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Rethinking Industrial Shed Construction - Consider Timber

Technical Design Guide issued by Forest and Wood Products Australia

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Authors

Timber Development Association NSW LTD

Professor Perry Forsythe
Faculty of Design Architecture and Building
University of Technology Sydney

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Introduction

Timber's sustainability credentials are attracting world-wide interest, and advancements in timber engineering have made timber an increasingly cost-competitive proposition.

Encouraging the construction industry to adopt innovative approaches needs information and evidence. Attention to technical design, construction costs and site processes is critical to show the value proposition of timber construction to customers and optimise its use.

This Guide aims to help those involved in the decision chain (such as cost managers, estimators, design professionals, building developers and project managers) gain a better understanding of the value that timber construction systems offer industrial shed projects.

The Guide is based on a research project that developed a model single-storey shed building with a timber solution and compared it with conventional steel portal construction. The timber solution was designed to optimise functional performance, constructability and cost-effectiveness and provides guidance for compliance under the National Construction Code (NCC). This Guide provides an explanation of decision-making issues when developing timber solutions.

The Guide was revised to update the cost plans for all design options as there has been a significant shift in costs since the original cost plan was developed in 2014. The revision also included corrections made to the Bill of Quantities.

2

What Drives Decisions When Choosing Industrial Shed Construction Systems

A key objective of the project was to provide an understanding of the decision drivers along the customer/supply chain for the selection of industrial construction systems. Key areas of exploration included:

- Benchmarking against existing industrial shed construction systems, especially steel portal frame constructions. A steel solution for the model building is provided in Section 5.3 for comparative purposes.
- Understanding the nature of the overall delivery supply chain and related work flows – especially construction scheduling, productivity and prefabrication issues.
- Optimising the regulatory framework where it affects the viability of timber solutions.

3

Project Development

The research project was developed by a series of expert/stakeholder meetings, interviews, concept development sessions, design charrettes, cost planning studies, construction programming studies and detailed design studies aimed at developing the model shed building and a cost-effective timber solution for it.

A team of experts worked together to provide input to the development process.
Core collaborators included:

- **The Timber Development Association (TDA)**: A market development association for the timber industry and the project leader for this work, on behalf of the timber industry.
- **The University of Technology Sydney (UTS)**: A technology-driven university with an integrated understanding of the building industry and specific expertise in timber construction. The university co-developed the research method and mediated the strategic direction of the timber solutions in terms of detailed design, cost and site productivity issues.
- **Arup Ltd**: A global multi-disciplinary engineering firm with expertise spanning structural, acoustic, fire and services engineering. Arup Ltd provided design and engineering input into the timber solution and the corresponding steel solution.
- **Taylor Thompson Whitting Consulting Engineers**: An engineering firm with specialised services in structural, civil and facade engineering who provided the structural design for the re-engineered steel solution.
- **BCIS**: A global subsidiary of the Royal Institute of Chartered Surveyors who specialise in gathering building cost data used for reporting on cost trends for a variety building forms. BCIS provided quantity surveying, cost estimating and cost planning input for both the timber solution and the corresponding concrete solution.
- **Engineered timber manufacturers, suppliers and industry associations** (including Tilling Timber, Hyne Timber, Meyer Timber, Nelson Pine Industries, Carter Holt Harvey Wood Products, MiTek): Their input helped ensure the practical viability, design properties and availability of appropriate timber componentry.

Using the above team, two timber portal concept designs were developed (revolving around different portal, girt and purlin assemblies). Both were debated, tested against construction logistics and rationalised for cost, construction flow, structural performance and services integration. These design concepts were then tested more broadly on a cross section of building owners, developers, designers and contractors for critical feedback.

The designs considered included:

- Version 1: Timber Portals based on 6.7 m bay spacing (as detailed in Timber Solution 1)
- Version 2: Timber Portals based on 10.0 m bay spacing (as detailed in Timber Solution 2)

These were compared against a typical steel portal design utilising an 8.0 m spacing bay spacing (as detailed in Steel Solution).

Different bay spaces were used to test the robustness of the timber solution, relative to the steel option. In each case, the spacing was selected by the design engineer based on common scenarios faced in practice.

4

The Model Industrial Shed – the Basis for Comparison and Solution Development

The model shed is shown Figure 1. The model demonstrates a prototypical situation for modelling spatial, loading and fire resistance conditions, providing a neutral base for creating both the timber and competing steel solutions. The basic spatial characteristics of the model are provided in Table 1.

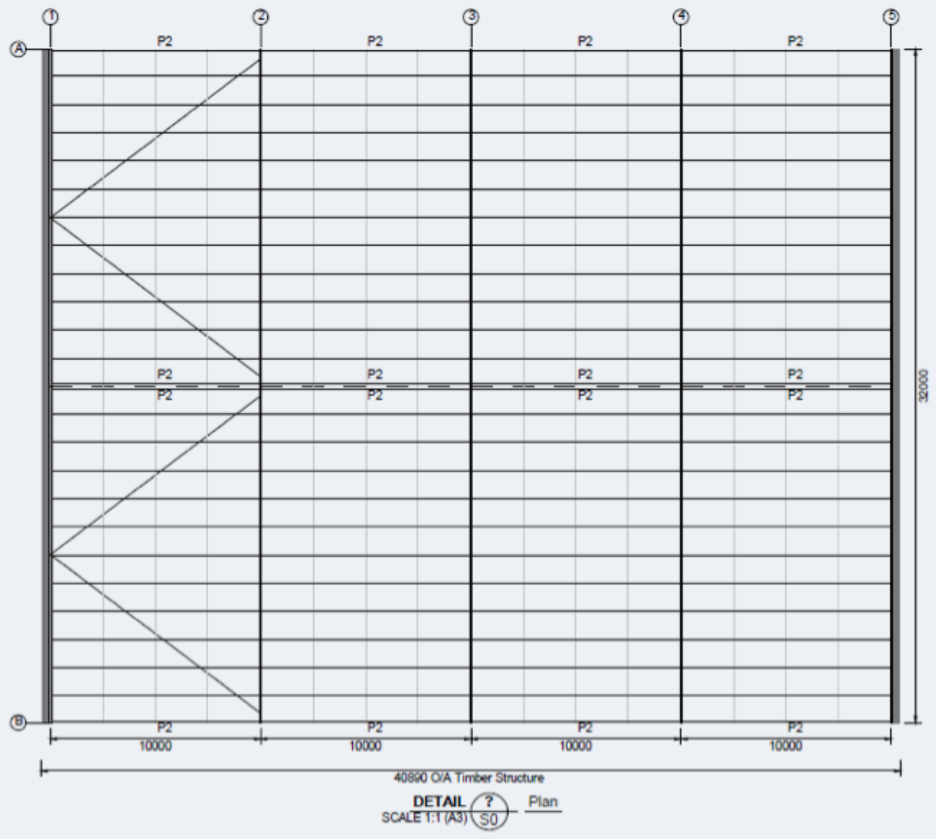


Figure 1: Plan of the industrial building (10 m timber bay shown).

Item	What was used in the model	Relevance and Reasons
Height	• Single storey construction • 8.0 m overall height • 5.0 m to underside of eaves	• This represents a typical height for buildings of this style
Area	• 32.0 m span x 40.0 m length • 1,200 m^2 footprint/GFA	• The area and length-to-width ratio are a common size for industrial sheds
Setbacks	• External wall distances are at least 3.0 m from property boundaries	• The location of the building relative to other buildings/properties affects façade fire resistance requirements
NCC Building classification	• Class 7b building i.e. a wholesale distribution shed	• The classification influences performance and compliance requirements

Table 1: Key spatial characteristics of the model shed building.

In considering information about the model shed, it is important to realise that the only differences between the timber solution(s) and competing steel solution concern the footing, portal, purlins and girts construction. Other aspects are the same. Even so, discussion that clarifies NCC performance requirements and design settings (as relevant to the competing solutions) can be found under the dedicated sub-headings below.

4.1 Key Structural Parameters

Parameters applied to the model:

- Wind speed: Region A and Terrain Category 2 exposure.
  - Wind direction, Shielding multiplier and Topographic multiplier all set as 1.
- Foundation: Moderately reactive clay soil conditions applied to footing design.

Reasons:

- The selected wind speed deals with typical conditions the model building would likely face in real world conditions.
- The selected foundation is common in large parts of the greater Sydney basin and other parts of Australia where these buildings would often be found. If poorer foundations were encountered, then this would likely favour the timber solution(s), i.e. using larger bay spacings and lighter construction.

4.2 Fire Resistance (based on NCC requirements)

Parameters applied to the model:

- The Type of construction used was Type C, therefore:
  - external walls: no fire resistance requirements as they are more than 3.0 m from the boundary
  - external columns: not applicable
  - common or fire wall: not applicable
  - internal wall: not applicable (no internal walls are present in the design)
  - roof: no fire resistance requirement under the stated Building classification.

