Project No. 22-21

DESIGN OF A GLULAM-ARCHED MOUNTAIN HUT NEAR WHISTLER, BRITISH COLUMBIA

(Li, 2022)

Prepared for:

Industry Project Committee, BCIT Civil Engineering Department
########
########
Jacquie Russell, Instructor, BCIT Communications Department

Prepared by:

########

Submitted on: April 13th, 2022

Department of Civil Engineering
British Columbia Institute of Technology
Burnaby, BC

Disclaimer

The work represented in the client report is the result of a student project at the British Columbia Institute of Technology. Any analysis or solution presented in this report must be reviewed by a professional engineer before implementation. While the student’s performance in the completion of this report may have been reviewed by a faculty advisor, such review and any advice obtained therefrom does not constitute professional certification of the work. This report is made available without any representation as to its use in any particular situation and on the strict understanding that each reader accepts full liability for the application of its contents.

April 13th, 2022

######
######
######
Vancouver, ######

Dear ####,

Submission of Final Report on Design of Glulam-Arched Mountain Hut Near Whistler, British Columbia

Here is the formal report on the design of a glulam-arched mountain for back country use near Whistler, British Columbia. The scope of the report covers member design, spacing, and specification for a mountain hut subject to gravity and lateral loads. The report does not cover seismic design considerations.

The main outcome of this report are the specifications of the glulam arches which comprise the main structural elements of the hut. I found a 130 mm x 342 mm section comprised of 17 mm thick layers of 24 EX Douglas-Fir Larch are sufficient to withstand the applied dead, live, snow, and wind loads. Performing this project has enhanced my understanding of structural mechanics, methods of numerical solutions, and understanding of building code as it relates to small structures.

I would like to thank you for the guidance and feed-back offered throughout the project which made the process all the more enriching. I would also like to thank my faculty sponsor, Kian Karimi, for his continued patience and support.

I can be reached at ####### or at ######## for questions or comments regarding this report.

Sincerely,

#######

cc: Kian Karimi, Faculty Advisor
Jacquie Russell, Communication Instructor

Attachment: Final report for Design of Glulam-Arched Mountain Hut Near Whistler, British Columbia

Summary

The purpose of this project was to design a glulam-arched structure that was suitable for use as a back-country hut. Large snow and wind loads combined with remote access conditions ensured that the preferred structure would be relatively lightweight and largely pre-fabricated.

This project provides a design for a glulam-arched structure. The primary structural members of this design consist of 130 mm x 342 mm D.Fir-Larch 24-EX arches with approximate lengths of 6.3 m for each half of the arch. Each half-arch is comprised geometrically of a lower straight-vertical section which transitions into a constant radius arc in the upper sections.

Dead, live, snow, and wind loads were calculated using various methods and approximations. As no site-specific data for snow and wind loads were available for the proposed elevation, ground snow loads and wind pressures were adopted from the designers of the nearby ‘Kees and Claire’ Hut.

For the purpose of calculating internal forces, the arches were assumed to be pinned at both the peak and base connections. As a ‘three-pinned-arch’, the structure is determinant; allowing internal forces to be calculated through equilibrium equations alone. As the structure has a somewhat complex geometry, a numerical model was created to calculate the bending moment, shear, and normal forces acting through-out the members under various load combinations.

In general, the largest normal and shear forces were observed at the base and the peak of the arches, respectively, while the largest bending moments occurred mid-span near the transition from vertical to curved sections of the arch.

Resistance values for compression, bending moment, and shear were calculated using clauses from CSA-086 (2017) with supplementary information and procedures from CWC-2017. Considerations for radial tension strength and bearing strength were also made following similar clauses.

Though this project does not consider seismic forces, a lateral resistance system was considered against factored wind loads. As the profile of the building is unconventional, general approximations for the NBCC 2015 static wind force calculation procedure were made. The lateral resistance system consists of 13 mm plywood nailed to the exterior of the arches with 2.5” common spiral nails at 75 mm on center.

The connections at both the peak and base of the arches are quite similar comprising of 2-6mm steel plates on either side of the member with 2x ½” through bolts. At the base of the arches, a continuous glulam beam spans the five foundation piers with a similar set of connections.

The foundations are only considered in compression for this design with the approximate sizing based on an assumed bearing pressure of 100 kPa for the site. Reinforcement design is based on minimum steel requirements as described in CSA-A23 2019.

Table of Contents

List of Illustrations

List of Figures

List of Tables

1.0 Introduction

The purpose of this project was to design a glulam-arched structure for use as a recreational mountain hut on the Spearhead Traverse, a popular back-country area between Whistler and Blackcomb Mountain.

Demand for back-country huts in the region have steadily risen with increased interest in back-country activities over the last number of years. The Spearhead Huts Society, a non-profit organization, has completed the first of a three huts planned for the area. The intention of this project was to produce a structural design suitable for the remaining two development phases.

The project was supported by ######, a world leader in advanced timber engineering and design. ######'s portfolio spans two decades and boasts over 2000 completed projects. ######, an engineer with Equilibrium has graciously agreed to lend some expertise to the project.

Though this project is strictly conceptual and holds no commercial element, Equilibrium encouraged the project as a way for me to gain experience in wood design and construction. Equilibrium was also involved in the design of the newly constructed 'Kees and Claire' Hut which was the first phase of the Spearhead development.

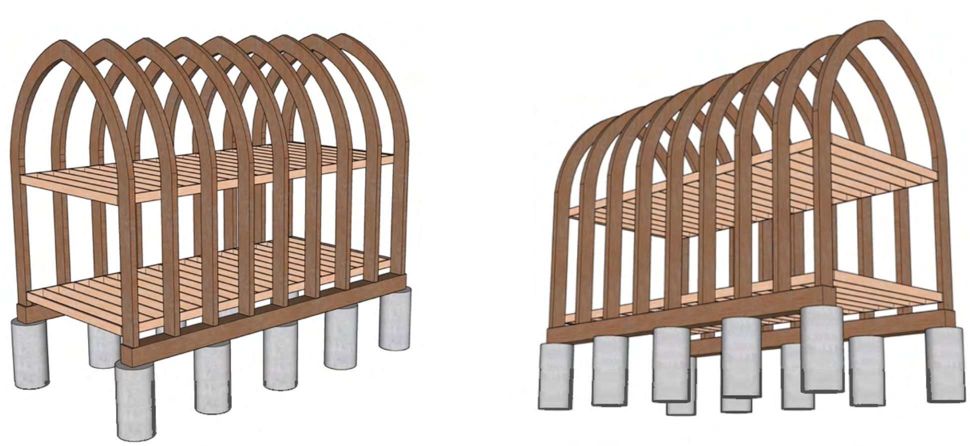


Figure 1.1 Concept Renders of Glulam-Arch Structure

The scope of the project was the structural design of the glulam arches, lateral resistance, connections, and foundation under dead, live, wind, and snow loads. Seismic design was not included in this project. Included in the deliverables for this project is the following:

- Set of Structural Plans
- Member Sizes and Specifications
- Overview of Numerical Model Used

- Supporting Hand Calculations

This report will cover the background of back-country huts in the area, environmental loads and assumptions used, calculation of member internal forces, and determination of resistance values.

2.0 Background

Hut design is well documented in and around the Whistler area. Dating back to the 1960's, glulam-arched huts have been designed and built in the Whistler back-country capable of withstanding the heavy weather and rugged terrain.

2.1 Arch Design for Mountain Huts

The glulam-arch design has a number of advantages for use in snowy, remote locations. Short building timelines in remote areas require a design which is simple, strong, and quickly buildable. The arch is a strong, light-weight shape which lends itself well to prefabrication and transport by helicopter.

Glulam-arches are a common design for mountain huts in the Coast Mountain Range. Dating back to the 1960's, approximately twenty glulam-arch huts have been designed and built in the region. Figure 2.1 below shows an early design for a glulam-arch hut.

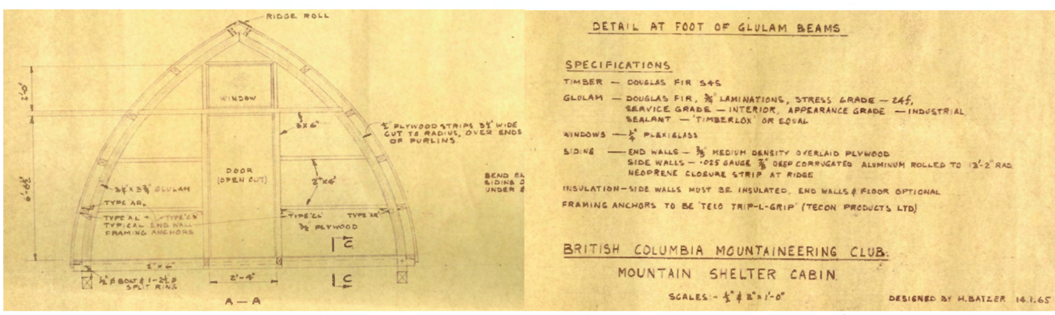


Figure 2.1: British Columbia Mountaineering Club Mountain Shelter Cabin from 1964
(Digital Museums Canada, 2021)

The design of a glulam-arch structure is largely a function of the arch geometry, member thickness, and supporting connections. Since the huts function in a remote region with heavy wind and snow loads, structural efficiency is a paramount design consideration.

2.2 Location

The Spearhead Traverse is an approximately 40 km route back-country route which runs along the Spearhead and Fitzsimmons Ranges between Whistler and Blackcomb Ski areas. The route is popular in both summer and winter with back-country skiers and hikers drawing hundreds of visitors per season. Commonly, the route is done in three to four days with participants back-country camping along the way.

Since its establishment as a route in 1964, a continual uptake in popularity has created a demand for permanent shelters to be built along the route. Currently, the Spearhead Huts Society, a non-profit organization responsible for development of the huts along the Spearhead Traverse and others in the region, has recently completed the first of three phases of development approved for the route with the opening of the “Kees and Claire Hut” in 2019. Designs for the other two hut locations are currently being evaluated with phase two construction dates aimed for the summer of 2024. Figure 2.2 below shows the Spearhead Traverse as well as the proposed locations of the huts.

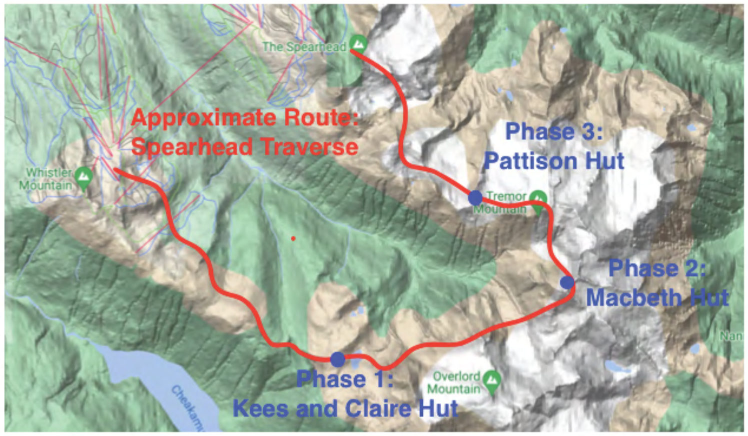


Figure 2.2: Spearhead Traverse Route: Proposed Hut Locations for Phase 1,2, and 3.
(Google, 2022)

The scope of this project will be to design a mountain hut which could be used at any one of these locations. Since the project will focus on structural considerations of the hut, simplifying assumptions will be made to generalize the region and the site.

3.0 Loads

Load values used in this design were obtained from a variety of sources. In the case of live loads, values were obtained directly from NBCC 2015. Dead, snow and wind loads, however, required further consideration.

3.1 Dead and Live Loads

Calculation of dead loads were based on member weights described in the Wood Design Manual. For the purpose of evaluating internal forces within members, unit weights per length of member were evaluated and treated as uniformly distributed loads.

Live loads on both the upper and lower floors were taken from the NBCC and assumed to be 1.9 kPa. A summary of dead and live loads is shown in table 3.1.1 below:

Table 3.1.1. Specified Dead and Live Loads

Member	Material	Unit Weight	Quantity / Area Req. (m^2)	Total Weight (kN)	Dead Wight of Stucture
Arches	D.Fir-Larch, Glulam	4800 (N/m^3)	18	24.5	
Joists	SPF, Sawn	4800 (N/m^3)	46	6.4	
Floor Sheathing	Plywood (19 mm)	133 (N/m^2)	75 (m^2)	10.0	
Exterior Sheathing	Plywood (13 mm)	65 (N/m^2)	123 (m^2)	8.0	52.7 kN or 5370 kg
Insulation	Rockwool	28 (N/m^2)	46 (m^2)	1.3	
Roof	24 Ga Aluminum	20 (N/m^2)	123 (m^2)	2.5	
	Live Load		**Reference**		
Lower Floor	1.9 kPa		NBCC 2015 4.1.5.3		
Upper Floor	1.9 kPa		NBCC 2015 4.1.5.3		

3.2 Snow and Wind Loads

As an alpine mountain hut, it is expected the structure would be subject to extraordinary wind and snow loads. A special attempt was made to determine specific, high elevation wind and snow loading values for the region.

Ultimately, the only regionally specific data which could be found were from the Resort Municipality of Whistler (RMW). RMW provides a ground snow load adjustment factor for elevations up to 1000 m, well below the intended elevation of 1800 m (The Resort Municipality of Whistler, 2017).

As a result, ground snow load and wind pressures were borrowed from the design values of the nearby, 'Kees and Claire Hut' which were graciously supplied by the designers. Design loadings are summarized in table 3.2.1 below:

Table 3.2.1 Design Values for Ground Snow, Rain Snow load and Wind Pressures.

	Adopted Design Values	NBCC Values for Whistler	Reference
Ground snow load, Ss	14 kPa	9.5 kPa	NBCC 2015 Division B, Appendix C, Table C-2
Rain snow load, Sr	0.9 kPa	0.9 kPa	
Wind pressure, 1/50	0.5 kPa	0.32 kPa	
Wind pressure, 1/10	.25 kPa	0.25 kPa	

4.0 Structural Design

The structural design of the hut is broken up into four main categories: Arch, lateral resistance, connection, and foundation design. Though the procedure is slightly varied for each category, they all use values calculated from the numerical model to satisfy CSA-086 design requirements.

Internal forces of the members were determined using the method of sections. Since the geometry of the structure is relatively complicated, a numerical model was created to calculate the internal forces iteratively along the arches at finite intervals at varied loading conditions. In order to simplify the calculations, some basic assumptions about the loadings needed to be made.

4.1 Numerical Model Assumptions

Assumption #1 - For the purpose of calculating wind load, the roof is assumed to begin at the transition between the vertical and curved section of the hut (3.068 m from foundation). The areas of the curved and flat sections of the roof as then used in accordance with NBCC 2015 4.1.7.5 for calculation of external pressure coefficients.

Using the external pressure coefficients, an overall wind force is calculated for the entire structure from each aspect. That overall wind force is then assumed to act evenly against the structure.

Assumption #2 - Shear resistance is split evenly between the foundation and the exterior sheathing. The floor diaphragms do not provide lateral support.

Assumption #3 - Lateral support of the arches on the compression face is provided only at the upper and lower floor level ledgers. Other sections are assumed to be laterally unsupported. In reality, an inner wall material (plywood or planks) would be present and offer some lateral support but is not considered.

Assumption #4 - All members are untreated and subject to dry service conditions.

Assumption #5 - Each arch segment forms a three hinged arch with pin supports at the top and bottom.

4.2 Numerical Model Results

As described above, the numerical model uses the method of sections to evaluate the internal forces within each arch segment. As a three-pinned-arch, the structure is determinant. Figure 4.2 below shows the free body diagram of a half section of the arch which was used as the basis for the numerical model.

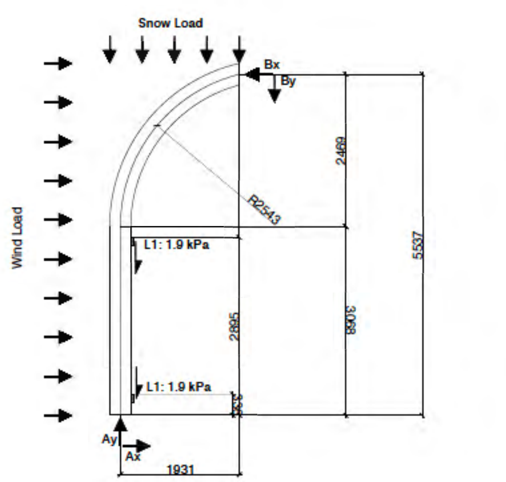


Figure 4.2: Free Body Diagram of Half Arch Segment

Reaction forces at the bottom pin support are calculated by using moment equilibrium equations at the upper pin support. Internal shear and thrust forces are calculated by summing up the forces acting in the horizontal and vertical directions and translating them to a normal and tangential axis by method of matrix transformation. Detailed calculations can be found in Appendix B.

As expected, maximum thrust (compression) was observed at the lower support for all load combinations. The largest shear forces were observed at the peak for cases with large vertical loads. Additionally, maximum bending moments were calculated to be at or nearby the transition from vertical to curved wall section. Axial compression and bending interactions were calculated at each point along the arch for each load combination. Maximum internal forces are summarized in table 4.2.1 below:

Table 4.2.1: Maximum Factored Internal Forces in Glulam Arch

	Maximum Factored Load	Location	NBCC Load Combination
Thrust (kN)	39.18	Arch Base	1.25D+1.5S+0.4W
Bending Moment (kNm)	38.91	Transition	1.25D+1.5L+0.4W
Shear (kN)	20.01	Arch Peak	1.25D+1.5S+0.4W
Interaction	0.74	Transition	1.25D+1.5L+0.4W

4.3 Arch Design

Design of the glulam arches follow the design procedure presented by the Canadian Wood Council (CWC, 2017) which conform to CSA-086 standards (CSA 086-14, 2017).

The CWC design method states criteria for bending moment, shear, and compression resistance must be satisfied for glulam arches with additional criteria for slenderness, lateral stability, and depth to weight ratio (CWC, 2017):

Detailed in the following sections of this report, table 4.3.1 below summarizes and compares the maximum factored load and resistance values based on CSA-086 2017.

Table 4.3.1 Summary for Glulam Arch Design

	Material:	24f-EX Doug Fir-Larch	
	Section Width (mm):	130	
	Section Depth (mm):	342	
	Lamination Thickness (mm):	17.1	
	Member Length (mm):	6447	
	Largest Unsupported Length (mm):	3175	
	Maximum Factored Load	**Resistance**	**Design Criteria**
Thrust (kN)	39.18	452	$P_r > P_f$
Bending Moment (kNm)	38.91	51.5	$M_r > M_f$
Shear (kN)	20.01	51	$V_r > V_f$
Interaction	0.74	-	< 1

4.3.1. Radial Tension Strength

For curved glulam, the radial tension strength and bending moment resistance must equal or exceed the factored bending moment applied to the member. In general, radial tension strength perpendicular to the grain often governs the design of the curved element.

In this case, the applied bending moments causes an increase in curvature which results in a compression perpendicular to the grain and is not applicable for this design (Sections 7.5.6.5 and 7.5.6.6 (CSA 086-14, 2017)).

4.3.2 Factored Bending Moment Resistance

Bending moment resistance was calculated based on clauses in section 7.5.6.5 of CSA-086 (CSA 086-14, 2017). Bending moment resistance was determined to be the governing factor of the design of the arches. Detailed bending moment calculations can be found in Appendix B with adjustment factors detailed in table 4.3.2 below:

Table 4.3.2 Bending Moment Resistance Factors

Bending Moment Resistance Factors (24f-EX Douglas Fir Larch)		
F_b (Tension) (Mpa)	30.6	Table 7.3
F_b (Compression) (Mpa)	30.6	Table 7.3
Section (mm)	342 x 130	-
Unsupported Length (m)	3.175	-
Lamination Thickness (mm)	17.1	-
C_b	11.1	7.5.6.4.3
K_L	0.97	7.5.6.4
K_x	0.91	7.5.6.5.2
K_{Zbg}	1.10	7.5.6.5.1

4.3.3 Factored Shear Resistance

The greatest factored shear forces occur at the arch-bases under high wind loads and at the peak for cases with large vertical loads. Since the arch is a uniform cross section, factored shear resistance values are calculated at the base of the peak where shear forces are the greatest and the cross section is reduced by the peak connection.

Factored shear resistance was calculated based on clause 7.5.7.2(b) of CSA-086 for members less than 2 m^3 in volume. Although the maximum shear force exists at the very bottom of the arch, shear resistance is calculated at a location slightly above, at the lower lag bolt. Detailed shear force calculations can be found in Appendix B and are summarized in table 4.3.3 below:

Table 4.3.3 Factored Shear Resistance Values

Shear Resistance		24f-EX Douglas Fir Larch
F_v (Mpa)	2.0	Table 7.3 CSA-086 2017
A_n (mm^2)	42510	-
V_r (kN)	51.0	7.5.7.2 CSA-086 2017

4.3.4 Factored Compressive Resistance

The compressive forces vary over the span of the arch with the largest values occurring at the base. In this design, the arches do not have any notches and are intended to achieve a full cross-sectional bearing with compression parallel to the grain direction.

Lateral stability values are based on the largest un-supported length which occur through the upper section of the arch. This assumption is perhaps too conservative. However, since the design of the arches is largely governed by bending, this assumption did not cause an over-sizing based on compression values.

Detailed compression resistance calculations can be found in Appendix B and are summarized in table 4.3.4 below:

Table 4.3.4 Compression Resistance Parallel to Grain

Compression Resistance Parallel to Grain 24f-EX Douglas Fir-Larch		
F_c (Mpa)	30.2	Table 7.3 CSA-086 2017
A_n (mm^2)	44460	130 x 342 mm
K_{zcg}	0.8	7.5.8.4.2 CSA-086 2017
K_c	0.53	7.5.8.5 CSA-086 2017
L_e (mm)	3175	Table A.6.5.6.1 CSA-086
C_c	24.4	7.5.8.2 CSA-086 2017
P_r (kN)	452.2	7.5.8.4 CSA-086 2017

4.3.5 Resistance to Combined Bending and Axial Load

The arches are subject to both a bending moment and axial compressive force. Although the largest compressive forces and bending moments occur at different sections of the member, the largest values will be used to satisfy the interaction equation.

