Wine History Project Pavilion

SLO County, CA

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Advised by,

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Senior Project

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Table of Contents

Introduction

The Wine History Pavilion Project is a continuing endeavor of Cal Poly students working on an exhibitive, traveling structure for the San Luis Obispo community. The project started during the 2019 Fall Quarter in the interdisciplinary Integrated Project Delivery (IPD) Studio and has progressed to the detailed design stage for its eventual fabrication and installation. This report discusses the detailed design stage that 4th year Architectural Engineering student, Douglas McArthur, worked on.

Project Partners

Wine History Project of San Luis Obispo County

The Wine History Project is a local organization who were the main sponsors of the project. Their goal is to document and preserve the unique wine and food history of San Luis Obispo County. The group, made up of historians and museum professionals, study the land, microclimates, grape varietals, growers and winemakers who have shaped the local wine history of SLO county.

Taylor and Syfan Consulting Engineers

Taylor and Syfan is a local structural engineering firm in San Luis Obispo and were the professional advisors of the project. Joel Neal and Michelle McCovey-Good had previous experience with temporarily installed structures and offered their structural engineering advice and judgment to help solve problems, develop the construction process, and review structural drawings and assembly plans.

Cal Poly Construction Management Department

The detailed design phase of the project was in collaboration with Kyle Bresnahan, a 3rd year Construction Management student. Greg Starzyk, a professor in the Construction Management department, was the project advisor who has been involved with the project from the start and

continues to lead it to fruition. He also is working with the college and industry members to raise money for the construction costs of the pavilion.

Background Information

As mentioned previously, the project originated in the Fall of 2019 as the focus of an interdisciplinary design studio in Cal Poly's College of Architecture and Environmental Design (CAED). The Wine History Project of SLO County had approached the CAED and wanted to work in conjunction to develop a pavilion to exhibit the research and collections of the organization.

The IPD studio made up of multiple teams of students including Architecture, Architectural Engineering, and Construction Management majors were tasked with designing and developing this pavilion. After ten weeks all the teams submitted design proposals including drawings, mockups, and models to present a panel of judges. A winning design was chosen which would be further developed to be fabricated and installed.

The Wine History Pavilion was intended for the display of wine-related historical artifacts by the Wine History Project. It needed to accommodate various exhibits of differing size and organization. The pavilion also needed to provide protection from the elements to both the visitors and exhibits housed within. A major consideration for the pavilion was the need to easily disassemble, transport, and reassemble it for relocation to other sites. For this reason, the design emphasizes ease of assembly, lightweight construction, and the minimizing of long-term impacts to the site.

Project Parameters

The project parameters consisted of an approximately 400 square feet pavilion that allowed room for exhibits and visitors to circulate in. It could be made of any materials and need only to be easily transportable. The pavilion was originally planned to be first installed at the local Saucelito Canyon tasting room and then relocated to other sites.

Winning Design

Out of the eight proposals, the design named “FLOW” was chosen to move forward and be constructed. The team consisted of two Architecture majors, Isha Sharma and Khanh Nguyen, two Construction Management majors, Anthony Cumpian and Antonio Rosales, and one Architectural Engineering major, Isaac Cameron.

Figure 1. FLOW Rendering by Isha Sharma and Khanh Nguyen

They developed a twenty-foot square pavilion made of all aluminum structural members. The roof was hyperbolic paraboloid shaped and supported by short truss-columns in opposite corners and slender vertical columns in the other corners. Clear, polycarbonate sheets covered the roof and protected the shelves and hanging displays within the structure.

Figure 2. FLOW Rendering by Isha Sharma and Khanh Nguyen

The proposal was chosen for its openness of design and adaptability. They planned that the roof could be split into multiple pieces, put together on the ground, lifted to its correct height with jacks and then install the columns to support it.

The final deliverables consisted of renderings, diagrams, a rhino model, and an initial set of structural calculations. These calculations covered the design of the aluminum structural members, a few connections, and an initial foundation design. For the full set of previous calculations see Isaac Cameron's project submission in Digital Commons with the URL: https://digitalcommons.calpoly.edu/arcesp/106 .

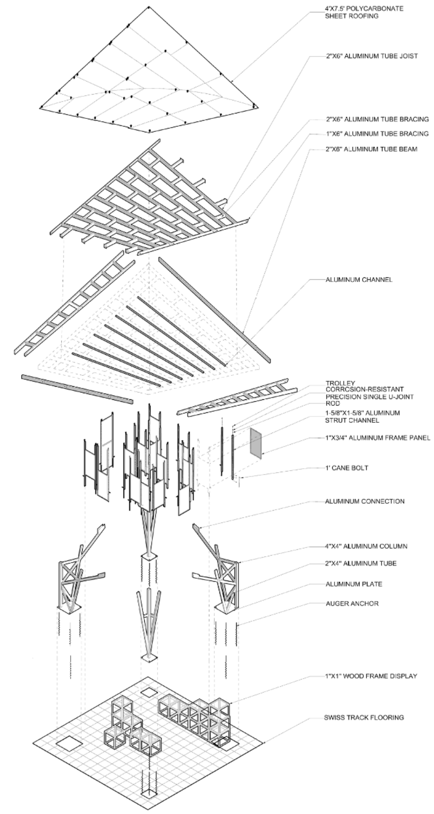


Figure 3. Blown Up Axonometric by Isha Sharma and Khanh Nguyen

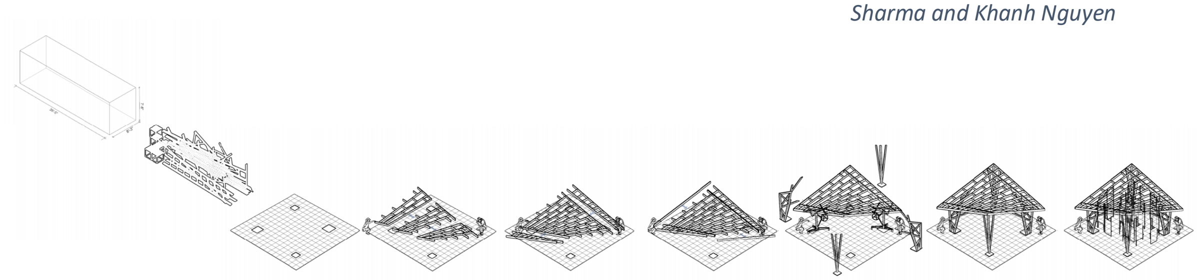


Figure 4. Proposed Construction Sequence by Anthony Cumpian and Antonio Rosales

Project Goals and Design

After the initial design was chosen, the next steps to move forward were to work on the detailed design of the Pavilion. More investigation needed to be done in order for the structure to actually be fabricated and constructed. A successful full-scale mockup had been made which

became the basis for the structural connections and other details. Much time was also spent understanding the original design and the intent of the students who developed it.

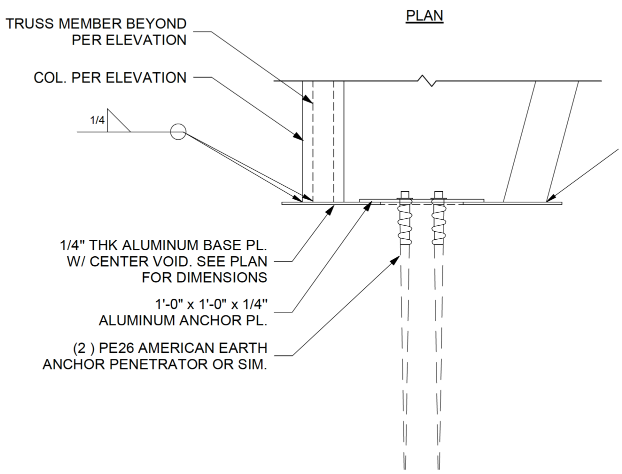


Figure 5. Truss Column Foundation Detail

From the original structural design, a couple aspects were pointed out that needed to be looked into including the foundations, assembly and disassembly plans and the connections that were needed for the assembly and disassembly. The foundations were previously overdesigned with a combined penetrator and tensile anchor system that were not thought to be effective in construction. The new design used the penetrators as well but were placed in conjunction with overlapping anchor and base plates to allow for much greater construction tolerances. The tolerances were a big concern from a construction perspective and so this design hopefully relieved that issue. After a good review of the initial foundation design, it was also noticed that the wind loading was much too conservative as well. The wind loading was redone taking into account the more openness of the structure. After the SAP analysis model was adjusted, it resulted in reduced lateral and uplift loads on the foundations.

Another aspect which took up many discussions between the student designers was the assembly and disassembly process. This was the main point of investigation for Kyle, the CM student, but also required a lot of collaboration with Doug on the structural engineering side and Greg, the project advisor. Many assembly scenarios were reviewed including using wall jacks, shoring systems, collapsible mechanisms, and hydraulic jacks. The roof structure was divided into seven, prefabricated segments which would be connected on the ground to form the full roof structure. These components were designed to each be around two hundred pounds so they could be easily managed by a few people. This became the basis when figuring

out how many and what type of structural connections were needed. In places where two segments would share one, two-inch wide rectangular beams, the section was divided into two, one-inch wide rectangular sections. These sections would then be bolted together along their length to form the complete roof. This was also planned to better accommodate the fastening and sealing of the roof sheathing, however that architectural detail was not developed as the roofing material was not yet decided.

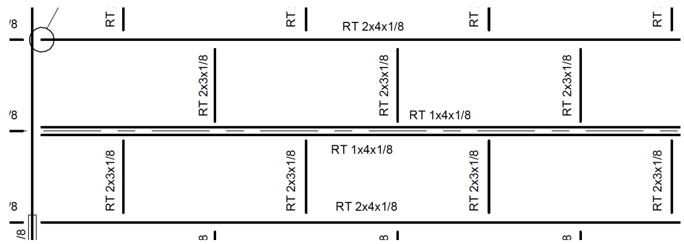


Figure 6. Framing Plan Projection

The final assembly process planned to use manual or hydraulic roof jacks on each side of the structure. The placement of each roof jack would be at the third point on each side, either on the high or low end to maximize the cantilever action. This would provide more stability during the roof lift and decrease the use of additional shoring and other equipment.

After a few weeks of working on the project, there were also a few other aspects that were found to be looked into. This included the temporary nature of the pavilion and the structural considerations required by the code. After much research, there was not found to be many regulations governing these temporary structures. It was determined that a lateral earthquake loading analysis was not needed. The engineers at Taylor and Syfan confirmed that stamped drawings submitted to the local jurisdiction were not needed. The project team however still wanted to comply with as many regulations as possible as a conventional structure would face. One part where this was addressed was the accessibility of the structure. The design was changed so the low corners were chamfered to further the setback and raise the corner elevation to not be as protruding.

One other large aspect that needed to be addressed was the lack of drawings for the structure. There only existed a few diagrammatic drawings and sketches to explain the construction of the pavilion. This became the main goal of this stage of the project, to develop a set of structural drawings and assembly instructions to accompany them. A foundation plan, framing plan,

elevations, and details were drafted in Revit to reflect the original design and the new changes. These drawings were important to convey the actual structure and type of members used and other design criteria. There were still many questions about the eventual fabrication and construction of the pavilion and so these drawings would act as a good information tool for the team working on the project in the future.

Challenges

This project was a very exciting opportunity to develop a student-designed structure and construct it for a real client. There were however many challenges that came along and most stemmed from the disconnect between the original group of designers and the current group working on the project. As mentioned before, the initial design was completed in a studio class and so after the class ended none of the students involved continued on the project. This was difficult as we only had some drawings, calculations, and a 3D model to go off of. Greg, the Project Advisor, was the only person who had been involved previously.

This disconnect resulted in a lot of effort trying to reconcile and understand the design. Many hours were spent between Kyle and I trying to settle on consistent angles, geometries, and other details not made clear in the initial design. We had to make these decisions ourselves while trying to stick with the original, winning proposal as much as possible. We also did not have any interaction with the project client, the Wine History Project, and so we had to act as architects for many decisions which was challenging but it was also a great learning opportunity.

Other challenges also came in the structural design during this phase. As mentioned previously there were questions of what was required for this temporary structure to be built to satisfy all rules and regulations. These were partially answered by the outside engineers, but many things still seemed to fall in a gray area. However, my faculty advisor, John Lawson, was a good help in determining what kind of questions needed to be asked and then figuring out a solution if I could not find an answer. The structural design of aluminum was also interesting and a bit of a

challenge as most students only have experience with steel design. While there are similarities between the two, aluminum still acts differently as a material especially when it comes to deflections. Luckily deflections did not become a governing issue as the structure does not have to carry large loads. I was able to use the original structural calculations completed by Isaac Cameron as a basis for any other details that needed to be designed and maintain a consistent design philosophy.

Project Future

The COVID-19 pandemic had a large impact of the future of the project and leaves many things in question. Mainly, funding is not yet secured for the project which will delay fabrication until the estimated costs are fully donated. The original goal was to have Cal Poly students fabricate and build the structure to be installed at Saucelito Canyon in June 2020. The project is currently on an indefinite hold until the safety of construction can be fully considered.