Reasons:

- The chosen parameters require no fire rating, which therefore removes the complexity that fire resistant construction can have on each material.
- Timber fire resistance is easier to achieve than steel construction fire resistance, due to timber's charring[1] capacity. Consideration of a fire rating would have skewed the result towards a timber outcome.

4.3 Sound Resistance (based on NCC requirements)

Parameters applied to the model:

- Not applicable. No sound resistance is required for 7B building classifications.

[1] Further information on Timber char capacity can be found in WoodSolution Guide No 3 - Timber-framed Construction for Commercial Buildings Class 5, 6, 9a & 9b - Design & construction guide for BCA compliant fire-rated construction

5

The Timber and Steel Solutions

The following section presents core design information for the two timber solutions and the competing steel solution (see Figure 2 for a section through 10.0 m bay timber solution).

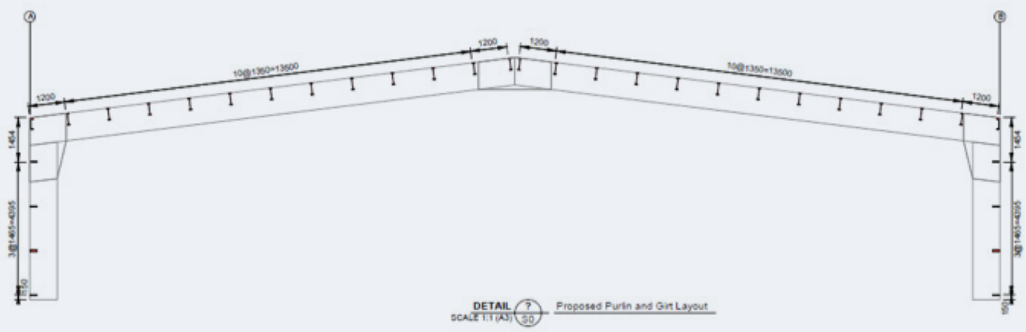


Figure 2: Section of Timber Portal Frame (10.0 m portal spacing shown).

5.1 Timber Solution 1 (6.7 m portal spacing) details

Refer to Appendix A for the structural drawing of Timber Solution 1. All timber elements are termite treated to H2S, and all fabricated components have one coat of finish weather protection.

- Columns:
  - Main – 1,220 x 135 mm block bonded LVL13
  - End Bay – 800 x 135 mm block bonded LVL13
- Rafter:
  - Main – 1,220 x 135 mm block bonded LVL13
  - End bay – 800 x 135 mm block bonded LVL13
- Eave Rafter: 400 x 135 mm block bonded LVL13
- Purlins: 300 x 45 mm LVL13
- Girts: End Bay – 300 x 45 mm LVL13
- Mullions: 400 x 63 mm LVL13
- Bracing: 24 mm diameter galvanised rod
- Flybrace: 90 x 45 LVL11

5.2 Timber Solution 2 (10.0 m portal spacing) details

Refer to Appendix B for the structural drawing of Timber Solution 2. All timber elements are termite treated to H2S, and all fabricated components have one coat of finish weather protection.

- Columns:
  - Main – 1,050 x 105 LVL16
- Rafter:
  - Main – 1,050 x 105 mm LVL16
  - End bay mullions – 400 and 300 x 63 mm LVL13
- Eave Rafter: 400 x 63 mm LVL13
- Purlins: 400 x 90 mm I-beam
- Girts:
  - Side Wall – 200 x 45 LVL13 @ 1465 cs
  - End Wall – 240 x 45 LVL13 @ 1550 cs
- Girt support columns:
  - Side Wall – 200 x 45 mm LVL13
  - End Wall – 240 x 45 mm LVL13
- Mullions: 400 x 63 mm LVL13
- Bracing: 24 mm diameter galvanised rod
- Lateral restraint blocking: 90 x 45 mm LVL13
- Flybrace: 90 x 45 mm LVL13

5.3 Steel Solution (8.0 m portal spacing) details

Refer to Appendix C for the structural drawing of the steel solution. All steel zinc is silicate treated.

- Columns:
  - Main – 530UB82
  - End Bay – 460 UB67
- Rafter:
  - Main – 530UB82
  - End Bay – 460UB67
- Purlin: 200Z24
- Girts: 200Z24 & one row of bridging
- Girt support columns: 250UB31
- Flybrace: 50 x 50 x 5 steel angle, 3 per rafter
- Bracing: 165 x 5 CHS

6

Cost Plan Results - Comparing the Timber and Concrete Solutions

Using the model industrial building described in Section 4, and the two timber solutions and the corresponding steel solution described in Section 5, a cost estimate and cost planning comparison helped determine the potential benefits of the timber solution.

The cost comparison was only undertaken for the parts of the building that were considered to have different costs under the competing scenarios. Some items were excluded, such as concrete slab, roof and wall sheeting, mechanical, electrical and plumbing. Effectively, the building superstructures were compared. Furthermore, construction costs that were also equal in all models were removed, such as crane costs, contractor's margin and all preliminaries. In order to create stable costing conditions, it was assumed that the building would be constructed in suburban Sydney.

The Cost Plan was initially developed by the Building Cost Information Service (BCIS), which independently measured off from supplied drawings, the quantities of materials used. This recent version continues to be based on this, with some amendments to take-off from errors that had been found. The updated steel and concrete price was obtained from the Australian Institute of Quantity Surveyors, Building Cost Index for March 2020. The timber prices were obtained as quotes from the market where needed. As the timber solution is a relatively new construction system, a price from the marketplace was necessary. The timber quote for both Timber Solutions was attained from Meyer Timber. Refer to Appendix D for full Cost Plan results.

A basic comparison of each model cost plan is shown in Table 1. Detailed results can be found in Appendix D.

Element	Timber Portal Solution 1 6.67 m Bay Spacing	Timber Portal Solution 2 10 m Bay Spacing	Steel Portal Solution 8.0 m Bay Spacing
Substructure	$22,160	$17,810	$36,490
Columns	$53,873	$23,815	$52,693
Roof	$192,083	$181,352	$186,640
External Walls	$44,612	$37,203	$43,638
Total	**$312,728**	**$260,180**	**$319,461**

Table 1: Comparison of material cost used in all three solutions.

Table 1 compares vital cost items that differentiate competing timber and steel solutions. The timber solution with the 10.0 m bay spacing is by far the cheapest of the three options (18.5% cheaper than steel), followed by the timber solution with the 6.67 m bay spacing (2.1% cheaper than steel).

There are a number of reasons the 10 m bay spacing is cheaper. The primary reason is that the building's components were designed using timber sizes that are available directly from the mill, without any need to fabricate, other than minor straight line cuts. This meant that there is no need to block bond elements together, unlike the 6.7 m bay spacing timber solution, saving considerable costs. Both the 6.7 m bay timber solution and the steel frame solution require fabrication that often increases the base cost of the element by many factors.

The other reason is that the wider bay spacing of the 10 m bay space timber solution had less timber in it than the 6.7 m bay space timber solution. The 10 m bay spaces timber solution had two fewer portal frames. Further reduction in the wood volume was by using I-beam purlins, instead of solid LVL. Even though girt and purlin costs are higher for the larger portal spacing, it is still the portal frame costs that dominate the overall cost profile for shed construction, and so where all other variables are equal, the larger bay spacing offers the lowest cost option.

It was also found that girt costs for the two timber solutions contributed only a minor proportion to overall costs difference and also remained relatively stable, irrespective of portal bay spacing. The inclusion of intermediate support columns means that the load on girts is less sensitive to changes in bay spacing. As such, timber I-beam girts offer a cost-effective and relatively cost-stable proposition, even as portal bay spacing change.

Further, purlins can be cost-effectively increased in span by simply increasing the depth of the plywood web of the 'I' beams used (i.e. by an extra 100 mm). Timber I-beam purlins may, therefore, provide a similarly cost-effective component in the steel solution (as a replacement for steel purlins).

7

Factors Affecting the Cost Competitiveness of Timber

The following section discusses other methods or techniques that may provide further savings to the timber solution. These methods or procedures have not been included in the costing exercise, described in Section 6.

7.1 Erection Onsite

For productivity and process improvement, an increasingly popular technique for the erection of timber portal buildings is to fabricate certain assemblies off the slab and then crane them into position. For instance, the rafter and purlin assemblies are typically fabricated off the deck for every second portal bay. These bay assemblies are then craned into place (see Figure 3), by sitting the rafters into the premade pockets of the pre-positioned columns. Once these assemblies are in place, the purlins for the neighbouring bays are placed in a more conventional manner. Overall, this approach improves cost and – to some extent – safety, as the amount of work undertaken at height is substantially reduced.

Figure 3: Timber portal roof structure constructed on the ground. *Image: Timberbuilt*

7.2 Timber Connectors

Most timber connectors are designed to mimic steel connection systems so that the approach to fabrication is similar for the two competing systems. Details on specific joints are provided below.

