Piazza di Ulivo: ARCE Patio Redesign

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1.0 INTRODUCTION

Piazza de Ulivo was Phase 1 of a multi-quarter initiative to redesign and bring life to a patio space adjacent to Engineering West (Building 21) in Spring of 2020. Located within the central courtyard of Engineering West (Hasslein Garden), the patio space previously contained a senior project pergola that collapsed and has been removed. The remaining elements from this previous structure were an inverted moment frame consisting of five concrete columns and beams joining them as shown in Figure 1. Additionally, a wooden bench with concrete pedestals remained under the shade of the existing olive tree. Desire within the Architectural Engineering (ARCE) department for the patio to not remain unused inspired a redesign to address issues with flooding and olive debris, while increasing usability and comfort within the space.

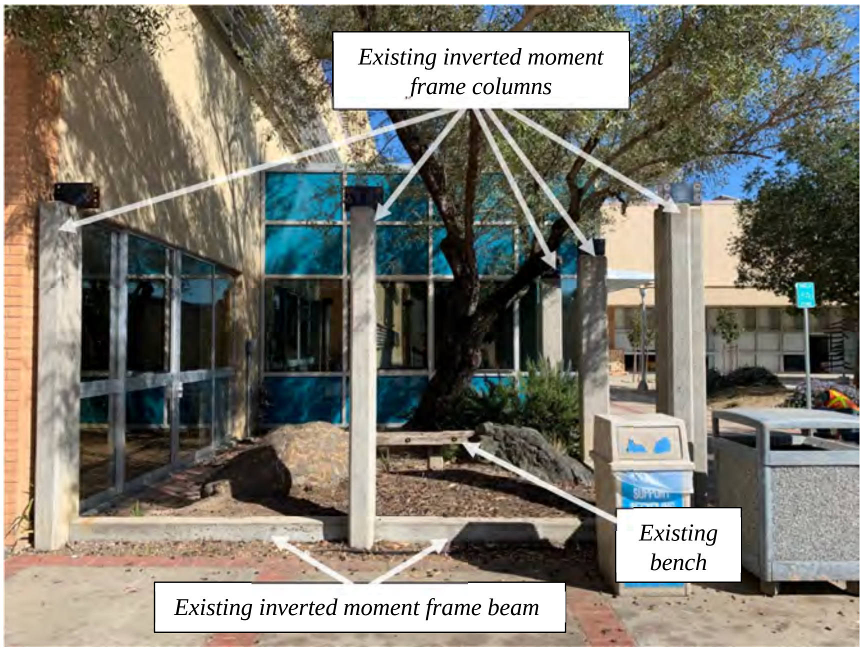


Figure 1 - West elevation of patio as seen from the exterior

1.1. Scope

The scope for this senior project was dependent on what could be completed within a quarter in regard to official university processes. As the location of the project was on Cal Poly's campus, a building permit was required for construction. A Cal Poly Facilities Building Permit requires a minimum of 6 weeks for review and may and may not be accepted in the first round of review. In the ARCE department, a senior project is typically 10 weeks long and this time frame cannot fully encompass an entire project timeline. The patio redesign project was expected to be a multiphase project split into the following phases:

- Phase 1: Design, Calculations, and Permit package draft
- Phase 2: Calculations, Details, Acquiring Funding, Submitting to Facilities
- Phase 3: Fabrication, Prototype fitting, in-situ Construction

This senior project encompassed Phase 1 which was divided into the following steps:

- Design Process
  - Site Documentation (as-built drawings and observations)
  - Identifying the User (architectural perspective)
  - User Perspective (obtaining user input)
  - Schematic Design (initial conceptual design)
  - Design Development (refining conceptual design)
  - Construction Documents
- Permit Package Draft
  - Contacting University Committees
  - Assembling Required Documents

Phase 1 involved as-built drawings, obtaining user input, and learning about the architectural perspective to develop the conceptual redesign for the patio. During this phase, the redesign considered adding a tiered roof-like structure and regrading the site. These modifications were intended to mitigate flooding risks by directing water away from an existing entryway. In addition to conceptual design, a Cal Poly Facilities permit draft was compiled as the final deliverable for the report to be used in subsequent phases of the project with different students.

1.2. Report Overview

This report documented the process of meeting Phase 1 requirements by first describing the site conditions and current user perspective. Consultations with three professional architects provided guidance on determining user perspectives and conceptual design considerations. Additional consultations with architects were planned but were unable to be conducted due to Covid-19 Shelter-At-Home orders. Observations on the use of the patio identified users and directed development of conceptual designs. With the user group defined, conceptual designs focused on how the patio could be used. Interviews were conducted with current users in order to gain perspective. This also provided an opportunity to present the initial designs for feedback. Specific concerns with the patio were clarified through the interview process and conceptual designs were refined.

The description and scope of this senior project is stated in Section 1. Section 2 of this report describes the motivation behind the proposed design and how it addressed the issues determined from users' perspectives. Given the time constraints on the project, project management was essential for progressing at a steady rate. In Section 3, logistic management techniques and limitations are discussed. The interactions with Cal Poly Committees and the process of completing the permit submittal package including supporting calculations are given in Section 4. Lastly, Section 5 describes what was learned from this senior project and provides recommendations for future steps and subsequent phases.

2.0 DESIGN PROCESS

The purpose of the design was to first meet the user’s needs and the foremost step was to identify the user. Observations of the patio and the surrounding area revealed that the patio was rarely occupied by students or faculty. Instances of use by ARCE faculty were typically of short duration for moving objects out of the conference room. Students that were observed using the patio were not in the ARCE department and were likely not aware of the proximity to the ARCE faculty offices and conference room. These students occasionally used the patio for phone calls, though Hasslein Garden was more commonly used for that purpose. Given the infrequent usage of the patio, there were three possible user bases to cater the redesign to: ARCE faculty, ARCE students, and users outside of the ARCE department. For guidance on the patio redesign, three professional architects were consulted to learn how to identify the user, start conceptual design, and gain feedback.

The project followed the steps listed below:

- Site Documentation
- Identifying the User
- User Perspective
- Schematic Design
- Design Development
- Construction Documents

2.1. Site Documentation

Before consulting with professional architects to learn how to identify the user, it was necessary to prepare information on the project. Details on the location of the patio and how it looked was especially important when discussing with people unfamiliar with the project and site. This information was provided through a site documentation packet that also served as a reference of the current existing state of the site.

Site documentation consisted primarily of photographs of the patio from inside, outside, and different views approaching the patio. Some interior and exterior photographs include a measurement instrument or objects to provide a sense of scale to the space. Figure 2(a) is an example of a photograph using a body for scale while Figure 2(b) is an example with a 12” architectural scale. Photographs from further away were intended to show how the site fits in to the surrounding area from the perspective of an approaching user. The complete site documentation file can be found in Appendix A.

In addition to photographs, the plans listed below were included in site documentation:

- Map of Cal Poly
- Building 21 Plan
- Enlarged Section of Building 21 Plan
- As-Built Plan

(a) (b)

Figure 2 - Example Photos w/ Scale Element

Plans provided a bird’s eye view map to show the layout of buildings or a portion of a building. These documents were included to capture a different perspective on how the site relates to its surroundings. Three plans were obtained from the Cal Poly Facilities website. The Map of Cal Poly showed where the patio is in relation to the Cal Poly university campus. Buildings adjacent to the site were shown in more detail in the Building 21 Plan. Due to the smaller footprint of the patio, an enlarged section of the Building 21 Plan was also included in site documentation. An as-built plan was developed during this Senior Project and shows detailed measurements of the site in its current state. All plans include a North arrow to convey orientation and a scale to give a sense of sizes. These plans were fundamental for communication about the patio because they provided context of the surroundings and were able to be referenced throughout the project.

As-Builts

To develop the as-built plans, measurements were taken in person at the site. Dimensions of the existing inverted concrete moment frame and bench were recorded using rulers and measuring tape. To record dimensions of the existing large rocks, the shapes were outlined using several thin wooden dowels and measurements were taken to the dowels with reference to the existing inverted moment frame beam. The average radius of the trunk of the existing olive tree was measured at the ground surface. Measurements were also recorded for the existing irrigation control value located at the site edge.

To measure the topography of the site, surveying equipment was not available due to limitations as discussed in Section 3 of this report. Instead, measurements were taken with a pole, cord, string line level, ruler, and measuring tape. The pole was marked with one-inch increments to act as an additional measurement tool. Using these limited supplies and

equipment resulted in less accurate measurements, however, was accurate enough to provide a sense of the topology of the site. To determine the location of measurements, the site was divided into a grid with 6” spacing. Wooden markers were placed to mark the grid intersections. To avoid damaging the existing rosemary plant, measurements were only taken around the perimeter of it. Then a cord was tied to an existing concrete column at a known height above the inverted moment frame beam and the other end of the cord extended to the pole. Measurements of the distance from the string to the ground surface were recorded at each marker. Placement of a string line level ensured that the cord remained horizontal during the entire recording process. This process was a basic form of differential leveling and the topology of the site was determined from the collected data. This resulted in measurements related to the elevation of the conference room. The completed as-built is shown in Figure 3 and is included in both Appendix A and Appendix C.

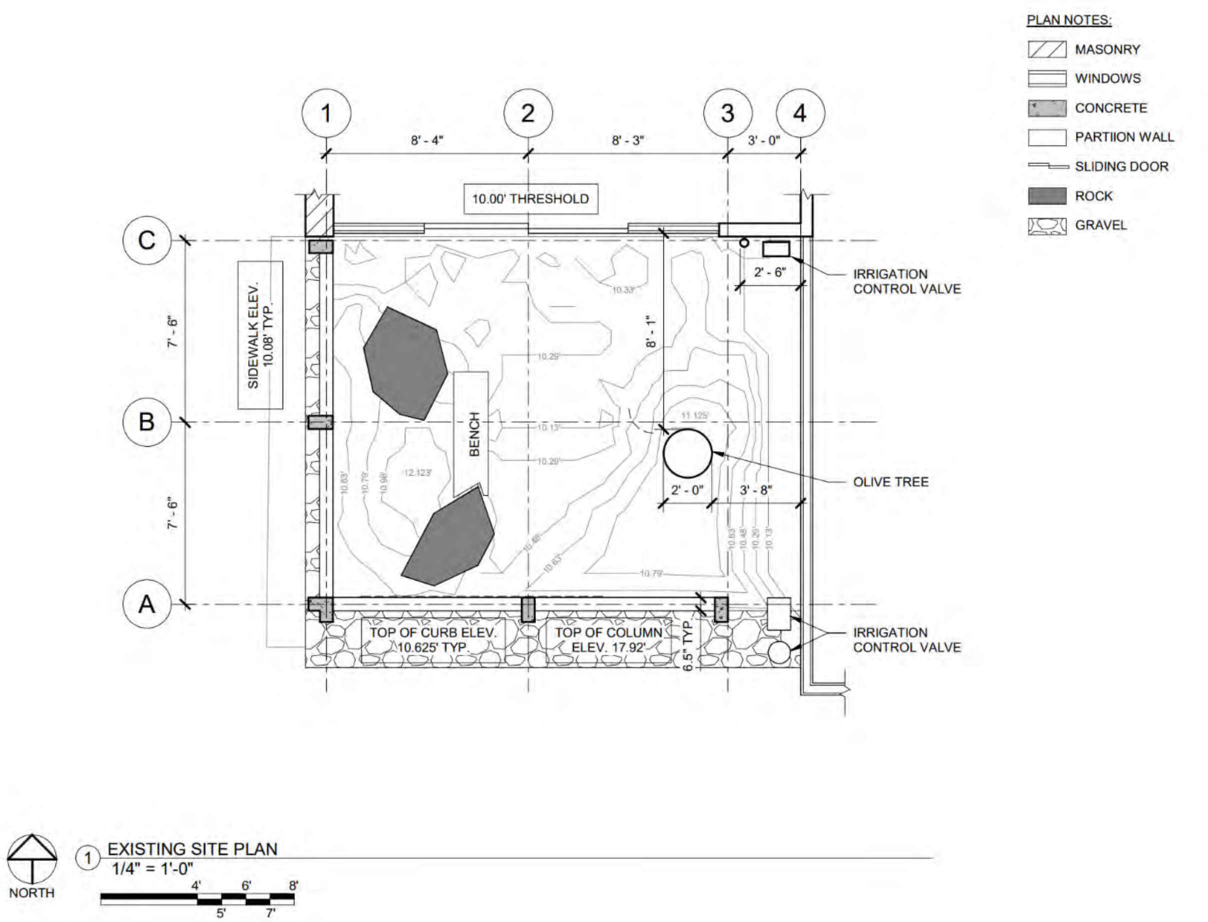


Figure 3 - As-Built Plan of Patio

2.2. Identifying the User

The preliminary task for identifying the user was to see if there was an existing user base from site observations. Performing observations before consulting with professional architects was also done to provide more context about the usage of the site.

Observations

The patio and the surrounding area were observed on six separate days, during three different 10-minute periods. It was determined that the most common users occupied spaces in the adjacent Hasslein Garden, but not the patio. Planter boxes and benches of the courtyard were used briefly by students waiting between classes. Both faculty and students were sometimes observed speaking on their cellphone in an area surrounded by bushes within Hasslein Garden. On some occasions, there would be no one for a span of time.

People were observed to walk by the patio without stopping. The bike racks and trash cans within ten feet of the site were commonly used. Within and around the patio, olives, olive pits, and olive leaves covered the ground. This layer of debris and the uneven pavers made walking within the patio difficult. Stains from the olives were also observed on the pavement outside of the patio.

The patio was not seen to be occupied during the observation periods, but students have been noted to use the space to make phone calls as discussed in Section 2.4. These students were not in the ARCE department and likely unaware of the patio’s proximity to faculty offices and conference room. For several minutes, a truck or golf cart may be parked next to the patio for facility maintenance.

From observations of the conference room adjacent to the patio, faculty meetings were held on a weekly basis and used primarily by professors holding individual meetings. Students were noted to use the conference room for job or internship interviews. Some faculty members regularly used the conference room to eat lunch.

2.3. Interviews

Phase 1 was initially intended to be an interdisciplinary project with ARCE, Architecture, and Landscape Architecture Students to provide each experience with working with students from different majors. 4^{th} and 5^{th} year architecture students were sought due to their more extensive studio experience and exposure to technical details in supporting courses. Students from either major were unavailable due to senior project scheduling conflicts and the Shelter-At-Home orders. In order to obtain an interdisciplinary perspective, industry professionals were consulted with. These professional architects would help identify issues with conceptual designs and how to approach the design process. Each architect was given the completed site documentation and details from observations. Olive debris and uneven terrain were identified as potential issues to be brought up during the interviews.

RRM Design Group

A multidisciplinary design firm with many alumni from Cal Poly, RRM Design Group was approached to gain the perspective of landscape architects. The two professionals consulted

at the San Luis Obispo office were Lance Wierschem and Chris Dufour. Local landscape architects were desired because of their familiarity with the local climate that could aid with recommendations. Below is a list of suggestions and key take-aways from the interview.

- Create a view rather than a gathering space
- Access issues if used as a gathering space
- Hasslein Garden is the communal area
- The view can be contemplative like a rock garden
- Make the patio a buffer (visual and physical barrier)
- Buffer does not have to be a wall, it can be a sculpture
- Find out CAED college plans for renovating the Hasslein Garden and Support Shop areas to coordinate the patio redesign
- Show ARCE capabilities with a complex/interesting form and structure
- Cantilever a shading structure over the bike area
- Take growth of olive tree into account (cantilever on interior of patio might be smaller to accommodate branches)
- Limit disturbance to tree as much as possible
- Use permeable pavers or consider a dry rock bed
- Take inspiration from the olive tree to inform design, see tree structures at the Santa Rosa skate park as an idea (see Figure 4(a))
- Possibly integrate a new trellis with the olive tree, integrate shade sales
- Tie design in with historical details or make an homage
- What is the history of the previous structure?
- Use uplighting on tree, sconces on columns
- Contain olives instead of capturing (for removal)
- Have arborist look at the tree

(a) *(b)*

Figure 4 - Sculptural Structures Referenced in Interviews w/ Professional Architects

Ryan Brockett

An architecture professor at Cal Poly and principal of the architecture firm BROCKITECTURE, Ryan Brockett was consulted on how to gain feedback and direction on identifying the user in addition to design ideas. The interview with Brockett took place standing next to the patio, which made conveying information about the site easier. Below are the suggestions and questions to consider from the interview.

- Consider the patio an extension of the conference room (imagine the conference room opening up to the patio to become an indoor-outdoor space)
- Using a vertical screen for privacy. How much privacy is desired?
- Should there be shading from the sun or rain?
- Planters used and integrated into outdoor seating
- Create a quiet reflective space
- Treat patio as a backdrop to conference room
- Add structural character to identify the ARCE department
- Use innovative connections or detailing
- Look at the Green Monster (see Figure 4(b)) There is a sense of feeling protected sitting next to the Green Monster
- Consider the CAED Support Shop noises, what materials can deafen the noise?
- How many people in the space?
- Sit inside the conference room. Think about the height of a screen required to limit the views you don’t like (from perspective of sitting down)

Brocket also suggested asking Cal Poly campus workers that park next to the patio why they park there specifically. Gaining feedback from a temporary user could affect design choices if the implemented design inhibits their ability to work. If the user was determined to be students or people in Hasslein Garden, the best way to gain opinions would be to sit next to the site with a board with information and ideas. Interviews would be done with people who pass by who are interested in giving opinions. This form of outreach would create more direct access to people who are generally in the area and potential users. If certain people were to be identified as the users, the best course of action would be to prepare a list of questions with graphics to illustrate conceptual designs.

Tom Di Santo

An architecture professor at Cal Poly and principal of the architecture firm M:OME, Tom Di Santo was consulted on potential ideas, how to zero in, and expand on design ideas. Di Santo’s expertise in furniture design and critical involvement in the Vellum furniture design competition opened up discussion for the possibility of furnishing the site and how to increase comfort. Below is a list of suggestions provided during the interview.

- San Luis Obispo climate would allow for indoor-outdoor space
- Patio area could be used for lunch, working on laptop outside, social space
- Put a deck, sweep olives into gap between boards

- Add ramp for accessibility, build around tree
- Replace conference room carpet with deck to make a seamless connection
- Remove mullions on conference room door to open up view
- Replace conference room windows with an overhead garage door (increase porosity)
- Use existing columns to add a wood privacy screen
- Use different pieces of wood, stagger slats, some horizontal slats as shelving
- Play with how materials overlap to effect light and privacy
- Potential Vellum furniture category with winning design chosen by ARCE department to be used inside the patio
- Stains as a patina to show history

Di Santo recommended to develop many conceptual ideas and allow the user to give feedback on what direction to take. He stressed that design is an iterative process and may involve interviewing users several times in order to determine the most important issues. For example, what was assumed to be a problem through observation might not be one at all for the user. While some ideas will be appealing to one person, another could provide insight on disadvantages. More information on disadvantages is discussed in Section 2.4: current user perspectives.

Reflection on Interviews

All consulted architects recommended using the existing structure and adding a new structurally innovative element. However, most of the suggestions from each professional architect varied and this revealed that everyone had a different design approach.

The landscape architects from RRM Design Group focused on visual enjoyment of the patio from a distance rather than making it occupiable. Wierschem and Dufour also emphasized the idea of creating a “buffer” or a perceived boundary. For example, a sculpture could help define the boundaries of the patio and act as a physical barrier. Some changes suggested to improve the appearance of the patio, such as creating a rock garden or replacing old pavers, would not require additional maintenance by University Facilities. Overall, these suggestions would cause minimal impact to the current use and maintenance of the patio.

Making the patio an extension of the ARCE conference room was a theme from the interviews with Brockett and Di Santo. In this case, the suggestions were related to the occupant comfort. The transition from an enclosed space to a completely open one would have abrupt changes in privacy and noise level. Inclusion of screens attached to the existing columns was discussed as a method to increase occupant comfort since they would provide partial enclosure. Protection from rain and sunlight were additional considerations for improving comfort.

From the interviews it was apparent that any changes to the patio would primarily impact users of the ARCE conference room and offices directly next to it. Since the conference room and offices were dedicated spaces for work and discussion of sensitive topics, increased occupancy in the patio could be disruptive. Because people commonly in the ARCE

conference room and offices would be most affected, they were determined to be the target user for the patio redesign.

2.4. Current User Perspectives

In order to aid the design process, it was important to gather input from the current user base of the patio. As such, interviews were conducted with current key users of the adjacent offices and conference room (Erika Clements and Jamie O'Kane). ARCE Department Head Al Estes denied an interview request as to not influence design choices and allow greater input from the rest of the department. Additional interview requests with ARCE professors who frequently used the conference room were declined due to the increased workload during the transition to online courses.

Before interviews with Clements and O'Kane took place, ideas were brainstormed to address issues with the patio. From observation of the site, the uneven pavers, tree roots, and layer of olive debris made walking within the patio difficult. Access to the site was hindered by the conference door being difficult to open. During rainier years, the conference room was known to experience flooding due to water pooling at the conference room door interface. The existing bench was also uncomfortable to use due to splintering of the wood surface that occurred over time.

<u>Schematic Design</u>

Inspired by the professional architects, the indoor-outdoor concept was pursued to create a space that was easier to access and use. The initial conceptual idea presented during the interviews with users consisted of three solid sloping panels connected to the top of the existing columns. This would direct rainfall runoff and olive debris to the base of the existing olive tree. In addition, a slatted screen with an integrated bench would be installed to increase privacy within the patio and provide new seating. The site would also be graded such that the ground sloped away from the conference room doors to mitigate flooding risk. Replacement of existing pavers with permeable pavers would also reduce flooding by allowing water to percolate through more easily. These ideas were sketched on plans and photographs of the patio to be shown during the interviews as part of the schematic design. Figure 5 shows an example of a schematic design.

<u>User Response to Schematic Design</u>

In general, the interviewees agreed that the present state of the patio caused issues for accessibility. Clements and O'Kane expressed their preference for an even walking surface and some management of olives. However, addressing the accessibility issues were not primary concerns because there were very few times a year that access through the patio was required. The conference room was typically used by the ARCE faculty as temporary

placement of materials for graduation, university events, or events for the Cal Poly student chapter of Structural Engineers Association of California (SEAOC). Entering through the patio to the conference room was more convenient for these events.

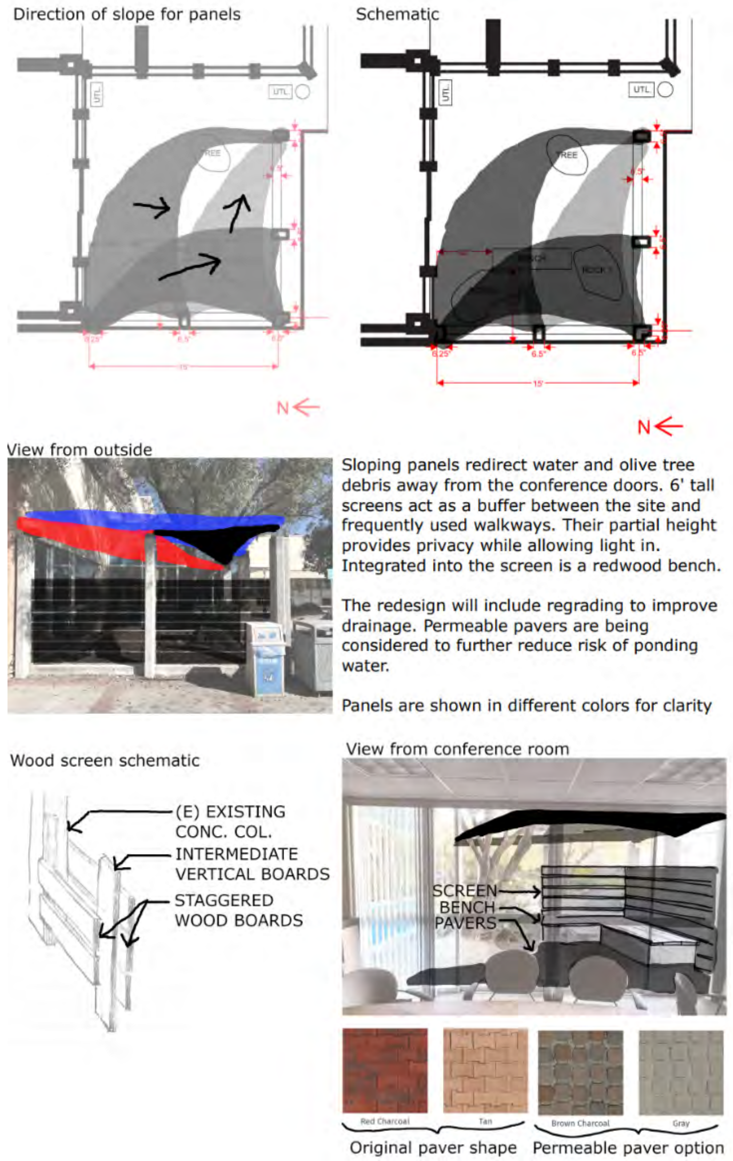


Figure 5 - Schematic Design Shown During Interviews w/ Users

Sunlight and outdoor views were the greatest concern for both Clements and O’Kane. During the interviews, they both mentioned how the collapse of the previous pergola significantly increased the amount of light entering into the offices, which was a welcome change. The proposed solid sloping panels would block sunlight, degrading the work environment. Addition of a screen wall would also block light and create a boxed in feel since they would no longer be able to see the outdoor areas. A screen wall may also introduce security concerns since it could provide privacy for people attempting to break into the conference room. This concern for security was based on a prior incident where the computers in the ARCE department were stolen.

The second most important concern was with noise transmission and distractions. It was stated that in almost every instance, the conference room doors are closed because occupants want privacy and quiet. Since the most frequent use of the conference room consists of faculty meetings, the faculty would not want information to be heard by someone outside. An indoor-outdoor space with the patio would likely end up unused for this reason. In addition, a screen wall or permanent furniture could make the patio seem more inviting to users outside of the department. There were recent instances where people have had personal conversations within the patio and, due to poor noise insulation, these conversations were heard and became distractions.

Reflection on Interviews

There were clear preferences identified from the interviews that would impact design decisions. Below is a summarized list in the order of importance.

1. Avoid blocking sunlight and outside views
2. Avoid bringing excess traffic into the patio
3. Even walking surface
4. Olive debris management

The information gathered helped guide the patio redesign and allowed for the elimination of certain design ideas such as using a screen wall. However, the current user perspective was also one which was accustomed to the state of the patio and as such not all input was directly used to guide the design. Another reason for this decision was the limited feedback gained from the user base and short timeframe of the project. Since some faculty members were unable to be interviewed, the opinions listed in this report may not represent that of the whole department. Clements and O’Kane also had limited availability for additional interviews. In order to meet the final deliverable deadline, interviews were concluded. The conceptual design was revised based on the user response and the design process was resumed.

2.5. Inspiration

Key precedents were used as drivers for the schematic design. One of the ideas inspired from consulting with professional landscape architects was using the existing olive tree as the focal point of the design. Curved forms were used for the tired roof-like structure to accommodate the olive branches while covering a large surface area. The primary precedent for the tiered and curved concept was the Ring-Around-A-Tree project designed by Tezuka Architects. Tiered platforms of the Tezuka Architects project served as an outdoor playground for kindergarteners and doubled as roofing for the classroom at the base.

A material appropriate for the tiered structure needed to allow light to pass through and have the ability to direct water flow. To inform the decision on what material to use, existing buildings with clear or translucent roofing were referenced. Polycarbonate was chosen as the preferrable material when compared to glass due to the former’s flexibility. The flexibility of

polycarbonate resulted in a compatible structural performance to the steel members as discussed in Section 4.4. An example of a polycarbonate roof can be seen in the UCLA Margo Leavin Graduate Art Studios designed by the architecture firm Johnston Marklee.

2.6. Design

Design Development

From user feedback on the schematic designs as discussed in Section 2.4, the idea of a screen wall and integrated bench were removed. The solid panels were also changed to a translucent polycarbonate supported by steel members. During the Design Development phase, specifics such as materials for each component of the structure were decided on. Due to the curved shape of the roof-like structure, Hollow Structural Sections (HSS) were chosen for the curved steel beams given their resistance to torsion. Polycarbonate material properties used in calculations were chosen from the PALRAM Sunlite ™ catalogue. Permeable pavers would be sourced from the local San Luis Obispo masonry manufacturer, AIR VOL BLOCK INC., in the style Eco-Permeable Pavers. Additional information about the specific materials can be found in Appendix C.

Grading the site such that rainwater runoff would flow away from the ARCE conference doors was an important part of the redesign. With regrading, the conference room elevation would be matched at the north edge of the patio. This would be the highest elevation within the patio, and the lowest elevation would be the southern edge along the inverted moment frame beam. Research was performed to confirm that the average precipitation during a typical rainstorm in San Luis Obispo would be less than the height of the exposed portion of the beam. The down sloping area transitioning into a level surface would allow the rainwater to percolate through permeable pavers into the ground. Since the existing soil at the site was determined to not be clay, percolation would not be affected. Grading of the surrounding pavement was confirmed to slope away from the site. To achieve adequate drainage a positive slope of ½" per 1' was suggested for both the pavers and roof-like tiered structure. A rendered view of the design is shown in Figure 6.

Construction Documents

By the start of the Construction Documents phase of the design process, member materials and sizes were finalized. Documents were created to specify how the roof-like structure was to be assembled. The design was intended to be student fabricated and assembled through the CAED Support Shop. While an innovative connection design such as torsional pins was desired, a suitable design could not be achieved within the short time frame of the project. Calculations for the steel members are described in more detail in Section 4.4.

For regrading of the site, demolition plans were created to specify the amount of soil removal required and the removal of large rocks on the site. A demolition plan is a diagrammatic plan similar to an as-built plan, but includes written instructions and information on what changes

need to be made to the site in preparation for construction of the new elements. Demolition would be carried out by Cal Poly Facilities. In addition to the demolition plan, a regrade plan was created to specify the infill elevation to allow for the permeable pavers to properly percolate water on the site. An example of one of these plans is shown in Figure 7.

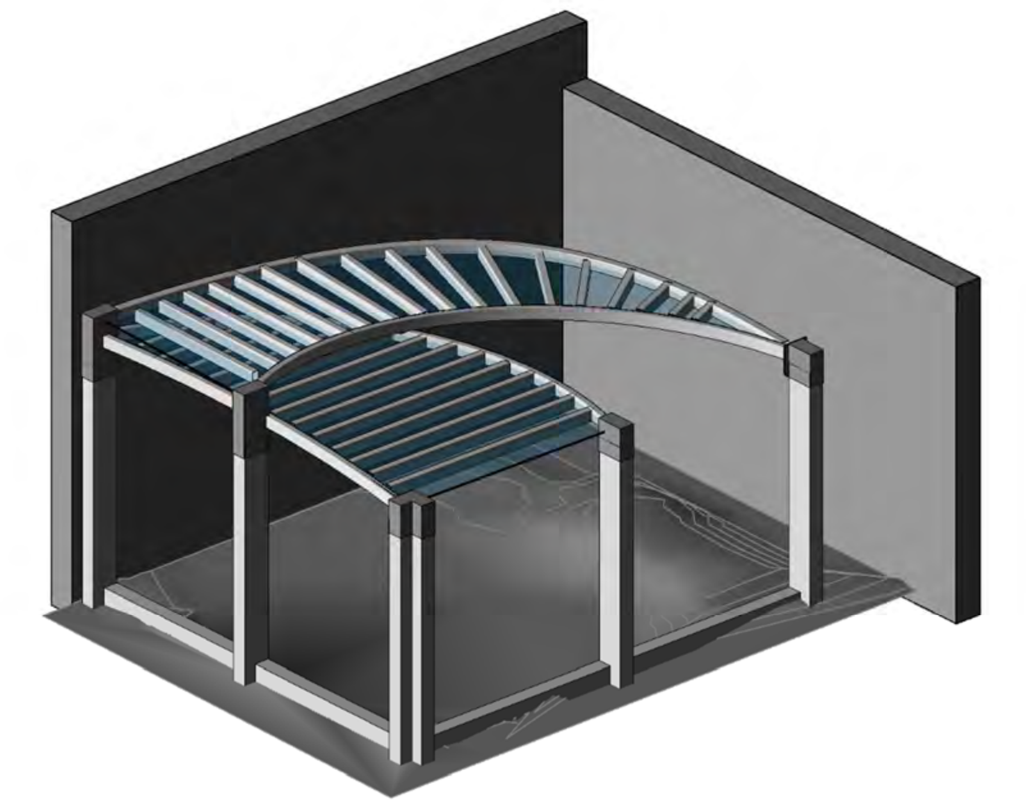


Figure 6 – Rendered Isometric View of Design

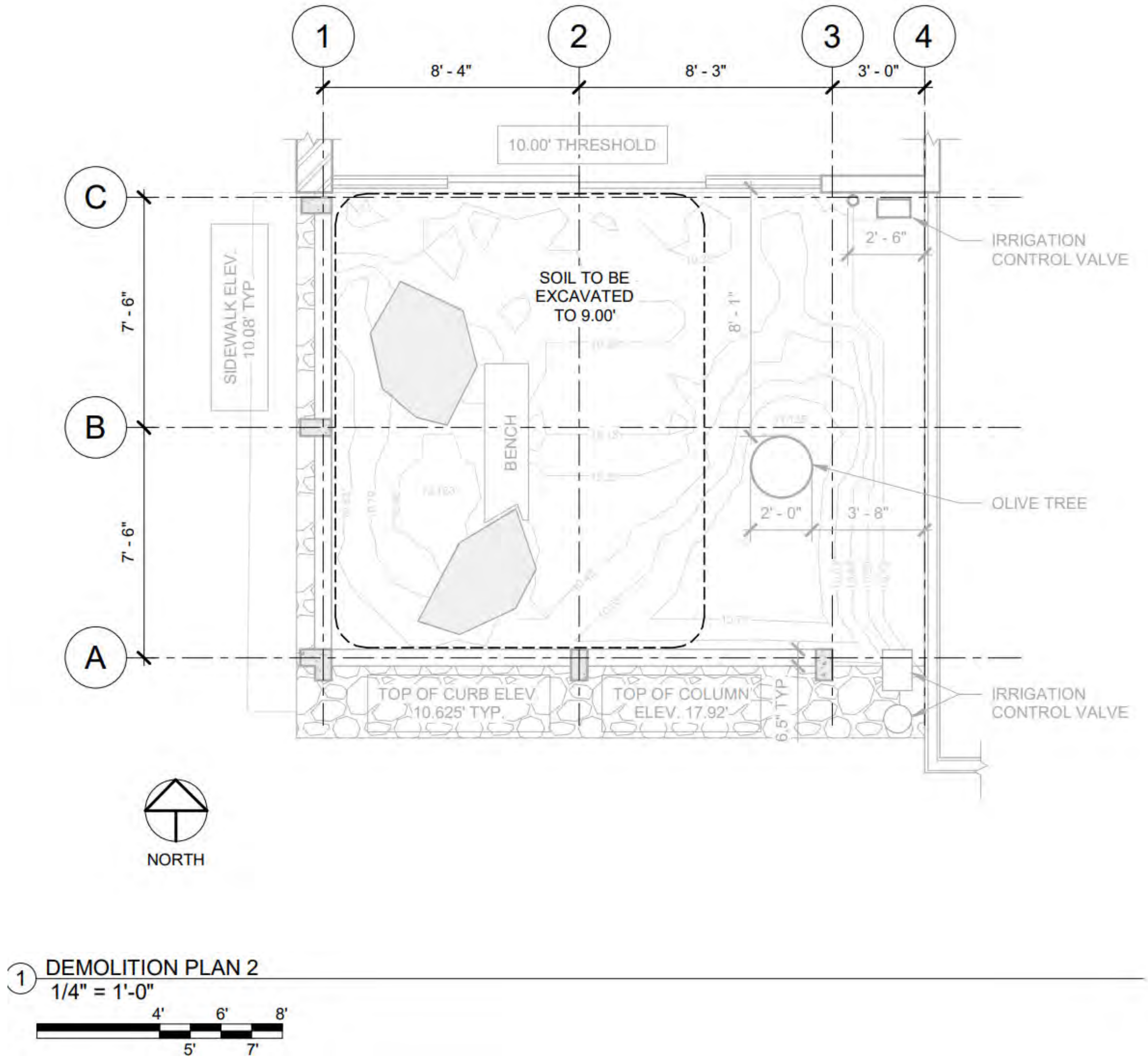


Figure 7 - Demolition Plan 2 out of 3

MANAGING A PROJECT: Start to Finish

In the first few meetings with advisor Craig Baltimore, this project was immediately determined to be highly impacted due to the limited number of weeks available. To complete Phase 1 of this project before the end of Spring quarter, planning deadlines was essential. The first step to ensure completion of the project was setting up weekly and progress meetings similar to industry practices. A Gantt chart, or a project schedule, was then developed after identifying key dates to create an expected timeline. Given the unique situations caused by the Covid-19 restrictions, this project was met with limitations that slowed progress.