There are also other future aspects to consider that were not related to COVID-19. One, being the site considerations of the project. Many assumptions were made throughout the design of the pavilion as the site was subject to change. More aspects may need to be addressed before construction starts such an confirming the soil type, levelness of the site, and topography which may affect the wind loading. There were also many assumptions made in the development of the installation process. The actual requirements of construction need to be further explored to determine required amount of labor, tools and supplies, and the level of skill needed for each assembly and disassembly of the structure.

Project Impacts

As with all projects there are many impacts stemming from global, cultural, social, environmental, and economic issues.

Global Impact

This project was very focused on the local community; however, it reflects the global view of San Luis Obispo County. The pavilion provides another avenue for SLO county to showcase its extensive and successful wine industry to the whole world. Many people from all over the

country and abroad come to SLO county to experience the wine and viticulture found here. San Luis Obispo is in a great location that is easily accessible to people who travel to California through the two major hubs, Los Angeles and San Francisco. The pavilion will be a great tool to further educate people on the subject of winemaking. The project may also have a global impact depending on where materials are sourced from.

Cultural Impact

The pavilion will help to preserve the rich culture of agriculture and viticulture found on the central coast of California. People who visit the wineries for wine tasting and other activities will be able to learn more about the winemaking process and how it has developed over the years. Many of the artifacts that the Wine History Project owns will be showcased in the pavilion as a physical representation of the culture found in SLO county. This is important as the pavilion provides a physical space for these ideas and processes to be explored and understood by all people. The pavilion will also be accessible to all people, even those underage, which will allow for more people to become interested in viticulture and winemaking industries. It opens up the door for possible collaboration with Cal Poly's own wine and viticulture program to inspire the next generation of growers and winemakers.

Social Impact

As a gathering space, the pavilion will allow for much social interaction to take place. The pavilion could possibly be staffed by Wine History Project Representatives who could provide much more context for the artifacts and information in the exhibits. Tourists and others will be able to become more curious about winemaking and it could inform their experiences as they explore the other parts of SLO county. Since the pavilion is designed to be transportable, it could be placed at specific wineries to highlight their own work or boost the visits at others. The pavilion could help visitors discover more diverse wineries and showcase the variety that can be found. The pavilion could also boost the reputations of the Wine History Project and Cal Poly, especially the College of Architecture and Environmental Design.

Environmental Impact

Throughout the design one of the main goals was to reduce the impact on the site. Besides drilling penetrators into the ground, there will not be many other impacts to the site. The pavilion will be located at wineries that are already highly visited so there will not be

disturbance to other sites. While the pavilion will be visited by people already visiting the wineries, there will also be people who travel just to visit the pavilion. This could result in increased car use as people drive to see the exhibit and create more congestion. On the building side of things, there are not many impacts besides the raw materials used to construct the pavilion. Aluminum is a lightweight, strong, and highly recyclable material that will be durable for the projects lifetime and then able to be deconstructed and reused for new projects. The largest impact comes from the manufacturing of the aluminum members and depends whether it is sourced locally or not. The structure has no lighting, water, or other mechanical systems and will not have much environmental impact after its initial construction.

Economic Impact

There will be considerable financial costs to build and install the structure. These still need to be determined as the future of the project becomes more predictable. In addition, the costs of each installation need to be determined as well as the responsible party paying for each time the pavilion moves. The pavilion could provide an economic benefit to San Luis Obispo county by an increase in visitors to the winery where it is located. This could benefit the local wine industry but also the Wine History Project and Cal Poly as people learn about their collaboration on the project.

Conclusion

Overall, this project has greatly developed the originals goals set in the IPD studio in the Fall of 2019. The collaboration between the Wine History Project and the CAED on an actual structure to contribute to the winemaking culture of San Luis Obispo was of great importance. There were many news articles written and a lot of excitement created as this project started and progressed. The Wine History Pavilion has a lot of potential to be a great addition to San Luis Obispo county and I am happy to be a part of that progress. While there are many steps still necessary to build the pavilion, the work that has been done in the detailed design stage has definitely allowed this project to be further expanded upon.

Personal Reflection

I was really excited to join this project as I was looking for an opportunity to work with people outside of my major on a senior project that had a real impact. I learned a lot during the few months that I have been involved and I am happy with the progress that has been made. As mentioned previously, there were many challenges throughout the project, and some were made even more exacerbated by the impacts of COVID-19.

During this stage in the project, I got to work with Kyle Bresnahan, a construction management major. This was really helpful as he was focused on the constructability of the pavilion which greatly informed the structural design. This project was unique as the construction process was intricately connected to the design of the structure. Oftentimes the structural engineer leaves the actual means of methods of construction up to the contractor, however this project required collaboration of both parties. Kyle and I worked well together, and I enjoyed being able to explain the structure to him as well and why some decisions were made in that regard. On a scale of 0 to 5, I think our success of working on a team together was a 4.

Despite many challenges and communication issues, I am still hopeful for the future of the project. I think as it progresses other ARCE students will need to continue to be involved to make sure the installation process is effective and collaborate with construction management students building it. I look forward to the day when the pavilion is finally built and able to showcase the history of San Luis Obispo.

APPENDIX A – Structural Drawings

GENERAL CRITERIA

1. STRUCTURAL DRAWINGS APPLY TO A TEMPORARY STRUCTURE. LONG TERM INSTALLATION OF PROJECT REQUIRES FURTHER CONSIDERATION.

2. THE STRUCTURAL DRAWINGS SHOW THE STRUCTURAL CONSTRUCTION REQUIREMENTS FOR THE BUILDING.

3. TYPICAL DETAILS ARE INTENDED TO APPLY TO APPLICABLE SITUATIONS UNLESS NOTED OTHERWISE.

4. WHERE MEMBER LOCATIONS ARE NOT SPECIFCALLY DIMENSIONED MEMBERS ARE LOCATED EITHER ON COLUMN LINES OF EQUALLY SPACED BETWEEN COLUMN LINES OR BETWEEN MEMBERS OTHERWISE LOCATED

DESIGN CRITERIA

1. APPLICABLE CODE:

  a. 2018 INTERNATIONAL BUILDING CODE (IBC)

  b. ASCE 7-16

  c. ALUMINUM DESIGN MANUAL 2010

2. DESIGN LOADS:

  a. DEAD LOADS – ACTUAL IN PLACE WEIGHTS OF ALL AMTERIALS SHOWN ON THE CONTRACT DOCUMENTS

    i. HANGING DISPLAY LOADS MUST BE 25lbs OR LESS, NOT INCLUDING SUPPORTING CHANNELS.

  b. LIVE LOAD- UNIFORM AS FOLLOWS

    i. ROOF TYPICAL 10 PSF

  c. WIND LOAD- BASED ON ASCE 7-16 CHAPTER 26 WITH EXPOSURE C CONDITION AND BASIC WIND SPEED OF 95MPH

    i. STRUCTURE CANNOT BE MORE THAN 50% ENCLOSED ON ANY SIDE.

  d. EARTHQUAKE ANALYSIS NOT COMPLETED FOR TEMPORARY STRUCTURE

  e. FOUNDATION DESIGN: NO SOILS REPORT COMPLETED. SOIL PRESSURES PRESCRIBED BY MIN. VALUES FROM THE IBC.

    ALLOWABLE BEARING PRESSURES:
      DL + LL = 1000 PSF
      LATERAL = 100 PSF/FT

MATERIAL CRITERIA

1. ALUMINUM:

  a. STRUCTURAL TUBING AND PLATES

    i. ALUMINUM ALLOY 6061-T6: TYPICAL

F_{tu}= 42 ksi	F_{tuw}= 24 ksi
F_{ty}= 35 ksi	F_{tyw}= 15 ksi
F_{cy}= 35 ksi	F_{cyw}= 15 ksi
F_{su}= 27 ksi	F_{suw}= 15 ksi
E= 10,100 ksi	

  b. WELDS

    i. 5356 FILLER MATERIAL
      F_{tu}= 35 ksi
      F_{su}= 17 ksi

ABBREVIATIONS

A.B.	ANCHOR BOLT
ARCH	ARCHITECTURAL
BAR	FLAT BAR
BM	BEAM
BOT	BOTTOM
BTWN	BETWEEN
CLR	CLEAR
COL	COLUMN
CONC	CONCRETE
CONN	CONNECTION
CONT	CONTINUOUS
C.P.	COMPLETE PENETRATION
C.W.	CONCRETE WALL
d	BOLT DIAMETER
DBL	DOUBLE
DET	DETAIL
DIA	DIAMETER
DIM	DIMENSION
DO	DITTO
DWG	DRAWING
EA	EACH
E.F.	EACH FACE
E.J.	EXPANSION JOINT
ELEV	ELEVATION
EMBED	EMBEDMENT
EQ	EQUAL
E.W.	EACH WAY
EXT	EXTERIOR
FDTN	FOUNDATION
FIN FL	FINISH FLOOR
FIN GR	FINISH GRADE
F.O.S.	FACE OF STEEL OR STUDS
FLG	FLANGE
F.P.	FULL PENETRATION
F.S.	FAR SIDE
FTG	FOOTING
GA	GAUGE
GALV	GALVANIZED
HORIZ	HORIZONTAL
H.S.B.	HIGH STRENGTH BOLT
I.F.	INSIDE FACE
ID	INISDE DIAMETER
INT	INTERIOR
JT	JOINT
L.L.H.	LONG LEG HORIZONTAL
L.L.V.	LONG LEG VERTICAL
LSH	LONG SLOTTED HOLE
LT.WT.	LIGHT WEIGHT
MAX.	MAXIMUM
M.B.	MACHINE BOLT
MET	METAL
MFR.	MANUFACTURER
MIN	MINIMUM
MISC	MISCELLANEAOUS
NO.	NUMBER
NOM	NOMINAL
N.S.	NEAR SIDE
N.T.S.	NOT TO SCALE
O.C.	ON CENTER
O.D.	OUTSIDE DIAMETER
O.F.	OUTSIDE FACE
O.H.	OPP. HAND.
OPNG	OPENING
OPP	OPPOSITE
PL.	PLATE
P.P.	PARTIAL PENETRATION
PEN	PENETRATION
RAD	RADIUS
REQ'D, REQ	REQUIRED
REINF	REINFORCING STEEL
RT	RECTANGULAR TUBE
SCHED.	SCHEDULE
SECT	SECTION
SHT	SHEET
SIM	SIMILAR
SPECS	SPECIFICATIONS
SQ	SQUARE
STIFF	STIFFENER
STD	STANDARD
SYM.	SYMMETRIC
T&B	TOP & BOTTOM
THK	THICK
THRD	THREADED
THRU	THROUGH
TYP	TYPICAL
U.N.O.	UNLESS OTHERWISE NOTED
VERT	VERTICAL
V.I.F.	VERIFY IN FIELD
W/	WITH
WF	WIDE FLANGE
WP	WORK POINT

SHEET LIST

THE WINE HISTORY PROJECT

SEAL: (IF REQ'D)

PROJECT:

WINE HISTORY PAVILION

SITE:

SAN LUIS OBISPO COUNTY

REVISIONS		
No.	DESC	No.

DRAWN BY: DNM

CHECKED BY:

PLOT DATE:

SHEET NAME:

GENERAL NOTES

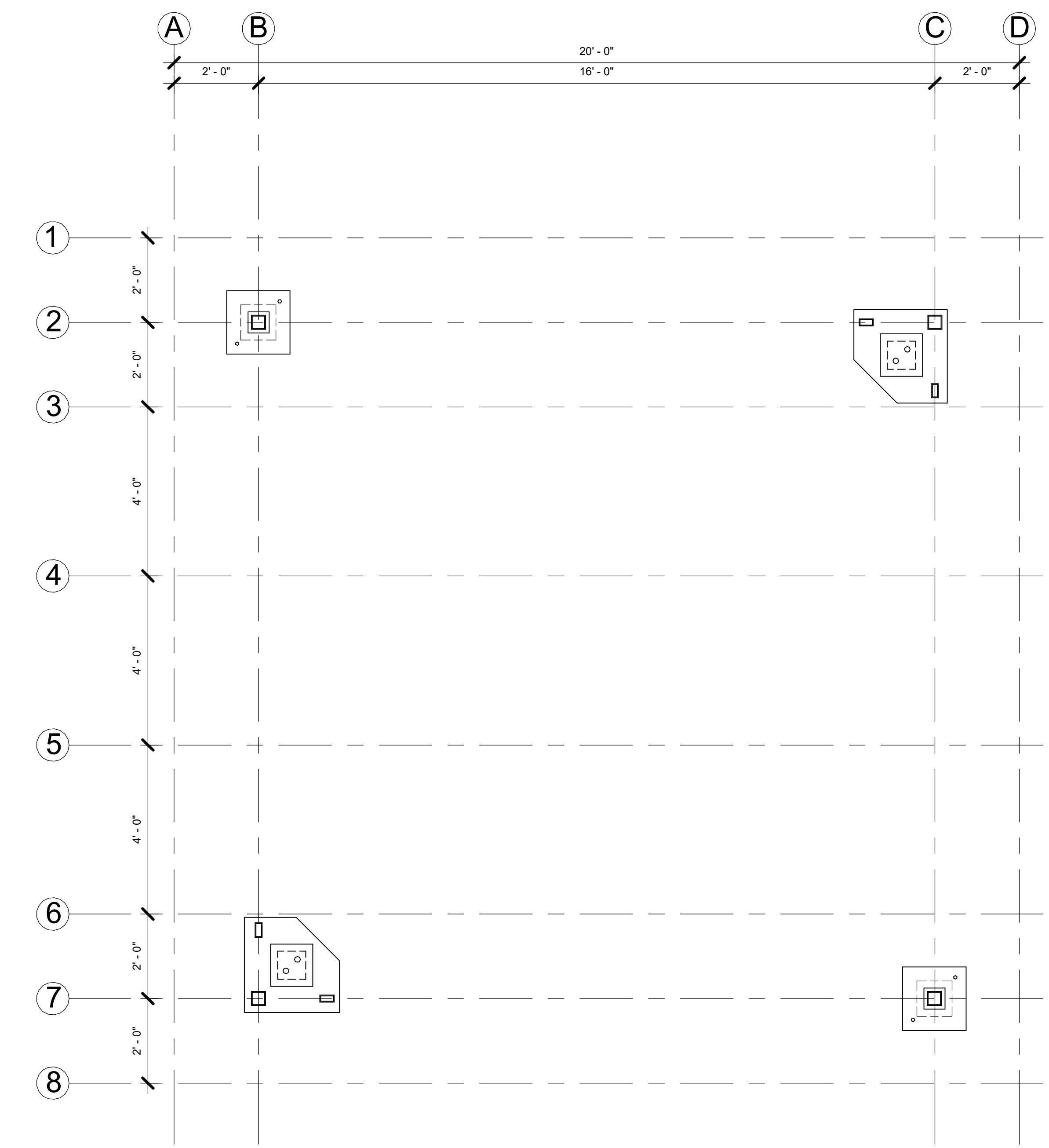
SCALE:

SHEET No.