7.2.1 Portal Frame Knee Connector

The connection between the portal frame column and the rafter is designed to transfer bending moments at this point and provides a complex connection for both timber and steel. In the two timber options, different approaches were taken to the key joints in the portal frames that aim to simplify fabrication on-site, using prepared components, including:

- **Timber Solution 1 (6.7 m portal spacing)** – This solution used a recently established moment connected, called QuickConnect[2], developed by the Structural Timber Innovation Company and Auckland University. The Quick-Connect moment connection is a moment resisting joint for timber portal frame buildings. It is based on a system of pre-tensioned rods which are placed at the upper and lower extremities of the portal frame members. Bending moment is transferred across the joint by means of a moment couple carried by steel rods. The rods are housed in U-shaped timber sleeves attached to the sides of the portal frame members, by inclined screws, refer to Figure 4.

[2] Further information can be found Quick Connect moment joints from the WoodSolutions Design Guide No. 33-EXPAN Quick Connect Moment Connection.

***Figure 4: Quick connect moment connector in Netball Central*[3]**
(Image: Geoff Ambler; Ethan Rohloff).

- Timber Solution 2 (10.0 m portal spacing) – LVL Gusset is a more traditional moment connector used for timber portal frames. The gussets are nailed onto the rafter and column with many nails. Often the nailing pattern contains many rings around the edge of gussets (see Figure 3).

7.2.2 Purlin and Girt Connection

In both timber solutions 1 and 2, the I-beam or LVL purlins and girts are connected to the main rafter through a block fixed to the side of the portal's rafter or column (fixed prior to purlin or girt's placement). For the I-beam purlin, the block is screw fixed to the web of the I-beam such that it fits between the two flanges of the I-beam and sits directly under the top flange of the I-beam. This provides a convenient means of locating the purlin, which is also able to rest on the block. The I-beam purlin is then screwed or nailed fixed through the web, into the block (see Figure 5).

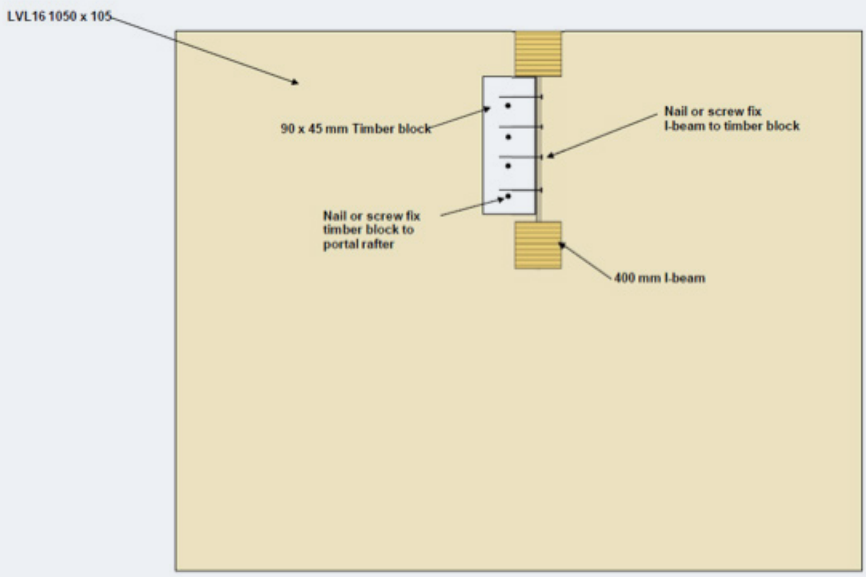


Figure 5: I-beam purling connection via timber block to rafter.

[3] Further information on Netball Central can be found in WoodSolutions web site - Case Studies

7.3 Timber Portal Frame Member Sizes

One aspect that differentiates the two timber solutions from the steel solution is the need for deeper column and rafter elements. The deeper columns and rafter impact of timber options can be reduced by mounting the purlins and girts to the side of the column or rafter. This results for Timber Solution 1 – 390 mm and Timber 2 Solution only 220 mm overall height increase. For instance:

- Steel solution: 610 UB with 200Z24 over purlins (830 mm overall depth)
- Timber Solution 1: 1,220 mm rafter and columns (1,220 mm overall depth)
- Timber Solution 2: 1,050 mm rafter (1,050 mm overall depth).

Further, the timber purlins and girts are designed as simply supported beams. This is primarily driven by the I-beams or LVL used for this purpose are not long enough to span continuously over multiple portal bay spacing, i.e. I-beam or LVL is commercially available to a maximum length is 13.2 m, while a double span purlin or girt would require up to 20.0 m length. Even so, the side mounting of the purlins and girts (mentioned above) does serve to assist in providing lateral stability to the portal rafters.

8

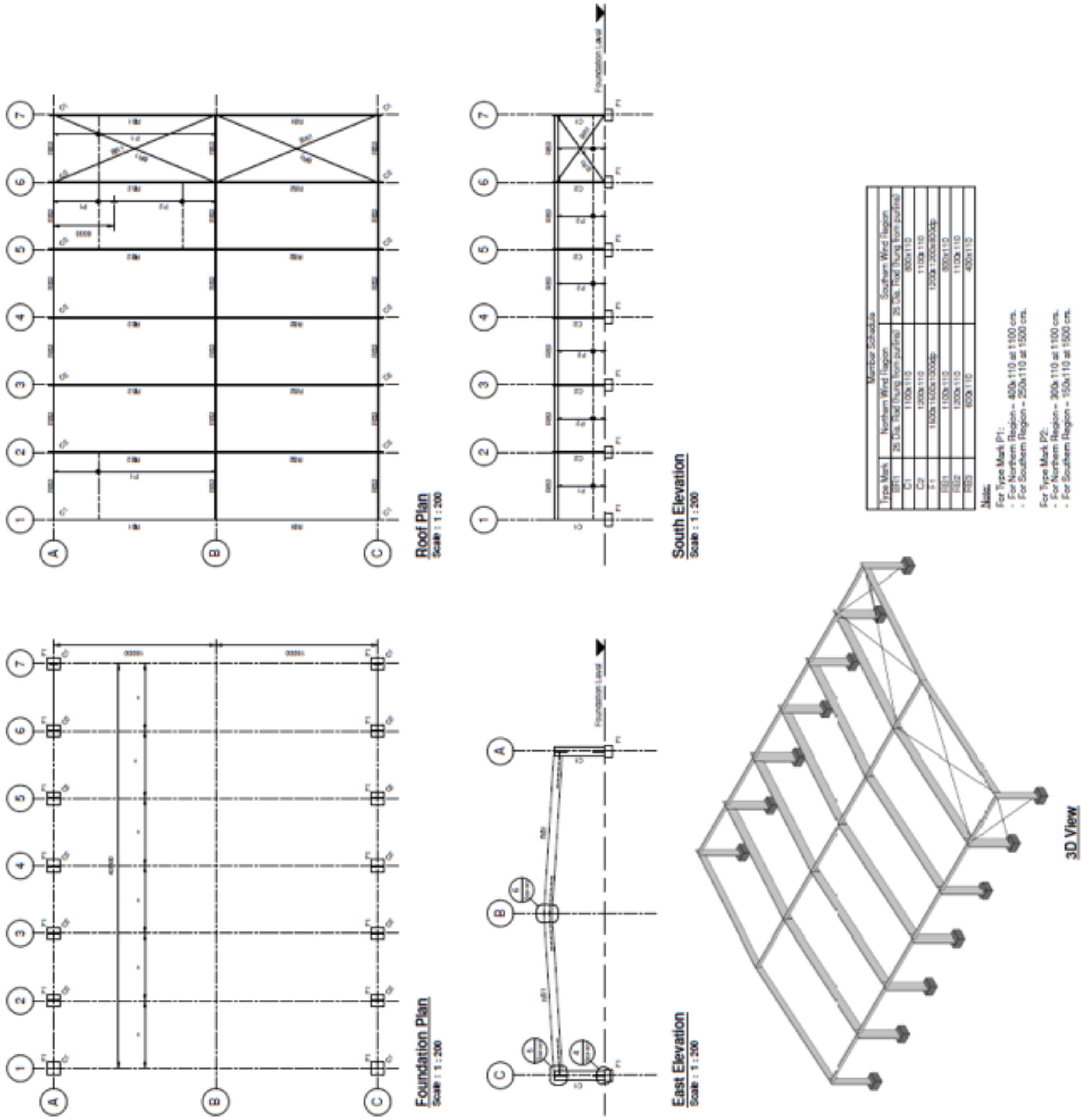
Conclusion

A model single-storey industrial shed was designed and priced using a timber solution, with two portal bay spacing considered, and a more conventional steel-framed solution for a theoretical location in suburban Sydney. The site was assumed to have no significant cost implications concerning site access, ground conditions or neighbouring properties. Furthermore, only the costs that were different were considered; this substantially meant only the superstructure was measured.

Timber Solution 2 (10.0 m bay spacing) was found to cost $59,281 or 18.5% less than the steel solution, while there was little difference between Timber Solution 1 and the steel solution. The significant cost difference between Timber Solution 2 and the steel solution and Timber Solution 1 was due to using timber elements that don't need a secondary fabrication process. Using timber sizes that are available from mills and only require minor cutting to length, resulted in these savings. Also, Timber Solution 2 had considerably less timber in it as the number of portal frames were less and the solution used I-beams instead of solid timber.