In reality, however, interaction values are generally quite a bit lower if calculated iteratively through-out the member span with values specific to each location. Detailed interaction calculations can be found in Appendix B and are summarized in table 4.3.5 below:

Table 4.3.5 Combined Bending and Axial Load Interaction

Resistance to Combined Bending and Axial Load		
P_e (kN)	4725	7.5.12 CSA-086 2017
E_{05} (MPa)	11136	Table 7.3 CSA-086 2017
P_r (kN)	452	7.5.8.4 CSA-086 2017
M_r (kNm)	51.5	7.5.6.5 CSA-086 2017
P_f (kN)	39.2	-
M_f (kNm)	38.1	-
I (mm_4 $x10^6$)	433	-
Interaction	0.85	7.5.12 CSA-086 2017

4.3.6 Arch Connection Design

Connection design was considered both at the base and the peaks of the arches. Since the member cross-sections are the same at the base and peak, maximum values were gathered and applied to a connection design that would satisfy both locations.

At the bases, the arches are not only subject to large lateral forces produced by wind loads but uplift forces as well. Uplift forces were calculated under the assumption that uplift resistance would only take place at either end of the building via the arch-to-foundation beam connections. In reality, these connections are present at every arch base but are not considered.

Similarly, the dead weight of the structure is not considered for calculation of the uplift resistance.

CWC-2017 provides criteria for connection design of wood members. In both the base and the peak, connections are specified based on the row shear and group tear-out both parallel and perpendicular to the direction of the grain. Connection specifications are summarized in table 4.3.6 below:

Table 4.3.6 Arch Base and Peak Connection Design

Location	Member Width (mm)	Connection
Base	130	2x 1/2" Φ Bolts with 6mm steel plates on either side
Peak	130	2x 1/2" Φ Bolts with 6mm steel plates on either side
Maximum Factored Loads		**Resistance**
Uplift (Tension)	20.75 kN	38 kN
Normal (Compression)	40 kN	N/A member assumed to bear on plate
Shear (Perpendicular to grain)	20.01 kN	22.6 kN

4.4 Lateral Resistance Design

Lateral resistance values are calculated based on wind forces acting on the narrow side of the building. Though it is expected that a greater overall wind force would develop on the long side of the building, a simplifying assumption was made. It is assumed that the lateral forces acting on the strong-axis of the arches are already resisted by the arches themselves and are accounted for in the overall arch design model. Therefore, lateral forces acting against the narrow side of the building will be considered.

Additionally, it is also assumed that the wind load will be split evenly between the foundation and the shear walls. CWC-2017 provides criteria for evaluating shear wall design based on both sheathing-to-framing connection strength and overall panel buckling strength. In this structure, connection strength governed the lateral design. Table 4.4 below summarizes material specifications and resistance values.

Table 4.4 Lateral Resistance Design

Sheathing:	12.5 mm Plywood (4 ply)
Blocking:	Yes
Nails:	2.5" Common Spiral Nails
spacing, s:	75 mm
Factored Lateral Load, V_{fs}:	3.9 kN / m
V_{rd} (Connection):	4.21 kN / m
V_{rd} (Panel Buckling):	19.7 kN / m
Design Criteria: $V_{rd} > V_{fs}$	

4.5 Upper and Lower Floor Design

The upper and lower floors of the hut are both assumed to be subject to a 1.9 kPa live load. The floor joists are connected to the interior of the arches via joist hangers and ledgers. Since it is assumed that the floors do not experience lateral forces, they are strictly treated as bending members and evaluated based on shear, bending moment resistance, and deflection. Ultimately, deflection governs the design of the joists. Table 4.5 below summarizes the design of the upper and lower floors.

Table 4.5: Upper and Lower Floor Design Values

Factored Live Load, L_f:	2.85 kPa	V_{max} (kN):	2.44
Factored Dead Load, D_f:	0.20 kPa	M_{max} (kN m):	2.44
Service Load:	3.05 kPa	$\Delta_{allowable}$ (mm):	22
Joist:	2x8 No.1/2 SPF	M_r (kN m):	4.5
Josit Spacing:	.400 m	V_r (kN):	9.4
Joist Length:	4 m	Δ_{uf} (mm):	14
Josit Spacing:	.400 m		

Joist hanger selection is based on information supplied by Simpson Strong-Tie (Simpson Strong-Tie, 2022).

Ledger connection design was based on the uniformly distributed shear load developed by the floor system which then passes from the ledgers to the arches. Although a bolt system was considered for this connection, it was found that 6x 3.5” common wire nails provide adequate shear resistance. Detailed calculations can be found in Appendix B.

4.6 Foundation Design

The initial plan for the foundation design was to set out simple piers for each arch base. As each pier would support one arch base, it seemed to be the simplest option. However once drawn, it was apparent that design specified too much concrete for the size of the structure.

Keeping in mind this structure is intended to be constructed in the back-country, it made sense to lower the number of piers specified and thus the amount of concrete required.

Though site specific data was not available, it is assumed that the bearing pressure of the ground is 100 kPa. Neither embedment depth of the piers into the ground or shear or moment effects on the foundations are considered. The foundation design is solely based on the area required and compression resistance of the piers themselves.

In order to minimize the number of piers required, a continuous glulam beam was introduced to span the foundation piers. The arch-bases then tie into the continuous beam and structure loads are transferred into the foundations. Using a continuous beam reduced the number of foundation piers from eighteen to ten. A detailed drawing and specification calculations can be found in Appendix B.

5.0 Conclusion

Alpine construction presents considerable challenges in both environmental loads and construction access. To address these challenges, this hut was design to use curved glulam-arches which provide large resistances to both bending and compression while lending itself well to pre-fabrication.

The glulam-arches are considered to act as three pinned arches with no bending moments applied to either the base or peak. The arches are connected similarly on both ends with 6 mm steel plates on either side with ½" bolts.

At the base of the arches, steel plates connect to a continuous foundation beam which spans the entire length of the structure, approximately 9.2 m long. Supporting the foundation beams are five foundation piers spaced approximately equally which transfer the structural loads into the ground.

Lateral resistance is provided by 13 mm sheathing applied to the exterior of the arches. The sheathing is specified to receive 2.5" common spiral nails space at 75 mm on center. Additionally, the panel seems are to be blocked between the arches for additional lateral support.

Inside the structure, both the upper and lower floors are suspended with joist hangers which are tied into a 2x8 No. 1/2 SPF ledger spanning the arches. The ledgers were also considered to be providing lateral support to the compression edges of the arches and were used in calculation of the unsupported length.

The upper and lower floors are comprised of 2x8 No. 1/2 SPF joists spaced at 400 mm on center with 19 mm plywood overlayed. The floor systems are not considered to be part of the lateral resistance system and only support applied live and dead loads.

The foundations are only considered in this project in terms of compression. Embedment depth, shear, and bending stresses are not considered as part of this project. Foundation size and reinforcement were based solely on an assumed bearing pressure of the soil, 100 kPa, and minimum requirements for reenforcing steel.

References

AITC. (2011). *Design of Tudor Arches with Structural Glued Laminated Timber.* Centennial, CO: American Institute of Timber Construction.

CSA 086-14. (2017). *Engineering Design in Wood.* Mississauga: CSA Group.

(2019). *CSA A23.3:19 Design of Concrete Structures.* Toronto, Ontairio: Standards Council of Canada.

CWC. (2017). Wood Design Manual. In C. W. Council, *Wood Design Manual* (pp. 674-688). Ottawa: Canadian Wood Council.

Digital Museums Canada. (2021). *communitystories.ca*. Retrieved from Whistler Museum and Archives Society: communitystories.ca

Google. (2022). *Google Maps*. Retrieved from https://www.google.com/maps/@50.0939314,-122.9266241,13.24z

Li, L. L. (2022). *Wendy Thompson Hut*. Retrieved from Accidentally Wes Anderson: https://accidentallywesanderson.com/photographer/lucy-le-lievre/

NBC. (2015). *National Building Code of Canada.* Ottawa: National Research Council of Canada.

Simpson Strong-Tie. (2022, April 12). *Wood construction connectors catalog*. Retrieved from strongtie.com: https://www.strongtie.com/resources/literature/wood-construction-connectors-catalog-cn

The Resort Municipality of Whistler. (2017). *RMOW Building Department bullitin regarding Snow Loading.* Whistler, British Columica: The Resort Municipality of Whistler.

Appendix A: Structural Drawings

Drawing 1: Side Elevations
Drawing 2: End Elevations
Drawing 3: Plan View
Drawing 4: Upper and Lower Floor Framing Plans
Drawing 5: Connections C1, C2, C3
Drawing 6: Connections C4

Drawing 1

Drawing 2

Drawing 3

Drawing 4

Drawing 5

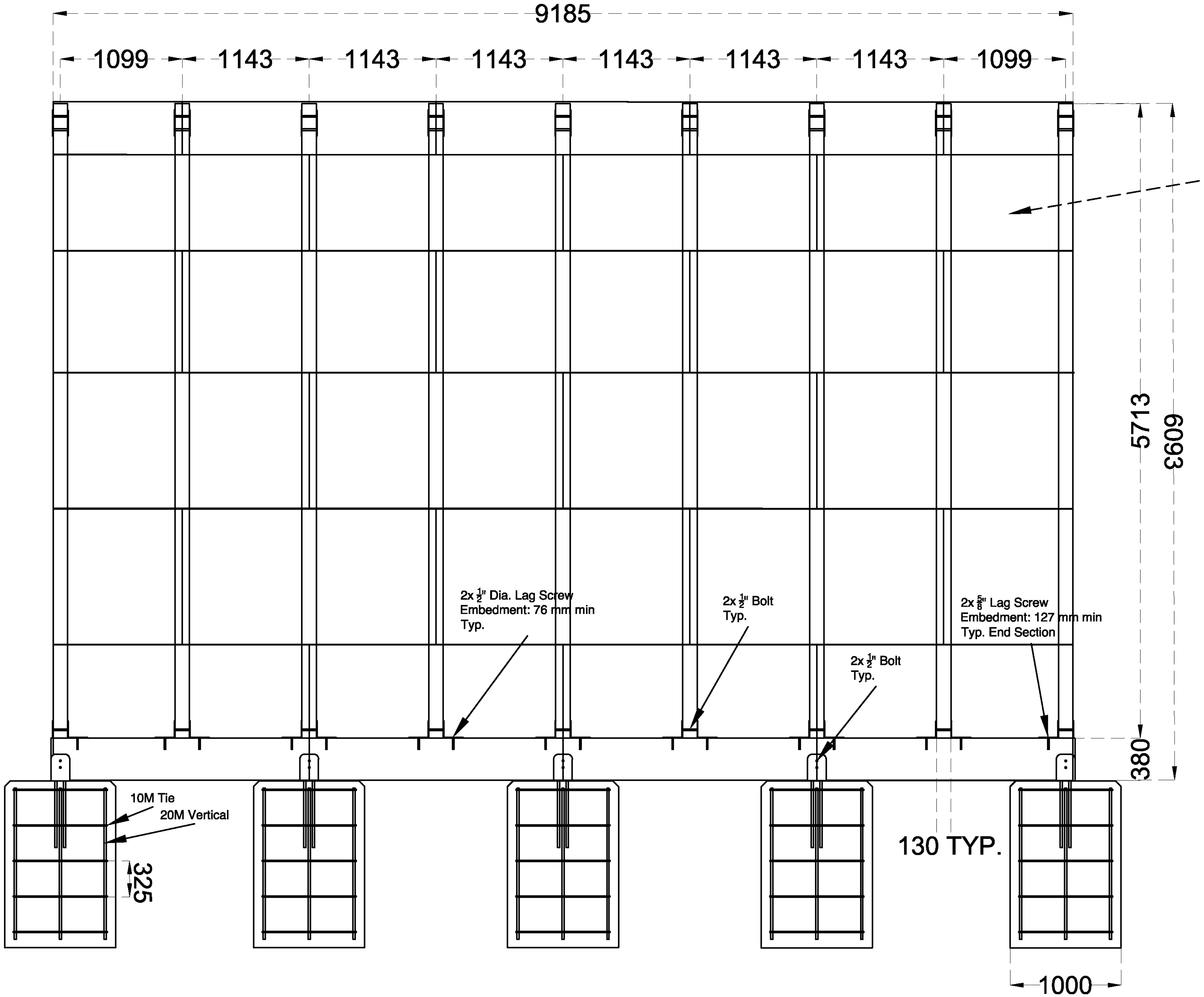
Drawing 6

Appendix B: Hand Calculations

Set 1 – Arch Design
Set 2 – Arch Ridge Connection
Set 3 – Arch Foundation Connection Design
Set 4 – Foundation Beam
Set 5 – Lateral Resistance Design
Set 6 – Joist Sizing
Set 7 – Floor Connection Design
Set 8 – Foundation Design

Appendix C: Numerical Model Results

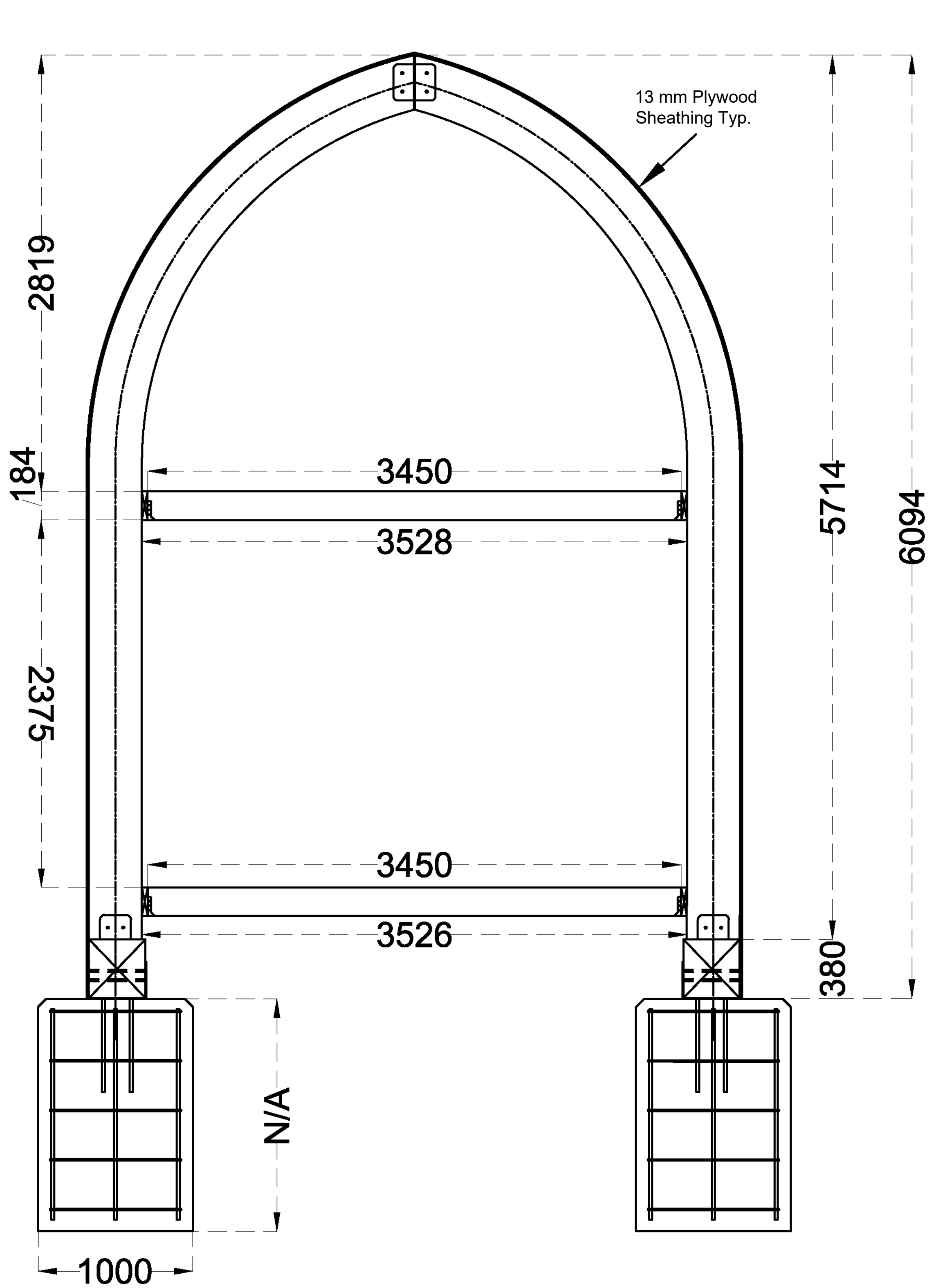
Case 1: 1.25D + 1.5L
Case 2: 1.25D + 1.5S
Case 3: 0.9D + 1.4W

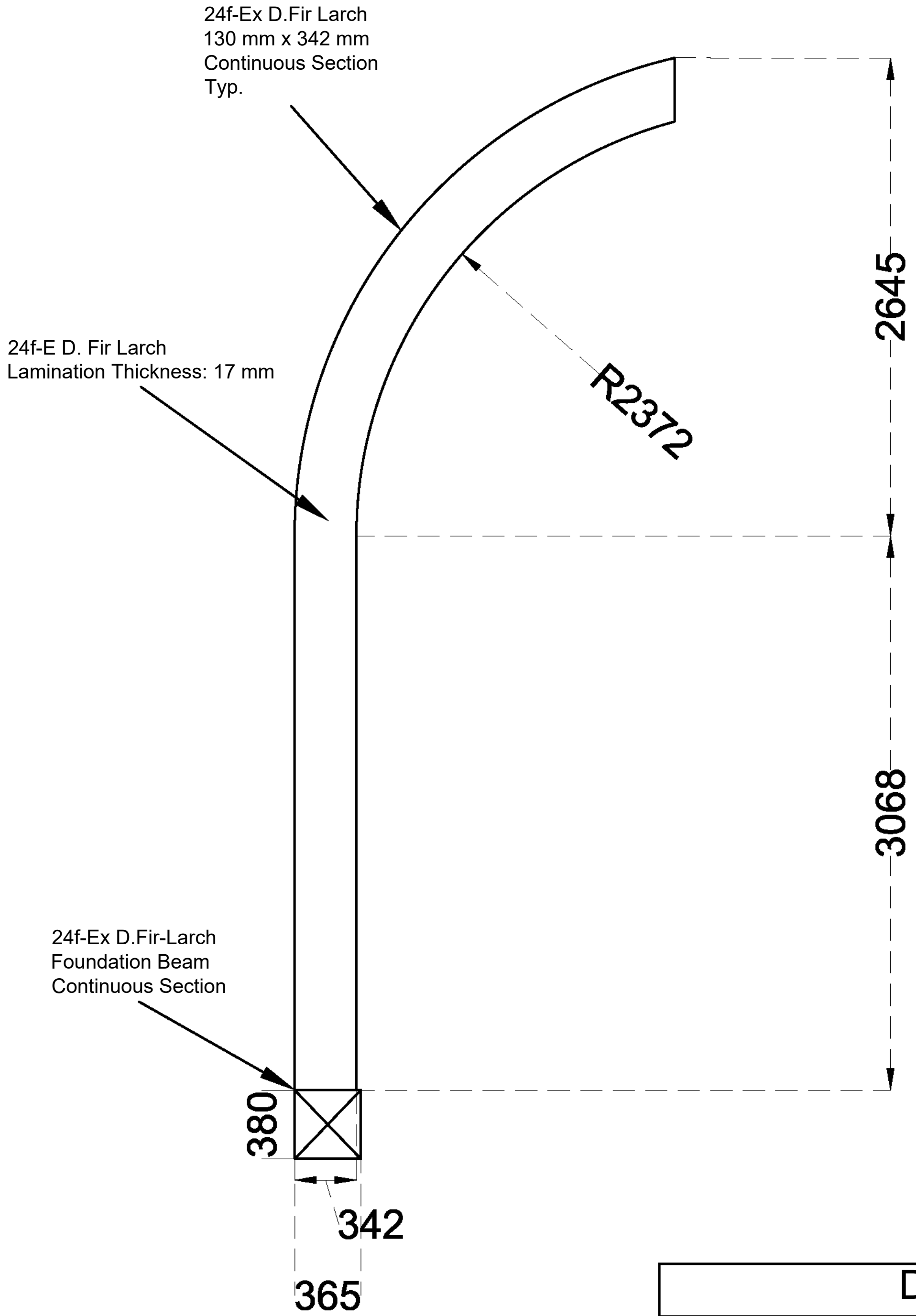


Notes:

- All measurements given in millimeters
- 13 mm Plywood Sheathing to be blocked along edges
- 13 mm Plywood Sheathing to be secured with 2.5"
- 13 mm Plywood Sheathing to have 4 mm horizontal gap between rows
- Common Spiral Nails @ 75 mm O.C.
- Lag screws to be pre-drilled no greater than 75 % shank diameter
- All glulam to be non-treated, under 15 % M.C.
- Connections to be 6 mm thick painted steel
- Upper and lower framing plans are the same

Drawn by: Fraser Howatson	
Title: Glulam-Arch Mountain Hut Side Elevation	
Industry Project No. 22-21	
2022-04-13	Drawing 1 of 6

