is less than 0.4 N/mm$^2$ so no specific shear reinforcement needed

**Support to retaining wall**

With $N$ = 15, allowable bearing pressure ≈ 125 kN/m$^2$

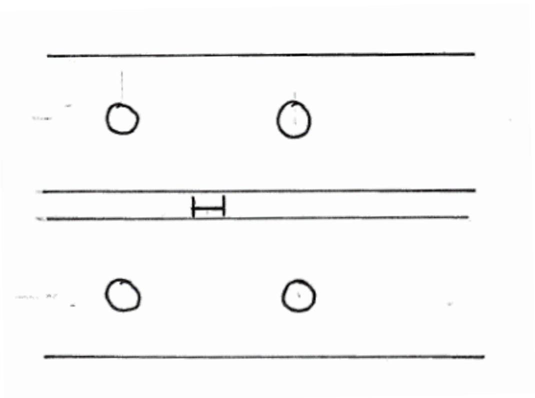
approximate vertical pressure, if base is 1.5 m wide

= 1600/(3.85 x 1.5) = 280 kN/m$^2$ so foundation is to be piled

Try 600 diameter pile. Area = 0.28 m$^2$

End bearing resistance = 0.28 x 1500 = 420 kN (a SLS resistance)

Try 4 piles, spaced at 3$d$ = 1.8 m



Load per pile = 1441/4 + 53/(1.8 x 2) = 375 kN (ULS)

Approximate factor ULS/SLS = 1.45

SLS load = 375 / 1.45 = 258 kN, < 420 kN, OK.

Refer to Brooker, section 3.4

Refer to Brooker, inside back cover

Refer to Brooker, figure 3.12

A preliminary review of the foundation, to confirm that pad footings are not possible

Standard spacing for piles

An approximate way to convert the ULS force into an SLS force, as the resistance of the pile is an SLS value.

Pile reinforcement

Load is small; adopt 0.4% reinforcement.

0.4/100 x 280000 = 1120 mm$^2$

Adopt 6 H 16 = 1210 mm$^2$

H 10 links at 300 mm spacing

Storage building foundations (Grid B)

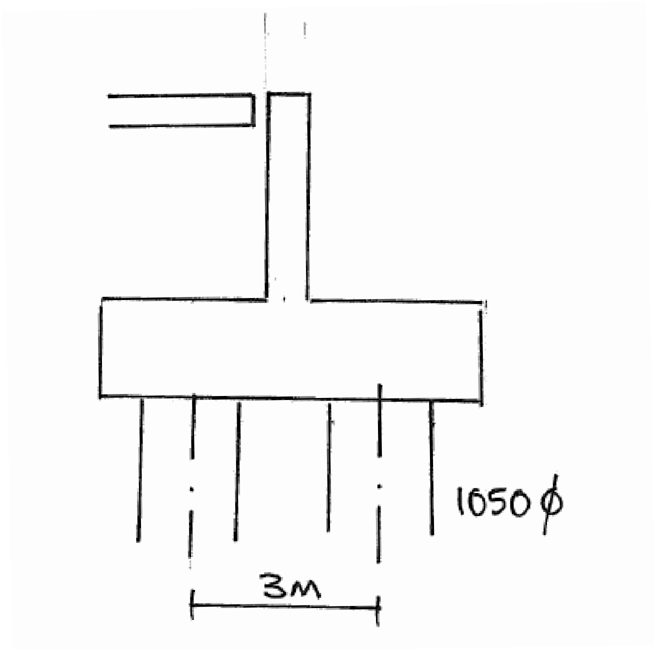
Axial load from column on Grid B = 13360 kN (Sheet 43)

Additional load from wind = 1125 x 14/7 = 2250 kN

This is in combination with the vertical loads so $\psi_0$ = 0.5

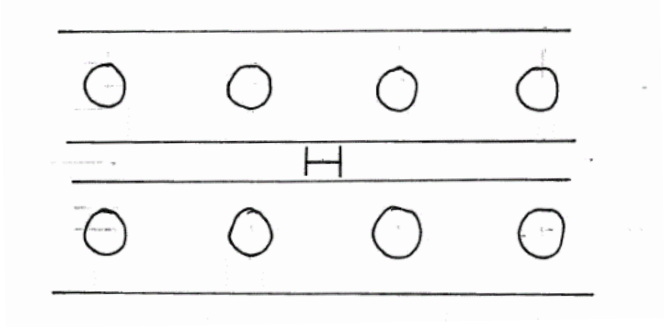
Total load = 13360 + 0.5 x 2250 = 14485 kN

Try 1050 diameter pile. Area = 0.525 m$^2$




End bearing resistance = 0.525 x 1500 = 1300 kN (a SLS resistance)

Try 8 piles, spaced at 3*d* = 3 m



Load per pile = 14485/8 + 53/(1.8 x 4) = 1815 kN (ULS)

Approximate factor ULS/SLS = 1.45

Refer to Brooker, inside back cover

Only the most highly loaded foundation is considered here. The vertical load is huge – so the foundation is very significant. With the clear spans specified, and the high imposed loading specified, foundation design is a key challenge in this question.

SLS load = 1815 / 1.45 = 1252 kN, < 1300 kN, OK.

**Pile reinforcement**

Load is small; adopt 0.4% reinforcement.