S.0

NOTES:
1. SEE DETAIL S.3/7 FOR FOUNDATION AT GRIDLINES 2B AND 7C.

2. SEE DETAIL S.3/8 FOR FOUNDATION AT GRIDLINES 7B AND 2C.

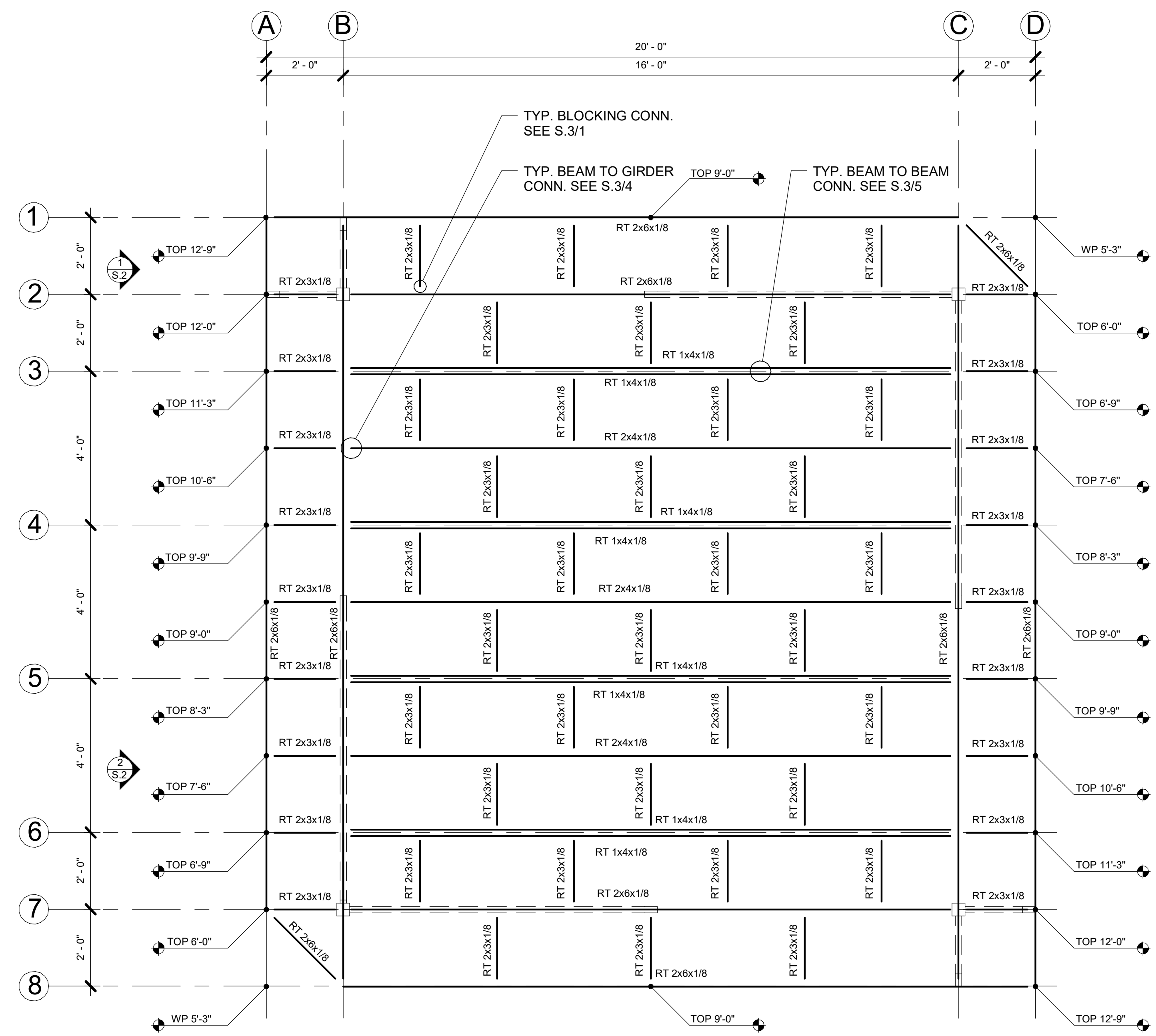


2 FOUNDATION PLAN
1/2" = 1'-0"

NOTES:
1. SPOT ELEVATIONS PROVIDED AT TOP OF EXTERIOR BEAMS.

2. DIMENSIONS PROVIDED ARE HORIZONTAL PROJECTIONS. THESE ARE NOT TO BE USED FOR ACTUAL LENGTHS OF MEMBERS.

3. INSTALLATION PER SEPARATE ASSEMBLY INSTRUCTIONS.



1 ROOF FRAMING PLAN PROJECTION
1/2" = 1'-0"

THE WINE HISTORY PROJECT

SEAL: (IF REQ'D)

PROJECT:

WINE HISTORY PAVILION

SITE:

SAN LUIS OBISPO COUNTY

REVISIONS		
No.	DESC	No.

DRAWN BY: DNM

CHECKED BY:

PLOT DATE:

SHEET NAME:

FOUNDATION AND FRAMING PLAN

SCALE:

1/2" = 1'-0"

SHEET No.

S.1

THE WINE HISTORY PROJECT

SEAL: (IF REQ'D)

PROJECT:
WINE HISTORY PAVILION

SITE:
SAN LUIS OBISPO COUNTY

REVISIONS

No.	DESC	No.

DRAWN BY: DNM

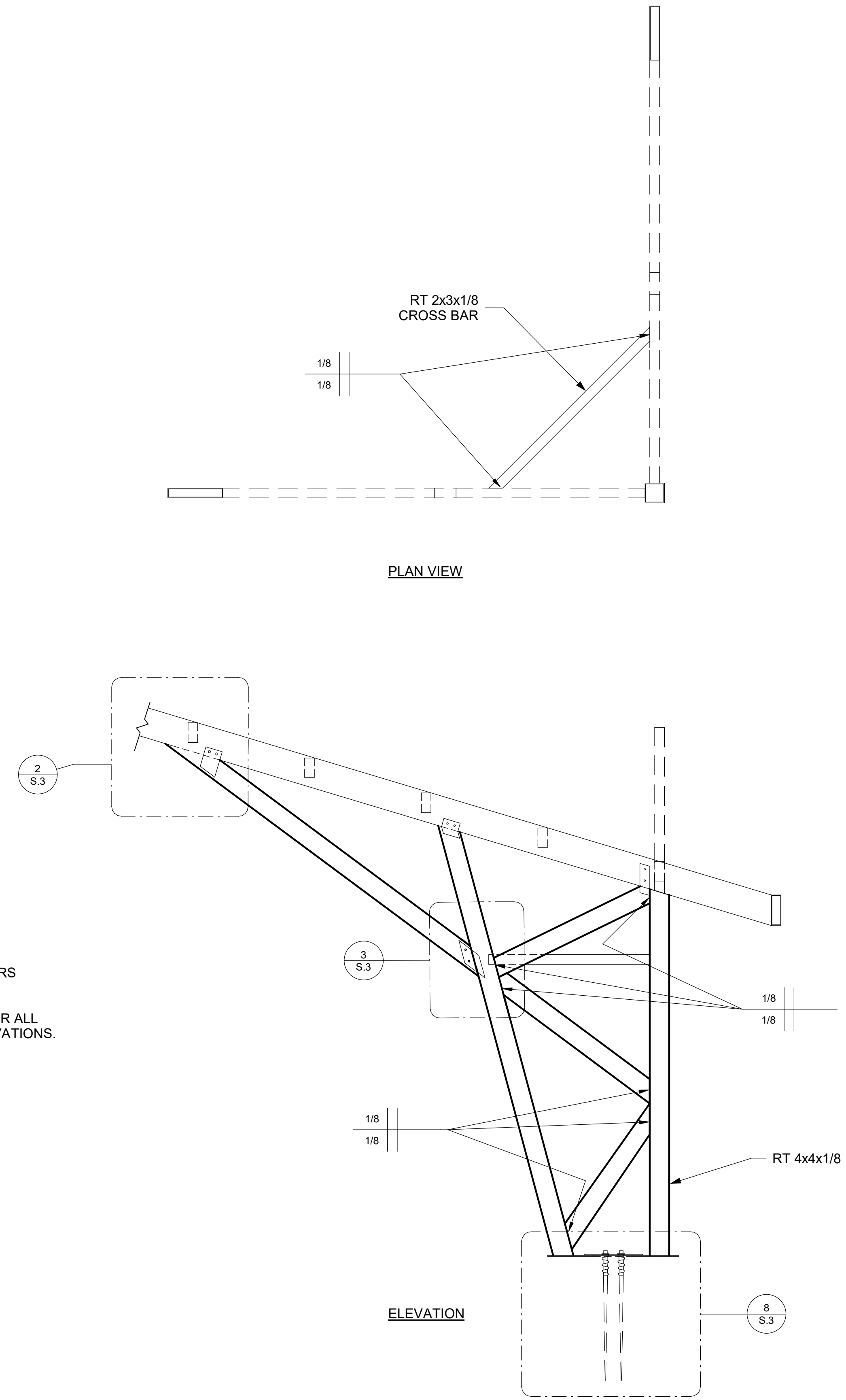
CHECKED BY:

PLOT DATE:

SHEET NAME:
ELEVATIONS

SCALE:
3/4" = 1'-0"