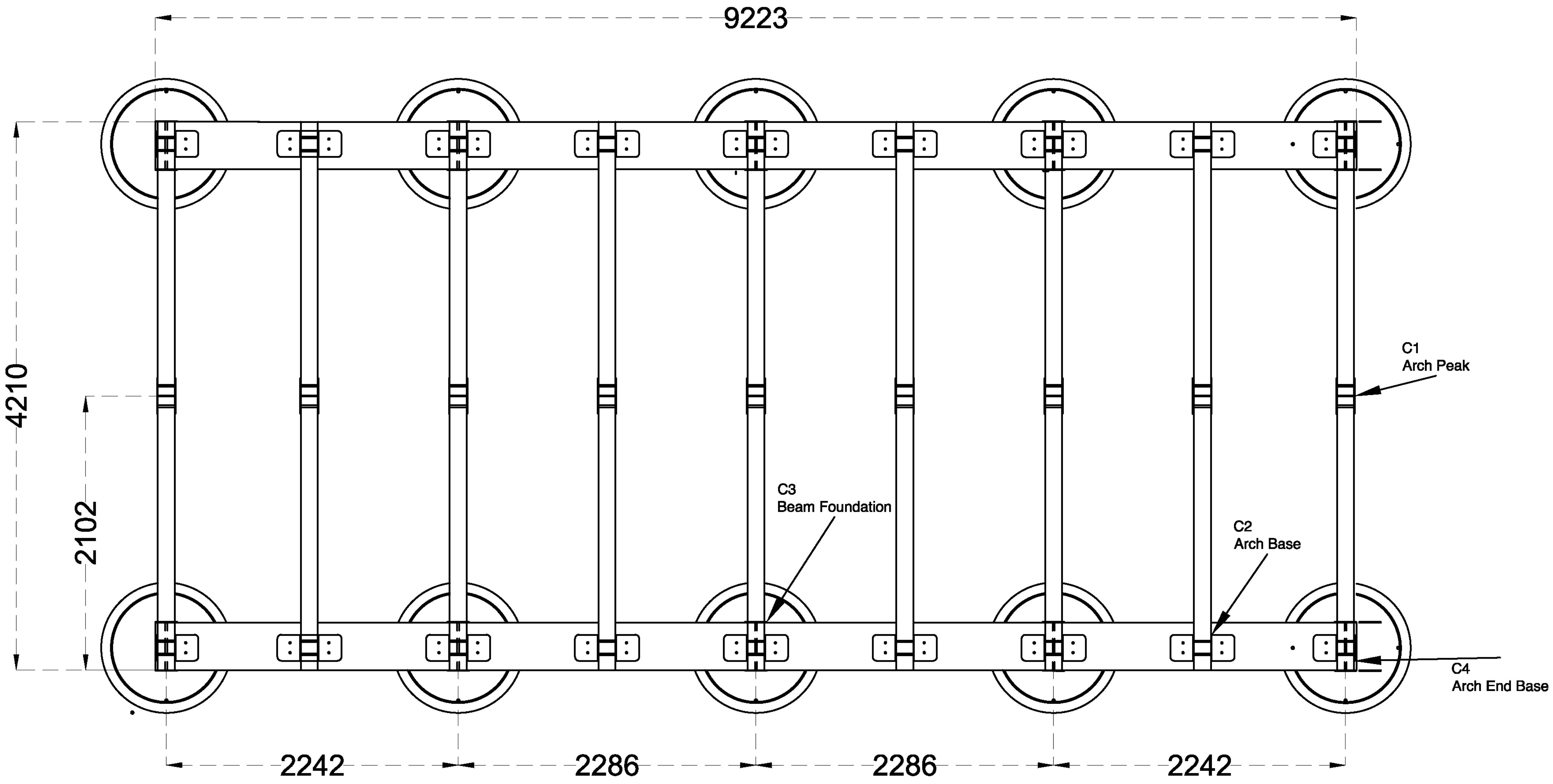




Notes:

- All measurements given in millimeters
- 13 mm Plywood Sheathing to be blocked along edges
- 13 mm Plywood Sheathing to be secured with 2.5"
- 13 mm Plywood Sheathing to have 4 mm horizontal gap between rows
- Common Spiral Nails @ 75 mm O.C.
- Lag screws to be pre-drilled no greater than 75 % shank diameter
- All glulam to be non-treated, under 15 % M.C.
- Connections to be 6 mm thick painted steel
- Upper and lower framing plans are the same

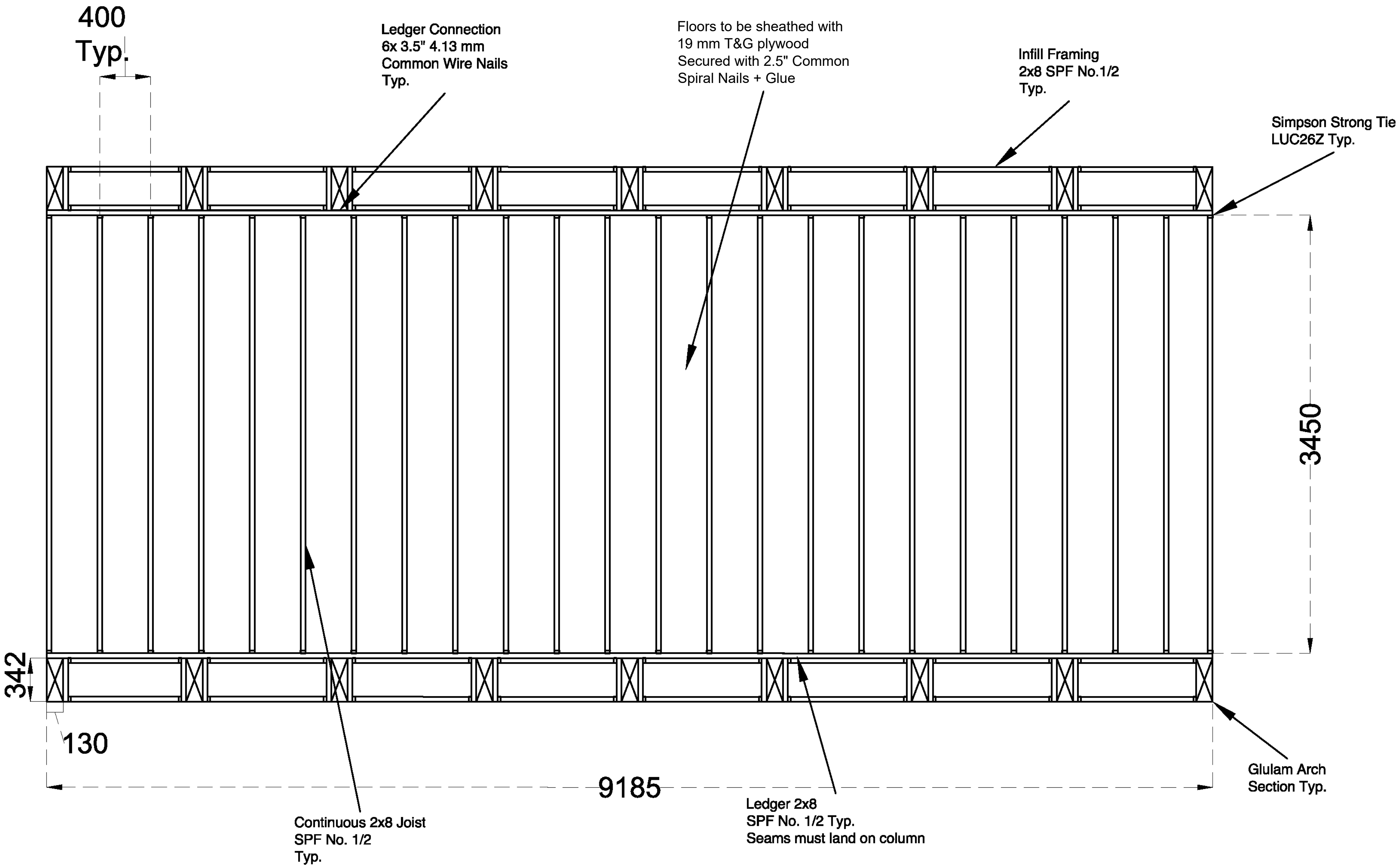
Drawn by: Fraser Howatson	
Title: Glulam-Arch Mountain Hut End Elevation	
Industry Project No. 22-21	
2022-04-13	Drawing 2 of 6



Notes:

- All measurements given in millimeters
- 13 mm Plywood Sheathing to be blocked along edges
- 13 mm Plywood Sheathing to be secured with 2.5"
- 13 mm Plywood Sheathing to have 4 mm horizontal gap between rows
- Common Spiral Nails @ 75 mm O.C.
- Lag screws to be pre-drilled no greater than 75 % shank diameter
- All glulam to be non-treated, under 15 % M.C.
- Connections to be 6 mm thick painted steel
- Upper and lower framing plans are the same

Drawn by: Fraser Howatson	
Title: Glulam-Arch Mountain Hut Plan View	
Industry Project No. 22-21	
2022-04-13	Drawing 3 of 6



Notes:

- All measurements given in millimeters
- 13 mm Plywood Sheathing to be blocked along edges
- 13 mm Plywood Sheathing to be secured with 2.5"
- 13 mm Plywood Sheathing to have 4 mm horizontal gap between rows
- Common Spiral Nails @ 75 mm O.C.
- Lag screws to be pre-drilled no greater than 75 % shank diameter
- All glulam to be non-treated, under 15 % M.C.
- Connections to be 6 mm thick painted steel
- Upper and lower framing plans are the same

Drawn by: Fraser Howatson

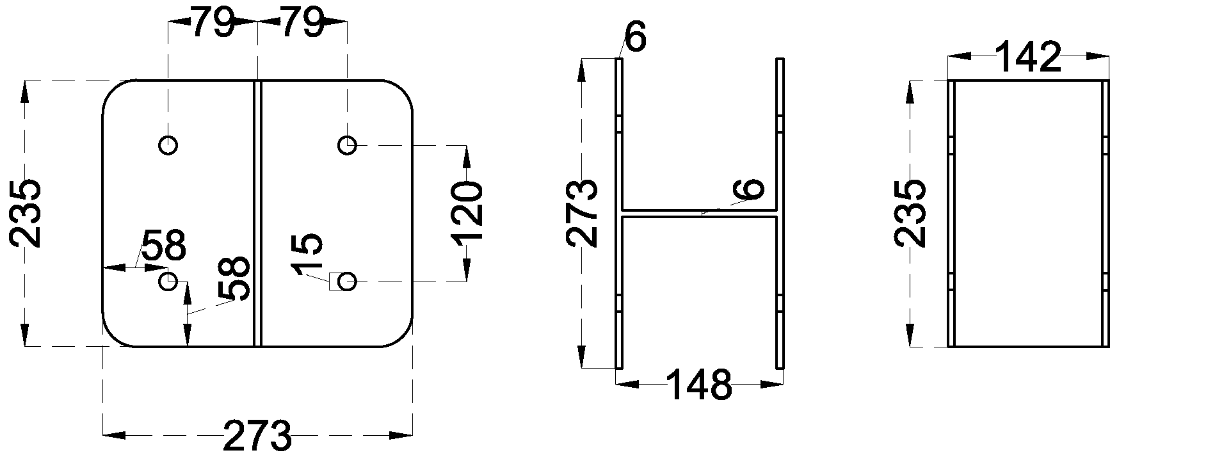
Title:

Glulam-Arch Mountain Hut
Upper and Lower Floor

Industry Project No. 22-21

2022-04-13

Drawing 4 of 6

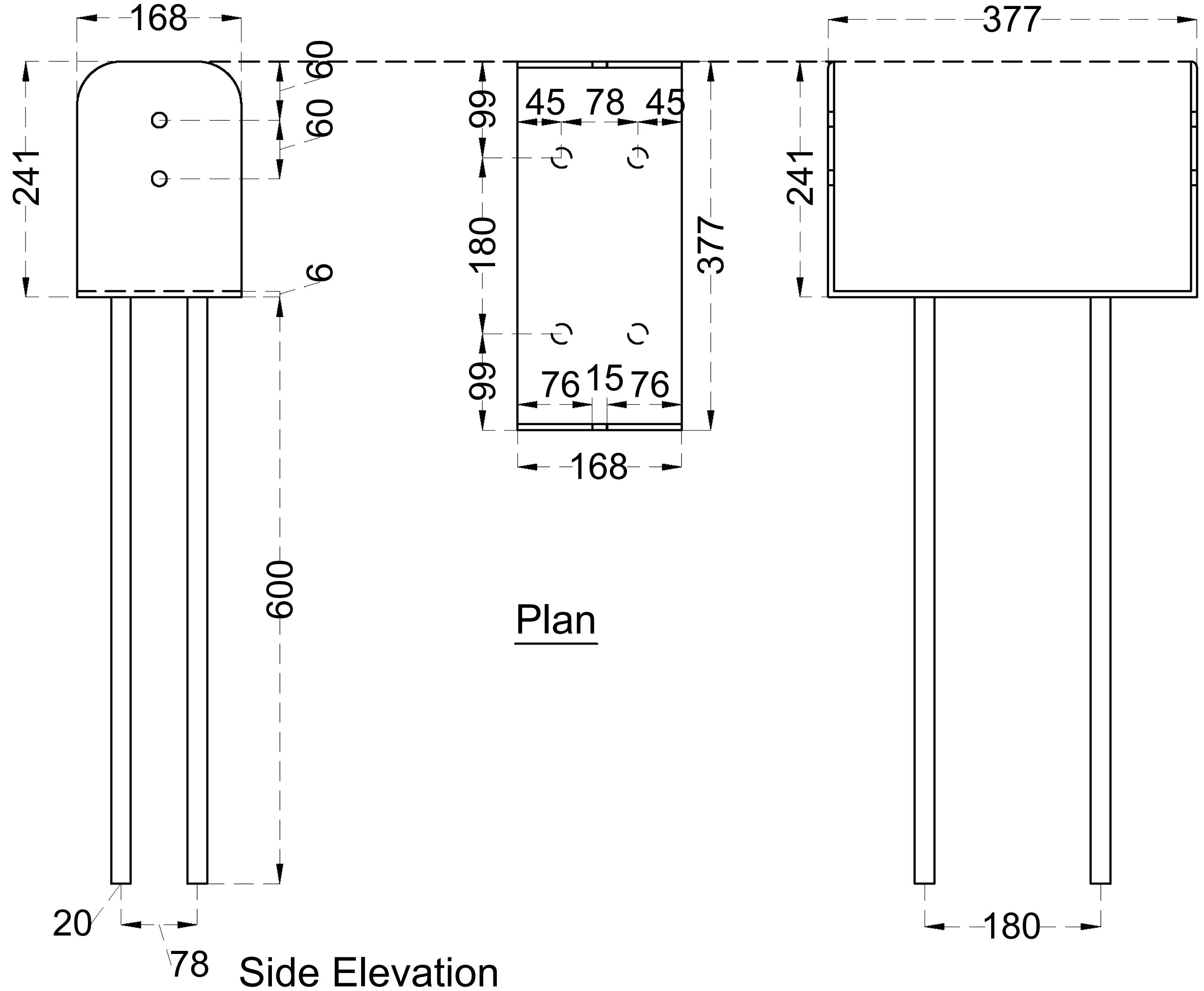


End Elevation

Plan

Side Elevation

C1: Arch Peak Connection

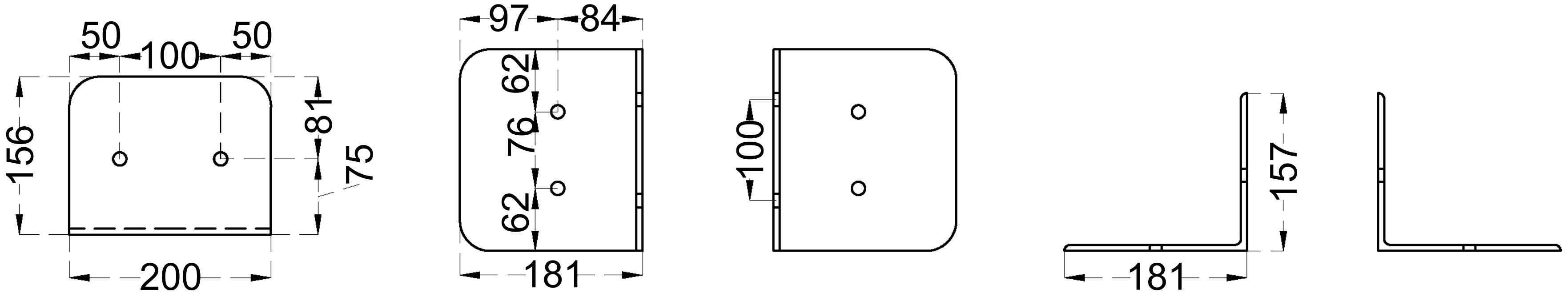


Plan

Side Elevation

End Elevation

C3: Foundation Beam Connection



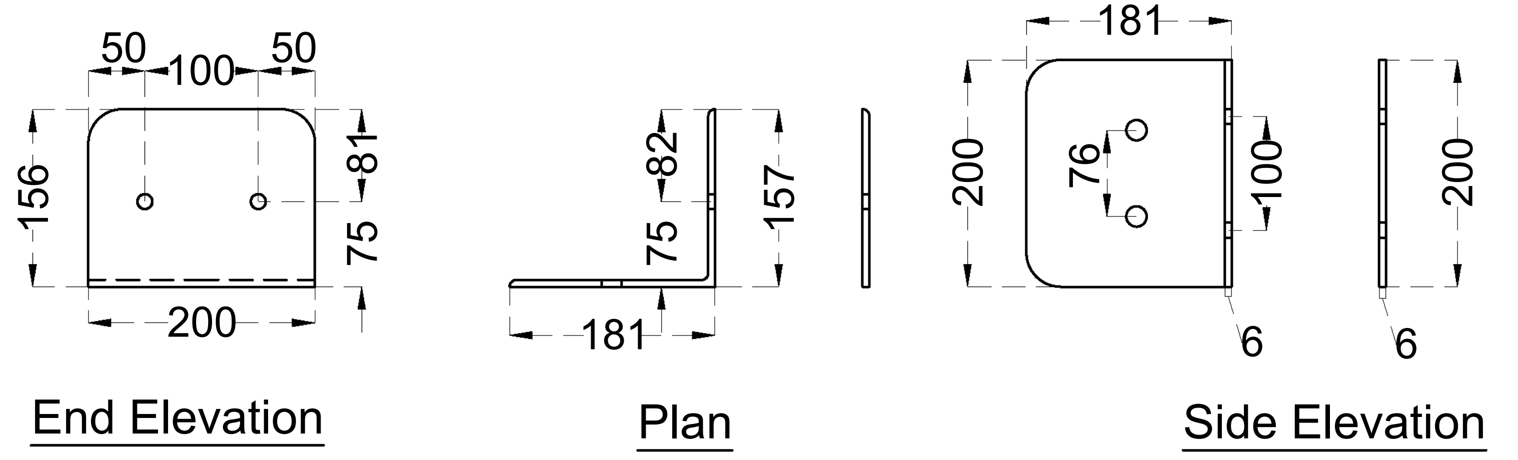
End Elevation

Plan

Side Elevation

C2: Arch Base Connection

Drawn by: Fraser Howatson	
Title: Glulam-Arch Mountain Hut Connections C1, C2, C3	
Industry Project No. 22-21	
2022-04-13	Drawing 5 of 6



C4: Arch Base End Connection

Notes:

- All measurements given in millimeters
- 13 mm Plywood Sheathing to be blocked along edges
- 13 mm Plywood Sheathing to be secured with 2.5"
- 13 mm Plywood Sheathing to have 4 mm horizontal gap between rows
- Common Spiral Nails @ 75 mm O.C.
- Lag screws to be pre-drilled no greater than 75 % shank diameter
- All glulam to be non-treated, under 15 % M.C.
- Connections to be 6 mm thick painted steel
- Upper and lower framing plans are the same

Drawn by: Fraser Howatson	
Title: Glulam-Arch Mountain Hut Connections C4	
Industry Project No. 22-21	
2022-04-13	Drawing 6 of 6

Appendix B: Hand Calculations

Set 1 – Arch Design
Set 2 – Arch Ridge Connection
Set 3 – Arch Foundation Connection Design
Set 4 – Foundation Beam
Set 5 – Lateral Resistance Design
Set 6 – Joist Sizing
Set 7 – Floor Connection Design
Set 8 – Foundation Design

BENDING MOMENT RESISTANCE (CSA-O86 2017 7.5.6.5)

Bending moment resistance is the less of:

(1) $M_{r1} = \phi F_b S K_x K_{zbg}$ $\qquad \phi F_b S = M_r'$

(2) $M_{r2} = \phi F_b S K_x K_L$

For 130 × 342 mm section: $M_r' = 58.4$ MPa
(Beam selection tables Wood Design Manual 2017 pg. 68)

$$K_x = 1 - 2000\left(\frac{t}{R}\right)^2 = 1 - 2000\left(\frac{17.1\text{ mm}}{2546\text{ mm}}\right)^2 = 0.91$$

$$K_{zbg} = \left(\frac{130}{b}\right)^{\frac{1}{10}}\left(\frac{610}{d}\right)^{\frac{1}{10}}\left(\frac{9100}{L}\right)^{\frac{1}{10}} \leq 1.3$$

$$= \left(\frac{130}{130}\right)^{\frac{1}{10}}\left(\frac{610}{342}\right)^{\frac{1}{10}}\left(\frac{9100}{6350}\right)^{\frac{1}{10}} = 1.1 \leq 1.3$$

Lateral Stability:

$$C_B = \sqrt{\frac{L_e d}{b^2}} = \sqrt{\frac{1.92\cdot(3175\text{ mm})(342\text{ mm})}{(130\text{ mm})^2}} = 11.1$$ (7.5.6.4.3 pg 49 CSA-O86 2017)

$$C_K = \sqrt{\frac{0.97 E K_{SE} K_T}{F_b}} = \sqrt{\frac{0.97(12800\text{ MPa})(1)(1)}{30.6\text{ MPa}}} = 20.1$$

$10 < C_B < C_K \quad \therefore \quad K_L = 1 - \frac{1}{3}\left(\frac{C_B}{C_K}\right)^4$ (7.5.6.4.4 (b) pg. 50 CSA-O86 2017)

$$K_L = 1 - \frac{1}{3}\left(\frac{11.1}{20.1}\right)^4 = 0.97$$

(1) $M_{r1} = (58.4\text{ MPa})(0.91)(1.1) = 58.4$ MPa

(2) $M_{r2} = (58.4\text{ MPa})(0.91)(0.97) = 51.5$ MPa

$\therefore$ $\boxed{M_r = M_{r2} = 51.5\text{ MPa}}$

Resistance to Combined Bending and Axial Load 7.5.12

$$\left(\frac{P_f}{P_r}\right)^2 + \left(\frac{M_f}{M_r}\right)\left[\frac{1}{1-\frac{P_f}{P_E}}\right] \leq 1$$

$P_r = 452.0$ kN
$M_r = 51.5$ kN m

$P_f = 39.18$ kN
$M_f = 38.91$ kN m

$$P_E = \frac{\pi^2 E_{os} K_{SE} K_T I}{Le^2}$$

$E_{os} = 0.87 \times 12400$ MPa Table 7.3
$= 11136$ MPa

$K_{SE} = 1.00$ Dry Service Conditions Table 7.4.2

$K_T = 1.00$ Untreated 7.4.4

$$I = \frac{bh^3}{12} = \frac{(130\,mm)(342\,mm)^3}{12} = 433 \times 10^6\,mm^4$$

$Le = k_e L = 1\,(3175\,mm) = 3175$ mm

$$P_E = \frac{\pi^2 (11136\,MPa)(1.00)^2 (4.33 \times 10^6\,mm^4)}{(3175\,mm)^2}$$

$P_E = 4725$ kN 7.5.12 CSA-086 2017 pg 63

$$\therefore \left(\frac{39.18\,kN}{452.0\,kN}\right) + \left(\frac{38.91\,kN\,m}{51.5\,kN\,m}\right)\left[\frac{1}{1-\frac{39.18\,kN}{4725\,kN}}\right] = 0.85 < 1$$

* The above equations uses maximum values taken from multiple locations in the arch. This is more conservation than reality.