It is recommended that industrial timber sheds be considered as a viable alternative to traditional steel frames. Importantly, the level of cost comparison with steel must go beyond a basic comparison of material costs, and must instead weigh up the full range of cost-sensitive issues affecting the construction process.

Appendix A: Timber Solution 1 – 6.7 m bay spacing

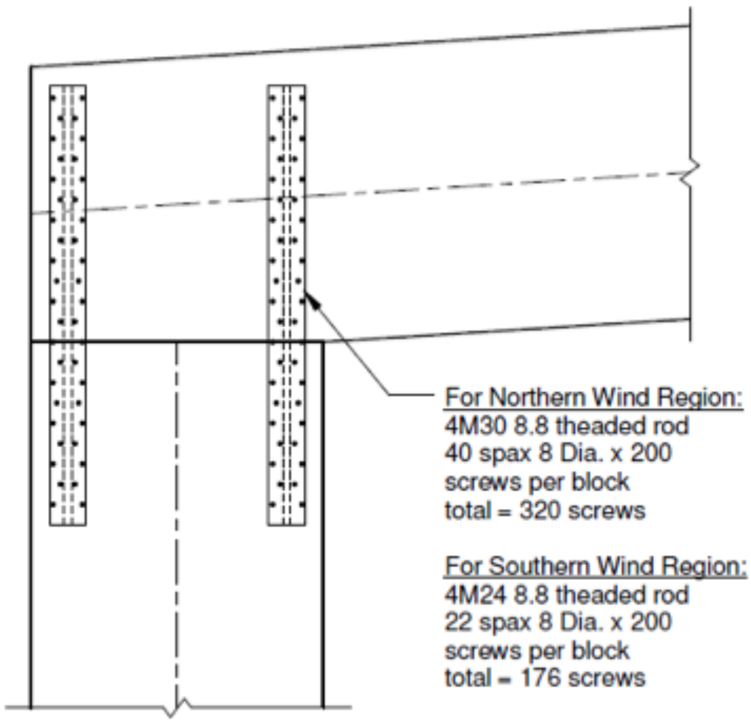


Member Schedule		
Type Mark	Northern Wind Region	Southern Wind Region
BH1	25 Dia. Rod (hung from purlins)	25 Dia. Rod (hung from purlins)
C1	1100x110	800x110
C2	1200x110	1100x110
F1	1600x1600x1000dp	1200x1200x800dp
RB1	1100x110	800x110
RB2	1200x110	1100x110
RB3	600x110	400x110

Note:

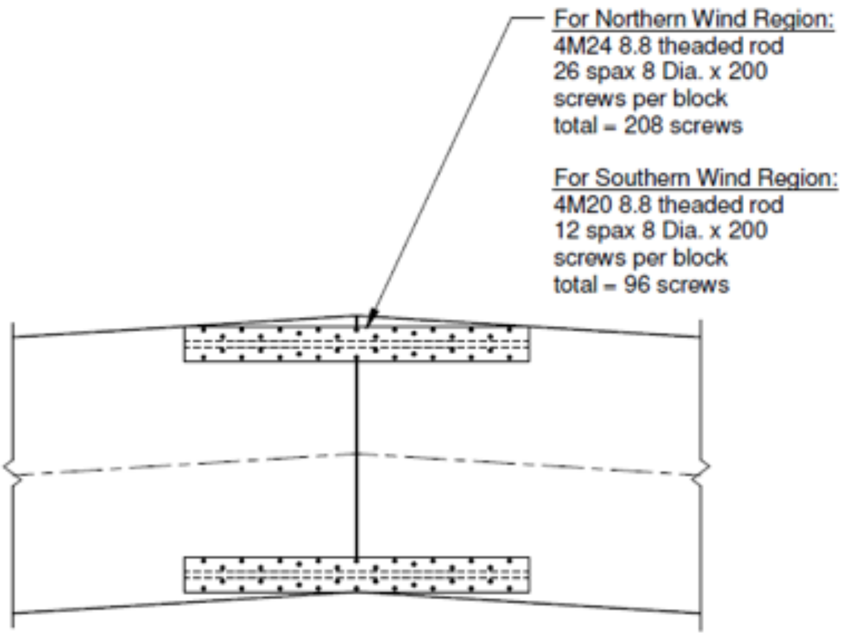
For Type Mark P1:
- For Northern Region – 400x110 at 1100 crs.
- For Southern Region – 250x110 at 1500 crs.

For Type Mark P2:
- For Northern Region – 300x110 at 1100 crs.
- For Southern Region – 150x110 at 1500 crs.