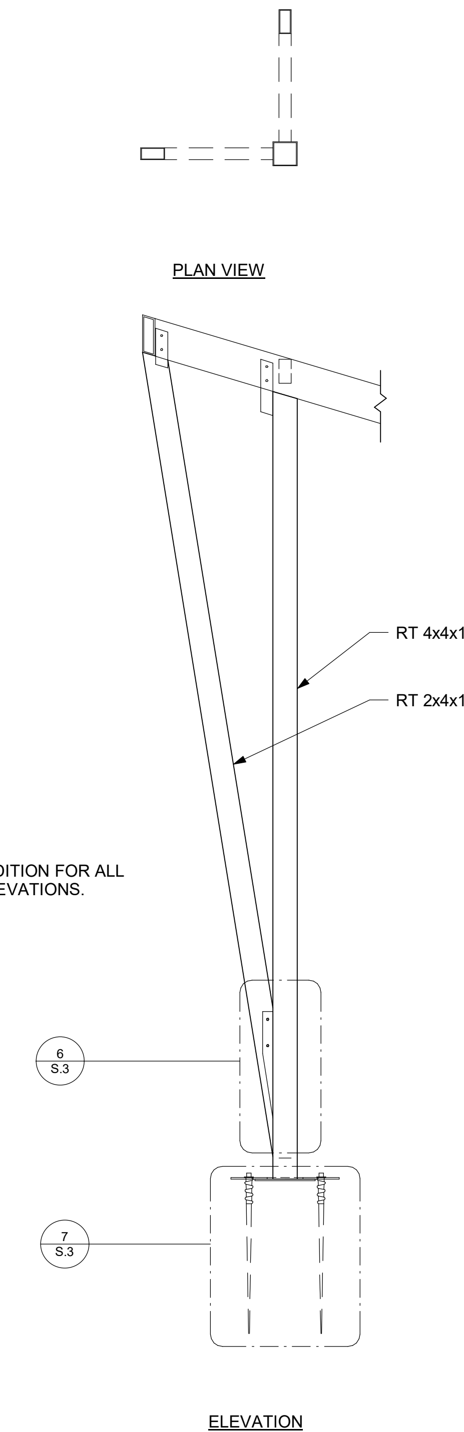
SHEET No.
S.2



NOTES:
1. ALL TRUSS MEMBERS 2x4x1/8 U.N.O

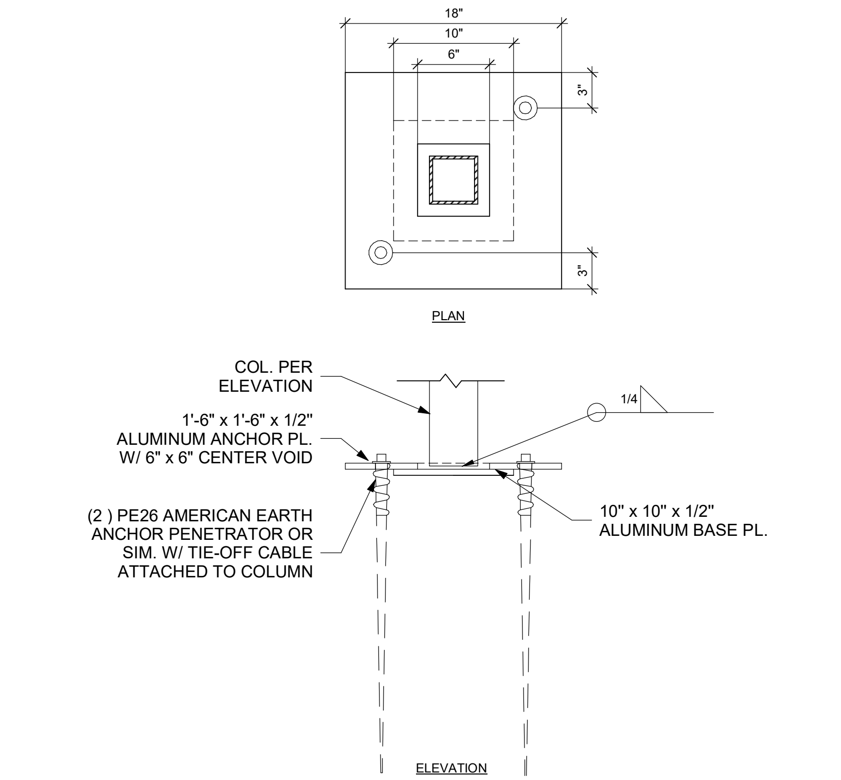
2. SIM. CONDITION FOR ALL TRUSS COLUMN ELEVATIONS.

2 GRID B COLUMN ELEVATION - TRUSS, SIM. AT OTHER LOCATIONS
3/4" = 1'-0"



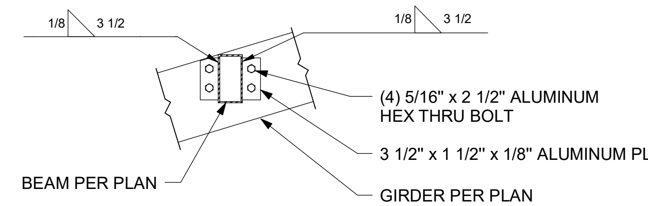
NOTES:
1. SIM. CONDITION FOR ALL COLUMN ELEVATIONS.

1 GRID B COLUMN ELEVATION - POLE
3/4" = 1'-0"



(7) COLUMN FOUNDATION
1 1/2" = 1'-0"

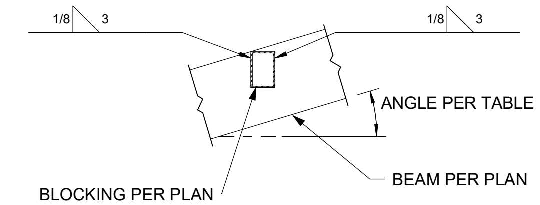
NOTES:
1. SIM. CONDITION WHEN BEAM MEMBER IS A BUILT UP SECTION



(4) BEAM TO GIRDER CONN. TYP.
1 1/2" = 1'-0"

NOTES:
1. BLOCKING TO REMAIN VERTICAL W/ RESPECT TO GROUND

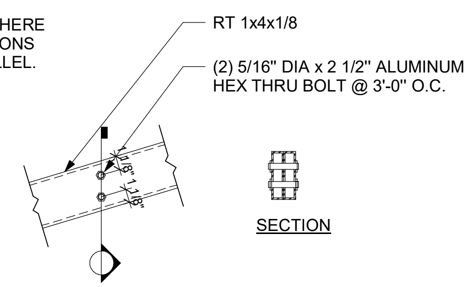
2. CUSTOM CUT REQ'D AT END END OF TUBE.



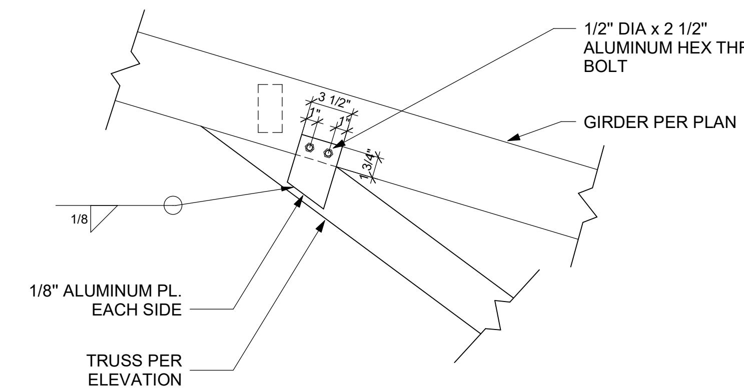
ANGLE	ALONG GRID
-20.875°	GRID 1
-16.7°	GRID 2
-12.525°	GRID 3
-8.35°	BTWN GRID 3 & 4
-4.175°	GRID 4
0°	BTWN GRID 4 & 5
4.175°	GRID 5
8.35°	BTWN GRID 5 & 6
12.525°	GRID 6
16.7°	GRID 7
20.875°	GRID 8

(1) BLOCKING CONN. TYP.
1 1/2" = 1'-0"

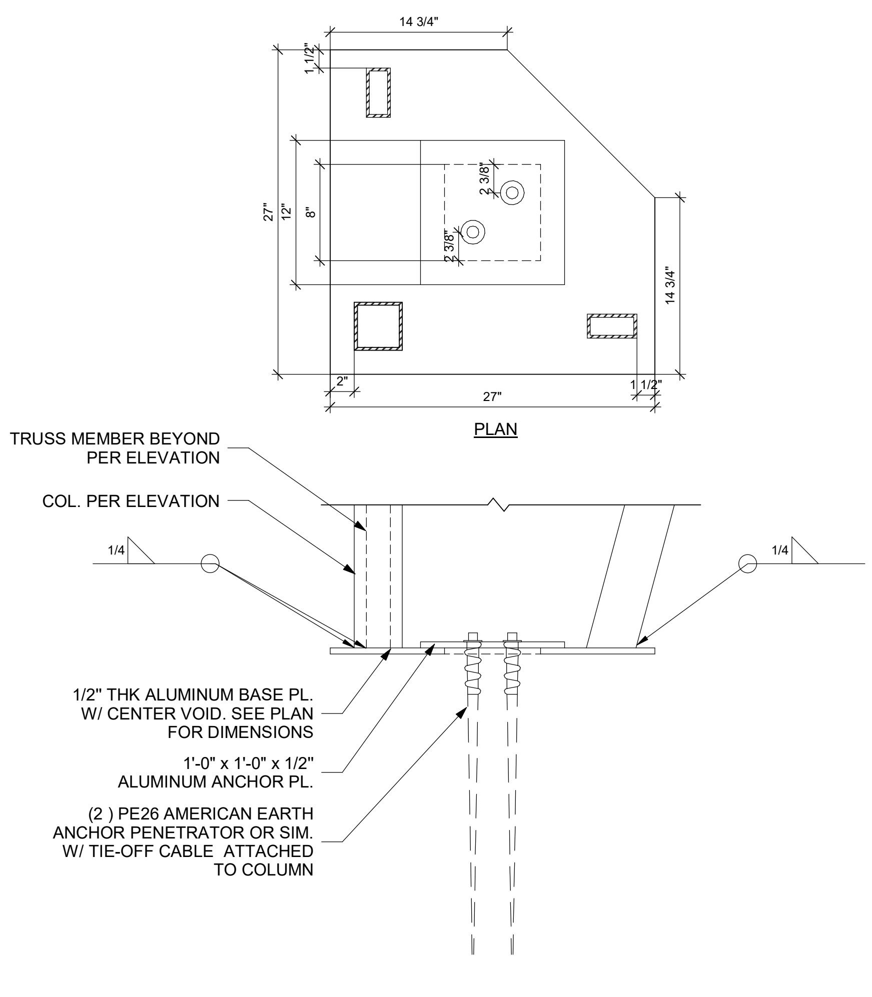
NOTES:
1. CONN. USED WHERE ASSEMBLY SECTIONS ATTACH IN PARALLEL.



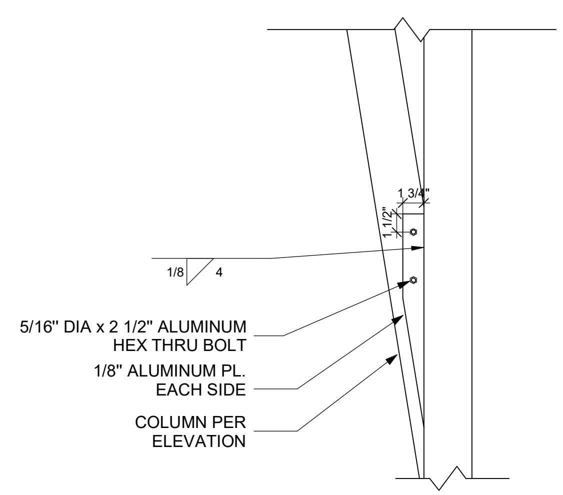
(5) BEAM TO BEAM CONNECTION PARALLEL
1 1/2" = 1'-0"



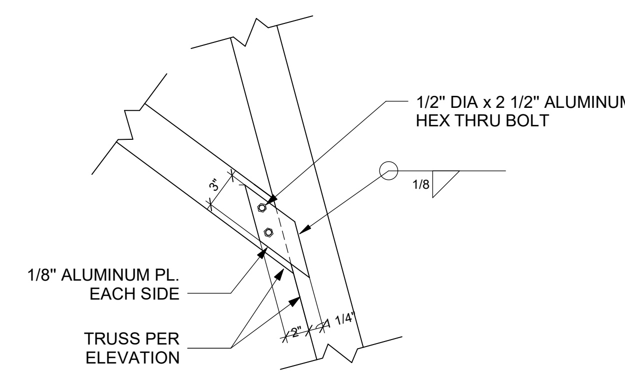
(2) TRUSS TO GIRDER CONN. TYP.
1 1/2" = 1'-0"



(8) TRUSS FOUNDATION
1 1/2" = 1'-0"



(6) TRUSS TO COLUMN CONN. - POLE
1 1/2" = 1'-0"



(3) TRUSS TO TRUSS PIECE CONNECTION
1 1/2" = 1'-0"

THE WINE HISTORY PROJECT

SEAL: (IF REQ'D)

PROJECT:
WINE HISTORY PAVILION

SITE:
SAN LUIS OBISPO COUNTY

REVISIONS

No.	DESC	No.

DRAWN BY: DNM

CHECKED BY:

PLOT DATE:

SHEET NAME:
DETAILS

SCALE:
1 1/2" = 1'-0"

SHEET No.
S.3

APPENDIX B – Revised Structural Calculations

MATERIAL CRITERIA - 2010 ALUMINUM DESIGN MANUAL

ALUMINUM ALLOY 6061-T6

$F_{tu} = 42ksi$ $F_{tuw} = 24ksi$

$F_{ty} = 35ksi$ $F_{tyw} = 15ksi$

$F_{cy} = 27ksi$ $F_{cyw} = 15ksi$

$F_{su} = 27ksi$ $F_{suw} = 15ksi$

$E = 10,100\ ksi$

5356 FILLER MATERIAL

$F_{tu} = 35ksi$

$F_{su} = 17ksi$

PRESCRIBED SOIL LOADS

(SILTY/CLAYEY SAND AND SILTY GRAVEL ASSUMED)

$P_{max} = 1000\ PSF$

$P_{LATERAL} = 100\ PSF/FT$

LOADING

DEAD LOADS:

ROOF SHEATHING	0.8 PSF
BLOCKING	0.42 PSF
BEAMS	1.15 PSF
PANEL TRACKS & FRAMES	1.68 PSF
MISC.	0.95 PSF
	5 PSF TO BEAMS
GIRDERS	0.23 PSF
MISC.	0.02 PSF
	5.25 PSF TO GIRDERS
COLUMNS	0.20 PSF
MISC.	0.05 PSF
	5.5 PSF TO COLUMNS

LIVE LOADS

UNOCCUPIED W/OUT STORAGE	10 PSF

ASCE 7-16 WIND LOAD CALCULATIONS (REVISED)

USING CH.27 DIRECTIONAL PROCEDURE (TABLE 27.2-1)

