

Mustang Sculpture

Architectural Engineering
California Polytechnic State University, San Luis Obispo

by:

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1.0 Introduction

During Spring 2016, twelve students began work on a senior project to design and build an iconic mustang sculpture with the help of artist Ivan McLean and under the supervision of Professor Craig Baltimore and the Kennedy Library Curator Catherine Trujillo. The sculpture was a part of a sustainability exhibit in Kennedy Library, “The Living Library”, that required the use of only recycled materials. The entire sculpture was conceived, designed and constructed in only 10 weeks and was a collaborative effort between students studying architectural engineering, architecture, graphic design and agricultural and environmental plant sciences. The success of the student collaboration in such a short time line was made possible by the team atmosphere of students, University, and industry. The published report by the Spring 2016 students, The Built ENVIRONMENT can be found here:

<http://digitalcommons.calpoly.edu/arcesp/17>

This Fall, two architectural engineering students had the opportunity to take the project to the next level and find a home for it on campus as a piece in the [campus art collection](#). The scope of the project included identifying a location, designing a foundation, assembling a proposal package and going through the permitting process, working with Cal Poly campus facilities, and installation. Due to delays during in the permitting process, the installation was unable to be completed. This senior project is to be considered a “first draft” and was an experience in the total approval process

1.1 Motivation for the Project and Formation of Team

In phase one of this project, the motivation started with the desire of professional artist, Ivan Mclean, to work with students on a Cal Poly campus sculpture. The phase two team, like the original 16 students involved in the first phase, hoped to become part of the legacy the mustang sculpture would leave. The students who previously worked on the project put so much time and effort into designing and building the sculpture, and motivated this team to find a home for the mustang sculpture on campus. The first phase of the project included only a two week long exhibit in the library, and the goal of the second phase was to find a permanent home and get more student exposure to this incredible project.

1.2 Final Product Goals

Final product goals for the Report were established early in the project timeline. The primary goal was having a safe sculpture installed in the planters in between building 21 and 187 by December 2016. The goal of the ARCE students was to satisfy their senior project requirements and leave a legacy on the Cal Poly campus. Senior project reports, would start up following the installation of the mustang sculpture projected for November 28th. Product goals also included full accountability of all persons throughout the duration of the project.

1.3 Design Process Overview

The design process started with the exploration of placement options for the mustang sculpture. In the consideration of locations, public safety and constructability were heavily considered, and followed with the decision to place the mustang sculpture in large planters seated between building 21 and building 187. The next consideration were the placement, orientation, and foundation type supporting the mustang sculpture. The team considered all possible loading scenarios and designed the footings accordingly.

1.4 Report Overview

The report offered a large spectrum of different types of student learning. The team was introduced to the importance of project-delivery; the design, fabrication, transport, and erection of the mustang sculpture all elements of consideration. The students were carefully placed into an interdisciplinary team that had to communicate effectively for success. Successful communication was accomplished through weekly meetings and shared file storage. Meetings acted as a common time to discuss the progression of the project and any other presented concerns. One main task of the team was the permitting process with:

- Cal Poly facilities
- Art Acquisition Committee
- Landscape Committee

The team remained aware to satisfy the final product goals two to three weeks should be allowed for the permitting process. This report summarizes the efforts of the team in preparing a calculations package for approval of professional engineer, Kevin Dong for approval with the committees mentioned.

2.0 Design Process

2.1 Location and Placement

The design process began by considering different placement options for the mustang sculpture. The team first visited the proposed site for the installation, which was two large planters seated between building 21 and building 187 (Figure 3, Page 6). The planters are currently unused and have great potential to house the mustang sculpture. The team of engineers and graphic designers worked together to create renderings of possible placements and compared each option, see figure 1. In comparing the different placement ideas, the team considered multiple orientations of the mustang sculpture, such as parallel to the length of the planter or at an angle facing outward. They also considered the difference between placing the mustang sculpture in either of the two possible planters and in either the east or west end. The original placement that was considered is shown in the rendering below.



Figure 1: Rendering of Proposed Location

The team also considered the movement of people through the walkway where the mustang sculpture was to be installed. Because the building has multiple entrances, the team chose an orientation that they believed would best showcase the mustang sculpture, and where it would face the greatest amount of people walking by. A sketch of the final location done by Kevin Church is shown below, figure 2.