0.4/100 x 860000 = 3440 $mm^2$

Adopt 8 H 25 = 3930 $mm^2$

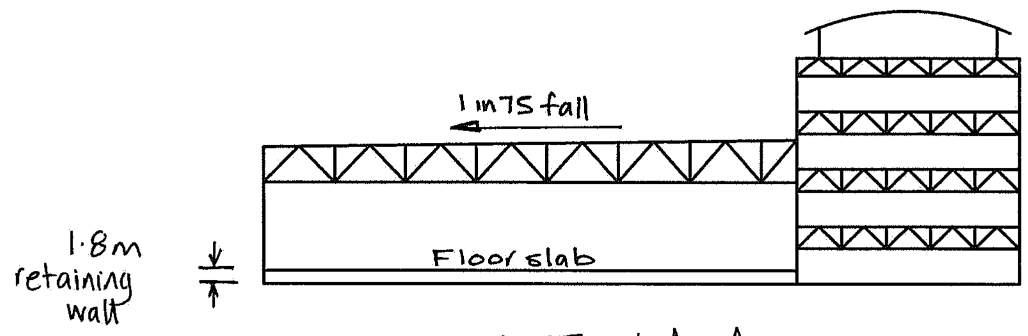
H 10 links at 300 mm spacing

**Storage building foundations (Grid C)**

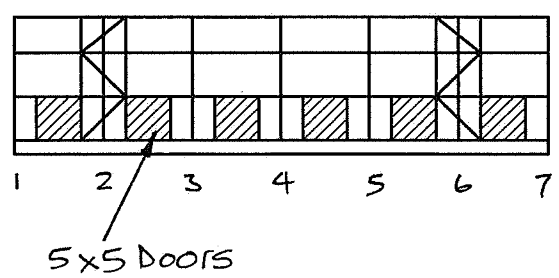
Adopt similar detail to grid B, but no retaining wall needed.

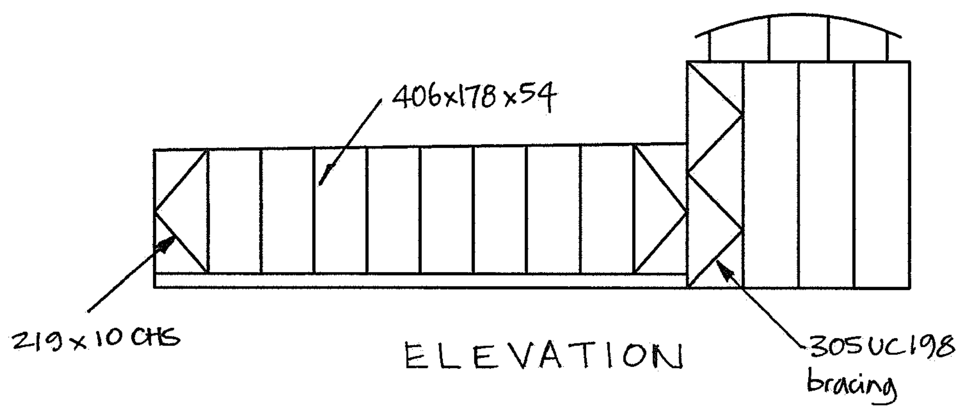
# 3 DRAWINGS

The following sheets reproduce the A3 drawings prepared for the scheme.