Detail 5

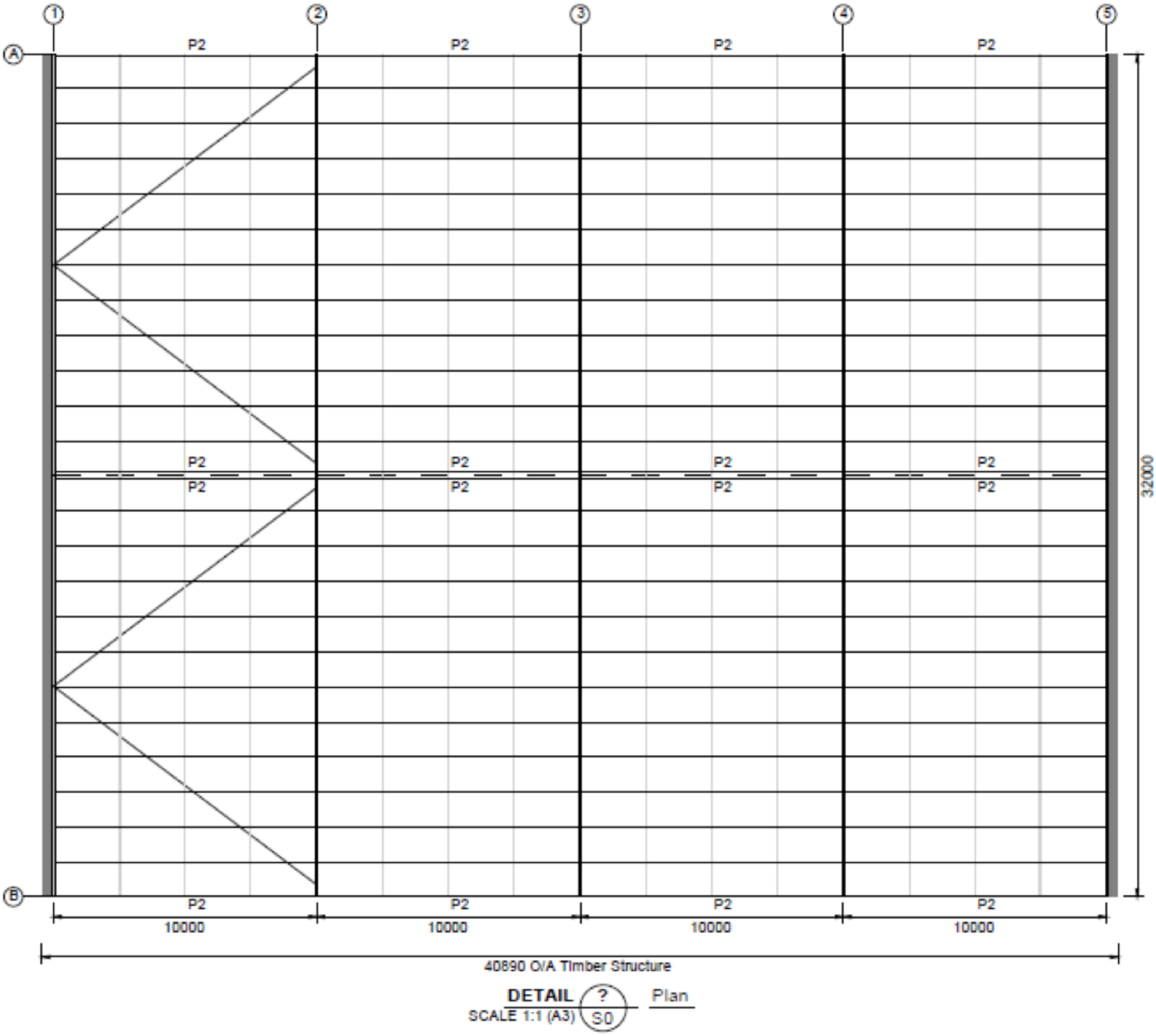
Scale : 1 : 20

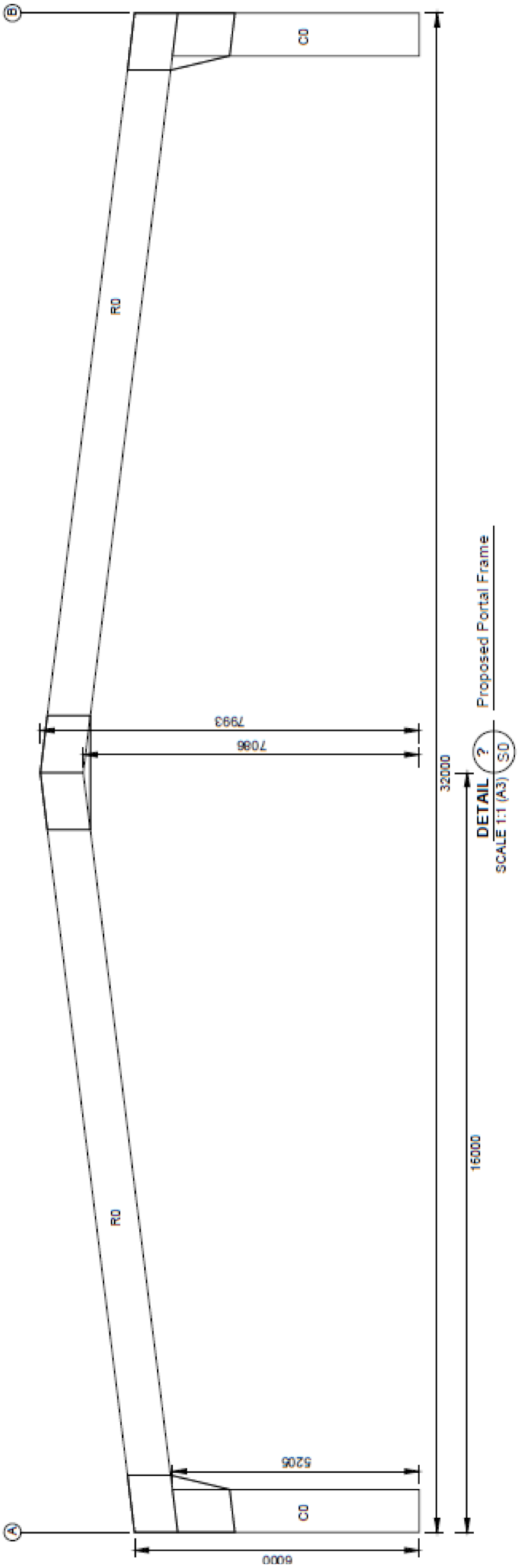


Detail 6

Scale : 1 : 20

Appendix B: Timber Solution 2 – 10 m bay spacing




Proposed Portal Frame
DETAIL
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C0
C0
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R0
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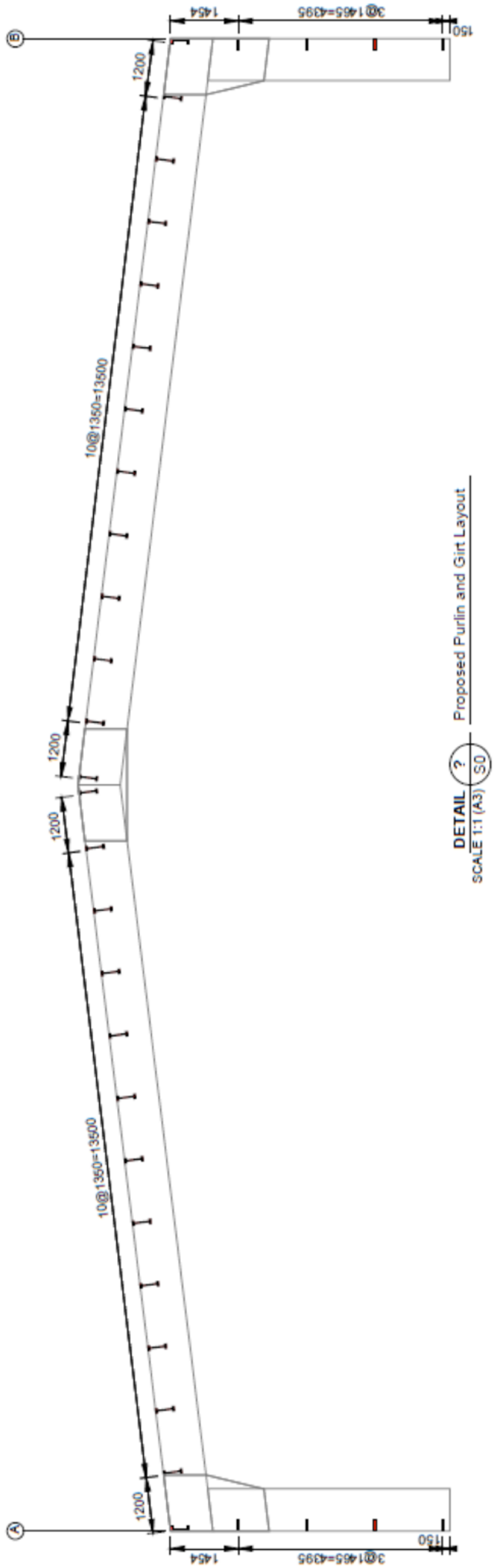
5206
6000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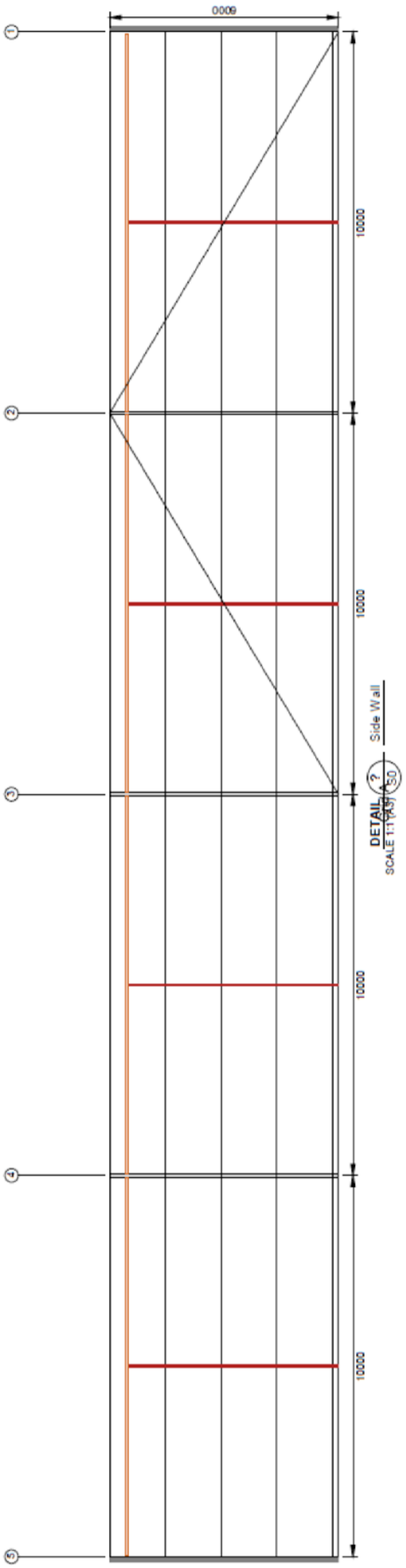
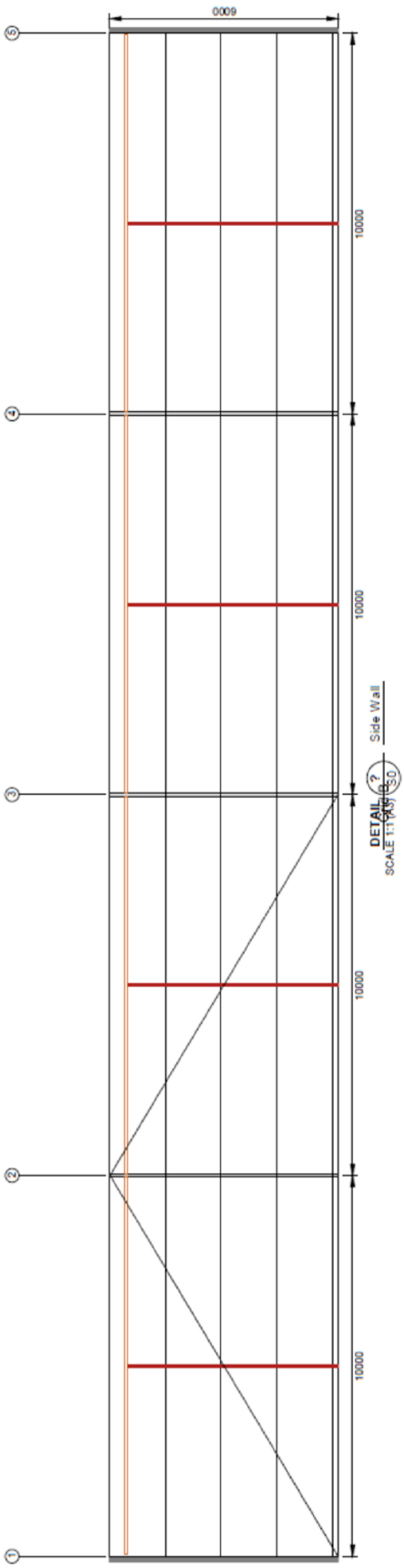
1200
1200
10@1350=13500
1200
DETAIL
SCALE 1:1 (A3)
?
S0
Proposed Purlin and Girt Layout