Figure 2: Artist Sketch by Kevin Church

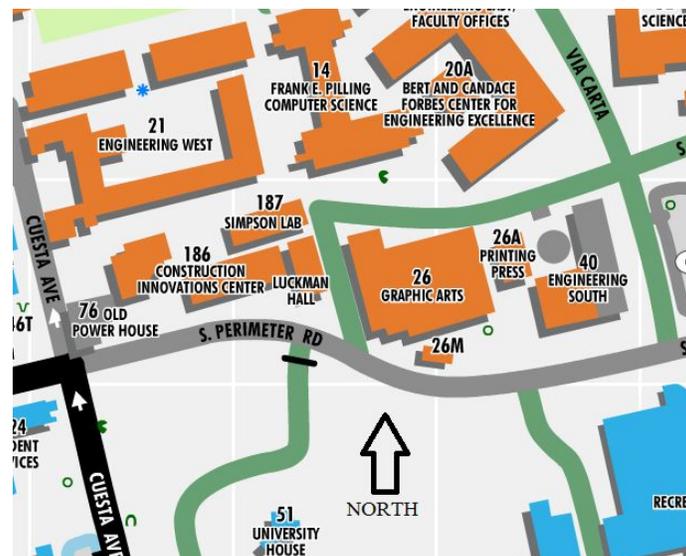


Figure 3: Proposed Location

2.2 Loading

The second phase of the project was to calculate all of the forces that the mustang sculpture could be subjected to after installation. These included forces due to seismic loading, wind loading and human loading, from students climbing on the structure. All of the calculations were calculated based on ASCE 7-10 and can be found in the attached proposal and should be considered a draft and reviewed prior to submitting to facilities for approval.

Since the mustang sculpture was a series of trusses, the team from the first phase of the project made an analysis model using RISA, a structural analysis software. This was done by assigning each node on the sculpture a 3D coordinate (x, y, z) and then connecting the appropriate nodes with members. During the second phase of the project, the team refined the RISA model by applying specific member types to each of the members on the model to more accurately represent the actual object. This was done so the analysis model accurately reflected the strength of the members as well as the weight of the mustang sculpture. The team then used the model to apply the different loads and analyze the reactions at each of the three support locations. The RISA model was also used to calculate the center of mass. Initially, the team found the center of mass based on the reactions in each of the supports due to the dead weight of the structure. These values were compared and verified by the center of gravity that is automatically calculated by RISA.

Due to the weight distribution of the mustang statue and only three legs used for support (a triangle), one of the support locations experienced uplift which became the governing case for design of the foundation. All three load cases amplified the uplift at the back right support. During the first phase of the project when installation occurred in the library, a large, heavy base plate was used as a counterweight to counteract the uplift force caused by the self-weight of the structure. For the second phase of the project, these base plates were no longer adequate, because the mustang sculpture faced larger loads when installed outside. The foundations designed during the second phase of the project were also designed to resist the uplift force caused by the governing load case. The following sections elaborate on each load case and describe their effect on the mustang sculpture.

2.3 Seismic Loading

Initial seismic calculations were done during the first phase of the project, but the senior project team worked to edit and refine them. The effects of seismic loading on the mustang sculpture were calculated in accordance with chapter 13 of ASCE 7-10. An approximate weight of 600lbs was found based on the materials used and compared with the weight calculated by the RISA model. The dimensions and the weight along with the location and type of structure dictate the factors used to calculate the seismic force.

2.4 Wind Loading

The wind load was determined through the process outlined in chapter 26 of ASCE 7-10. Because the mustang sculpture is a very open structure made of trusses, it is defined as “open signs, lattice structures” and the wind loads are calculated accordingly. The center of geometry was calculated using the projected solid area of the mustang sculpture seen below in figure 4. These were the approximate locations on the mustang sculpture where the structure would be subject to wind loading, refer to figure 5 and 6 on page 9. A wind load of approximately 2000 lbs was applied at the center of geometry which amplified the overturning effect and the uplift experienced at the back right support. Compared to the seismic loading and the human loading, the wind loading became the governing case of uplift and was therefore used to design the foundation.