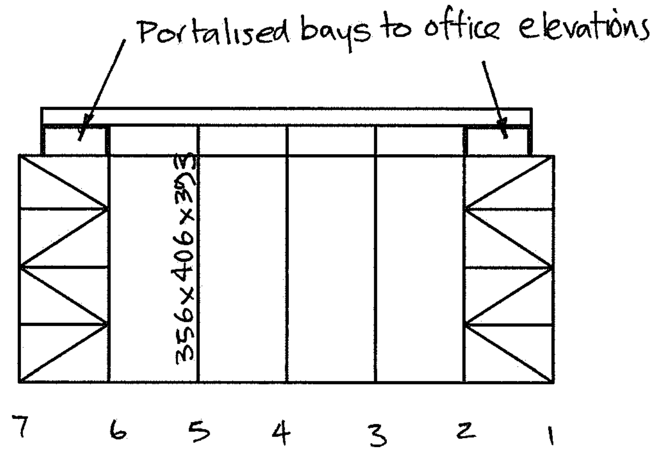


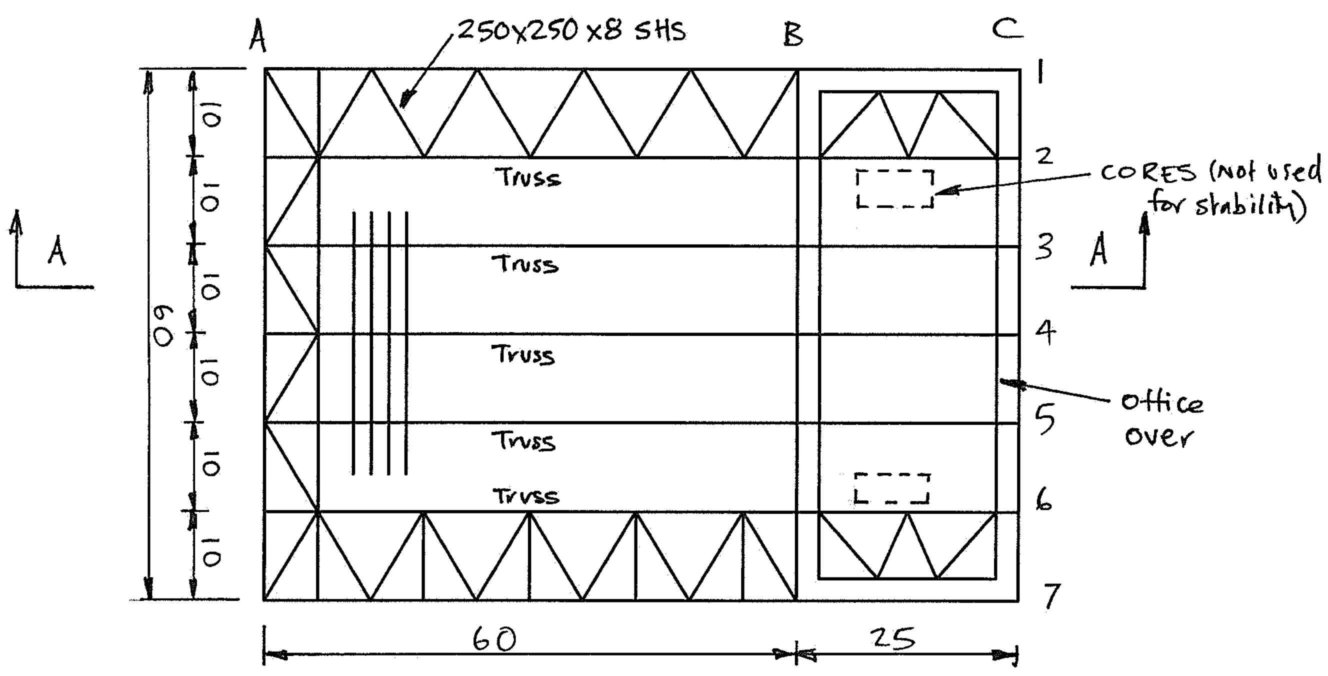

SECTION A-A



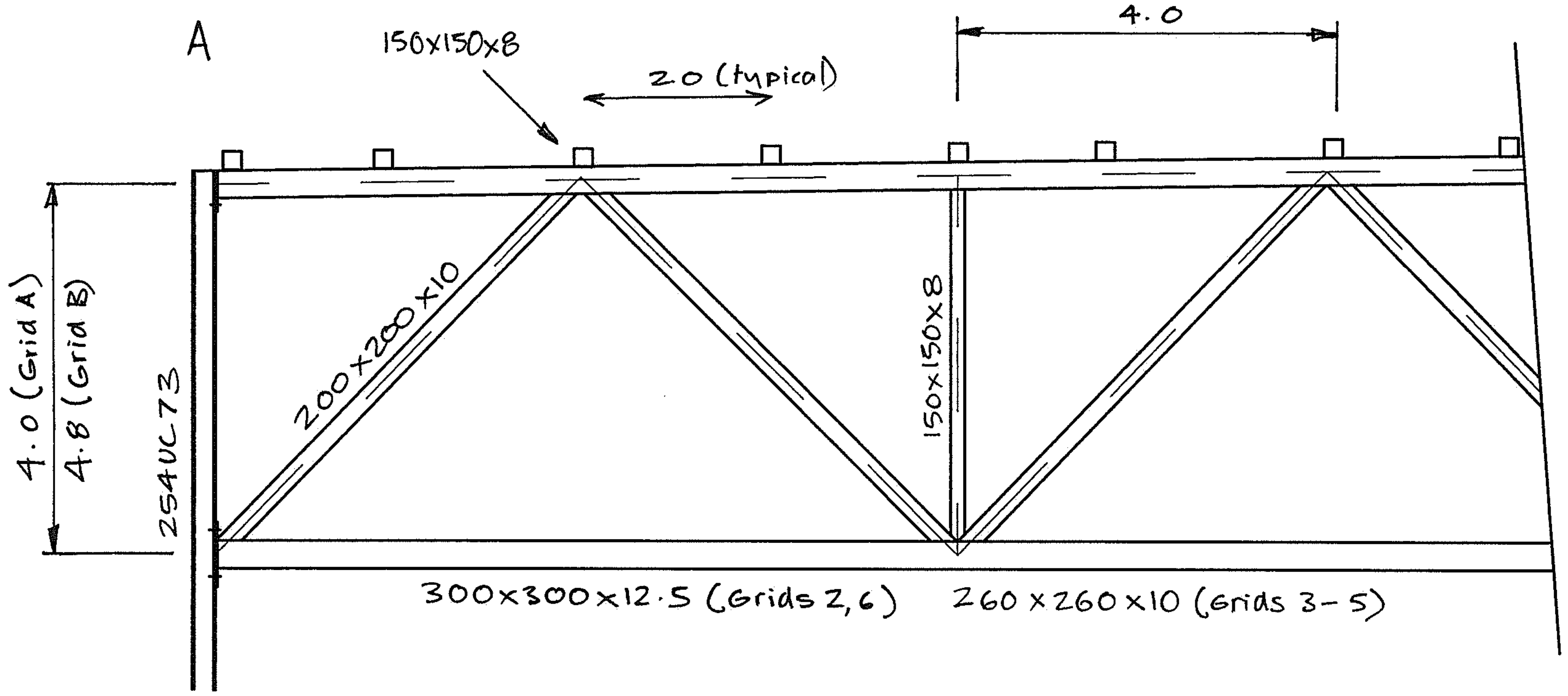

ELEVATION



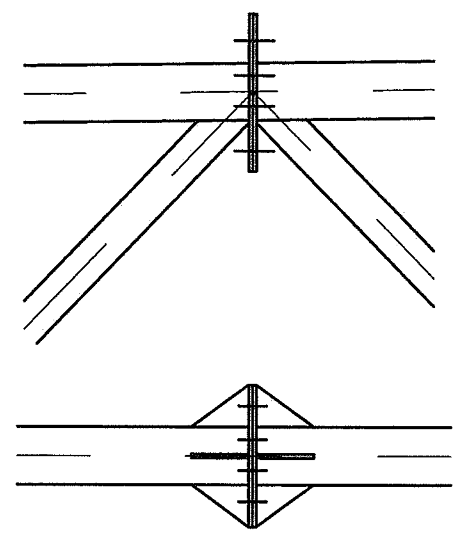