6000
10000
10000
10000
10000
DETAIL
Side Wall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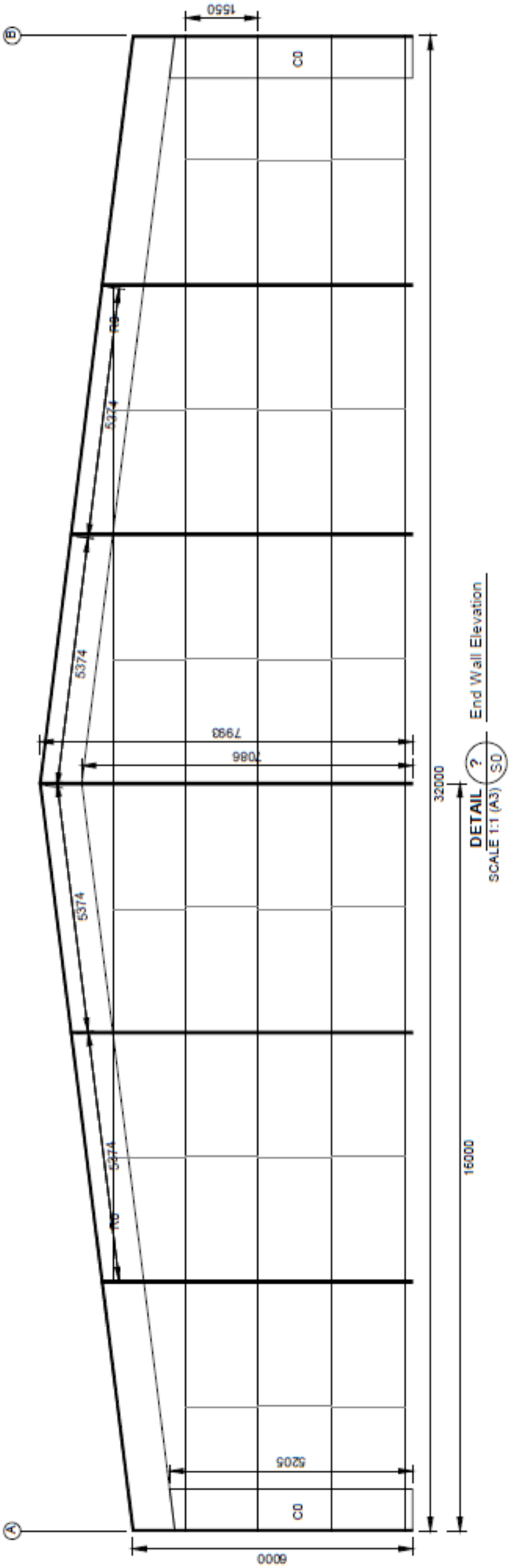
DETAIL
Side Wall


End Wall Elevation
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7086
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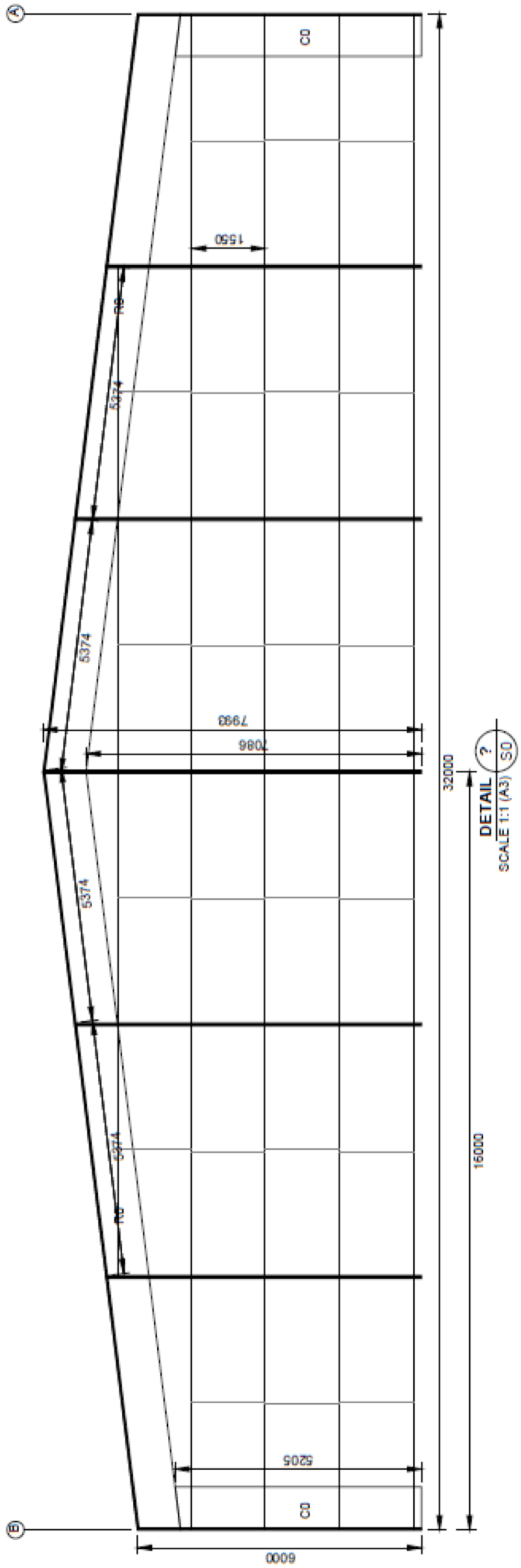
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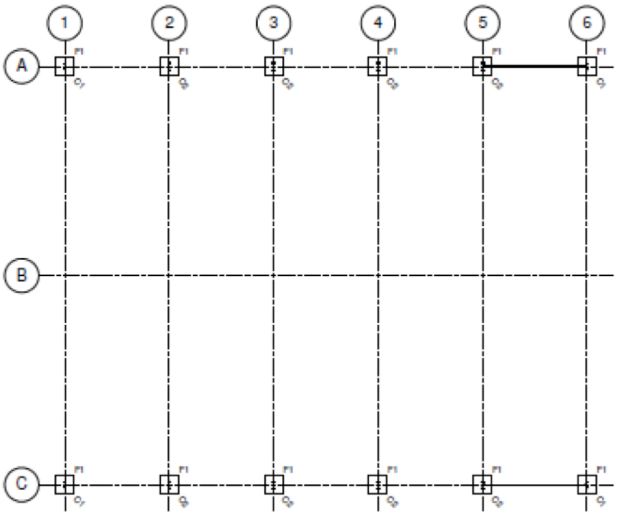
C0
A
B

Appendix C: Steel Solution – 8 m bay spacing



Foundation Plan
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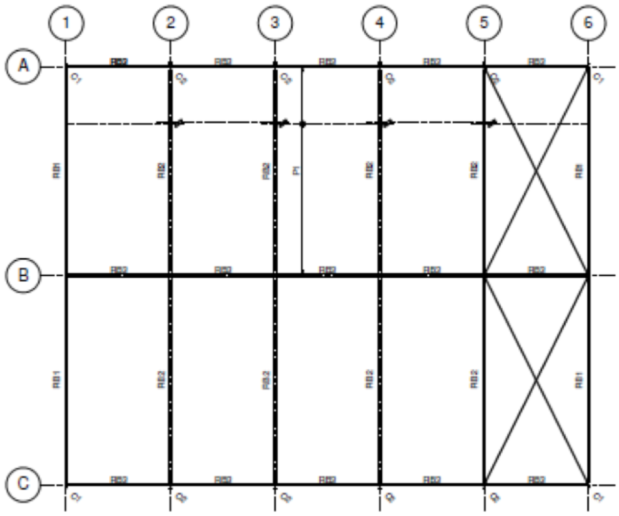

