MONASH University

ENGINEERING

ENG1001: Project 1
Carpark Footbridge

Team Members:

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- Lew Jie Hao (32271689)
- Justin Wong (30721725)
- Hue Hao Yuan (32279205)

11 / 12 / 2020

SUMMARY

This report presents a design for a covered steel footbridge to be constructed between the North1 multi-storey carpark and the Faculty of Engineering building. A design for the bridge was devised for optimal strength and stability. The design consists of trusses, a roof, and handrails. The bridge should be enough for students to get to their destination. The entire bridge is 50 meters, and we will be building two spans of 25 meters. In this report we will only be designing one span of the bridge which connects the carpark to the central column. Sufficient calculations and research was done to ensure a stable bridge that can shelter students from rain.

MONASH University

CONTENTS

1 INTRODUCTION

1.1 BRIEF DESCRIPTION OF PROJECT

A covered steel footbridge is to be constructed between the North1 multi-storey carpark and the Faculty of Engineering building (14 Alliance Lane). The bridge is to span 25 metres and approximately 3 metres above ground.

This report presents a design for this bridge. The bridge has been designed to cater for people to cross over between locations while not affecting the traffic below.

The bridge design is presented in the form of sketches of the sideview and a cross-section cut of the structure.

1.2 ASSUMPTIONS MADE

- We assume that the height of second floor of the Carpark and the North1 building is of the same height which is 3 meters.
- We assume that the self-weight of truss is 20kg/m
- We assume all loads are vertical
- We assume that the building site is completely flat with no elevations
- We assume loads are uniformly distributed
- We assume that the only weather conditions in the area are sun and rain.

2 TRUSS DESIGN

2.1 CONCEPT DESIGN

Location: The Bridge is designed in a straight line as in that case the bridge will pass through a grassy area beside the road that is not in use and is a perfect location for building a column as it would not obstruct the vehicles or pedestrians as well as making use of unwanted space.

Height: The **height of 3m** was chosen to allow vehicles to travel underneath the bridge. As this is in university, not lorries of any huge vehicles are expected. Therefore, a height of 3 m is suitable.

Depth of truss: **2.5m** using ratio given in the Project Brief [Appendix D]. This is to accommodate everyone with individually different heights.

Number of Span: **2** because we have I ideal location to place a column and each span is about 25 m only further division of spans is not necessary as the members will be able to support the load without going through yielding and Buckling

Width: The **width of 2.2 m** was chosen to allow 2 people to walk in opposite directions comfortably.

2.2 3-DIMENSIONAL VIEW (NOT TO SCALE)