PLAN

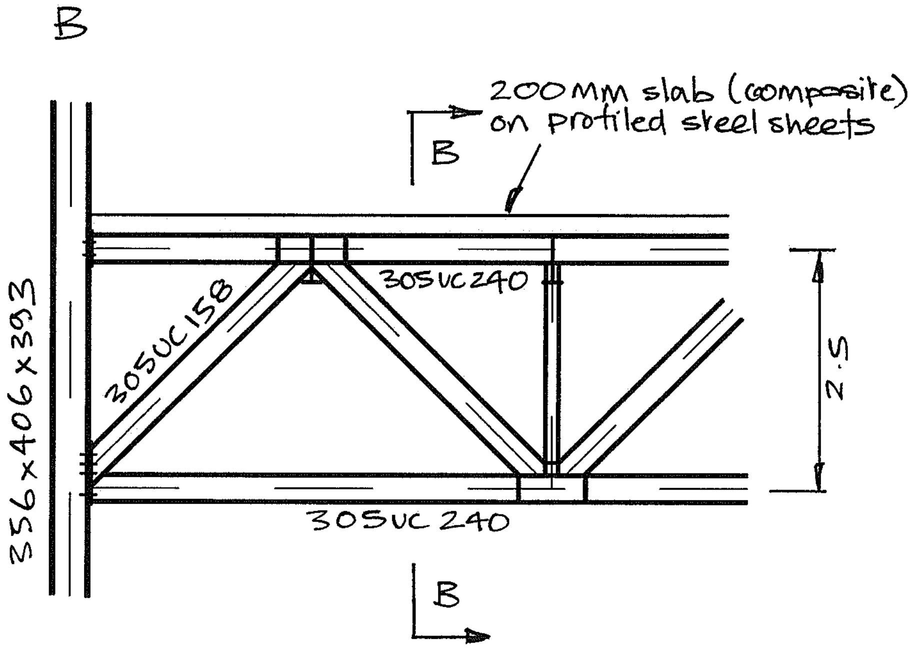
FACTORY AND OFFICE
GENERAL ARRANGEMENT



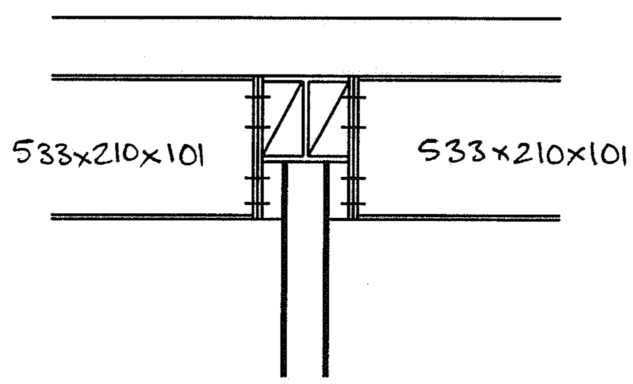

FACTORY TRUSS



TYPICAL SPLICE
(At 1/3 points)