2.7. Weekly Meetings

Weekly meetings occurred at the beginning of a week and were used to present and determine deliverables. Deliverables would consist of research, drawings, or calculations and were decided during the previous week's meeting. Progress meetings, typically towards the latter half of the week, were times to report difficulties in meeting deliverables or ask questions after beginning to work on deliverables. Both weekly and progress meetings were held in person before the start of Spring quarter and transitioned to online Zoom meetings. To provide a record of the weekly meetings, meeting minutes were created to document discussion topics and note required deliverables for the following week. Meeting minutes were essential for effective communication and ensuring that each person on the team was on the same page. Deliverables were due on either the next weekly meeting or on a progress meeting day. An example meeting minutes file format can be referenced in Appendix B.

2.8. Gantt Chart

A Gantt Chart is a bar schedule that depicts deliverable names, durations, start and end dates. It visually illustrates the amount of time available to complete a deliverable with the length of the bar. In the chart, bars overlapped with other bars to show the potential to multitask and be working on multiple deliverables simultaneously.

Since Phase 1 of this project was focused on the conceptual designs and not a final project, the most important deadline was the end of the quarter, June 12. To create a Gantt Chart, this last date was the starting point of tracing backwards the predicted amount of time to complete tasks. As Senior Projects Day would take place before the last day of the quarter, the Gantt Chart was adjusted accordingly. This chart was a living document and was periodically updated throughout the quarter to include new deliverables and adjust dates as the project developed.

2.9. Timeline

Figure 7 depicts the initial Gantt Chart, where tasks were all organized chronologically to get a sense of the timeline, and the Gantt Chart later in the quarter, which was more detailed and had tasks grouped together based on categories. The second Gantt chart also has a visual method of showing progress which helped keep tasks on track. A noticeable difference in the charts in the overlap of bars, indicating that multiple tasks could be worked on at the same time. Full-pages of these Gantt charts can be found in the Appendix B.

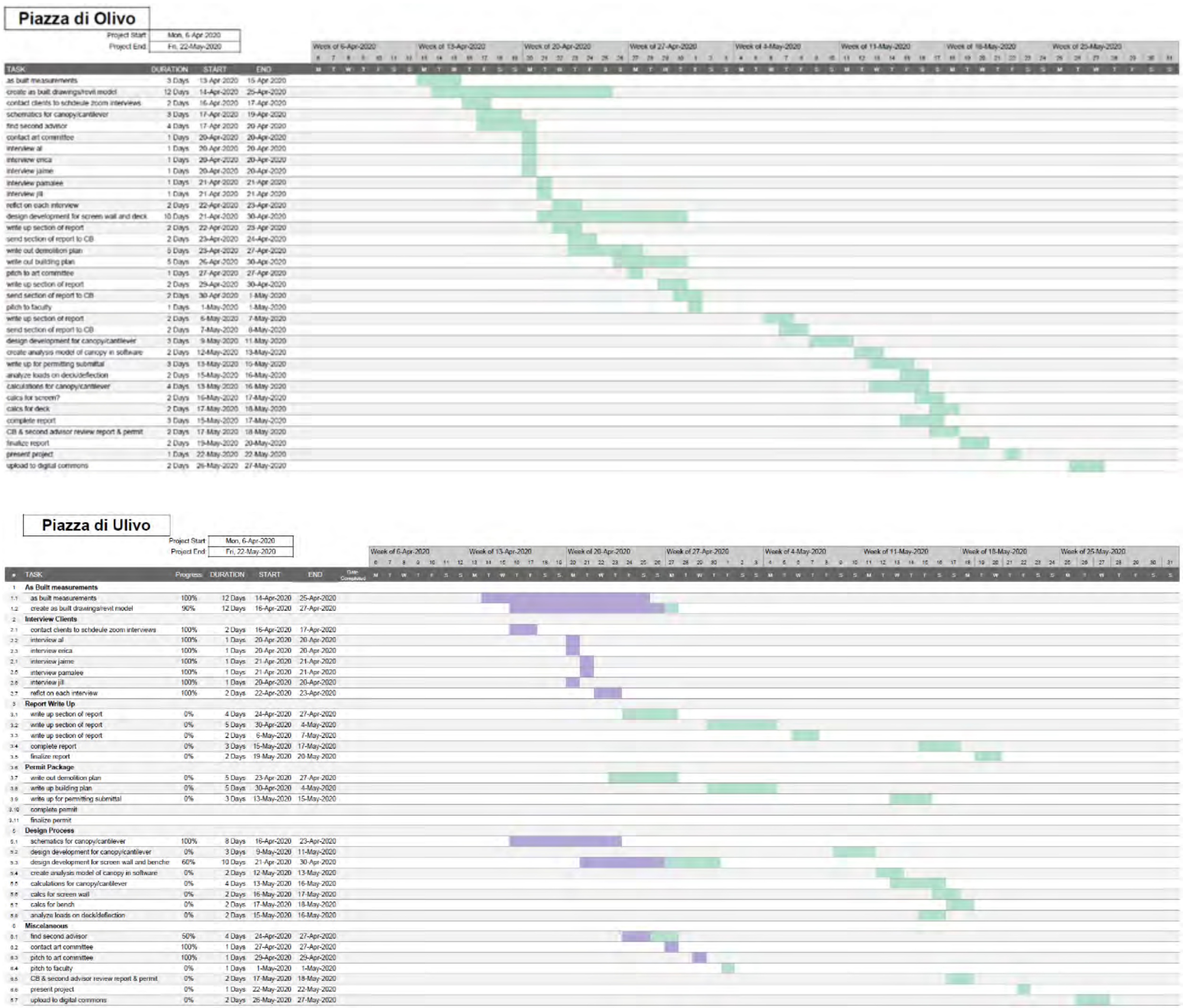


Figure 8 - Initial Gantt Chart (above) & Progress Gantt Chart (below)

2.10. Limitations

During Spring 2020, San Luis Obispo mandated Shelter At Home orders to limit the spread of Covid-19. Due to this, time and accessibility became the biggest constraint of this phase. Before the start of the quarter, Cal Poly extended spring break by one week, thereby reducing spring quarter to 9 weeks. The durations assigned to deliverables had to be reconsidered and resulted in reduced time spent designing the structure in order to complete calculations. The design phase was also impacted because there was less time to get a response and feedback after refining the schematics. Since many businesses transitioned to remote, the additional consultations with architects about the schematic designs were unable to be conducted. Cal Poly’s campus also became closed to students during Spring 2020, therefore restricting access to resources such as computer programs and tools as well as the site. While engineering software such as SAP 2000 or RISA were considered, ETABs was chosen due to

local access on personal computers as a result of an online course. The lack of access to the College of Architecture and Environmental Design (CAED) support shop also created challenges with acquiring accurate data. The support shop provides surveying equipment such as transits, tripods, and Philadelphia rods. Use of this equipment was planned for the creation of as-built drawings, but was no longer available and less accurate means were used instead as described in Section 2.1: Site Documentation.

3.0 CAL POLY PERMITTING PROCESS

For any construction on Cal Poly University campus, a permit is required. For this project, being Phase 1, a draft of the permit package was compiled. To start the permitting process, it was necessary to determine if the project fell under the jurisdiction of certain campus committees. Campus committees are governing bodies that would need to provide approval to projects that fall under their jurisdiction. If a project fell under the jurisdiction of a particular committee, then a date would need to be scheduled to present the project in order to gain approval. As such, contact to the relevant committees was made. The committees contacted were the Art Acquisition Committee and the Campus Landscape Committee.

Cal Poly Facilities is the governing body that issues the actual permits required to have any construction on campus. This meant that, in addition to the potential presentations to any committees, a permitting package would need to be compiled to present to facilities to then be approved.

3.1. Art Acquisition Committee

The Art Acquisition Committee (AAC) collects art for permanent or temporary display at Cal Poly. The AAC was contacted as previous senior projects have been required to gain the approval of this committee. Given the permanent nature of the patio redesign, it was not certain whether or not it would fall within the jurisdiction of the AAC.

Catherine J. Trujillo was a Curator of Creative Works for the Cal Poly Robert E. Kennedy Library and a member of the AAC. Trujillo was contacted to clarify if the patio redesign would need approval of the AAC. Given that the project was not commissioned by a department nor an original art installation, the project could be categorized as an outdoor recreational feature. Due to this, this project does not fall under the scope of the AAC.

Trujillo can be contacted at lib-artcollection@calpoly.edu and additional information about the AAC can be found at https://artcollection.calpoly.edu/policies/.

3.2. Campus Landscape Committee

James Mwangi, an ARCE professor and associate dean, was contacted to clarify if this project fell under college jurisdiction and if approval was required from the Landscape Committee. According to Mwangi, the patio space is under the CAED and will need department approval, however, the final permit will be issued by Cal Poly Facilities. To gain approval from the ARCE department, the Phase 1 design was pitched to faculty through Senior Project Presentation Day. Al Estes, Department Head, was emailed to confirm that he and the department are on board with the patio redesign project progressing forward in subsequent senior projects.

3.3. Facilities

The Cal Poly Facilities permit was discovered to be an open-ended document. Provided on the Facilities website is a one-page form with a non-exhaustive list of possible support documentation. Below is a list of items determined to be necessary to include as part of the permit package:

- As-built Plans
- Budget Estimation
- Demolition Plan
- Regrading Plan
- Construction Plan
- Hand Calculations
- Material Specifications

The draft permit package can be found in Appendix C. A second advisor, Brent Nuttall, was chosen to ensure the prepared draft had sufficient information and to act as industry oversight. Nuttall was an ARCE professor and was familiar with performing plan checks for industry projects. Because the permitting process was open-ended, Nuttall commented on any required documentation that was missing after a cursory review. Due to time constraints, a full review was not possible. Specific comments on the permit package draft are listed below. Included are reasons for the current design.

- Treatment of welds should be considered for the aesthetics.
  Treatment of the welds would be at the discretion of the group undertaking construction. If aesthetic welds cannot be produced, grinding the welds smooth is recommended, and should not reduce weld cross section beyond minimum weld thickness.
- The finish of the steel structure should be considered for aesthetics.
  Steel should be painted to prevent rusting and staining on the existing concrete columns unless that is desired in the final design.
- Consider using the same tube size with varying wall thicknesses instead of multiple sizes

Varying HSS sizes were chosen to meet deflection criteria without requiring unreasonably large or thick sections for the main beams. It is recommended that the design in this senior project report be iterated to improve the design.

- Provide calculations for the existing column elements and connections

  Due to time constraints, the existing strength of the concrete structure was not able to be investigated. For the similar, formal calculations were not provided for the connection details included in the permit package draft. It is recommended that investigation of the existing columns be conducted before finalizing the redesign of the patio.

- Concrete cover for the epoxy anchors is small. Check location of rebar in concrete columns so that they are not hit when drilling during installation. Depth of epoxy anchors are critical in performance of connections and should be specified on the details.

  More investigation is required for precise placement of epoxy anchors. Column caps were design to provide additional confinement for epoxy anchors. Calculations will need to be done to verify the final column connection design.

- Consider construction tolerance between steel connections and existing concrete columns

  Confinement from the column caps would require a tight fit on the columns therefore irregularities in the concrete surface should be smoothed to ensure an adequate fitment.

- Details specify welding combined with bolting on the same connection. Why?

  The angles at the ends of the curved beams would depend greatly on the in-situ fitment, therefore they would be measured at the site then taken to the shop to be cut. The beam would then be field welded in place at the site. The bolted end plate would allow for disassembly of the structure if required in the future. This is only possible because of the site’s close proximity to the support shop.

Information on the Cal Poly Facilities Requirements and forms can be found at https://afd.calpoly.edu/facilities/services/building-permits.

3.4. Calculations

Due to the time constraints of the project, analysis of the curved beams was performed with the aid of the structural engineering computer software ETABS to maximize time available for the project. Deflections for design and member design forces were extracted and strength of members was confirmed with hand calculations. Hand calculations followed AISC 360-16 procedures and specifications.

ETABS

ETABS was chosen for its familiarity from previous course work, accessibility in a remote work environment, and ability to model elements experiencing combined stresses from torsion, flexure, axial, and shear demands. The program was utilized in several ARCE courses and was available on personal computers while on campus resources were closed.

As curved beams were chosen for the tiered roof-like structure, modeling the beams accurately was considered. Curved beams can be modeled using beam elements by subdividing into multiple short, straight beam elements. Generally, more accurate analysis results from a larger number of segments. ETABS provided a built-in drawing tool for curved beams and can automatically segment them, however, it was important to maintain the slenderness of the beams by manually adjusting the segments to achieve a 5:1 length to depth ratio. Elements with a length to depth ratio less than 5:1 are governed by shear and the beam elements would not properly capture the behavior of the short segments. Given that the length to depth ratio was greater than 5:1 for the entire members, a flexural response was expected from the analysis.

In order to setup an ETABS model, some modelling assumptions first had to be made based on what would best capture the behavior of the designed structure. As mentioned, beam elements were used to model the main members of the structure. Because of the welded and bolted design of the connections to the existing columns, the beams were all modeled with fixed end connections. Additionally, the beams were all modeled as perfectly horizontal to simplify the ETABS model and analysis. The conservative loading utilized outweighed any increased demands from the slight slope included in the design for water drainage. All beam sections were modeled using ASTM A500 Gr. C steel with a yield stress of 50ksi as seen in Figure 9.

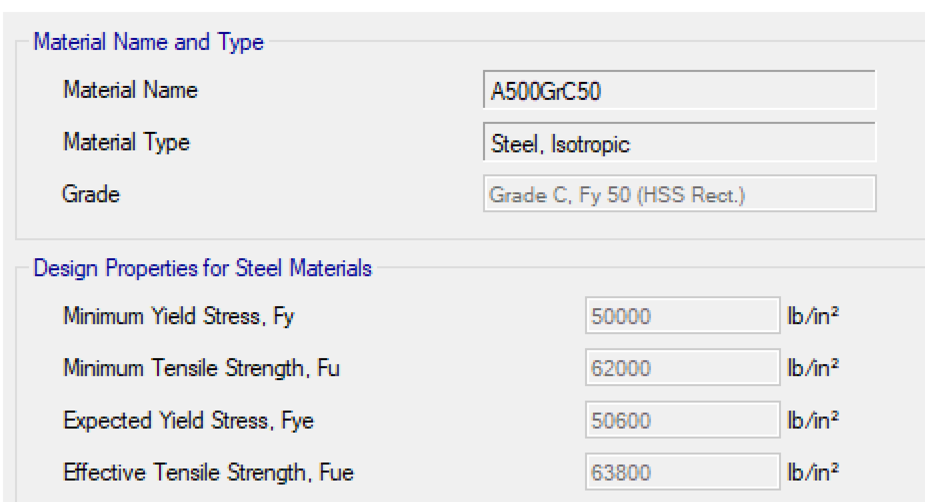


Figure 9 - ETABS Material Properties

Beams were referenced with labels relative to a key plan generated to keep a consistent naming scheme between the ETABS model and hand calculations as seen in Figure 10.

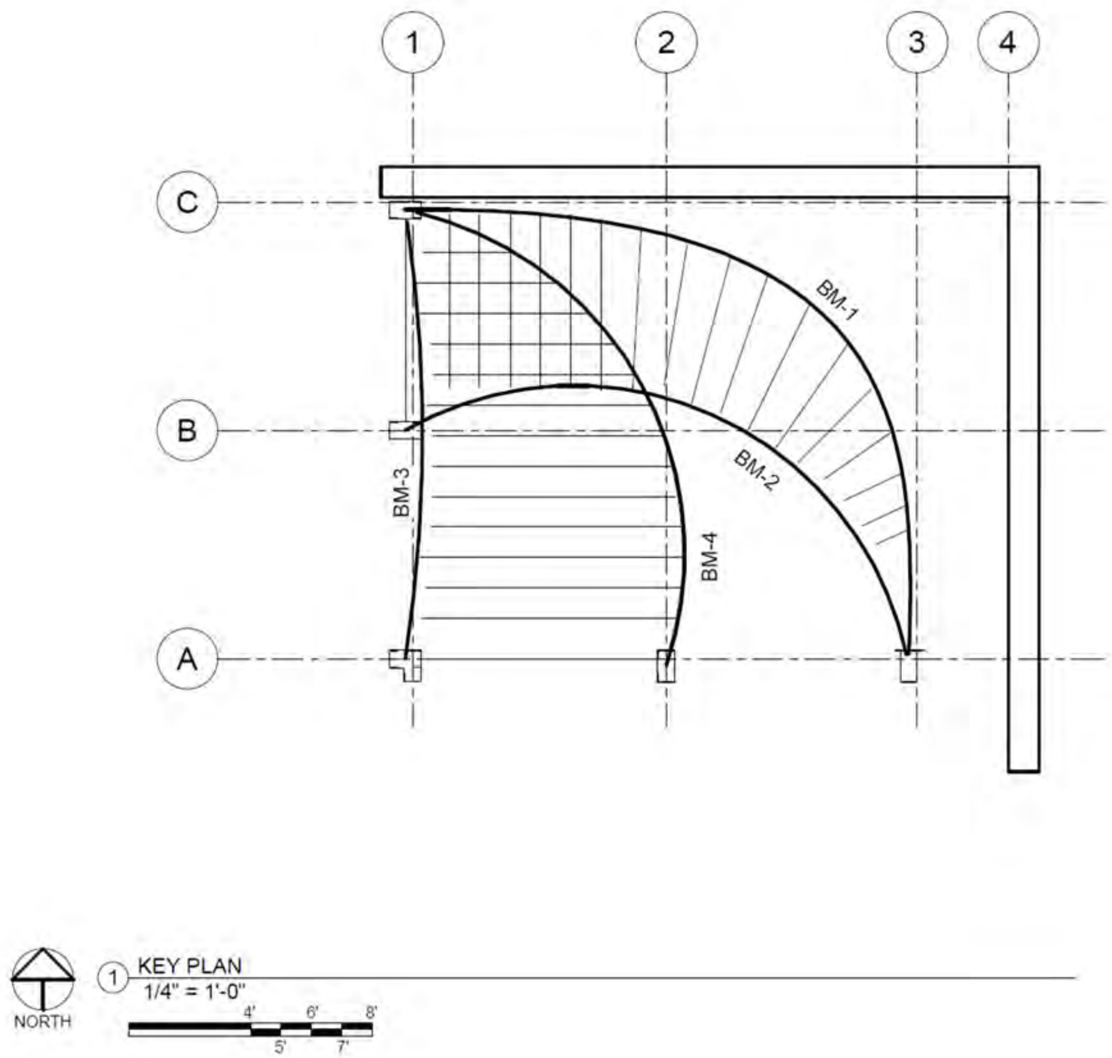


Figure 10 - Key Plan

Beam geometry involved curved members, however ETABS possessed functionality to allow for curved frame objects to be drawn based on certain parameters. For BM-1 a spline curve frame type was chosen with two internal control points as seen in Figure 11. BM-2, BM-3, and BM-4 all used a circular curve frame type with various third points selected to capture the desired radius of curvature which can be seen in Figure 12, Figure 13, and Figure 14 respectively. Additionally, all beams used automatic rigid end offsets based of the geometry with a rigid zone factor of 0 as seen in Figure 15. Frame auto mesh options can be seen in Figure 16 and were identical for all beams.

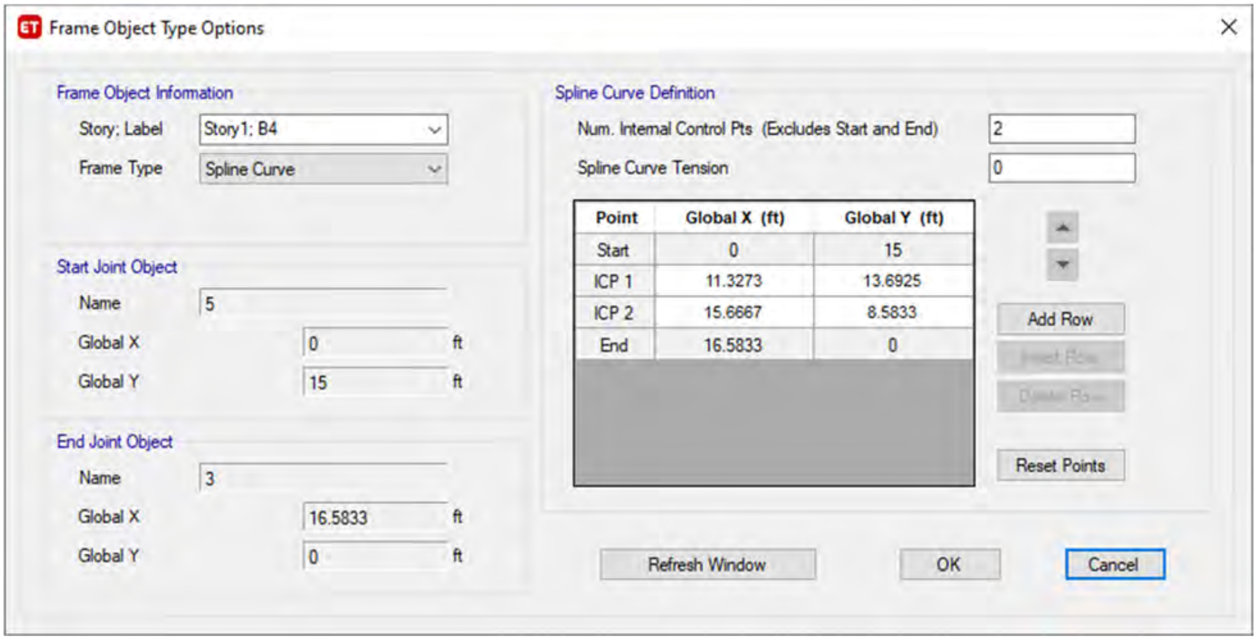


Figure 11 - BM-1 Curved Beam Geometry

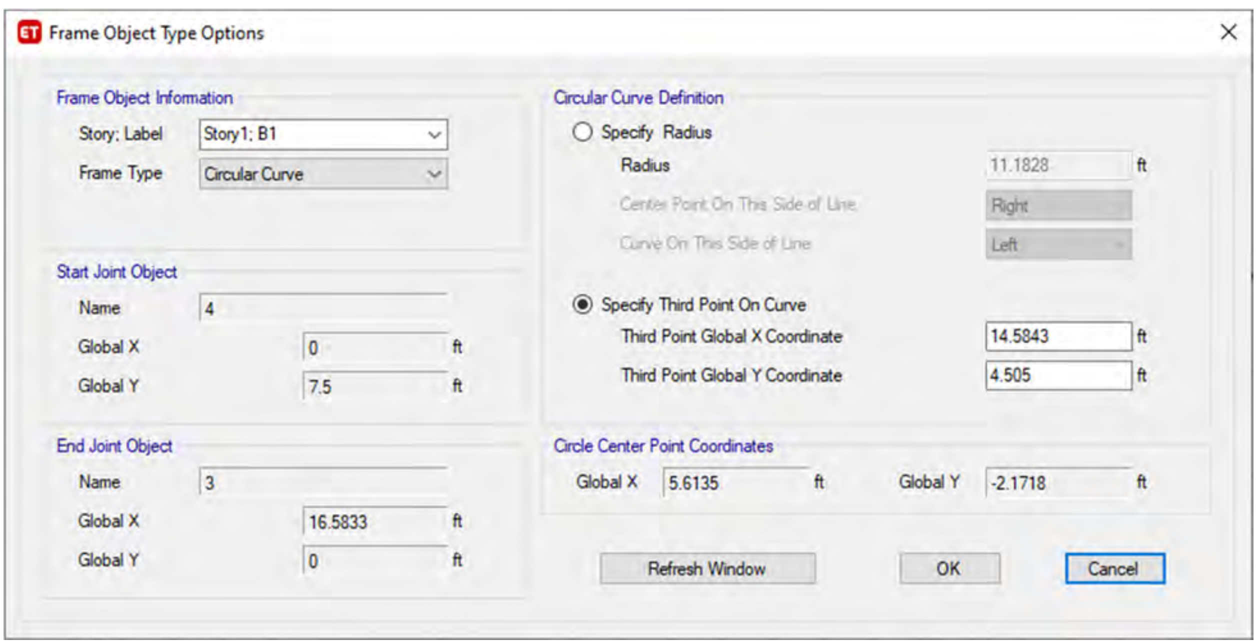


Figure 12 - BM-2 Curved Beam Geometry

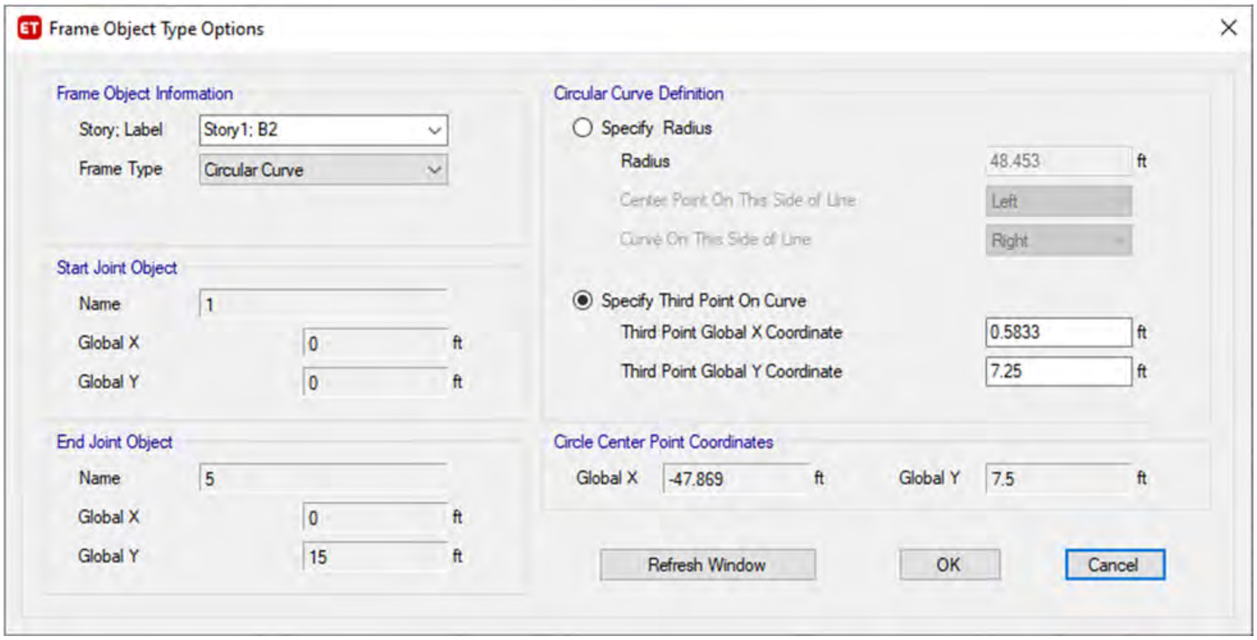


Figure 13 - BM-3 Curved Beam Geometry

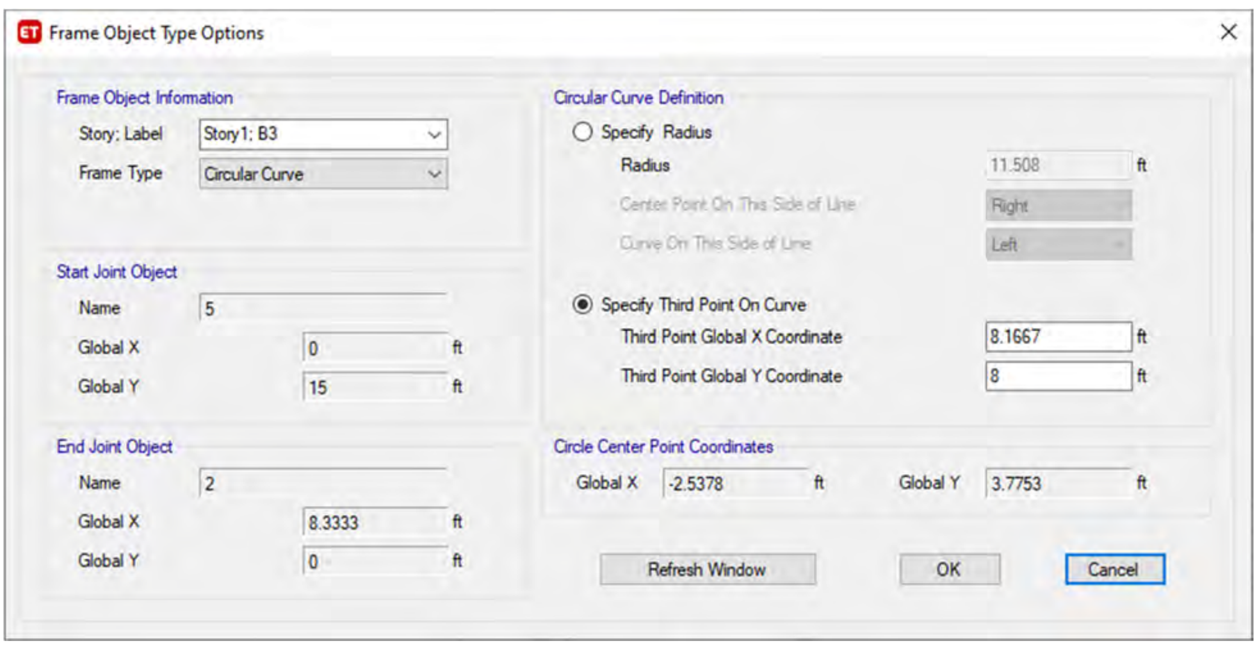


Figure 14 - BM-4 Curved Beam Geometry

Figure 15 - Beam Rigid End Length Offset Settings

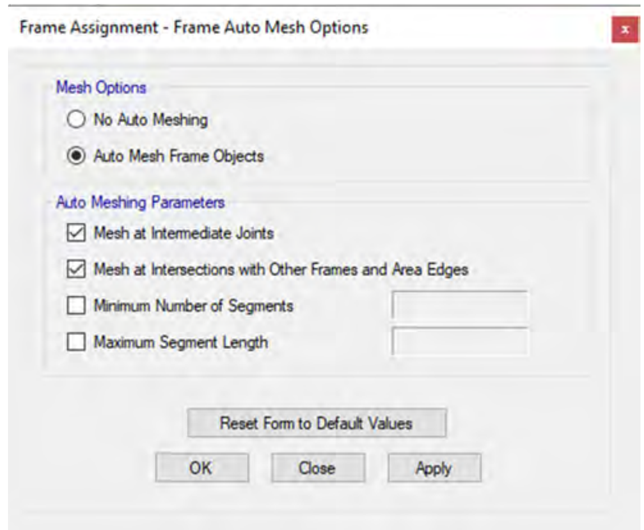


Figure 16 - Beam Auto Mesh Settings

To input loads into the ETABS model, three load patterns were created for dead loads, live roof loads, and wind loads. All load patterns excluded self-weight modifiers. The relevant load combinations were generated using ASCE 7-16 specifications and all load combinations were combined to be compared in an envelope load combination as seen in Figure 17. Then loads were applied as uniformly distributed loads in the gravity direction with magnitudes as seen in Figure 18, Figure 19, and Figure 20.