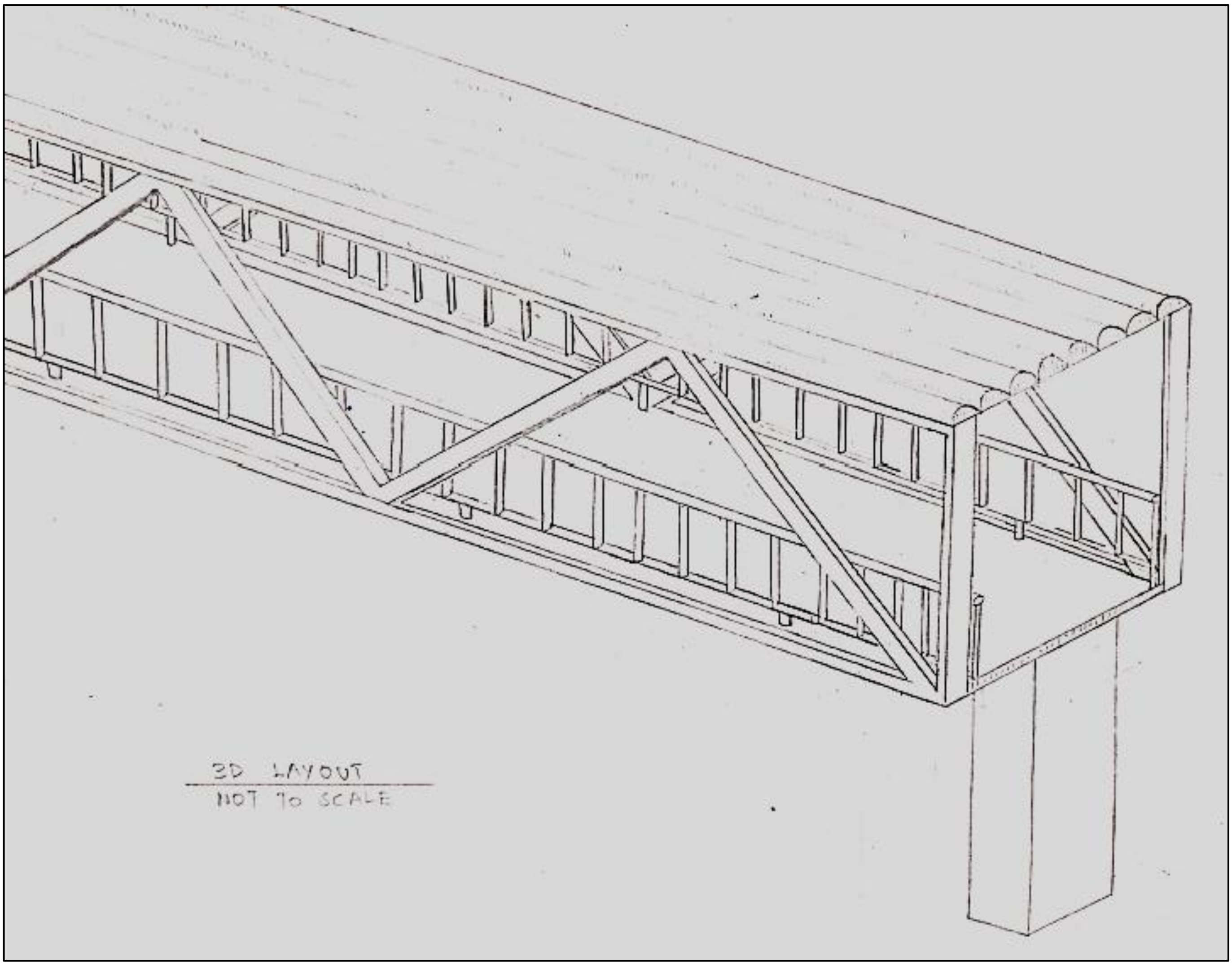


Figure 1

2.3 SECTION

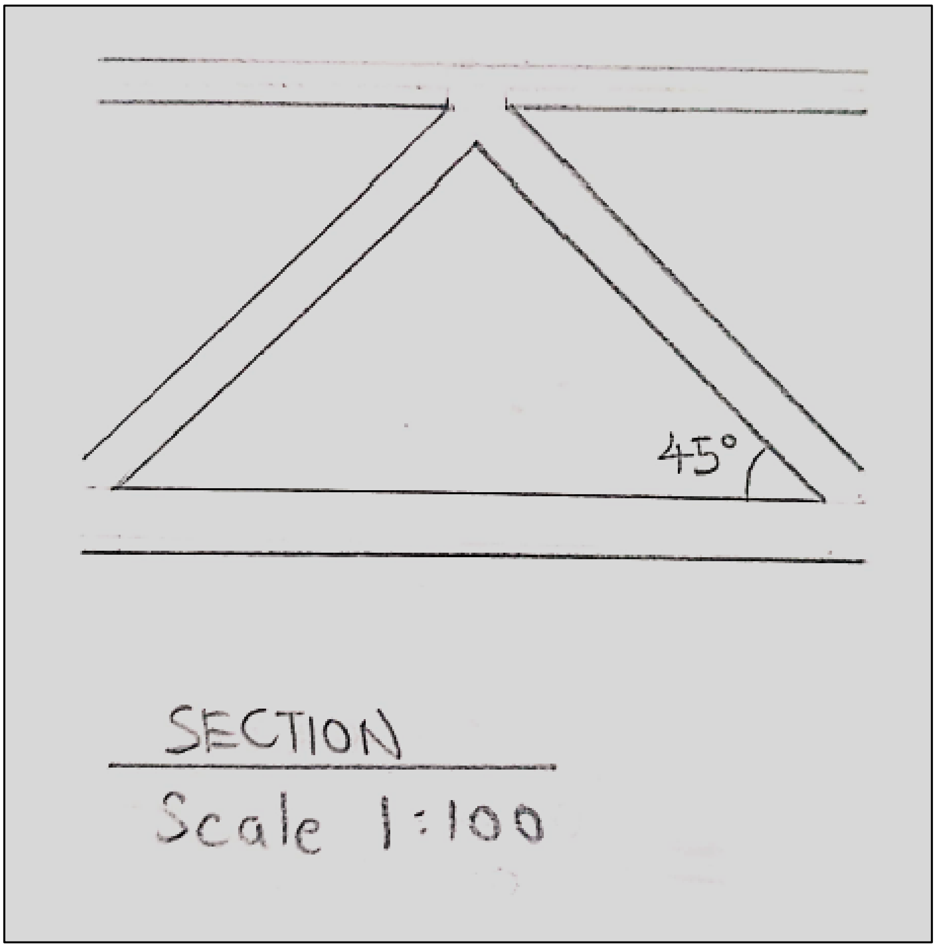


Figure 2

2.4 CROSS-SECTIONAL VIEW

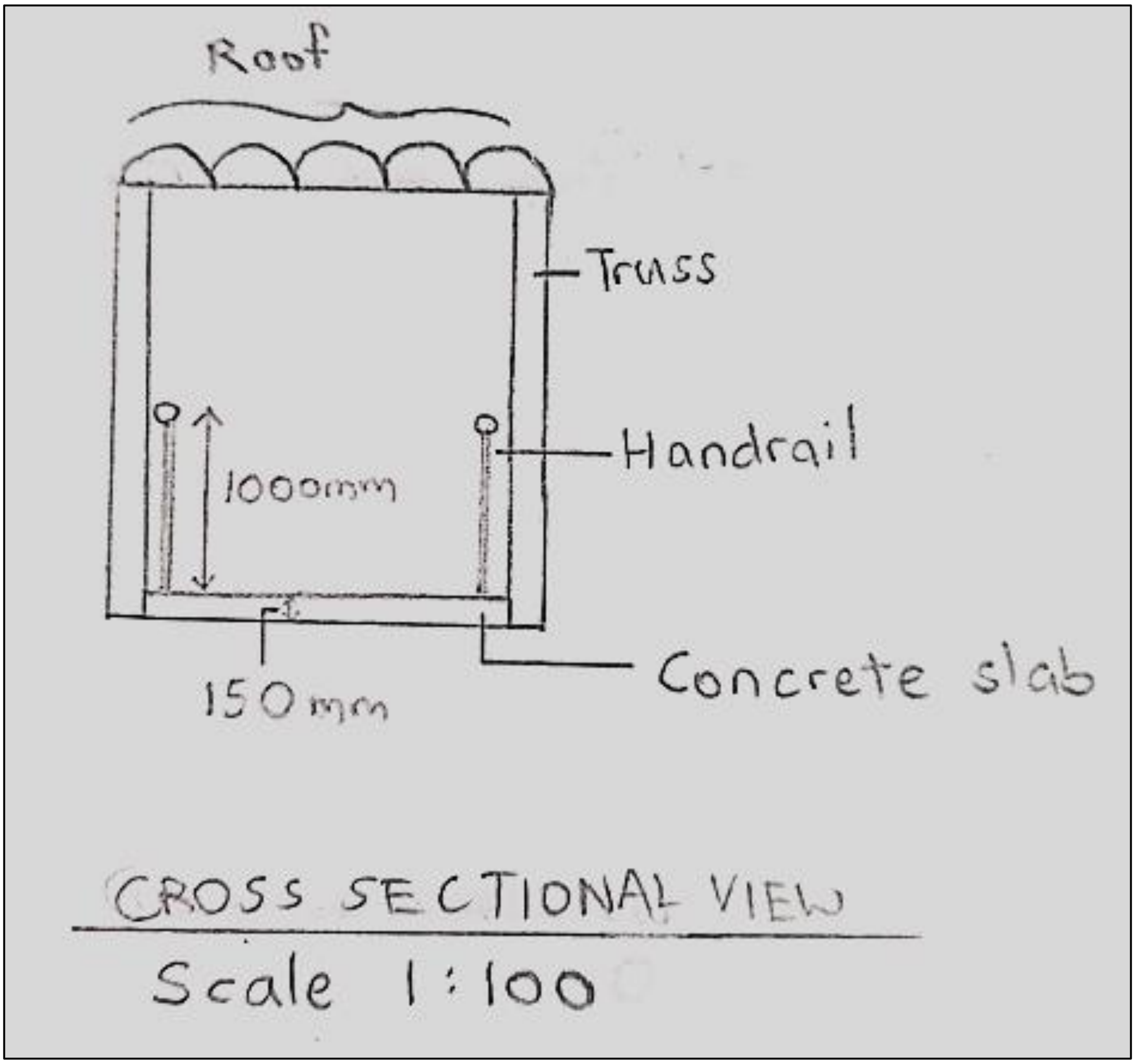


Figure 3

2.5 CROSS-SECTIONAL VIEW WITH COLUMN

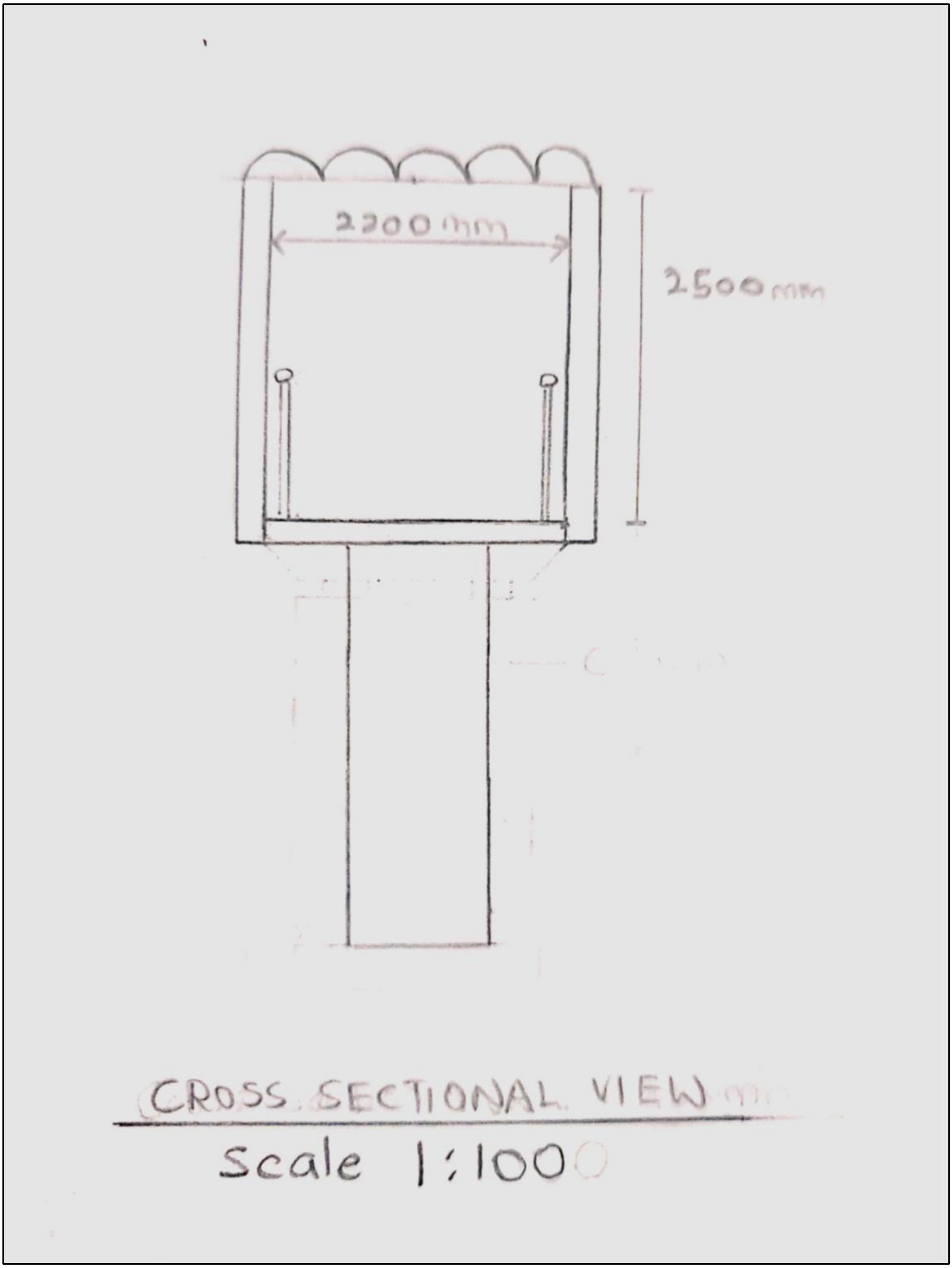
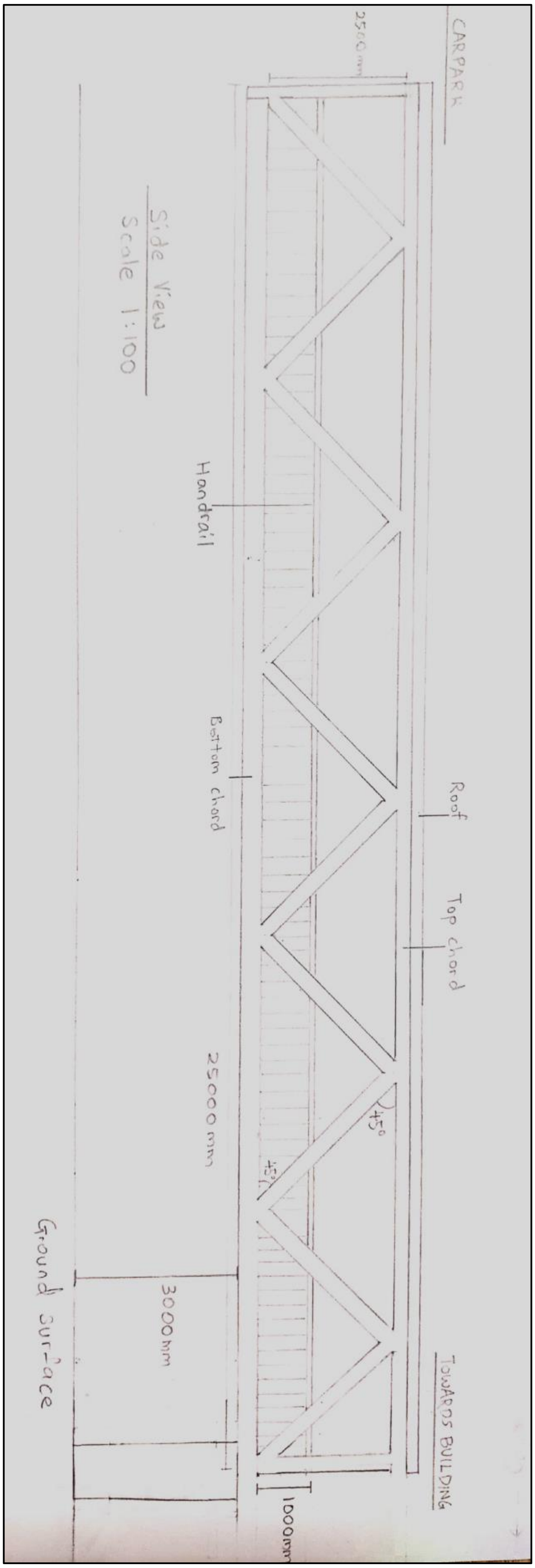


Figure 4

2.6 SIDE VIEW



CARPARK
2500mm
Side View
Scale 1:100
Handrail
Bottom chord
Roof
Top chord
25000mm
45°
45°
Ground surface
3000mm
1000mm
TOWARDS BUILDING

Figure 5

2.7 PLAN VIEW

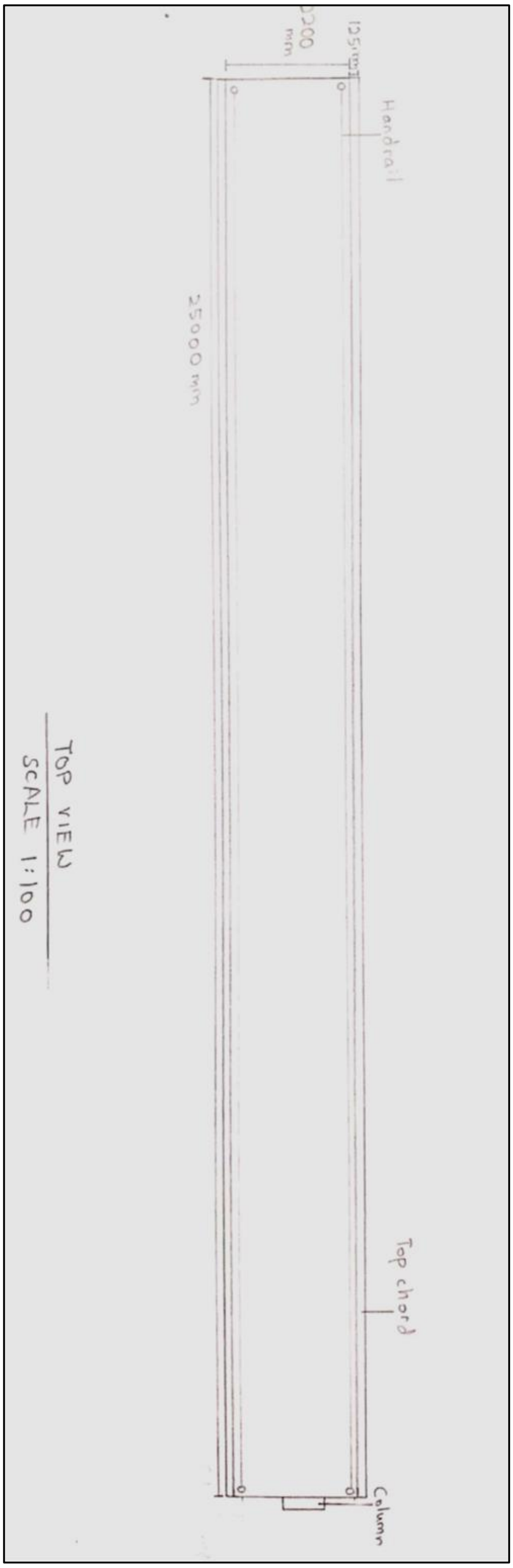


Figure 6

2.8 FABRICATION VIEW

The details on the steel members are shown in Table 1

Table 1

Steel Member Schedule		
Beam mark	**Profile**	**Material**
B1	75 X 75 X 5.0 SHS	350
B2	89 X 89 X 3.5 SHS	350
B3	20 X 20 X 1.6 SHS	350
B4	125 X 125 X 6.0 SHS	350
B5	OUT-OF-DESIGN	350
B6	OUT-OF-DESIGN	350
B7	OUT-OF-DESIGN	350