Roof Plan
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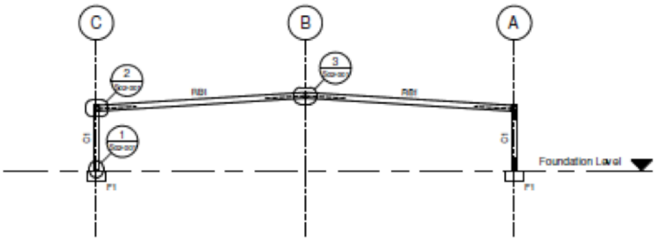
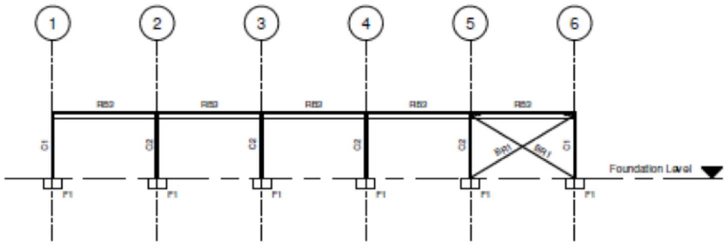
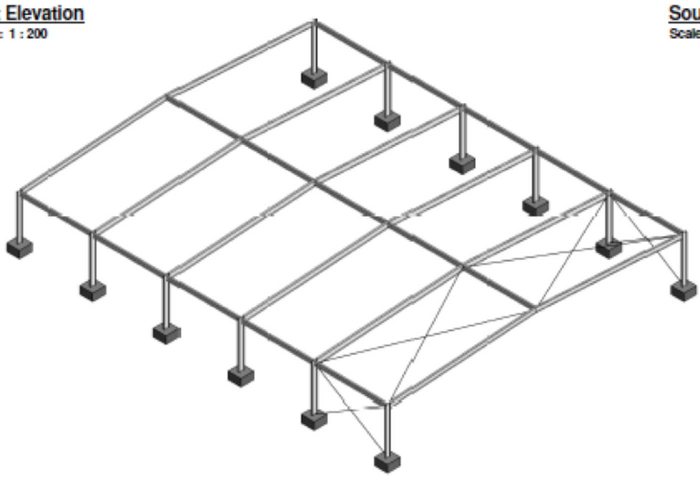


East Elevation
Scale : 1 : 200



South Elevation
Scale : 1 : 200

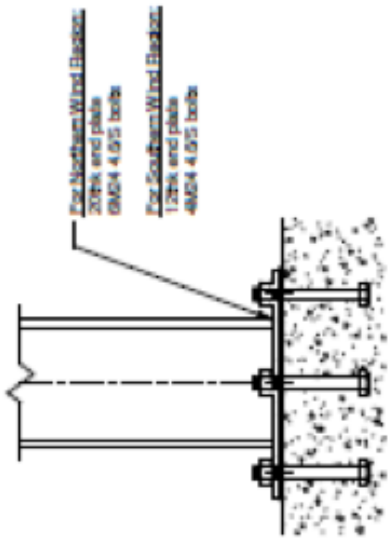


3D View

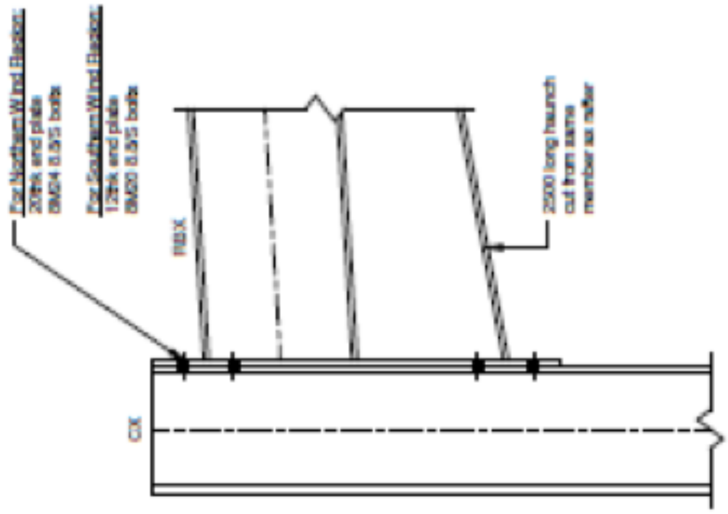
Member Schedule		
Type Mark	Northern Wind Region	Southern Wind Region
BR1	25 Dia. Rod (hung from purlins)	25 Dia. Rod (hung from purlins)
C1	460UB67	610UB101
C2	530UB82	610UB125
F1	1400x1400x800dp	1750x1750x1000dp
RB1	460UB67 x 3 rows of fly bracing	610UB101 x 3 rows of fly bracing
RB2	530UB82 x 3 rows of fly bracing	610UB125 x 3 rows of fly bracing
RB3	410UB54 x 3 rows of fly bracing	530UB82 x 3 rows of fly bracing

Note:

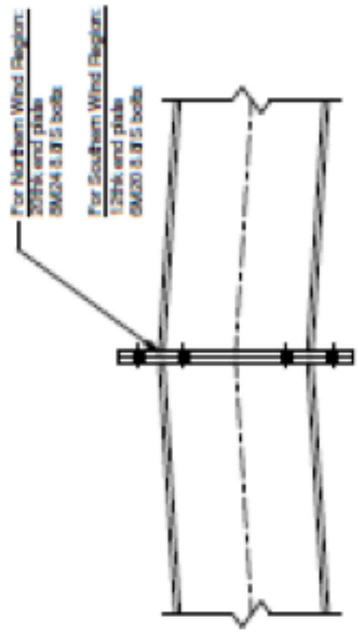
For Type Mark P1:
- For Northern Region – 250Z24/19 Purlins at 1600 crs. plus 1 row of bridging
- For Southern Region – 200Z24/19 Purlins at 1600 crs. plus 1 row of bridging



Detail 1
Scale : 1 : 10



Detail 2
Scale : 1 : 10



Detail 3
Scale : 1 : 10

Appendix D: Detailed Cost Information

Project Name: **Industrial Building – Timber Frame 6.67 m Bays - Timber Solution 1**

	Element	$/m² GFA	Quantity	Unit	Unit Rate ($)	Cost ($)
Industrial Steel Frame 8 m Bays			**1,280**	**m²**	**$244.32**	**$312,728**
Substructure		**$17.31**				**$22,160**
1	1,200 x 1,200 x 800 Column base, including excavation, concrete, reinforcement	$16.31	14	no.	$1,400	$19,600
2	Holding down bolt assembly comprising 4M24 bolts cast into concrete with cages	$1.70	14	no.	$155	$2,170
3	20 mm grout under base plates	$0.30	6	m²	$65	$390
Columns		**$42.09**				**$53,873**
1	1,220 x 135 LVL13 block bonded columns; 10 No.	$22.97	60	m	$490	$29,400
2	800 x 135 LVL13 block bonded columns; 4 No.	$8.01	24	m	$410	$10,250
3	Knee gusset; Quick Connect LVL13	$1.13	20	no.	$72	$1,440
4	Knee gusset; Quick Connect Screws 22 x 8 Dia x 200 mm per block, total 88 screws	$1.56	20	no.	$100	$2,000
5	Knee gusset; Quick Connect M20 threaded rod, bearing plate and nut	$4.69	40	no.	$150	$6,000
6	24 mm diameter rod bracing	$3.69	105	m	$45	$4,725
7	Allowance for steel plates and bolts fittings of 5% on structural steelwork	$0.05	0.4	t	$144	$58.00
Roof		**$150.06**				**$192,083**
1	1,220 x 135 LVL13 block bonded roof beams; 10 No.	$62.02	162	m	$490	$79,380
2	800 x 135 LVL13 block bonded roof beams; 4 No.	$20.82	65	m	$410	$26,650
3	400 x 135 LVL13 block bonded roof beams; 18 No.	$19.22	120	m	$205	$24,600
4	Purlins P1 @ 1,250 centres; 300 x 45 LVL13; 104 No.	$24.07	693	m	$44.45	$30,804
5	Purlins P2 @ 1,500 centres; 300 x 45 LVL13; 48 No.	$11.11	320	m	$44.45	$14,225
6	Ridge gusset; Quick Connect LVL13	$1.58	28	no.	$72	$2,016
7	Ridge gusset; Quick Connect Screws 12 x 8 Dia x 200 mm per block, total screws 48	$2.19	28	no.	$100	$2,800
8	Ridge gusset; Quick Connect M20 threaded rod, bearing plates and nuts	$6.56	56	no.	$150	$8,400
9	24 diameter galvanised roof bracing	$2.46	70	m	$45.00	$3,150
10	Allowance for steel plates and bolts fittings of 5% on structural steelwork	$0.05	0.4	t	$144	$58
External Walls		**$34.85**				**$44,612**
1	Mullions End Wall; 400 x 63 LVL13; 10 No.	$3.26	68	m	$61.30	$4,168
2	Mullions Side Wall; 400 x 63 LVL13; 12 No.	$2.87	60	m	$61.30	$3,678
3	Girts P1 @ 1250; 300 x 45 LVL13; 40 No.	$9.27	267	m	$44.45	$11,868
4	Girts P2 @ 1500; 300 x 45 LVL13; 84 No.	$19.45	560	m	$44.45	$24,898
Preliminaries Adjustment		**$0**				**$0**
1	Provision of time-related preliminaries based on the duration of structure construction time	0	0	weeks	-	0
2	Preliminaries based on reduced Construction duration of:	0	0	weeks	-	0
Total Cost						**$312,728**

Notes

1. The cost estimates are priced in March 2020 and based on construction in the Sydney Region.
2. Concrete and steel rates are based on the Australian Institute of Quantity Surveyors, Building Cost Index, March 2020.
3. Excavation rates include for backfilling and removal of surplus material from the site a distance of about 10 kilometres. Excavation rates do not include for shoring or planking and strutting.
4. All concrete is N20 unless otherwise stated.
5. Rates for reinforcement include for bending, tying, supports and placing, rolling margin and bending schedules.
6. The timber costs have been obtained from the market place, through Meyer Timber.
7. All timber elements are H2S termite treated.
8. All fabricated timber element have been sanded finish, simple CNC fabrication, CAD shop drawings provided, one coat of finish for construction period weather protection, and wrapped for transport.
9. The cost comparison of steel and timber frames uses the steel frame construction program duration as the base, and subsequently, there is no adjustment to the preliminaries.
10. The steelwork is assumed to be pre-fabricated and bolted together on-site with minimum welding required.
11. Provision has included for 5% steelwork fittings.
12. Structural steel includes rolling margin, hand cleaning shop priming, erection complete with all necessary temporary bracing and an allowance of 8% of the fabricated cost to cover shop detailing.
13. The crane costs are assumed equivalent for all models.
14. Contractor’s margin is not included.