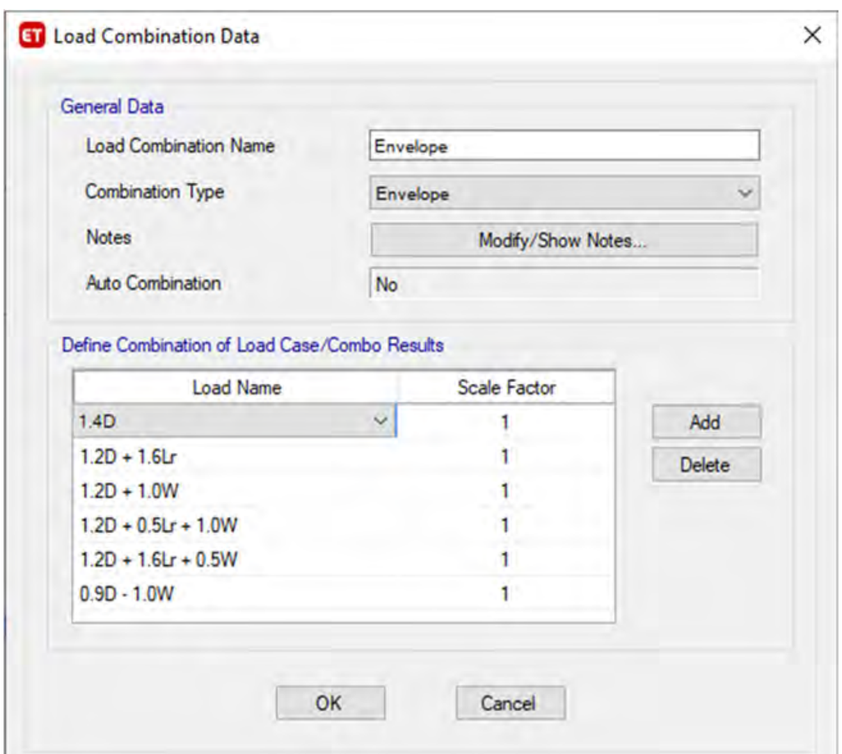


Figure 17 - Load Combinations & Envelope

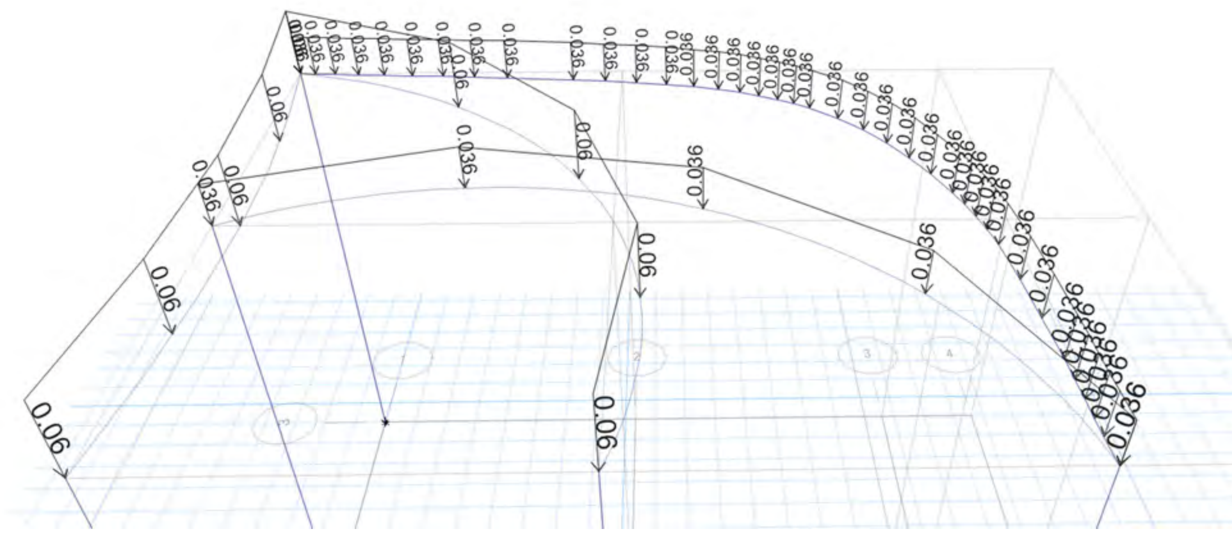


Figure 18 - Applied Dead Loads (klf)

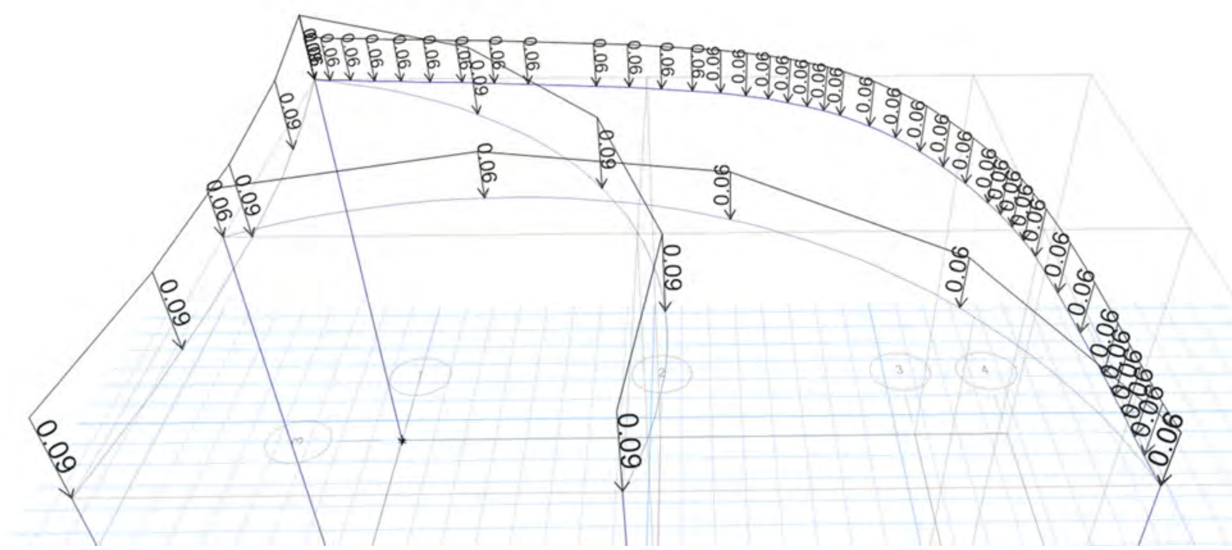


Figure 19 - Applied Roof Live Loads (klf)

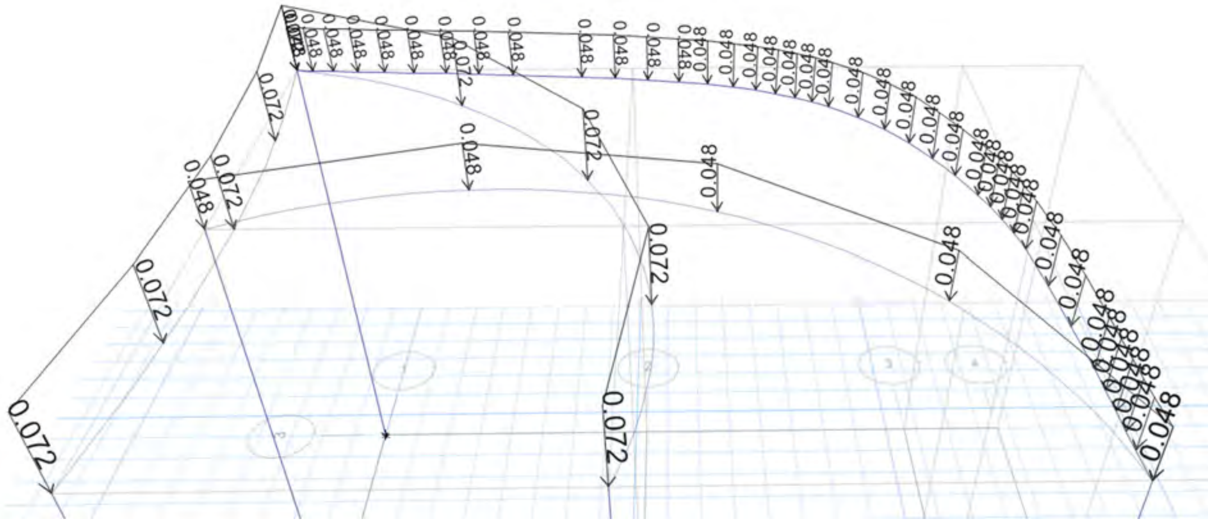


Figure 20 - Applied Wind Loads (klf)

As it was determined that deflection governed the design of the beams, deflection results were taken from ETABS and used to iterate the sizing of the beams quicker than a hand analysis was able. The deflections pulled from ETABS were due to service live roof loads in the vertical direction as seen in Figure 21. It is important to note that these deflection results are conservative because of the fact that the applied loads were based on the assumption that beams experienced a uniform tributary width along their lengths. From the shape of the panels, the tributary width changed along the length of the beam and was lower at one end.

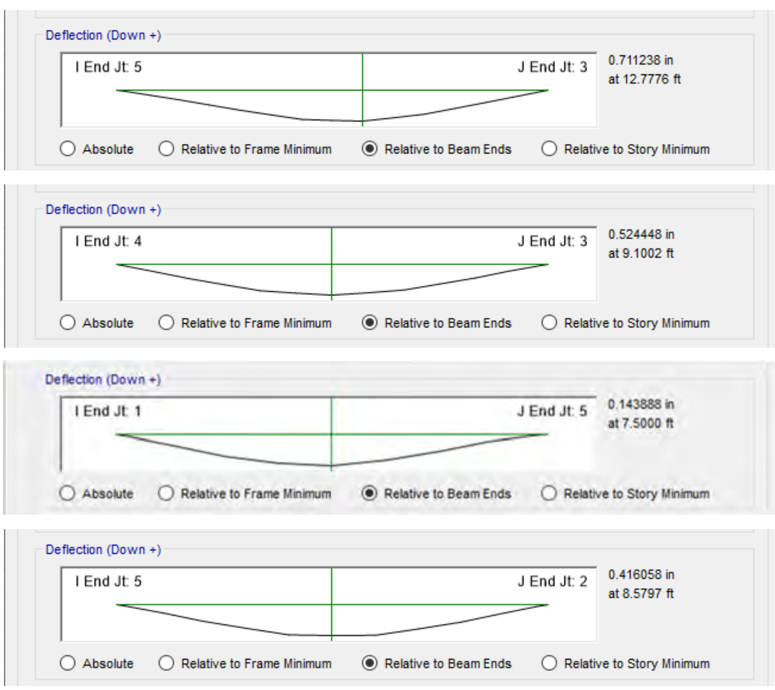


Figure 21 - Max Live Load Deflections BM-1 (top) to BM-4 (bot)

Member force results were pulled from the envelope load combination and absolute maximums were used for major and minor axis bending and shear forces, axial forces, and torsional forces, The member force summaries for beams BM-1, BM-2, BM-3, and BM-4 can be seen in Figure 22, Figure 23, Figure 24, and Figure 25 respectively. Because the beam forces were maximums, they did not coincide at the same point along the length of the member. This resulted in conservative member forces for analysis, however this was not an issue because of the deflection criteria governing the design of the beams.

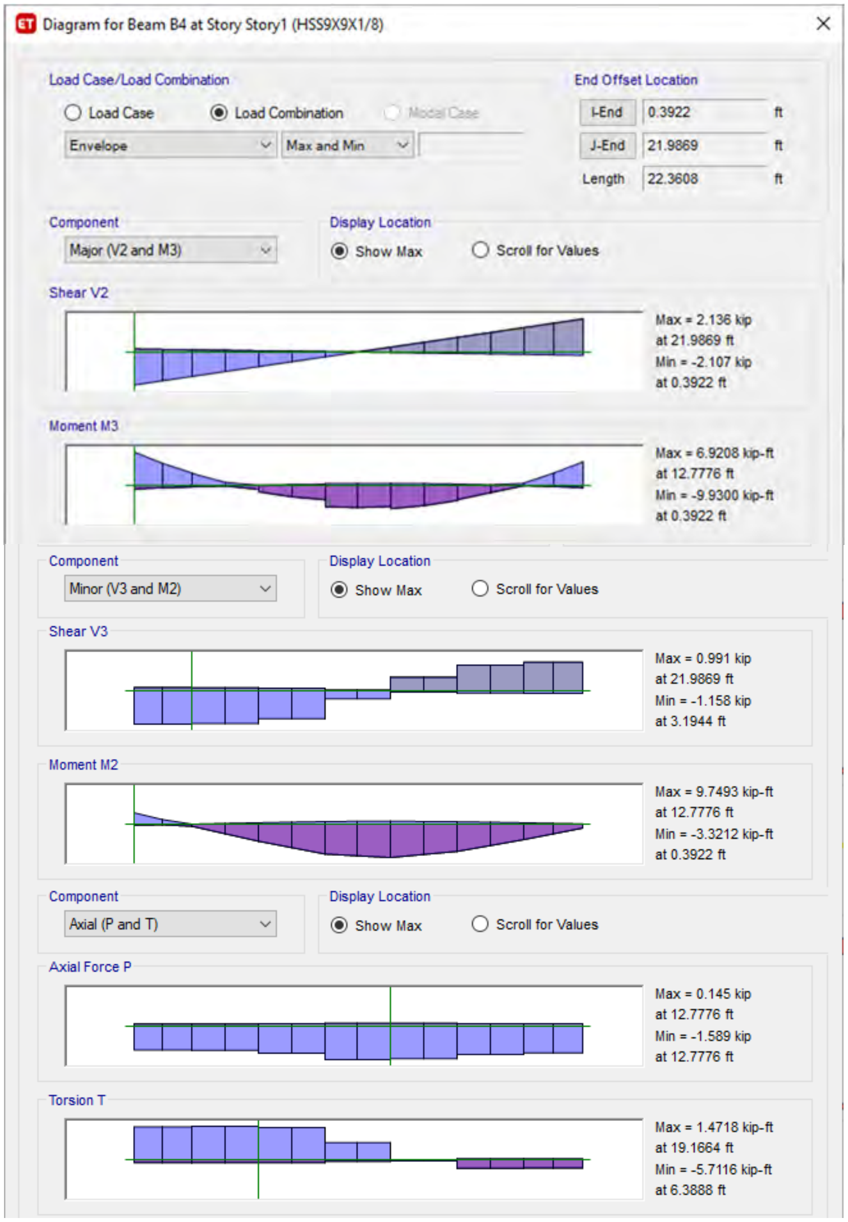


Figure 22 - BM-1 Member Force Summary

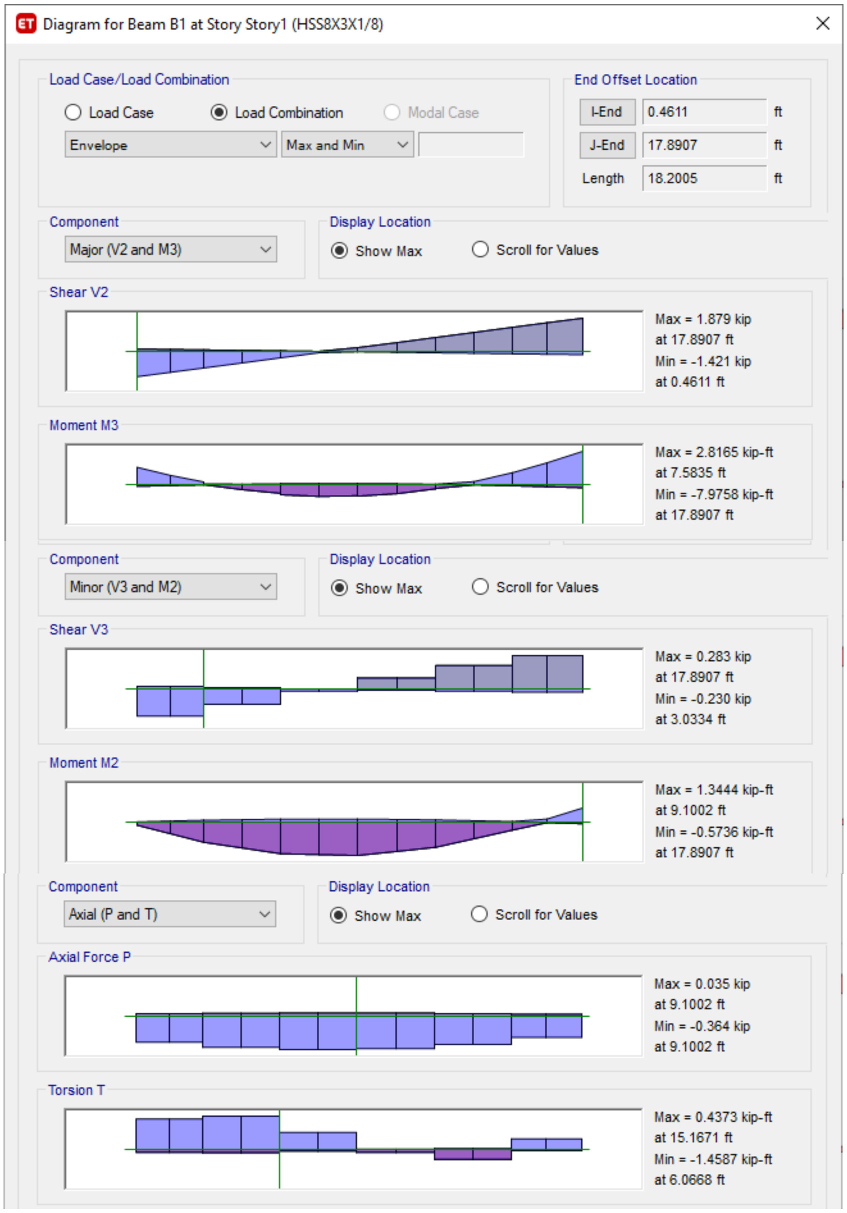


Figure 23 - BM-2 Member Force Summary

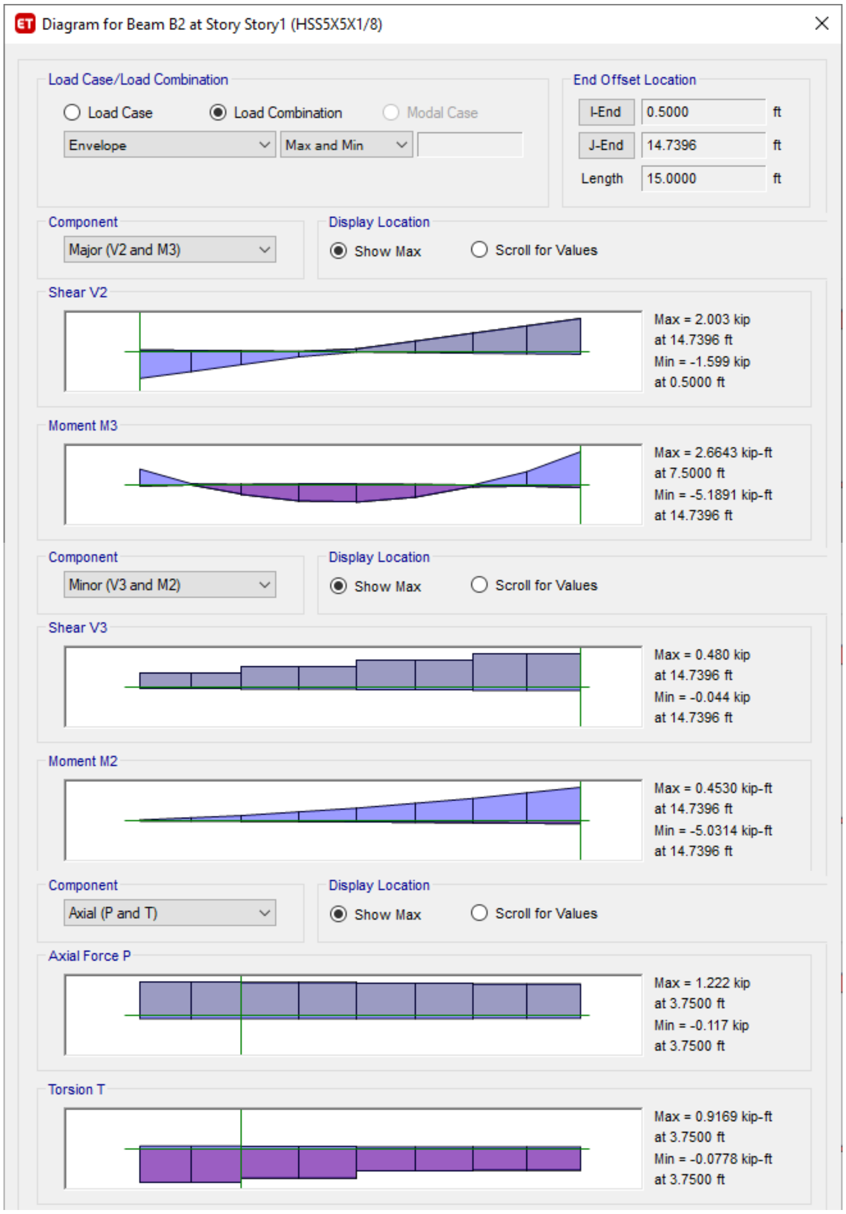


Figure 24 - BM-3 Member Force Summary

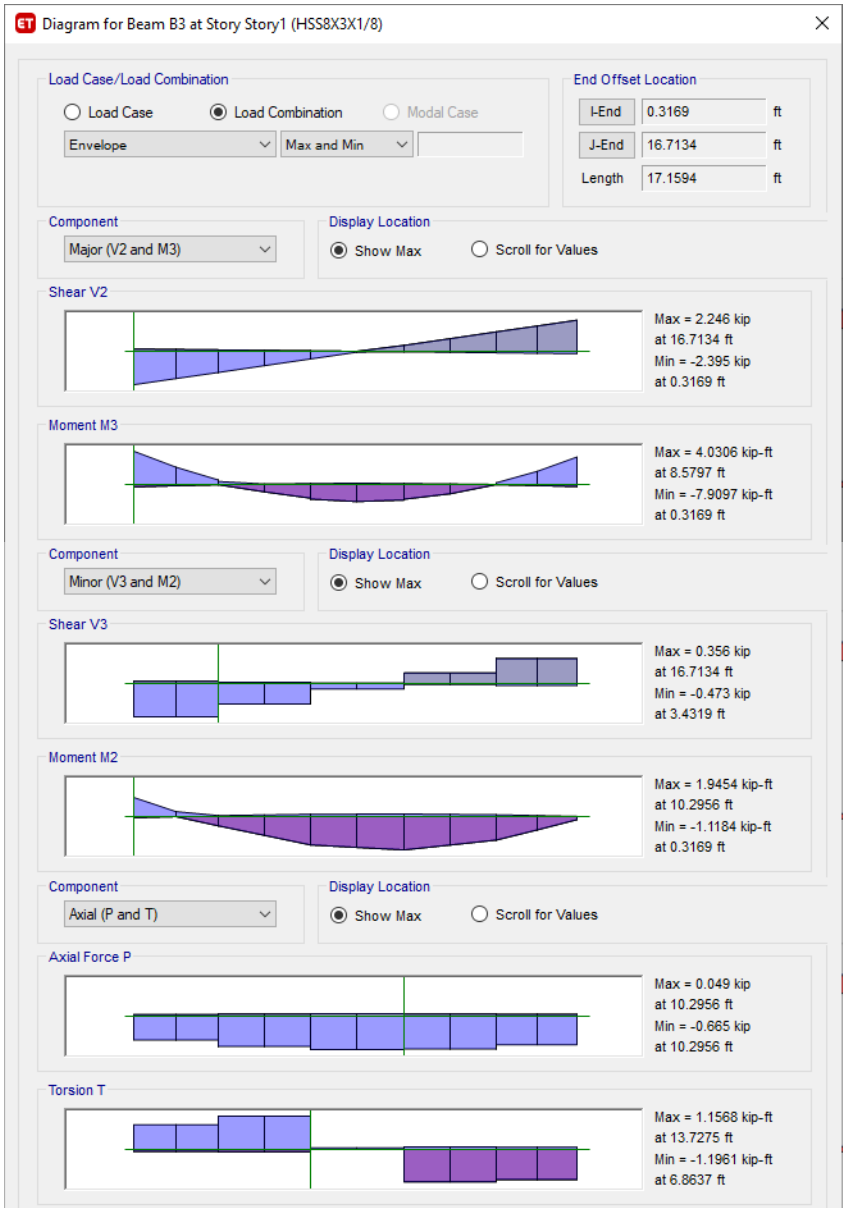


Figure 25 - BM-4 Member Force Summary

Hand Calculations

Hand calculations were used to verify the strength of the members and verify that the selected members for deflection provided sufficient strength. The complete hand calculation package that outlined the design and explains certain assumptions and decisions can be found in Appendix C as a part of the permit package draft.

The allowable deflection of the California Building Code (CBC) Table 1604.3 was based on the sensitivity to deflection of what the deflecting member is supporting. A ceiling supporting a brittle material, such as plaster or stucco, has a smaller allowable deflection because to prevent the material from supporting loads, before the structural members engage, and cracking. Ceilings supporting flexible materials were allowed to deflect more because the material was less likely to crack. It is important to note that the allowable deflections are maximum values. Allowable deflection criteria can be stricter in instances that can impact the comfort and functionality of the structure. For example, floors that deflect significantly can feel bouncy and uncomfortable for occupants. Elevator cable support beams have very small allowable deflections to maintain function. Since the function of the tiered roof-like structure would not be sensitive to deflections, a stricter allowable deflection criterion was not used.

For this senior project, the polycarbonate panels were determined to be flexible and assumed to be able to deflect significantly without yielding. For these reasons, an allowable of deflection L/180 was used to reduce member sizes. This also would provide a visual and tactile warning to any individuals that wish to climb the structure while still remaining completely safe for any nearby occupants.

4.0 CONCLUSIONS

Considerations were made on the design impacts of this senior project with respect to economic, global, and sustainability concerns.

<u>Economic</u>

The patio redesign presented in this report would require minimal to no maintenance by Cal Poly Facilities for the tiered roof-like structure or the new pavers. By not adding more plants to the patio, the maintenance for landscaping was limited to only the existing olive tree and rosemary plant. As such, cost for maintenance would not increase. Additionally, open graded subbase can be a recycled material, reducing economic cost of procuring material. Economic costs would also be reduced with a student constructed project while providing valuable construction and fabrication experience. CAED support shop facilities would be utilized in the fabrication process.

<u>Global</u>

A similar design philosophy of interdisciplinary collaboration has been used in many urban environments and such a process is not limited to this project. The utilization of small spaces can benefit communities by providing more green spaces and bring more

richness to quality views. Improving views to the outdoors would increase occupant productivity by providing a connection to nature and spaces to destress.

Sustainability

Sustainability of the project was always a consideration for the material choices. Steel is a recyclable and reusable material that lasts much longer than the previously implemented wooden senior project which utilized wood. The proposed pavers have a long lifetime and, when implemented correctly, would allow for water percolation into the ground without heavily impacting the site or needing drainage pipes. Allowing rainwater to be collected in the retention area reduces runoff. In the long run, reduced runoff reduces erosion and sedimentation of waterways. There would also be reduced demand on the municipal water systems used to treat storm water. As previously mentioned, the open graded subbase can be a recycled material. This reduces need and demand of new raw materials.

Final Reflection

Through this senior project, many lessons were learned about managing a project and design from both the architectural and structural perspective.

Due to the quarter shortening from 10 weeks to 9 weeks, managing a project proved to be the most difficult aspect of this senior project. Planning was done in the form of a Gantt chart, but the shortened time frame required diligence to complete tasks in time. The most limiting factor for this senior project was time. Because the final deliverable for this senior project was a Cal Poly Facilities permit draft, the amount of time allocated for the design process was strictly followed. While time limited the design process, it also facilitated decision making.

From the architectural perspective, the greatest lesson learned was that the design process is iterative and could potentially go on forever. Schematic designs could be revised and presented to the user multiple times in order to dial in on the ideal solution for the patio redesign. By having a specific date set to choose a design to move forward with, progress towards completing the permit package was possible. Additionally, communication was essential for interviews. Through interviews with professional architects and the users, pictures and plans were the best ways of providing information. In addition, completing site documentation and having conceptual ideas before the interviews was important to have a starting place for discussion.

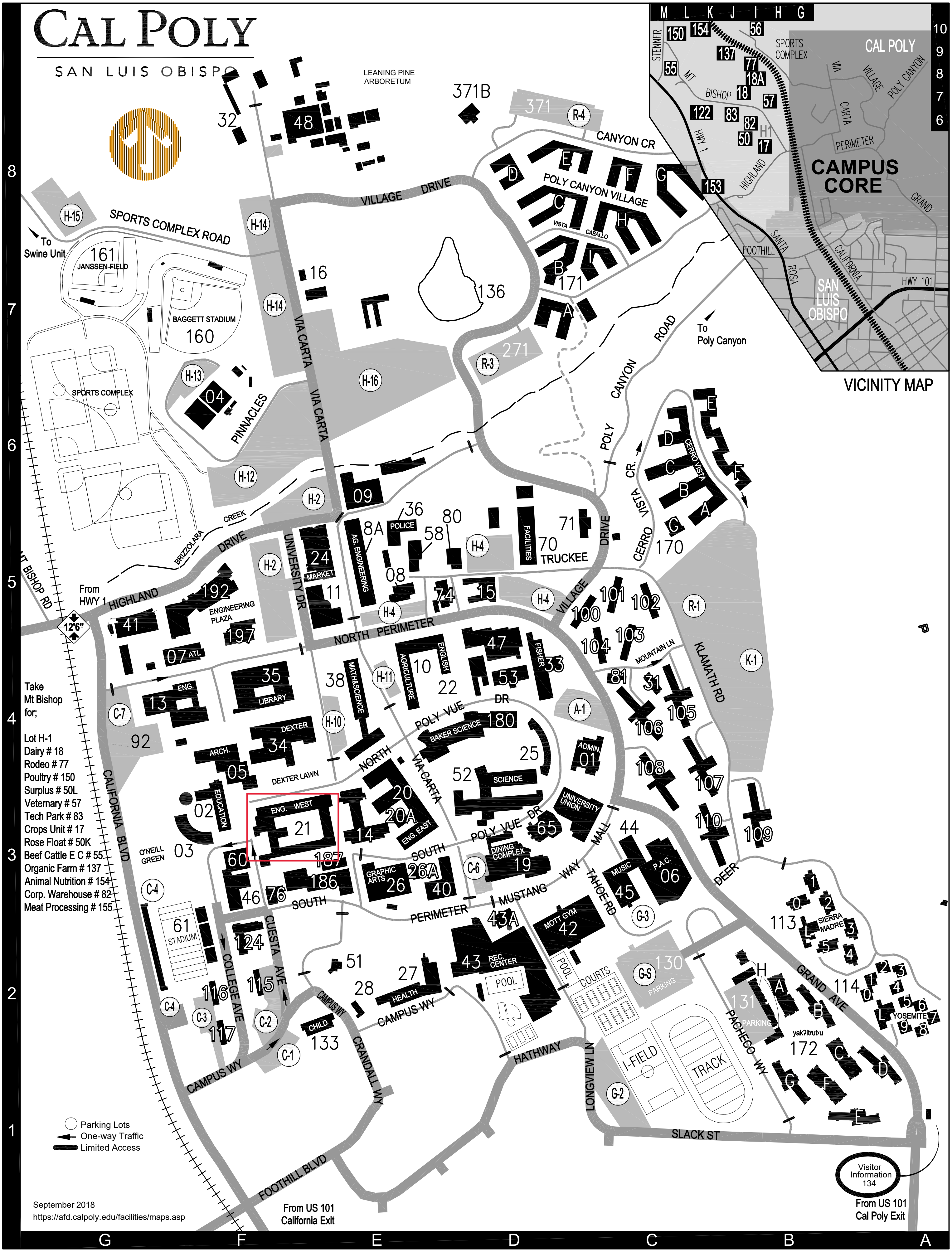
From the structural perspective, the chosen design required visually large members for the given loading. The member sizes needed to be increased because deflections were the controlling factor due to the clear span length. Engineering judgment was developed through this senior project to relate how the depth of the members related to the length. For the members stated in this report, the length to depth ratio was on average 30:1. This ratio agreed with beam design theory in ARCE courses since large length to depth ratios are governed by

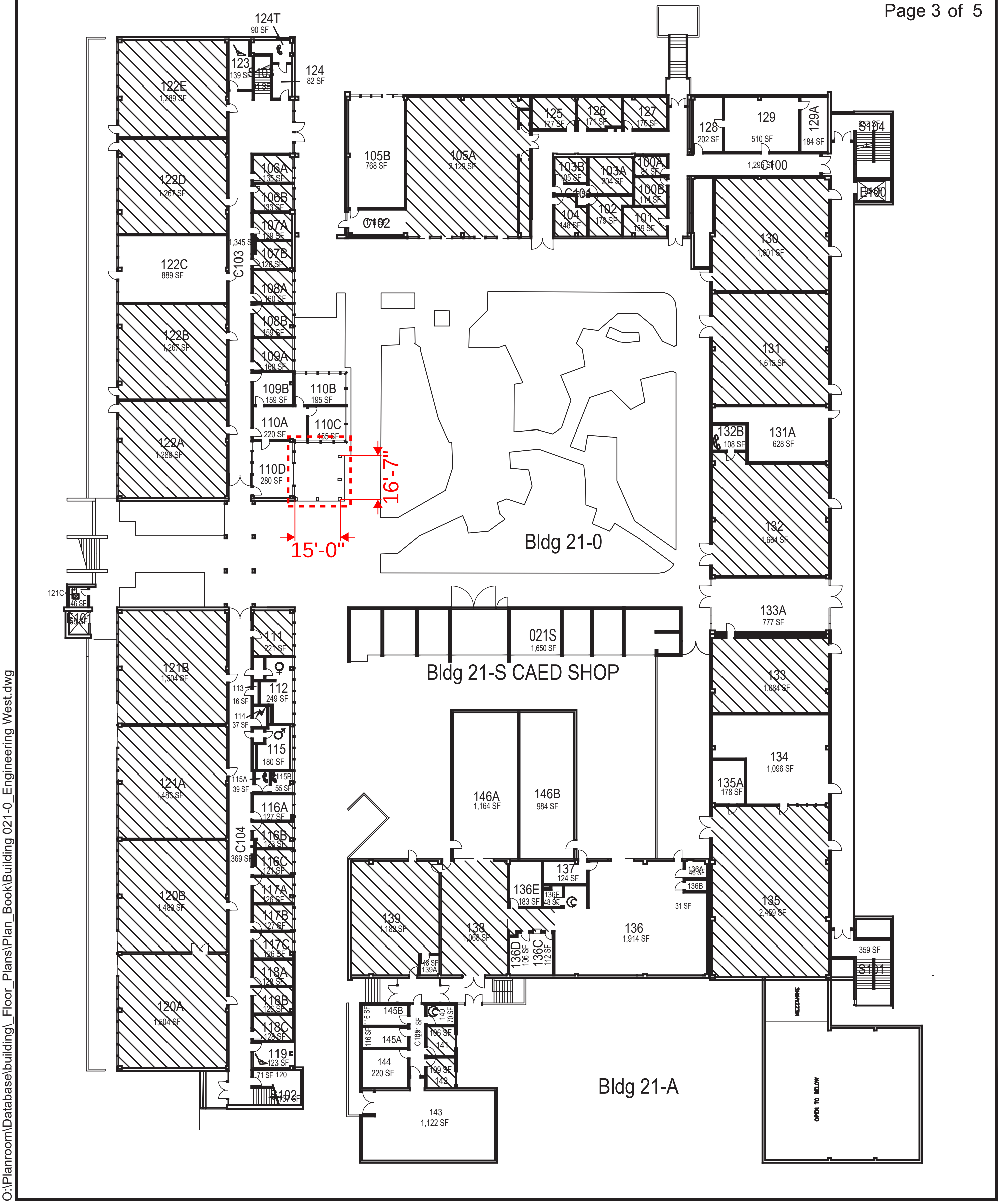
deflection. When completing calculations, building engineering judgement was important in order to recognize when an answer seemed unreasonable and requires further investigation.