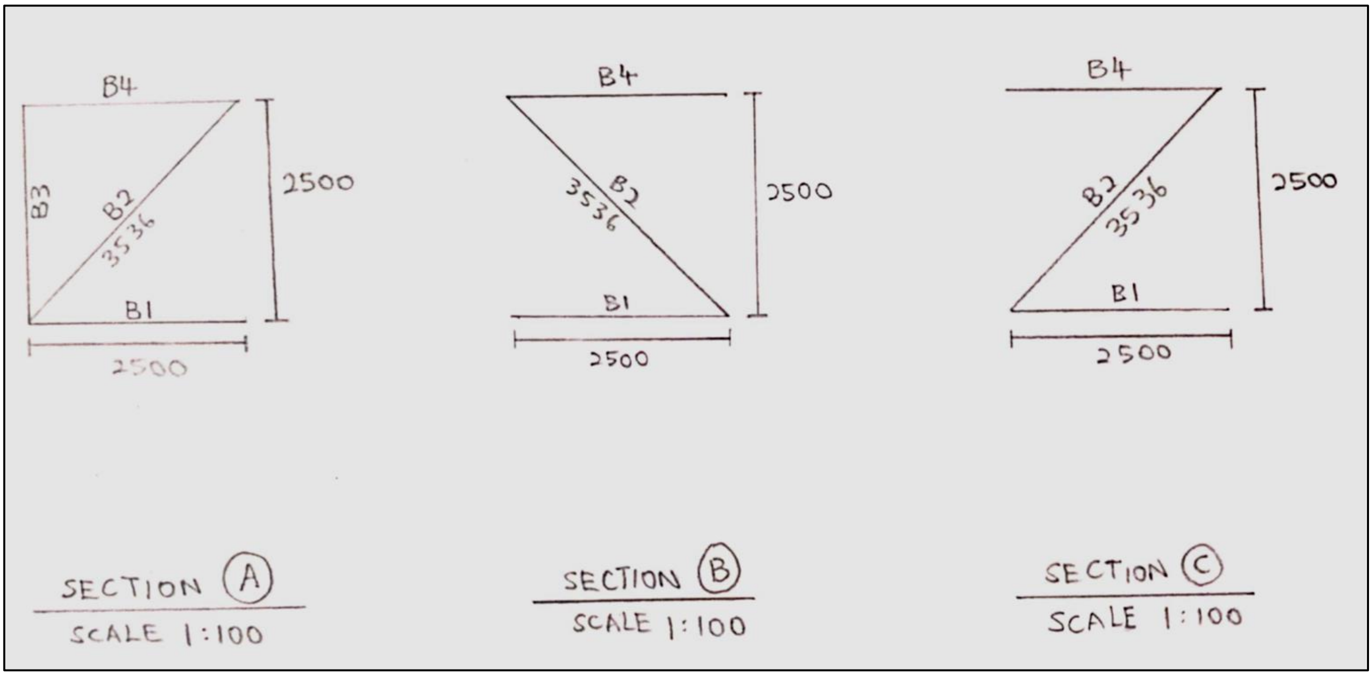


Figure 7

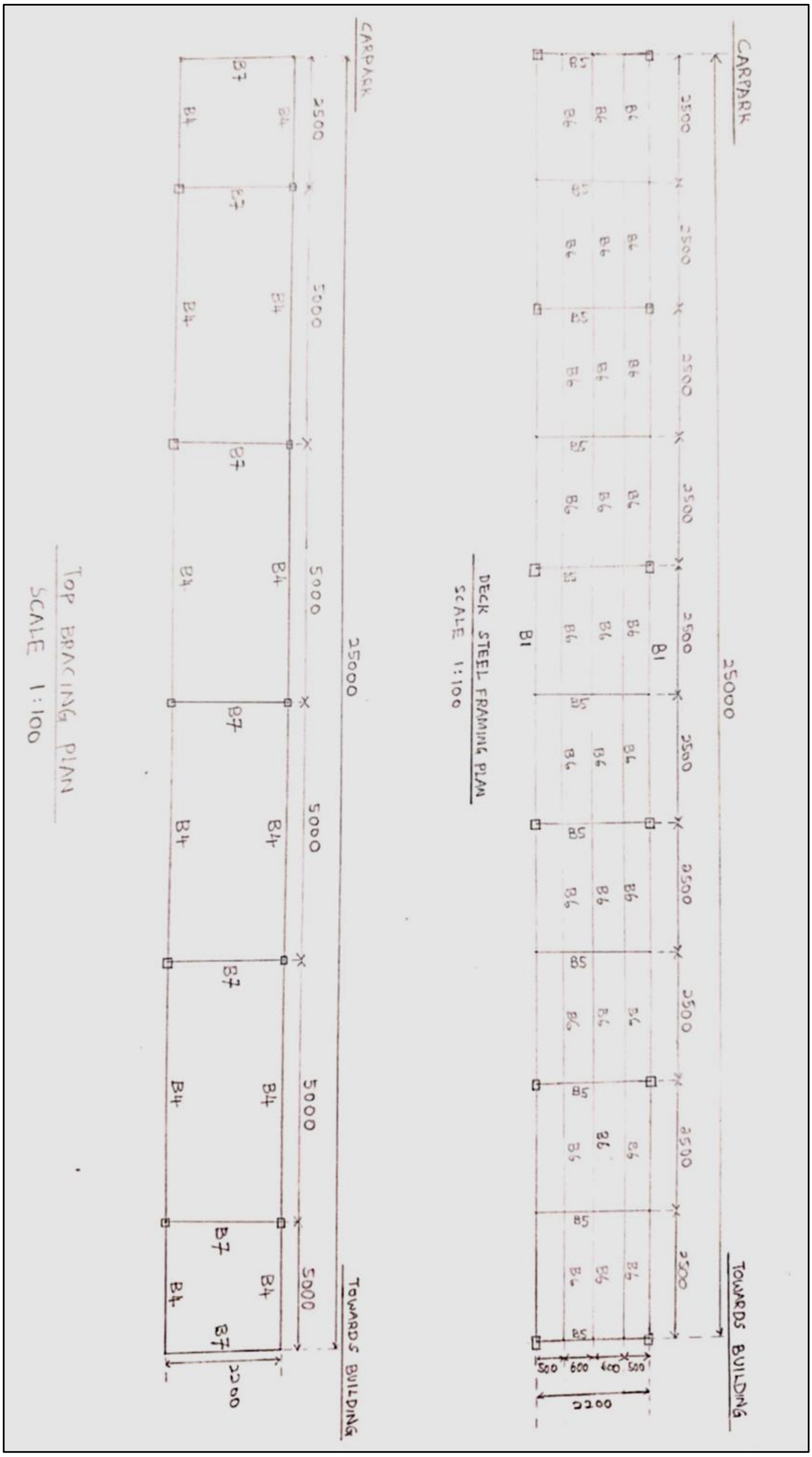

CARPARK
TOWARDS BUILDING
25000
DECK STEEL FRAMING PLAN
SCALE 1:100
CARPARK
TOWARDS BUILDING
25000
TOP BRACING PLAN
SCALE 1:100

Figure 8

2.9 SITE DRAWING

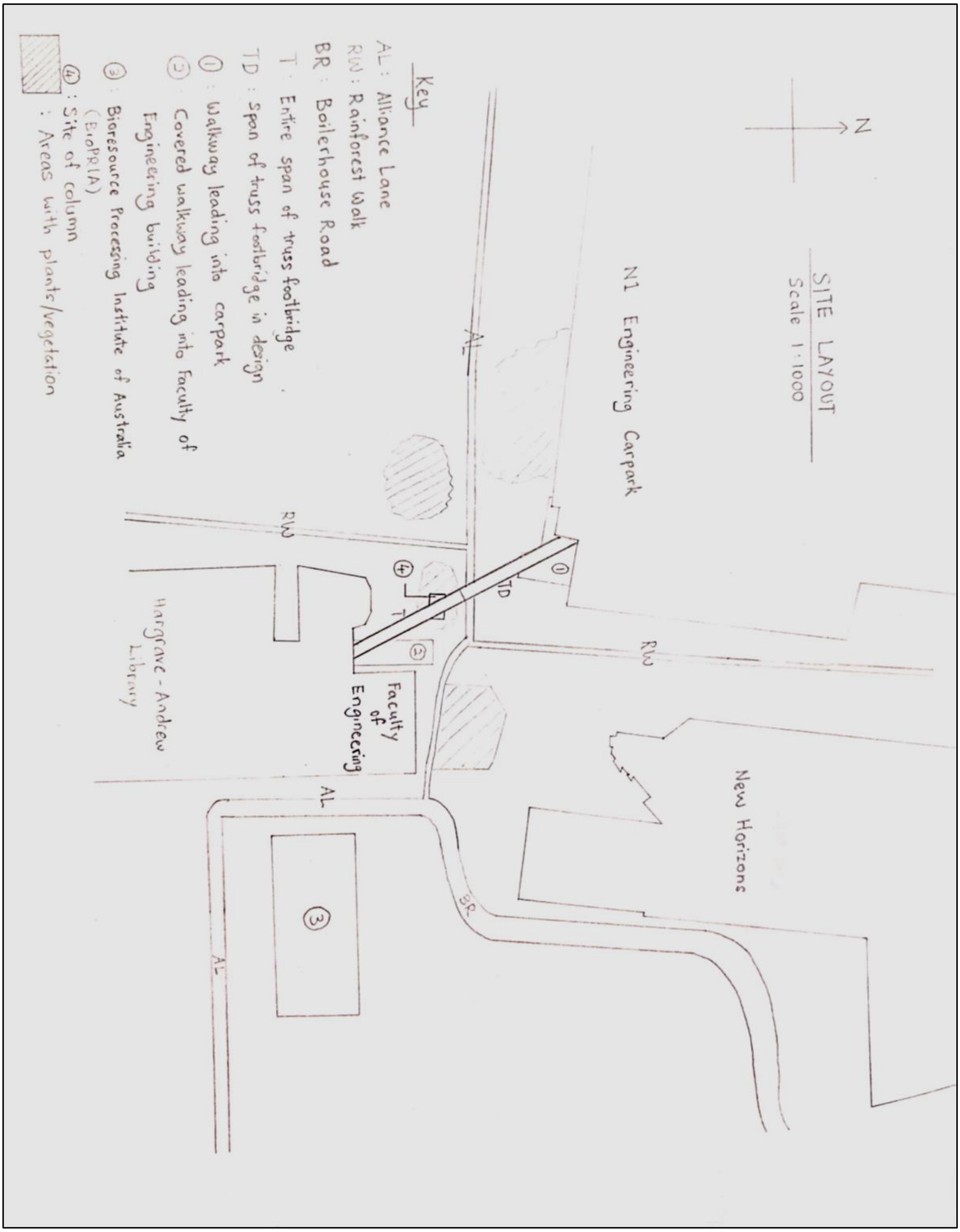


Figure 9

3 STRUCTURAL ANALYSIS

3.1 BRIDGE LOADING

3.1.1 Loading Diagram

The figure below shows the Bridge loading diagram.