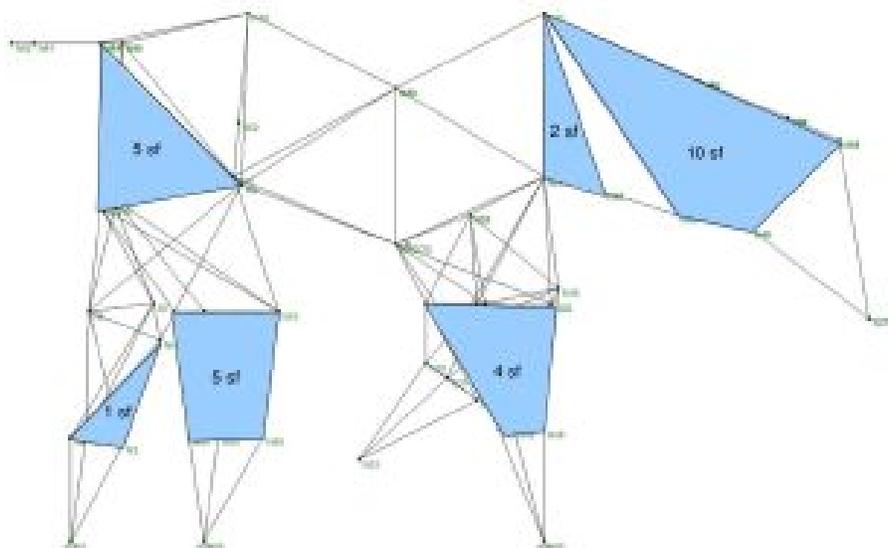


Figure 4: Projected Solid Area of Mustang Sculpture

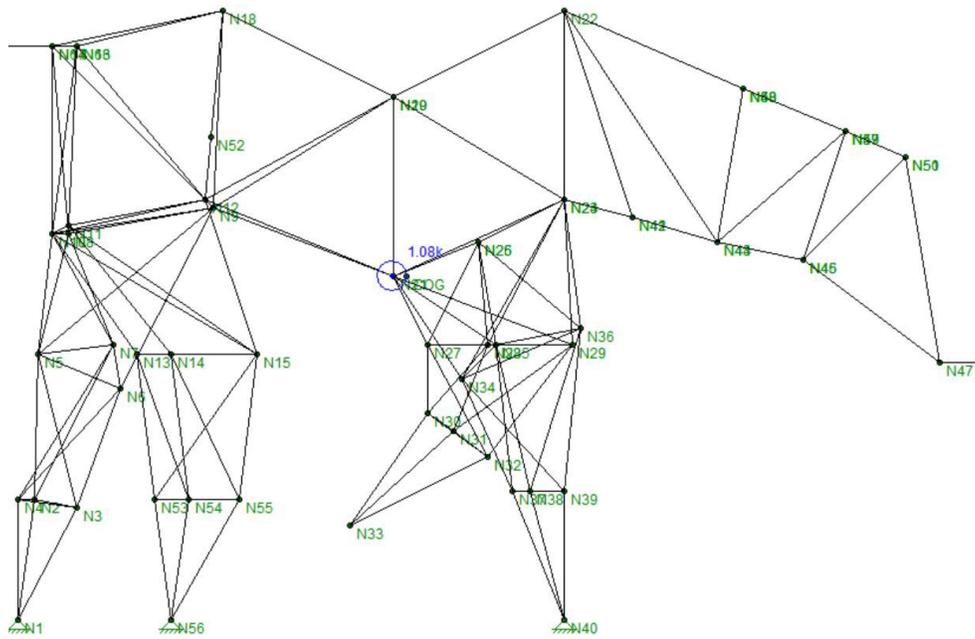


Figure 5: Elevation View of Center of Geometry for Wind Loading

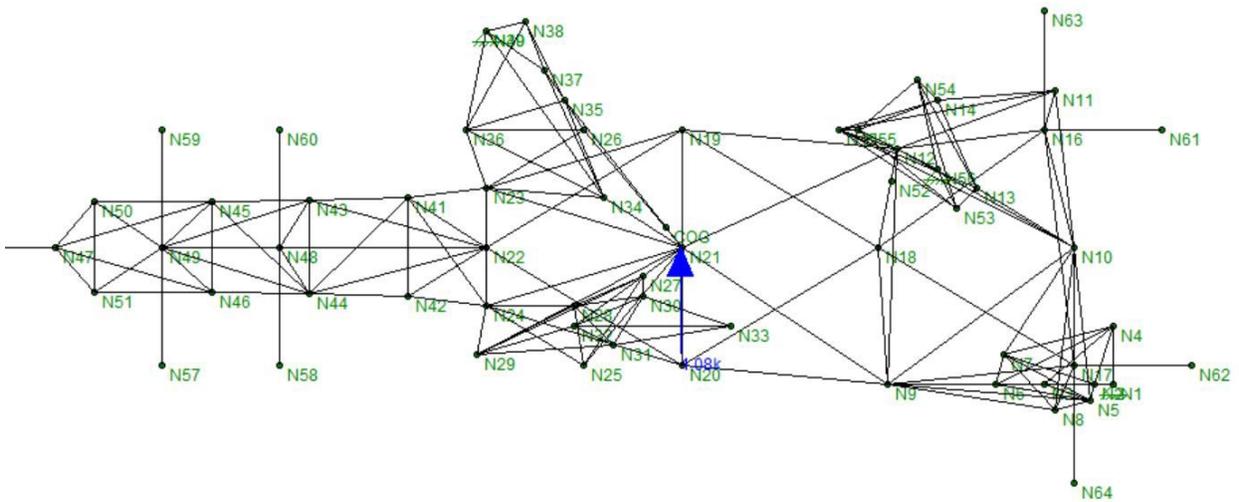


Figure 6: Plan View of Center of Geometry for Wind Loading

2.5 Human Loading

In order to accurately predict the effects of people climbing on, leaning on and shaking the mustang sculpture, the team modeled and analyzed multiple cases of human loading. Each human was modeled to create a downward force of 200 lbs and an outward force of 100 lbs, see figure 7 and 8. The team checked cases of people climbing on both the front and back as well as on the left and right sides and many combinations of these cases as well. The governing load case considering human loading is shown in the figure below. This model was made to represent two people climbing on the left side of the head and neck of the horse, greatly amplifying the overturning effect. The reactions created at the support locations were not greater than those created by the wind load, so therefore the foundation was designed in accordance with the wind load.