Given that the member sizes determined would look large and intrusive in the space, the design presented in this report was not the most ideal design since the tiered roof-like structure may block more sunlight than desired. Additional design iterations were recommended to refine the tiered roof-like structure to meet the users' needs. Below are additional suggestions and important considerations for subsequent senior project groups.

- Consult with those working in the buildings directly adjacent to the patio
- Light and relative quiet was the most important factors
- See who in the ARCE faculty currently spends more time in the conference room and who else would be most impacted by changes
- Avoid disrupting existing olive tree
- Conduct additional interviews with users and professional architects
- The design group would ideally be composed of students from different disciplines such as architecture and land scape architecture
- Consider arching the curved beams rather than having them on a relatively horizontal plane. A confined arch could decrease member sizes
- Consult with Mark Cabrinha (Architecture Professor and CAED Associate Dean of Academic Affairs) about tessellations for further iteration on the tiered roof-like structure or wall screens
- Perform sun analysis to see how the light comes into the office throughout the year
- Do not attach new structures directly to the existing Building 21
- Speak with ARCE Professor Craig Baltimore about Cal Poly colors/materials corresponding to department and administrative controlled buildings (blue, gray, or brick) (Construction Innovations Building is an example)
- Limit depth of overhead members to reduce chance of touching tree branches
- Iterate on connection details. Connections are often the weak link
- Investigate existing strength of the inverted concrete moment frame
- If using HSS, match sizes and varying thicknesses of the sections
- Ensure adequate concrete cover for any new epoxy anchors

5.0 APPENDIX A: Site Documentation


CAL POLY
SAN LUIS OBISPO
LEANING PINE ARBORETUM
371B
371
CANYON CR
POLY CANYON VILLAGE
VILLAGE DRIVE
SPORTS COMPLEX ROAD
To Swine Unit
161
JANSSEN FIELD
BAGGETT STADIUM
160
SPORTS COMPLEX
PINNACLES
VIA CARTA
136
171
271
To Poly Canyon
POLY CANYON ROAD
CERRO VISTA
BRIZZOLARA CREEK
HIGHLAND DRIVE
MT BISHOP RD
From HWY 1
12'6"
ENGINEERING PLAZA
UNIVERSITY DR
MARKET
AG. ENGINEERING
POLICE
FACILITIES
TRUCKEE
VILLAGE DRIVE
170
NORTH PERIMETER
ATL
ENG.
LIBRARY
MATH&SCIENCE
AGRICULTURE
ENGLISH
FISHER
MOUNTAIN LN
KLAMATH RD
DEXTER
POLY VUE DR
BAKER SCIENCE
ADMIN
ARCH.
DEXTER LAWN
SCIENCE
UNIVERSITY UNION
EDUCATION
ENG. WEST
ENG. EAST
O'NEILL GREEN
SOUTH PERIMETER
GRAPHIC ARTS
DINING COMPLEX
MUSTANG WAY
TAHOE RD
MALL
MUSIC
P.A.C.
DEER
SIERRA MADRE
STADIUM
COLLEGE AVE
CUESTA AVE
MOTT GYM
REC. CENTER
POOL
COURTS
PARKING
GRAND AVE
YOSEMITE
HEALTH
CAMPUS WY
CHILD
CRANDALL WY
HATHWAY
LONGVIEW LN
I-FIELD
TRACK
PACHECO WY
SLACK ST
CALIFORNIA BLVD
FOOTHILL BLVD
Take Mt Bishop for;
Lot H-1
Dairy # 18
Rodeo # 77
Poultry # 150
Surplus # 50L
Veternary # 57
Tech Park # 83
Crops Unit # 17
Rose Float # 50K
Beef Cattle E C # 55
Organic Farm # 137
Animal Nutrition # 154
Corp. Warehouse # 82
Meat Processing # 155
Parking Lots
One-way Traffic
Limited Access
September 2018
https://afd.calpoly.edu/facilities/maps.asp
From US 101 California Exit
From US 101 Cal Poly Exit
Visitor Information 134
VICINITY MAP
CAL POLY
CAMPUS CORE
SPORTS COMPLEX
STENNER
MT BISHOP
HWY 1
HIGHLAND
PERIMETER
VIA CARTA
VILLAGE
POLY CANYON
GRAND
FOOTHILL
SANTA ROSA
CALIFORNIA
HWY 101
SAN LUIS OBISPO
G F E D C B A
M L K J I H G



CAL POLY
SAN LUIS OBISPO
Facilities

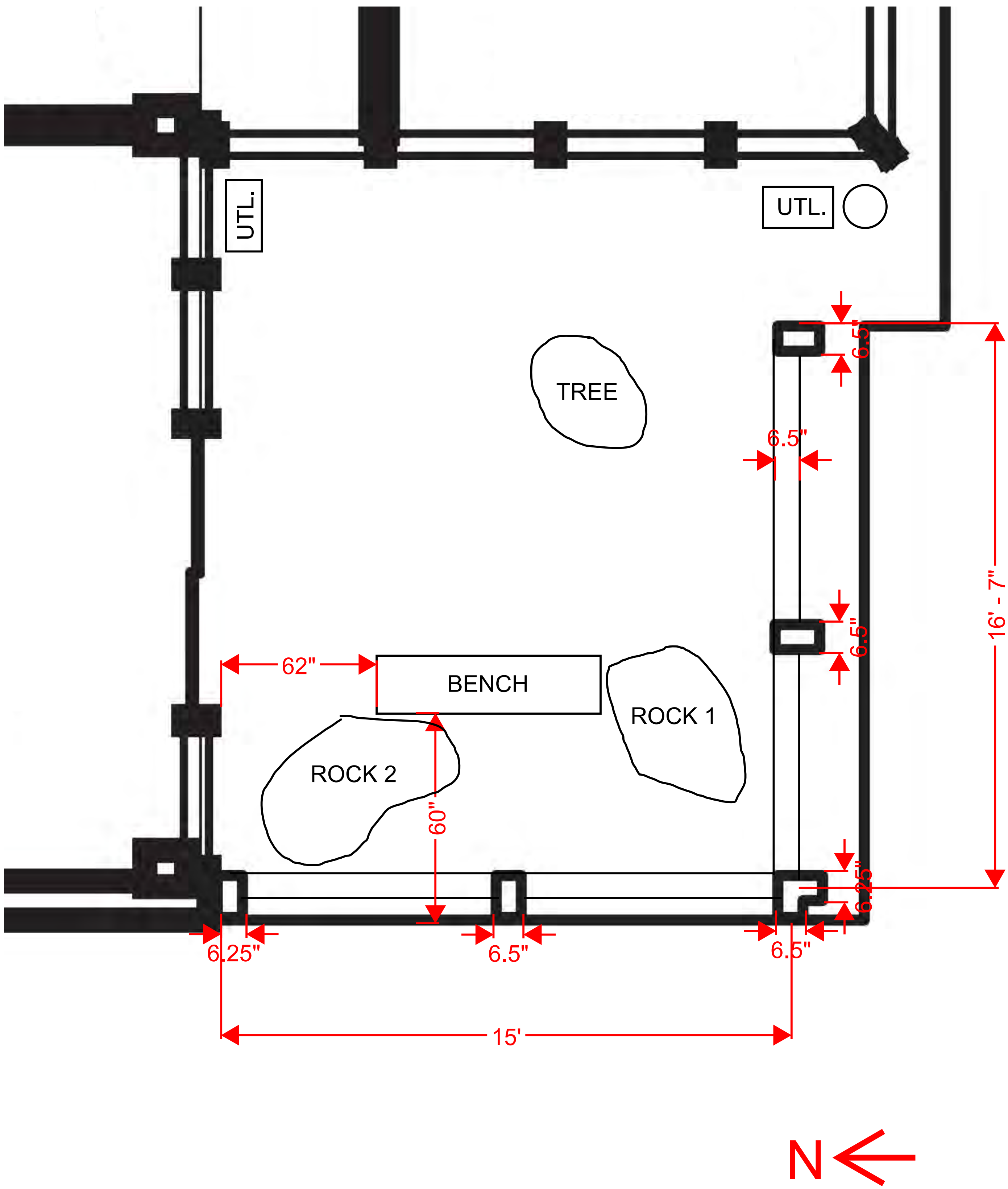
Engineering West

Floor 2
Space Data http://afd.calpoly.edu/facilities/spacefacility/space_data.asp

August 2019

1"=45'

CLOSE UP OF FACITILITIES PLAN



Piazza di Ulivo

COLMAHA INC.

COLMAHA

DATE:
5/14/2020 2:01:00 PM

SITE:
Engineering West
California Polytechnic
State University,
San Luis Obispo

CHECKED BY:
CB

DRAWN BY:
SH,DC

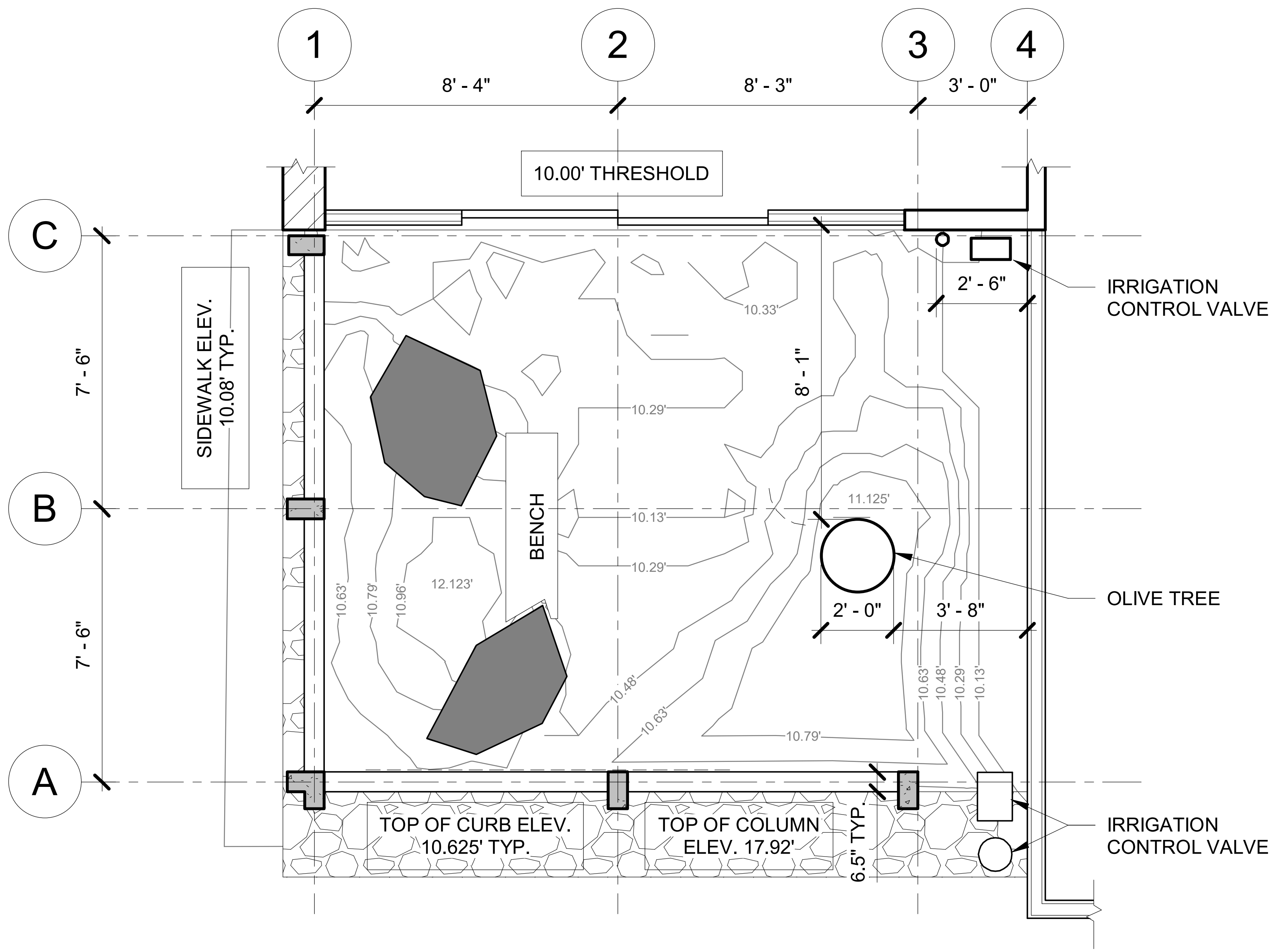
SCALE:
1/4" = 1'-0"

SHEET NAME:
EXISTING SITE PLAN

SHEET NUMBER:
S1.1

PLAN NOTES:

- MASONRY
- WINDOWS
- CONCRETE
- PARTIION WALL
- SLIDING DOOR
- ROCK
- GRAVEL



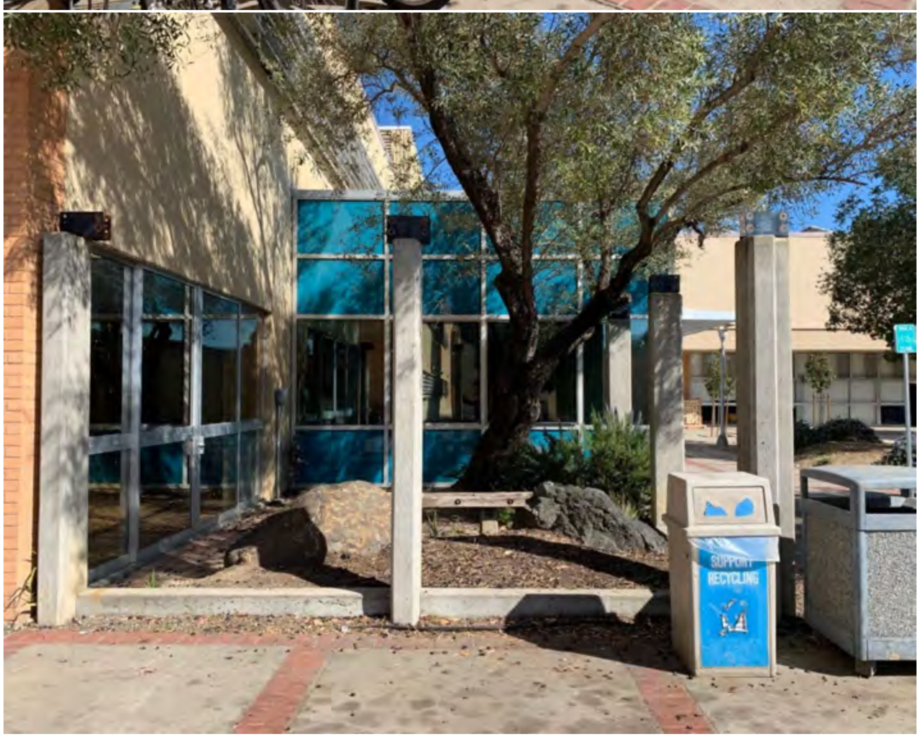
NORTH

1 EXISTING SITE PLAN
1/4" = 1'-0"

4' 6' 8'
5' 7'

APPROACHING FROM NORTH WEST

NOTE CAMPUS VEHICLES AND STUDENT BIKES



APPROACHING FROM WEST

TRASH CANS

OLIVE STAINS ON PAVEMENT

TREE EXTENDING BEYOND COLUMNS

APPROACHING FROM SOUTH WEST

TRASHCANS

APPROACHING FROM SOUTH EAST

SOUTH VIEW OF INTERIOR

SLIDING DOOR TO CONFERENCE ROOM

CLOSE UP OF BENCH

CLOSE UP OF COLUMN

CLOSE UP OF CURB

CLOSE UP OF ROCK 1

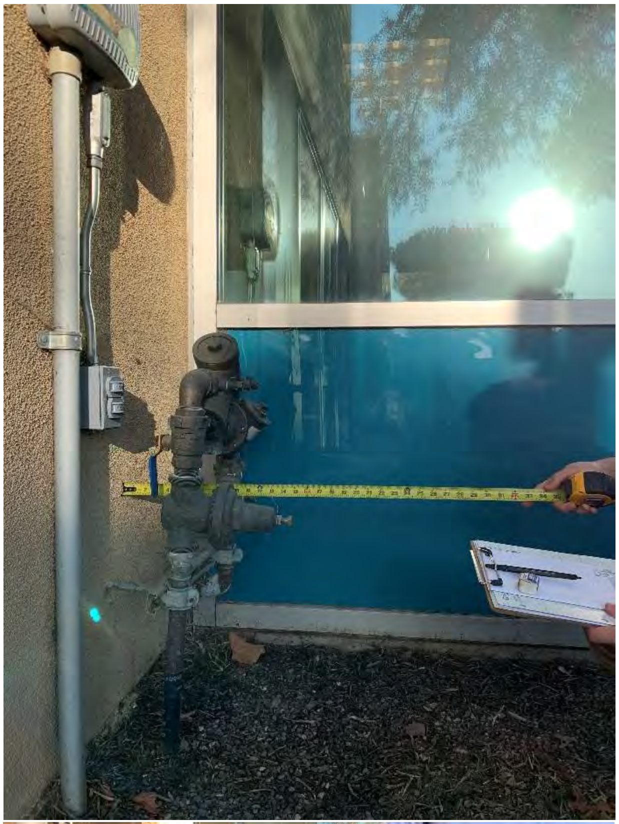
CLOSE UP OF ROCK 2

CLOSE UP OF CORNER COLUMN

CLOSE UP OF PLATE AT TOP OF COLUMN

TOP OF NORTH WEST COLUMN

TOP OF SOUTH EAST COLUMN



UTILITIES AT NORTH EAST CORNER

VIEW OF WINDOW OPENING INTO SITE AND UTILITIES ACCESS

VIEW OF UTILITIES ACCESS FROM EXTERIOR

SHRUB EXTENDING OUTSIDE OF CURB


HUMAN FOR SCALE

LEAVES

VIEW OF BRANCHES IN PROXIMITY TO COLUMN

ADDITIONAL VIEW OF BRANCH NEAR COLUMN

GAP BETWEEN NORTH WEST COLUMN AND BUILDING 21

OLIVES ON GROUND INSIDE SITE

OLIVE STAINS ON PAVEMENT OUTSIDE OF SITE

OLIVE CADAVERS OUTSIDE SITE

UNEVEN PAVERS

VIEW OF SITE FROM CONFERENCE ROOM

CEILING AND TOP OF SLIDING DOOR

VIEW OF SITE FROM INSIDE CONFERENCE ROOM

VIEWS OF SITE FROM OFFICE WINDOW 1

VIEW OF SITE FROM OFFICE WINDOW 2

ADDITIONAL IMAGE FROM OFFICE 2

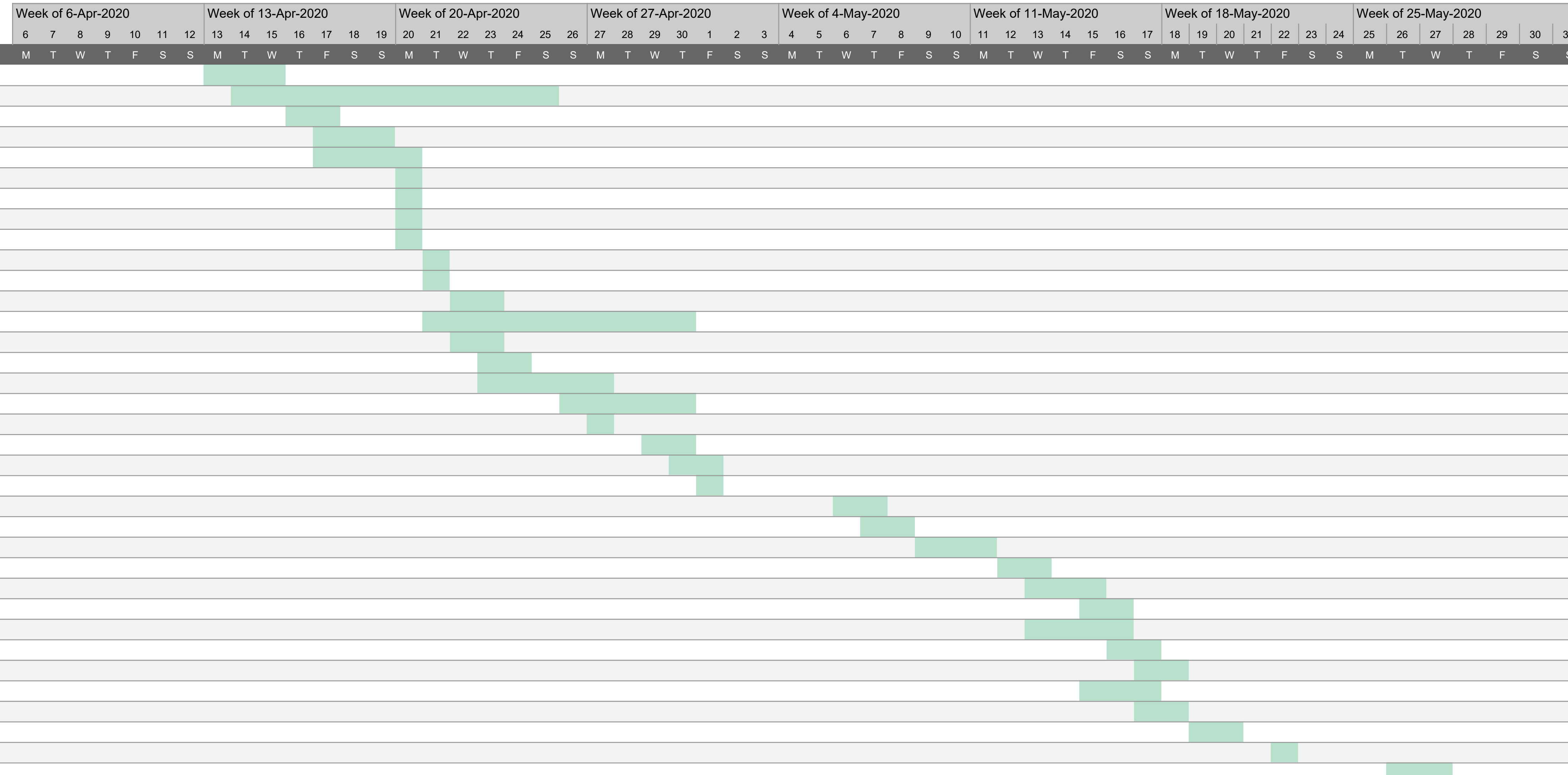
NOTE CLOSED WINDOW BLIND

6.0 APPENDIX B: Gantt Chart and Example Forms

Piazza di Olivo

Project Start:	Mon, 6-Apr-2020
Project End:	Fri, 22-May-2020

TASK	DURATION	START	END
as built measurements	3 Days	13-Apr-2020	15-Apr-2020
create as built drawings/revit model	12 Days	14-Apr-2020	25-Apr-2020
contact clients to schdeule zoom interviews	2 Days	16-Apr-2020	17-Apr-2020
schematics for canopy/cantilever	3 Days	17-Apr-2020	19-Apr-2020
find second advisor	4 Days	17-Apr-2020	20-Apr-2020
contact art committee	1 Days	20-Apr-2020	20-Apr-2020
interview al	1 Days	20-Apr-2020	20-Apr-2020
interview erica	1 Days	20-Apr-2020	20-Apr-2020
interview jaime	1 Days	20-Apr-2020	20-Apr-2020
interview pamalee	1 Days	21-Apr-2020	21-Apr-2020
interview jill	1 Days	21-Apr-2020	21-Apr-2020
reflct on each interview	2 Days	22-Apr-2020	23-Apr-2020
design development for screen wall and deck	10 Days	21-Apr-2020	30-Apr-2020
write up section of report	2 Days	22-Apr-2020	23-Apr-2020
send section of report to CB	2 Days	23-Apr-2020	24-Apr-2020
write out demolition plan	5 Days	23-Apr-2020	27-Apr-2020
write out building plan	5 Days	26-Apr-2020	30-Apr-2020
pitch to art committee	1 Days	27-Apr-2020	27-Apr-2020
write up section of report	2 Days	29-Apr-2020	30-Apr-2020
send section of report to CB	2 Days	30-Apr-2020	1-May-2020
pitch to faculty	1 Days	1-May-2020	1-May-2020
write up section of report	2 Days	6-May-2020	7-May-2020
send section of report to CB	2 Days	7-May-2020	8-May-2020
design development for canopy/cantilever	3 Days	9-May-2020	11-May-2020
create analysis model of canopy in software	2 Days	12-May-2020	13-May-2020
write up for permitting submittal	3 Days	13-May-2020	15-May-2020
analyze loads on deck/deflection	2 Days	15-May-2020	16-May-2020
calculations for canopy/cantilever	4 Days	13-May-2020	16-May-2020
calcs for screen?	2 Days	16-May-2020	17-May-2020
calcs for deck	2 Days	17-May-2020	18-May-2020
complete report	3 Days	15-May-2020	17-May-2020
CB & second advisor review report & permit	2 Days	17-May-2020	18-May-2020
finalize report	2 Days	19-May-2020	20-May-2020
present project	1 Days	22-May-2020	22-May-2020
upload to digital commons	2 Days	26-May-2020	27-May-2020



Piazza di Ulivo

Project Start: Mon, 6-Apr-2020
Project End: Fri, 22-May-2020

#	TASK	Progress	DURATION	START	END	Date Completed
1	**As Built measurements**					
1.1	as built measurements	100%	12 Days	14-Apr-2020	25-Apr-2020	
1.2	create as built drawings/revit model	90%	12 Days	16-Apr-2020	27-Apr-2020	
2	**Interview Clients**					
2.1	contact clients to schdeule zoom interviews	100%	2 Days	16-Apr-2020	17-Apr-2020	
2.2	interview al	100%	1 Days	20-Apr-2020	20-Apr-2020	
2.3	interview erica	100%	1 Days	20-Apr-2020	20-Apr-2020	
2.1	interview jaime	100%	1 Days	21-Apr-2020	21-Apr-2020	
2.5	interview pamalee	100%	1 Days	21-Apr-2020	21-Apr-2020	
2.6	interview jill	100%	1 Days	20-Apr-2020	20-Apr-2020	
2.7	reflct on each interview	100%	2 Days	22-Apr-2020	23-Apr-2020	
3	**Report Write Up**					
3.1	write up section of report	0%	4 Days	24-Apr-2020	27-Apr-2020	
3.2	write up section of report	0%	5 Days	30-Apr-2020	4-May-2020	
3.3	write up section of report	0%	2 Days	6-May-2020	7-May-2020	
3.4	complete report	0%	3 Days	15-May-2020	17-May-2020	
3.5	finalize report	0%	2 Days	19-May-2020	20-May-2020	
3.6	**Permit Package**					
3.7	write out demolition plan	0%	5 Days	23-Apr-2020	27-Apr-2020	
3.8	write up building plan	0%	5 Days	30-Apr-2020	4-May-2020	
3.9	write up for permitting submittal	0%	3 Days	13-May-2020	15-May-2020	
3.10	complete permit					
3.11	finalize permit					
5	**Design Process**					
5.1	schematics for canopy/cantilever	100%	8 Days	16-Apr-2020	23-Apr-2020	
5.2	design development for canopy/cantilever	0%	3 Days	9-May-2020	11-May-2020	
5.3	design development for screen wall and benche	60%	10 Days	21-Apr-2020	30-Apr-2020	
5.4	create analysis model of canopy in software	0%	2 Days	12-May-2020	13-May-2020	
5.5	calculations for canopy/cantilever	0%	4 Days	13-May-2020	16-May-2020	
5.6	calcs for screen wall	0%	2 Days	16-May-2020	17-May-2020	
5.7	calcs for bench	0%	2 Days	17-May-2020	18-May-2020	
5.8	analyze loads on deck/deflection	0%	2 Days	15-May-2020	16-May-2020	
6	**Miscelaneous**					
6.1	find second advisor	50%	4 Days	24-Apr-2020	27-Apr-2020	
6.2	contact art committee	100%	1 Days	27-Apr-2020	27-Apr-2020	
6.3	pitch to art committee	100%	1 Days	29-Apr-2020	29-Apr-2020	
6.4	pitch to faculty	0%	1 Days	1-May-2020	1-May-2020	
6.5	CB & second advisor review report & permit	0%	2 Days	17-May-2020	18-May-2020	
6.6	present project	0%	1 Days	22-May-2020	22-May-2020	
6.7	upload to digital commons	0%	2 Days	26-May-2020	27-May-2020	

Senior Project Weekly Meeting Notes

Date: April 20, 2020 **Time**: 3:30 PM – 4:30 PM

Location: Zoom Meeting

Project Name: Piazza de Ulivo

Attendees:

Name	Position	Email
Dr. Craig Baltimore (CB)	Advisor	cbaltimo@calpoly.edu
David Colman (DC)	Student	dcolman@calpoly.edu
Sophia Ha (SH)	Student	soha@calpoly.edu

Meeting Notes

Discussion

1. Gantt chart is living. Add number to completed things with completed date. Include files to summary notes to help us find things when we are closer to the end. See email attachment on 4/20 agenda. Some Gantt charts are organized by subject and others by date. As it changes, send it to CB
2. Erika interview:
    a. Strong opinions on natural light and how changes may affect her work environment
    b. Good points about security about offices and conference room with increased concealment
    c. Concern about too much cover from the screen walls. Wants a lot of natural light
    d. Currently the door has 4 security measures (locks and some pins) so would be very hard to open on its own. Security issues can be addressed
    e. Think about natural light. Could be cool to monitor with light sensor, put light study into project for someone to carry on
    f. Students in the area are distracting, how to make the area look less inviting to them? From her experience, many students will sit on the bench and have phone conversations and have to fight them off. Make benches more concealed with tall foliage
    g. Write up concerns and how to address it in for record keeping
    h. Very keen on repaving and having a flat service for occasions when the doors are open like order of the engineer and open house
3. Al informal interview and first impressions:
    a. Concern about closing off area because he wants access to bring things in and out of the conference room more easily
    b. Doesn't want to necessarily ban students from using the space
    c. Wants to know about material of panels and thickness
    d. Didn't want the final judgement and wants to get input from more faculty
    e. Interested in updates and may know possible donors
4. Lesson from interviewing people, western culture: people tell you what is wrong and rarely give positive input

5. Jill will not be interviewed
6. Waiting for Pamalee response
7. Jaimie interview scheduled. Note responses and where concerns lie among interviewees
8. Design development of screen wall: Need a path for access outside and for gardener
9. Loose planters may not be allowed on campus (it is considered movable)
10. Go to landscape architect when designing planters because there are many things to consider: hardiness of plants, how it looks in different seasons, fighting off bees?, root bound issues
11. Panel material: solid panels or fabric? Come up with design first
12. As-built model:
    a. Plan with dimensions: locate rocks, bench, valves, tree
    b. Plan with contour lines
    c. Door governs all, as-built plan will help us know how to grade the area
    d. True north and reference north needed on plan
    e. Try and extend building a little bit for more context
    f. Surveying walk contour or grid method
    g. Put existing threshold, bottom of door elevation, at 10'
13. Existing, demolition, paving needed for permit at least
14. Demolition plan and regrading:
    a. Copy over existing plan "rock to be removed","…subbase…2"sand", "dirt removed to elevation…", "tree limbs to be cut back…"
    b. Diagrammatic and simple
    c. Where is the dirt going to be dumped? Go to Kevin Piper from Agriculture and ask
    d. What to do about the rocks? Landscape places (Central Coast Landscapers) "you guys want rocks?" "can I put a note on your board that I have two rocks , I am a student"
    e. Chances are facilities will be doing the work unless students do it
15. Gantt chart in good shape, start writing about Erika interview. Just put summary down. don't have to address concerns yet
16. Pick something for canopy and stick with it. Decide on Thursday "this is what it will look like"
17. Get as-built plan done next week
18. First draft permit: don't write in third person. "meetings were held every week". Writing will take a lot of time to do and review. Remember to send to CB in sections
    a. 3/4 of write ups for the senior project reports aren't written on time
    b. Summary is same for permit and report!
19. Contact art committee this week
20. As builts, start on summary rough drafts, permitting table of contents need to be completed
21. Project senior project: 3 sections self-contained
    a. Experience of working with governing agency. Second part?
    b. How to manage project from start to finish (gantt chart, etc.) engineering included?
    c. Design: first section?
    d. Takes time to do things professionally

Deliverables

Item	Description	RP	Due
1	Finish as-built plans	SH,DC	4/27
2	Update Gantt Chart timeline and summary	SH,DC	4/27
3	Contact Art Committee	SH	4/27
4	Write section of Senior Project Report	SH,DC	4/27
5	Decide on canopy concept	SH,DC	4/23
6	Permit table of contents and summary drafts	SH,DC	4/27

Deliverables Description

1. As-builts should have contour lines, dimensions, and True North arrow
2. Update Gantt chart and send to CB. Include summaries for each completed task
3. Contact Catherine Trujillo about Art Committee requirements
4. Begin writing sections for report about finished tasks and experiences
5. Decide on design to pursue until feedback from faculty can narrow down direction
6. Plan out permit report and write out table of contents and summary

Please notify of any revisions, clarifications, or additions within 48 hours of receipt

Sincerely,

Sophia Ha

(http://www.calpoly.edu/)

Administration & Finance (/)

A&F Services (/services) my CalPoly login (https://myportal.calpoly.edu)

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A&F HOME (/) / FACILITIES MANAGEMENT & DEVELOPMENT (/FACILITIES/) / SERVICES (/FACILITIES/SERVICES/) / BUILDING PERMITS

Building Permits

Cal Poly's Building Permit Program formalizes all project planning and code compliance reviews performed by various departments, auxiliaries and committees. Permit requests are submitted to the Facilities Management & Development Help Center.