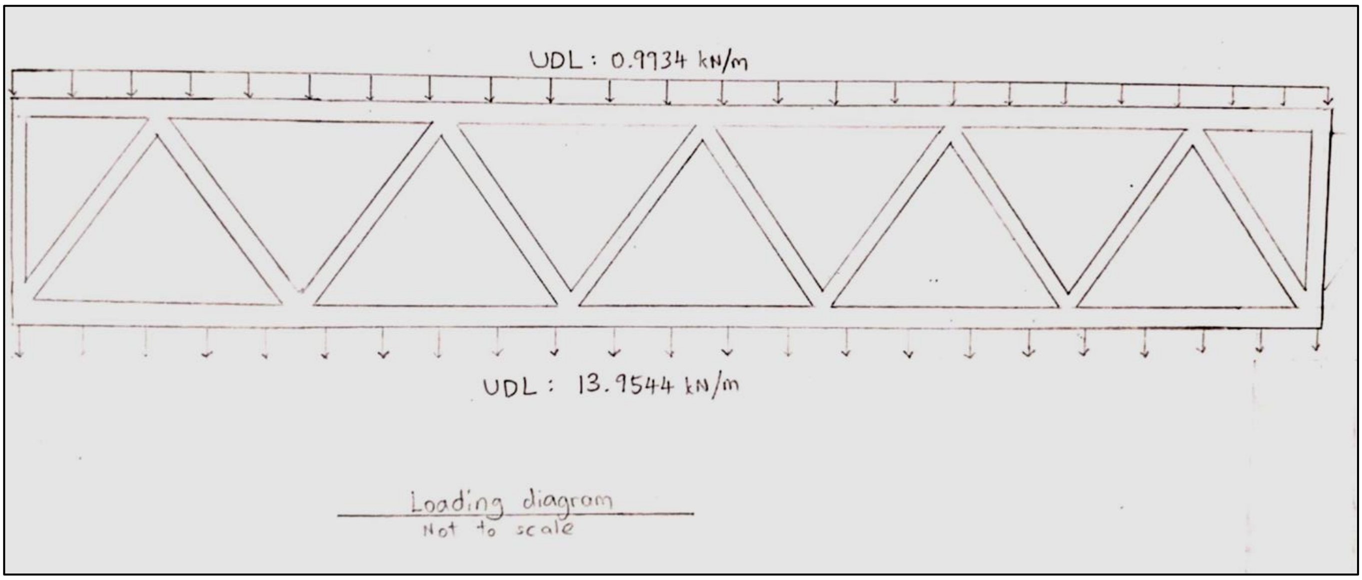


Figure 10

3.1.2 Bridge Loading values

From calculations in Appendices, we have calculated the loading forces acting on the truss.

Where the loading values are:

- Roof Weight: 0.0458 kPa
- Truss Self-Weight: 1.7348 kN/m (both sides)
- Roof Maintenance Load: 0.25 kPa
- Concrete Slab Weight: 3.6 kPa
- Handrail Load: 0.36 kN/m (per side)
- Pedestrian Live Load: 5 kPa

Force acting on roof

= 1.2 (Dead Load: Roof Weight [3] + Truss Self-Weight/2 [Appendix D]) + 1.5(Live Load: Roof Maintenance Load)

Force acting on slab

= 1.2 (Dead Load: Concrete Slab Weight [2] + Handrail Load [4] + Truss Self-Weight/2 [Appendix D]) + 1.5(Live Load: Pedestrian Live Load [1])

The values are listed in the Table 2

Table 2

Force acting on roof (kN/m)	0.9934
Force acting on slab (kN/m)	13.9544

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3.2 METHOD OF JOINTS

From calculations in Appendices, we have calculated the member forces in each member of the truss using method of joints. The values are listed in the Table 3 Based on the labels in Figure 11.

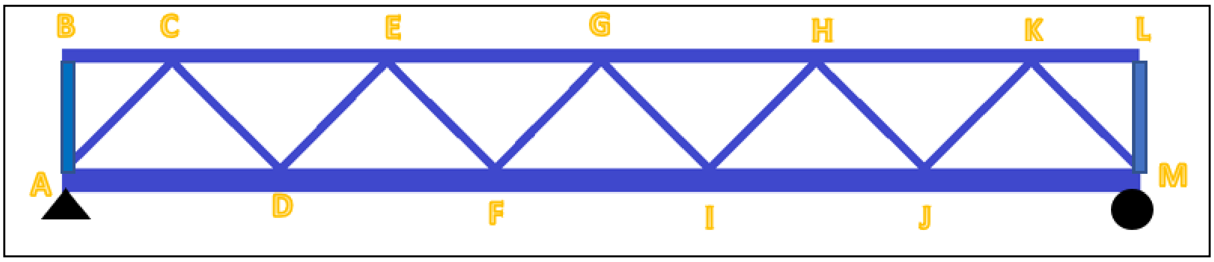

Figure 11

Table 3

Member	Forces (kN)
AB, JM	150.7198
DF, IJ	374.9368
FI	449.6758
BC, KL	0
CE, HK	-297.7143
EG, GH	-447.1994
AC, KM	-213.15
CD, KJ	207.8816
DE, JH	-109.2091
EF, HI	102.1847
FG, IG	-3.5122
BA, LM	-1.2418

3.3 METHOD OF SECTIONS

3.3.1 Introduction

We performed one Method of Sections check. This is to be done at an appropriate location in the truss, in order to verify your Method of Joints results.

3.3.2 Diagram for Method of Sections

We decide to make the Cut as per the diagram as per Figure 12

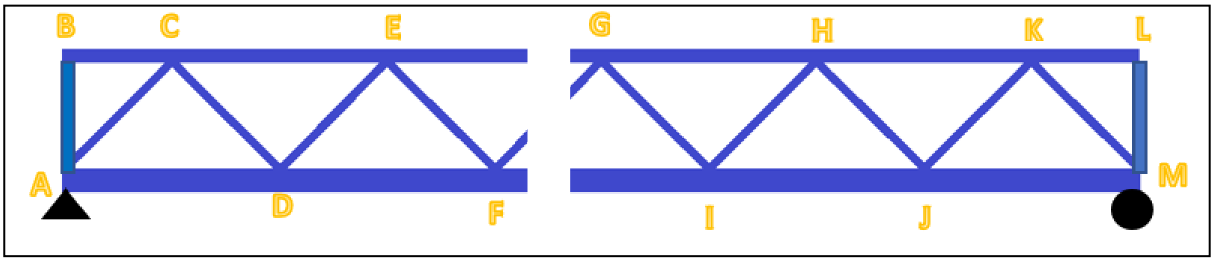

Figure 12

Label the Forces acting on the members in right section on Figure 13

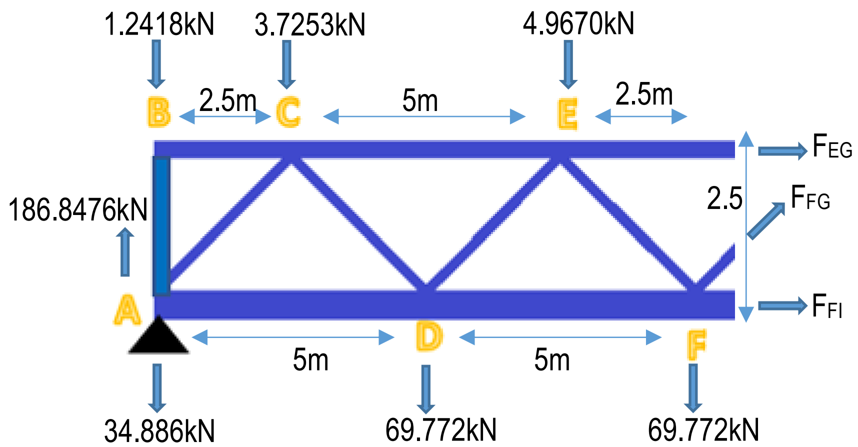

Figure 13

3.3.3 Calculate the Forces F_{EG}

Summation of moments about F should equal to zero. Assume anticlockwise as positive moment.

$$F_{EG} = -447.1923 \text{ kN}$$

3.3.4 Calculate the Forces F_{FG}

Summation of vertical forces should equal to zero. Assume upwards is positive.

$$F_{FG} = -3.5122$$

3.3.5 Calculate the Force F_{FI}

Summation of horizontal forces should equal to zero. Assume right is positive.

$$F_{FI} = 449.6758$$

3.3.6 Verifying the Methods of Joints

Since The values of F_{EG} , F_{FG} and F_{FI} from both the methods of joints and method of sections produce the same values, it verifies the values of member forces calculated using method of joints.

4 DETAILED DESIGN CHECK ON TRUSS

4.1 INTRODUCTION

After completing analysis of member forces, truss members and columns can be designed. All members are to be designed as steel square hollow sections (SHS) [5]. Design Tables can be found in the appendix.

For truss member design, a single member size is designed for all bottom chord members; all top chord members; all diagonals members and all vertical members. i.e., There will be 4 different member designs.

Tension members checked for yielding failure, and compression members for yield and/or buckling failure.

4.2 MEMBER FORCES

From Member Analysis, member forces are shown in Table 4.

Table 4

Bottom Chord Members (kN)		Top Chord Members (kN)		Diagonal Members (kN)		Vertical Members (kN)	
AD, JM	150.7198	**BC, KL**	0	**AC, KM**	-213.15	**BA, LM**	-1.2418
DF, IJ	374.9368	**CE, HK**	-297.7143	**CD, KJ**	207.8816		
FI	449.6758	**EG, GH**	-447.1994	**DE, JH**	-109.2091		
				EF, HI	102.1847		
				FG, IG	-3.5122		

(note: negative force represents compression)

The labels for each member are shown in Figure 14.

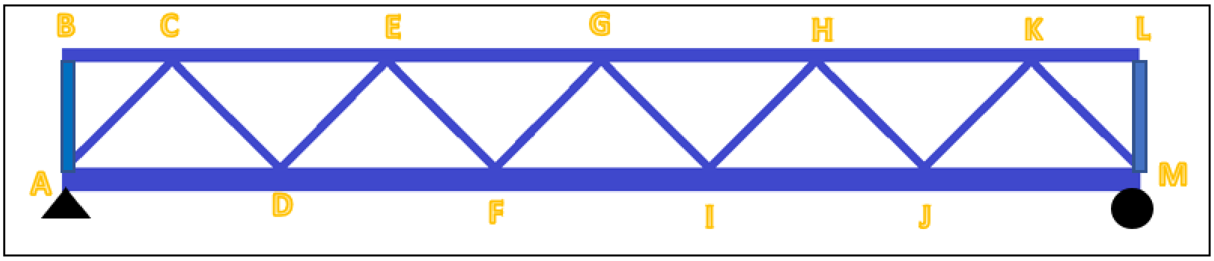

Figure 14

4.3 MAXIMUM TENSION AND COMPRESSION FORCES

From data in Table 1, the maximum tension and compression forces for members are shown in Table 5.

Table 5

Bottom Chord Members	
Maximum Tension (kN)	449.6758
Maximum Compression (kN)	0
Top Chord Members	
Maximum Tension (kN)	0
Maximum Compression (kN)	447.1994
Diagonal Members	
Maximum Tension (kN)	207.8816
Maximum Compression (kN)	213.15
Vertical Members	
Maximum Tension (kN)	0
Maximum Compression (kN)	1.2418

4.4 CHECK DESIGN FOR BUCKLING

Check the design condition for buckling to determine the minimum required Second Moment of Area, I from those listed in SHS tables [5] based on Euler's Buckling Load as shown Equation 1

$$P \leq \frac{\pi^2 * E * I}{(le)^2}$$

where P is the Compression Force, E is the Young's Modulus, I is the Second Moment of Area and le is the Effective Length. Take the Young's modulus of steel as 200,000 MPa.

Since all joints of a truss are assumed to be pin supports, the Effective Length of each member is equal to the actual length of the member. Hence,

$$P \leq \frac{\pi^2 * E * I}{l^2}$$

$$I \geq \frac{P * l^2}{\pi^2 * E} \quad (1)$$

The minimum required Second Moment of Area, I is calculated in Table 6.