Compressive Resistance 7.5.8.4

$P_r = \phi F_c A K_{Zcg} K_c$

$\phi = 0.8$

$F_c = f_c (K_D K_H K_{Sc} K_c)$

$K_c = \left[1.0 + \frac{F_c K_{Zcg} C_c^3}{35 E_{05} K_{SE} K_T} \right]^{-1}$

$f_c = 30.2 \text{ MPa}$ 7.3

$K_D = 1.00$ 5.3.2.2

$K_H = 1.00$ 6.4.4

$K_{Sc} = 1.00$ 7.4.2

$K_T = 1.00$ 6.4.3

$E_{05} = 0.87E = 0.87(12800 \text{ MPa})$

$E_{05} = 11136 \text{ MPa}$ 7.5.8.5 CSA-086 2017 pg. 61

$C_c = \frac{Le}{b}$ or $\frac{Le}{d} \Rightarrow \frac{3175 \text{ mm}}{130 \text{ mm}}$ or $\frac{3175 \text{ mm}}{342 \text{ mm}}$

$C_c = 24.4$ (7.5.8.2 CSA-086 2017 pg. 60)

$K_{Zcg} = 0.68(Z)^{-0.13} = 0.68(0.28 \text{ m}^3)^{-0.13}$
$= 0.80$

$K_c = \left[1.0 + \frac{(30.2 \text{ MPa})(0.80)(24.3)^3}{35(11136 \text{ MPa})(1)(1)} \right]^{-1}$

$K_c = 0.53$ (7.5.8.5 CSA-086 2017 pg. 61)

$P_r = 0.8(30.2 \text{ MPa})(130 \times 342 \text{ mm}^2)(0.80)(0.53) \times 10^{-3}$

$P_r = 452.0 \text{ kN}$ (7.5.8.4.2 CSA-086 2017 pg. 61)

SHEAR RESISTANCE: (CSA-086 2017 7.5.7.2)

$V_r = \phi F_v \frac{2A_g}{3}$ * valid for beams under $2.0\ m^3$ and members other than beams

* $V_{ARCH} = (.130)(.342)(6.350) = 0.28\ m^3 < 2.0\ m^3$

$F_v = f_v(K_D K_H K_{SV} K_T)$

$f_v = 2.0\ MPa$ (Table 7.3 pg 46)
$K_D = 1.00$ 5.3.2.2
$K_H = 1.00$ 6.4.4
$K_{SV} = 1.00$ 7.4.2
$K_T = 1.00$ 6.4.3

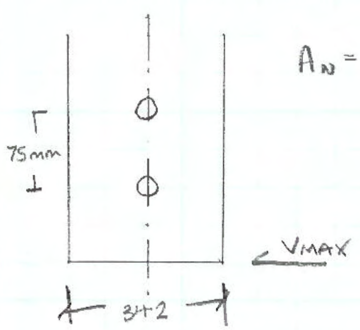
$F_v = 2.0\ MPa$

$V_r = 0.9(2.0\ MPa)(130\ mm \times 342\ mm) \cdot \left(\frac{2}{3}\right) \times 10^{-3}$

$V_r = 53.4\ kN$ for gross cross-section of beam

* No notches are present in the glulam arches but both top and bottom supports will have 2x 13 mm bolts spaced 75 mm O.C.

* Assume holes are bored @ 15 mm



$A_N = (130 \times (342 - 15)) = 42510\ mm^2$

$V_r = 0.9(2.0\ MPa)(42510\ mm^2)\left(\frac{2}{3}\right) \times 10^{-3}$

$\boxed{V_r = 51.0\ kN}$

CSA-O86 2017 7.5.6.6 Radial Resistance

(3) Bending moment tends to increase curvature, the corresponding radial stress is compression parrallel to grain.

$M_r = \phi F_{TP} \frac{2A}{3} R K_{Ztp}$

Member: 130 x 342 24f-Ex D.Fl
A (mm^2): 44460
t (mm): 17.1
R (mm): 2546

f_{tp} = 7.0 MPa (Table 7.3)

$F_{TP} = f_{tp}(K_D \times K_H \times K_{STP} \times K_T)$
F_{TP} = 7.0 MPa

K_D :	1.00	5.3.2.2
K_H :	1.00	6.4.4
K_{Stp} :	1.00	7.4.2
K_T :	1.00	6.4.3

$K_{Ztp} = \frac{20}{(AR\beta)^{0.2}}$ (7.5.6.6.1)

β: enclosed angle between 0.85 of factored bending mont ≙ 41° or 0.72 rad.

$= \frac{20}{(44460\,mm^2 \times 2546\,mm \times 0.72\,rad)^{0.2}}$

K_{Ztp} = 0.52

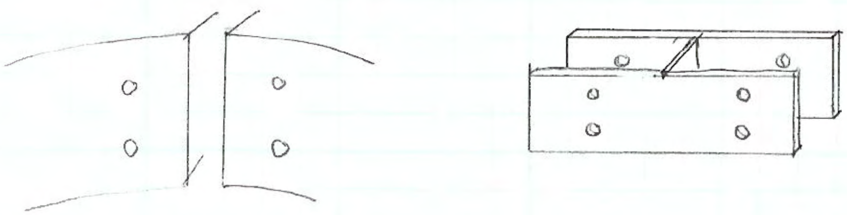
$M_r = 0.9(7.0\,MPa) \cdot \frac{2}{3} \cdot 44460\,mm^2 \times 2546\,mm \times 0.52$

= 247.2 kNm > M_f

Ridge Connection, Arches

* FROM MODEL, $P_{MAX} = 8.5$ kN, $V_{MAX} = 20$ kN @ PEAK CONNECTION

Try $\frac{1}{2}$" ϕ Bolts, 2x spaced @ 75 mm O.C. with 6 mm steel plates on either side.



← connection detail adopted from CWC-2017 Detail 7.32 pg 547

For $\frac{1}{2}$" ϕ Bolts in 130 mm D.Fir-L Glulam

$PR_F = 17.0$ kN (row shear)
$G_{rT} = 76$ kN (group tear out)
$Q'_u = 11.3$ kN (perp to grain yield resistance)

CWC-2017 Double shear 6 mm side plate pg 435

$PR_{rT} = PR_F n_c n_R (K_D K_{SV} K_T)$

$PR_{rt} = 17.0\,kN(2)(1)$
$= 34.0\,kN > P_{MAX}$

$K_D = 1.0$
$K_{SV} = 1.0$
$K_T = 1.0$
$K_{ST} = 1.0$

$PG_{RT} = 34.0\,kN + 76\,kN$
$= 110\,kN$

$J_{TR} = 1.00$ Table 7.9 CWC-2017 pg. 452

$Q_u = Q'_u n_c n_R (K_{DY} K_{SF} K_T)$
$= 11.3\,kN(1)(2)$

$K_{DY} = 1.00$
$K_{SF} = 1.00$

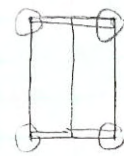
$Q_u = 22.6\,kN > V_{MAX}$

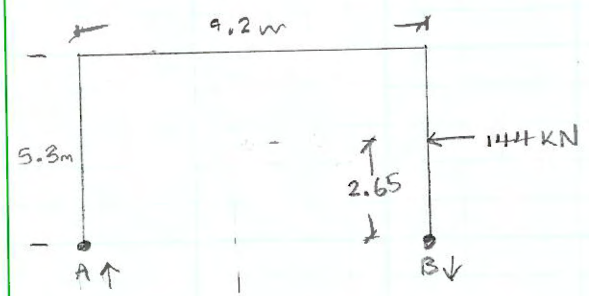
USE 2 × $\frac{1}{2}$ϕ" spaced @ 75 mm with 6 mm steel plates on either side.

Arch / Foundation Connection Design

* Conservative holddown calculation is based on only 2x rows of hold-downs being present located at opposite ends of structure

Plan view:





Estimated equivilent factored wind load = 144 KN

* Ignoring dead load of structure

$\Sigma M_A = 0 = -B_y(9.2m) + 144\,KN(2.65m) = 0 \quad B_y = 41.5\ KN/row$

∴ Factored hold-down > 20.75 KN

Connection Shear load:

\# of arch/foundation connections = 18

maximum factored wind force = 144 kN

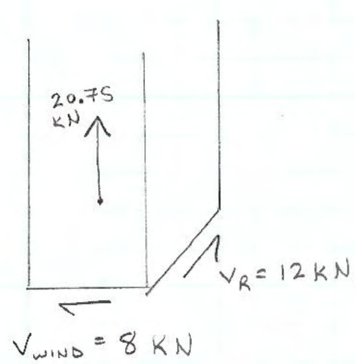
∴ Factored Shear-Load/connection = 8 KN

Normal Force (Thrust):

Maximum Factored Thrust at Base = 39.18 KN

* full section bearing (not included for connection design)

Overview (Potential Forces)

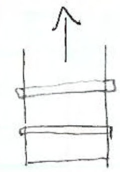


Connection Needs to resist

12 KN translation force

21 KN uplift force

Uplift Resistance, Parallel to Grain



$P_r = PR_F n_c n_R (K_D K_{SV} K_T)$

or

$PR_F n_c (K_D K_{SV} K_T) + G_{rT} J_{Tr} (K_D K_{St} K_T)$

$K_D = 1.00$, $K_{SV} = 1.00$, $K_T = 1.00$, $K_{ST} = 1.00$ } CWC-2017 pg 385

n_r - number of rows
n_c - number of fasteners / row

double shear bolt & dowel selection tables for 6 mm side plate

member thickness = 130 mm

CWC-2017 pg. 435 ($\frac{1}{2}''$ bolt) - spaced @ 78 mm

$PR_F = 17.0$ kN
$GR_T = 86.9$ kN
$Q_u' = 11.3$ kN

try 1× row of 2× $\frac{1}{2}''\phi$ bolts spaced at 76 mm

$P_r = 17.0(2) = 38.0$ kN > Max uplift force

Shear Resistance, perpandicular to grain

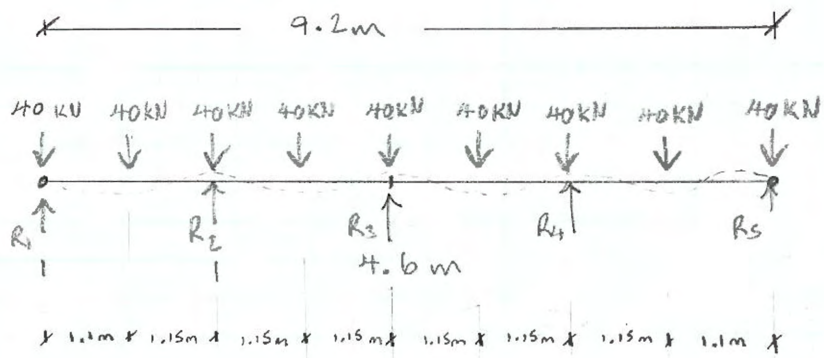
$Q_u = Q_u' n_c n_r (K_{Dy} K_{SF} K_T)$

$= (11.3 \text{ kN})(2)(1)(1 \times 1 \times 1)$

$Q_u = 22.6$ kN > Max shear force

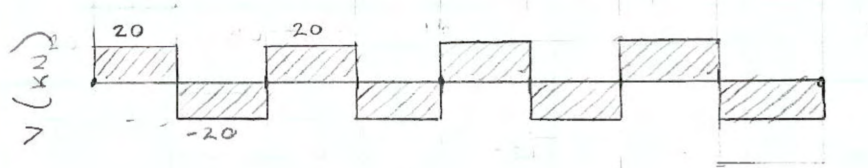
USE 1 row of 2× $\frac{1}{2}''\phi$ bolts spaced @ 76 mm or greater

Continuous Span Beam: Foundation Connection.



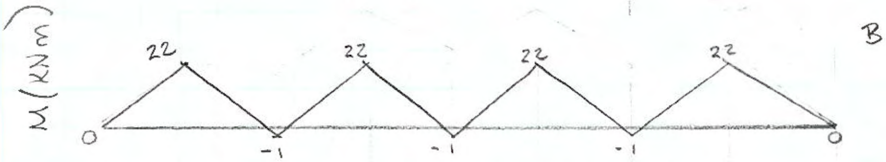
$F_y = -9(40KN) = 360$ KN

R_1 : 60 KN
R_2 : 80 KN
R_3 : 80 KN
R_4 : 80 KN
R_5 : 60 KN



S.F.D $V_{f MAX}$: 20 KN

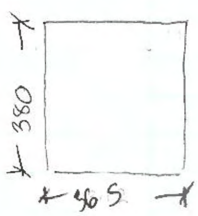
$M_{f max}$: 22 KN m



B.M.D

* Assumes point loads instead of UDL

Try: 365 mm × 380 mm D.FIR-L 24EX



* Beam needs to be at least as wide as the arches are deep = 342

From Glulam Beam Selection Tabe pg 73 CWC-2017

$M_r' = 242$ kNm
$V_r = 166$ KN

7.5.6.5
$K_x = 1$ (Flat)

$$K_{zbg} = \left(\frac{130}{b}\right)^{\frac{1}{10}} \left(\frac{610}{d}\right)^{\frac{1}{10}} \left(\frac{9100}{L}\right)^{\frac{1}{10}}$$

b = 342
d = 380
L ≅ 2.25 m

$$C_B = \sqrt{\frac{L_e d}{b^2}}$$

$K_{zbg} = 1.09$

$L_e = 1.68(2.25m)$

$K_L = 1$ ($C_b < 10$ – CSA-2017 7.5.6.4.4)

$C_B = 3.50$

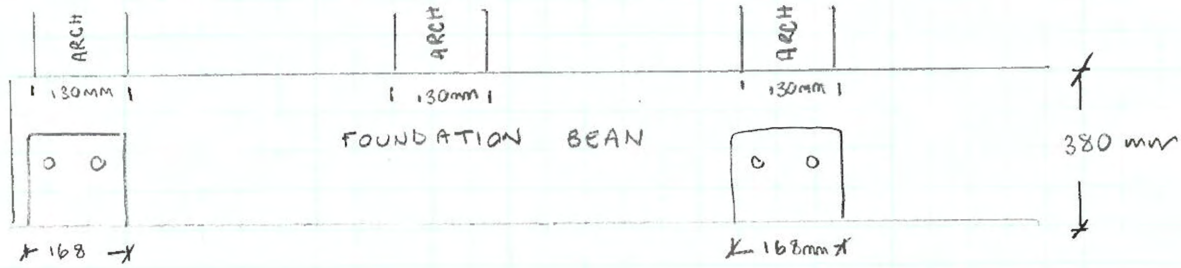
Use 380 × 342 D.Fir-L Glulam

∴ $M_r = 242$ kNm >> M_f

$V_r = 166$ KN >> V_{MAX}

* This beam is quite large compared to the demand but is justified due to service location & sensitivity to deflections.

Bearing Resistance, Q_r:



$Q_r = q_r \cdot L_b$

$q_r = 0.8 F_{cp} b K_B K_{Zcp}$

$F_{cp} = 7.0\text{MPa}(0.8)(0.65 \times 1 \times 1)$
$= 3.64$ MPa

$q_r = 0.8(3.64\text{MPa})(342\text{mm})(1 \times 1.15)$
$= 1145$ KN/m

D.Fir Larch 24-EX

$f_{cp} = 7.0$ MPa CSA-086 Table 7.3
$b = 342$ mm (section in bearing)
$K_B = 1.00$ CWC-207 Figure 6.2 pg. 300

$K_{Zcp} = 1.15$ CWC-2017 Figure 6.3 pg. 301

$K_D = 0.65$ CWC-207 pg. 299
$K_{Scp} = 1.0$ "dry service"
$K_T = 1.0$ untreated

For bearing @ Arches, mid-span:

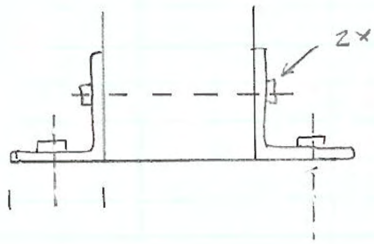
$Q_r = q_r \cdot L_b$ $\quad$ L_b – bearing length
$= 1145 \text{ kN/m} \cdot (0.130\text{ m})$
$= 148.8 \text{ kN} > P_{ARCH}$

For bearing near supports:

$Q_r' = \frac{2}{3} q_r L_b'$ $\quad$ $L_b' = (130\text{ mm} + 168\text{ mm})/2 = 149$ mm
$= \frac{2}{3}(1145 \frac{\text{KN}}{\text{m}})(0.149\text{ m})$
$= 113.7 \text{ KN} > R_1, R_2$ (60 kN, 80 KN)

342 mm x 380 mm D.Fir-Larch Glulam is okay in bearing.

LAG SCREW CONNECTION TO FOUNDATION BEAM.



* LAG SCREWS TO BE PRE-DRILLED 60-75% of shank

FOUNDATION BEAM

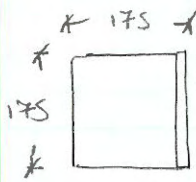
Lateral Shear, Pr (Parallel / Perp. to grain)

V_f = 8 kN (Assumes wind load is balanced over all arches)

$P_r = P_r' n_{Fe} n_r K'$

$K' = K_D K_{SF} K_T = (1.0 \times 1.0 \times 1.0) = 1.0$

Try a base plate of 175 mm × 175 m



$\Sigma A_s = (175 \times 175) \times (7 \times 2 + 2)$

$\Sigma A_s = 490\,000\ mm^2$

* Excludes the plates at the ends of the foundation beam - end grain

$A_m = (9200 \times 342) = 3146400$ $\frac{A_m}{\Sigma A_s} = 6.42$

∴ $n_{Fe} = 2$ Table 7.21 CWC-2017 pg. 510
$n_r = 1$

Try: 1/2" ϕ Lag screws with 102 mm embedment

$P_r' = 6.39$ kN
$Q_r' = 4.26$ kN
$P_{rw}' = 80$ N/mm

$P_r = P_r' n_{Fe} n_r K'$
$= (6.39\ kN)(2)(2)(1)$
$= 25.6\ kN > 8\ kN$ ✓

$Q_r' = Q_r' n_{Fe} n_R K'$
$= (4.26\ kN)(2)(2)(1)$
$= 17.04\ kN > 12\ kN$ ✓

* At end arches, connection requires 5/8" ϕ lag screws embedded 127 mm to avoid having to drill into the end grain.

LAG SCREW CONNECTION TO FOUNDATION BEAM: (CONT)

Withdrawl Resistance, P_{rw}:

$P_{rw} = P_{rw}' L_t n_F K' J_e$

$P_{rw} = \left(80 \frac{N}{mm}\right)(102)(4)(1)(1)$

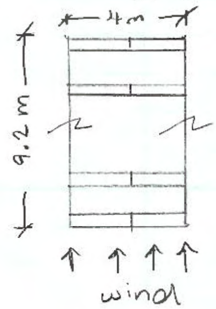
$P_{rw} = 32.6$ kN $> P_{UPLIFT}$

$n_F = 2$
$K' = 1$
$J_e = 1$ (not installed to end grain)
$L_p = 102$ mm

∴ USE $\phi \frac{1}{2}$" lag screws embedded 102 mm with 6 mm side plates on each side of arch-bases except for the end sections – $\phi \frac{5}{8}$" embedded 127 mm only on one side.