Building Permits fall into two categories: 1) Permits initiated by Facilities Planning & Capital Projects as part of a project and 2) Permits initiated by a campus entity which is not part of a project. If your project has a Facilities Project Manager they will handle the permitting process for you.

Under specific circumstances a Department or Auxiliary may undertake a project with their own resources. Please allow a minimum of six weeks when submitting a permit request to allow for inspections, plan review, and State Fire Marshall approval. Please include supporting documentation with your permit request such as a scope description, specifications, plans, drawings, photos, etc. and be sure that it is signed by the authorizing entity for your department.

Activities Requiring a Building Permit

- Any furniture installation
- Activities involving building or roof structures
- Activity that will disturb any building surface (interior or exterior)
- Any activity with temporary membrane structures, tents, or canopies
- Any activity in or adjacent to a designated waterway, creek or drainage route
- Any activity that may add, alter or modify ada requirements
- Any underground or overhead work
- Awnings and trellises
- Building additions, alterations, remodels and/or tenant improvements
- Electrical, mechanical, plumbing or building additions or alterations
- Equipment installation requiring more than plug and cord
- Garden walls and retaining walls
- Landscaping and related improvements or modifications, including drainage
- Patios, decks and fences
- Satellite dish or antenna installations, modifications or removals on campus
- Security & intrusion alarms including keypads, card swipes, panic buttons etc.

About(/facilities/about)

Service Request Help Center (/facilities/service-request-help-center)

Planning & Capital Projects (/facilities/planning-capital-projects/)

Campus Maps (/facilities/campus-maps/)

Services(/facilities/services)

Architectural Trades (/facilities/services/ trades)

Building Permits (/facilities/services/buil permits)

Bulletin Boards (/facilities/services/bulle boards)

Cold or Hot (/facilities/services/cold-hot)

Custodial Services (/facilities/services/cus services)

Events(/facilities/services/event

Fleet Services (/facilities/services/fleet services)

Key Shop (/facilities/services/key-shop)

Landscape Services (/facilities/services/la services)

Lost and Found (/facilities/services/lost-and-found)

Mechanical Trades (/facilities/services/n trades)

Minor Construction (/facilities/services/ construction-renov

- Signage installation, modification or removal

*Please note this list is not inclusive. You can find the permit form here (/facilities/service-request-help-center)!

Questions?

Facilities Management & Development Help Center

805-756-5555 (tel:805-756-5555)

facilities-cbs@calpoly.edu (mailto:facilities-cbs@calpoly.edu)

Facilities Notifications

Sidewalk Closure - South Perimeter Road

(/facilities/about/news#notificatior 2)

Jun 17, 2019, 07:00 am — Aug 23, 2020, 05:00 pm

Facilities

1 Grand Ave, Building 70 (https://maps.calpoly.edu/place/bldg-070-0/), San Luis Obispo, CA 93407

Phone: 805-756-5555

facilities-cbs@calpoly.edu (mailto:sustainability@calpoly.edu)

Use to request authorization for Department-directed jobs

CAL POLY
Administration & Finance
Facilities Management & Development

BUILDING PERMIT APPLICATION FORM

Submit completed form to facilities-cbs@calpoly.edu
Questions? Call Facilities Help Center 805-756-5555

Applicant's Name: *(Applicant will be the primary contact for this project)*	Today's Date:	
Phone Number:	Department:	
Alternate Phone Number:	Email Address:	
Optional: Names and Phone numbers of other involved parties *(Supervisor, Dean, Advisor etc.)*		
Project Name:	Bldg. Name:	
	Bldg. #:	
Who is doing the work? *(Check all that apply)*	Room #:	
☐ Contractor	☐ Student Project	☐ Other *(Explain)*
☐ Department Labor		
Source of Funding:	Estimated Cost/Budget:	

Description of Project:

*****Email supporting documents** such as scope, plans, specifications, location, etc. to:*
facilities-cbs@calpoly.edu ***and*** Mike Hogan at mhogan@calpoly.edu

Status of Project:	☐ Proposal *(We can only review the concept, not issue a permit)*	
	☐ Plans Ready to Review	☐Under Construction *oops! call x5555*
Approval Signature:		
Academic Departments Require Dean's Signature (Non-Academic Departments Require Division or Department Head Signature)		*(Please Print Name)*

Office Use Only

Project Number: SR_______________

Time Window:

REV 1/19 **FAC-10A**

Email Application Form to facilities-cbs@calpoly.edu

7.0 APPENDIX C: Permit Package

Use to request authorization for Department-directed jobs

BUILDING PERMIT APPLICATION FORM

CAL POLY
Administration & Finance
Facilities Management & Development

Submit completed form to facilities-cbs@calpoly.edu
Questions? Call Facilities Help Center 805-756-5555

Applicant's Name: David Colman, Sophia Ha *(Applicant will be the primary contact for this project)*	Today's Date: 06/08/21
Phone Number: (408) 717 - 1688 (David)	Department: Architectural Engineering
Alternate Phone Number: (408) 714 - 9398 (Sophia)	Email Address: dcolman@calpoly.edu, soha@calpoly.edu
Optional: Names and Phone numbers of other involved parties *(Supervisor, Dean, Advisor etc.)*	Craig Baltimore (Advisor) cbaltimo@calpoly.edu
Project Name: Piazza Di Ulivo : ARCE Patio Redesign	Bldg. Name: Engineering West Bldg. #: 21
Who is doing the work? *(Check all that apply)*	Room #: N/A

☐ Contractor	☑ Student Project	☐ Other *(Explain)*
☐ Department Labor		

Source of Funding:	Estimated Cost/Budget: $4400

Description of Project:

Repaving and addition of new structure to existing concrete structure adjacent to Building 21

*****Email supporting documents** such as scope, plans, specifications, location, etc. to:*
facilities-cbs@calpoly.edu ***and*** Mike Hogan at mhogan@calpoly.edu

Status of Project:	☐ Proposal *(We can only review the concept, not issue a permit)*	
	☐ Plans Ready to Review	☐Under Construction *oops! call x5555*
Approval Signature:		
Academic Departments Require Dean's Signature (Non-Academic Departments Require Division or Department Head Signature)		*(Please Print Name)*

Office Use Only

Project Number: SR_______________

Time Window:

REV 1/19 **FAC-10A**

Email Application Form to facilities-cbs@calpoly.edu

TABLE OF CONTENTS

INTRODUCTION

Piazza de Ulivo was an initiative started to redesign and bring life to a patio space adjacent to Engineering West (Building 21). Located within the central courtyard of Engineering West (Hasslein Garden), the patio space previously contained a senior project pergola that collapsed and has been removed. The remaining elements from this previous structure were an inverted moment frame consisting of five concrete columns and beams joining them as shown in Figure 1. Additionally, a wooden bench with concrete pedestals remained under the shade of the existing olive tree.

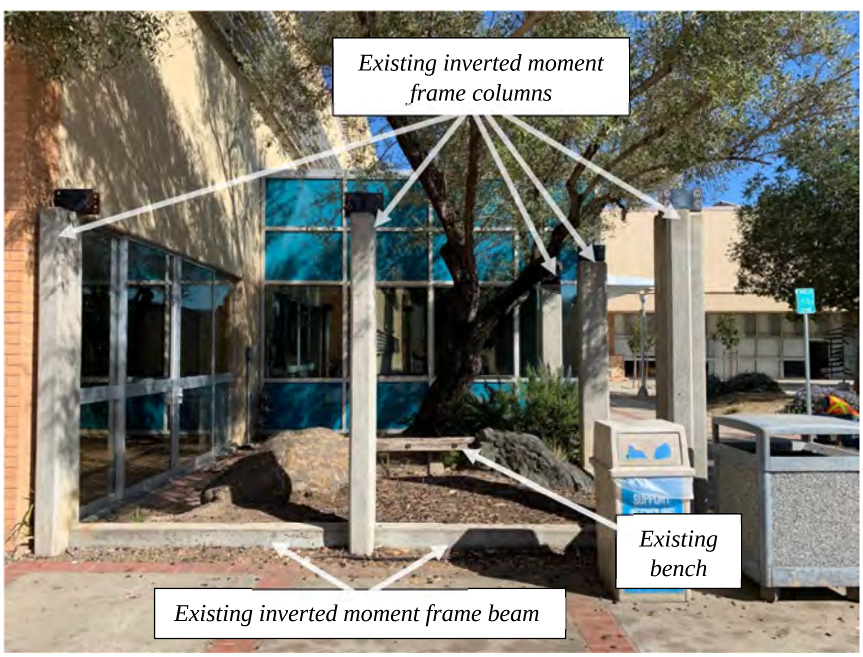


Figure 1 - West elevation of patio as seen from the exterior

This proposal contains calculations and details for the fabrication and construction of a new tiered roof-like structure to attach to the existing concrete structure as shown in Figure 2. Flor clarity, the existing olive tree and rosemary plant are not rendered. Details on demolition and repaving of the site are also included. The existing columns will support roof panels constructed of 12mm polycarbonate panels attached to curved steel members. Panel framing will consist of steel HSS, angles, and bolted plate connections of sections listed below:

- HSS 9x9x1/8
- HSS 8x3x1/8
- HSS 5x5x1/8
- HSS 4x2x1/8
- 1/4” Steel Plate
- 3x2x3/16 Steel Angle

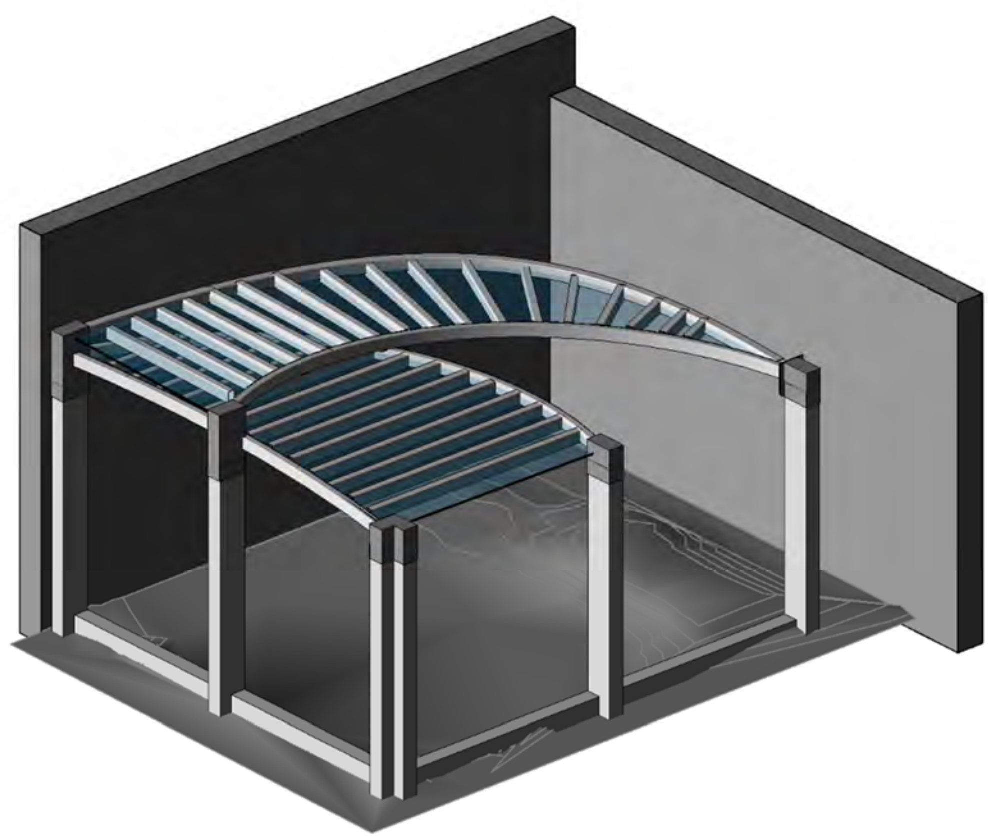
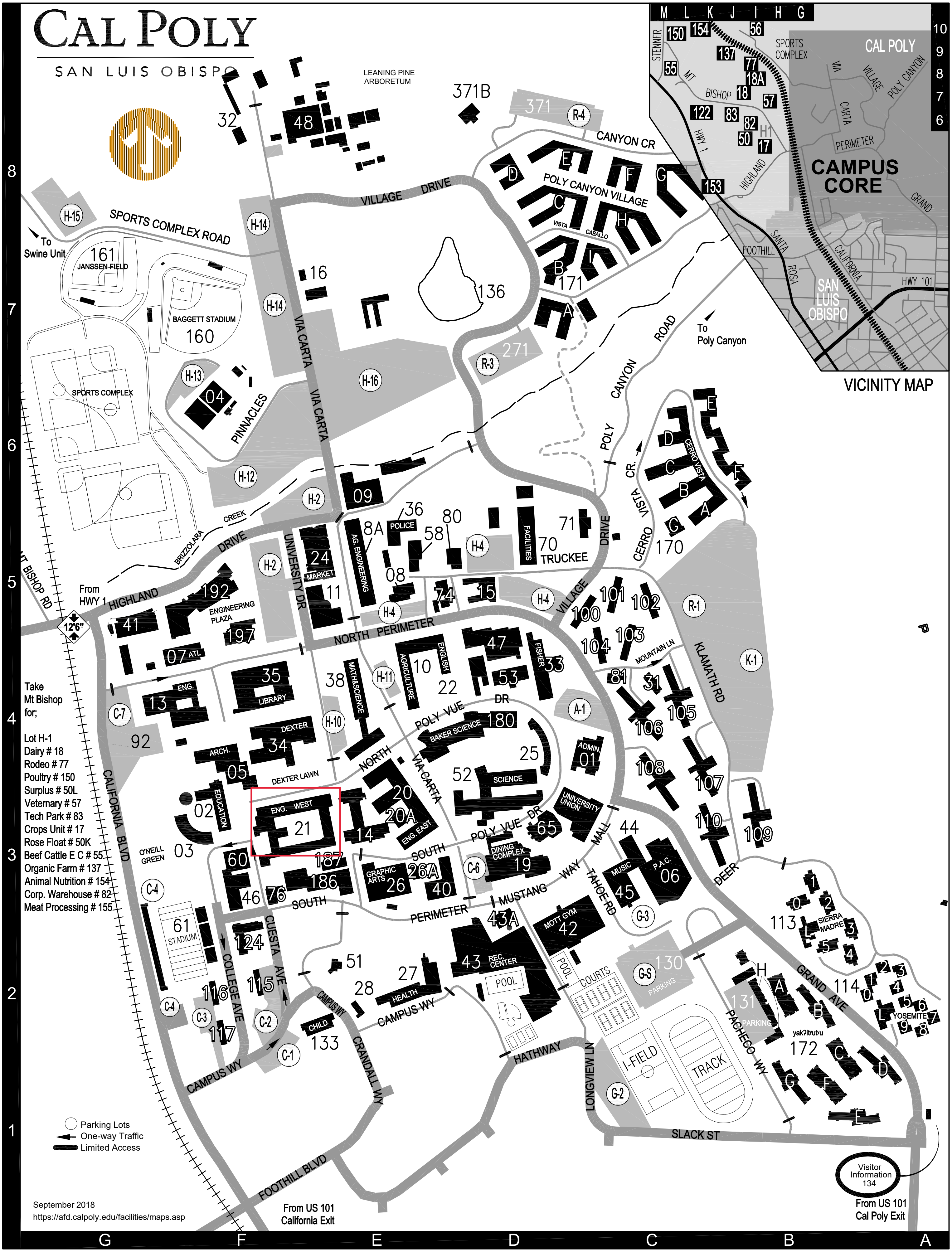


Figure 2 - Rendered View of Design



CAL POLY
SAN LUIS OBISPO
LEANING PINE ARBORETUM
371B
371
R-4
CANYON CR
POLY CANYON VILLAGE
VISTA CABALLO
VILLAGE DRIVE
SPORTS COMPLEX ROAD
To Swine Unit
161
JANSSEN FIELD
BAGGETT STADIUM
160
SPORTS COMPLEX
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H-14
H-13
H-12
H-16
H-2
H-4
H-10
H-11
R-3
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171
16
32
48
04
PINNACLES
VIA CARTA
To Poly Canyon
POLY CANYON ROAD
CERRO VISTA
VISTA CR.
170
BRIZZOLARA CREEK
HIGHLAND DRIVE
MT BISHOP RD
From HWY 1
12'6"
09
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AG. ENGINEERING
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POLY VUE DR
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BAKER SCIENCE
DEXTER
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ARCH.
05
DEXTER LAWN
NORTH
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52
SCIENCE
C-7
92
Take Mt Bishop for;
Lot H-1
Dairy # 18
Rodeo # 77
Poultry # 150
Surplus # 50L
Veternary # 57
Tech Park # 83
Crops Unit # 17
Rose Float # 50K
Beef Cattle E C # 55
Organic Farm # 137
Animal Nutrition # 154
Corp. Warehouse # 82
Meat Processing # 155
CALIFORNIA BLVD
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EDUCATION
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O'NEILL GREEN
ENG. WEST
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20A
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SOUTH PERIMETER
GRAPHIC ARTS
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C-6
DINING COMPLEX
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MUSTANG WAY
TAHOE RD
MUSIC
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P.A.C.
06
DEER
C-4
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STADIUM
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CUESTA AVE
COLLEGE AVE
43A
MOTT GYM
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G-3
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SIERRA MADRE
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28
HEALTH
43
REC. CENTER
POOL
COURTS
G-S
130
PARKING
131
GRAND AVE
114
YOSEMITE
116
115
C-3
C-2
117
C-1
CHILD
133
CAMPUS WY
CRANDALL WY
HATHWAY
LONGVIEW LN
I-FIELD
TRACK
PACHECO WY
172
G-2
SLACK ST
FOOTHILL BLVD
Parking Lots
One-way Traffic
Limited Access
September 2018
https://afd.calpoly.edu/facilities/maps.asp
From US 101 California Exit
Visitor Information 134
From US 101 Cal Poly Exit
VICINITY MAP
SPORTS COMPLEX
STENNER
MT BISHOP
HWY 1
HIGHLAND
153
CAL POLY
VIA VILLAGE
POLY CANYON
CARTA
PERIMETER
CAMPUS CORE
GRAND
FOOTHILL
SANTA ROSA
CALIFORNIA
HWY 101
SAN LUIS OBISPO
150
154
56
137
55
77
18A
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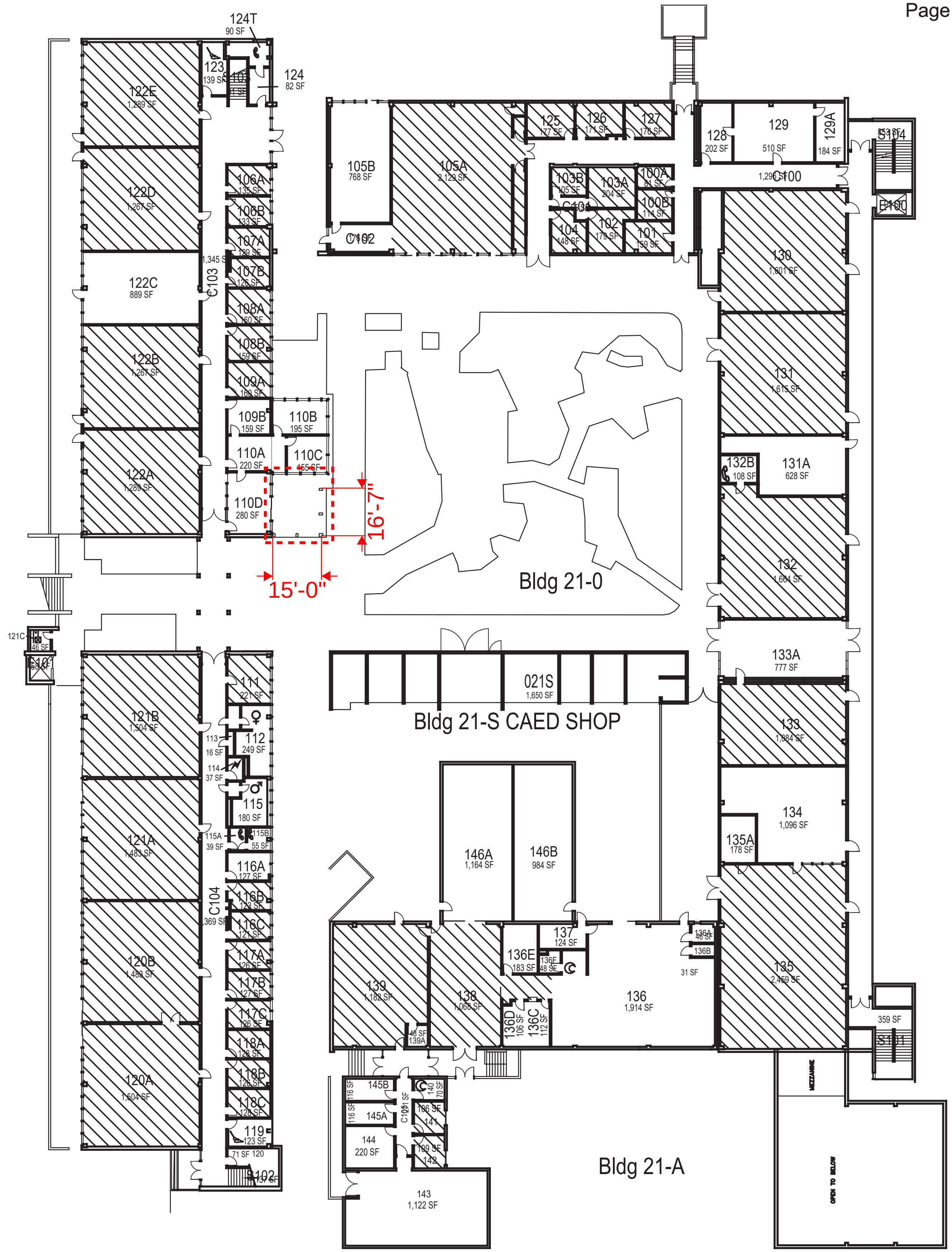


O:\Planroom\Database\building_Floor_Plans\Plan_Book\Building 021-0_Engineering West.dwg

August 2019

CAL POLY
SAN LUIS OBISPO
Facilities

Engineering West

Floor 2
Space Data http://afd.calpoly.edu/facilities/spacefacility/space_data.asp

1"=45'

PIAZZA DI ULIVO

BUDGET ESTIMATION

STEEL COST ESTIMATE

ASSUMED UNIT COST OF STEEL $1.25/lb

SECTION	UNIT WEIGHT	QUANTITY	WEIGHT (lbs)
HSS 9x9x1/8	14.96 plf	28'	418.88
HSS 5x5x1/8	8.16 plf	15'	122.40
HSS 8x3x1/8	9.01 plf	42'	378.42
HSS 4x2x1/8	4.75 plf	180'	855.00
1/4" PLATE	10.21 psf	16 SF	163.36
L 3x2x3/16	3.07 plf	80'	+ 245.60
			2,183.66 lbs

2,183.66 lbs
× $1.25/lbs

$2,730.00

PAVER COST ESTIMATE

AREA TO BE PAVED: ≈ 180 SF

QUOTE FROM AIRVOL (805) 543-1314

$3.60/SF ← PERMEABLE PAVERS

180 SF
× $3.60/SF

$650

POLY CARBONATE COST ESTIMATE

PALRAM PALSUN UV2 60"x92" PANELS
12 mm CLEAR

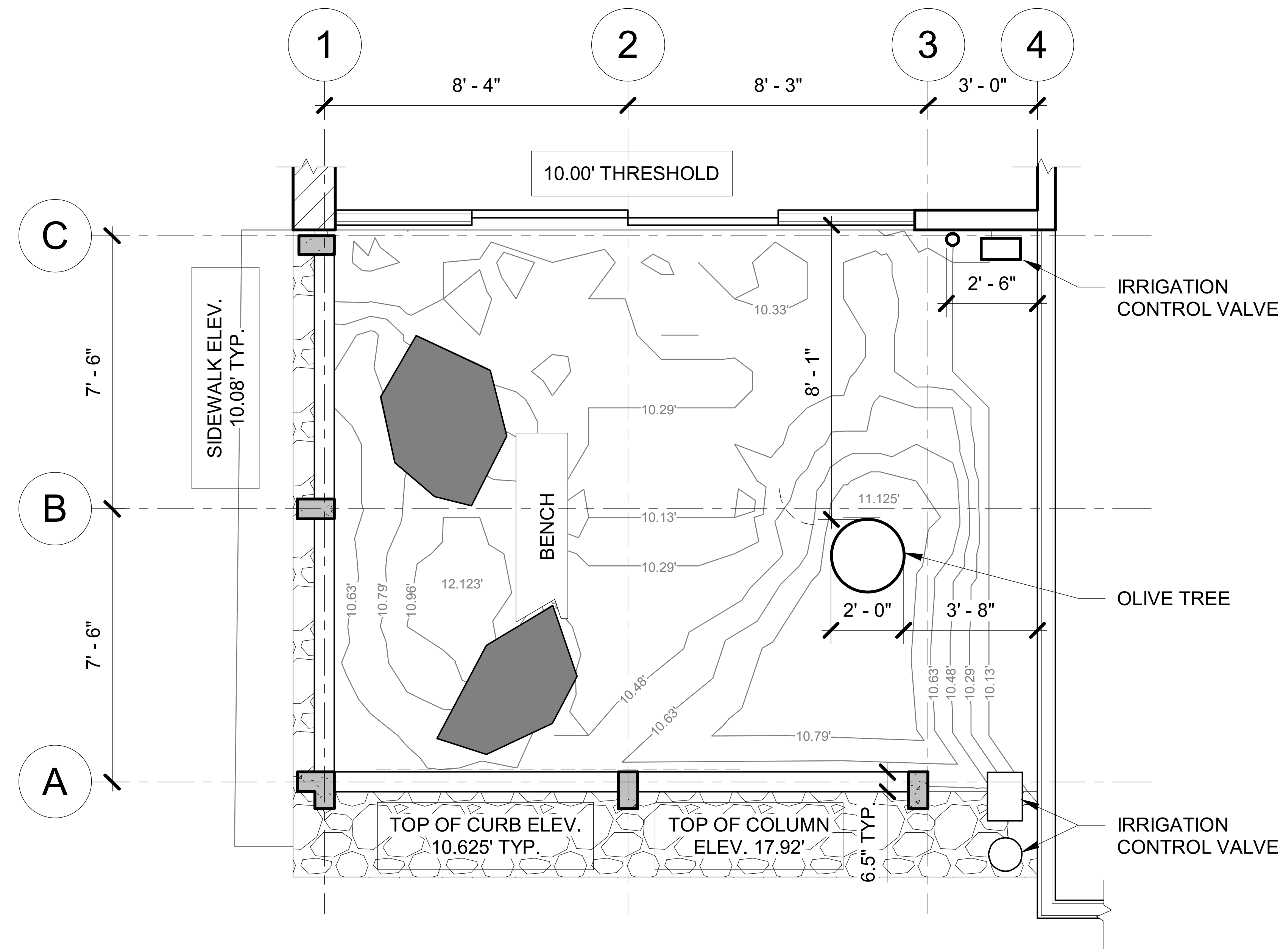
LOW CURRENT AVAILABILITY DUE TO COVID-19 PANDEMIC DEMAND FOR FACE SHIELDS

NO QUOTE/PRICING PROVIDED

APPROXIMATE ≈ $1000

TOTAL MATERIAL COST ESTIMATE

2,730 + 650 + 1,000 = $4,400



PLAN NOTES:

- MASONRY
- WINDOWS
- CONCRETE
- PARTIION WALL
- SLIDING DOOR
- ROCK
- GRAVEL

NORTH

1 EXISTING SITE PLAN
1/4" = 1'-0"

4' 6' 8'
5' 7'

Piazza di Ulivo

COLMAHA INC.

COLMAHA

DATE:
5/14/2020 2:01:00 PM

SITE:
Engineering West
California Polytechnic
State University,
San Luis Obispo

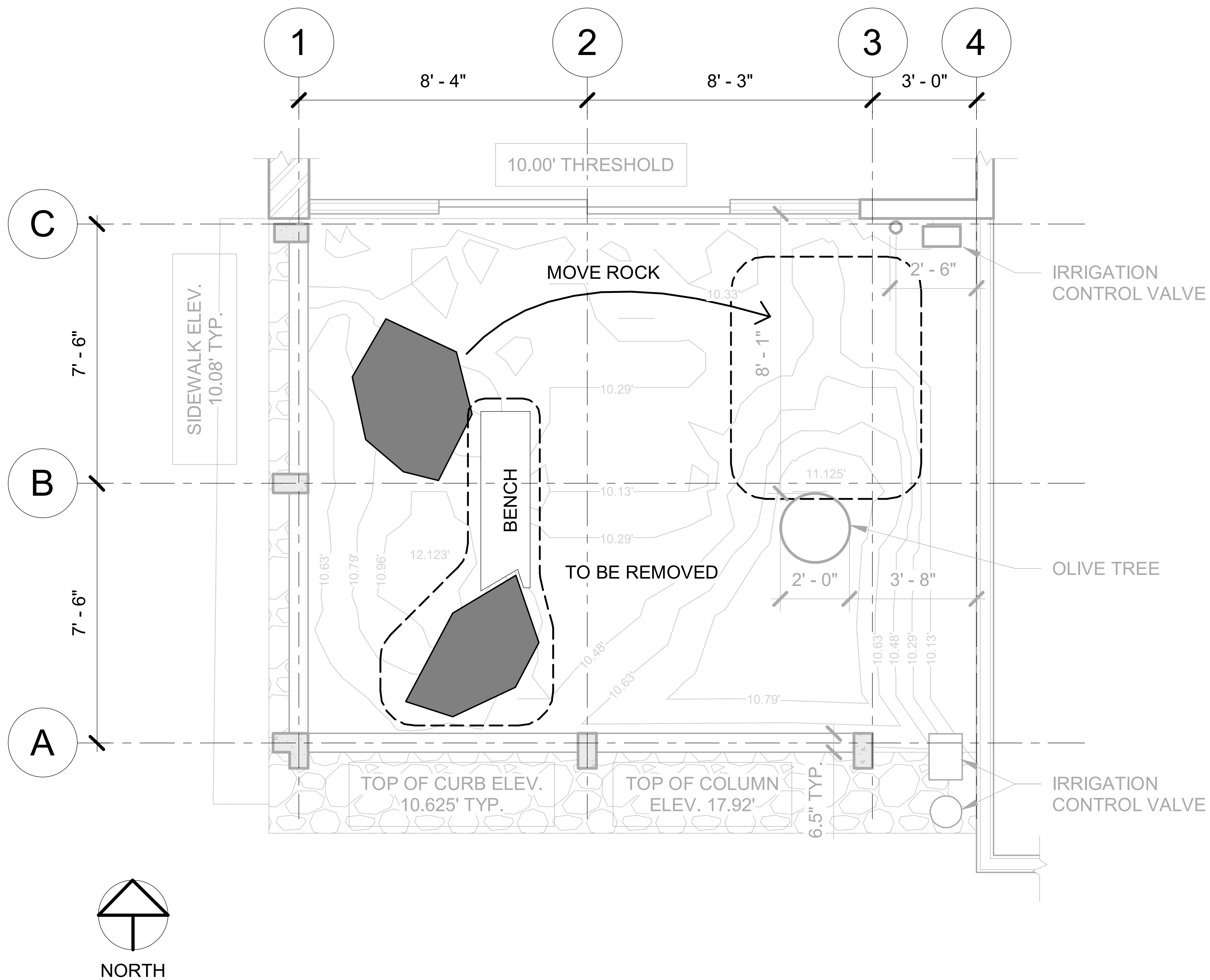
CHECKED BY:
CB

DRAWN BY:
SH,DC

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

SHEET NAME:
EXISTING SITE PLAN

SHEET NUMBER:
S1.1



1 DEMOLITION PLAN 1
1/4" = 1'-0"

Piazza di Ulivo

COLMAHA INC.