Table 6

Bottom Chord Members	
Doesn't experience buckling as maximum compression is 0kN	
Top Chord Members	
Maximum Compression, P (N)	447199.4
Length of member, l (mm)	5000
Young's Modulus, (MPa)	200000
minimum required Second Moment of Area, I (10^6mm^4)	**5.6638**
Diagonal Members	
Maximum Compression (N)	213150
Length of member, l (mm)	3535.534
Young's Modulus, (MPa)	200000
minimum required Second Moment of Area, I (10^6mm^4)	**1.3498**
Vertical Members	
Maximum Compression (N)	1241.8
Length of member, l (mm)	2500
Young's Modulus, (MPa)	200000
minimum required Second Moment of Area, I (10^6mm^4)	**0.0039**

(Note: The length of top chord members is set to 5 because it's okay to ignore BC and KI as they are zero force members)

4.5 CHECK DESIGN FOR YIELDING

Check the design condition for yielding to determine the minimum required Cross-Sectional Area, A from those listed in SHS tables [5] based on Equation 2.

$$F \leq \sigma_y * A$$
$$A \geq \frac{F}{\sigma_y} \ (2)$$

where F is the Maximum Axial Force on member, σ_y is the yield stress and A is the cross-sectional area. Note that Grade 350 steel in the sections tables means the yield strength of the steel is 350 MPa.

The minimum required Cross-Sectional Area, A is calculated in Table 7.

Table 7

Bottom Chord Members	
Maximum Axial Force on member, F (N)	449675.8
Yield Stress, σ_y (MPa)	350
minimum required Cross-Sectional Area, A (mm^2)	**1284.788**
Top Chord Members	
Maximum Axial Force on member, F (N)	447199.4
Yield Stress, σ_y (MPa)	350
minimum required Cross-Sectional Area, A (mm^2)	**1277.713**
Diagonal Members	
Maximum Axial Force on member, F (N)	213150
Yield Stress, σ_y (MPa)	350
minimum required Cross-Sectional Area, A (mm^2)	**609**
Vertical Members	
Maximum Axial Force on member, F (N)	1241.8
Yield Stress, σ_y (MPa)	350
minimum required Cross-Sectional Area, A (mm^2)	**34**

5.3 Material Selection

Hence using the information calculated in Table 6 and Table 7, compare the values to those listed in the SHS tables [5] to obtain the best designation for each type of member.

The result obtained is shown in Table 8.

Table 8

Bottom Chord Members	
minimum required Second Moment of Area, I (10^6mm^4)	0
minimum required Cross-Sectional Area, A (mm^2)	1284.788
Best Designation (mm x mm x mm SHS)	**75 x 75 x 5.0 SHS**
Top Chord Members	
minimum required Second Moment of Area, I (10^6mm^4)	5.6638
minimum required Cross-Sectional Area, A (mm^2)	1277.713
Best Designation (mm x mm x mm SHS)	**125 x 125 x 6.0 SHS**
Diagonal Members	
minimum required Second Moment of Area, I (10^6mm^4)	1.3498
minimum required Cross-Sectional Area, A (mm^2)	609
Best Designation (mm x mm x mm SHS)	**89 x 89 x 3.5 SHS**
Vertical Members	
minimum required Second Moment of Area, I (10^6mm^4)	0.0039
minimum required Cross-Sectional Area, A (mm^2)	34
Best Designation (mm x mm x mm SHS)	**20 x 20 x 1.6 SHS**

5 DETAILED DESIGN CHECK OF COLUMN

5.1 INTRODUCTION

The column of our bridge is made of Grade C350LO Steel Hollow Sections. The column will experience axial compression. Thus, the member must be checked for yield and/or buckling failure.

5.2 COMPRESSION FORCES

Since the Column must support 2 pairs of trusses, the maximum compression force experienced by the column is has follows.

$$Compression\ on\ Column = 4 * Reaction\ Force$$
$$Compression\ on\ Column = 4 * 186.8476kN$$
$$Compression\ on\ Column = 747.3904kN$$

5.3 CHECK DESIGN FOR BUCKLING

Check the design condition for buckling to determine the minimum required Second Moment of Area, I from those listed in SHS tables [5] based on Euler's Buckling Load as shown Equation 3.

$$P \le \frac{\pi^2 * E * I}{(le)^2} \quad (3)$$

where P is the Compression Force, E is the Young's Modulus, I is the Second Moment of Area and le is the Effective Length. Take the Young's modulus of steel as 200,000 MPa.

Since we are taking two case,

Case 1: The Column is pinned at both ends

Case 2: The Column is fixed at one end and free at the other

Therefore, the Effective Length of the column is equal to the k times of the actual length of column where k = 1, 2. Hence,

$$P \le \frac{\pi^2 * E * I}{(\mathrm{k} * l)^2}$$
$$I \ge \frac{(\mathrm{k} * l)^2 * P}{\pi^2 * E}$$

P = 747,390.4 N

l = 3000 mm

E = 200,000 MPa

Using the above values, calculate the minimum required Second Moment of Area, I.

$$I \ge \frac{(1 * 3000)^2 * 747{,}390.4}{\pi^2 * 200{,}000} \text{ or } I \ge \frac{(2 * 3000)^2 * 747{,}390.4}{\pi^2 * 200{,}000}$$

Case 1: $I \ge 3.4 * 10^6\ mm^4$

Case 2: $I \ge 13.6 * 10^6\ mm^4$

Therefore, the minimum required Second Moment of Area, I for the column is $1.6698 * 10^6\ mm^4$

5.4 CHECK DESIGN FOR YIELDING

Check the design condition for yielding to determine the minimum required Cross-Sectional Area, A from those listed in SHS tables [5] based on Equation 4.

$$P \leq \sigma_y * A$$
$$A \geq \frac{P}{\sigma_y} \ (4)$$

where P is the Compression on column, σ_y is the yield stress and A is the cross-sectional area. Note that Grade 350 steel in the sections tables means the yield strength of the steel is 350 MPa. [5]

P = 747,390.4 N

σ_y = 350 MPa

The minimum required Cross-Sectional Area, A is calculated in below

$$A \geq \frac{747{,}390.4}{350}$$
$$A \geq \frac{747{,}390.4}{350}$$
$$A \geq 2135.4 \, mm^2$$

Therefore, the minimum required Cross-Sectional Area, A for the column is $2135.4 \, mm^2$

5.5 MATERIAL SELECTION

Hence using the information calculated above, compare the values to those listed in the SHS tables to obtain the best designation for the column.

From SHS tables,

For Case 1,

The optimal design for the column is **125 mm x 125 mm x 5.0 mm SHS** Grade C350LO Steel Hollow Sections. [5]

For Case 2,

The optimal design for the column is **200 mm x 200 mm x 5.0 mm SHS** Grade C350LO Steel Hollow Sections. [5]

6 DISCUSSION AND CONCLUSION

6.1 DISCUSSION

After analysing the truss members, we have realised that the final truss member sizes(weights) are less than the estimated value of truss weight (20kg/m). Therefore, the loading design is conservative.

As for the columns, we analysed the two cases. The first case being that the column was pinned at both ends and the second case was the column being fixed on one end and free on the other. We realised that case 1 is a better scenario. This is because the effective length of case 2 is double the effective length of case 1. Hence the minimum required Second Moment of Area of case 2 is four times the minimum required Second Moment of Area of case 1. Hence, a bigger size and larger weight of Grade C350LO Steel Hollow Section has two be used to support the structure.

In our calculations, we took all loads to act vertically and thus did not consider the load path for the horizontal loads such as wind or rain. The load travels from the truss members and travels along to the truss to the concrete slab then to the column and finally into the ground. The truss members which are parallel to direction of load (i.e., B5 ,B6 ,B7) will experience only axial tension and compression whereas the other members and the column will experience axial forces, shear forces and bending.

6.2 CONCLUSION

The design of the bridge to be constructed between the North1 multi-storey carpark and the Faculty of Engineering building (14 Alliance Lane) has been presented and discussed in this report. The design consists of trusses, a roof and handrails. The bridge should be enough for students to get to their destination without getting wet by rain.

7 REFERENCES

[1]Australian/ New zealand standard (2002,Jun.). *Structural design actions Permanent, imposed and other actions* [Online]. Available: https://lms.monash.edu/pluginfile.php/11461670/mod_folder/content/0/as1170%20extracts.pdf?forcedownload=1

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[3]Lysaght. *Lysaght Mini Orb* [Online]. Available: https://lms.monash.edu/pluginfile.php/11461670/mod_folder/content/0/roof%20sheeting%20info.pdf?forcedownload=1

[4]Barrett Ancillary Products. *PRODUCT MANUAL STOCK RANGE & TECHNICAL DATA* [Online]. Available: https://www.barrettsteel.com/BarrettSteel/media/BarrettSteel/Downloads/Barrett-Steel-Handrail-A6-composite-72dpi.pdf?ext=.pdf

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APPENDIX A PERSONAL CONTRIBUTION AND LEARNING

A.1 Jie Hao

- Bridge design
- Loading diagram
- 3D diagram
- Fabrication drawing
- Site layout

A.2 Avvienash Jaganathan

- Method of sections
- Analysis of Truss
- Analysis of Columns

A.3 Hue Hao Yuan

- Calculations of external force
- Calculations of member force
- Loads
- Appendix

A.4 Justin Wong

- Introduction
- Summary
- Conclusion

A.5 Everybody:

- Loading on Truss
- Concept Design
- Force Calculation
- Method of Joints
- Discussion

A.6 Report Sections

Section	Done by:	Checked by:
Summary	Justin Wong	Hue Hao Yuan
Introduction	Justin Wong	Hue Hao Yuan
Truss Design	Jie Hao	Justin Wong
Structural Analysis (Bridge Loading Diagram)	Jie Hao	Avvienash Jaganathan
Structural Analysis (Bridge Loading)	Hue Hao Yuan	Avvienash Jaganathan
Structural Analysis (Method of Joints)	Hue Hao Yuan	Jie Hao
Structural Analysis (Method of Sections)	Avvienash Jaganathan	Hue Hao Yuan
Detailed Design Check on Truss	Avvienash Jaganathan	Jie Hao
Detailed Design Check on Column	Avvienash Jaganathan	Justin Wong
Discussion	All Members	All Members
Conclusion	Justin Wong	Hue Hao Yuan
Appendix	Hue Hao Yuan	Avvienash Jaganathan
Reference	Justin Wong	Jie Hao

APPENDIX B CALCULATIONS

PAGE	Appendix 1 Loading	DESIGNED:	Hao Yuan
CLIENT	The client	CHECKED	Jie Hao
PROJECT	ENG1001 Carpark Truss Footbridge	DATE:	8/12/20
JOB NO.			

Force acting on the structure

Force acting on structure comprises a combination of :

- Force acting on the roof, Fr
- Force acting on the slab, Fs

Geometry values used

Span of truss being designed = 25m

Depth of truss = 2.5m

Width of footbridge = 2.2m

Span / depth ratio = 10

Loads

C areas where people may congregate

Type of activity	Uniformly distributed load / kPa
C3	5.0

As 1170 extracts Table 3.1

Pedestrian live load = 5kPa

Type of activity	Specific uses	Uniformly distributed actions / kPa
R2 other roofs	i) structural elements	(1.8/A + 0.12) but not less than 0.25

Table 3.2

PAGE	Appendix : loading	DESIGNED:	Hao Yuan
CLIENT	The client	CHECKED	Jie Hao
PROJECT	ENG1001 Carpark Truss Footbridge	DATE:	8/12/20
JOB NO.			