① RISK CATEGORY II - T1.5-1

② $V = 95$ mph - FIGURE 26.5-1B

③ SURFACE ROUGHNESS = C PER 26.7.2

EXPOSURE CATEGORY = C PER 26.7.3

$K_d = 0.85$ PER T 26.6-1

$K_{zt} = 1.0$ PER 26.8.2

$K_e = 1.0$ PER 26.9

$G = 0.85$ PER 26.11.1

PARTIALLY OPEN / OPEN BUILDING
$GC_{pi} = \pm 0.18$ PER T. 26.13-1

④ FOR EXPOSURE C & h=15' PER T 26.10-1
$K_z = 0.85$

⑤ $q_z = 0.00256 K_z K_{zt} K_d K_e V^2$ [psf/mph²]

$= 0.00256(0.85)(1.0)(0.85)(1.0)(95^2)$

$= 16.69$ psf

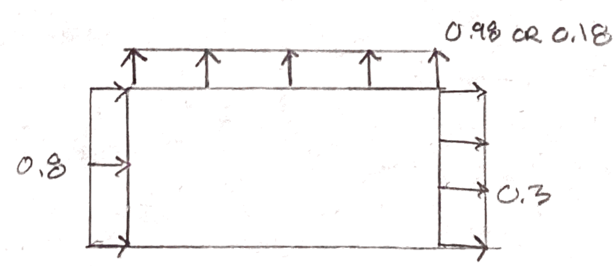
⑥ PER FIG. 27.3-1

$C_p = 0.8$ (WINDWARD)

$C_p = -0.3$ (LEEWARD)

$h/L = 12/20 = 0.6$

$C_p = -0.98$ or -0.18



C_p VALUES

⑦ $P = q_z GC_p - q_z(GC_{pi})$

$= 16.69\,psf\,(0.85)C_p - 16.69\,psf\,(\pm 0.18)$

$= 16.69\,psf\,(0.85C_p \pm 0.18)$

$P_{WINDWARD} = 16.69\,psf\,(0.85(0.8) + 0.18)$

$= 14.35\,psf$

$P_{LEEWARD} = 16.69\,psf\,(0.85(-0.3) - 0.18)$

$= -7.26\,psf$

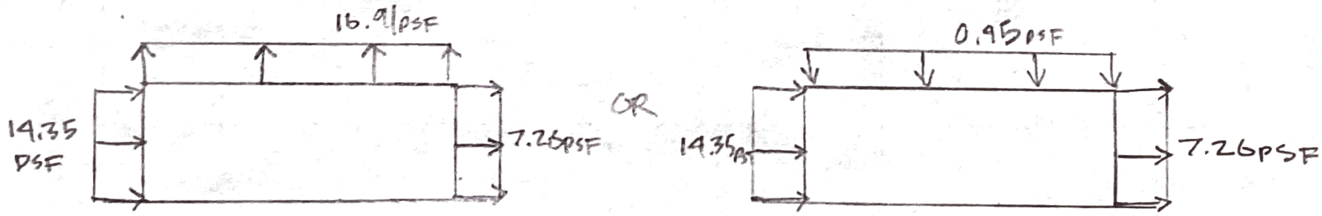
$P_{UPLIFT} = 16.69\,psf\,(0.85(-0.98) - 0.18)$

$= -16.91\,psf$

$P_{DOWN} = 16.69\,psf\,(0.85(-0.18) + 0.18)$

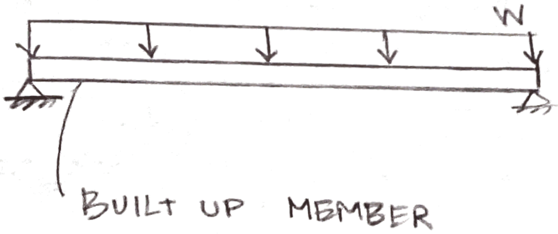
$= 0.45\,psf$

FINAL DESIGN VALUES



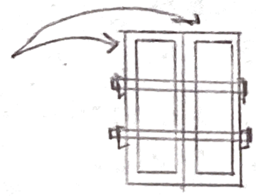
THESE LOADING VALUES WILL BE USED IN THE SAP 2000 MODEL TO PRODUCE REVISED ASD FOUNDATION DEMAND LOADS.

REVISED BEAM DESIGN



TRIB WIDTH = 2ft

$L_B = 4ft$



b = 2in
d = 4in
t = 0.125in
J = 1.21in⁴

$A = 1.19in^2(2) = 2.38in^2$
$I_x = 2.04in^4(2) = 4.08in^4$
$S_x = 1.02in^3(2) = 2.04in^3$
$r_x = 1.31in(2) = 2.62in$
$I_y = 0.201in^4(2) = 0.402in^4$
$S_y = 0.403in^3(2) = 0.806in^3$
$r_y = 0.412in(2) = 0.824in$

DEMAND

DL = 5 PSF
LL = 10 PSF

FROM WIND CALCS

W = 16.91psf↑ OR 0.45psf↓

LOAD COMBOS

(3) = 1.2D + 1.6L + 0.5W
= 1.2(5) + 1.6(10) + 0.5(0.45)
= 22.2PSF

(5) = 0.9D + 1.0W
= 0.9(5) + 1.0(-16.91)
= -12.41 PSF ↑

∴ USE 22.2PSF FOR GRAVITY DESIGN

$$V_u = \frac{WL}{2} = \frac{22.2PSF(2ft)(16ft)}{2} = 0.355K$$

$$M_u = \frac{WL^2}{8} = \frac{22.2PSF(2ft)(16ft)^2}{8} = 1.42K\text{-}ft$$

CAPACITY

PER TA3.5, USE WELD-AFFECTED PROPERTIES FOR ENTIRE LENGTH AND CROSS SECTION DUE TO WELDING OF BLOCKING

BUCKLING CONSTANTS, T. B.4.2, TB4.1
-COMP. IN BEAM FLANGES
FOR WELD-AFFECTED ZONES
$k = 1.0ksi$

$B_c = F_{cy}\left(1+\left(\frac{F_{cy}}{1000k}\right)^{1/2}\right)$ — INTERCEPT

$= 15ksi\left(1+\left(\frac{15ksi}{1000}\right)^{1/2}\right)$

$= 16.84$

$D_c = \frac{B_c}{20}\left(\frac{6B_c}{E}\right)^{1/2}$ — SLOPE

$= \frac{16.84}{20}\left(\frac{6(16.84)}{10{,}100ksi}\right)^{1/2}$

$= 0.0842$

$C_c = \frac{2B_c}{3D_c}$ — INTERSECTION

$= \frac{2(16.84)}{3(0.0842)}$

$= 133.3$

FLEXURAL DESIGN

$\phi_{RUPTURE} = 0.75$ PER F.1

$\phi = 0.9$

$C_b = 1.0$ PER F.1.1a

LATERAL-TORSIONAL BUCKLING - F.3.1

$M_n = F_b S_c$

$S_2 = \left(\frac{C_c}{1.6}\right)^2 = \left(\frac{133.3}{1.6}\right)^2 = 6943$

$\frac{2 L_b S_c}{C_b \sqrt{I_y J}} = \frac{2(4ft)(12in/ft)(2.04in^3)}{1.0\sqrt{0.402in^4(1.21in^4)}} = 280.8 < S_2$

∴ INELASTIC BUCKLING

$F_b = B_c - 1.6 D_c \sqrt{\frac{2 L_b S_c}{C_b \sqrt{I_y J}}}$

$= 16.84 - 1.6(0.0842)\sqrt{280.8}$

$= 14.6ksi$

$M_n = 14.6ksi(2.04in^3)$

$= 2.48 k\text{-}ft$

CHECK FLEXURE

$M_n = F_{tuw} S_x$

$= 24ksi(2.04in^3)$

$= 4.08k\text{-}ft$

$\phi M_n = 0.9(2.48k\text{-}ft)$

$= \boxed{2.23k\text{-}ft}$

OR

$\phi M_n = 0.75(4.08k\text{-}ft)$

$= 3.06k\text{-}ft$

$\phi M_n = 2.23k\text{-}ft > M_u = 1.42k\text{-}ft$ ✓

CHECK SHEAR

$\phi_v = 0.9$ PER G.1

$V_n = F_s A_w$

FOR WELD-AFFECTED PER G.1-2

$F_s = F_{so}(1 - A_{wz}/A_g) + \frac{F_{sw} A_{wz}}{A_g}$

$= 27ksi\left(1 - \frac{2(3in)(0.125in)}{2.38in^2}\right) + \frac{15ksi(2(3)(0.125))}{2.38in^2}$

$= 23.2ksi$

$V_n = 23.2ksi(4in)(0.125in) = 11.6k$

$\phi V_n = 0.9(11.6) = 10.4k > V_u = 0.35k$ ✓

CHECK DEFLECTION

PER 2018 IBC TABLE 1604.3

$\Delta_{LIVE} = L/180$ | $\Delta_{D+L} = L/120$
$= 16ft(12)/180$ | $= 16ft(12)/120$
$= 1.07in$ | $= 1.6in$

$W_L = 10PSF(2ft)$ | $W_{D+L} = 15PSF(2ft)$
$= 20PLF$ | $= 30PLF$

$\Delta_L = \frac{5WL^4}{384EI} = \frac{5(20plf)(16ft)^4}{384(10{,}100in^4)(4.08in^4)}(12in/ft)^3\left(\frac{1k}{1000lb}\right)$

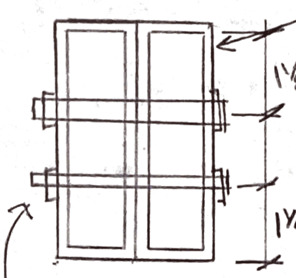
$= 0.72in < 1.07in$ ✓

$\Delta_{D+L} = \frac{5WL^4}{384EI} = \frac{5(30plf)(16ft)^4}{384(10{,}100in^4)(4.08in^4)}(12in/ft)^3\left(\frac{1k}{1000lb}\right)$

$= 1.07in < 1.6in$ ✓

USE DBL RT 1x4x1/8 FOR INTERIOR-CONNECTING BEAMS

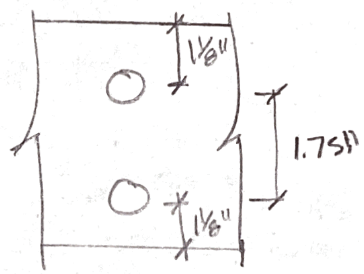
BEAM TO BEAM PARALLEL CONNECTION



THIS CONNECTION IS FOR TWO SECTIONS THAT MEET TOGETHER ON THE SAME GRID LINE. THIS BOLTED CONNECTION WILL BE DONE IN THE FIELD TO BUILD THE ROOF.

CAPACITY

CHECK BOLT GEOMETRY



PER J.3.4

$d_{EDGE\,MIN} = 1.5D = 1.5(5/16 in)$

$= 0.47 in < 1.125 in$

PER J.3.3.

$d_{s\,MIN} = 2.5(D) = 2.5(\quad)$

$= 0.78 in < 1.75 in$

BOLT SHEAR RUPTURE

$R_n = \pi\left(D - \frac{1.91}{n}\right)^2 (5/16)(F_{su})$ (Eq J.3-2) n=18 per A16

$= \pi\left(\frac{1}{2}" - \frac{1.91}{18}\right)^2 (5/16)(24ksi)$

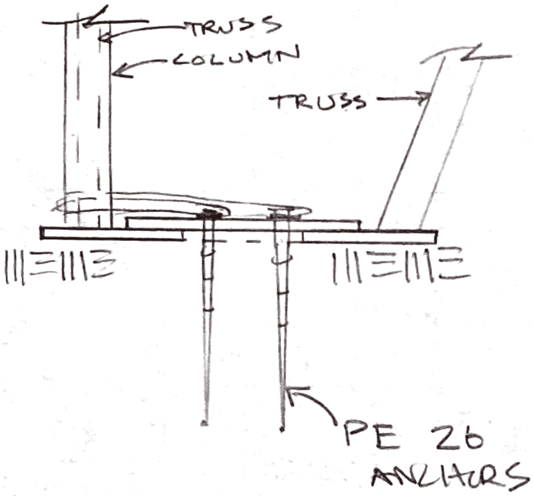
$= 3.66K$

$V_n = R_n(2\,BOLTS) = 2(3.66K) = 7.31K$

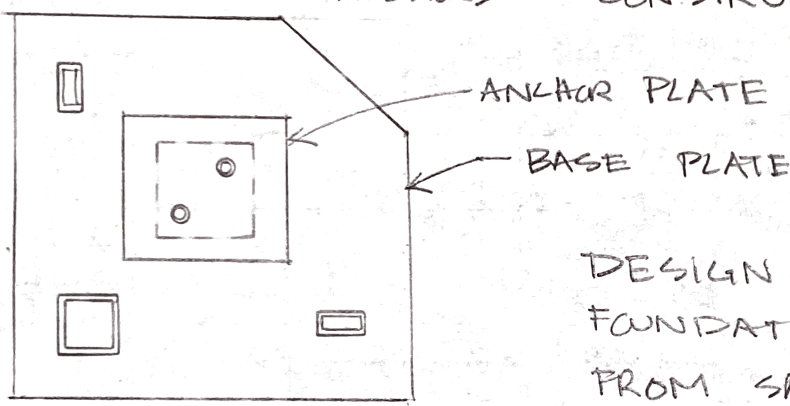
$\phi V_n = 0.65(7.31) = 4.75K$

FROM BEAM DESIGN, $V_u = 0.405K < \phi V_n$ ✓

TRUSS-COLUMN FOUNDATION DESIGN



THE FOUNDATION USES AN ANCHOR PLAN ON TOP OF A BASE PLATE W/ A VOID. THESE ARE FASTENED TOGETHER WITH A PENETRATOR ANCHOR. THE VOID ALLOWS FOR CONSIDERABLE CONSTRUCTION TOLERANCES.