COLMAHA

DATE:
6/10/2021 7:31:00 AM

SITE:
Engineering West
California Polytechnic State University,
San Luis Obispo

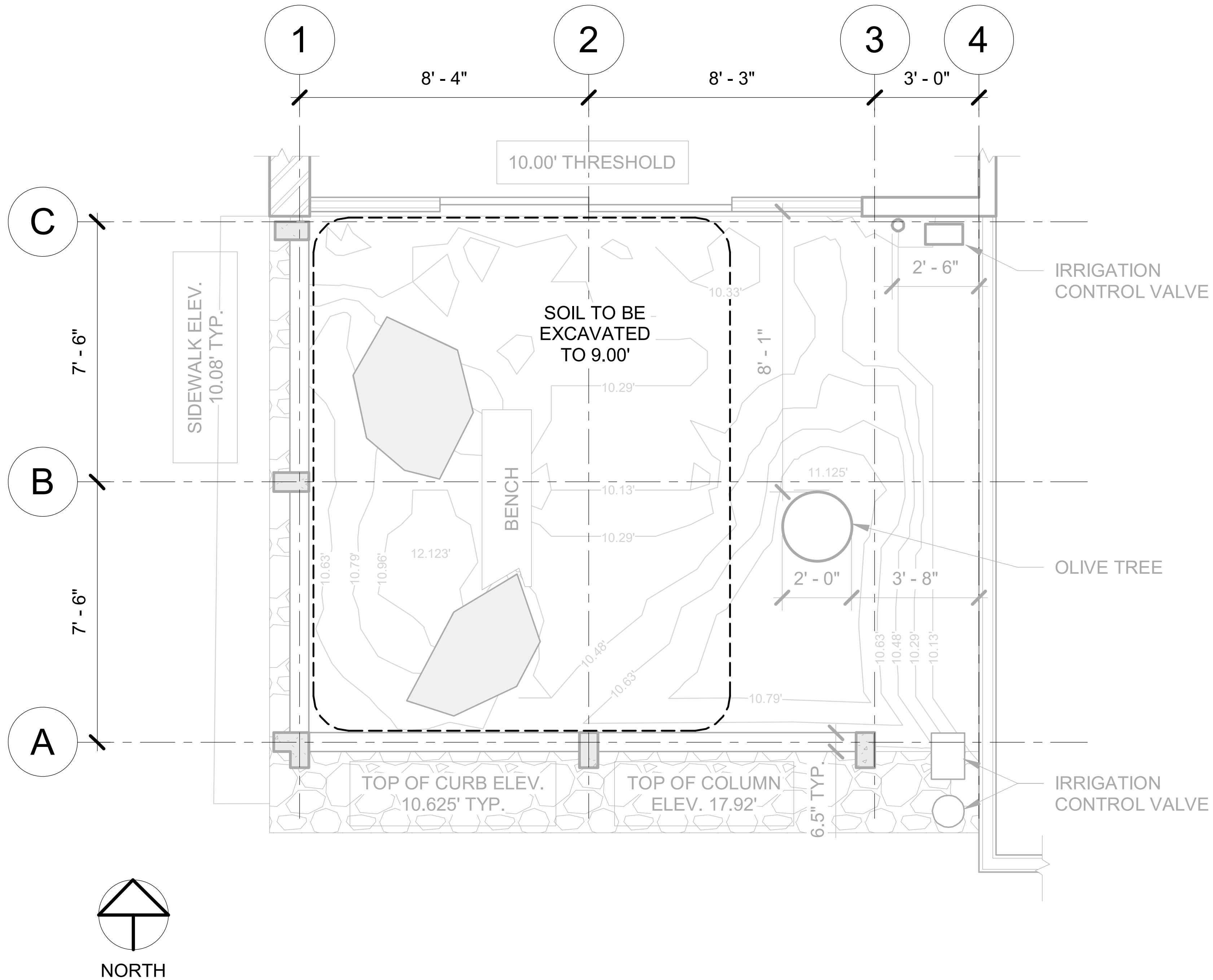
CHECKED BY:
CB

DRAWN BY:
SH,DC

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

SHEET NAME:
DEMOLITION PLAN 1

SHEET NUMBER:
S1.1



1 DEMOLITION PLAN 2
1/4" = 1'-0"

4' 6' 8'
5' 7'

Piazza di Ulivo

COLMAHA INC.

DATE:
6/10/2021 7:31:00 AM

SITE:
Engineering West
California Polytechnic
State University,
San Luis Obispo

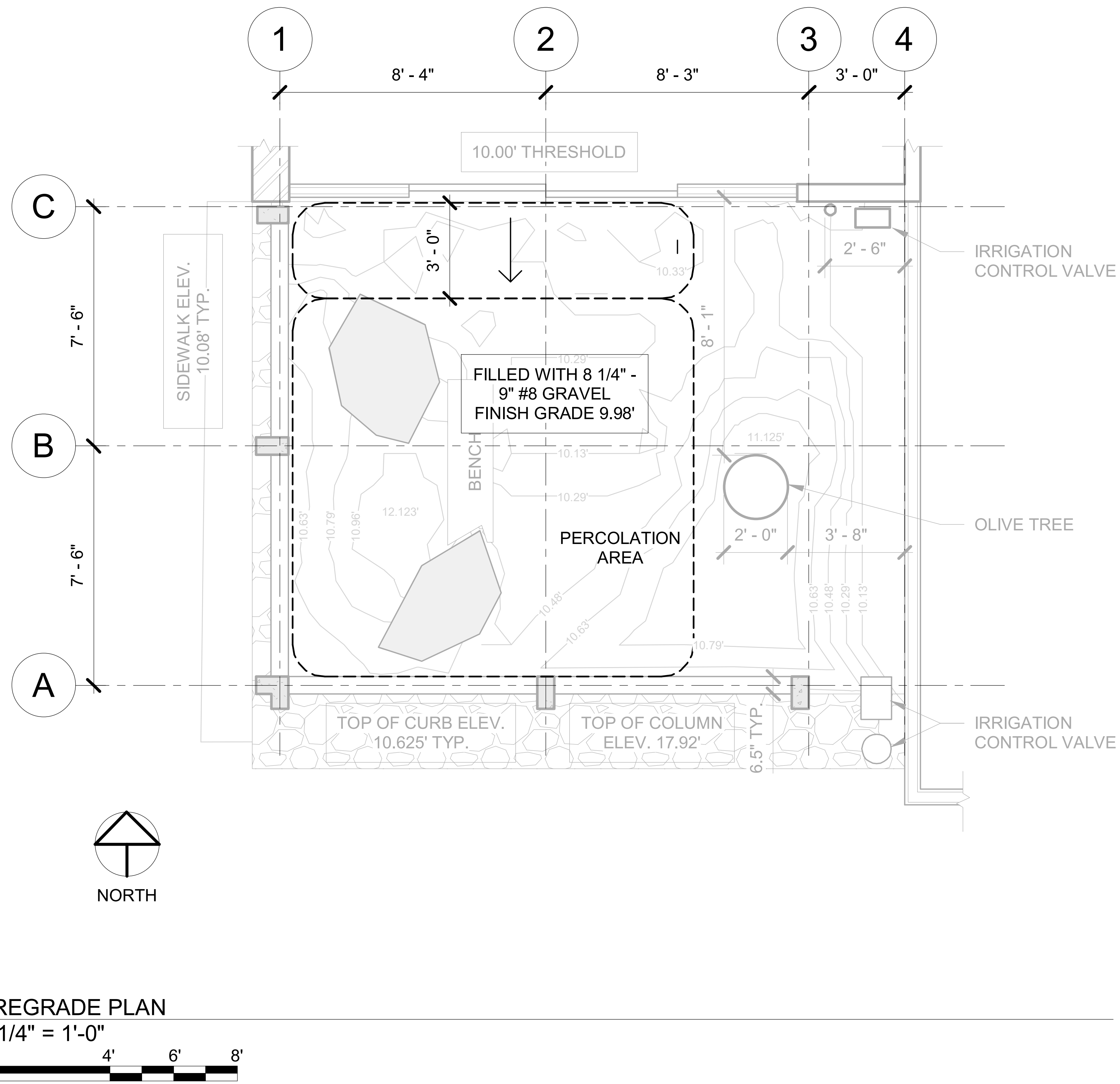
CHECKED BY:
CB

DRAWN BY:
SH,DC

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

SHEET NAME:
DEMOLITION PLAN 2

SHEET NUMBER:
S1.2



1 REGRADE PLAN
1/4" = 1'-0"

Piazza di Ulivo

COLMAHA INC.

DATE: 6/10/2021 7:31:00 AM

SITE: Engineering West California Polytechnic State University, San Luis Obispo

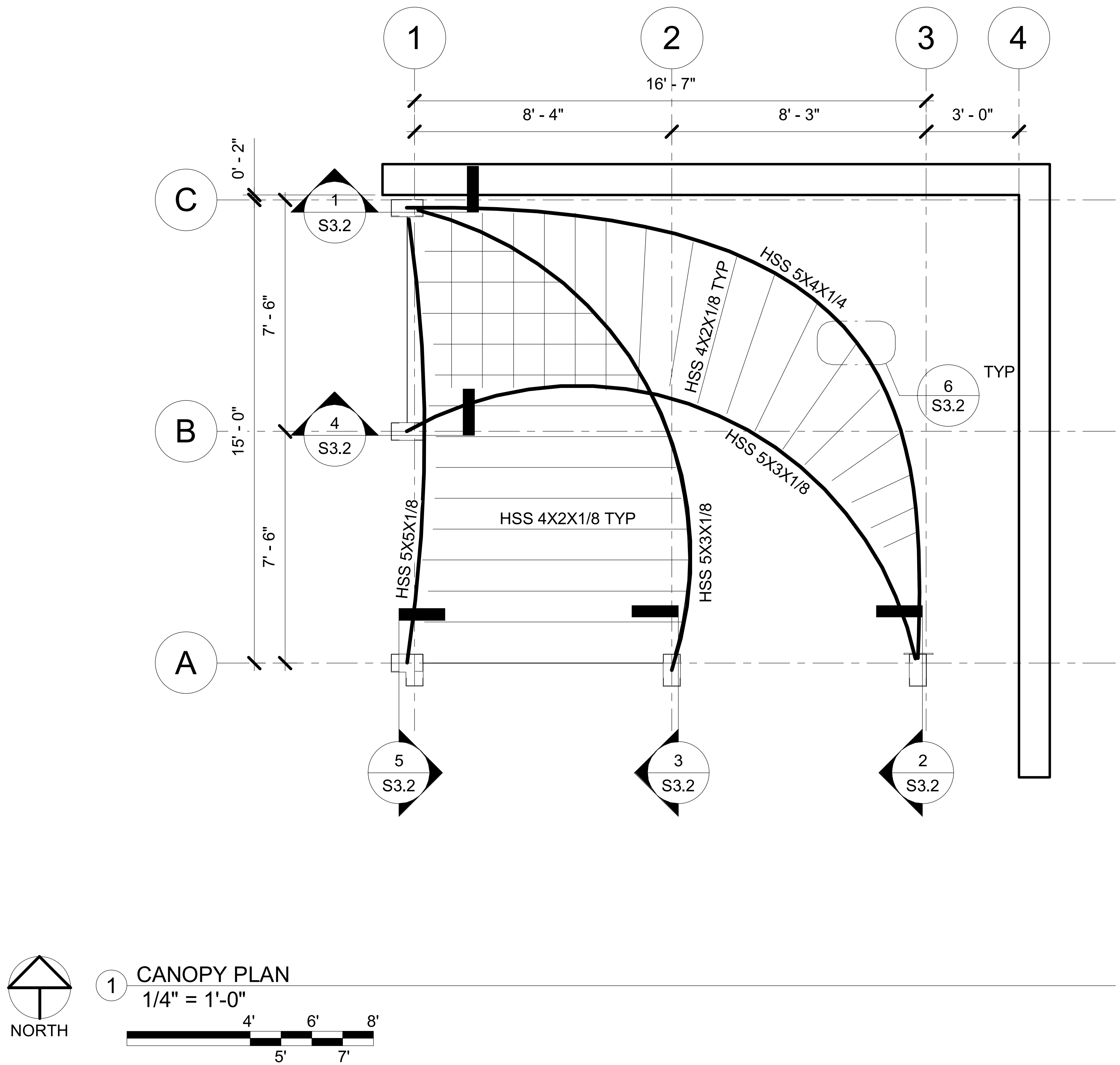
CHECKED BY: CB

DRAWN BY: SH,DC

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

SHEET NAME: REGRADE PLAN

SHEET NUMBER: S1.3



1 CANOPY PLAN
1/4" = 1'-0"

Piazza di Ulivo

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COLMAHA

DATE:
6/10/2021 7:31:00 AM

SITE:
Engineering West
California Polytechnic
State University,
San Luis Obispo

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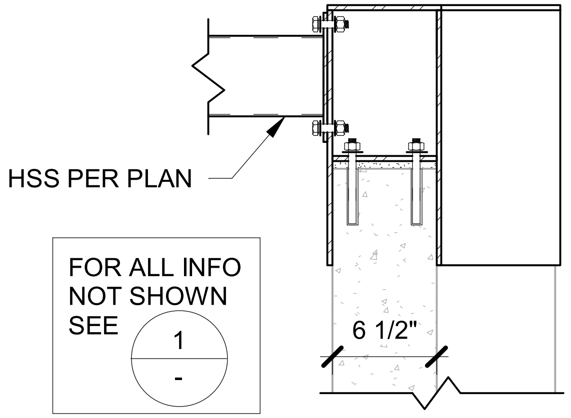
CB

DRAWN BY:
SH,DC

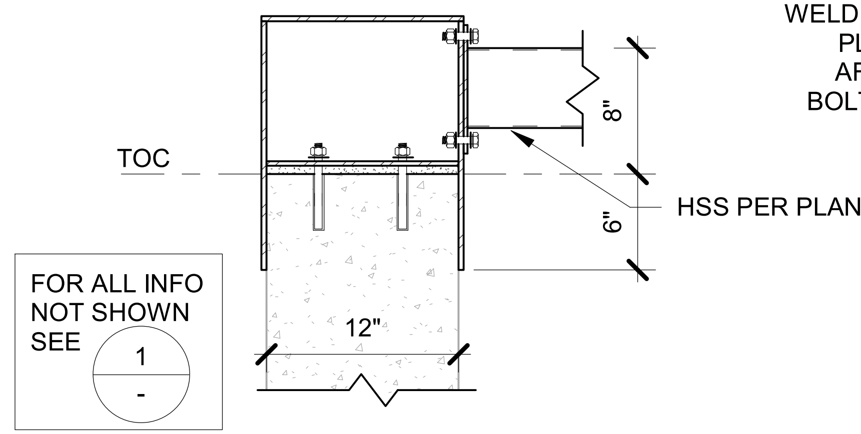
SCALE:
1/4" = 1'-0"

SHEET NAME:
CANOPY PLAN

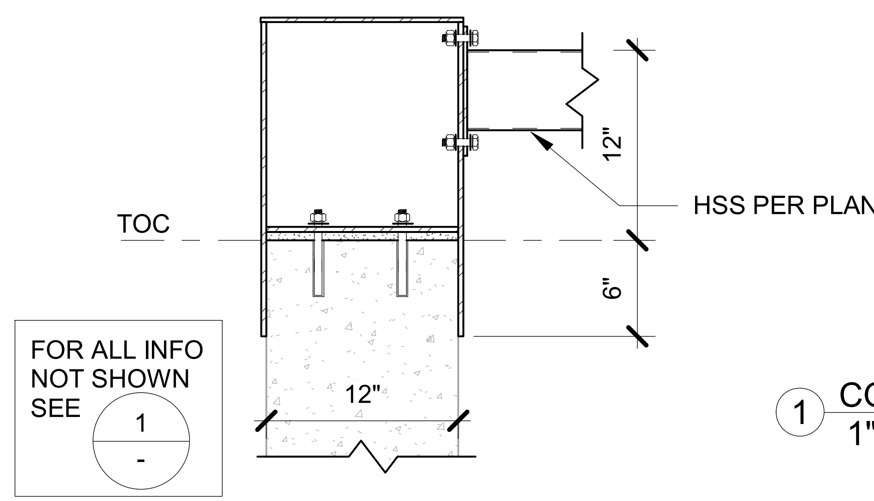
SHEET NUMBER:
S2.1



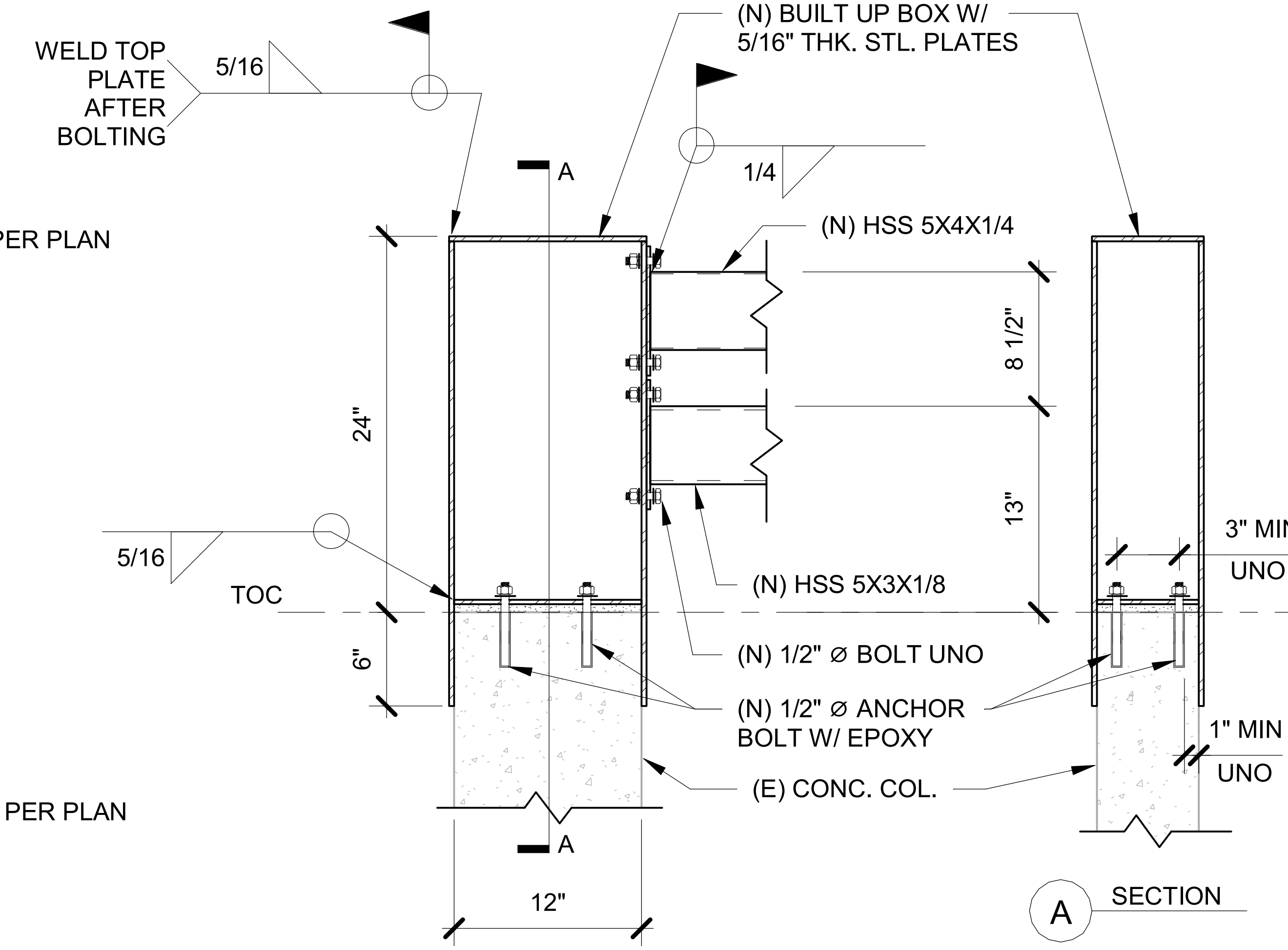
5 CONNNECTION TO COL A1
1" = 1'-0"



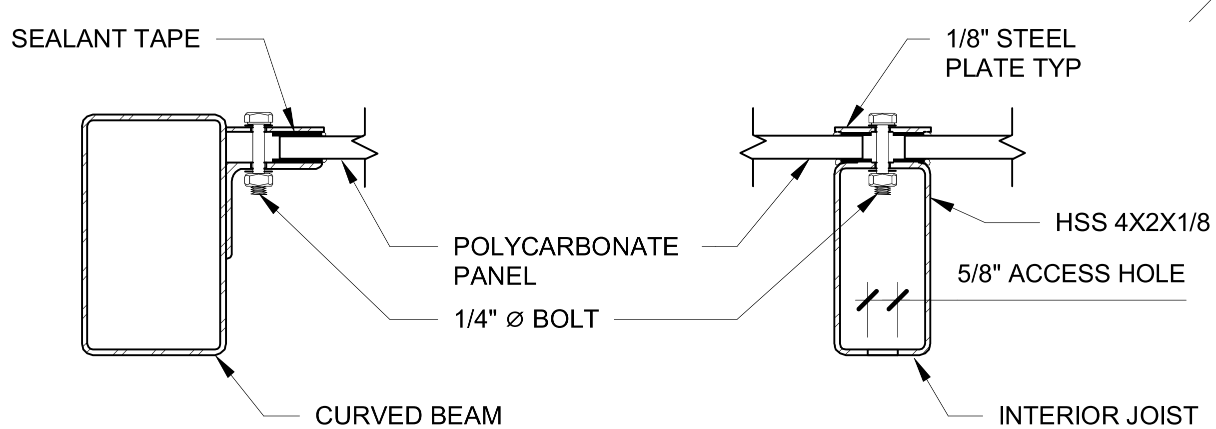
3 CONNECTION TO COL A2
1" = 1'-0"



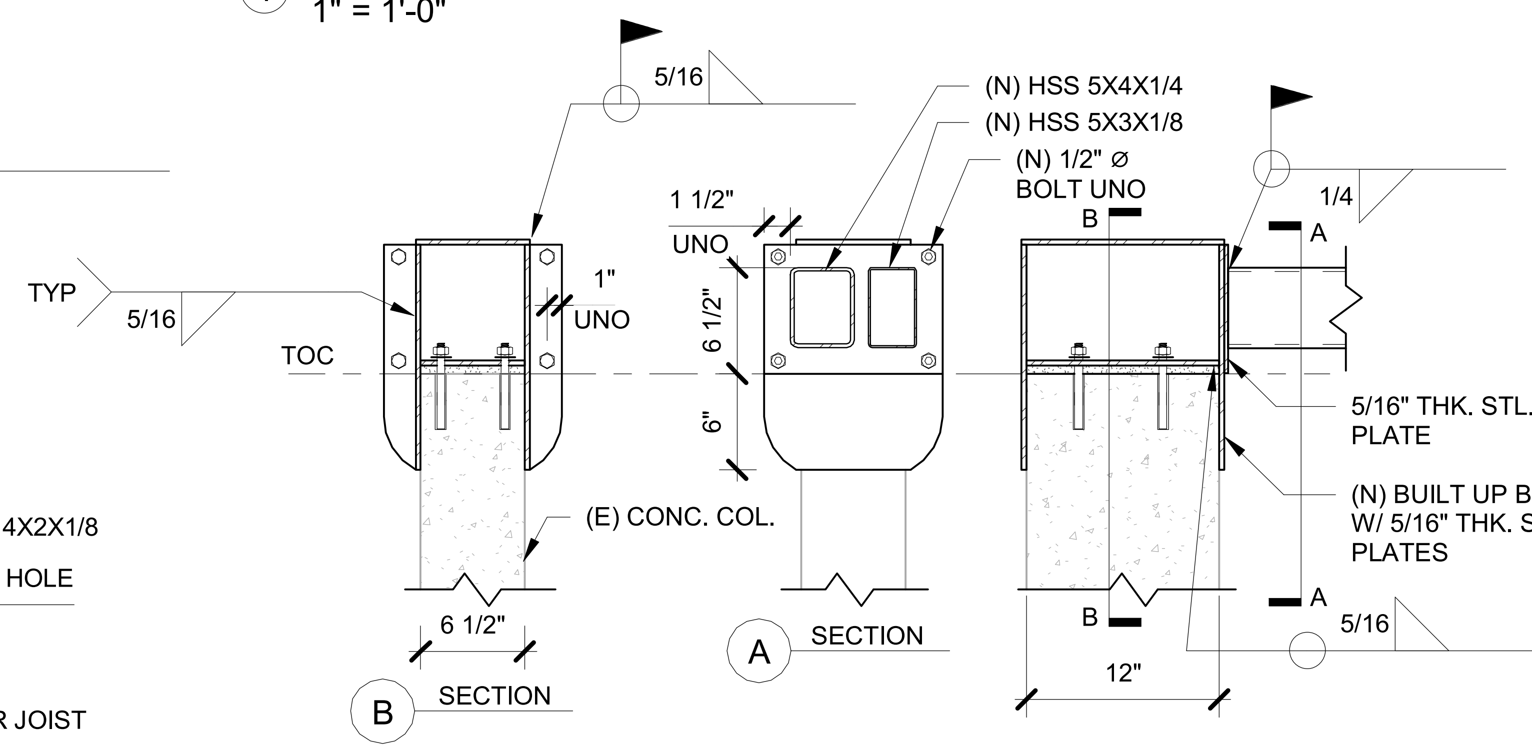
4 CONNECTION TO COL B1
1" = 1'-0"



1 CONNECTION TO COL C1
1" = 1'-0"



6 TYP PANEL CONNECTIONS
3" = 1'-0"



2 CONNECTION TO COL A3
1" = 1'-0"

Piazza di Ulivo

COLMAHA INC.

COLMAHA

DATE:
6/10/2021 7:31:01 AM

SITE:
Engineering West
California Polytechnic
State University,
San Luis Obispo

CHECKED BY:
CB

DRAWN BY:
SH,DC

SCALE:
As indicated

SHEET NAME:
CONNECTION
DETAILS

SHEET NUMBER:
S3.2

ETABS Documentation

As curved beams were chosen for the tiered roof-like structure, modeling the beams accurately was considered. Curved beams can be modeled using beam elements by subdividing into multiple short, straight beam elements. Generally, more accurate analysis results from a larger number of segments. ETABS provided a built-in drawing tool for curved beams and can automatically segment them, however, it was important to maintain the slenderness of the beams by manually adjusting the segments to achieve a 5:1 length to depth ratio. Elements with a length to depth ratio less than 5:1 are governed by shear and the beam elements would not properly capture the behavior of the short segments. Given that the length to depth ratio was greater than 5:1 for the entire members, a flexural response was expected from the analysis.

In order to setup an ETABS model, some modelling assumptions first had to be made based on what would best capture the behavior of the designed structure. As mentioned, beam elements were used to model the main members of the structure. Because of the welded and bolted design of the connections to the existing columns, the beams were all modeled with fixed end connections. Additionally, the beams were all modeled as perfectly horizontal to simplify the ETABS model and analysis. The conservative loading utilized outweighed any increased demands from the slight slope included in the design for water drainage. All beam sections were modeled using ASTM A500 Gr. C steel with a yield stress of 50ksi as seen in Figure 8.

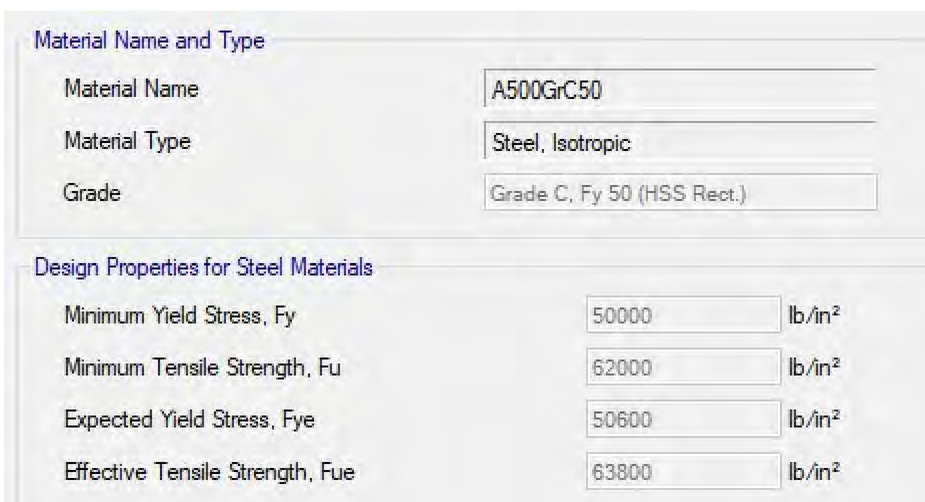


Figure 1 - ETABS Material Properties

Beams were referenced with labels relative to a key plan generated to keep a consistent naming scheme between the ETABS model and hand calculations as seen in Figure 9.

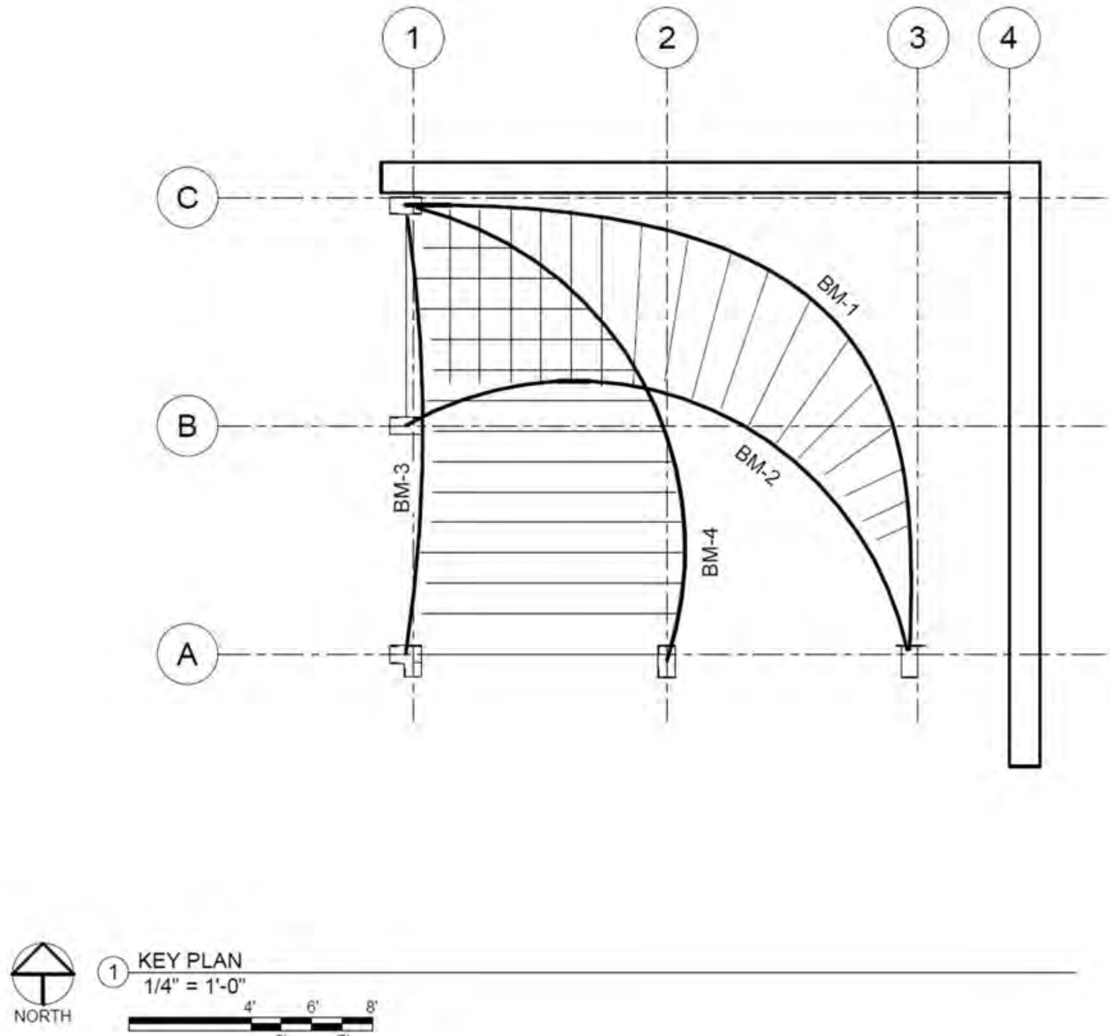


Figure 2 - Key Plan

Beam geometry involved curved members, however ETABS possessed functionality to allow for curved frame objects to be drawn based on certain parameters. For BM-1 a spline curve frame type was chosen with two internal control points as seen in Figure 10. BM-2, BM-3, and BM-4 all used a circular curve frame type with various third points selected to capture the desired radius of curvature which can be seen in Figure 11, Figure 12, and Figure 13 respectively. Additionally, all beams used automatic rigid end offsets based of the geometry with a rigid zone factor of 0 as seen in Figure 14. Frame auto mesh options can be seen in Figure 15 and were identical for all beams.