Maintainence roof load $= \frac{1.8}{Area} + 0.12$

$= \frac{1.8}{(\text{width of footbridge} \times \text{span of truss})} + 1.2$

$= \frac{1.8}{(2.2 \times 2.5)} + 1.2$

$= 0.15\,kPa$ (since $0.15 < 0.25$, we use $0.25\,kPa$

Mass

	kg/m^2
Colorbond	4.58

AS/NZS 2728:1997

Roof weight $= 4.58 \times \frac{10}{1000} = 0.0458\,kPa$

Concrete Slab thickness = 0.15m

Concrete Slab density = $24\,kN/m^3$

Concrete slab weight = concrete slab density × concrete slab thickness

$= 24\,kN/m^3 \times 0.15\,m$

$= 3.6\,kPa$

Handrail load = 0.36kN/m per side

PAGE	Appendix : loading	DESIGNED:	Hao Yuan
CLIENT	The client	CHECKED	Jie Hao
PROJECT	ENG1001 Carpark Truss Footbridge	DATE:	8/12/2020
JOB NO.			

Truss self weight $= \text{Initial estimate} \times 120\% \times \frac{10}{1000}$

$= 20kg/m \times 120\% \times \frac{10}{1000}$

$= 0.24\ kN/m$

PAGE	Appendix : force on structure	DESIGNED:	Hao Yuan
CLIENT	The client	CHECKED	Jie Hao
PROJECT	ENG1001 Carpark Truss Footbridge	DATE:	8/12/20
JOB NO.			

Calculations of force acting on structure

→ Assume ULS

Selfweight of truss per side = weight of truss per meter × (top length + bottom length + vertical length + diagonal length).

$= 0.24 \times (25m + 25m + 5m + 10m + 10\sqrt{12.5}m)$

$= 21.6853kN$

Self weight of truss per meter (both included) $= \frac{21.6853kN}{25m} \times 2$

$= 1.7348 \ kN/m$

$F_r = 1.2 \times \text{Dead load} + 1.5 \times \text{Live load}$

$= 1.2 \times (\text{Roof weight} + \frac{\text{Truss self weight}}{2}) \times 1.5 (\text{Roof maintainence load})$

$= 1.2 \times (0.0458kPa + \frac{1.7348}{2}) \times (1.5 \times 0.25kPa \times 2.2m)$

$= 1.9868 \ kNm^{-1}$ for 2 sides.

$F_s = 1.2 \times \text{Dead load} + 1.5 \times \text{live load}$

$= 1.2 \times (\text{concrete slab weight} + \text{handrail load} + \frac{\text{Truss self weight}}{2})$
$+ 1.5 (\text{Pedestrian live load})$

PAGE	Appendix : force on structure	DESIGNED:	Hao Yuan
CLIENT	The client	CHECKED	Jie Hao
PROJECT	ENG1001 Carpark Truss Footbridge	DATE:	10/12/2020
JOB NO.			

$F_s = 1.2[(3.6\,kPa \times 2.2) + (0.36\,kNm^{-1} \times 2\,side)$
$+ (0.5 \times 1.7348\,kNm^{-1})] + 1.5 \times 5\,kPa \times 2.2\,m$

$F_s = 27.9089\,kNm^{-1}$ for 2 sides

Hence, for 1 side

$\rightarrow F_r = \frac{1.9868\,kNm^{-1}}{2}$

$= 0.9934\,kN/m$

$F_s = \frac{27.9089\,kNm^{-1}}{2}$

$= 13.9544\,kN/m$

PAGE	Appendix : Method of joints	DESIGNED:	Hao Yuan
CLIENT	The client	CHECKED	Jie Hao
PROJECT	ENG1001 Carpark Truss Footbridge	DATE:	8/12/20
JOB NO.			

Member force using method of joints

Horizontal reaction = 0N

Vertical reaction, $F_y = (2\times 1.2418 + 2\times 3.7253 + 3\times 4.9670)/2$

$= 186.8476 kN$

B: $-BA + (1.2418) = 0$

$BA = -1.2418 kN$

A

A_y : $186.8476 + (-34.886) - 1.2418 + AC\cos 45 = 0$

$AC = -213.15 kN$

A_x : $AD + AC\cos 45 = 0$

$AD = 150.7198 kN$

C

C_y : $-3.7253 + 213.15\cos 45 - CD\cos 45 = 0$

C_x : $CE + AC\cos 45 + CD\cos 45 = 0$

$CD = 207.8816 kN$

$CE = -297.7143 kN$

D

$D_y = -69.772 + 207.8816\cos 45 + DE\cos 45 = 0$

$DE = -109.2091 kN$

PAGE	Appendix : method of joint	DESIGNED:	Hao Yuan
CLIENT	The client	CHECKED	Jie Hao
PROJECT	ENG1001 Carpark Truss Footbridge	DATE:	8/12/20
JOB NO.			

D_x : $-AD - CD\cos(45) - DE\cos 45 + DF = 0$

$DF - (150.7198) - (207.8816)\cos 45 - (109.2091\cos 45) = 0$

$DF = 374.9368\,kN$

E

E_y : $DE\cos 45 - E_y - EF\cos 45 = 0$

$109.2091\cos 45 - 4.9670 - EF\cos 45 = 0$

$EF : 102.1847\,kN$

E_x : $CE + DE\cos(45) + EF\cos(45) + EG = 0$

$297.7143 + 109.2091\cos(45) + 102.1847\cos(45) + EG = 0$

$EG : -447.1994\,kN$

F

F_y : $-69.772 + EF\cos(45) + FG\cos(45) = 0$

$-69.772 + 102.1847\cos(45) + FG\cos(45) = 0$

$FG = -3.5122\,kN$

F_x : $-374.9368 - 102.1847\cos(45) - 3.5122\cos 45 + FI = 0$

$FI = 449.6758\,kN$

PAGE	Appendix : method of joint	DESIGNED:	Hao Yuan
CLIENT	The client	CHECKED	Jie Hao
PROJECT	ENG1001 Carpark Truss Footbridge	DATE:	8/12/20
JOB NO.			

Using Symmetry,

- AD = JM
- BC = KL
- EG = GH
- DF = IJ
- CE = HK
- AC = KM
- CD = KJ
- DE = JH
- EF = HI
- FG = IG
- BA = LM

Table 4

Bottom chord members (kN)		Top chord members (kN)		Diagonal members (kN)		Vertical members (kN)	
AD, JM	150.7198	BC, KL	0	AC, KM	-213.15	BA, LM	-1.2918
DF, IJ	374.9368	CE, HK	-297.7143	CD, KJ	207.8816		
FI	449.6758	EG, GH	-447.1994	DE, JH	-109.2091		
				EF, HI	102.1847		
				FG, IG	-3.5122		

PAGE	Appendix : Method of sections	DESIGNED:	Hao Yuan
CLIENT	The client	CHECKED	Jie Hao
PROJECT	ENG1001 Carpark Truss Footbridge	DATE:	10/12/2020
JOB NO.			

Method of section check

→ moment

$\Sigma M@F = 0$

$34.886(10) + 1.2418(10) + 3.7253(7.5) +$

$69.772(5) + 4.9670(2.5) - 186.8476(10) - 2.5F_{EG} = 0$

$\Rightarrow 348.86 + 12.418 + 27.93975 + 348.86 + 12.4175 - 1868.476 = 2.5F_{EG}$

$\Rightarrow F_{EG} = -447.1923$

→ Vertical forces

$\Sigma(F_{vertical}) = 0$

$-34.886 - 1.2418 - 3.7253 - 69.772 - 4.9670 - 69.772$

$+186.8476 + F_{FG} \times \cos 45 = 0$

$F_{FG} = -3.5122$

→ Horizontal force

$\Sigma(F_{horizontal}) = 0$

$\Rightarrow -447.1923 - 3.1522 \times \cos 45 + F_{FI} = 0$

$F_{FI} = 449.6758$

PAGE	Appendix : buckling	DESIGNED:	Hao Yuan
CLIENT	The Client	CHECKED	Jie Hao
PROJECT	ENG1001 Carpark Truss Footbridge	DATE:	10/12/2020
JOB NO.			

Compression forces

compression on column = 4 × reaction force

= 4 × 186.8476 kN

= 747.3904 kN

Check design for buckling

$$P \le \frac{\pi^2 \times E \times I}{(Le)^2}$$

$$\le \frac{\pi^2 \times E \times I}{(0.7 \times l)^2}$$

$$I \ge \frac{(k \times l)^2 \times P}{\pi^2 \times E}$$

→ Case 1, k=1

$$I \ge \frac{(1 \times 3000\,mm)^2 \times (747390.4\,N)}{\pi^2 \times (200000\,MPa)}$$

$$\ge 13.4 \times 10^6\,mm^4$$

→ Case 2, k=2

$$I \ge \frac{(2 \times 3000)^2 \times 747390.4}{\pi^2 \times 200000}$$

$$\ge 13.6 \times 10^6\,mm^4$$

PAGE	Appendix : yielding	DESIGNED:	Hao Yuan
CLIENT	The client	CHECKED	Jie Hao
PROJECT	ENG1001 Carpark Truss Footbridge	DATE:	10/12/2020
JOB NO.			

Check design for yielding

$P \leq \sigma_y \times A$

$A \geq \frac{P}{\sigma_y}$

$\geq \frac{747390.4}{350}$

$\geq 2135.4 mm^2$

APPENDIX C SHS TABLES

SHS

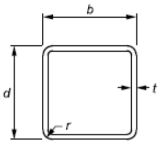
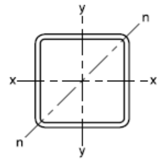


TABLE 3.1(a)

DIMENSIONS AND PROPERTIES

TUBELINE® SQUARE HOLLOW SECTIONS

GRADE C350L0 (AS 1163)