Lateral Resistance Design:

* It is assummed that lateral forces acting against the strong axis of the arches is already accounted for in the general arch design. ∴ Lateral forces against the weak axis will be considered.



total factored wind force = 144 KN

* Assume 50% is pick-up by foundation
* Shear wall on either side

$V_{fs} = 144\text{ KN} \times 0.5 \times 0.5 \div 9.2\text{ m}$

$V_{fs} = 3.9\text{ KN/m}$

CWC-2017 pg. 608

$v_{rs} = \phi V_d J_D n_s J_{us} J_s J_{hd}$ (a) (sheathing to framing)

or

$\phi v_{pb} K_D K_s K_T$ (b) (panel buckling)

$K_D = 1.15$
$K_{SF} = 1.0$
$K_T = 1.0$

$V_d = N_u / s \qquad N_u = n_u(K_D K_{SF} K_T)$

Try 12.5 mm OSB with 2.5" Common spiral nails @ 75 mm O.C. (3")

Sheathing to Framing (a)

$n_u = 0.279\text{ KN}(1.15) = 0.321\text{ KN} \qquad V_d = \frac{0.321\text{ KN}}{0.075\text{ m}} = 4.28\ \frac{\text{KN}}{\text{m}}$

$J_s = 1 - \left(\frac{150 - s}{150}\right)^{4.2} = 1 - \left(\frac{150 - 75}{150}\right)^{4.2}$

$J_s = 0.95$

$J_D = 1.3$ — CWC-2017 pg 609
$n_s = 1.0$ — "
$J_{us} = 1.0$ — "
$J_{HD} = 1.0$ — "

$\therefore v_{RS} = 0.8\left(4.28\ \frac{\text{KN}}{\text{m}}\right)(1.3)(1^3)(0.95) = 4.23\ \frac{\text{KN}}{\text{m}}$

(b) Panel Buckling Strength CWC-2017 pg 609

$V_{RS} = \phi \, V_{pb} K_D K_S K_T$

$\phi = 0.8$

$K_D = 1.15$
$K_S = 1.0$
$K_T = 1.0$

$$V_{pb} = K_{pb} \frac{\pi^2 t^2}{3000\, b} \left(B_{a,0} \, B_{a,90} \right)^{\frac{1}{4}}$$

$$K_{pb} = 1.7(\eta + 1)\exp\left(\frac{-\alpha}{0.05\eta + 0.75}\right) + (0.5\eta + 0.8)$$

$$\alpha = \frac{a}{b}\left(\frac{B_{a,90}}{B_{a,0}}\right)^{\frac{1}{4}}$$

$a = 2286$ mm (larger panel dim)
$b = 1220$ mm (smaller panel dim)

$$\eta = \frac{2 B_v}{\sqrt{B_{a,0} B_{a,90}}}$$

$B_v = 5700$ N/mm^2
$B_{a,0} = 55000$ N/mm^2
$B_{a,90} = 57000$ N/mm^2
CSA-086 Table 9.3B pg 68

$\eta = 0.20$

$\alpha = 1.89$

$K_{pb} = 0.90$

$$V_{pb} = \frac{(0.90)\pi^2 (12.5\,\text{mm})^2}{3000(1220\,\text{mm})} \left(55000 \frac{\text{N}}{\text{mm}} \cdot 57000 \frac{\text{N}}{\text{mm}} \right)^{\frac{1}{4}}$$

$V_{pb} = 21.5$ kN/m

$V_{RS} = 0.8(21.5 \frac{\text{kN}}{\text{m}})(1.15)$
$V_{RS} = 19.7$ kN/m

$V_{pb} >> V_s$ ∴ sheathing to connection governs

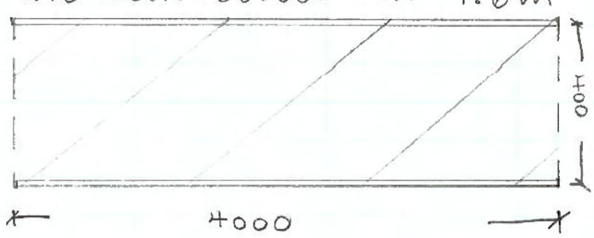
$V_{rs} = 4.3 \frac{\text{kN}}{\text{m}} > V_{fs}$

∴ **Use 12.5 mm plywood with 2.5" Common Spiral Nails @ 75 mm o.c.**

Joist Sizing: Lower + Upper Floor

Try 2×6 SPF Joists spaced @ 400 mm with 19 mm ply sub-floor

Trib Area: 1600000 mm^2 = 1.6 m^2



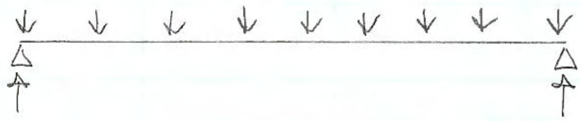
L: 1.9 kPa L_f: 2.85 kPa
D: 0.163 kPa D_f: 0.20 kPa

Total factored Service Load: 3.05 kPa

$w_f = 3.05\ kPa \cdot 0.400\,m$

$= 1.22\ kN/m$

Joist Weight: 4.8 N ⇒ 0.03 kPa
Ply Weight: 133 N/m^2 ⇒ 0.133 kPa



$R = \frac{w_f L}{2} = \frac{1.22\frac{kN}{m} \cdot 4.0\ m}{2} = 2.44\ kN = V_{f\,max}$

$M_{f\,max} = \frac{w_f L^2}{8} = \frac{(1.22\frac{kN}{m})(4.0\,m)^2}{8} = 2.44\ kNm = M_{f\,max}$

$M_r = \phi F_b S K_{Zb} K_L$ - Bending Moment Resistance (6.5.4 CSA-086 2017)
$F_b = f_b(K_D K_H K_{Sb} K_L)$

SPF NO 1/2
f_b = 11.8 MPa
f_v = 1.5 MPa
f_{cp} = 5.3 MPa
} pg. 24 TABLE 6.3.1.A CSA-086 207

K_D = 1.00   5.3.2.2
K_H = 1.4   Table 6.4.4
K_{Sb} = 1.00   Table 6.4.2
K_L = 1.00   Table 6.4.3

$M_r = 0.9(16.5\,MPa)(215\times10^3\,mm^3)(1.4)(1)$

$M_r = 4.5\ kNm > M_{f\,max}$

$F_b = 11.8\,MPa \times 1.4$
$F_b = 16.5\ MPa$

K_{Zb} = 1.4   Table 6.4.5
K_L = 1   6.5.4.2

2 × 6 SPF No1/2 is okay in bending

Joist Sizing: Lower & Upper Floor Combined

Shear Resistance

$V_r = \phi F_v \frac{2A_n}{3} K_{zv}$ CSA-086 2017 6.5.5.2

$F_v = f_v(K_D K_H K_{sv} K_T)$

$F_v = 1.5\ MPa(1 \times 1.4 \times 1 \times 1)$
$= 2.1\ MPa$

CSA-086:
- $f_v = 1.5\ MPa$ Table 6.3.1.A
- $K_D = 1.00$ 5.3.2.2
- $K_H = 1.4$ Table 6.4.4
- $K_{sv} = 1.00$ Table 6.4.2
- $K_T = 1.00$ Table 6.4.3
- $K_{zv} = 1.4$ Table 6.4.5

$A_n = A_g = (38\ mm \times 140\ mm) = 5320\ mm^2$

$V_r = 0.9(2.1\ MPa)\frac{2}{3}(5320\ mm^2) \cdot 1.4 \times 10^{-3}$

$V_r = 9.4\ kN > V_{MAX}$

2 × 6 SPF No 1/2 is okay in shear

Deflection Check:

Unfactored Service Load: L: 1.9 kPa, D: 0.16 kPa

$w = (1.9 + 0.16) \cdot .400\ m$

$w_{SER} = 0.82\ kN/m$

Simply Supported Beam: UDL

$\Delta_{max} = \frac{5wL^4}{384EI}$ CWC-2017 pg. 930

$E = 9500\ MPa$ (No.1 SPF) CSA-086 Table 6.3.1A

$I = 8.66 \times 10^6\ mm^4$ CWC-2017 pg. 904

$$\Delta_{MAX} = \frac{5(0.82\frac{kN}{m})(4\ m)^4}{384(9500\ MPa)(8.66 \times 10^6\ mm^4)}$$

$= 33\ m$ $\Delta_{ALLOW} = \frac{L}{180} = \frac{4000\ mm}{180} = 22\ mm$

∴ 2 × 6 NOT OKAY IN DEFLECTION

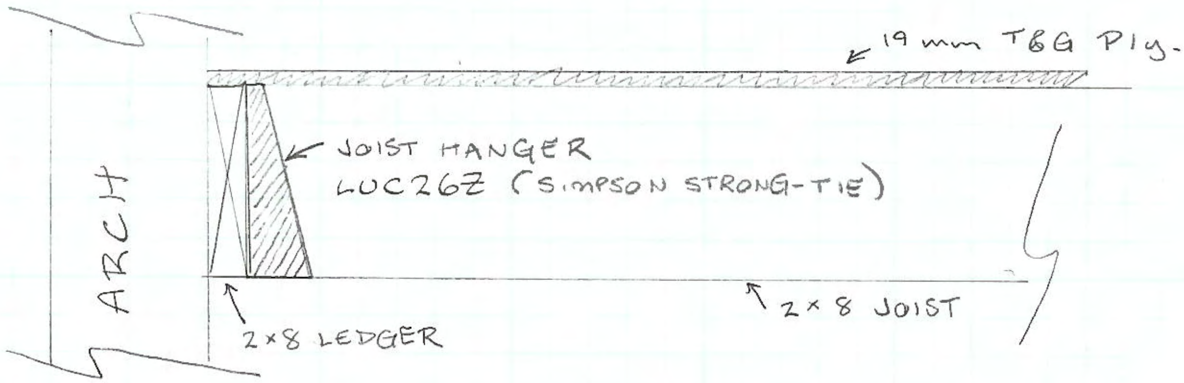
TRY 2×8 (38 × 184) $I = 19.8 \times 10^6\ mm^4$ CWC-2017 pg 904

$$\Delta_{MAX} = \frac{5(0.82\frac{kN}{m})(4\ m)^4}{384(9500\ MPa)(19.8 \times 10^6\ mm^4)}$$

$= 14\ m < \Delta_{ALLOW}$

USE 2 × 8 SPF No 1/2 @ 400 mm O.C.

Connection Design: Upper & Lower Floor



Joist Hanger Selection:

$N_r = \phi n_u K'$ CWC-2017 pg. 526

N_r = Factored resistance of joist hanger
n_u = ultimate resistance of joist hanger

$K' = K_D K_{SF} K_T$

$\phi = 0.6$
$K_D = 1.00$ CSA-O86 TABLE 5.3.2.2.
$K_{SF} = 1.00$ CWC-2017 pg. 329
$K_T = 1.00$ Untreated.

$\therefore N_r = 0.6 n_u$

$V_{MAX} = 2.44$ kN / joist

$$n_u > \frac{N_r}{0.6} = \frac{2.44 \text{ kN}}{0.6} = 4.1 \text{ kN}$$

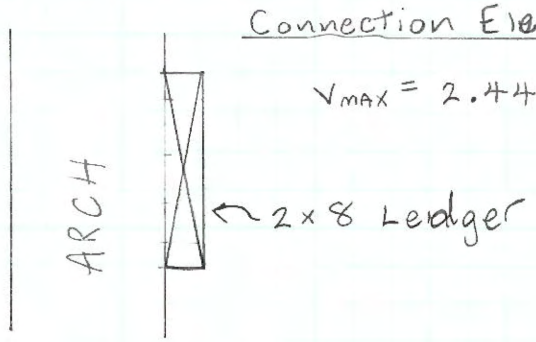
FACE MOUNTED HANGERS: SIMPSON STRONG-TIE
(REFERENCE TABLE IN APPENDIX)

LUC26Z – Factored Resistanc = 5.07 kN (Normal, SPF) – see joist selection table

Ledger Connection

Connection Elev.

$V_{MAX} = 2.44$ kN



Plan View

TRY NAILS: CWC-2017 (7.2 pg 327)

$N_r = N_r' n_s n_F K' J_F$

N_r = factored lateral resistance

$n_s = 1$ (# of shear planes)

n_F = # of nails

$K' = K_D K_{SF} K_T$
$= 1.0 \times 1.0 \times 1.0$
$= 1.0$

$J_F = J_E J_A J_B J_D = 1$

$J_E = 1.0$ (side grain)
$J_A = 1.0$ (not toe nailed)
$J_B = 1.0$ (unclinched)
$J_D = 1.0$ (not shearwall or diaphram)

$N_r = N_r' n_s n_F$

* Minimum Penentration into Glulam = 5 nail ϕ

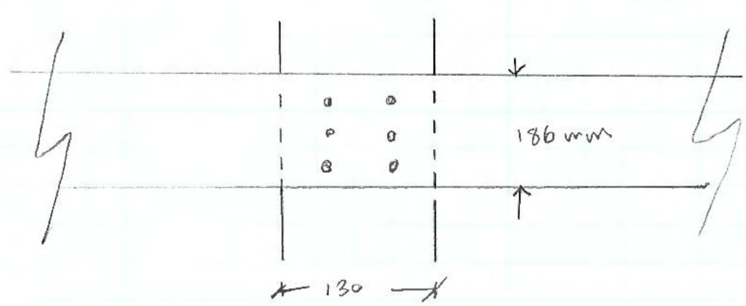
$N_r > V_{max}$

Try 3.5" 4.12 mm ϕ Common Wire Nails (CWC-2017- Nail Selection Table)

$N_r' n_s = 0.807$ kN

$$n_{F\,req} = \frac{2.44 \text{ kN}}{0.807 \text{ kN}} = 3 \text{ nails}$$

∴ **Use 6 × 3.5" 4.12 mm ϕ common wire nail to attach 2×6 ledger to glulam arch.**



* Each arch is capable of producing a P_{MAX} of 40 KN

$A = 130 \times 342$ mm
$= 44460$ mm^2

* Assume a soil bearing pressure of 100 KPa

$q_{ALLOW} = 100 \text{ KPa} = \frac{P_{MAX}}{A_{REQ}}$ $A = \frac{80 \text{ KN}}{100 \text{ KPa}} = 0.8 \text{ m}^2$

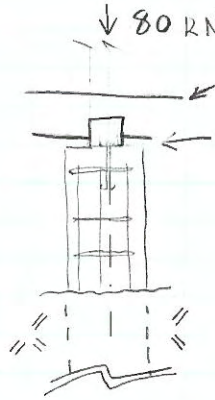
* Assume circular concrete foundations:

$\phi = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4(0.8 \text{ m}^2)}{\pi}}$ $\phi = 0.90$ m
$= 1.0$ m

Load Conditions

$P_{MAX} = 40$ KN
$V_{MAX} = 12$ KN

$f'_c = 25$ MPa
$f_y = 400$ MPa



Tied Columns 10.10.4 b) CSA-A23 2019

$P_{r,max} = (0.2 + 0.002h) P_{ro} < 0.80 P_{ro}$

$P_{ro} = \alpha_1 \phi_c f'_c (A_g - A_{st}) + \phi_s f_y A_{st}$

A_g - gross area of colomn
A_{st} - total area of steal (1x tie included)

Try 4x 20M vertical w/ 10M tie spaced at 320 mm O.C.

* outer ϕ of tie should be 600 mm allowing for 75 mm concrete coverage on all sides.

$A_g = \frac{\pi}{4}(750\text{mm})^2 = 441786 \text{ mm}^2$ $A_{st} = 4(300\text{mm}^2) + \frac{\pi}{4}(600^2 - 590^2)$
$= 10526 \text{ mm}^2$

$P_{ro} = (0.8125)(0.65)(25\text{MPa})(441786\text{mm}^2 - 10526\text{mm}^2) + 0.9(400\text{ MPa})(10526\text{mm}^2)$

$P_{ro} = 9483$ KN

$P_{rMAX} = 7586$ KN $>> P_f$

Appendix C: Numerical Model Results

Case 1: 1.25D + 1.5L
Case 2: 1.25D + 1.5S
Case 3: 0.9D + 1.4W

radius (m)		2.546
Josit Spacing (m)		1.143
dead wight (kN/m)		1.143
Floor Trib Area (m^2)		2.19
Total Arch Length (m)		6.429
Curved Arch Length (m)		3.362
Straigth Arch Length (m)		3.067
Forces (kN)		
	x	y
L1y		-6.98
L2y		-6.98
Arch $_{tot}$		-8.55
Snow $_{tot}$		0.00
S		0.00
W (kN/m)		0.78
Ray		22.51
Rax	9.67	0.00

	D	factor	L	Factor	S	Factor		
Floor 1	0.27	1.25	1.9	1.5				
Floor 2	0.27	1.25	1.9	1.5				
Arch + Shell	0.93	1.25	0	1.5				
Snow					7.282	1		
Wind (kN/m)							1.95	0.4

Max	
Shear	13.11
Thrust	-22.51
Moment	-28.31
Interaction	0.55

Ss (kPa)	14.3	Adopted from Resort Muni
Sr (kPa)	0.99	
Is	1.0	
Cb	0.8	
Cw	0.5	
Cs	0.44	
Ca	1	
S (kPa)	3.5068	

Distance Along Axis (m)	Centerline (m) X	Y	Phi (deg)	Hor. (kN)	Vert. (kN)	N (kN)	V (kN)	M (kN m)	Roof Angle	Cs	Snow Load (kPa)	Snow Load (kN)	Wind Load (kN)	Interaction
0.000	0	0	0.0	-9.67	-22.5	-22.51	9.67	0.00	90.0	0.0	0.00	0.00	0.0	0.00
0.061	0	0.061	0.0	-9.62	-22.4	-22.44	9.62	-0.59	90.0	0.0	0.00	0.00	0.0	0.01
0.123	0	0.123	0.0	-9.57	-22.4	-22.37	9.57	-1.18	90.0	0.0	0.00	0.00	0.1	0.03
0.184	0	0.184	0.0	-9.53	-22.3	-22.30	9.53	-1.77	90.0	0.0	0.00	0.00	0.1	0.04
0.244	0	0.244	0.0	-9.48	-15.3	-15.25	9.48	-2.34	90.0	0.0	0.00	0.00	0.2	0.05
0.246	0	0.246	0.0	-9.48	-15.2	-15.18	9.48	-2.35	90.0	0.0	0.00	0.00	0.2	0.05
0.307	0	0.307	0.0	-9.43	-15.1	-15.11	9.43	-2.93	90.0	0.0	0.00	0.00	0.2	0.06
0.368	0	0.368	0.0	-9.38	-15.0	-15.04	9.38	-3.51	90.0	0.0	0.00	0.00	0.3	0.07
0.430	0	0.430	0.0	-9.33	-15.0	-14.97	9.33	-4.08	90.0	0.0	0.00	0.00	0.3	0.08
0.491	0	0.491	0.0	-9.29	-14.9	-14.90	9.29	-4.65	90.0	0.0	0.00	0.00	0.4	0.09
0.552	0	0.552	0.0	-9.24	-14.8	-14.83	9.24	-5.22	90.0	0.0	0.00	0.00	0.4	0.10
0.614	0	0.614	0.0	-9.19	-14.8	-14.76	9.19	-5.79	90.0	0.0	0.00	0.00	0.5	0.11
0.675	0	0.675	0.0	-9.14	-14.7	-14.69	9.14	-6.35	90.0	0.0	0.00	0.00	0.5	0.12
0.737	0	0.737	0.0	-9.10	-14.6	-14.62	9.10	-6.91	90.0	0.0	0.00	0.00	0.6	0.14
0.798	0	0.798	0.0	-9.05	-14.6	-14.55	9.05	-7.47	90.0	0.0	0.00	0.00	0.6	0.15
0.859	0	0.859	0.0	-9.00	-14.5	-14.48	9.00	-8.02	90.0	0.0	0.00	0.00	0.7	0.16
0.921	0	0.921	0.0	-8.95	-14.4	-14.41	8.95	-8.57	90.0	0.0	0.00	0.00	0.7	0.17
0.982	0	0.982	0.0	-8.90	-14.3	-14.34	8.90	-9.12	90.0	0.0	0.00	0.00	0.8	0.18
1.043	0	1.043	0.0	-8.86	-14.3	-14.27	8.86	-9.67	90.0	0.0	0.00	0.00	0.8	0.19
1.105	0	1.105	0.0	-8.81	-14.2	-14.20	8.81	-10.21	90.0	0.0	0.00	0.00	0.9	0.20
1.166	0	1.166	0.0	-8.76	-14.1	-14.13	8.76	-10.75	90.0	0.0	0.00	0.00	0.9	0.21
1.228	0	1.228	0.0	-8.71	-14.1	-14.06	8.71	-11.28	90.0	0.0	0.00	0.00	1.0	0.22
1.289	0	1.289	0.0	-8.66	-14.0	-13.99	8.66	-11.82	90.0	0.0	0.00	0.00	1.0	0.23
1.350	0	1.350	0.0	-8.62	-13.9	-13.92	8.62	-12.35	90.0	0.0	0.00	0.00	1.1	0.24
1.412	0	1.412	0.0	-8.57	-13.9	-13.85	8.57	-12.87	90.0	0.0	0.00	0.00	1.1	0.25
1.473	0	1.473	0.0	-8.52	-13.8	-13.78	8.52	-13.40	90.0	0.0	0.00	0.00	1.2	0.26
1.535	0	1.535	0.0	-8.47	-13.7	-13.71	8.47	-13.92	90.0	0.0	0.00	0.00	1.2	0.27
1.596	0	1.596	0.0	-8.42	-13.6	-13.64	8.42	-14.44	90.0	0.0	0.00	0.00	1.2	0.28
1.657	0	1.657	0.0	-8.38	-13.6	-13.57	8.38	-14.95	90.0	0.0	0.00	0.00	1.3	0.29
1.719	0	1.719	0.0	-8.33	-13.5	-13.50	8.33	-15.47	90.0	0.0	0.00	0.00	1.3	0.30
1.780	0	1.780	0.0	-8.28	-13.4	-13.43	8.28	-15.98	90.0	0.0	0.00	0.00	1.4	0.31
1.841	0	1.841	0.0	-8.23	-13.4	-13.36	8.23	-16.48	90.0	0.0	0.00	0.00	1.4	0.32
1.903	0	1.903	0.0	-8.18	-13.3	-13.29	8.18	-16.99	90.0	0.0	0.00	0.00	1.5	0.33
1.964	0	1.964	0.0	-8.14	-13.2	-13.22	8.14	-17.49	90.0	0.0	0.00	0.00	1.5	0.34
2.026	0	2.026	0.0	-8.09	-13.1	-13.15	8.09	-17.99	90.0	0.0	0.00	0.00	1.6	0.35
2.087	0	2.087	0.0	-8.04	-13.1	-13.08	8.04	-18.48	90.0	0.0	0.00	0.00	1.6	0.36
2.148	0	2.148	0.0	-7.99	-13.0	-13.01	7.99	-18.97	90.0	0.0	0.00	0.00	1.7	0.37
2.210	0	2.210	0.0	-7.94	-12.9	-12.94	7.94	-19.46	90.0	0.0	0.00	0.00	1.7	0.38
2.271	0	2.271	0.0	-7.90	-12.9	-12.87	7.90	-19.95	90.0	0.0	0.00	0.00	1.8	0.39
2.332	0	2.332	0.0	-7.85	-12.8	-12.80	7.85	-20.43	90.0	0.0	0.00	0.00	1.8	0.40
2.394	0	2.394	0.0	-7.80	-12.7	-12.73	7.80	-20.91	90.0	0.0	0.00	0.00	1.9	0.41
2.455	0	2.455	0.0	-7.75	-12.7	-12.66	7.75	-21.39	90.0	0.0	0.00	0.00	1.9	0.42
2.517	0	2.517	0.0	-7.71	-12.6	-12.59	7.71	-21.86	90.0	0.0	0.00	0.00	2.0	0.43
2.578	0	2.578	0.0	-7.66	-12.5	-12.52	7.66	-22.33	90.0	0.0	0.00	0.00	2.0	0.44
2.639	0	2.639	0.0	-7.61	-12.4	-12.45	7.61	-22.80	90.0	0.0	0.00	0.00	2.1	0.44
2.701	0	2.701	0.0	-7.56	-12.4	-12.38	7.56	-23.27	90.0	0.0	0.00	0.00	2.1	0.45
2.762	0	2.762	0.0	-7.51	-12.3	-12.31	7.51	-23.73	90.0	0.0	0.00	0.00	2.2	0.46
2.803	0	2.803	0.0	-7.48	-5.3	-5.28	7.48	-24.04	90.0	0.0	0.00	0.00	2.2	0.47
2.823	0	2.823	0.0	-7.47	-5.2	-5.21	7.47	-24.19	90.0	0.0	0.00	0.00	2.2	0.47
2.885	0	2.885	0.0	-7.42	-5.1	-5.14	7.42	-24.65	90.0	0.0	0.00	0.00	2.3	0.48
2.946	0	2.946	0.0	-7.37	-5.1	-5.07	7.37	-25.10	90.0	0.0	0.00	0.00	2.3	0.49
3.008	0	3.008	0.0	-7.32	-5.0	-5.00	7.32	-25.55	90.0	0.0	0.00	0.00	2.3	0.50
3.069	0	3.069	0.0	-7.27	-4.9	-4.93	7.27	-26.00	90.0	0.0	0.00	0.00	2.4	0.51
3.381	0.019	3.381	7.0	-7.03	-4.6	-5.40	6.42	-27.72	83.0	0.0	0.00	0.00	2.6	0.54
3.511	0.038	3.509	9.9	-6.93	-4.4	-5.55	6.06	-28.10	80.1	0.0	0.00	0.00	2.7	0.55
3.611	0.057	3.607	12.2	-6.85	-4.3	-5.66	5.79	-28.26	77.8	0.0	0.00	0.00	2.8	0.55
3.695	0.077	3.689	14.1	-6.79	-4.2	-5.74	5.56	-28.31	75.9	0.0	0.00	0.00	2.9	0.55
3.769	0.096	3.760	15.8	-6.73	-4.1	-5.80	5.36	-28.28	74.2	0.0	0.00	0.00	2.9	0.55
3.836	0.115	3.825	17.3	-6.68	-4.1	-5.85	5.18	-28.19	72.7	0.0	0.00	0.00	3.0	0.55
3.898	0.134	3.884	18.7	-6.64	-4.0	-5.90	5.01	-28.07	71.3	0.0	0.00	0.00	3.0	0.55
3.956	0.153	3.938	20.0	-6.59	-3.9	-5.93	4.86	-27.91	70.0	0.0	0.00	0.00	3.1	0.54
4.011	0.172	3.989	21.2	-6.56	-3.8	-5.89	4.75	-27.71	68.8	0.030	1.16	0.07	3.1	0.54
4.062	0.191	4.037	22.4	-6.52	-3.6	-5.85	4.64	-27.50	67.6	0.059	1.33	0.08	3.2	0.53
4.111	0.210	4.083	23.5	-6.48	-3.5	-5.79	4.55	-27.26	66.5	0.086	1.48	0.08	3.2	0.53
4.158	0.230	4.126	24.5	-6.45	-3.4	-5.73	4.47	-27.00	65.5	0.113	1.64	0.09	3.2	0.53
4.204	0.249	4.166	25.5	-6.42	-3.2	-5.67	4.40	-26.73	64.5	0.138	1.78	0.09	3.3	0.52
4.247	0.268	4.206	26.5	-6.39	-3.1	-5.60	4.34	-26.44	63.5	0.163	1.92	0.10	3.3	0.51
4.289	0.287	4.243	27.5	-6.36	-2.9	-5.53	4.29	-26.13	62.5	0.187	2.06	0.10	3.3	0.51
4.330	0.306	4.279	28.4	-6.33	-2.8	-5.45	4.25	-25.81	61.6	0.210	2.19	0.10	3.3	0.50
4.370	0.325	4.314	29.3	-6.30	-2.6	-5.37	4.21	-25.48	60.7	0.232	2.32	0.11	3.4	0.50
4.409	0.344	4.348	30.1	-6.28	-2.5	-5.29	4.18	-25.14	59.9	0.254	2.44	0.11	3.4	0.49
4.446	0.363	4.380	31.0	-6.25	-2.3	-5.21	4.16	-24.78	59.0	0.275	2.56	0.11	3.4	0.48
4.483	0.383	4.411	31.8	-6.23	-2.2	-5.12	4.15	-24.42	58.2	0.295	2.68	0.11	3.4	0.47
4.519	0.402	4.442	32.6	-6.20	-2.0	-5.04	4.14	-24.05	57.4	0.316	2.80	0.11	3.5	0.47