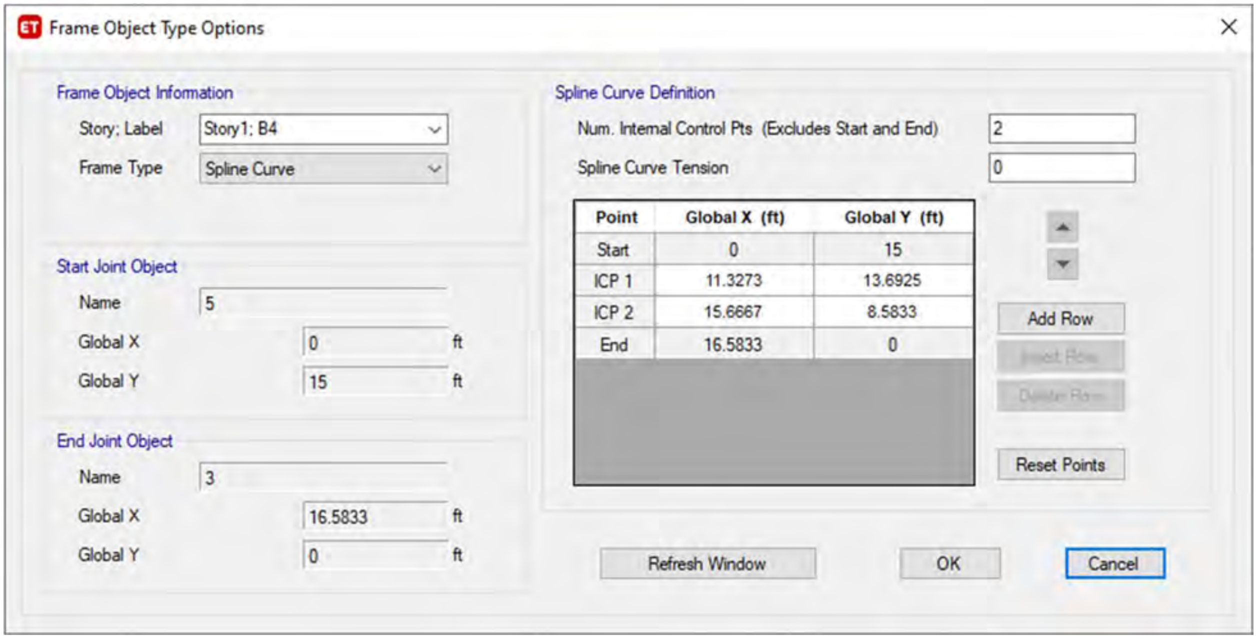


Figure 3 - BM-1 Curved Beam Geometry

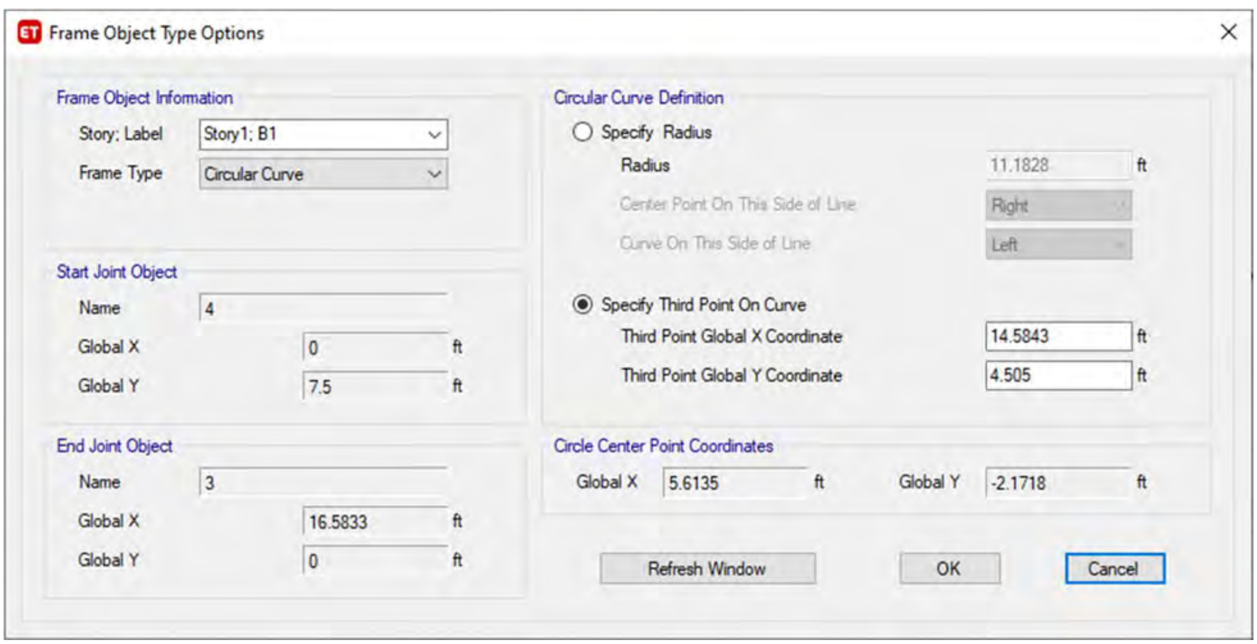


Figure 4 - BM-2 Curved Beam Geometry

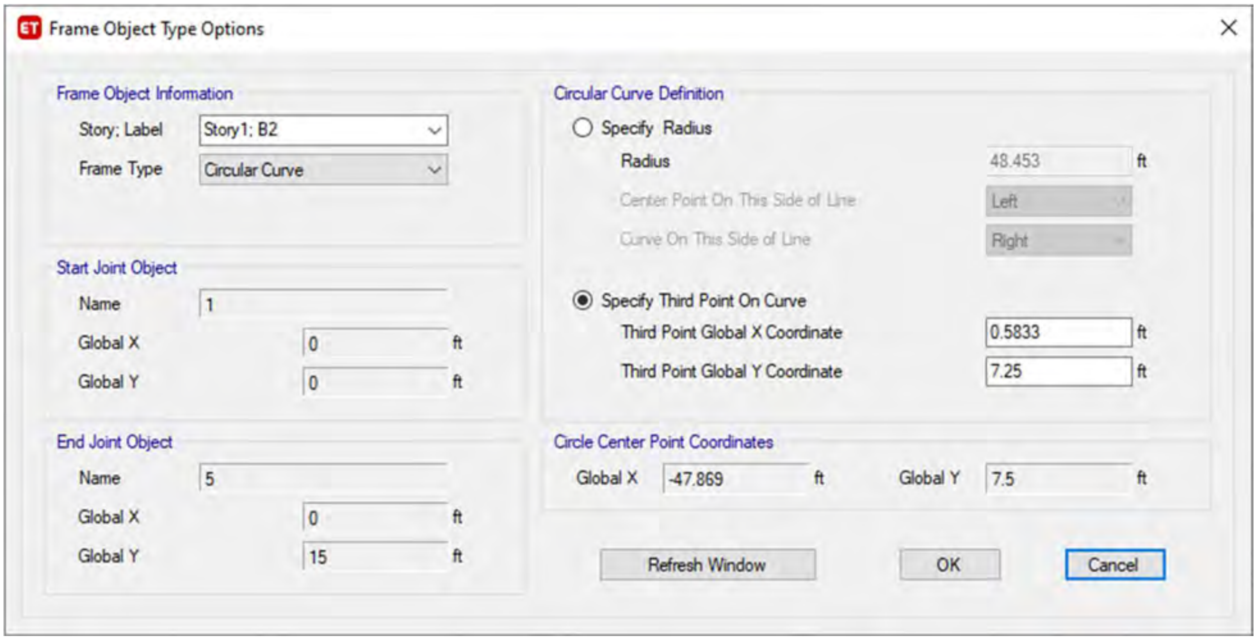


Figure 5 - BM-3 Curved Beam Geometry

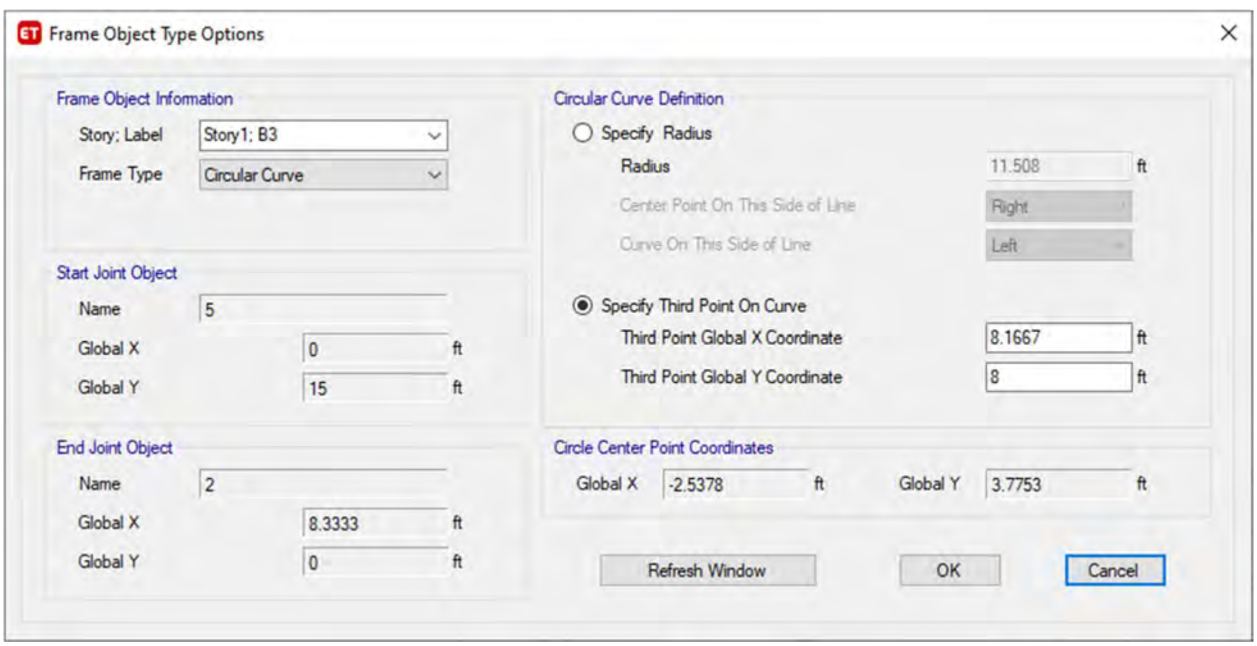


Figure 6 - BM-4 Curved Beam Geometry

Figure 7 - Beam Rigid End Length Offset Settings

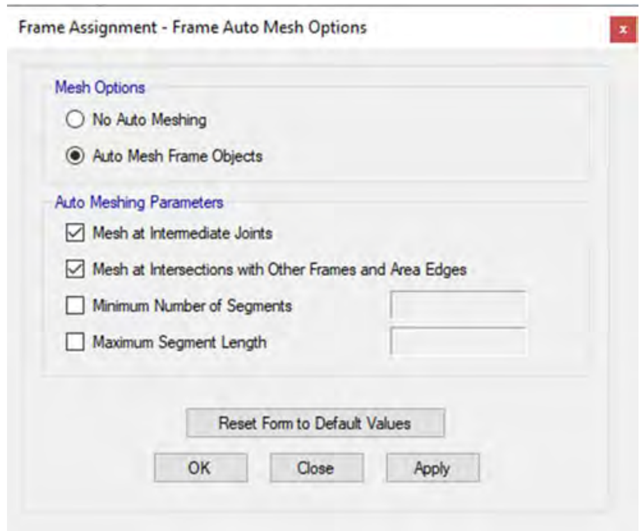


Figure 8 - Beam Auto Mesh Settings

To input loads into the ETABS model, three load patterns were created for dead loads, live roof loads, and wind loads. All load patterns excluded self-weight modifiers. The relevant load combinations were generated using ASCE 7-16 specifications and all load combinations were combined to be compared in an envelope load combination as seen in Figure 16. Then loads were applied as uniformly distributed loads in the gravity direction with magnitudes as seen in Figure 17, Figure 18, and Figure 19.

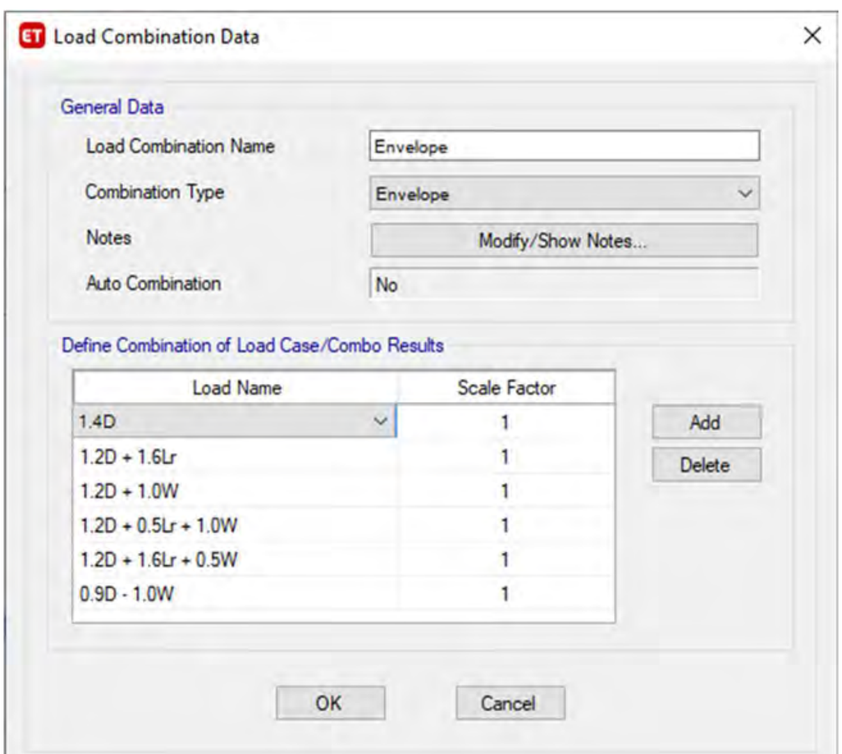


Figure 9 - Load Combinations & Envelope

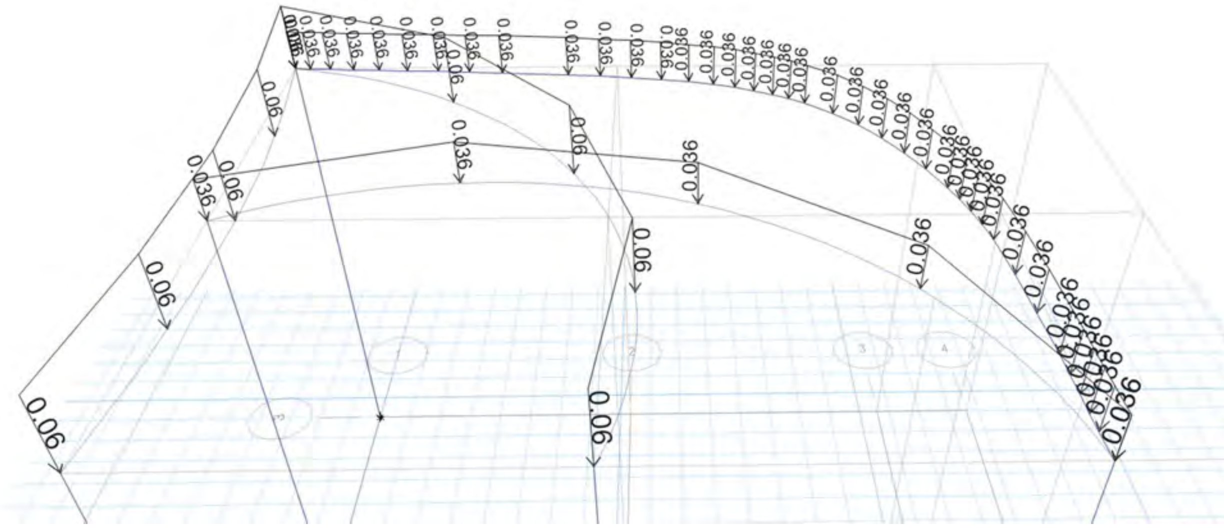


Figure 10 - Applied Dead Loads (klf)

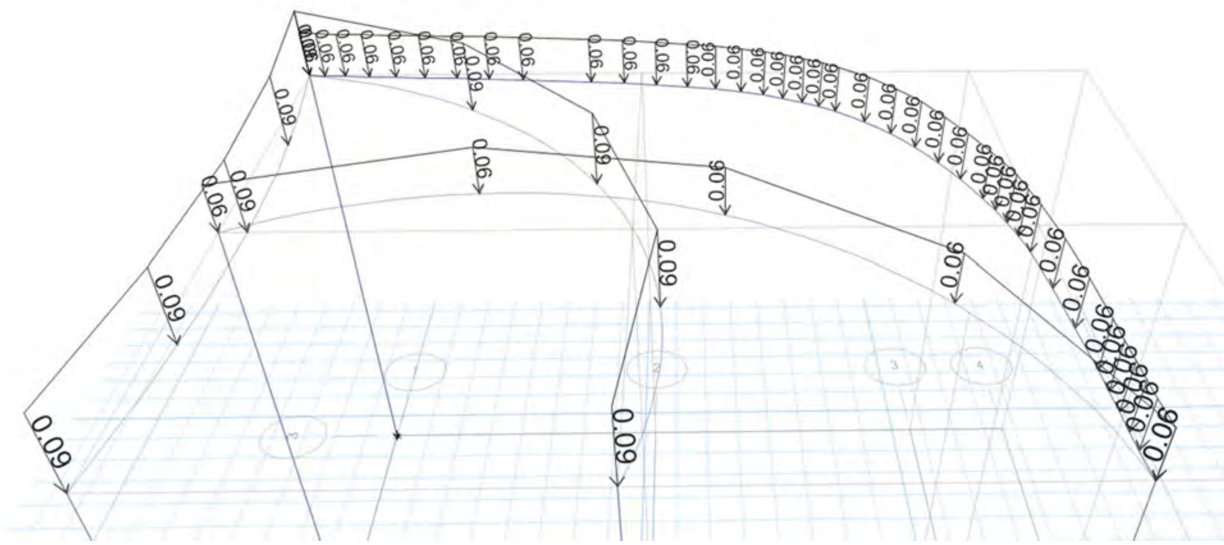


Figure 11 - Applied Roof Live Loads (klf)

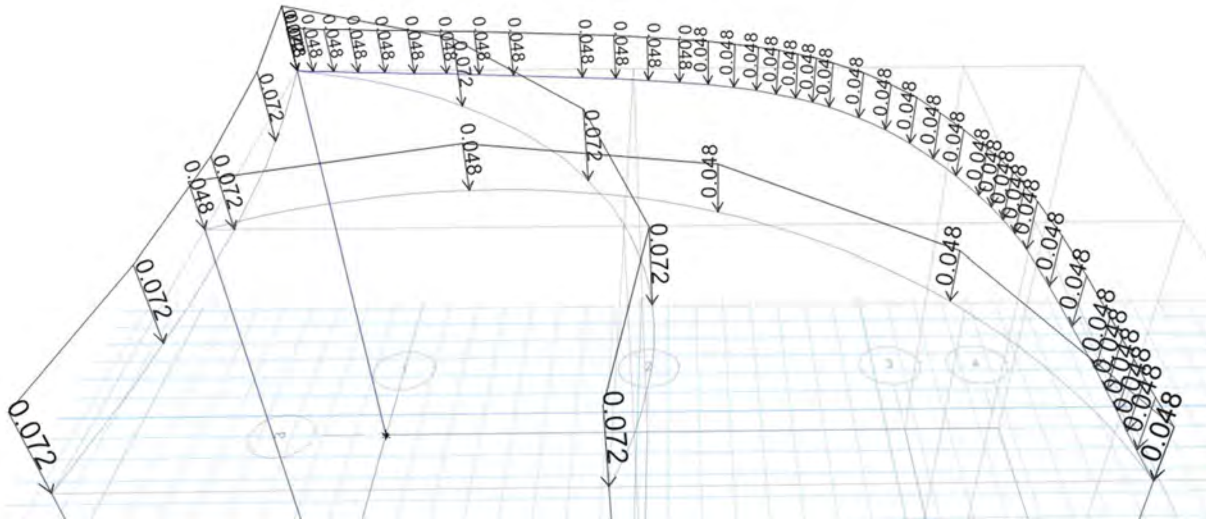


Figure 12 - Applied Wind Loads (klf)

As it was determined that deflection governed the design of the beams, deflection results were taken from ETABS and used to iterate the sizing of the beams quicker than a hand analysis was able. The deflections pulled from ETABS were due to service live roof loads in the vertical direction as seen in Figure 20. It is important to note that these deflection results are conservative because of the fact that the applied loads were based on the assumption that beams experienced a uniform tributary width along their lengths. From the shape of the panels, the tributary width changed along the length of the beam and was lower at one end.

Figure 13 - Max Live Load Deflections BM-1 (top) to BM-4 (bot)

Member force results were pulled from the envelope load combination and absolute maximums were used for major and minor axis bending and shear forces, axial forces, and torsional forces, The member force summaries for beams BM-1, BM-2, BM-3, and BM-4 can be seen in Figure 21, Figure 22, Figure 23, and Figure 24 respectively. Because the beam forces were maximums, they did not coincide at the same point along the length of the member. This resulted in conservative member forces for analysis, however this was not an issue because of the deflection criteria governing the design of the beams.

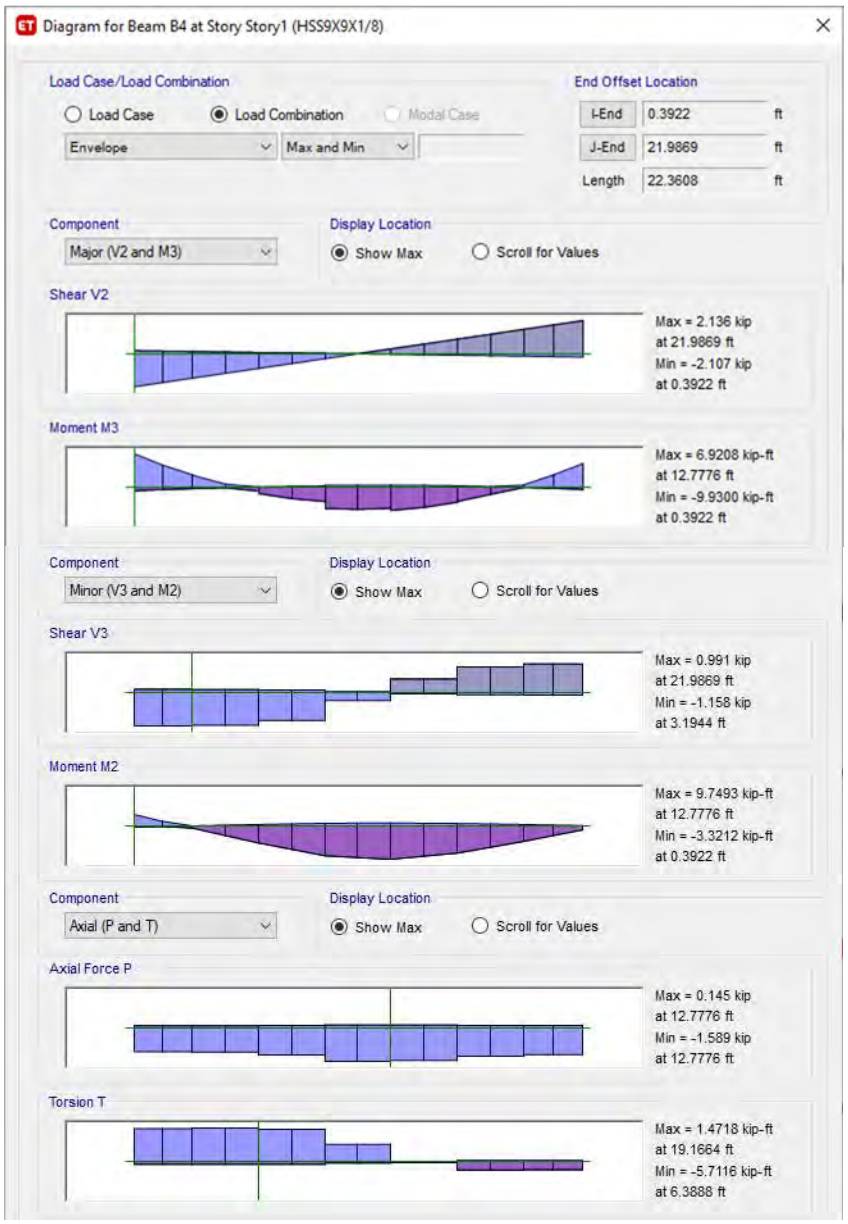


Figure 14 - BM-1 Member Force Summary

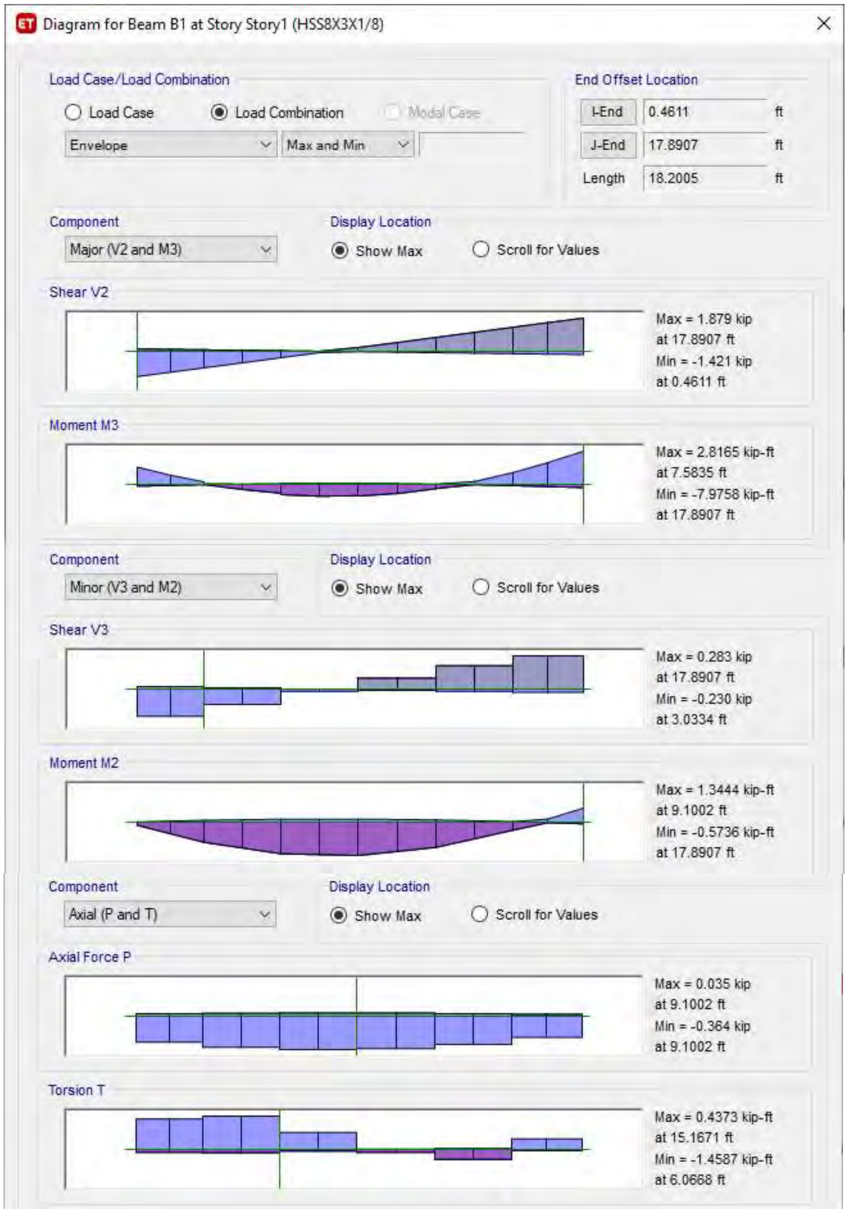


Figure 15 - BM-2 Member Force Summary

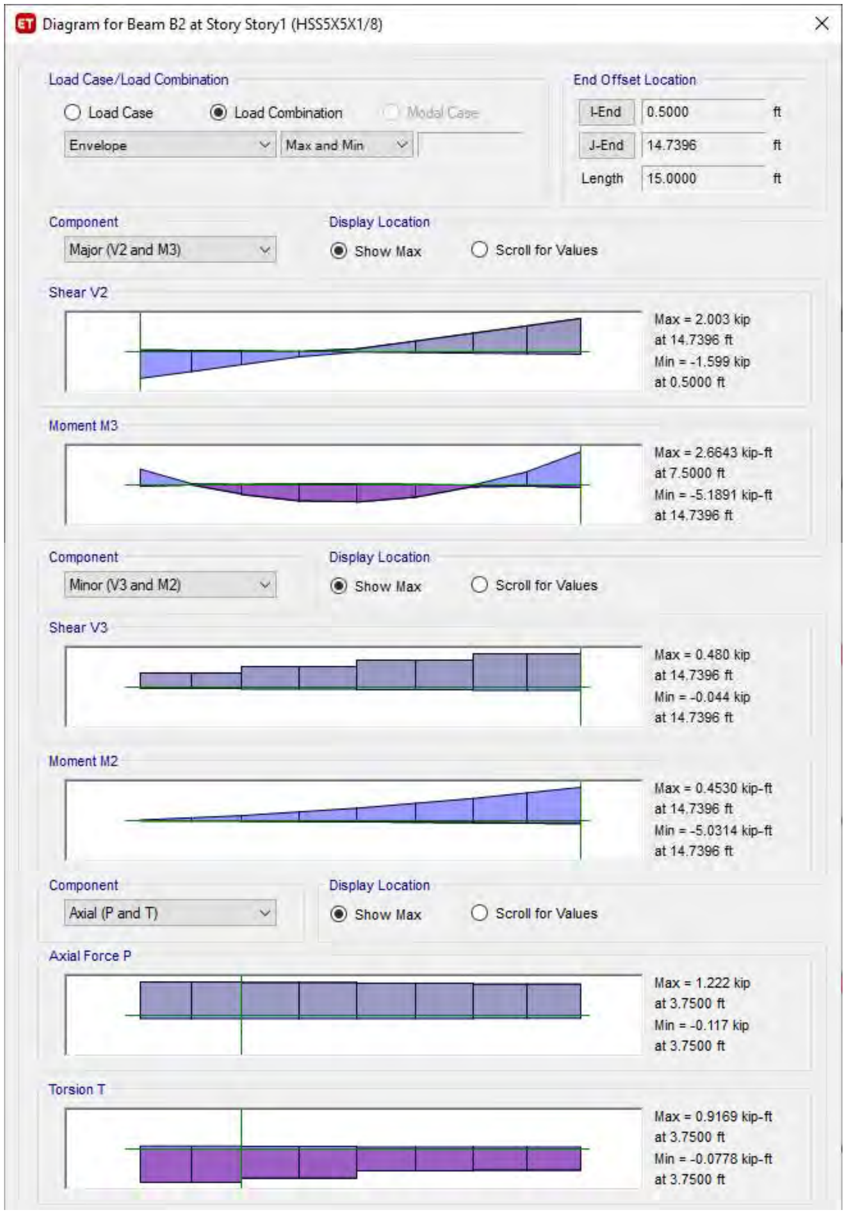


Figure 16 - BM-3 Member Force Summary

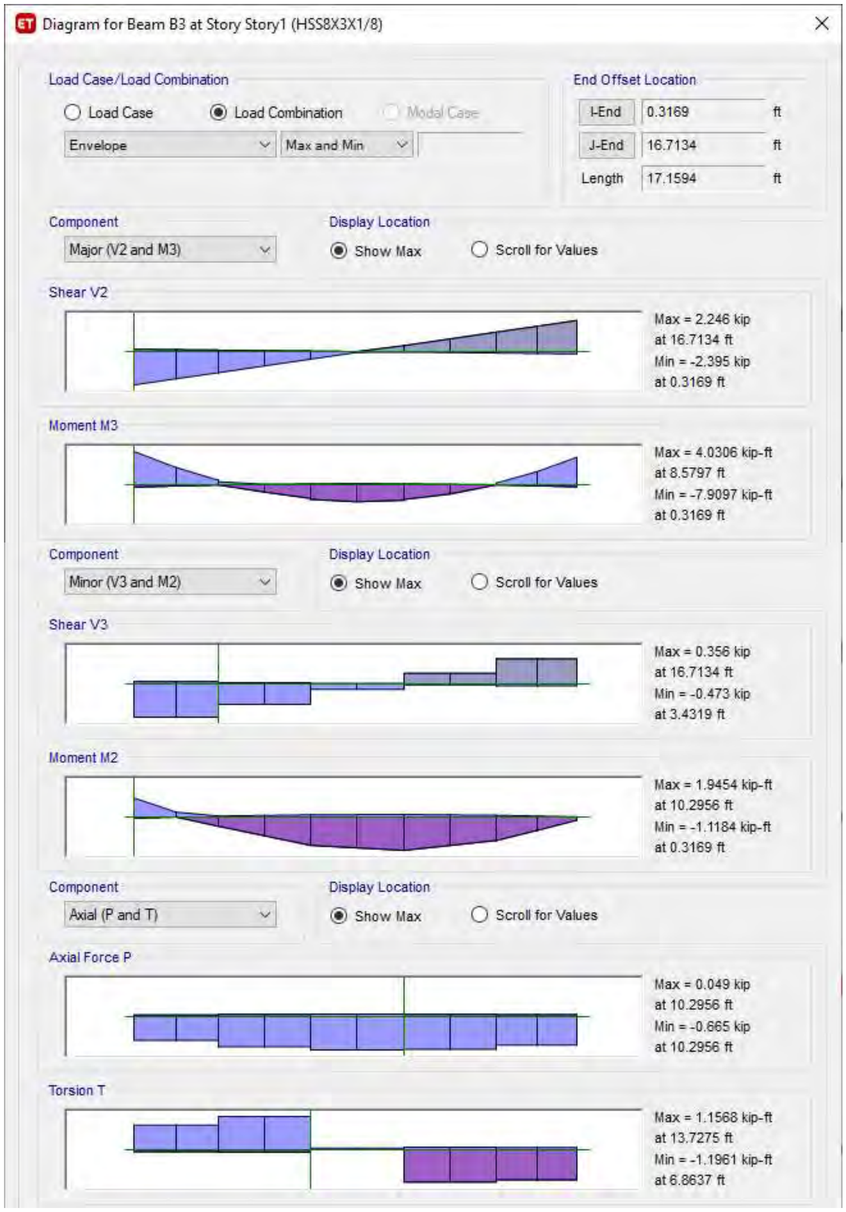


Figure 17 - BM-4 Member Force Summary

Hand Calculations

Hand calculations were used to verify the strength of the members and verify that the selected members for deflection provided sufficient strength.

The allowable deflection of the California Building Code (CBC) Table 1604.3 was based on the sensitivity to deflection of what the deflecting member is supporting. A ceiling supporting a brittle material, such as plaster or stucco, has a smaller allowable deflection because to prevent the material from supporting loads, before the structural members engage, and cracking. Ceilings supporting flexible materials were allowed to deflect more because the material was less likely to crack. It is important to note that the allowable deflections are maximum values. Allowable deflection criteria can be stricter in instances that can impact the comfort and functionality of the structure. For example, floors that deflect significantly can feel bouncy and uncomfortable for occupants. Elevator cable support beams have very small allowable deflections to maintain function. Since the function of the tiered roof-like structure would not be sensitive to deflections, a stricter allowable deflection criterion was not used.

The polycarbonate panels were determined to be flexible and assumed to be able to deflect significantly without yielding. For these reasons, an allowable of deflection L/180 was used to reduce member sizes. This also would provide a visual and tactile warning to any individuals that wish to climb the structure while still remaining completely safe for any nearby occupants.