Element		$/m² GFA	Quantity	Unit	Unit Rate ($)	Cost ($)
Industrial Timber 10 m Bay			**1,280**	**m²**	**$203.27**	**$260,180**
Substructure		**$13.81**				**$17,810**
1	1,600 x 1,600 x 800 mm Column base, including excavation, concrete, reinforcement	$12.50	10	no.	$1,600	$16,000
2	Holding down bolt assembly comprising 4M24 bolts cast into concrete with cages	$1.21	10	no.	$155	$1,550
3	20 mm grout under base plates	$0.20	4	m²	$65	$260
Columns		**$18.61**				**$23,815**
1	1,050 x 105 LVL16 columns; 10 No.	$14.87	52	m	$366	$19,032
2	24 mm diameter rod bracing	$3.69	105	m	$45	$4,725
3	Allowance for steel plates and bolts fittings of 5% on structural steelwork	$0.05	0.4	t	$144	$58
Roof		**$116.81**				**$181,352**
1	1,050 x 105 LVL16 columns; 10 No.	$46.61	163	m	$366	$59,658
2	Knee gusset; 63 4x-band LVL13	$10.39	20	no.	$665	$13,300
3	Ridge gusset; 63 4x-band LVL13	$5.20	10	no.	$665	$6,650
4	Purlins; HJ400 90 I-beam	$40.22	1,040	m	$49.50	$51,480
5	Eaves beam; 400 x 63 LVL13; 8 No.	$3.93	82	m	$61.30	$5,027
6	Fly braces; 90 x 45 LVL13 screwed to rafter and purlin	$2.31	80	no.	$37.00	$2,960
7	Lateral restraint; 90 x 45 LVL nailed to underside of purlins 1,350 mm long	$2.19	56	no.	$50.00	$2,800
8	Lateral restraint; 90 x 45 LVL blocking piece to fix purlins	$4.10	210	no.	$25.00	$5,250
9	24 diameter galvanised roof bracing	$1.83	52	m	$45.00	$2,340
10	Allowance for steel plates and bolts fittings of 5% on structural steelwork	$0.03	0.4	t	$144	$58
External Walls		**$29.06**				**$37,203**
1	Mullions End Wall; 400 x 63 LVL13; 10 No.	$3.54	74	m	$61.30	$4,536
2	Mullions Side Wall; 400 x 63 LVL13; 8 No.	$2.30	48	m	$61.30	$2,942
4	Girts Side Wall; 200 x 45 LVL13; 32 No.	$11.88	400	m	$38.00	$15,200
5	Girts End Wall; 240 x 45 LVL13; 10 No.	$9.65	305	m	$40.50	$12,352
6	24 mm diameter rod bracing	$1.65	47	m	$45.00	$2,115
7	Allowance for steel plates and bolts fittings of 5% on structural steelwork	$0.05	0.4	t	$144	$58
Preliminaries Adjustment		**$0**				**$0**
1	Provision of time-related preliminaries based on the duration of structure construction time	0	0	weeks	-	0
2	Preliminaries based on reduced Construction duration of:	0	0	weeks	-	0
Total Cost						**$260,180**

Notes

1. The cost estimates are priced in March 2020 and based on construction in the Sydney Region.

2. Concrete and steel rates are based on the Australian Institute of Quantity Surveyors, Building Cost Index, March 2020.

3. Excavation rates include for backfilling and removal of surplus material from the site a distance of about 10 kilometres. Excavation rates do not include for shoring or planking and strutting.

4. All concrete is N20 unless otherwise stated.

5. Rates for reinforcement include for bending, tying, supports and placing, rolling margin and bending schedules.

6. The timber costs have been obtained from the market place, through Meyer Timber.

7. All timber elements are H2S termite treated.

8. All fabricated timber element have been sanded finish, simple CNC fabrication, CAD shop drawings provided, one coat of finish for construction period weather protection, and wrapped for transport.

9. The cost comparison of steel and timber frames uses the steel frame construction program duration as the base; and subsequently, there is no adjustment to the preliminaries.

10. Knee and Ridge gussets include a nailing allowance.

11. The steelwork is assumed to be pre-fabricated and bolted together on-site with minimum welding required.

12. Provision has been included for 5% steelwork fittings.

13. Structural steel includes rolling margin, hand cleaning shop priming, erection complete with all necessary temporary bracing and an allowance of 8% of the fabricated cost to cover shop detailing.

14. The crane costs are assumed equivalent for all models.

15. The contractor's margin is not included.

Project Name: Industrial Building – Steel Frame 8 m Bays - Steel Solution

Element		$/m² GFA	Quantity	Unit	Unit Rate ($)	Cost ($)
Industrial Steel Frame 8 m Bays			**1,280**	**m²**	**$249.57**	**$319,461**
Substructure		**$28.51**				**$36,490**
1	1,750 x 1,750 x 1,000 Column base, including excavation, concrete, reinforcement	$26.95	12	No.	$2,875	$34,500
2	Holding down bolt assembly comprising 4M24 bolts cast into concrete with cages	$1.45	12	No.	$155	$1,860
3	20 grout under base plates	$0.10	2	m²	$65	$130
Columns		**$41.17**				**$52,693**
1	460UB67 Column; 4 No.	$9.94	1.61	t	$7,900	$12,719
2	530UB82 Column; 8 No.	$24.32	3.94	t	$7,900	$31,126
3	165 x 5 CHS bracing	$4.94	40	m	$158	$6,320
4	Allowance for steel plates and bolts fittings of 5% on structural steelwork	$1.98	0.32	t	$7,900	$2,528
Roof		**$145.81**				**$186,640**
1	310UB40 Roof beam; 4 No.	$15.92	2.58	t	$7,900	$20,382
2	460UB67 Roof beam; 8 No.	$53.33	8.64	t	$7,900	$68,256
3	165 x 5 CHS Roof beam; 15 No.	$14.57	2.36	t	$7,900	$18,644
4	50 x 50 x 5 steel angle in fly bracing	$6.20	122	no.	$65	$7,930
5	165 x 5 CHS bracing	$15.18	123	m	$158	$19,434
6	Allowance for plates and bolts fixings 5% on structural steelwork	$5.06	0.82	t	$7,900	$6,478
7	200Z24/19 Galvanised purlins	$30.86	1,056	m	$37.40	$39,494
8	Bridging between 200Z24/19 Galvanised purlins	$4.70	161	m	$37.40	$6,021
External Walls		**$34.09**				**$43,638**
1	200Z24/19 Galvanised girts	$20.80	712	m	$37.40	$26,629
2	Sag rod between 200Z24/19 Galvanised girts	$4.46	112	m	$51.00	$5,712
3	250UB31 Mullion including zinc silicate treatment; 6 No	$8.39	1.36	t	$7,900	$10,744
4	Allowance for plates bolts and connections 5% on structural steelwork	$0.43	0.07	t	$7,900	$553
Preliminaries Adjustment		**$0**				**$0**
1	Provision of time-related preliminaries based on the duration of structure construction time	0	0	weeks	-	0
2	Preliminaries based on reduced Construction duration of:	0	0	weeks	-	0
Total Cost						**$319,461**

Notes

1. The cost estimates are priced in March 2020 and based on construction in the Sydney Region.
2. Concrete and steel rates are based on the Australian Institute of Quantity Surveyors, Building Cost Index, March 2020
3. Excavation rates include for backfilling and removal of surplus material from the site a distance of about 10 kilometres. Excavation rates do not include for shoring or planking and strutting.
4. All concrete is N20 unless otherwise stated.
5. Rates for reinforcement include for bending, tying, supports and placing, rolling margin and bending schedules.
6. The steelwork is assumed to be pre-fabricated and bolted together on-site with minimum welding required.
7. Provision has been included for 5% steelwork fittings.
8. Structural steel includes rolling margin, hand cleaning shop priming, erection complete with all necessary temporary bracing and an allowance of 8% of the fabricated cost to cover shop detailing.
9. The cost comparison of steel and timber frames uses the steel frame construction program duration as the base; and subsequently, there is no adjustment to the preliminaries.
10. The crane costs are assumed equivalent for all models.
11. The contractor's margin is not included.

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