Distance Along Axis (m)	Centerline (m) X	Centerline (m) Y	Phi (deg)	Hor. (kN)	Vert. (kN)	N (kN)	V (kN)	M (kN m)	Roof Angle	Cs	Snow Load (kPa)	Snow Load (kN)	Wind Load (kN)	Interaction
4.554	0.421	4.471	33.4	-6.18	-1.9	-4.95	4.14	-23.66	56.6	0.335	2.91	0.12	3.5	0.46
4.588	0.440	4.500	34.2	-6.16	-1.7	-4.86	4.14	-23.27	55.8	0.355	3.02	0.12	3.5	0.45
4.622	0.459	4.527	34.9	-6.13	-1.5	-4.77	4.15	-22.86	55.1	0.374	3.13	0.12	3.5	0.44
4.655	0.478	4.554	35.7	-6.11	-1.4	-4.68	4.16	-22.45	54.3	0.392	3.23	0.12	3.6	0.44
4.688	0.497	4.581	36.4	-6.09	-1.2	-4.60	4.18	-22.03	53.6	0.411	3.34	0.12	3.6	0.43
4.719	0.517	4.606	37.1	-6.07	-1.1	-4.51	4.21	-21.61	52.9	0.429	3.44	0.13	3.6	0.42
4.751	0.536	4.631	37.9	-6.05	-0.9	-4.42	4.23	-21.17	52.1	0.446	3.54	0.13	3.6	0.41
4.782	0.555	4.656	38.5	-6.03	-0.7	-4.33	4.27	-20.73	51.5	0.464	3.64	0.13	3.6	0.40
4.812	0.574	4.679	39.2	-6.02	-0.6	-4.24	4.31	-20.28	50.8	0.481	3.74	0.13	3.7	0.39
4.842	0.593	4.702	39.9	-6.00	-0.4	-4.15	4.35	-19.82	50.1	0.498	3.84	0.13	3.7	0.39
4.872	0.612	4.725	40.6	-5.98	-0.2	-4.06	4.39	-19.36	49.4	0.514	3.93	0.13	3.7	0.38
4.901	0.631	4.747	41.2	-5.96	-0.1	-3.98	4.45	-18.88	48.8	0.531	4.03	0.13	3.7	0.37
4.930	0.650	4.769	41.9	-5.95	0.1	-3.89	4.50	-18.41	48.1	0.547	4.12	0.14	3.7	0.36
4.959	0.670	4.790	42.5	-5.93	0.3	-3.80	4.56	-17.92	47.5	0.563	4.21	0.14	3.7	0.35
4.987	0.689	4.810	43.2	-5.91	0.4	-3.72	4.62	-17.43	46.8	0.579	4.30	0.14	3.8	0.34
5.014	0.708	4.831	43.8	-5.90	0.6	-3.63	4.69	-16.93	46.2	0.595	4.39	0.14	3.8	0.33
5.042	0.727	4.850	44.4	-5.88	0.8	-3.55	4.76	-16.43	45.6	0.610	4.48	0.14	3.8	0.32
5.069	0.746	4.870	45.0	-5.87	1.0	-3.47	4.83	-15.91	45.0	0.625	4.57	0.14	3.8	0.31
5.096	0.765	4.889	45.6	-5.85	1.1	-3.39	4.91	-15.40	44.4	0.640	4.65	0.14	3.8	0.30
5.123	0.784	4.907	46.2	-5.84	1.3	-3.31	4.99	-14.87	43.8	0.655	4.74	0.14	3.8	0.29
5.149	0.803	4.925	46.8	-5.82	1.5	-3.23	5.07	-14.34	43.2	0.670	4.82	0.15	3.8	0.28
5.175	0.823	4.943	47.4	-5.81	1.7	-3.15	5.16	-13.81	42.6	0.685	4.91	0.15	3.9	0.27
5.201	0.842	4.960	48.0	-5.80	1.8	-3.07	5.25	-13.26	42.0	0.699	4.99	0.15	3.9	0.26
5.227	0.861	4.978	48.6	-5.78	2.0	-3.00	5.34	-12.72	41.4	0.714	5.07	0.15	3.9	0.25
5.252	0.880	4.994	49.1	-5.77	2.2	-2.92	5.44	-12.16	40.9	0.728	5.16	0.15	3.9	0.24
5.277	0.899	5.011	49.7	-5.76	2.4	-2.85	5.54	-11.60	40.3	0.742	5.24	0.15	3.9	0.23
5.302	0.918	5.027	50.3	-5.74	2.6	-2.78	5.64	-11.04	39.7	0.756	5.32	0.15	3.9	0.21
5.327	0.937	5.042	50.8	-5.73	2.7	-2.71	5.75	-10.46	39.2	0.770	5.40	0.15	3.9	0.20
5.352	0.956	5.058	51.4	-5.72	2.9	-2.64	5.85	-9.89	38.6	0.784	5.48	0.15	3.9	0.19
5.376	0.976	5.073	51.9	-5.71	3.1	-2.58	5.97	-9.30	38.1	0.798	5.55	0.15	4.0	0.18
5.400	0.995	5.088	52.5	-5.70	3.3	-2.51	6.08	-8.71	37.5	0.812	5.63	0.16	4.0	0.17
5.424	1.014	5.102	53.0	-5.69	3.5	-2.45	6.20	-8.12	37.0	0.825	5.71	0.16	4.0	0.16
5.448	1.033	5.117	53.5	-5.67	3.7	-2.39	6.31	-7.52	36.5	0.839	5.79	0.16	4.0	0.15
5.472	1.052	5.131	54.1	-5.66	3.8	-2.33	6.44	-6.91	35.9	0.852	5.86	0.16	4.0	0.13
5.495	1.071	5.144	54.6	-5.65	4.0	-2.27	6.56	-6.30	35.4	0.865	5.94	0.16	4.0	0.12
5.519	1.090	5.158	55.1	-5.64	4.2	-2.22	6.69	-5.68	34.9	0.878	6.01	0.16	4.0	0.11
5.542	1.110	5.171	55.7	-5.63	4.4	-2.16	6.82	-5.06	34.3	0.891	6.09	0.16	4.0	0.10
5.565	1.129	5.184	56.2	-5.62	4.6	-2.11	6.95	-4.43	33.8	0.904	6.16	0.16	4.0	0.09
5.588	1.148	5.197	56.7	-5.61	4.8	-2.06	7.08	-3.80	33.3	0.917	6.24	0.16	4.1	0.07
5.611	1.167	5.209	57.2	-5.60	5.0	-2.01	7.22	-3.16	32.8	0.930	6.31	0.16	4.1	0.06
5.634	1.186	5.221	57.7	-5.59	5.2	-1.97	7.36	-2.51	32.3	0.943	6.38	0.17	4.1	0.05
5.656	1.205	5.233	58.2	-5.58	5.4	-1.92	7.50	-1.86	31.8	0.956	6.46	0.17	4.1	0.04
5.679	1.224	5.245	58.7	-5.57	5.6	-1.88	7.64	-1.20	31.3	0.968	6.53	0.17	4.1	0.02
5.701	1.243	5.257	59.2	-5.57	5.7	-1.84	7.79	-0.54	30.8	0.981	6.60	0.17	4.1	0.01
5.723	1.263	5.268	59.7	-5.56	5.9	-1.80	7.93	0.13	30.3	0.993	6.67	0.17	4.1	0.00
5.737	1.275	5.275	60.1	-5.55	6.1	-1.78	8.03	0.56	29.9	1.001	6.72	0.11	4.1	0.01
5.745	1.282	5.279	60.2	-5.55	6.1	-1.77	8.08	0.80	29.8	1	6.71	0.06	4.1	0.02
5.767	1.301	5.290	60.7	-5.54	6.3	-1.74	8.23	1.48	29.3	1	6.71	0.17	4.1	0.03
5.789	1.320	5.300	61.2	-5.53	6.5	-1.71	8.38	2.16	28.8	1	6.71	0.17	4.1	0.04
5.811	1.339	5.311	61.7	-5.52	6.7	-1.68	8.53	2.85	28.3	1	6.71	0.17	4.1	0.06
5.833	1.358	5.321	62.2	-5.52	6.9	-1.66	8.68	3.54	27.8	1	6.71	0.17	4.2	0.07
5.854	1.377	5.331	62.7	-5.51	7.1	-1.64	8.83	4.23	27.3	1	6.71	0.17	4.2	0.08
5.876	1.396	5.341	63.2	-5.50	7.3	-1.62	8.98	4.93	26.8	1	6.71	0.16	4.2	0.10
5.897	1.416	5.350	63.6	-5.49	7.5	-1.60	9.14	5.63	26.4	1	6.71	0.16	4.2	0.11
5.918	1.435	5.360	64.1	-5.48	7.7	-1.59	9.29	6.34	25.9	1	6.71	0.16	4.2	0.12
5.940	1.454	5.369	64.6	-5.48	7.8	-1.58	9.44	7.05	25.4	1	6.71	0.16	4.2	0.14
5.961	1.473	5.378	65.1	-5.47	8.0	-1.57	9.59	7.77	24.9	1	6.71	0.16	4.2	0.15
5.982	1.492	5.387	65.5	-5.46	8.2	-1.57	9.75	8.49	24.5	1	6.71	0.16	4.2	0.16
6.003	1.511	5.395	66.0	-5.46	8.4	-1.57	9.90	9.21	24.0	1	6.71	0.16	4.2	0.18
6.024	1.530	5.404	66.5	-5.45	8.6	-1.57	10.05	9.94	23.5	1	6.71	0.16	4.2	0.19
6.044	1.550	5.412	67.0	-5.44	8.8	-1.58	10.20	10.67	23.0	1	6.71	0.16	4.2	0.21
6.065	1.569	5.420	67.4	-5.44	9.0	-1.58	10.36	11.41	22.6	1	6.71	0.16	4.2	0.22
6.086	1.588	5.428	67.9	-5.43	9.1	-1.59	10.51	12.15	22.1	1	6.71	0.16	4.2	0.24
6.106	1.607	5.435	68.4	-5.43	9.3	-1.61	10.66	12.89	21.6	1	6.71	0.16	4.2	0.25
6.127	1.626	5.443	68.8	-5.42	9.5	-1.62	10.82	13.64	21.2	1	6.71	0.16	4.3	0.27
6.147	1.645	5.450	69.3	-5.41	9.7	-1.64	10.97	14.39	20.7	1	6.71	0.16	4.3	0.28
6.168	1.664	5.457	69.7	-5.41	9.9	-1.66	11.13	15.15	20.3	1	6.71	0.16	4.3	0.29
6.188	1.683	5.464	70.2	-5.40	10.0	-1.68	11.28	15.91	19.8	1	6.71	0.16	4.3	0.31
6.209	1.703	5.471	70.7	-5.40	10.2	-1.71	11.43	16.68	19.3	1	6.71	0.16	4.3	0.32
6.229	1.722	5.478	71.1	-5.39	10.4	-1.74	11.59	17.44	18.9	1	6.71	0.16	4.3	0.34
6.249	1.741	5.484	71.6	-5.39	10.6	-1.77	11.74	18.22	18.4	1	6.71	0.15	4.3	0.35
6.269	1.760	5.491	72.0	-5.38	10.8	-1.80	11.89	18.99	18.0	1	6.71	0.15	4.3	0.37
6.289	1.779	5.497	72.5	-5.38	10.9	-1.84	12.04	19.77	17.5	1	6.71	0.15	4.3	0.38
6.309	1.798	5.503	72.9	-5.37	11.1	-1.87	12.20	20.56	17.1	1	6.71	0.15	4.3	0.40
6.329	1.817	5.509	73.4	-5.37	11.3	-1.91	12.35	21.34	16.6	1	6.71	0.15	4.3	0.41
6.349	1.836	5.514	73.8	-5.36	11.5	-1.96	12.50	22.14	16.2	1	6.71	0.15	4.3	0.43
6.369	1.856	5.520	74.3	-5.36	11.6	-2.00	12.65	22.93	15.7	1	6.71	0.15	4.3	0.45
6.389	1.875	5.525	74.7	-5.36	11.8	-2.05	12.80	23.73	15.3	1	6.71	0.15	4.3	0.46
6.409	1.894	5.530	75.2	-5.35	12.0	-2.10	12.96	24.54	14.8	1	6.71	0.15	4.3	0.48
6.429	1.913	5.535	75.6	-5.35	12.2	-2.16	13.11	25.34	14.4	1	6.71	0.15	4.3	0.49

radius (m)	2.546
Josit Spacing (m)	1.143
dead wight (kN/m)	1.143
Floor Trib Area (m^2)	2.19
Total Arch Length (m)	6.429
Curved Arch Length (m)	3.362
Straigth Arch Length (m)	3.067

Forces (kN)	x	y
L1y		-4.90
L2y		-4.90
$Arch_{tot}$		-8.55
$Snow_{tot}$		0.00
S		0.00
W (kN/m)		0.78
Ray		18.36
Rax	11.80	0.00

	D	factor	L	Factor	S	Factor		
Floor 1	0.27	1.25	1.9	1				
Floor 2	0.27	1.25	1.9	1				
Arch + Shell	0.93	1.25	0	1				
Snow					7.282	1.5		
Wind (kN/m)							1.95	0.4

Ss (kPa)	14.3	Adopted from Resort Muni
Sr (kPa)	0.99	
Is	1.0	
Cb	0.8	
Cw	0.5	
Cs	0.44	
Ca	1	
S (kPa)	3.5068	