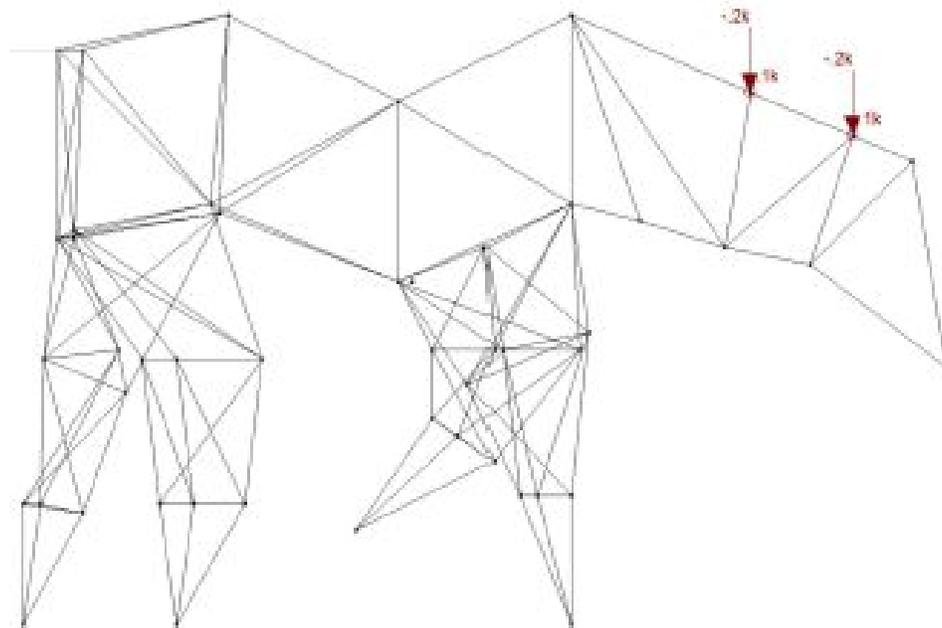


Figure 7: Elevation View of Human Loading

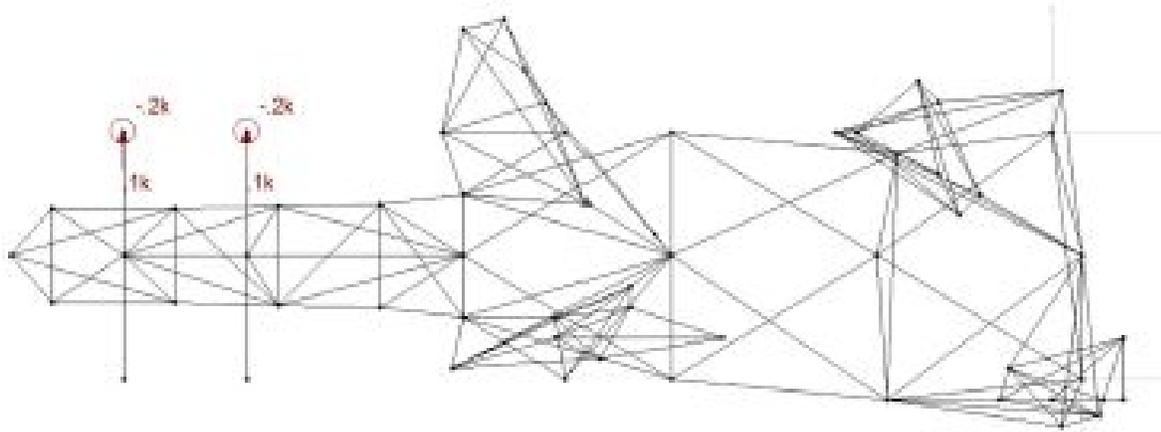


Figure 8: Plan View of Human Loading

2.6 Facilities Consideration

For the next phase of the project, the team verified with facilities to make sure that the planters were of adequate depth to install the foundations. The team also made sure that there was no piping that could be affected by the installation of the concrete footings. Because nothing lies underneath the soil in the planter at the proposed location, the depth of the foundation was not restricted at all. Facilities stated the the planters were previously lawn areas but have been mulched with wood chips so irrigation was not a factor that needed to be considered in the design of the concrete footings either. Facilities will configure the irrigation system around the mustang sculpture foundation if they chose to incorporate irrigation at that location in the future.

3. Approval Process

3.1 Timeline

Proposed Timeline

Phase I. Support

- Reach out to previous students and faculty for letter of support
 - Craig Baltimore, Al Estes, President Armstrong, Industry professionals, etc.
- [DUE: 10/4/16]

Phase 2. Schematic Design

- Initial models
 - Collaborate with Habib, ART major, on potential orientations of mustang sculpture
- [DUE: 10/6/16]

Phase 3. Design Development

- Foundation design for seismic, wind, and human loading completed
 - Reviewed by advisor, Craig Baltimore
- [DUE: 10/4/16]

Phase 4. Permitting

- Pre-permit meeting with Mike Hogan, Cal Poly facilities
- [DUE: 10/5/16]

Phase 5. Construction Documents

- Calculations package assembled ready for stamping
- [DUE: 10/11/16]

Phase 6. Safety

- Evaluate all safety concerns
 - ADA
 - Ears
- Ensure all necessary parts are accounted for and no repairs are needed
- [DUE: 10/18/16]

Phase 7. Permitting

- Proposal submitted to Cal Poly facilities and Art Acquisition Committee
- [DUE: 10/25/16]

Phase 8. Construction and Installation

- Concrete poured and mustang sculpture installed in proposed location
- [DUE: 11/8/16]

Due to delays in the stamping and permitting process the team was unable to complete the installation and construction phase of the project. The final timeline below reflects the executed timeline finished by December 2016.