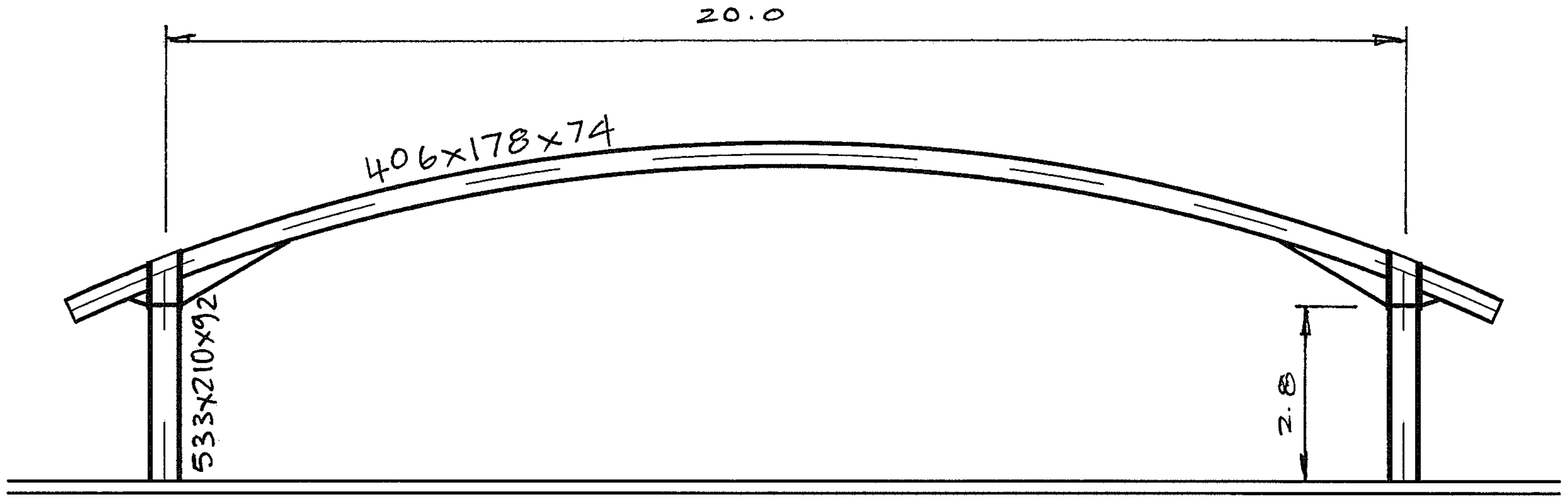

STORAGE BUILDING TRUSS



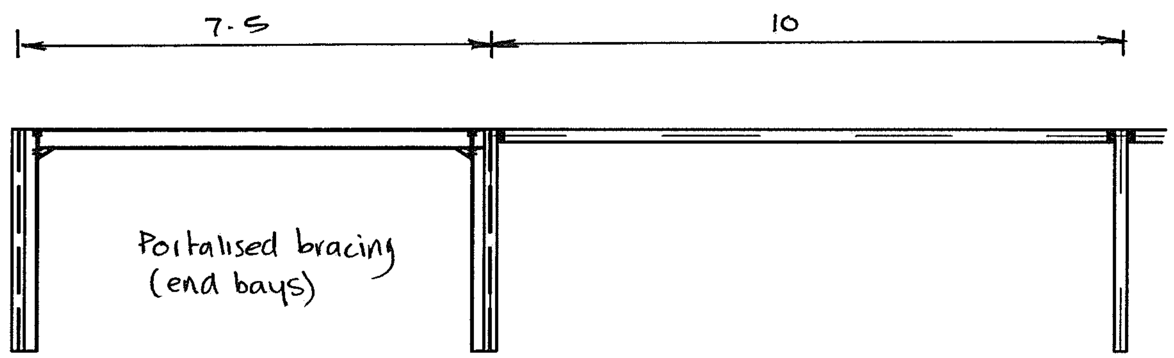

SECTION B-B

All steel S355

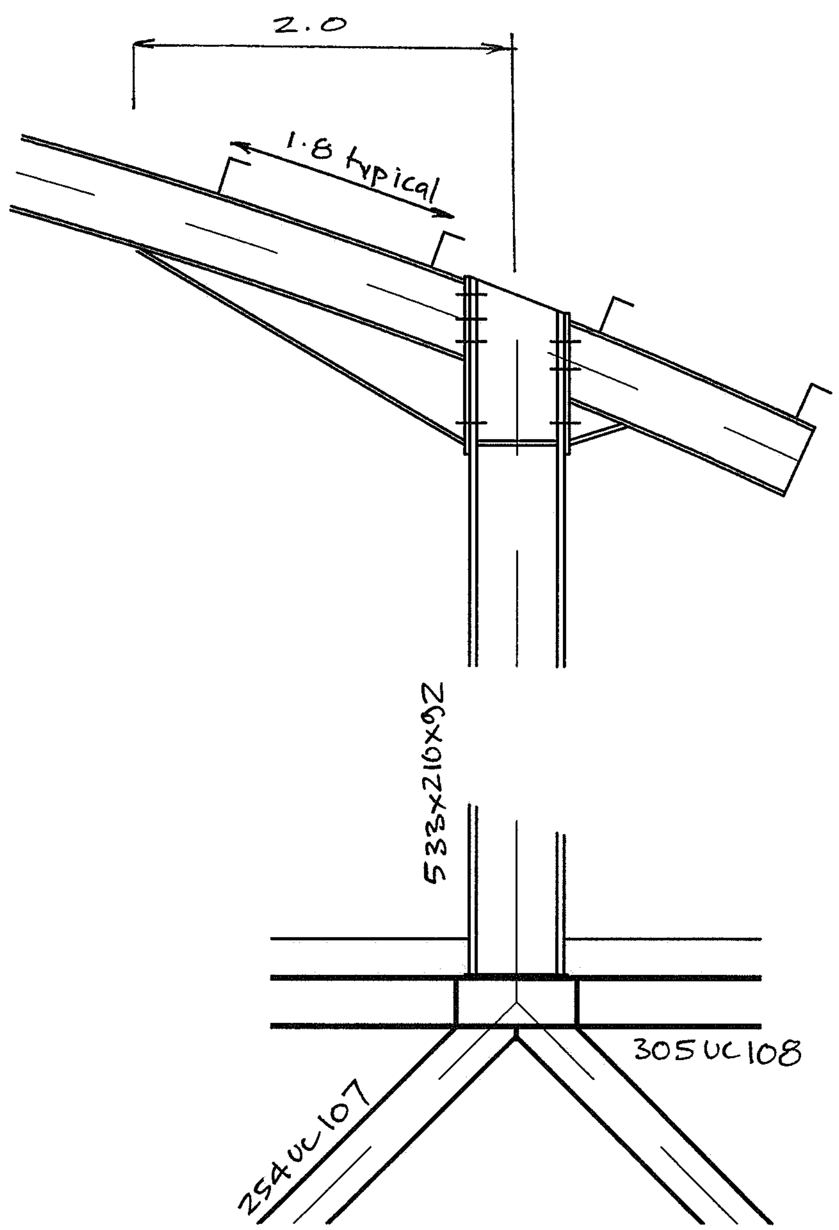
TYPICAL TRUSS
ARRANGEMENT




CROSS SECTION



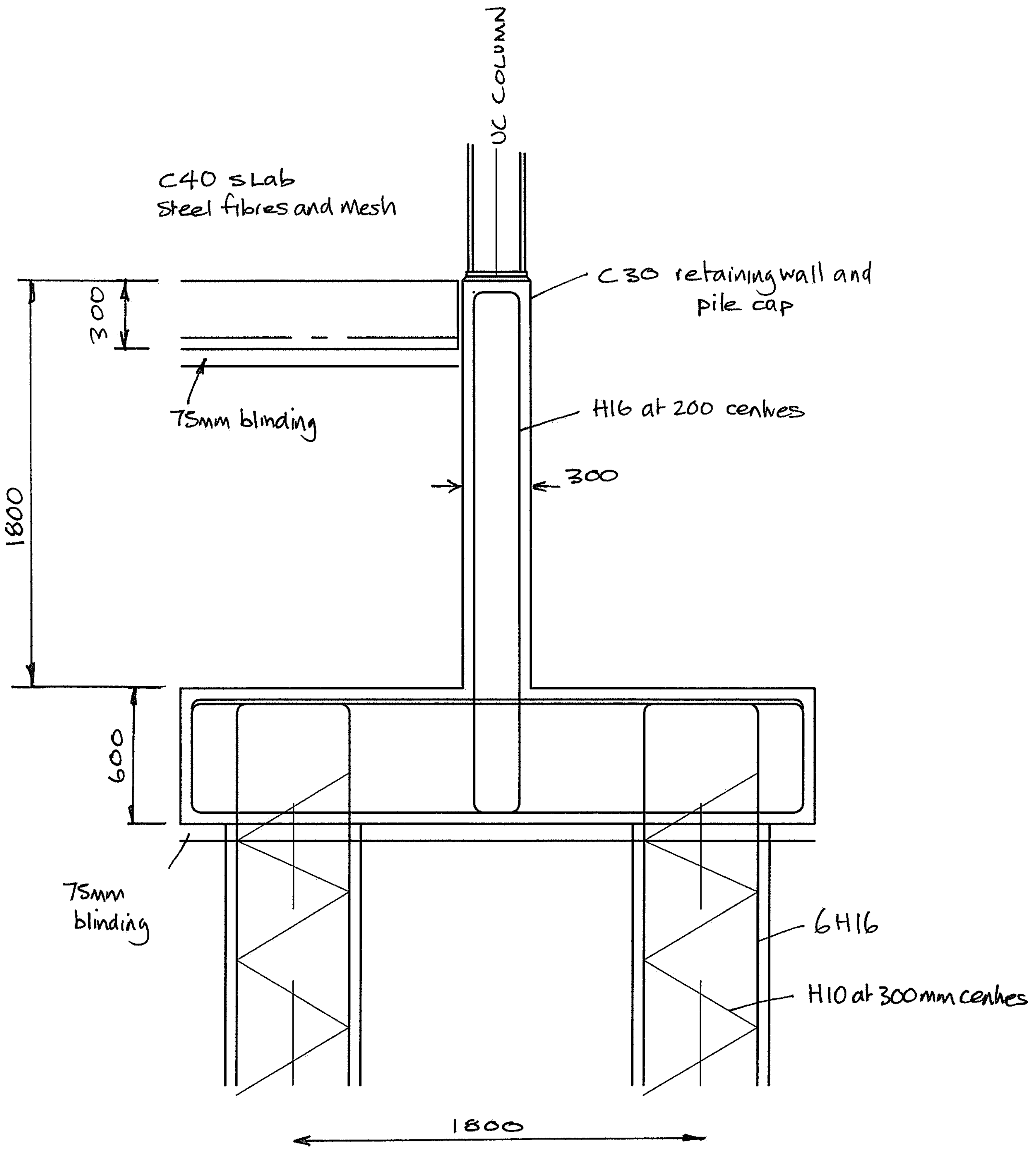

PART ELEVATION




TYPICAL CONNECTION DETAILS

ALL STEEL S355

OFFICE STRUCTURE
GENERAL ARRANGEMENT




Dimensions in mm.

RETAINING WALL AND
FOUNDATION DETAILS

# 4 METHOD STATEMENT

Preliminaries

- The site should be secured to prevent unauthorised access by member of the public.
- As there is much working at height, full PPE must be worn, including fall arrest equipment and safe methods of work must be established and followed.