DIMENSION AND RATIOS					PROPERTIES								PROPERTIES FOR DESIGN TO AS 4100			
Designation	Mass per m	External Surface Area		$\frac{b-2t}{t}$	Gross Section Area	About x-, y- and n-axis					Torsion Constant	Torsion Modulus	Form Factor	About x- and y-axis		
d b t		per m	per t		A_g	I_x	Z_x	Z_n	S_x	r_x	J	C	k_f	λ_e	Compactness[3]	Z_e
mm mm mm	kg/m	m^2/m	m^2/t		mm^2	$10^6 mm^4$	$10^3 mm^3$	$10^3 mm^3$	$10^3 mm^3$	mm	$10^6 mm^4$	$10^3 mm^3$			(C,N,S)	$10^3 mm^3$
250x250x9.0 SHS	65.9	0.961	14.6	25.8	8400	79.8	639	477	750	97.5	129	972	1.00	30.5	N	744
6.0 SHS	45.0	0.974	21.7	39.7	5730	56.2	450	330	521	99.0	88.7	681	0.853	46.9	S	409
200x200x9.0 SHS	51.8	0.761	14.7	20.2	6600	39.2	392	297	465	77.1	64.5	599	1.00	23.9	C	465
6.0 SHS	35.6	0.774	21.8	31.3	4530	28.0	280	207	327	78.6	44.8	425	1.00	37.1	N	294
5.0 SHS	29.9	0.779	26.0	38.0	3810	23.9	239	175	277	79.1	37.8	362	0.890	45.0	S	223
150x150x9.0 SHS	37.7	0.561	14.9	14.7	4800	15.4	205	159	248	56.6	26.1	316	1.00	17.4	C	248
6.0 SHS	26.2	0.574	22.0	23.0	3330	11.3	150	113	178	58.2	18.4	229	1.00	27.2	C	178
5.0 SHS	22.1	0.579	26.2	28.0	2810	9.70	129	96.1	151	58.7	15.6	197	1.00	33.1	N	144
125x125x9.0 SHS	30.6	0.461	15.1	11.9	3900	8.38	134	106	165	46.4	14.5	208	1.00	14.1	C	165
6.0 SHS	21.4	0.474	22.1	18.8	2730	6.29	101	76.5	120	48.0	10.4	154	1.00	22.3	C	120
5.0 SHS	18.2	0.479	26.3	23.0	2310	5.44	87.1	65.4	103	48.5	8.87	133	1.00	27.2	C	103
4.0 SHS	14.8	0.483	32.7	29.3	1880	4.52	72.3	53.6	84.5	49.0	7.25	110	1.00	34.6	N	78.9
100x100x9.0 SHS	23.5	0.361	15.4	9.11	3000	3.91	78.1	63.6	98.6	36.1	7.00	123	1.00	10.8	C	98.6
6.0 SHS	16.7	0.374	22.4	14.7	2130	3.04	60.7	47.1	73.5	37.7	5.15	93.6	1.00	17.4	C	73.5
5.0 SHS	14.2	0.379	26.6	18.0	1810	2.66	53.1	40.5	63.5	38.3	4.42	81.4	1.00	21.3	C	63.5
4.0 SHS	11.6	0.383	32.9	23.0	1480	2.23	44.6	33.5	52.6	38.8	3.63	68.0	1.00	27.2	C	52.6
3.0 SHS	8.96	0.390	43.5	31.3	1140	1.77	35.4	26.0	41.2	39.4	2.79	53.2	1.00	37.1	N	37.1
2.5 SHS	*7.53*	*0.391*	*52.0*	*38.0*	*959*	*1.51*	*30.1*	*21.9*	*34.9*	*39.6*	*2.35*	*45.2*	*0.891*	*45.0*	*S*	*28.1*
2.0 SHS	6.07	0.393	64.7	48.0	774	1.23	24.6	17.8	28.3	39.9	1.91	36.9	0.706	56.8	S	20.2

NOTES:
1. This table is calculated in accordance with AS 4100 using design yield stress f_y = 350 MPa and design tensile strength f_u = 430 MPa as per AS 4100 table 2.1 for AS 1163 grade C350L0.
2. Grade C350L0 is cold formed and therefore is allocated the CF residual stresses classification in AS 4100.
3. C = Compact Section; N = Non-compact Section; S = Slender Section; as defined in AS 4100.
4. For Square and Rectangular Hollow Sections the outside corner radius r used in calculating the section properties is equal to $2t$ for sections with thickness $t \leq 3.0$mm and $2.5t$ for sections with $t > 3.0$mm.
5. Sizes shown in *Italics:* These sizes may not be stocked in all states or minimum order quanitites may apply

SHS

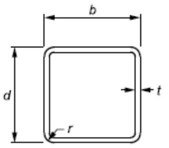
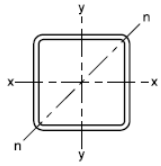


TABLE 3.1(c)

DIMENSIONS AND PROPERTIES

TUBELINE® SQUARE HOLLOW SECTIONS

GRADE C350L0 (AS 1163)



DIMENSION AND RATIOS					PROPERTIES								PROPERTIES FOR DESIGN TO AS 4100			
Designation	Mass per m	External Surface Area		$\frac{b-2t}{t}$	Gross Section Area	About x-, y- and n-axis					Torsion Constant	Torsion Modulus	Form Factor	About x- and y-axis		
d b t		per m	per t		A_g	I_x	Z_x	Z_n	S_x	r_x	J	C	k_f	λ_e	Compactness(3)	Z_e
mm mm mm	kg/m	m²/m	m²/t		mm²	10⁶mm⁴	10³mm³	10³mm³	10³mm³	mm	10⁶mm⁴	10³mm³			(C,N,S)	10³mm³
40 x 40 x4.0 SHS	4.09	0.143	34.9	8.00	521	0.105	5.26	4.36	6.74	14.2	0.192	8.33	1.00	9.47	C	6.74
3.0 SHS	3.30	0.150	45.3	11.3	421	0.0932	4.66	3.61	5.72	14.9	0.158	7.07	1.00	13.4	C	5.72
2.5 SHS	2.82	0.151	53.7	14.0	359	0.0822	4.11	3.13	4.97	15.1	0.136	6.21	1.00	16.6	C	4.97
2.0 SHS	2.31	0.153	66.4	18.0	294	0.0694	3.47	2.61	4.13	15.4	0.113	5.23	1.00	21.3	C	4.13
1.6 SHS	1.88	0.155	82.3	23.0	239	0.0579	2.90	2.15	3.41	15.6	0.0927	4.36	1.00	27.2	C	3.41
35 x 35 x3.0 SHS	2.83	0.130	45.8	9.67	361	0.0595	3.40	2.67	4.23	12.8	0.102	5.18	1.00	11.4	C	4.23
2.5 SHS	2.42	0.131	54.2	12.0	309	0.0529	3.02	2.33	3.69	13.1	0.0889	4.58	1.00	14.2	C	3.69
2.0 SHS	1.99	0.133	66.8	15.5	254	0.0451	2.58	1.95	3.09	13.3	0.0741	3.89	1.00	18.3	C	3.09
1.6 SHS	1.63	0.135	82.7	19.9	207	0.0379	2.16	1.62	2.57	13.5	0.0611	3.26	1.00	23.5	C	2.57
30 x 30 x2.0 SHS	1.68	0.113	67.4	13.0	214	0.0272	1.81	1.39	2.21	11.3	0.0454	2.75	1.00	15.4	C	2.21
1.6 SHS	1.38	0.115	83.3	16.8	175	0.0231	1.54	1.16	1.84	11.5	0.0377	2.32	1.00	19.8	C	1.84
25 x 25 x3.0 SHS	1.89	0.0897	47.4	6.33	241	0.0184	1.47	1.21	1.91	8.74	0.0333	2.27	1.00	7.49	C	1.91
2.5 SHS	1.64	0.0914	55.7	8.00	209	0.0169	1.35	1.08	1.71	8.99	0.0297	2.07	1.00	9.47	C	1.71
2.0 SHS	1.36	0.0931	68.3	10.5	174	0.0148	1.19	0.926	1.47	9.24	0.0253	1.80	1.00	12.4	C	1.47
1.6 SHS	1.12	0.0945	84.1	13.6	143	0.0128	1.02	0.780	1.24	9.44	0.0212	1.54	1.00	16.1	C	1.24
20 x 20 x1.6 SHS	0.873	0.0745	85.4	10.5	111	0.00608	0.608	0.474	0.751	7.39	0.0103	0.924	1.00	12.4	C	0.751

NOTES:
1. This table is calculated in accordance with AS 4100 using design yield stress f_y = 350 MPa and design tensile strength f_u = 430 MPa as per AS 4100 table 2.1 for AS 1163 grade C350L0.
2. Grade C350L0 is cold formed and therefore is allocated the CF residual stresses classification in AS 4100.
3. C = Compact Section; N = Non-compact Section; S = Slender Section; as defined in AS 4100.
4. For Square and Rectangular Hollow Sections the outside corner radius r used in calculating the section properties is equal to $2t$ for sections with thickness $t \leq 3.0$mm and $2.5t$ for sections with $t > 3.0$mm.

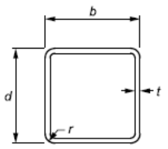
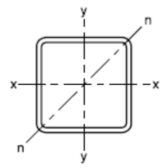


TABLE 3.2

DIMENSIONS AND PROPERTIES

TUBELINE® SQUARE HOLLOW SECTIONS

GRADE C350L0 (TUBELINE 350L0 - TYPE 2)



DIMENSION AND RATIOS					PROPERTIES								PROPERTIES FOR DESIGN TO AS 4100			
Designation	Mass per m	External Surface Area		$\frac{b-2t}{t}$	Gross Section Area	About x-, y- and n-axis					Torsion Constant	Torsion Modulus	Form Factor	About x- and y-axis		
d b t		per m	per t		A_g	I_x	Z_x	Z_n	S_x	r_x	J	C	k_f	λ_e	Compactness(4)	Z_e
mm mm mm	kg/m	m²/m	m²/t		mm²	10⁶mm⁴	10³mm³	10³mm³	10³mm³	mm	10⁶mm⁴	10³mm³			(C,N,S)	10³mm³
15 x 15 x1.8 SHS	0.681	0.0538	79.1	6.33	86.7	0.00239	0.318	0.262	0.414	5.25	0.00431	0.491	1.00	7.49	C	0.414
13 x 13 x1.8 SHS	0.568	0.0458	80.7	5.22	72.3	0.00142	0.218	0.184	0.290	4.42	0.00262	0.339	1.00	6.18	C	0.290

NOTES:
1. In this table, the properties of these products are calculated in accordance with AS 4100 using design yield stress f_y = 350 MPa and design tensile strength f_u = 380.
2. Type 2 products are not made strictly in accordance with AS 1163. Care should be used when designing structures using these products.
3. Grade C350L0 is cold formed and therefore is allocated the CF residual stresses classification in AS 4100.
4. C = Compact Section; N = Non-compact Section; S = Slender Section; as defined in AS 4100.
5. For Square and Rectangular Hollow Sections the outside corner radius r used in calculating the section properties is equal to $2t$ for sections with thickness $t \leq 3.0$mm and $2.5t$ for sections with $t > 3.0$mm.

APPENDIX D REFERENCE IMAGES

D.1 Truss Self-Weight

Project 1 information_week 2

Cross-section cut through 'indicative' footbridge

Aim to complete by the end of week 3:

1. Decide on the **span and depth** of your footbridge truss.
2. Decide on the **width** of your footbridge.
3. Calculate all the loading on your footbridge as detailed in Section 3 of the brief;
   - Live load on flooring (AS1170 extract provided)
   - Live load on the roof (As1170 extract provided)
   - Weight of concrete floor slab (google thickness)
   - Weight of roof sheeting (catalogue info provided)
   - Balustrade and hand rail (google)
   - Self weight of truss (20 kg/m initial estimate) + increase by 20% to allow for ancillary steelwork in roof and floor

At this point calculate all of the above loading as UDL loads on 'one' truss (one side of the footbridge) and we will discuss the application to the truss next week

D.2 Span-to-depth ratio

A general rule of thumb for **steel truss designs**, is to have a span-to-depth ratio between 10-20, where the span is the distance between (column/building) supports and the depth is the height/depth of the proposed truss. Decide on the depth of your truss structure based on this rule-of-thumb.

e.g. if the truss span = 20m, the truss depth should be between 1.0 and 2.0m (refer to Figure 2).

D.3 Concrete Density

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concrete density

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around 2,400 kilograms per cubic metre

The density of concrete varies, but is around 2,400 **kilograms per cubic metre** (150 lb/cu ft). Reinforced concrete is the most common form of concrete.

en.wikipedia.org › wiki › Properties_of_concrete

Properties of concrete - Wikipedia

APPENDIX E HANDRAIL LOADS

HANDRAIL STANDARDS

LOADING CATEGORIES

LIGHT DUTY 0.22kN/m	MEDIUM DUTY 0.36kN/m	HEAVY DUTY 0.74kN/m
For light access stairs and gangways not more than 600mm wide.	Regular two way pedestrian traffic in industrial and storage areas. Except designated escape routes.	Designated escape routes and pedestrian traffic using stairs, landings, corridors, ramps, external balconies, edges of roofs and footways providing these areas are not susceptible to overcrowding.