Final Timeline

Phase I. Support

- Reach out to previous students and faculty for letter of support
 - Craig Baltimore, Al Estes, President Armstrong, Industry professionals, etc.
- [OCCURRED: 10/4/16]

Phase 2. Schematic Design

- Initial models
 - Collaborate with Habib, ART major, on potential orientations of mustang sculpture
- [OCCURRED: 10/5/16]

Phase 3. Design Development

- Foundation design for seismic, wind, and human loading completed
 - Reviewed by advisor, Craig Baltimore
- [OCCURRED: 10/25/16]

Phase 4. Permitting

- Pre-permit meeting with Mike Hogan, Cal Poly facilities
- [OCCURRED: 10/10/16]

Phase 5. Construction Documents

- Calculations package assembled ready for stamping
- [OCCURRED: 12/8/16]

Phase 6. Safety

- Evaluate all safety concerns
 - ADA
 - Ears
- [OCCURRED: 10/20/16]

Phase 7. Permitting

- Proposal submitted to Cal Poly facilities and Art Acquisition Committee
- [OCCURRED: 12/16/16]

Phase 8. Recommendations

- Recommendations for the installation and construction to be executed in the next part of this project
- [DUE: 12/17/16]

Phase two of the project included the permitting process with the Art Acquisition Committee, Campus Landscape Committee, and Cal Poly Facilities.

3.2 Art Acquisition Committee

In order to receive approval from the Art Acquisition Committee (AAC), the team submitted their proposal along with a request form to have the mustang sculpture become part of the campus art collection, specifically the outdoor collection. This form can be found in the appendix of the report. Catherine Trujillo, the head of the AAC, was notified of this request and has notified the team that she will present the proposal in the following committee meeting. The AAC recommends policy, guidelines and procedures on the oversight, use, display and other implementation of the University Art Collections, including collecting scope, acquisition, management and deaccession of artwork. When approved by the AAC, a plaque is to be installed with the installation of the mustang sculpture identifying it as a piece in the campus art collection and providing its identification.

3.3 Campus Landscape Committee

The team was also required to get permission from the Campus Landscape Committee (CLC). The CLC is a subset of the campus planning committee and is in charge of the ongoing assessment of the landscape on campus. They can also make recommendations for landscaping of new projects or replacement plantings. At this point, no landscaping has been incorporated into this phase of the project, however there are recommendations for collaboration in section 4 of this report.

3.4 Cal Poly Facilities

Cal Poly Facilities requires a proposal for all student projects to be installed on campus, which must be approved by Mike Hogan, the construction inspector. The complete proposal is included in the appendix of this report, which contains sketches, loading analysis results, foundation design, construction drawings and renderings of the proposed installation. Along with the proposal, the facilities construction request form has been completed and included in the appendix.

In order to optimize the time required for Facilities approval, a “pre-permit” meeting was arranged with Cal Poly facilities, Mike Hogan. The team had a meeting with Mike Hogan to discuss the requirements and timeline of the proposal approval process. Mr. Hogan noted that a stamped set of calculation by a licensed engineer, would allow the team to

bypass the engineering fee usually charged by facilities to cover the cost of an engineering review.

4. Foundation for Implementation Phase

Refer to The Built ENVIRONMENT report, <http://digitalcommons.calpoly.edu/arcesp/17>, for the installation and assembly instructions of the mustang sculpture. The below is the team's recommendations after rigorous research for the construction and installation of the mustang sculpture at the proposed location.

4.1 Installation Location

If the installation team decides to change the installation location from the original intent, we suggest doing a study of the flow of people through the surrounding area. This study would highlight where to place the mustang sculpture, so it gets maximum exposure to the student body that pass by. The details of the decision made for the placement of the mustang sculpture can be found in section 2.0 Design Process.

4.2 Construction Materials

The team's recommendations for concrete supply are Hanson Aggregate or Freshcrete, both local in San Luis Obispo. The concrete suppliers advise a week's notice for scheduling. The calculations performed for three isolated concrete footings required for approximately 3 yd³ of concrete to be poured. The team budgeted \$500 for the concrete, per quotes from Hanson Aggregate and Freshcrete.

Per the engineering calculations provided in the proposal, the concrete footings designed also require #4 rebar in order to achieve adequate strength. Each footing will contain approximately 64' of rebar (8 bars that are 3.5' long top and bottom) leading to a total of 192' required total for all of the footings. The rebar can be purchased at Home Depot, or another hardware store, for approximately \$4.50/3'. The team budgeted \$350 for the rebar, leaving a little extra in the budget if more rebar needs to be purchased.

Formwork will also be required for the construction phase of the project. The team has budgeted \$250 for formwork, including plywood, 2x4's and nails.