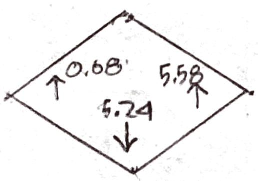


DESIGN LOADS FOR THE FOUNDATION WERE TAKEN FROM SAP 2000 USING THE JOINT REACTIONS AT THE PINNED BASES. ASD LOAD COMBINATIONS WERE USED FOR THE FOOTING AND LRFD LOADS FOR THE BASE PLATE.

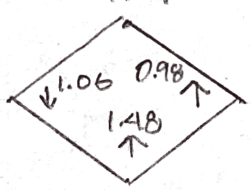
ASSUME SOIL CLASS 3 (SILTY/CLAYEY SAND AND SILTY GRAVEL)

ASD GOVERNING LOADS (K)

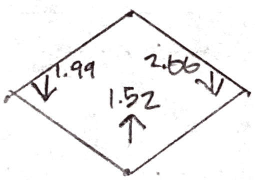
OVERTURNING



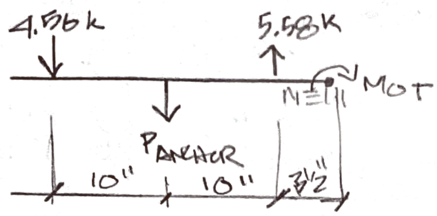
UPLIFT



BEARING



CHECK OVERTURNING



PENETRATOR LOAD CAPACITIES TAKEN FROM AMERICAN EARTH ANCHORS CATALOG. FOR PE26

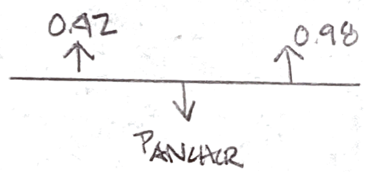
$P_{ANCHOR} = 1{,}100$ lb /ANCHOR (SOIL CLASS 3)

$\therefore 2 P_{ANCHOR} = 2(1{,}100) = 2.2K$

$\Sigma M \Rightarrow M_{OT} = -4.56K(23.5in) - 2.2K(13.5in) + 5.58(3.5in)$

$= -117.3$ K-in < 0 ✓

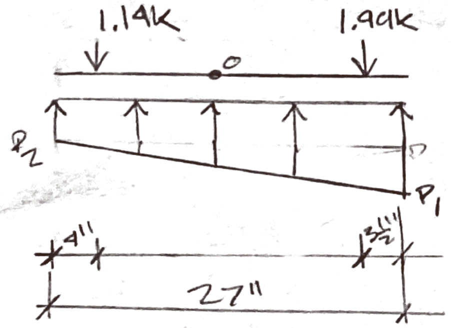
CHECK UPLIFT



$\Sigma F_y = 0: \quad 0.42K + 0.98K - 2(P_{ANCHOR}) = 0$

$P_{ANCHOR} = 0.7K < 1.1K$ ✓

CHECK BEARING



PER 2018 IBC T 1806.2
$P_{ALL} = 1000 psf$ FOR THE MOST CONSERVATIVE VALUE SINCE SOIL IS UNKNOWN

$\Sigma M_o = 0: +1.14k(9.5in) - 1.99k(10in) + \frac{P_1(27in)^2}{2}(5in)$ (MIDDLE)

$P_1 = +0.005 ksi$

$\Sigma F_y = 0: -1.14k - 1.99k + 0.005ksi(27in)^2/2 + P_2(27in)^2$

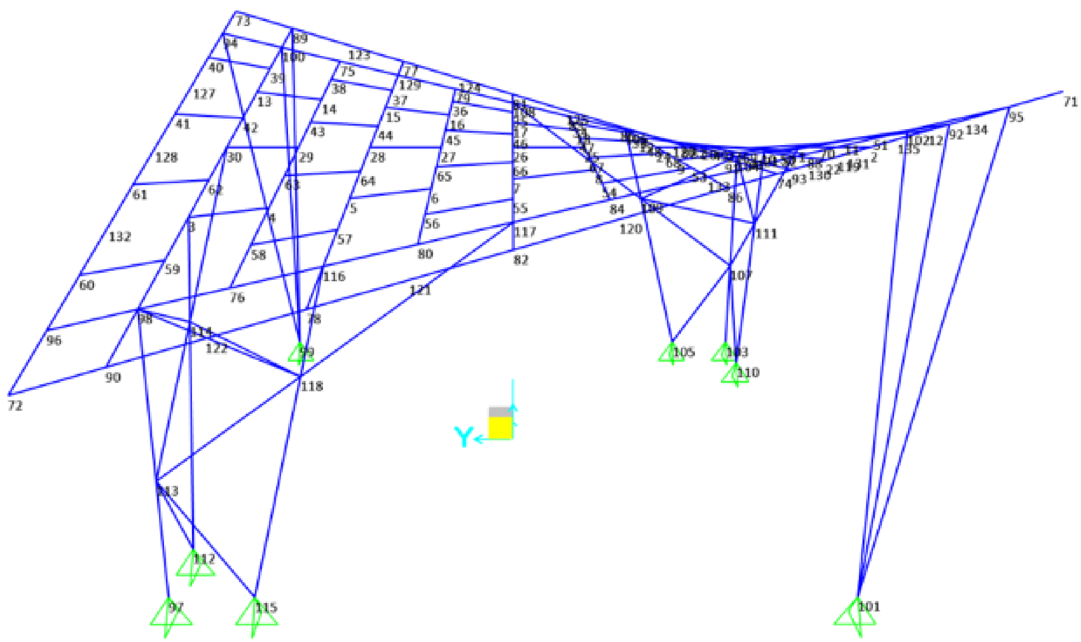
$P_2 = -0.0018 ksi$

$P_{MAX} = P_1 + P_2 = (0.005ksi - 0.0018ksi)(1000 lb/k)(12in/ft)^2$
$= 457 psf$

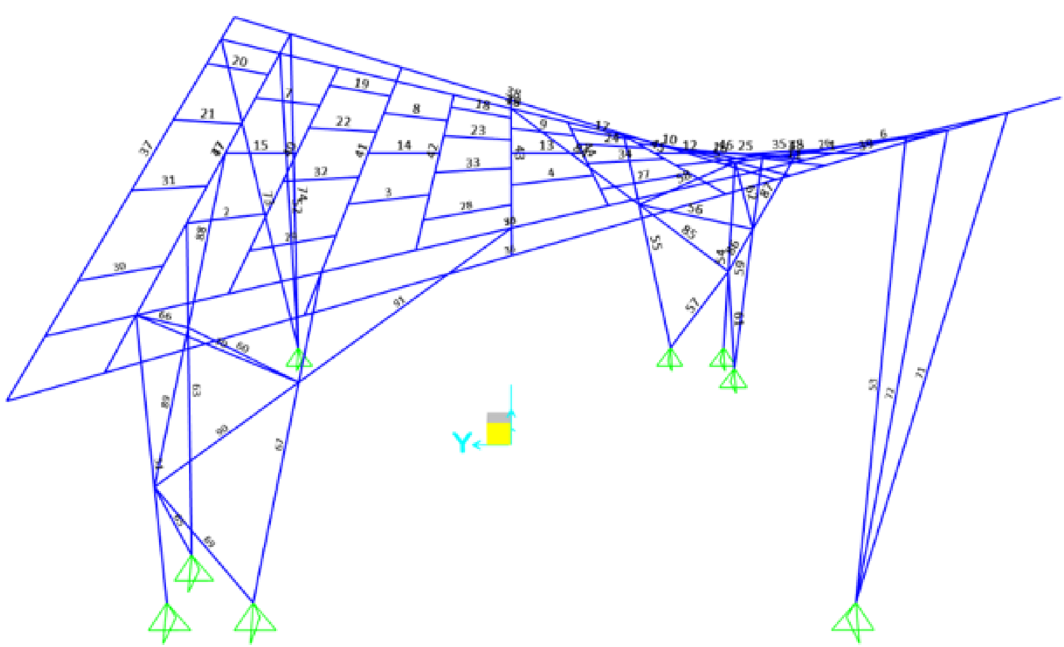
$P_{MAX} < P_{ALL} = 1000 psf$ ✓

SAP 2000 Analysis Model

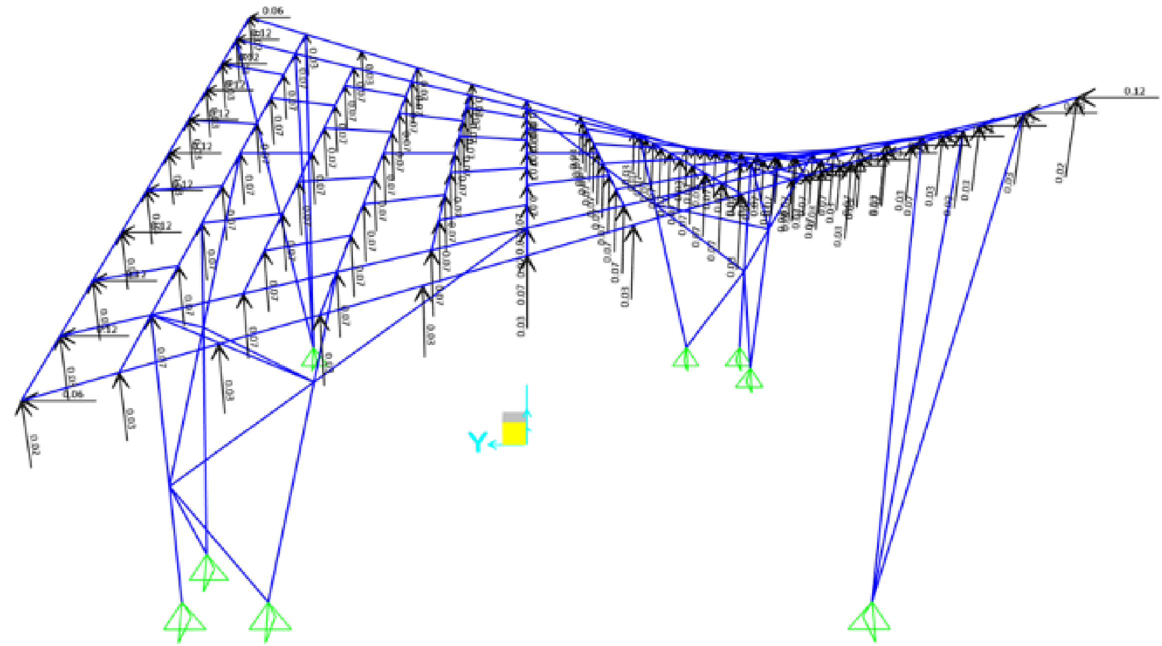
Joint Labels



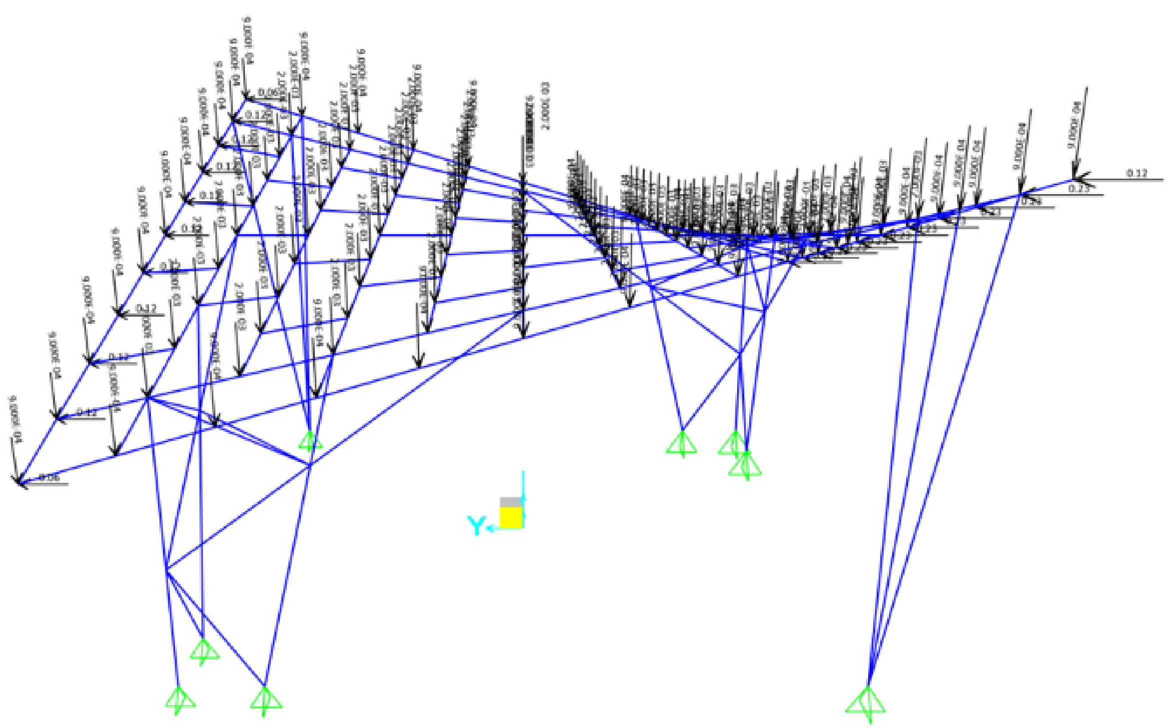
Frame Labels



Wind Loading (Uplift)