Sequence of work

- The made ground is to be removed.
- Hard standing is to be provided at all foundation locations, so that the piles may be installed.
- Blinding is to be cast for the pile caps (grid C) and bases of the retaining walls (grids A, B, 1 and 7). This operation can be completed in stages, as the piles are completed in sequence.
- The retaining walls and pile caps are to be cast. This operation can be programmed to follow in sequence after the blinding.
- Fill is to be compacted over the area of the factory. The fill must be compacted and levelled to provide hard standing for the storage and assembly of the steel superstructure, and for cranes and mobile elevating working platforms (MEWPS) to operate within and adjacent to the footprint of the building.

Factory superstructure

- Factory steel erection is to commence with pairs of columns and bracing at corner A1, with columns, bracing and eaves members in both orthogonal direction.
- Pairs of columns at B1 are to be erected, with bracing and horizontal members in each direction.
- Columns on grid 1, between A and B are to be erected, together with the eaves members.
- Two 60 m trusses are to be assembled, and braced into a box at intervals with temporary cross bracing between the two trusses.
- Using two cranes, the pair of trusses is to be erected on grids 2 and 3, onto the columns already erected on grids 2 and 3.
- Whilst still held on the cranes, the roof bracing between grids 1 and 2 is to be installed from MEWPS, and the secondary steel members (hollow section box members) between the two trusses on grids 2 and 3.
- Once stabilised, the cranes may be released.
- Until the N-S bracing adjacent to grid A is installed, temporary bracing in the E-W direction is required on each grid line 2 – 6.
- Each truss on grids 4 to 6 is erected in the same manner, being held on the craned until stabilised by the secondary steelwork.
- Columns, eaves members and bracing on grids 6 to 7 is erected.

Storage building superstructure

- Columns and vertical bracing are to be erected on grid C (generally two storey columns)
- Major trusses are to be erected from grid 1 to 7. Each truss is to be located horizontally with temporary bracing.
- As each truss is erected, secondary beams spanning 10 m N-S to the next truss are to be installed (using the second crane) at third points before releasing the crane.
- Each floor is completed in the same manner, with upper storey column spliced above the second floor level.
- Edge protection is installed on the edge beams before the steelwork is erected.
- Temporary flooring is required, and prefabricated support frames to allow the MEWPS to traverse within the footprint of the building.
- Temporary staircases are installed as each storey is completed.
- Vertical bracing is installed as the erection proceeds.
- At the uppermost storey the portal columns to the office are bolted to the top of the steelwork at that level.
- The curved rafter is installed. Temporary props are used until the second portal frame is installed, and roof bracing erected.
- Erection of the office frames proceeds, with the purlins installed after each frame, to provide stability.

Storage structure floors

- Profiled steel sheet is laid on the floor beams and shot fired to the steelwork.
- Shear studs are through-deck welded to the supporting steel beams
- Edge strip is fixed around the perimeter of the floor slab, and any openings.
- Pumped concrete is cast to the specified thickness, and finished.

Ground floor slabs

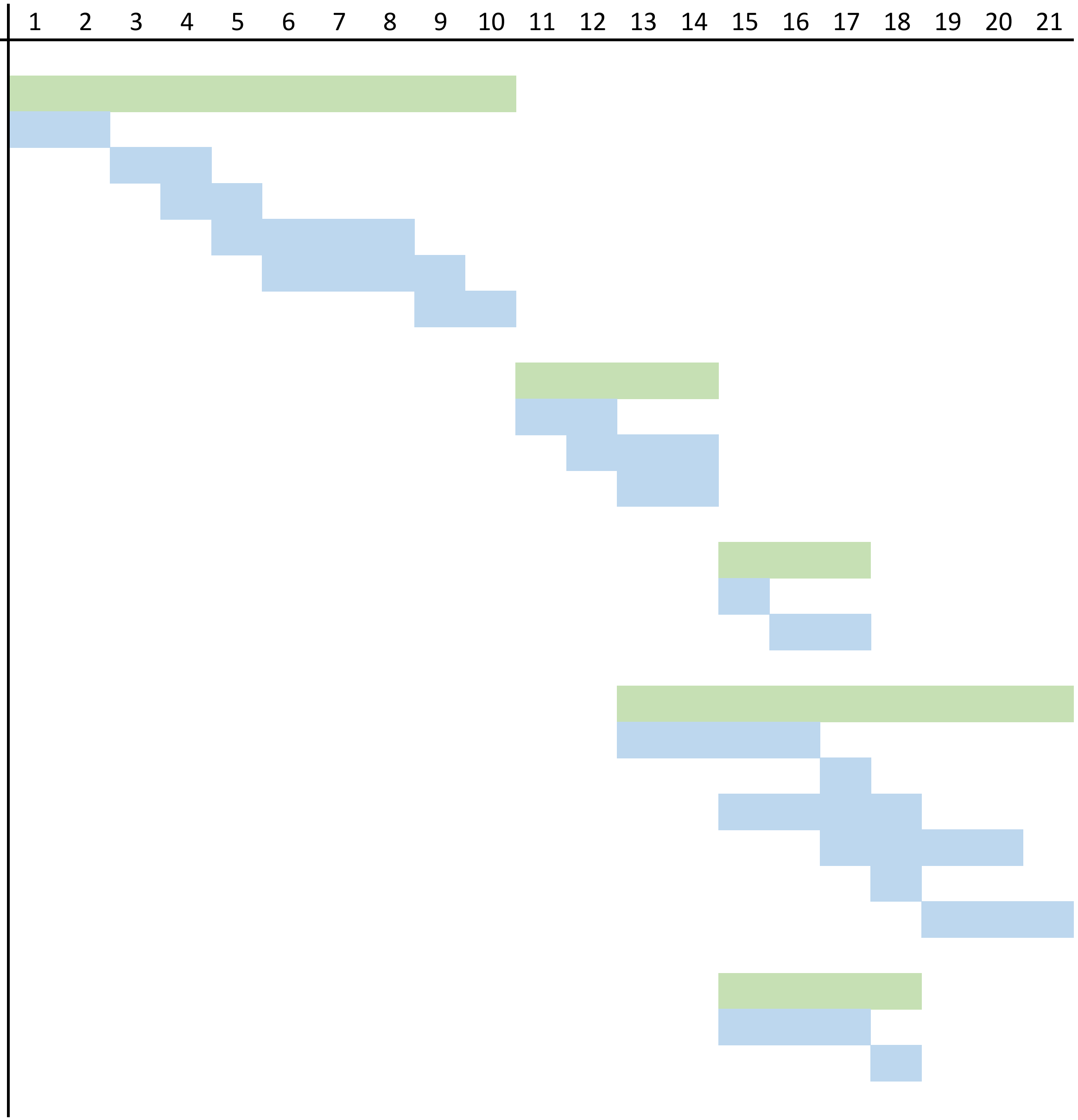
- Once work overhead has been completed, (or in the storage building, once the first suspended floor has been cast), the sub base may be levelled and blinded.
- Insulation and reinforcement is laid, and construction joints shuttered
- Compressible filler is introduced between the retaining wall and the slab.
- The fibre-reinforced concrete is laid, compacted and finished.