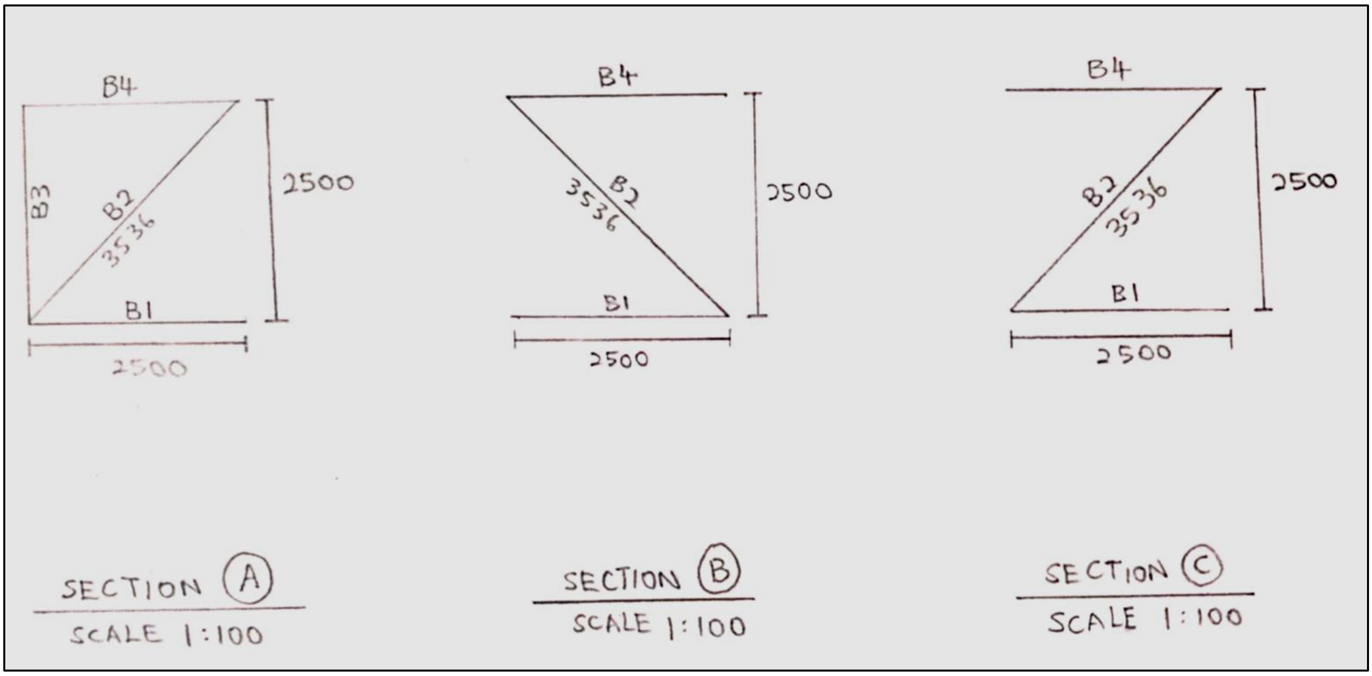
MAXIMUM SPACING FOR 1100MM HIGH STANDARDS

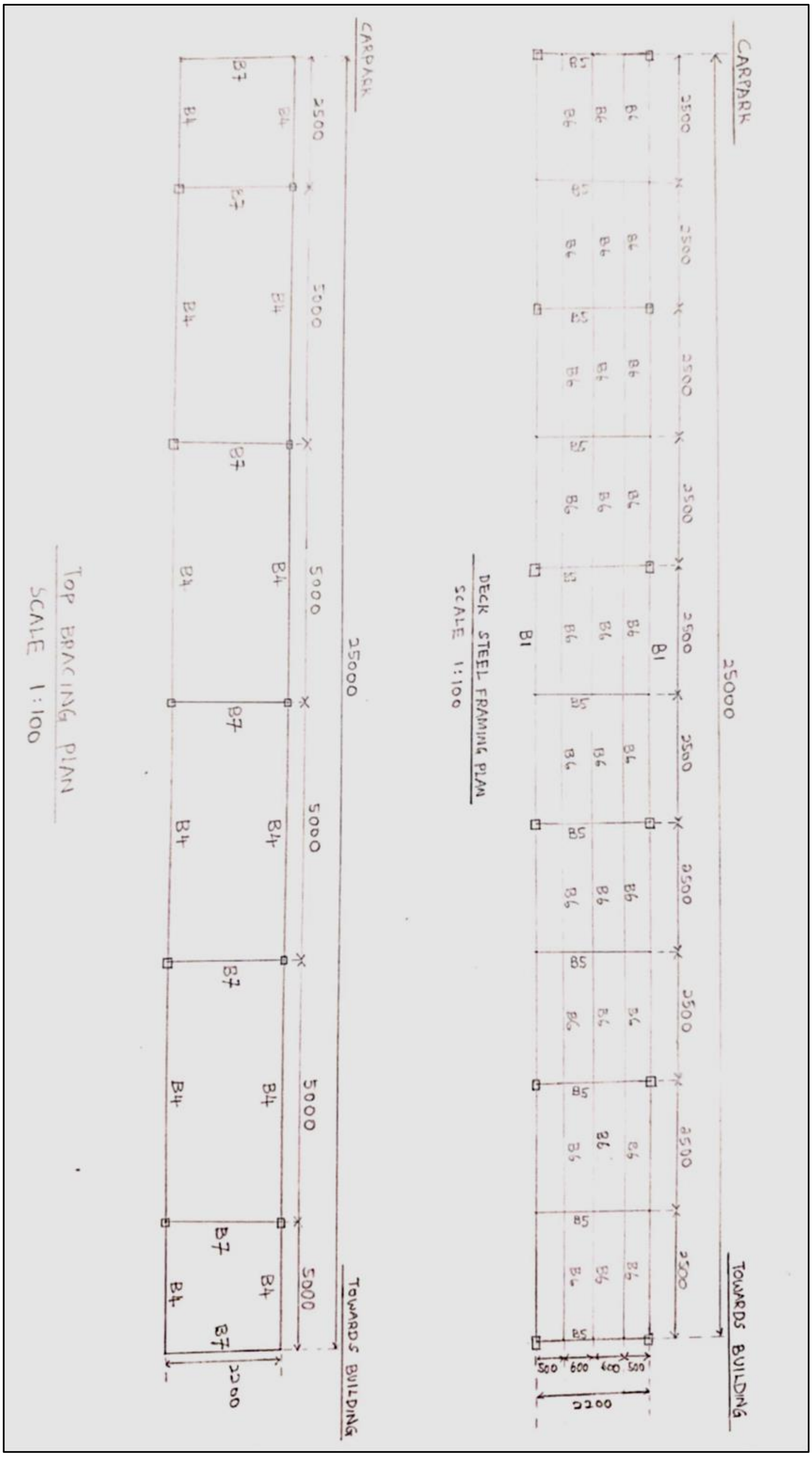
TUBULAR			
Handrail Shank Size	0.22kN/m	0.36kN/m	0.74kN/m
33.7 x 3.0	1600	1000	-
42.4 x 3.0	2000	1600	-
48.3 x 4.0	2250	2000	1700
60.3 x 4.0	-	-	1800

- This table has been constructed as a guide only and assumes a steel to steel fixing in each case.
- Designers should allow for relevant bolt size, number of bolts, base plate size and handrail pitch when fixing into concrete or other low density materials.

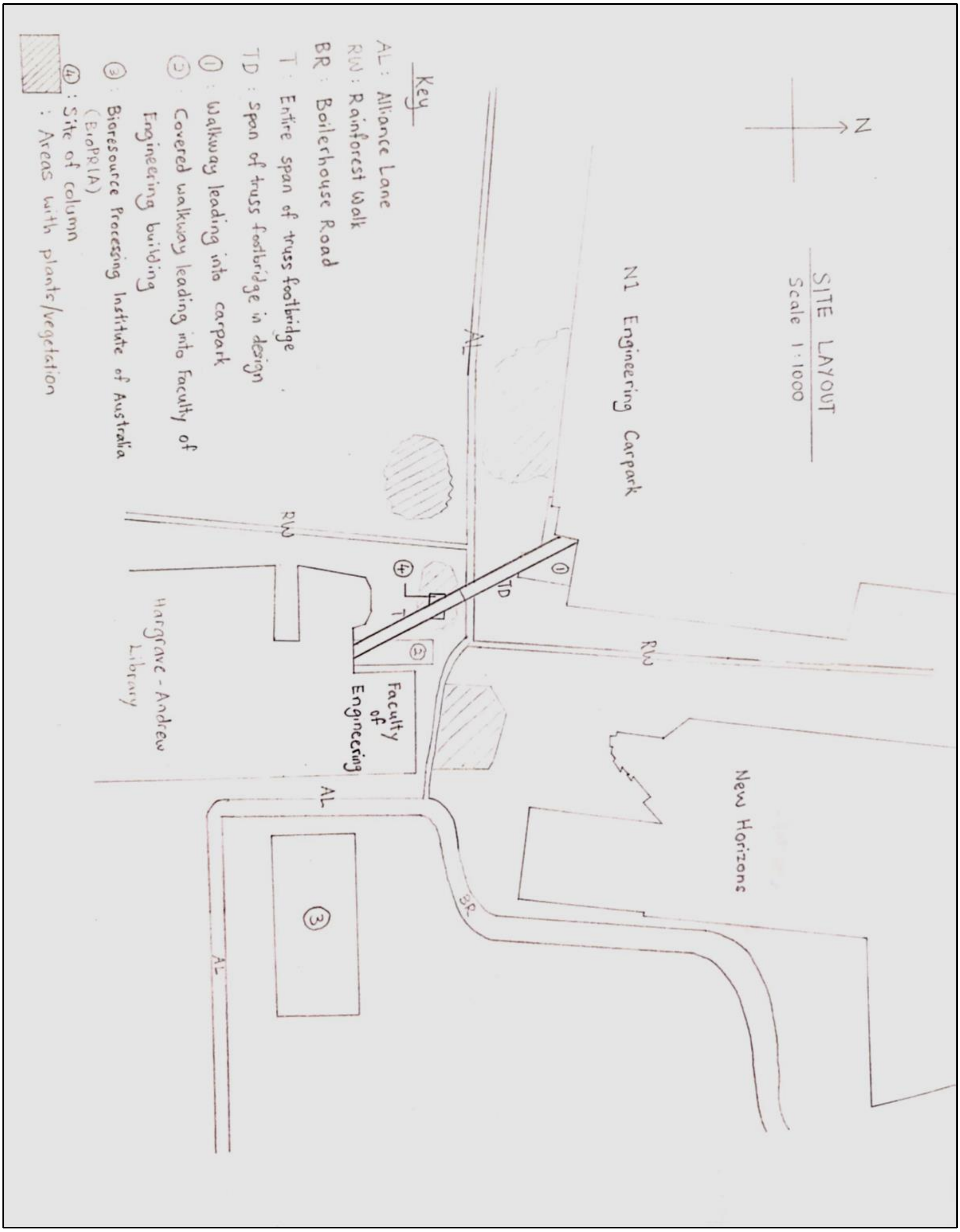
APPENDIX G FABRICATION AND SITE DRAWING

G.1 Fabrication Drawing




CARPARK
TOWARDS BUILDING
25000
DECK STEEL FRAMING PLAN
SCALE 1:100
CARPARK
TOWARDS BUILDING
25000
TOP BRACING PLAN
SCALE 1:100

G.2 Site Drawing



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