	Max	
Shear	20.05	kN
Thrust	-18.36	kN
Moment	-38.15	kNm
Interaction	0.74	

Distance Along Axis (m)	Centerline (m) X	Y	Phi (deg)	Hor. (kN)	Vert. (kN)	N (kN)	V (kN)	M (kN m)	Roof Angle	Cs	Snow Load (kPa)	Snow Load (kN)	Wind Load (kN)	Interaction	Max
0.000	0	0	0.0	-11.80	-18.4	-18.36	11.80	0.00	90.0	0.0	0.00		0.0	0.00	0.74
0.061	0	0.061	0.0	-11.75	-18.3	-18.29	11.75	-0.72	90.0	0.0	0.00		0.0	0.02	
0.123	0	0.123	0.0	-11.70	-18.2	-18.22	11.70	-1.44	90.0	0.0	0.00		0.1	0.03	
0.184	0	0.184	0.0	-11.65	-18.1	-18.15	11.65	-2.16	90.0	0.0	0.00		0.1	0.04	
0.244	0	0.244	0.0	-11.61	-13.2	-13.18	11.61	-2.85	90.0	0.0	0.00		0.2	0.06	
0.246	0	0.246	0.0	-11.60	-13.1	-13.11	11.60	-2.87	90.0	0.0	0.00		0.2	0.06	
0.307	0	0.307	0.0	-11.56	-13.0	-13.04	11.56	-3.58	90.0	0.0	0.00		0.2	0.07	
0.368	0	0.368	0.0	-11.51	-13.0	-12.97	11.51	-4.29	90.0	0.0	0.00		0.3	0.08	
0.430	0	0.430	0.0	-11.46	-12.9	-12.90	11.46	-5.00	90.0	0.0	0.00		0.3	0.10	
0.491	0	0.491	0.0	-11.41	-12.8	-12.83	11.41	-5.70	90.0	0.0	0.00		0.4	0.11	
0.552	0	0.552	0.0	-11.36	-12.8	-12.75	11.36	-6.40	90.0	0.0	0.00		0.4	0.13	
0.614	0	0.614	0.0	-11.32	-12.7	-12.68	11.32	-7.09	90.0	0.0	0.00		0.5	0.14	
0.675	0	0.675	0.0	-11.27	-12.6	-12.61	11.27	-7.79	90.0	0.0	0.00		0.5	0.15	
0.737	0	0.737	0.0	-11.22	-12.5	-12.54	11.22	-8.48	90.0	0.0	0.00		0.6	0.17	
0.798	0	0.798	0.0	-11.17	-12.5	-12.47	11.17	-9.16	90.0	0.0	0.00		0.6	0.18	
0.859	0	0.859	0.0	-11.12	-12.4	-12.40	11.12	-9.85	90.0	0.0	0.00		0.7	0.19	
0.921	0	0.921	0.0	-11.08	-12.3	-12.33	11.08	-10.53	90.0	0.0	0.00		0.7	0.21	
0.982	0	0.982	0.0	-11.03	-12.3	-12.26	11.03	-11.21	90.0	0.0	0.00		0.8	0.22	
1.043	0	1.043	0.0	-10.98	-12.2	-12.19	10.98	-11.88	90.0	0.0	0.00		0.8	0.23	
1.105	0	1.105	0.0	-10.93	-12.1	-12.12	10.93	-12.56	90.0	0.0	0.00		0.9	0.25	
1.166	0	1.166	0.0	-10.89	-12.1	-12.05	10.89	-13.23	90.0	0.0	0.00		0.9	0.26	
1.228	0	1.228	0.0	-10.84	-12.0	-11.98	10.84	-13.89	90.0	0.0	0.00		1.0	0.27	
1.289	0	1.289	0.0	-10.79	-11.9	-11.91	10.79	-14.56	90.0	0.0	0.00		1.0	0.28	
1.350	0	1.350	0.0	-10.74	-11.8	-11.84	10.74	-15.22	90.0	0.0	0.00		1.1	0.30	
1.412	0	1.412	0.0	-10.69	-11.8	-11.77	10.69	-15.87	90.0	0.0	0.00		1.1	0.31	
1.473	0	1.473	0.0	-10.65	-11.7	-11.70	10.65	-16.53	90.0	0.0	0.00		1.2	0.32	
1.535	0	1.535	0.0	-10.60	-11.6	-11.63	10.60	-17.18	90.0	0.0	0.00		1.2	0.34	
1.596	0	1.596	0.0	-10.55	-11.6	-11.56	10.55	-17.83	90.0	0.0	0.00		1.2	0.35	
1.657	0	1.657	0.0	-10.50	-11.5	-11.49	10.50	-18.48	90.0	0.0	0.00		1.3	0.36	
1.719	0	1.719	0.0	-10.45	-11.4	-11.42	10.45	-19.12	90.0	0.0	0.00		1.3	0.37	
1.780	0	1.780	0.0	-10.41	-11.4	-11.35	10.41	-19.76	90.0	0.0	0.00		1.4	0.39	
1.841	0	1.841	0.0	-10.36	-11.3	-11.28	10.36	-20.40	90.0	0.0	0.00		1.4	0.40	
1.903	0	1.903	0.0	-10.31	-11.2	-11.21	10.31	-21.03	90.0	0.0	0.00		1.5	0.41	
1.964	0	1.964	0.0	-10.26	-11.1	-11.14	10.26	-21.66	90.0	0.0	0.00		1.5	0.42	
2.026	0	2.026	0.0	-10.21	-11.1	-11.07	10.21	-22.29	90.0	0.0	0.00		1.6	0.43	
2.087	0	2.087	0.0	-10.17	-11.0	-11.00	10.17	-22.92	90.0	0.0	0.00		1.6	0.45	
2.148	0	2.148	0.0	-10.12	-10.9	-10.93	10.12	-23.54	90.0	0.0	0.00		1.7	0.46	
2.210	0	2.210	0.0	-10.07	-10.9	-10.86	10.07	-24.16	90.0	0.0	0.00		1.7	0.47	
2.271	0	2.271	0.0	-10.02	-10.8	-10.79	10.02	-24.78	90.0	0.0	0.00		1.8	0.48	
2.332	0	2.332	0.0	-9.97	-10.7	-10.72	9.97	-25.39	90.0	0.0	0.00		1.8	0.49	
2.394	0	2.394	0.0	-9.93	-10.7	-10.65	9.93	-26.00	90.0	0.0	0.00		1.9	0.51	
2.455	0	2.455	0.0	-9.88	-10.6	-10.58	9.88	-26.61	90.0	0.0	0.00		1.9	0.52	
2.517	0	2.517	0.0	-9.83	-10.5	-10.51	9.83	-27.21	90.0	0.0	0.00		2.0	0.53	
2.578	0	2.578	0.0	-9.78	-10.4	-10.44	9.78	-27.81	90.0	0.0	0.00		2.0	0.54	
2.639	0	2.639	0.0	-9.73	-10.4	-10.37	9.73	-28.41	90.0	0.0	0.00		2.1	0.55	
2.701	0	2.701	0.0	-9.69	-10.3	-10.30	9.69	-29.01	90.0	0.0	0.00		2.1	0.57	
2.762	0	2.762	0.0	-9.64	-10.2	-10.23	9.64	-29.60	90.0	0.0	0.00		2.2	0.58	
2.803	0	2.803	0.0	-9.61	-5.3	-5.28	9.61	-30.00	90.0	0.0	0.00		2.2	0.58	
2.823	0	2.823	0.0	-9.59	-5.2	-5.21	9.59	-30.19	90.0	0.0	0.00		2.2	0.59	
2.885	0	2.885	0.0	-9.54	-5.1	-5.14	9.54	-30.78	90.0	0.0	0.00		2.3	0.60	
2.946	0	2.946	0.0	-9.50	-5.1	-5.07	9.50	-31.36	90.0	0.0	0.00		2.3	0.61	
3.008	0	3.008	0.0	-9.45	-5.0	-5.00	9.45	-31.95	90.0	0.0	0.00		2.3	0.62	
3.069	0	3.069	0.0	-9.40	-4.9	-4.93	9.40	-32.52	90.0	0.0	0.00		2.4	0.63	
3.381	0.019	3.381	7.0	-9.16	-4.6	-5.66	8.53	-35.10	83.0	0.0	0.00	0.00	2.6	0.68	
3.511	0.038	3.509	9.9	-9.06	-4.4	-5.92	8.16	-35.96	80.1	0.0	0.00	0.00	2.7	0.70	
3.611	0.057	3.607	12.2	-8.98	-4.3	-6.11	7.87	-36.53	77.8	0.0	0.00	0.00	2.8	0.71	
3.695	0.077	3.689	14.1	-8.92	-4.2	-6.26	7.62	-36.94	75.9	0.0	0.00	0.00	2.9	0.72	
3.769	0.096	3.760	15.8	-8.86	-4.1	-6.38	7.41	-37.26	74.2	0.0	0.00	0.00	2.9	0.72	
3.836	0.115	3.825	17.3	-8.81	-4.1	-6.48	7.21	-37.52	72.7	0.0	0.00	0.00	3.0	0.73	
3.898	0.134	3.884	18.7	-8.76	-4.0	-6.58	7.03	-37.71	71.3	0.0	0.00	0.00	3.0	0.73	
3.956	0.153	3.938	20.0	-8.72	-3.9	-6.66	6.86	-37.87	70.0	0.0	0.00	0.00	3.1	0.74	
4.011	0.172	3.989	21.2	-8.68	-3.7	-6.63	6.74	-37.98	68.8	0.030	1.74	0.11	3.1	0.74	
4.062	0.191	4.037	22.4	-8.64	-3.6	-6.59	6.64	-38.06	67.6	0.059	1.99	0.12	3.2	0.74	
4.111	0.210	4.083	23.5	-8.61	-3.4	-6.53	6.55	-38.12	66.5	0.086	2.23	0.13	3.2	0.74	
4.158	0.230	4.126	24.5	-8.57	-3.2	-6.47	6.47	-38.14	65.5	0.113	2.45	0.13	3.2	0.74	
4.204	0.249	4.166	25.5	-8.54	-3.0	-6.40	6.41	-38.15	64.5	0.138	2.67	0.14	3.3	0.74	
4.247	0.268	4.206	26.5	-8.51	-2.8	-6.32	6.36	-38.13	63.5	0.163	2.88	0.14	3.3	0.74	
4.289	0.287	4.243	27.5	-8.48	-2.6	-6.24	6.32	-38.09	62.5	0.187	3.09	0.15	3.3	0.74	
4.330	0.306	4.279	28.4	-8.45	-2.4	-6.15	6.29	-38.04	61.6	0.210	3.28	0.15	3.3	0.74	
4.370	0.325	4.314	29.3	-8.43	-2.2	-6.06	6.27	-37.97	60.7	0.232	3.47	0.16	3.4	0.74	
4.409	0.344	4.348	30.1	-8.40	-2.0	-5.96	6.25	-37.88	59.9	0.254	3.66	0.16	3.4	0.74	
4.446	0.363	4.380	31.0	-8.38	-1.8	-5.86	6.25	-37.78	59.0	0.275	3.84	0.17	3.4	0.73	
4.483	0.383	4.411	31.8	-8.35	-1.6	-5.76	6.26	-37.67	58.2	0.295	4.02	0.17	3.4	0.73	
4.519	0.402	4.442	32.6	-8.33	-1.4	-5.65	6.27	-37.54	57.4	0.316	4.19	0.17	3.5	0.73	
4.554	0.421	4.471	33.4	-8.30	-1.2	-5.55	6.29	-37.40	56.6	0.335	4.36	0.18	3.5	0.73	
4.588	0.440	4.500	34.2	-8.28	-0.9	-5.44	6.32	-37.25	55.8	0.355	4.53	0.18	3.5	0.72	
4.622	0.459	4.527	34.9	-8.26	-0.7	-5.33	6.35	-37.08	55.1	0.374	4.69	0.18	3.5	0.72	

4.655	0.478	4.554	35.7	-8.24	-0.5	-5.22	6.40	-36.90	54.3	0.392	4.85	0.18	3.6	0.72	
4.688	0.497	4.581	36.4	-8.22	-0.3	-5.11	6.44	-36.72	53.6	0.411	5.01	0.19	3.6	0.71	
4.719	0.517	4.606	37.1	-8.20	-0.1	-5.00	6.50	-36.52	52.9	0.429	5.16	0.19	3.6	0.71	
4.751	0.536	4.631	37.9	-8.18	0.2	-4.89	6.56	-36.31	52.1	0.446	5.31	0.19	3.6	0.71	
4.782	0.555	4.656	38.5	-8.16	0.4	-4.77	6.63	-36.09	51.5	0.464	5.46	0.19	3.6	0.70	
4.812	0.574	4.679	39.2	-8.14	0.6	-4.66	6.70	-35.86	50.8	0.481	5.61	0.20	3.7	0.70	
4.842	0.593	4.702	39.9	-8.12	0.9	-4.55	6.78	-35.62	50.1	0.498	5.76	0.20	3.7	0.69	
4.872	0.612	4.725	40.6	-8.11	1.1	-4.44	6.87	-35.37	49.4	0.514	5.90	0.20	3.7	0.69	
4.901	0.631	4.747	41.2	-8.09	1.3	-4.33	6.96	-35.11	48.8	0.531	6.04	0.20	3.7	0.68	
4.930	0.650	4.769	41.9	-8.07	1.6	-4.22	7.05	-34.84	48.1	0.547	6.18	0.20	3.7	0.68	
4.959	0.670	4.790	42.5	-8.06	1.8	-4.12	7.16	-34.56	47.5	0.563	6.32	0.21	3.7	0.67	
4.987	0.689	4.810	43.2	-8.04	2.0	-4.01	7.26	-34.27	46.8	0.579	6.45	0.21	3.8	0.67	
5.014	0.708	4.831	43.8	-8.02	2.3	-3.90	7.37	-33.98	46.2	0.595	6.59	0.21	3.8	0.66	
5.042	0.727	4.850	44.4	-8.01	2.5	-3.80	7.49	-33.67	45.6	0.610	6.72	0.21	3.8	0.65	
5.069	0.746	4.870	45.0	-7.99	2.8	-3.70	7.61	-33.36	45.0	0.625	6.85	0.21	3.8	0.65	
5.096	0.765	4.889	45.6	-7.98	3.0	-3.59	7.74	-33.04	44.4	0.640	6.98	0.21	3.8	0.64	
5.123	0.784	4.907	46.2	-7.96	3.3	-3.49	7.87	-32.70	43.8	0.655	7.11	0.22	3.8	0.64	
5.149	0.803	4.925	46.8	-7.95	3.5	-3.39	8.00	-32.36	43.2	0.670	7.24	0.22	3.8	0.63	
5.175	0.823	4.943	47.4	-7.94	3.8	-3.30	8.14	-32.01	42.6	0.685	7.36	0.22	3.9	0.62	
5.201	0.842	4.960	48.0	-7.92	4.0	-3.20	8.28	-31.66	42.0	0.699	7.49	0.22	3.9	0.62	
5.227	0.861	4.978	48.6	-7.91	4.3	-3.11	8.43	-31.29	41.4	0.714	7.61	0.22	3.9	0.61	
5.252	0.880	4.994	49.1	-7.90	4.5	-3.02	8.58	-30.92	40.9	0.728	7.73	0.22	3.9	0.60	
5.277	0.899	5.011	49.7	-7.88	4.8	-2.93	8.74	-30.54	40.3	0.742	7.85	0.23	3.9	0.59	
5.302	0.918	5.027	50.3	-7.87	5.0	-2.84	8.90	-30.15	39.7	0.756	7.98	0.23	3.9	0.59	
5.327	0.937	5.042	50.8	-7.86	5.3	-2.75	9.06	-29.75	39.2	0.770	8.09	0.23	3.9	0.58	
5.352	0.956	5.058	51.4	-7.85	5.5	-2.67	9.23	-29.34	38.6	0.784	8.21	0.23	3.9	0.57	
5.376	0.976	5.073	51.9	-7.83	5.8	-2.59	9.40	-28.93	38.1	0.798	8.33	0.23	4.0	0.56	
5.400	0.995	5.088	52.5	-7.82	6.1	-2.51	9.58	-28.50	37.5	0.812	8.45	0.23	4.0	0.55	
5.424	1.014	5.102	53.0	-7.81	6.3	-2.43	9.76	-28.07	37.0	0.825	8.56	0.24	4.0	0.55	
5.448	1.033	5.117	53.5	-7.80	6.6	-2.36	9.94	-27.63	36.5	0.839	8.68	0.24	4.0	0.54	
5.472	1.052	5.131	54.1	-7.79	6.9	-2.28	10.12	-27.19	35.9	0.852	8.79	0.24	4.0	0.53	
5.495	1.071	5.144	54.6	-7.78	7.1	-2.21	10.31	-26.73	35.4	0.865	8.91	0.24	4.0	0.52	
5.519	1.090	5.158	55.1	-7.77	7.4	-2.15	10.51	-26.27	34.9	0.878	9.02	0.24	4.0	0.51	
5.542	1.110	5.171	55.7	-7.76	7.7	-2.08	10.70	-25.80	34.3	0.891	9.13	0.24	4.0	0.50	
5.565	1.129	5.184	56.2	-7.75	7.9	-2.02	10.90	-25.32	33.8	0.904	9.24	0.24	4.0	0.49	
5.588	1.148	5.197	56.7	-7.74	8.2	-1.96	11.11	-24.83	33.3	0.917	9.35	0.25	4.1	0.48	
5.611	1.167	5.209	57.2	-7.73	8.5	-1.90	11.31	-24.33	32.8	0.930	9.47	0.25	4.1	0.47	
5.634	1.186	5.221	57.7	-7.72	8.8	-1.85	11.52	-23.83	32.3	0.943	9.57	0.25	4.1	0.46	
5.656	1.205	5.233	58.2	-7.71	9.0	-1.80	11.73	-23.32	31.8	0.956	9.68	0.25	4.1	0.45	
5.679	1.224	5.245	58.7	-7.70	9.3	-1.75	11.95	-22.80	31.3	0.968	9.79	0.25	4.1	0.44	
5.701	1.243	5.257	59.2	-7.69	9.6	-1.71	12.17	-22.27	30.8	0.981	9.90	0.25	4.1	0.43	
5.723	1.263	5.268	59.7	-7.68	9.9	-1.66	12.39	-21.74	30.3	0.993	10.01	0.25	4.1	0.42	
5.737	1.275	5.275	60.1	-7.68	10.0	-1.64	12.53	-21.39	29.9	1.001	10.08	0.17	4.1	0.42	
5.745	1.282	5.279	60.2	-7.67	10.1	-1.62	12.61	-21.20	29.8	1	10.07	0.09	4.1	0.41	
5.767	1.301	5.290	60.7	-7.67	10.4	-1.59	12.84	-20.65	29.3	1	10.07	0.25	4.1	0.40	
5.789	1.320	5.300	61.2	-7.66	10.7	-1.56	13.06	-20.09	28.8	1	10.07	0.25	4.1	0.39	
5.811	1.339	5.311	61.7	-7.65	11.0	-1.53	13.29	-19.53	28.3	1	10.07	0.25	4.1	0.38	
5.833	1.358	5.321	62.2	-7.64	11.2	-1.51	13.51	-18.97	27.8	1	10.07	0.25	4.2	0.37	
5.854	1.377	5.331	62.7	-7.63	11.5	-1.49	13.74	-18.39	27.3	1	10.07	0.25	4.2	0.36	
5.876	1.396	5.341	63.2	-7.63	11.8	-1.48	13.96	-17.81	26.8	1	10.07	0.25	4.2	0.35	
5.897	1.416	5.350	63.6	-7.62	12.1	-1.47	14.19	-17.23	26.4	1	10.07	0.25	4.2	0.33	
5.918	1.435	5.360	64.1	-7.61	12.3	-1.47	14.42	-16.64	25.9	1	10.07	0.25	4.2	0.32	
5.940	1.454	5.369	64.6	-7.60	12.6	-1.46	14.64	-16.04	25.4	1	10.07	0.24	4.2	0.31	
5.961	1.473	5.378	65.1	-7.60	12.9	-1.47	14.87	-15.44	24.9	1	10.07	0.24	4.2	0.30	
5.982	1.492	5.387	65.5	-7.59	13.1	-1.47	15.10	-14.83	24.5	1	10.07	0.24	4.2	0.29	
6.003	1.511	5.395	66.0	-7.58	13.4	-1.48	15.32	-14.22	24.0	1	10.07	0.24	4.2	0.28	
6.024	1.530	5.404	66.5	-7.58	13.7	-1.50	15.55	-13.60	23.5	1	10.07	0.24	4.2	0.26	
6.044	1.550	5.412	67.0	-7.57	13.9	-1.52	15.78	-12.97	23.0	1	10.07	0.24	4.2	0.25	
6.065	1.569	5.420	67.4	-7.56	14.2	-1.54	16.00	-12.34	22.6	1	10.07	0.24	4.2	0.24	
6.086	1.588	5.428	67.9	-7.56	14.4	-1.56	16.23	-11.70	22.1	1	10.07	0.24	4.2	0.23	
6.106	1.607	5.435	68.4	-7.55	14.7	-1.59	16.46	-11.06	21.6	1	10.07	0.24	4.2	0.21	
6.127	1.626	5.443	68.8	-7.55	15.0	-1.63	16.68	-10.41	21.2	1	10.07	0.24	4.3	0.20	
6.147	1.645	5.450	69.3	-7.54	15.2	-1.66	16.91	-9.75	20.7	1	10.07	0.24	4.3	0.19	
6.168	1.664	5.457	69.7	-7.53	15.5	-1.70	17.14	-9.09	20.3	1	10.07	0.23	4.3	0.18	
6.188	1.683	5.464	70.2	-7.53	15.7	-1.75	17.36	-8.43	19.8	1	10.07	0.23	4.3	0.16	
6.209	1.703	5.471	70.7	-7.52	16.0	-1.80	17.59	-7.76	19.3	1	10.07	0.23	4.3	0.15	
6.229	1.722	5.478	71.1	-7.52	16.3	-1.85	17.82	-7.08	18.9	1	10.07	0.23	4.3	0.14	
6.249	1.741	5.484	71.6	-7.51	16.5	-1.91	18.04	-6.40	18.4	1	10.07	0.23	4.3	0.12	
6.269	1.760	5.491	72.0	-7.51	16.8	-1.96	18.27	-5.71	18.0	1	10.07	0.23	4.3	0.11	
6.289	1.779	5.497	72.5	-7.50	17.0	-2.03	18.49	-5.01	17.5	1	10.07	0.23	4.3	0.10	
6.309	1.798	5.503	72.9	-7.50	17.3	-2.09	18.72	-4.31	17.1	1	10.07	0.23	4.3	0.08	
6.329	1.817	5.509	73.4	-7.49	17.5	-2.16	18.94	-3.61	16.6	1	10.07	0.23	4.3	0.07	
6.349	1.836	5.514	73.8	-7.49	17.8	-2.24	19.16	-2.90	16.2	1	10.07	0.23	4.3	0.06	
6.369	1.856	5.520	74.3	-7.49	18.0	-2.32	19.39	-2.18	15.7	1	10.07	0.23	4.3	0.04	
6.389	1.875	5.525	74.7	-7.48	18.3	-2.40	19.61	-1.46	15.3	1	10.07	0.23	4.3	0.03	
6.409	1.894	5.530	75.2	-7.48	18.5	-2.48	19.83	-0.73	14.8	1	10.07	0.23	4.3	0.01	
6.429	1.913	5.535	75.6	-7.47	18.8	-2.57	20.05	0.00	14.4	1	10.07	0.23	4.3	0.00	
Distance Along Axis (m)	Centerline (m) X	Y	Phi (deg)	Hor. (kN)	Vert. (kN)	N (kN)	V (kN)	M (kN m)	Roof Angle	Cs	Snow Load (kPa)	Snow Load (kN)	Wind Load (kN)	Interaction	Max

radius (m)	2.546
Josit Spacing (m)	1.143
dead wight (kN/m)	1.143
Floor Trib Area (m^2)	2.19
Total Arch Length (m)	6.429
Curved Arch Length (m)	3.362
Straigth Arch Length (m)	3.067

Forces (kN)	x	y
L1y		-4.69
L2y		-4.69
$Arch_{tot}$		-6.16
$Snow_{tot}$		0.00
S		0.00
W (kN/m)		2.73
Ray		15.54
Rax	14.23	0.00

	D	factor	L	Factor	S	Factor	W	Factor
Floor 1	0.27	0.9	1.9	1				
Floor 2	0.27	0.9	1.9	1				
Arch + Shell	0.93	0.9	0	1				
Snow					7.282	0		
Wind (kN/m)							1.95	1.4

	Max	
Shear	**14.23**	**kN**
Thrust	**-15.54**	**kN**
Moment	**-32.54**	**kNm**
Interaction	**0.63**	

Ss (kPa)	14.3	Adopted from Resort Muni
Sr (kPa)	0.99	
Is	1.0	
Cb	0.8	
Cw	0.5	
Cs	0.44	
Ca	1	
S (kPa)	3.5068	