# 5 PROGRAMME

The construction programme is shown on the following page

**Construction Programme**

| Activity | Duration |
|---|---|
| **Initial works** | 10 |
| Establish site | 2 |
| Remove made ground | 2 |
| Provide hard standing | 2 |
| Install piles | 4 |
| Retaining walls and pile caps | 4 |
| Fill and hard stading in footprint | 2 |
| | |
| **Factory superstructure** | 4 |
| Erect steelwork | 2 |
| Roof cladding | 3 |
| Wall cladding | 2 |
| | |
| **Factory floor** | 3 |
| Sub-base preparation and blinding | 1 |
| Casting of slab | 2 |
| | |
| **Storage building** | 9 |
| Storage building steelwork | 4 |
| Office steelwork | 1 |
| Decking | 4 |
| Floor concrete | 4 |
| Office cladding | 1 |
| Cladding to storage building | 3 |
| | |
| **Storage building ground floor slab** | 4 |
| Sub-base preparation and blinding | 3 |
| Casting of slab | 1 |



# 6 CLIENT LETTER

A Designer
Ascot, Berkshire SL5 7QN

30 May 2017

Dear Sir,

RE: Installation of cranes in the factory area

With reference to your requirement to install two cranes running East to West supported on the perimeter columns and a central row of columns within the factory, we have the following comments:

1. For economic reasons, we advise that the steel framing of the factory roof structure should be redesigned to utilize the central columns to be installed running East-West in the factory area. We propose that this new central line of columns on grid 4 be extended vertically to support the roof structure, which will be reconfigured. The roof steelwork will be simpler that the original scheme and overall less expensive.
2. The cranes will increase the vertical loading on the perimeter columns and add to the foundation loads. Larger columns and foundations will be required.
3. New foundations will be required to support the central line of columns.
4. Crane operations produce significant lateral loads in each direction, so additional bracing will be required to convey these loads to the foundations.
5. The dynamic loads due to the cranes are likely to cause fatigue in the supporting steelwork and connections.
6. Depending on the operating class of the cranes, it may be necessary to specify Execution Class 3 and select a steelwork contractor qualified to this standard. (Execution Class 2 is the default standard for buildings).

We propose the following solution:

1. A central line of columns will be introduced on grid 4, with foundations. These new columns will extend to roof level, supporting the roof structure.

2. The orientation of the primary roof trusses in the roof of the factory building to be re-aligned from an East-West direction to a North-South direction. The roof trusses will be supported on the elevations and on the central line of columns. Because the span of the trusses has reduced to 30 m, the trusses will be significantly lighter than those in the original scheme.
3. Crane girders will be introduced running in the East-West direction. The crane girders will be supported on the perimeter columns, and each side of the new central columns.
4. The steelwork currently specified must be verified for fatigue loading, including the connections between crane girders and supporting steelwork.
5. Additional vertical bracing will be required, on the elevations (grids 1 and 7) and along the central line of columns on grid 4.
6. Additional horizontal bracing at roof level will be required, to carry lateral loads from the cranes and convey this, via vertical bracing on grids A and B, to the foundations.

The proposed changes will result in

1. Additional design costs.
2. Additional cost and time required to construct the new foundations
3. Additional cost for the foundations required to carry increased load

Please note that the cost of the additional steelwork to support the cranes will be offset by the reduced costs of the roof steelwork.

Yours sincerely

## Steel Construction Institute

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## British Constructional Steelwork Association

BCSA is the national organisation for the steel construction industry: its Member companies undertake the design, fabrication and erection of steelwork for all forms of construction in building and civil engineering. Industry Members are those principal companies involved in the direct supply to all or some Members of components, materials or products. Corporate Members are clients, professional offices, educational establishments etc which support the development of national specifications, quality, fabrication and erection techniques, overall industry efficiency and good practice.

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