4.3 Site Excavation

The site must be excavated in preparation for the formwork placement and the concrete pour. This excavation is proposed to be done by students and no power tools should be needed. The site is currently composed of soil mulched with wood chips and approximately 4 yd³ of soil will need to be removed. The team suggests contacting facilities in relation to removal of the soil once it has been excavated from the site. Once the excavation is completed, the team can begin to build and install the formwork.

4.4 Installation Materials

The foundation design with the consideration of wind loading, seismic loading, and human loading showed uplift at the back right support. During the first phase of the project this was recognized by placing a large base plate to counteract the uplift force due to self-weight of the mustang sculpture. In the installation process for phase two, the uplift force must be considered in the placement of anchor bolts on each supporting foundation. For ease of construction, the team recommends using Simpson Set Epoxy Adhesive with $\frac{5}{8}$ " threaded anchor bolts. The proper placement of the anchor bolts connecting the base plates to the foundation is critical for the design, and will likely be more accurate by drilling holes for the threaded anchors with epoxy adhesive. With this method, the mustang structure can be assembled in place and the holes can be drilled precisely where the existing holes in the base plates sit on the foundation. The team recommends a proper embedment depth of 11" if using the epoxy anchor bolts. This embedment depth is needed to engage all of the concrete for the uplift loading.

Threaded anchor bolts may be used as well, however the installation becomes more tedious. The team suggests the construction of formwork to ensure proper alignment of anchor bolts in the three support locations. After investigation the team found the use of plywood and 2x4s for formwork in installation of threaded anchor bolts. The plywood and 2x4's would be used to create a template to mark the exact location of the existing holes on the base plates. This template would then be used to place the threaded anchor bolts into the foundation, prior to the actual installation of the mustang sculpture. This method requires precision and accuracy, because the anchor bolts need to line up exactly with the holes on the base plates for smooth installation.

5.0 Conclusion

Throughout the course of the project, the team of engineering students worked hard in collaboration with the graphic design student, the curatorial advisor Catherine Trujillo, the faculty advisor Craig Baltimore, Cal Poly Facilities, the Art Acquisition Committee, the Campus Landscape Committee, and Professor and Associate Dean Kevin Dong. Due to delays in the stamping and permitting process, the team was unable to install the mustang sculpture on campus in the proposed location. However, they have carefully prepared for another team to take over for phase three of the project, and set the stage for a flawless installation. The team was faced with challenges and struggles similar to those experienced in the work force, and has learned about the permitting and approval process along the way.

Final product goals for the Report were established early in the project timeline. The primary goal was having a safe sculpture installed in the planters in between building 21 and 187 by December 2016. The goal of the ARCE students was to satisfy their senior project requirements and leave a legacy on the Cal Poly campus. Senior project reports, would start up following the installation of the mustang sculpture projected for November 28th. Product goals also included full accountability of all persons throughout the duration of the project.

5.1 Challenges

The team's biggest constraint on this project was time. On day one of the second phase of this project, the team ran through a proposed timeline to ensure success. In the proposed timeline three weeks were allotted for the stamping and permitting process to provide proper time for the pouring of concrete foundations. Due to delays in the stamping and permitting process, the mustang sculpture was unable to be erected by December 2016. The team learned high-impact construction projects and the design iteration process over the course of 11 weeks.

5.2 Aspirations

The team hopes for another group of students to continue out the legacy of the mustang sculpture in a phase three. In order for a smooth progression of this project, the team has provided recommendations for the construction and installation of the mustang sculpture.

6.0 Acknowledgements

This phase of the project would not be made possible without the support throughout from faculty. The team would like to give special thanks to advisor, Craig Baltimore who aided the students in presenting a professional calculation package. Catherine Trujillo, library curator, assisted the team with the proposal process through weekly meetings. Catherine additionally the head of the Art Acquisition Committee, guided students through a seamless approval process. Kevin Dong (Professional Engineer) who commented on initial calculations. Through the help of Kevin, Catherine, and Craig the team made a complete proposal to submit to Cal Poly facilities, Mike Hogan. Mike Hogan from the start of the project communicated the necessary criteria for approval at the scheduled pre permitting meeting for approval with Cal Poly facilities. Lastly, Habib did an excellent job generating graphics for all possible location of the mustang sculpture in the early stages of this project.

7.0 Appendix

See following page for submitted Cal Poly Facilities proposal