Distance Along Axis (m)	Centerline (m) X	Y	Phi (deg)	Hor. (kN)	Vert. (kN)	N (kN)	V (kN)	M (kN m)	Roof Angle	Cs	Snow Load (kPa)	Snow Load (kN)	Wind Load (kN)	Interaction	Max
0.000	0	0	0.0	-14.23	-15.5	-15.54	14.23	0.00	90.0	0.0	0.00	0.00	0.0	0.00	0.63
0.061	0	0.061	0.0	-14.06	-15.5	-15.47	14.06	-0.87	90.0	0.0	0.00	0.00	0.2	0.02	
0.123	0	0.123	0.0	-13.89	-15.4	-15.40	13.89	-1.73	90.0	0.0	0.00	0.00	0.3	0.03	
0.184	0	0.184	0.0	-13.73	-15.3	-15.33	13.73	-2.57	90.0	0.0	0.00	0.00	0.5	0.05	
0.244	0	0.244	0.0	-13.56	-10.6	-10.57	13.56	-3.39	90.0	0.0	0.00	0.00	0.7	0.07	
0.246	0	0.246	0.0	-13.56	-10.5	-10.50	13.56	-3.41	90.0	0.0	0.00	0.00	0.7	0.07	
0.307	0	0.307	0.0	-13.39	-10.4	-10.43	13.39	-4.24	90.0	0.0	0.00	0.00	0.8	0.08	
0.368	0	0.368	0.0	-13.22	-10.4	-10.36	13.22	-5.05	90.0	0.0	0.00	0.00	1.0	0.10	
0.430	0	0.430	0.0	-13.05	-10.3	-10.29	13.05	-5.86	90.0	0.0	0.00	0.00	1.2	0.11	
0.491	0	0.491	0.0	-12.89	-10.2	-10.22	12.89	-6.66	90.0	0.0	0.00	0.00	1.3	0.13	
0.552	0	0.552	0.0	-12.72	-10.2	-10.15	12.72	-7.44	90.0	0.0	0.00	0.00	1.5	0.15	
0.614	0	0.614	0.0	-12.55	-10.1	-10.08	12.55	-8.22	90.0	0.0	0.00	0.00	1.7	0.16	
0.675	0	0.675	0.0	-12.38	-10.0	-10.01	12.38	-8.98	90.0	0.0	0.00	0.00	1.8	0.18	
0.737	0	0.737	0.0	-12.22	-9.9	-9.94	12.22	-9.74	90.0	0.0	0.00	0.00	2.0	0.19	
0.798	0	0.798	0.0	-12.05	-9.9	-9.87	12.05	-10.48	90.0	0.0	0.00	0.00	2.2	0.20	
0.859	0	0.859	0.0	-11.88	-9.8	-9.80	11.88	-11.22	90.0	0.0	0.00	0.00	2.3	0.22	
0.921	0	0.921	0.0	-11.71	-9.7	-9.73	11.71	-11.94	90.0	0.0	0.00	0.00	2.5	0.23	
0.982	0	0.982	0.0	-11.54	-9.7	-9.66	11.54	-12.66	90.0	0.0	0.00	0.00	2.7	0.25	
1.043	0	1.043	0.0	-11.38	-9.6	-9.59	11.38	-13.36	90.0	0.0	0.00	0.00	2.9	0.26	
1.105	0	1.105	0.0	-11.21	-9.5	-9.52	11.21	-14.05	90.0	0.0	0.00	0.00	3.0	0.27	
1.166	0	1.166	0.0	-11.04	-9.4	-9.45	11.04	-14.74	90.0	0.0	0.00	0.00	3.2	0.29	
1.228	0	1.228	0.0	-10.87	-9.4	-9.38	10.87	-15.41	90.0	0.0	0.00	0.00	3.4	0.30	
1.289	0	1.289	0.0	-10.71	-9.3	-9.31	10.71	-16.07	90.0	0.0	0.00	0.00	3.5	0.31	
1.350	0	1.350	0.0	-10.54	-9.2	-9.24	10.54	-16.72	90.0	0.0	0.00	0.00	3.7	0.33	
1.412	0	1.412	0.0	-10.37	-9.2	-9.17	10.37	-17.36	90.0	0.0	0.00	0.00	3.9	0.34	
1.473	0	1.473	0.0	-10.20	-9.1	-9.10	10.20	-18.00	90.0	0.0	0.00	0.00	4.0	0.35	
1.535	0	1.535	0.0	-10.04	-9.0	-9.03	10.04	-18.62	90.0	0.0	0.00	0.00	4.2	0.36	
1.596	0	1.596	0.0	-9.87	-9.0	-8.96	9.87	-19.23	90.0	0.0	0.00	0.00	4.4	0.37	
1.657	0	1.657	0.0	-9.70	-8.9	-8.89	9.70	-19.83	90.0	0.0	0.00	0.00	4.5	0.39	
1.719	0	1.719	0.0	-9.53	-8.8	-8.82	9.53	-20.42	90.0	0.0	0.00	0.00	4.7	0.40	
1.780	0	1.780	0.0	-9.36	-8.7	-8.75	9.36	-21.00	90.0	0.0	0.00	0.00	4.9	0.41	
1.841	0	1.841	0.0	-9.20	-8.7	-8.68	9.20	-21.57	90.0	0.0	0.00	0.00	5.0	0.42	
1.903	0	1.903	0.0	-9.03	-8.6	-8.61	9.03	-22.13	90.0	0.0	0.00	0.00	5.2	0.43	
1.964	0	1.964	0.0	-8.86	-8.5	-8.54	8.86	-22.68	90.0	0.0	0.00	0.00	5.4	0.44	
2.026	0	2.026	0.0	-8.69	-8.5	-8.47	8.69	-23.21	90.0	0.0	0.00	0.00	5.5	0.45	
2.087	0	2.087	0.0	-8.53	-8.4	-8.40	8.53	-23.74	90.0	0.0	0.00	0.00	5.7	0.46	
2.148	0	2.148	0.0	-8.36	-8.3	-8.33	8.36	-24.26	90.0	0.0	0.00	0.00	5.9	0.47	
2.210	0	2.210	0.0	-8.19	-8.3	-8.26	8.19	-24.77	90.0	0.0	0.00	0.00	6.0	0.48	
2.271	0	2.271	0.0	-8.02	-8.2	-8.19	8.02	-25.27	90.0	0.0	0.00	0.00	6.2	0.49	
2.332	0	2.332	0.0	-7.85	-8.1	-8.12	7.85	-25.75	90.0	0.0	0.00	0.00	6.4	0.50	
2.394	0	2.394	0.0	-7.69	-8.0	-8.05	7.69	-26.23	90.0	0.0	0.00	0.00	6.5	0.51	
2.455	0	2.455	0.0	-7.52	-8.0	-7.98	7.52	-26.70	90.0	0.0	0.00	0.00	6.7	0.52	
2.517	0	2.517	0.0	-7.35	-7.9	-7.91	7.35	-27.15	90.0	0.0	0.00	0.00	6.9	0.53	
2.578	0	2.578	0.0	-7.18	-7.8	-7.84	7.18	-27.60	90.0	0.0	0.00	0.00	7.0	0.54	
2.639	0	2.639	0.0	-7.02	-7.8	-7.77	7.02	-28.04	90.0	0.0	0.00	0.00	7.2	0.55	
2.701	0	2.701	0.0	-6.85	-7.7	-7.70	6.85	-28.46	90.0	0.0	0.00	0.00	7.4	0.55	
2.762	0	2.762	0.0	-6.68	-7.6	-7.63	6.68	-28.88	90.0	0.0	0.00	0.00	7.5	0.56	
2.803	0	2.803	0.0	-6.57	-2.9	-2.88	6.57	-29.15	90.0	0.0	0.00	0.00	7.7	0.57	
2.823	0	2.823	0.0	-6.51	-2.8	-2.81	6.51	-29.28	90.0	0.0	0.00	0.00	7.7	0.57	
2.885	0	2.885	0.0	-6.34	-2.7	-2.74	6.34	-29.68	90.0	0.0	0.00	0.00	7.9	0.58	
2.946	0	2.946	0.0	-6.18	-2.7	-2.67	6.18	-30.06	90.0	0.0	0.00	0.00	8.1	0.58	
3.008	0	3.008	0.0	-6.01	-2.6	-2.60	6.01	-30.43	90.0	0.0	0.00	0.00	8.2	0.59	
3.069	0	3.069	0.0	-5.84	-2.5	-2.53	5.84	-30.80	90.0	0.0	0.00	0.00	8.4	0.60	
3.381	0.019	3.381	7.0	-4.99	-2.2	-2.77	4.69	-32.15	83.0	0.0	0.00	0.00	9.2	0.62	
3.511	0.038	3.509	9.9	-4.64	-2.0	-2.80	4.22	-32.43	80.1	0.0	0.00	0.00	9.6	0.63	
3.611	0.057	3.607	12.2	-4.37	-1.9	-2.79	3.87	-32.53	77.8	0.0	0.00	0.00	9.9	0.63	
3.695	0.077	3.689	14.1	-4.15	-1.8	-2.77	3.58	-32.54	75.9	0.0	0.00	0.00	10.1	0.63	
3.769	0.096	3.760	15.8	-3.95	-1.7	-2.74	3.33	-32.48	74.2	0.0	0.00	0.00	10.3	0.63	
3.836	0.115	3.825	17.3	-3.78	-1.7	-2.70	3.11	-32.39	72.7	0.0	0.00	0.00	10.5	0.63	
3.898	0.134	3.884	18.7	-3.61	-1.6	-2.66	2.92	-32.26	71.3	0.0	0.00	0.00	10.6	0.63	
3.956	0.153	3.938	20.0	-3.46	-1.5	-2.61	2.74	-32.11	70.0	0.0	0.00	0.00	10.8	0.62	
4.011	0.172	3.989	21.2	-3.33	-1.5	-2.56	2.57	-31.93	68.8	0.030	0.00	0.00	10.9	0.62	
4.062	0.191	4.037	22.4	-3.19	-1.4	-2.51	2.42	-31.74	67.6	0.059	0.00	0.00	11.0	0.62	
4.111	0.210	4.083	23.5	-3.07	-1.3	-2.45	2.28	-31.53	66.5	0.086	0.00	0.00	11.2	0.61	
4.158	0.230	4.126	24.5	-2.95	-1.3	-2.40	2.15	-31.31	65.5	0.113	0.00	0.00	11.3	0.61	
4.204	0.249	4.166	25.5	-2.84	-1.2	-2.34	2.03	-31.08	64.5	0.138	0.00	0.00	11.4	0.60	
4.247	0.268	4.206	26.5	-2.73	-1.2	-2.28	1.92	-30.84	63.5	0.163	0.00	0.00	11.5	0.60	
4.289	0.287	4.243	27.5	-2.63	-1.1	-2.22	1.81	-30.59	62.5	0.187	0.00	0.00	11.6	0.59	
4.330	0.306	4.279	28.4	-2.53	-1.1	-2.17	1.71	-30.33	61.6	0.210	0.00	0.00	11.7	0.59	
4.370	0.325	4.314	29.3	-2.44	-1.0	-2.11	1.61	-30.06	60.7	0.232	0.00	0.00	11.8	0.58	
4.409	0.344	4.348	30.1	-2.35	-1.0	-2.05	1.53	-29.79	59.9	0.254	0.00	0.00	11.9	0.58	
4.446	0.363	4.380	31.0	-2.26	-1.0	-1.99	1.44	-29.51	59.0	0.275	0.00	0.00	12.0	0.57	
4.483	0.383	4.411	31.8	-2.17	-0.9	-1.93	1.36	-29.22	58.2	0.295	0.00	0.00	12.1	0.57	
4.519	0.402	4.442	32.6	-2.09	-0.9	-1.86	1.29	-28.93	57.4	0.316	0.00	0.00	12.1	0.56	
4.554	0.421	4.471	33.4	-2.01	-0.8	-1.80	1.22	-28.64	56.6	0.335	0.00	0.00	12.2	0.56	
4.588	0.440	4.500	34.2	-1.93	-0.8	-1.74	1.15	-28.33	55.8	0.355	0.00	0.00	12.3	0.55	
4.622	0.459	4.527	34.9	-1.85	-0.8	-1.68	1.09	-28.03	55.1	0.374	0.00	0.00	12.4	0.54	

Distance Along Axis (m)	Centerline (m) X	Y	Phi (deg)	Hor. (kN)	Vert. (kN)	N (kN)	V (kN)	M (kN m)	Roof Angle	Cs	Snow Load (kPa)	Snow Load (kN)	Wind Load (kN)	Interaction	Max
4.655	0.478	4.554	35.7	-1.78	-0.7	-1.62	1.03	-27.72	54.3	0.392	0.00	0.00	12.4	0.54	
4.688	0.497	4.581	36.4	-1.71	-0.7	-1.57	0.97	-27.41	53.6	0.411	0.00	0.00	12.5	0.53	
4.719	0.517	4.606	37.1	-1.64	-0.6	-1.51	0.92	-27.09	52.9	0.429	0.00	0.00	12.6	0.53	
4.751	0.536	4.631	37.9	-1.57	-0.6	-1.45	0.87	-26.77	52.1	0.446	0.00	0.00	12.7	0.52	
4.782	0.555	4.656	38.5	-1.50	-0.6	-1.39	0.82	-26.45	51.5	0.464	0.00	0.00	12.7	0.51	
4.812	0.574	4.679	39.2	-1.44	-0.5	-1.33	0.77	-26.12	50.8	0.481	0.00	0.00	12.8	0.51	
4.842	0.593	4.702	39.9	-1.38	-0.5	-1.27	0.73	-25.79	50.1	0.498	0.00	0.00	12.9	0.50	
4.872	0.612	4.725	40.6	-1.32	-0.5	-1.21	0.69	-25.46	49.4	0.514	0.00	0.00	12.9	0.49	
4.901	0.631	4.747	41.2	-1.25	-0.4	-1.16	0.65	-25.13	48.8	0.531	0.00	0.00	13.0	0.49	
4.930	0.650	4.769	41.9	-1.20	-0.4	-1.10	0.62	-24.79	48.1	0.547	0.00	0.00	13.0	0.48	
4.959	0.670	4.790	42.5	-1.14	-0.4	-1.04	0.59	-24.45	47.5	0.563	0.00	0.00	13.1	0.47	
4.987	0.689	4.810	43.2	-1.08	-0.3	-0.99	0.56	-24.11	46.8	0.579	0.00	0.00	13.1	0.47	
5.014	0.708	4.831	43.8	-1.03	-0.3	-0.93	0.53	-23.77	46.2	0.595	0.00	0.00	13.2	0.46	
5.042	0.727	4.850	44.4	-0.97	-0.3	-0.88	0.50	-23.42	45.6	0.610	0.00	0.00	13.3	0.45	
5.069	0.746	4.870	45.0	-0.92	-0.2	-0.83	0.47	-23.08	45.0	0.625	0.00	0.00	13.3	0.45	
5.096	0.765	4.889	45.6	-0.87	-0.2	-0.77	0.45	-22.73	44.4	0.640	0.00	0.00	13.4	0.44	
5.123	0.784	4.907	46.2	-0.82	-0.2	-0.72	0.43	-22.38	43.8	0.655	0.00	0.00	13.4	0.43	
5.149	0.803	4.925	46.8	-0.77	-0.2	-0.67	0.41	-22.02	43.2	0.670	0.00	0.00	13.5	0.43	
5.175	0.823	4.943	47.4	-0.72	-0.1	-0.61	0.39	-21.67	42.6	0.685	0.00	0.00	13.5	0.42	
5.201	0.842	4.960	48.0	-0.67	-0.1	-0.56	0.38	-21.31	42.0	0.699	0.00	0.00	13.6	0.41	
5.227	0.861	4.978	48.6	-0.62	-0.1	-0.51	0.36	-20.96	41.4	0.714	0.00	0.00	13.6	0.41	
5.252	0.880	4.994	49.1	-0.58	0.0	-0.46	0.35	-20.60	40.9	0.728	0.00	0.00	13.6	0.40	
5.277	0.899	5.011	49.7	-0.53	0.0	-0.41	0.34	-20.24	40.3	0.742	0.00	0.00	13.7	0.39	
5.302	0.918	5.027	50.3	-0.49	0.0	-0.37	0.33	-19.88	39.7	0.756	0.00	0.00	13.7	0.39	
5.327	0.937	5.042	50.8	-0.45	0.0	-0.32	0.32	-19.52	39.2	0.770	0.00	0.00	13.8	0.38	
5.352	0.956	5.058	51.4	-0.41	0.1	-0.27	0.31	-19.15	38.6	0.784	0.00	0.00	13.8	0.37	
5.376	0.976	5.073	51.9	-0.36	0.1	-0.22	0.31	-18.79	38.1	0.798	0.00	0.00	13.9	0.36	
5.400	0.995	5.088	52.5	-0.32	0.1	-0.18	0.30	-18.42	37.5	0.812	0.00	0.00	13.9	0.36	
5.424	1.014	5.102	53.0	-0.28	0.2	-0.13	0.30	-18.05	37.0	0.825	0.00	0.00	13.9	0.35	
5.448	1.033	5.117	53.5	-0.24	0.2	-0.09	0.29	-17.69	36.5	0.839	0.00	0.00	14.0	0.34	
5.472	1.052	5.131	54.1	-0.21	0.2	-0.04	0.29	-17.32	35.9	0.852	0.00	0.00	14.0	0.34	
5.495	1.071	5.144	54.6	-0.17	0.2	0.00	0.29	-16.95	35.4	0.865	0.00	0.00	14.1	0.33	
5.519	1.090	5.158	55.1	-0.13	0.3	0.04	0.29	-16.57	34.9	0.878	0.00	0.00	14.1	0.32	
5.542	1.110	5.171	55.7	-0.10	0.3	0.09	0.30	-16.20	34.3	0.891	0.00	0.00	14.1	0.31	
5.565	1.129	5.184	56.2	-0.06	0.3	0.13	0.30	-15.83	33.8	0.904	0.00	0.00	14.2	0.31	
5.588	1.148	5.197	56.7	-0.03	0.3	0.17	0.30	-15.46	33.3	0.917	0.00	0.00	14.2	0.30	
5.611	1.167	5.209	57.2	0.01	0.4	0.21	0.31	-15.08	32.8	0.930	0.00	0.00	14.2	0.29	
5.634	1.186	5.221	57.7	0.04	0.4	0.25	0.31	-14.71	32.3	0.943	0.00	0.00	14.3	0.29	
5.656	1.205	5.233	58.2	0.07	0.4	0.29	0.32	-14.33	31.8	0.956	0.00	0.00	14.3	0.28	
5.679	1.224	5.245	58.7	0.11	0.4	0.32	0.33	-13.95	31.3	0.968	0.00	0.00	14.3	0.27	
5.701	1.243	5.257	59.2	0.14	0.5	0.36	0.34	-13.57	30.8	0.981	0.00	0.00	14.4	0.26	
5.723	1.263	5.268	59.7	0.17	0.5	0.40	0.35	-13.19	30.3	0.993	0.00	0.00	14.4	0.26	
5.737	1.275	5.275	60.1	0.19	0.5	0.42	0.35	-12.95	29.9	1.001	0.00	0.00	14.4	0.25	
5.745	1.282	5.279	60.2	0.20	0.5	0.43	0.36	-12.82	29.8	1	0.00	0.00	14.4	0.25	
5.767	1.301	5.290	60.7	0.23	0.6	0.47	0.37	-12.44	29.3	1	0.00	0.00	14.5	0.24	
5.789	1.320	5.300	61.2	0.26	0.6	0.50	0.38	-12.05	28.8	1	0.00	0.00	14.5	0.23	
5.811	1.339	5.311	61.7	0.29	0.6	0.54	0.39	-11.67	28.3	1	0.00	0.00	14.5	0.23	
5.833	1.358	5.321	62.2	0.31	0.6	0.57	0.41	-11.29	27.8	1	0.00	0.00	14.5	0.22	
5.854	1.377	5.331	62.7	0.34	0.6	0.60	0.42	-10.91	27.3	1	0.00	0.00	14.6	0.21	
5.876	1.396	5.341	63.2	0.37	0.7	0.63	0.44	-10.53	26.8	1	0.00	0.00	14.6	0.20	
5.897	1.416	5.350	63.6	0.39	0.7	0.66	0.45	-10.14	26.4	1	0.00	0.00	14.6	0.20	
5.918	1.435	5.360	64.1	0.42	0.7	0.69	0.47	-9.76	25.9	1	0.00	0.00	14.6	0.19	
5.940	1.454	5.369	64.6	0.44	0.7	0.72	0.48	-9.37	25.4	1	0.00	0.00	14.7	0.18	
5.961	1.473	5.378	65.1	0.47	0.8	0.75	0.50	-8.99	24.9	1	0.00	0.00	14.7	0.17	
5.982	1.492	5.387	65.5	0.49	0.8	0.78	0.52	-8.60	24.5	1	0.00	0.00	14.7	0.17	
6.003	1.511	5.395	66.0	0.52	0.8	0.81	0.54	-8.21	24.0	1	0.00	0.00	14.7	0.16	
6.024	1.530	5.404	66.5	0.54	0.8	0.83	0.56	-7.83	23.5	1	0.00	0.00	14.8	0.15	
6.044	1.550	5.412	67.0	0.56	0.9	0.86	0.58	-7.44	23.0	1	0.00	0.00	14.8	0.14	
6.065	1.569	5.420	67.4	0.58	0.9	0.88	0.60	-7.05	22.6	1	0.00	0.00	14.8	0.14	
6.086	1.588	5.428	67.9	0.61	0.9	0.91	0.62	-6.66	22.1	1	0.00	0.00	14.8	0.13	
6.106	1.607	5.435	68.4	0.63	0.9	0.93	0.64	-6.27	21.6	1	0.00	0.00	14.9	0.12	
6.127	1.626	5.443	68.8	0.65	1.0	0.95	0.66	-5.89	21.2	1	0.00	0.00	14.9	0.11	
6.147	1.645	5.450	69.3	0.67	1.0	0.97	0.69	-5.50	20.7	1	0.00	0.00	14.9	0.11	
6.168	1.664	5.457	69.7	0.69	1.0	0.99	0.71	-5.11	20.3	1	0.00	0.00	14.9	0.10	
6.188	1.683	5.464	70.2	0.71	1.0	1.01	0.73	-4.71	19.8	1	0.00	0.00	14.9	0.09	
6.209	1.703	5.471	70.7	0.72	1.1	1.03	0.76	-4.32	19.3	1	0.00	0.00	15.0	0.08	
6.229	1.722	5.478	71.1	0.74	1.1	1.05	0.78	-3.93	18.9	1	0.00	0.00	15.0	0.08	
6.249	1.741	5.484	71.6	0.76	1.1	1.07	0.80	-3.54	18.4	1	0.00	0.00	15.0	0.07	
6.269	1.760	5.491	72.0	0.78	1.1	1.09	0.83	-3.15	18.0	1	0.00	0.00	15.0	0.06	
6.289	1.779	5.497	72.5	0.79	1.1	1.10	0.85	-2.76	17.5	1	0.00	0.00	15.0	0.05	
6.309	1.798	5.503	72.9	0.81	1.2	1.12	0.88	-2.36	17.1	1	0.00	0.00	15.0	0.05	
6.329	1.817	5.509	73.4	0.83	1.2	1.13	0.91	-1.97	16.6	1	0.00	0.00	15.1	0.04	
6.349	1.836	5.514	73.8	0.84	1.2	1.15	0.93	-1.58	16.2	1	0.00	0.00	15.1	0.03	
6.369	1.856	5.520	74.3	0.86	1.2	1.16	0.96	-1.18	15.7	1	0.00	0.00	15.1	0.02	
6.389	1.875	5.525	74.7	0.87	1.3	1.17	0.99	-0.79	15.3	1	0.00	0.00	15.1	0.02	
6.409	1.894	5.530	75.2	0.89	1.3	1.18	1.01	-0.39	14.8	1	0.00	0.00	15.1	0.01	
6.429	1.913	5.535	75.6	0.90	1.3	1.20	1.04	0.00	14.4	1	0.00	0.00	15.1	0.00	