Wind Loading (Downdraft)



Foundation Forces (ASD)

TABLE: Joint Reactions				
Joint	**OutputCase**	**F1**	**F2**	**F3**
97	5a (D+0.6W)	-0.007005	0.023	4.985
99	5a (D+0.6W)	0	-1.849E-17	-0.158
101	5a (D+0.6W)	0	-5.053E-17	-0.454
103	5a (D+0.6W)	0.006931	-0.00446	-1.739
105	5a (D+0.6W)	-0.011	-1.1	1.398
110	5a (D+0.6W)	0.065	0.006651	-0.818
112	5a (D+0.6W)	-0.043	0.001831	-0.526
115	5a (D+0.6W)	-0.011	-1.003	-5.235
97	6b (D+0.75(0.6W)+0.75Lr)	0.018	-0.029	-1.524
99	6b (D+0.75(0.6W)+0.75Lr)	0	1.027E-16	0.96
101	6b (D+0.75(0.6W)+0.75Lr)	0	7.365E-17	0.692
103	6b (D+0.75(0.6W)+0.75Lr)	-0.02	0.042	-6.73
105	6b (D+0.75(0.6W)+0.75Lr)	-0.012	-0.681	7.531
110	6b (D+0.75(0.6W)+0.75Lr)	-0.11	-0.0003895	2.059
112	6b (D+0.75(0.6W)+0.75Lr)	0.129	0.006939	1.994
115	6b (D+0.75(0.6W)+0.75Lr)	-0.005356	-0.896	2.657
97	7a (0.6D+0.6W)	-0.008235	0.025	5.244
99	7a (0.6D+0.6W)	0	-2.591E-17	-0.231
101	7a (0.6D+0.6W)	0	-5.796E-17	-0.527
103	7a (0.6D+0.6W)	0.008248	-0.006748	-1.475
105	7a (0.6D+0.6W)	-0.011	-1.107	1.063
110	7a (0.6D+0.6W)	0.073	0.006877	-0.982
112	7a (0.6D+0.6W)	-0.05	0.001598	-0.678
115	7a (0.6D+0.6W)	-0.011	-0.996	-5.579
Text	Text	Kip	Kip	Kip

Foundation Forces (LRFD)

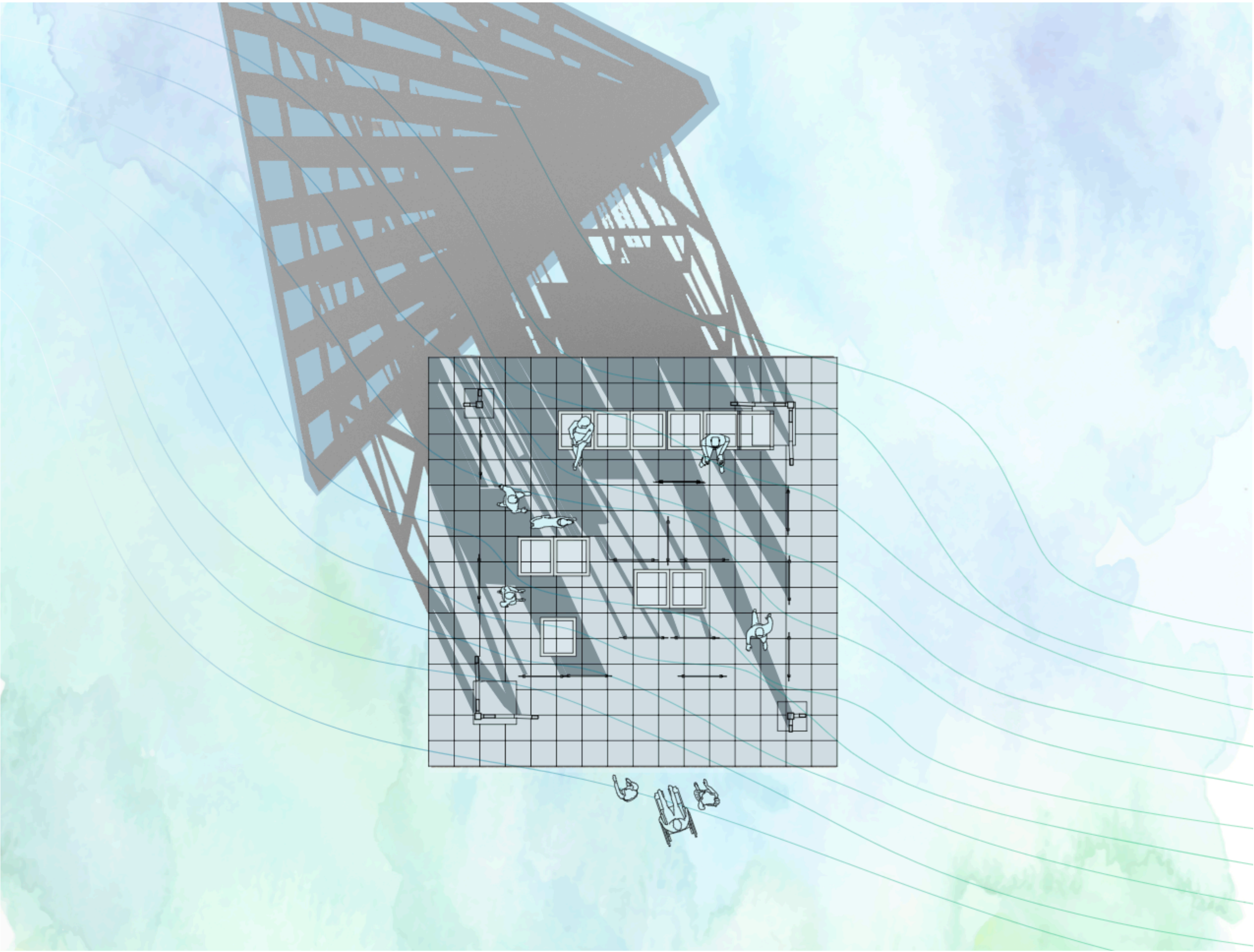
TABLE: Joint Reactions				
Joint	OutputCase	F1	F2	F3
Text	Text	Kip	Kip	Kip
97	1 (1.4D)	0.004	-0.008	-0.893
99	1 (1.4D)	0.000	0.000	0.257
101	1 (1.4D)	0.000	0.000	0.250
103	1 (1.4D)	-0.005	0.008	-0.927
105	1 (1.4D)	0.000	0.023	1.176
110	1 (1.4D)	-0.026	-0.001	0.575
112	1 (1.4D)	0.026	0.001	0.537
115	1 (1.4D)	0.000	-0.023	1.177
97	3b (1.2D+1.6Lr+0.5W)	0.022	-0.032	-0.550
99	3b (1.2D+1.6Lr+0.5W)	0.000	0.000	1.263
101	3b (1.2D+1.6Lr+0.5W)	0.000	0.000	0.827
103	3b (1.2D+1.6Lr+0.5W)	-0.025	0.057	-9.704
105	3b (1.2D+1.6Lr+0.5W)	-0.019	-1.241	10.711
110	3b (1.2D+1.6Lr+0.5W)	-0.135	0.001	2.512
112	3b (1.2D+1.6Lr+0.5W)	0.166	0.010	2.531
115	3b (1.2D+1.6Lr+0.5W)	-0.011	-1.512	1.979
97	4b (1.2D+W+0.5Lr)	0.014	-0.005	5.605
99	4b (1.2D+W+0.5Lr)	0.000	0.000	1.093
101	4b (1.2D+W+0.5Lr)	0.000	0.000	0.263
103	4b (1.2D+W+0.5Lr)	-0.017	0.054	-12.414
105	4b (1.2D+W+0.5Lr)	-0.033	-2.668	12.984
110	4b (1.2D+W+0.5Lr)	-0.064	0.009	1.539
112	4b (1.2D+W+0.5Lr)	0.125	0.013	1.907
115	4b (1.2D+W+0.5Lr)	-0.025	-2.838	-4.481
97	5a (0.9D+W)	-0.020	0.064	13.431
99	5a (0.9D+W)	0.000	0.000	-0.523
101	5a (0.9D+W)	0.000	0.000	-1.303
103	5a (0.9D+W)	0.020	-0.015	-4.248
105	5a (0.9D+W)	-0.029	-2.887	3.182
110	5a (0.9D+W)	0.177	0.017	-2.430
112	5a (0.9D+W)	-0.118	0.005	-1.673
115	5a (0.9D+W)	-0.030	-2.619	-14.285

APPENDIX C – Presentation Slides

WINE HISTORY PROJECT PAVILION

DOUG MCARTHUR

CAL POLY ARCE SENIOR PROJECTS DAY - JUNE 4TH, 2020



OVERVIEW

- Project partners
- Background Information
- Design
- Challenges
- Future Outlook
- Takeaways

PROJECT PARTNERS

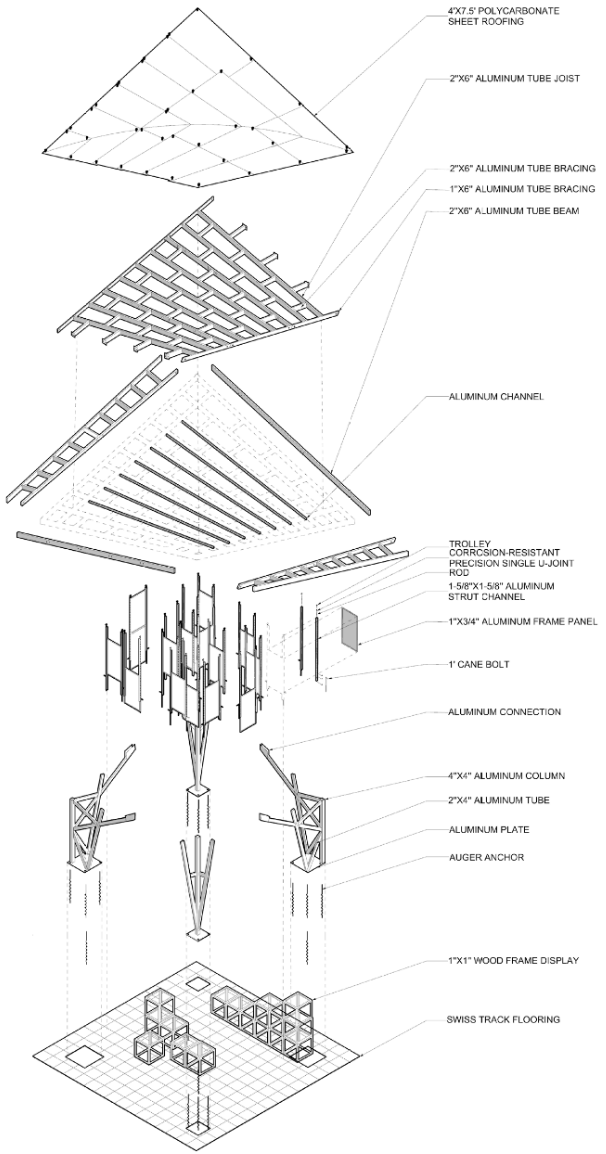
- Wine History Project of San Luis Obispo County
- Taylor and Syfan Consulting Engineers
- Cal Poly CM Department