BEAM LOADING

LOADING ASSUMPTIONS

A UNIFORM TRIBUTARY WIDTH WAS TAKEN @ THE WIDEST POINT OF EACH PANEL & USED TO CONSERVATIVELY SIMPLIFY THE BEAM LOADING

BEAMS B1 & B2 TRIB. WIDTH: 6'-0"

DEAD

INTERIOR FRAMING @ 12" O.C. ∴ 5plf ⇒ 5psf TYP.

TRIB WIDTH (POLYCARB. + INT. FRAMING)

6' (0.13psf + 5psf) = 30.78 ≈ 31plf

EXT. FRAMING

31plf + 15plf = 36plf

LIVE

(½) TRIB WIDTH (LIVE) =

(½) 6 (20) = 60plf

BEAMS B2 & B3 TRIB. WIDTH: 8'-7"

DEAD

TRIB WIDTH (POLYCARB + INT. FRAMING)

8.5833' (0.13psf + 5psf) = 44.0325 ≈ 45psf

EXT. FRAMING

45plf + 15lf = 60plf

LIVE

½ TRIB WIDTH (LIVE)

½ (8.5833) 20 = 85.833 ≈ 90plf

LOAD TAKE OFF

DEAD LOADS

POLYCARBONATE (12mm) $3 kg/m^2 \approx 0.13$ psf

SECONDARY FRAMING 5 plf

PRIMARY FRAMING 15 plf

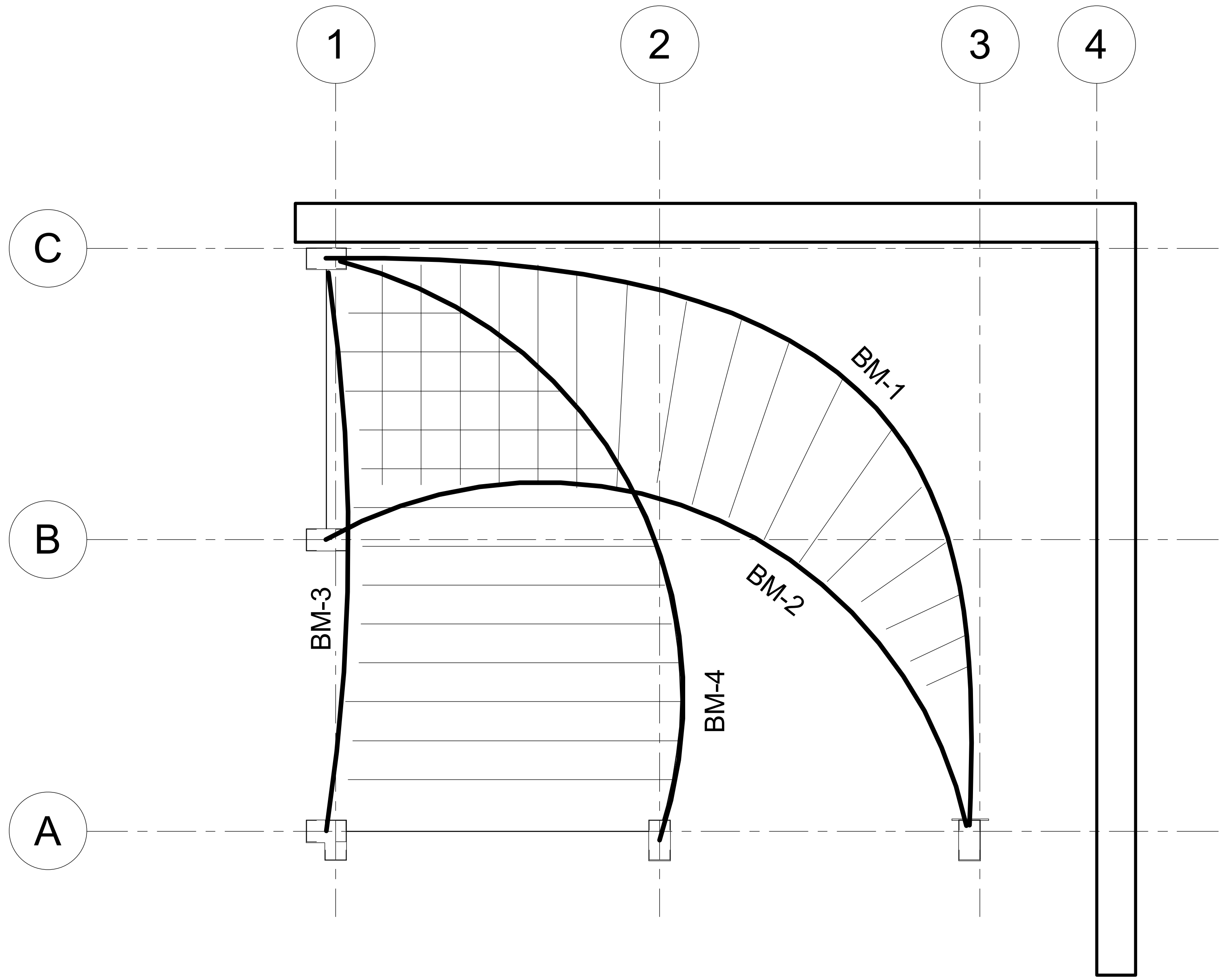
LIVE LOADS

ROOF LIVE LOAD 20 psf

WIND LOADS ASCE 7-16

RISK CAT. II	T. 1.5-1
$V = 92$ mph	F. 26.5-1B
$K_d = 0.85$	
EXPOSURE: B	26.7
$K_{zt} = 1$	26.8
$K_e = 1$	26.9
$G_f = 0.85$	26.11
LOW RISE OPEN	26.12
(GC_{pi}) 0.00	T. 26.13-1
K_z & $K_h = 0.57$	T. 26.10-1
$q_z = 0.00256 K_z K_{zt} K_d K_e V^2$	(26.10-1)
$q_z = 10.4981$ psf	
$C_N = \pm 1.2$	F. 27.3-4
$p = q_h G C_N$	(27.3-2)
$p = 10.7080 \le 16$ psf $=$ USE 16 psf	

16 psf < 20 psf ∴ LIVE LOAD GOVERNS



NORTH

1 KEY PLAN
1/4" = 1'-0"

4' 6' 8'
5' 7'

Piazza di Ulivo

COLMAHA INC.

COLMAHA

DATE:
6/10/2021 7:30:59 AM

SITE:
Engineering West
California Polytechnic
State University,
San Luis Obispo

CHECKED BY:
CB

DRAWN BY:
SH,DC

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

SHEET NAME:
KEY PLAN

SHEET NUMBER:
00

BEAM CALCULATIONS

REFERENCES

MATERIAL PROPETIES (ASTM A500 GR. C)

AISC 360-16 T. 2-4

$F_y = 50$ ksi
$F_u = 62$ ksi
$E = 29{,}000$

BM-1 DESIGN TRY $\boxed{\text{HSS } 9\times9\times1/8}$

SECTION PROPERTIES

T. 1-11

$A_g = 4.09\ in^2$ $I_{xy} = 53.5\ in^4$
$h = 9''$ $S_{xy} = 11.9\ in^3$
$b = 9''$ $r_{xy} = 3.62''$
$t_{design} = 0.116''$ $Z_{xy} = 13.6\ in^3$
$b/t = 74.6$ $J = 114\ in^4$
$h/t = 74.6$ $C = 6.41\ in^3$

Weight $= 14.96$ plf ≤ 15 plf assumed

BEAM GEOMETRY

ETABS

LENGTH $L = 26.7379'$

DEFLECTION CHECK

NOTE: DEFLECTION CONTROLS ALL BEAMS BY A WIDE MARGIN

DEFLECTION CRITERIA (LIVE)
$L/360$

$L = 26.7379' \Rightarrow \frac{26.7379(12)}{360} = 0.8913''$

MAX DEFLECTION

ETABS

$\Delta_{max} = 0.7112'' \le 0.8913''$ ✓

DEMAND vs CAPACITY SUMMARY

DEMAND (ETABS)	CAPACITY	d/c
P_u = −1.589 kip	ϕP_n = −103.627 kip	0.015
M_{ux} = 9.93 k-ft	ϕM_{px} = 51 k-ft	0.1951
M_{uy} = 9.7493 k-ft	ϕM_{py} = 51 k-ft	0.191
V_{ux} = 2.136 kip	ϕV_{nx} = 44.36 kip	0.048
V_{uy} = 1.158 kip	ϕV_{ny} = 44.36 kip	0.019
T_u = 5.7116 k-ft	ϕT_n = 32.329 k-ft	0.177

AISC 360-16 (H1-1b)

$$\frac{P_r}{2P_c} + \left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}}\right) = 0.394 \le 1.0 \checkmark$$

BEAM CALCULATIONS (CONTINUED)

REFERENCES

BM-1 DESIGN (CONTINUED)

AXIAL CAPACITY (COMPRESSION)

AISC 360-16

$L_c = KL$

T C-A-7.1 $\quad k=1$ (CONSERVATIVE)

$L_c = L$

(E3-4) $\quad F_e = \frac{\pi^2 E}{(L_c/r)^2} = \frac{\pi^2(29000)}{(28.174/3.62)^2} = 36.43$ ksi

$F_y/F_e = 1.37 \leq 2.25$

(E3-2) $\quad F_{cr} = \left(0.658^{F_y/F_e}\right)F_y = \left(0.658^{1.37}\right)50$

$F_{cr} = 28.15$ ksi

(E3-1) $\quad P_n = F_{cr} A_g = 28.15(4.09)$

$P_n = 115.14$ kip

E1. $\quad \phi_c = 0.9 \quad \phi P_n = 103.6$ kip ≥ 1.589 kip ✓

FLEXURAL CAPACITY (BOTH AXES SAME)

(F7-1) $\quad M_n = M_p = F_y Z = 50(13.6)$

$M_n = 680$ k-in

F1. $\quad \phi_b = 0.9 \quad \phi M_n = \frac{612 \text{ k-in}}{12} = 51 \text{ k-ft} \geq \begin{cases} 9.93 \text{ k-ft} ✓ \\ 9.75 \text{ k-ft} ✓ \end{cases}$

SHEAR CAPACITY (BOTH AXES SAME)

$k_v = 5 \qquad \sqrt{k_v E/F_y} = 53.85$

$h/t_w = 74.6 \geq 1.37\sqrt{k_v E/F_y}$

(G2-11) $\quad C_{v2} = \frac{1.51 k_v E}{(h/t_w)^2 F_y} = \frac{1.51(5)29000}{(74.6)^2\, 50}$

$C_{v2} = 0.7869$

(G4-1) $\quad V_n = 0.6F_y \underbrace{A_w}_{2ht} C_{v2} = 0.6(50)2(9)0.116(0.7869)$

$V_n = 49.29$ kip

G1. $\quad \phi_v = 0.9 \quad \phi V_n = 44.36 \text{ kip} \geq \begin{cases} 2.136 \text{ kip} ✓ \\ 1.158 \text{ kip} ✓ \end{cases}$

BEAM CALCULATIONS (CONTINUED)

REFERENCES

BM-1 DESIGN (CONTINUED)

TORSIONAL CAPACITY

$\sqrt{E/F_y} = 24.08$

$h/t = 74.6 > 3.07\sqrt{E/F_y}$

AISC 360-16 (H3-5)

$F_{cr} = \frac{0.458\pi^2 E}{(h/t)^2} = \frac{0.458\pi^2(29000)}{(74.6)^2}$

$F_{cr} = 23.56$ ksi

(H3-1)

$T_n = F_{cr} C = 23.56(18.3\, in^3)$

$T_n = 431.06$ k-in

$\phi_T = 0.9 \quad \phi T_n = \frac{387.95 \text{ k-in}}{12} = 32.3 \text{ k-ft} \geq 5.7 \text{ k-ft}$ ✓

COMBINED STRESSES

H3.2

d/c (torsion) $= 0.17 < 20\% \therefore$ USE (H1-1)

$\frac{P_r}{P_c} = 0.015 < 0.2$

(H1-1b)

$\frac{P_r}{2P_c} + \left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}}\right) = 0.394 \leq 1.0$ ✓

BEAM CALCULATIONS (CONTINUED)

REFERENCES

BM-3 DESIGN $\boxed{\text{TRY HSS } 5\times5\times1/8}$

SECTION PROPERTIES

AISC 360-16 TB 1-11

$A_g = 2.23\ in^2$ $I_{xy} = 8.8\ in^4$
$h = 5''$ $S_{xy} = 3.52\ in^3$
$b = 5''$ $r_{xy} = 1.99''$
$t_{design} = 0.116''$ $Z_{xy} = 4.07\ in^3$
$b/t = 40.1$ $J = 13.7\ in^4$
$h/t = 40.1$ $C = 5.53\ in^3$

Weight $= 8.16\ plf \leq 15\ plf$ assumed

BEAM GEOMETRY

ETABS

LENGTH $L = 15'$

DEFLECTION CHECK

L/360 DEFL. CRITERIA

$$L = 15' \Rightarrow \frac{15(12)}{360} = 0.5''$$

ETABS

MAX DEFL
$\Delta_{max} = 0.1439'' \leq 0.5''$ ✓

DEMAND vs CAPACITY SUMMARY

DEMAND (ETABS)	CAPACITY	d/C
$P_u = 1.222$ kip	$\phi P_n = 100.35$	0.012
$M_{ux} = 5.19$ k-ft	$\phi M_{px} = 15.2625$	0.340
$M_{uy} = 5.03$ k-ft	$\phi M_{py} = 15.2625$	0.330
$V_{ux} = 2.003$ kip	$\phi V_{nx} = 31.32$	0.064
$V_{uy} = 0.48$ kip	$\phi V_{ny} = 31.32$	0.015
$T_u = 0.9169$ kft	$\phi T_n = 12.443$	0.074

AISC 360-16 (H1-1b)

$$\frac{P_r}{2P_c} + \left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}}\right) = 0.676 \leq 1.0 \checkmark$$

$$\frac{P_r}{P_c} = 0.012 < 0.2 \therefore \text{USE (H1-1b)}$$

ALSO: NEGLECT TORSION B/C d/c(torsion) = 0.07 < 20%

BEAM CALCULATIONS (CONTINUED)

REFERENCES — BM-3 DESIGN (CONTINUED)

AXIAL CAPACITY (TENSION)

AISC 360-16

(D2-2) $P_n = F_u A_e$ TENSILE RUPTURE CONTROLS

$\phi_t = 0.75$

D3- $A_e = A_g$ ONLY FOR HSS & PLATES

$P_n = 62(2.23) = 138.26$ kip

$\phi P_n = 100.35$ kip ≥ 1.22 kip

FLEXURAL CAPACITY (BOTH AXES SAME)

(F7-1) $M_n = M_p = F_y Z = 50(4.07)$

$M_n = 203.5$ k-in

F1. $\phi_b = 0.9$ $\phi M_n = \frac{203.5 \text{ k-in}}{12} = 15.26$ k ft $\geq \begin{cases} 5.19 \text{ k-ft} \checkmark \\ 5.03 \text{ k-ft} \checkmark \end{cases}$

SHEAR CAPACITY (BOTH AXES SAME)

$k_v = 5$ $\sqrt{k_v E/F_y} = 53.85$

$h/t_w = 40.1 \leq 1.1\sqrt{k_v E/F_y}$

(G2-9) $C_{v2} = 1$

(G4-1) $V_n = 0.6 F_y \underbrace{A_w}_{2ht} C_{v2} = 0.6(50)2(5)0.116(1)$

$V_n = 34.8$ kip

$\phi_v = 0.9$ $\phi V_n = 31.32$ kip $\geq \begin{cases} 2.00 \text{ kip} \checkmark \\ 0.48 \text{ kip} \checkmark \end{cases}$

TORSIONAL CAPACITY

$\sqrt{E/F_y} = 24.08$ $h/t = 40.1 \leq 2.45\sqrt{E/F_y}$

(H3-3) $F_{cr} = 0.6F_y = 0.6(50)$

$F_{cr} = 30$ ksi

(H3-1) $T_n = F_{cr} C = 30(5.53)$

$T_n = 165.9$ k-in

$\phi_T = 0.9$ $\phi T_n = \frac{149.31 \text{ k-in}}{12} = 12.44$ k-ft ≥ 0.92 kft $\checkmark$

BEAM CALCULATIONS (CONTINUED)

BM-2 & BM-4 DESIGN TRY $\boxed{HSS\ 8\times3\times1/8}$

SECTION PROPERTIES

AISC 360-16 T. 1-11

$A_g = 2.46\ in^2$	$I_x = 19.3\ in^4$	$I_y = 4.2\ in^4$
$h = 8''$	$S_x = 4.83\ in^3$	$S_y = 2.8\ in^3$
$b = 3''$	$r_x = 2.8''$	$r_y = 1.31''$
$t_{design} = 0.116''$	$Z_x = 6.11\ in^3$	$Z_y = 3.07\ in^3$
$b/t = 22.9$	$J = 11.3\ in^4$	
$h/t = 66$	$C = 5.27\ in^3$	

Weight = 9.01 plf ≤ 15 plf assumed

BEAM GEOMETRY

ETABS BM-2: $L = 18.20'$

BM-4: $L = 17.16'$

DEFLECTION CHECK

BM-2: $L/360 = \frac{18.2(12)}{360} = 0.607''$

ETABS $\Delta_{max} = 0.524'' \le 0.607''$ ✓

BM-4: $L/360 = \frac{17.16(12)}{360} = 0.572''$

ETABS $\Delta_{max} = 0.416'' \le 0.572''$ ✓

BM-2 DEMAND vs CAPACITY SUMMARY

DEMAND (ETABS)	CAPACITY	d/C
$P_u = -0.364$ kip	$\phi P_n = -19.99$ kip	0.018
$M_{ux} = 9.98$ k-ft	$\phi M_{px} = 22.91$ k-ft	0.435
$M_{uy} = 1.34$ k-ft	$\phi M_{py} = 11.51$ k-ft	0.117
$V_{ux} = 1.979$ kip	$\phi V_{nx} = 44.98$ kip	0.044
$V_{uy} = 0.283$ kip	$\phi V_{ny} = 18.79$ kip	0.015
$T_u = 1.4587$ k-ft	$\phi T_n = 10.601$ k-ft	0.138

AISC 360-16 (H1-1b)

$$\frac{P_r}{2P_c} + \left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}}\right) = 0.561 \le 1.0 \checkmark$$

d/c (torsion) = 0.138 < 20% ∴ NEGLECT TORSION & USE (H1-1)

BEAM CALCULATIONS (CONTINUED)

REFERENCES

BM-2 & BM-4 DESIGN (CONTINUED)

BM-4 DEMAND vs CAPACITY SUMMARY

DEMAND (ETABS)	CAPACITY	d/c
P_u = -0.665 kip	ϕP_n = -22.49 kip	0.027
M_{ux} = 7.90 k-ft	ϕM_{px} = 22.91 k-ft	0.345
M_{uy} = 1.95 k-ft	ϕM_{py} = 11.51 k-ft	0.169
V_{ux} = 2.395 kip	ϕV_{nx} = 44.98 kip	0.053
V_{uy} = 0.473 kip	ϕV_{ny} = 18.791 kip	0.025
T_u = 1.1961 k-ft	ϕT_n = 10.601 k-ft	0.113

AISC 360-16
(H1-1b)

$$\frac{P_r}{2P_c}+\left(\frac{M_{rx}}{M_{cx}}+\frac{M_{ry}}{M_{cy}}\right)=0.528\leq 1.0 \checkmark$$

$\frac{P_r}{P_c} < 0.2$ ∴ USE (H1-1b)

& d/c (torsion) < 20% ∴ NEGLECT TORSION

BM-2 AXIAL CAPACITY (COMPRESSION)

T. C-A-7.1

$L_c = KL$

$k=1$ (conservative)

$L_c = L$

E(3-4)

$$F_e=\frac{\pi^2 E}{(L_c/r)^2}=\frac{\pi^2(29000)}{(18.2/1.31)^2}=10.297\text{ ksi}$$

r_y weaker

$F_y/F_e = 4.85 > 2.25$

(E3-3)

$F_{cr}=0.877F_e = 9.03$ ksi

(E3-1)

$P_n = F_{cr}A_g = 9.03(2.46\text{ in}^2)$

$P_n = 22.21$ kip

E1.

$\phi_c = 0.9$ $\quad \underline{\phi P_n = 19.99 \text{ kip}} \geq 0.364 \text{ kip} \checkmark$

BM-4 AXIAL CAPACITY (COMPRESSION)

T. C-A-7.1

$k=1$ (conservative)

$L_c = KL = L$

$$F_e=\frac{\pi^2 E}{(L_c/r)^2}=\frac{\pi^2(29000)}{(17.16/1.31)^2}=11.58\text{ ksi}$$

$F_y/F_e = 4.32 > 2.25$

(E3-3)

$F_{cr} = 0.877F_e = 10.16$ ksi

BEAM CALCULATIONS (CONTINUED)

REFERENCES

BM-2 & BM-4 DESIGN (CONTINUED)

BM-4 AXIAL CAPACITY (CONTINUED)

AISC 360-16

(E3-1) $P_n = F_{cr} A_g = 10.16\,(2.46\,in^2)$

$P_n = 24.99$ kip

E1. $\phi_c = 0.9 \quad \underline{\phi P_n = 22.49\ kip} \geq 0.665\ kip$ ✓

FLEXURAL CAPACITY (BM-2 & BM-4 SAME)

MAJOR AXIS

(F7-1) $M_n = M_p = F_y Z_x = 50(6.1)$

$M_n = 305$ k-in

F1. $\phi_b = 0.9 \quad \phi M_n = \frac{274.95\,k\text{-}in}{12} = 22.91\ k\text{-}ft \left\{ \begin{array}{l} 9.97\ k\text{-}ft ✓ (BM-2) \\ 2.91\ k\text{-}ft ✓ (BM-4) \end{array} \right.$

MINOR AXIS

(F7-1) $M_n = M_p = F_y Z_y = 50(3.07)$

$M_n = 153.5$ k-in

F1. $\phi_b = 0.9 \quad \phi M_n = \frac{138.15\,k\text{-}in}{12} = 11.56\ k\text{-}ft \left\{ \begin{array}{l} 1.34\ k\text{-}ft ✓ (BM-2) \\ 1.95\ k\text{-}ft ✓ (BM-4) \end{array} \right.$

SHEAR CAPACITY (BM-2 & BM-4 SAME)

MAJOR AXIS

$k_v = 5 \quad \sqrt{k_v E/F_y} = 53.85$

$h/t_w = 66 \leq 1.37\sqrt{k_v E/F_y}$

(G2-10) $C_{v2} = \frac{1.10\sqrt{k_v E/F_y}}{h/t_w} = 0.898$

(G4-1) $V_n = 0.6 F_y \underbrace{A_w}_{2ht} C_{v2} = 0.6(50)\,2(8)\,0.116\,(0.898)$

$V_n = 49.97$ kip

$\phi_v = 0.9 \quad \underline{\phi V_n = 31.32\ kip} \geq \left\{ \begin{array}{l} 1.98\ kip\ (BM-2) ✓ \\ 2.40\ kip\ (BM-4) ✓ \end{array} \right.$

BEAM CALCULATIONS (CONTINUED)

BM-2 & BM-4 DESIGN (CONTINUED)

SHEAR CAPACITY (CONTINUED)

MINOR AXIS

$k_v = 5 \quad \sqrt{k_v E/F_y} = 53.85$

$h/t_w = 22.9 \leq 1.1\sqrt{k_v E/F_y}$

(G 2-9) $C_{v2} = 1$

(G4-1) $V_n = 0.6 F_y \underbrace{A_w}_{2ht} C_{v2} = 0.6(50)2(3)0.116(1)$

$V_n = 20.88 \text{ kip}$

$\phi_v = 0.9 \quad \phi V_n = 18.792 \text{ kip} \geq \begin{cases} 0.283 \text{ kip (BM-2)} \\ 0.473 \text{ kip (BM-4)} \end{cases}$ ✓ ✓

TORSIONAL CAPACITY

$\sqrt{E/F_y} = 24.08 \quad h/t = 66 \leq 3.07\sqrt{E/F_y}$

(H3-4) $F_{cr} = \dfrac{0.6F_y(2.45\sqrt{E/F_y})}{(h/t)} = \dfrac{0.6(50)(2.45\sqrt{E/F_y})}{66}$

$F_{cr} = 26.82 \text{ ksi}$

(H3-1) $T_n = F_{cr} C = 30(5.27)$

$T_n = 141.341 \text{ k-in}$

$\Phi_T = 0.9 \quad \phi T_n = \dfrac{127.21 \text{ k-in}}{12} = 10.60 \text{ k-ft} \geq \begin{cases} 1.459 \text{ k-ft (BM-2)} \\ 1.196 \text{ k-ft (BM-4)} \end{cases}$ ✓ ✓

BEAM CALCULATIONS (CONTINUED)

REFERENCES

INTERNAL FRAMING DESIGN

DESIGN OF INTERIOR FRAMING IS FOR PINNED SUPPORT CONDITIONS & IS DESIGNED FOR L/180 DEFLECTION CRITERIA.

DEFLECTION DESIGN

MAX SPAN: 8'-7" = 103"

CRITERIA: L/180 = 103/180 = 0.572"

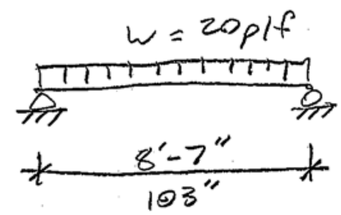
ROOF LIVE LOAD: 20 psf

TRIB WIDTH = 1'-0"

SERVICE LIVE LOAD L = 20 plf

TRY HSS 4x2x1/8

$$\Delta_{max} = \frac{5wL^4}{384EI}$$



SECTION PROPERTIES.

A = 1.3 in²
h = 4"
b = 2"
I_x = 2.65 in⁴
Z_x = 1.66 in³

$$\Delta_{max} = \frac{5(0.02klf)(103)^4}{384(29000 ksi)\,2.65}$$

Δ_{max} = 0.381" < 0.572" ✓

STRENGTH CHECK

FLEXURAL CAPACITY

DEMAND: DEAD = 5 plf
LIVE = 20 plf
1.2D + 1.6L = 38 plf

$M_u = \frac{wL^2}{8}$ = 50 k-in

AISC 360-16 (F 7-1)

CAPACITY: $M_n = M_p = F_y Z_x = 50(1.66)$
M_n = 83 k-in

F1. $\phi_b = 0.9$ ϕM_n = 74.7 k-in ≥ 50 k-in ✓

Notes: The table depicting the typical properties of PALSUN FR sheet appears below. Note that some of the displayed properties are typical to polycarbonate (the material PALSUN FR is made of) while others relate to a typical 3 mm (1/8 in.) thick PALSUN FR sheet.

Conditions, units and values in U.S. Customary units are presented in the table within parentheses. All the results depicted in this table were obtained by following the indicated ASTM method except where another method is indicated by the appearance of this symbol (b).

PALSUN® FR

Material: UV protected Fire Retardant Polycarbonate Sheet

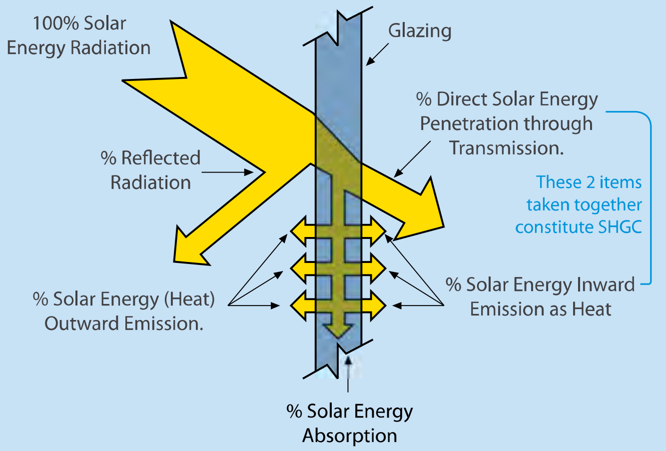
Updated: 10/11/18 (MDW)

Property	Conditions (U.S. Customary)	Test Method	Units - SI (U.S. Customary)	Value (U.S. Customary)
Physical				
Density		D-1505	g/cm^3 (lb/ft^3)	1.2 (75)
Water Absorption	24 hr. @ 23°C	D-570	%	0.15
Mechanical				
Tensile strength at yield	10 mm/min (0.4 in./min)	D-638	MPa (psi)	62 (9,000)
Tensile strength at break	10 mm/min (0.4 in./min)	D-638	MPa (psi)	65 (9500)
Elongation at yield	10 mm/min (0.4 in./min)	D-638	%	6
Elongation at break	10 mm/min (0.4 in./min)	D-638	%	110
Tensile Modulus of Elasticity	10 mm/min (0.4 in. /min)	D-638	MPa (psi)	2,378 (345,000)
Flexural Modulus	1.3 mm/min (0.05 in./min)	D-790	MPa (psi)	2,378 (345,000)
Flexural Strength at Yield	1.3 mm/min (0.05 in./min)	D-790	MPa (psi)	93 (13,500)
Rockwell Hardness		D-785	R scale / M scale	125 / 70
Abrasion (Taber Process)	100 Cycles, CS-10S Wheel, 500g	D-1044	% Haze	N/A
Compressive Strength	1.3 mm/min (.05 in./min)	D-695	MPa (psi)	86 (12,500)
Compressive Modulus	1.3 mm/min (.05 in./min)	D-695	MPa (psi)	2378 (345,000)
Shear strength at Break	1.3 mm/min (.05 in./min)	D-732	MPa (psi)	68 (10,000)
Shear Modulus	1.3 mm/min (.05 in./min)	D-732	MPa (psi)	786 (114,000)
Thermal				
Long Term Service Temperature			°C (°F)	-75 to +100 (-175 to +212)
Short Term Service Temperature			°C (°F)	-75 to +120 (-175 to +250)
Heat Deflection Temperature	Load: 1.82 Mpa (264 psi)	D-648	°C (°F)	132 (270)
Vicat Softening Temperature	Load: 1 kg (2.2 lb)	D-1525	°C (°F)	150 (300)
Coefficient of Linear Thermal Expansion		D-696	10^{-5}/°C (10^{-5}/°F)	6.5 (3.6)
Thermal Conductivity		C-177	W/m°K (Btu-in./hr-ft^2-°F)	0.21 (1.46)
Specific Heat Capacity		C-351	kJ/kg°K (Btu/lb°F)	1.26 (0.31)
Optical				
Haze	3 mm (0.12 in.) Clear Sheet	D-1003	%	<0.5
Light Transmission	3 mm (0.12 in.) Clear Sheet	D-1003	%	89
Refractive Index	Clear Sheet	D-542		1.59
Yellowness Index	3 mm (0.12 in.) Clear Sheet	D-1925		<1
Electrical				
Dielectric Constant	50 Hz	D-150		3
	1 MHz	D-150		2.9
Dissipation Factor	50 Hz	D-150		0.9
	1 MHz	D-150		11
Dielectric Strength Short Time	500 V/s	D-149	kV/mm (V/mil)	>30 (>770)
Surface Resistance	Ketley	D-257	Ohm	5.1×10^{15}
Volume Resistance	Ketley	D-257	Ohm-cm	1.3×10^{17}
Hot Wire Ignition (HWI)		UL746a	Ignition Range (PLC)	UL File #E221255
High Current Arc Ignition (HAI)		UL746a	Number of Arcs to Cause Ignition (PLC)	UL File #E221255
UL Flame Class		UL94	Flame Rating	V-0
Relative Temperature Index (RTI)		UL 746b	C°(°F)	80 (176)

Solar Transmission Properties

Solar energy transmission is an extremely important consideration with transparent materials. Geographic location and typical thermal/optical properties of the specific glazing are the main factors influencing solar heat gain. Various types of PALSUN—textured, tinted, opal, diffused, and heat blocking SolarSmart™ sheets—can be used to deliver the exact quantity and quality of light desired. Each of these products transmit different amounts of direct light in varying levels of light diffusion, which may help to spread the light throughout the structure or enclosure. The sheets also vary in their selectivity index (SI) values, which determines how efficiently they keep heat out while letting more "cool light" in (See next page for more information on SolarSmart™ products). Although colors and tints reduce the percentage of visible light transmitted through the sheets, solar energy is still absorbed by the glazing itself, and in turn transferred by convection and far IR radiation from the heated glazing into the building. PALSUN sheets with embossed or matte surfaces, or diffuser colors, diminish glare and harsh light, preventing damage by direct irradiance. However, solar energy is still transmitted through and increases the solar heat gain inside the structure.

Figure 4: Solar Radiation Schematic Behavior Through Light Transmitting Material



Color*	% Light Transmission ASTM D-1003	%Haze ASTM D-1003	Solar Heat Gain (SHGC) ASTM E-424-71	Shading Coefficient ASTM E-424-71
Clear	90	<1	0.87	1.00
Bronze	20	<1	0.45	0.52
	35	<1	0.56	0.64
	50	<1	0.65	0.75
Solar Grey	20	<1	0.44	0.51
	35	<1	0.56	0.64
	50	<1	0.65	0.75
White Opal	28	100	0.32	0.37
White Diffuser	80	100	0.87	1.00
	70	100	0.68	0.79
Solar Ice	20	100	0.37	0.45
Solar Control	20	67	0.33	0.36
	35	52	0.45	0.52
	50	50	0.54	0.61
Solar Olympic	20	35	0.41	0.47
	35	20	0.52	0.60
	50	63	0.63	0.73
Smart Green	70	42	0.58	0.67
Smart Blue	70	42	0.57	0.65
Bluish Breeze	70	42	0.55	0.63

SolarSmart™ Selective Solar Control Technology

*Values in the table above relate to 3 mm Sheet. Further information on additional products is available upon request.

Terminology Used in the Table
% Haze (ASTM D-1003): the percentage of transmitted light which, in passing through the specimen, deviates more than 2.5° from the incident beam by forward scattering.
% Light Transmission (ASTM D-1003): Percentage of incident visible light that passes through an object.

% Solar Heat Gain (SHGC): The percent of incident solar radiation transmitted by an object which includes the direct solar transmission plus the part of the solar absorption reradiated inward.
Shading Coefficient (ASTM E424-71): The ratio of the total solar radiation transmitted by a given material to that transmitted by normal glass, whose light transmission is 87%. It can be calculated by: SC = (1.15 x SHGC)