BACKGROUND

Wine History Pavilion

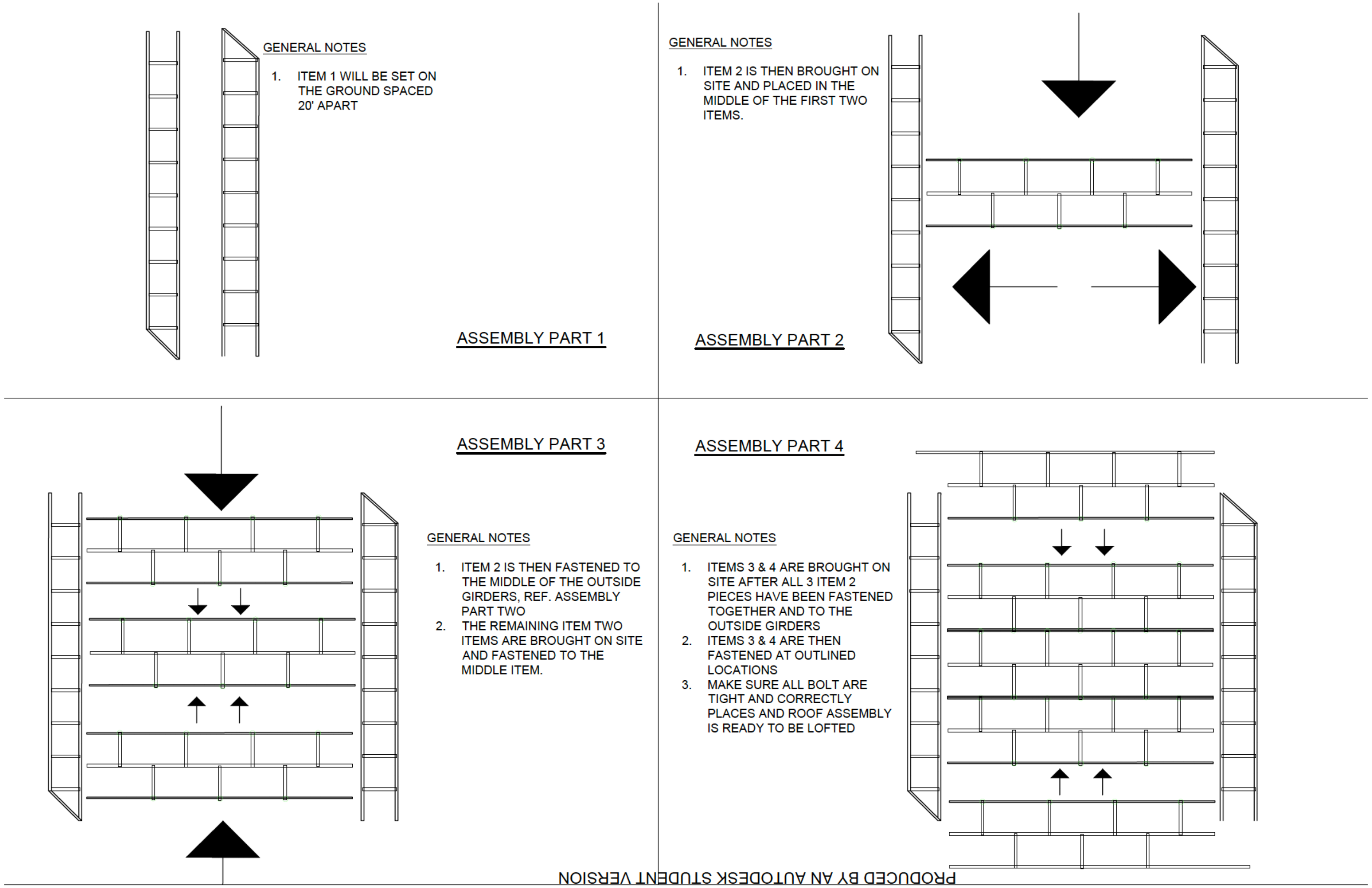
- IPD Studio Fall 2019
- ARCH, ARCE, and CM Students
- Design parameters
  - Exhibit space
  - Transportable
  - Ease of assembly
  - Minimized site impact

WINNING DESIGN - FLOW



PARTS TO BE INVESTIGATED

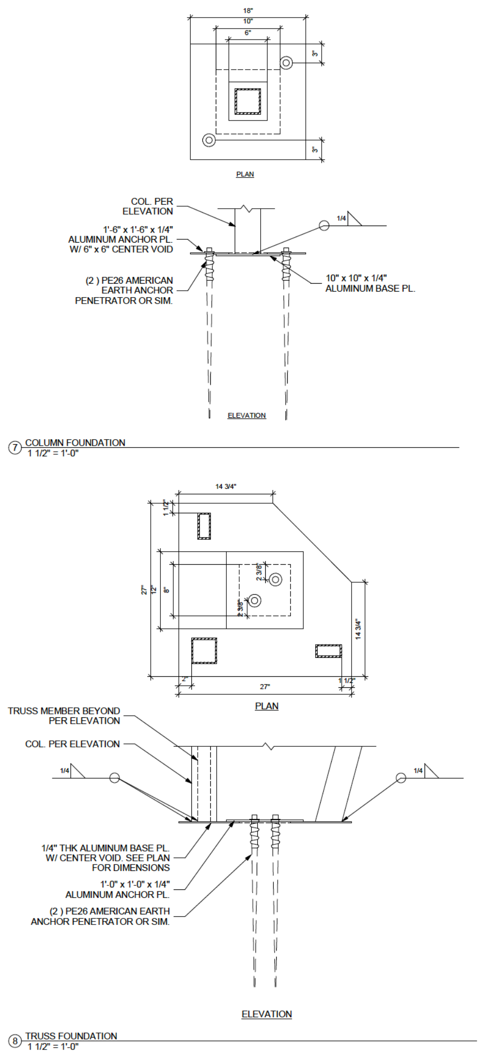
- Temporary structure requirements
- Foundations
- Feasibility of assembly/disassembly
- Connections to aid in assembly/disassembly
- Developed structural drawings



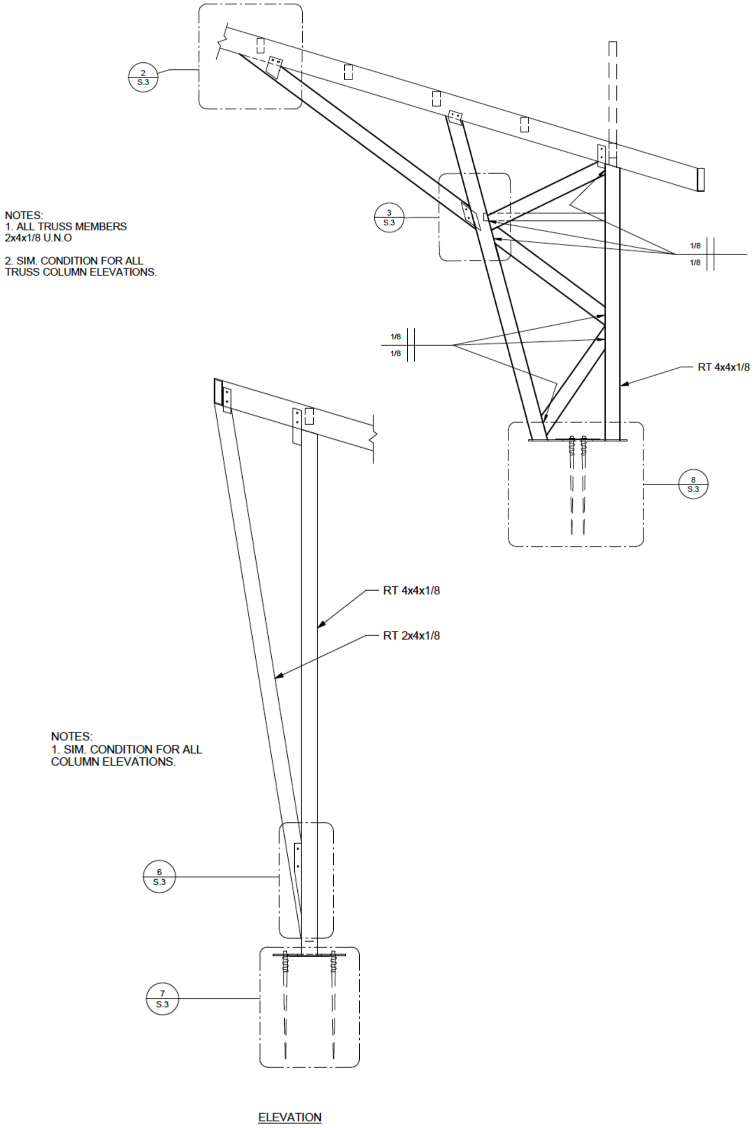
ASSEMBLY

- 7 Pieces
- More Manageable
- Build roof on ground
- Lift with roof jacks on each side

DRAWINGS



PLAN
COL. PER ELEVATION
1'-6" x 1'-6" x 1/4" ALUMINUM ANCHOR PL. W/ 6" x 6" CENTER VOID
(2) PE26 AMERICAN EARTH ANCHOR PENETRATOR OR SIM.
10" x 10" x 1/4" ALUMINUM BASE PL.
ELEVATION
COLUMN FOUNDATION
1 1/2" = 1'-0"
PLAN
TRUSS MEMBER BEYOND PER ELEVATION
COL. PER ELEVATION
1/4" THK ALUMINUM BASE PL. W/ CENTER VOID. SEE PLAN FOR DIMENSIONS
1'-0" x 1'-0" x 1/4" ALUMINUM ANCHOR PL.
(2) PE26 AMERICAN EARTH ANCHOR PENETRATOR OR SIM.
ELEVATION
TRUSS FOUNDATION
1 1/2" = 1'-0"



NOTES:
1. ALL TRUSS MEMBERS 2x4x1/8 U.N.O
2. SIM. CONDITION FOR ALL TRUSS COLUMN ELEVATIONS.
RT 4x4x1/8
RT 4x4x1/8
RT 2x4x1/8
NOTES:
1. SIM. CONDITION FOR ALL COLUMN ELEVATIONS.
ELEVATION

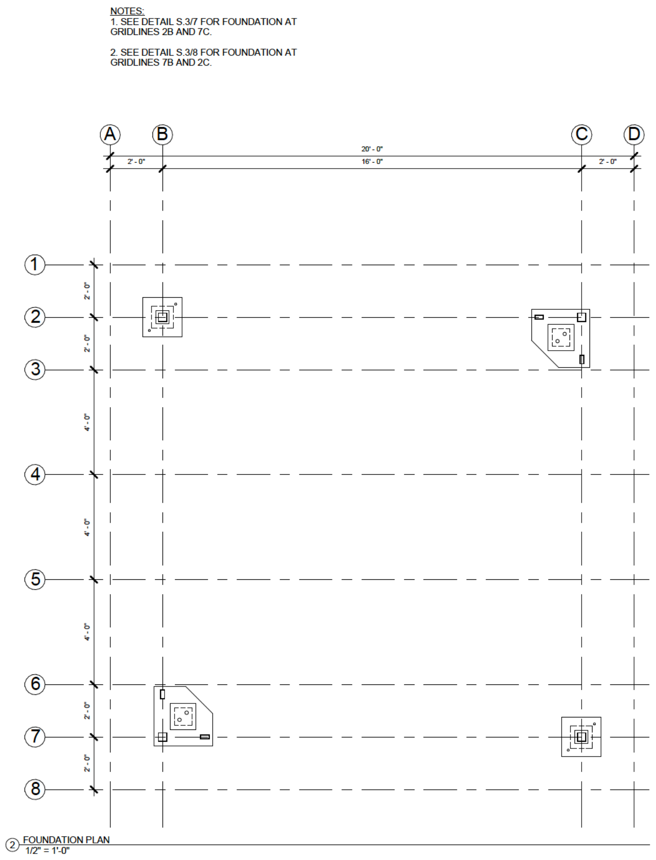
CHALLENGES

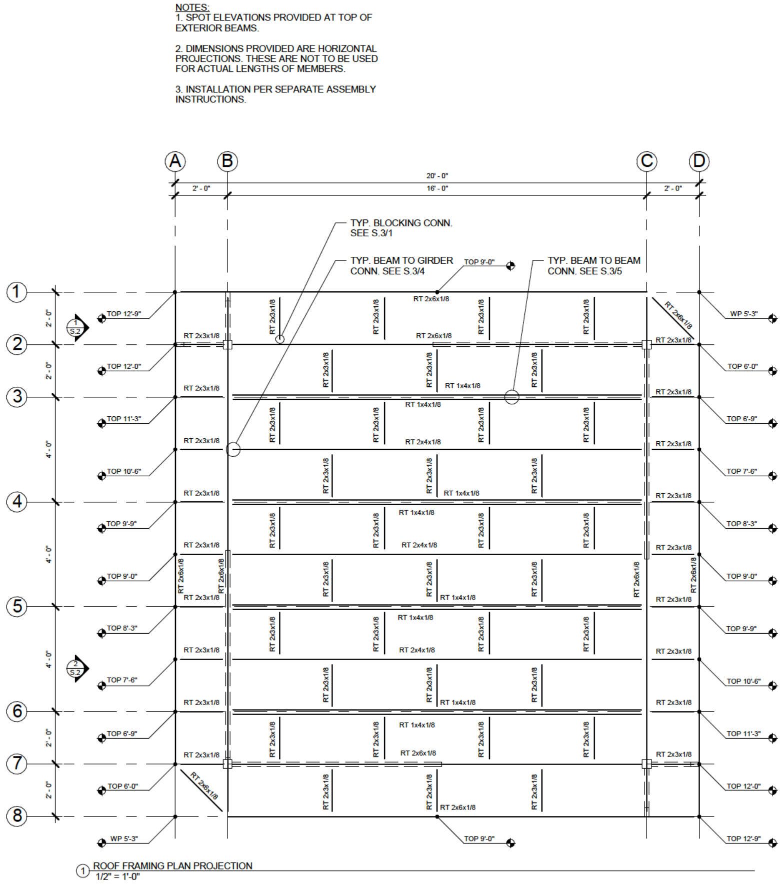
Maintaining provided design

Lack of interaction with other parties

Understanding aluminum design

Deciding necessary information for construction





FUTURE OF PROJECT

FUNDING

SITE CONSIDERATIONS

CONSTRUCTION NEEDS

ACKNOWLEDGEMENTS

- IPD Team FLOW
  - ARCE: Isaac Cameron
  - ARCH: Isha Sharma and Khanh Nguyen
  - CM: Anthony Cumpian and Antonio Rosales
- Project Partner: Kyle Bresnahan
- Project Advisor: Greg Starzyk
- Faculty Advisor: John Lawson

*Credit for all renderings to the FLOW team

TAKEAWAYS AND QUESTIONS