Modular House Restoration

A Senior Project presented by:

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Advisor:

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to:
Architectural Engineering Department
California Polytechnic State University
San Luis Obispo, CA

In Partial Fulfillment
of the Requirements for the Degree
Bachelor of Science
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# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of Figures</td>
<td>2</td>
</tr>
<tr>
<td>1.0 Introduction/Scope</td>
<td>3</td>
</tr>
<tr>
<td>2.0 Stairs</td>
<td>5</td>
</tr>
<tr>
<td>2.1 Materials</td>
<td>6</td>
</tr>
<tr>
<td>2.2 Fabrication</td>
<td>6</td>
</tr>
<tr>
<td>2.3 Installation</td>
<td>8</td>
</tr>
<tr>
<td>3.0 Handrail</td>
<td>11</td>
</tr>
<tr>
<td>3.1 Materials</td>
<td>11</td>
</tr>
<tr>
<td>3.2 Fabrication</td>
<td>11</td>
</tr>
<tr>
<td>3.3 Installation</td>
<td>11</td>
</tr>
<tr>
<td>4.0 Guardrail</td>
<td>13</td>
</tr>
<tr>
<td>4.1 Materials</td>
<td>13</td>
</tr>
<tr>
<td>4.2 Fabrication</td>
<td>13</td>
</tr>
<tr>
<td>4.3 Installation</td>
<td>15</td>
</tr>
<tr>
<td>5.0 Roof</td>
<td>16</td>
</tr>
<tr>
<td>5.1 Materials</td>
<td>16</td>
</tr>
<tr>
<td>5.2 Demolition of Existing Roof</td>
<td>17</td>
</tr>
<tr>
<td>5.3 Installation of New Roof</td>
<td>18</td>
</tr>
<tr>
<td>6.0 Reflections</td>
<td>20</td>
</tr>
<tr>
<td>6.1 Reflection: Michael Blanchard</td>
<td>20</td>
</tr>
<tr>
<td>6.2 Reflection: Abby Lentz</td>
<td>21</td>
</tr>
<tr>
<td>7.0 References</td>
<td>21</td>
</tr>
<tr>
<td>8.0 Appendix</td>
<td>22</td>
</tr>
<tr>
<td>Appendix A: Railing Calculations</td>
<td>22</td>
</tr>
<tr>
<td>Appendix B: Verco Decking Catalog Page</td>
<td>23</td>
</tr>
<tr>
<td>Appendix C: Construction Documents</td>
<td>24</td>
</tr>
</tbody>
</table>
List of Figures

Figure 1: New Modular House Staircase
Figure 2: Cut plan for steel plates
Figure 3: (Left) Using the Plasma Cutter to cut out all pieces for staircase. (Right) Shop welding the pieces of the staircases together.
Figure 4: Drilling bolt holes in stiffener plates and risers
Figure 5: Plan view of entry stairs. Lowest step is flush with front face of column.
Figure 6: Field welding stair (A, B) to attach to structure
Figure 7: Staircase CAD drawings
Figure 8: The new steps were installed as individual pieces. Individual steps made handling the heavy steel easier.
Figure 9: Stiffener plates were used to reinforce the steps and to bolt the segments together.
Figure 9: Railing installed
Figure 10: Railing is bolted through the post at the bottom and bolted through a base plate at the higher post.
Figure 11: Finished railing installed
Figure 12: Railing frame fabrication
Figure 13: Railing field installation
Figure 14: Guardrail installed (sign infill still to be installed)
Figure 15: (Left) Roof demolition from above. (Right) Collapsed roof pieces after dropping a roof module.
Figure 16: Decking attachment detail.
Figure 17: Pre-drilled holes are prepped for installation with an adhesive sealant.
Figure 18: Installing ledger to structural framing while temporarily clamped.
Figure 19: Roof after all decking is installed.
1.0 Introduction/Scope

The aim of this senior project is to help restore the vitality of Poly Canyon by continuing the renovation of the Modular House. The Modular house was originally built in 1969 as living quarters for caretakers of Poly Canyon. The two-story structure was built as a series of 8 foot (ft.) by 8 ft. wall, floor and ceiling frames in a 2x3 bay floor plan. The 8 ft squares were filled with 2 standard sized 4 ft. by 8 ft. plywood sheets. Since its original construction, triangular expansions have been added to the floor plan of the original layout. Also, in the early 2000’s, street signs were added as cladding for weatherproofing.

Soon after the College of Architecture and Environmental Design could no longer afford to have caretakers living in the structures, the Modular House fell into disrepair from disuse and vandalism, forcing the structure to be closed off to public access. A senior project group in Spring 2017 did a sizable amount of work to renovate the structure and reopen the Modular House to the public. The 2017 group removed the walls and floors. The ground floor was replaced with concrete on metal decking, and the ground floor walls were replaced with a perimeter guardrail. The guardrail reused the old street-sign cladding as infill to help maintain the architectural integrity of the structure.

Two critical issues were needed to be addressed after the work by the 2017 group. The first issue is that the new concrete floor contained a 2 ft. by 8 ft. opening in the transition to a bay set 2 ft below the main ground floor elevation and a similar 2 ft.-7 in. by 2 ft. opening in the transition to a bay set 2 ft. above the main ground floor elevation. Plans for staircases to bridge these gaps were made by the 2017 group, but were not carried out. The openings allow a fall over 3 ft. and the public was allowed to enter the structure after the completion of the 2017 renovations, so the openings in the floor posed a safety hazard.

The second issue was the weathering of the existing ceiling. Because the walls were removed, the existing acoustical tile ceiling began to degrade from the elements. The exposure caused the tiles to start to fall. This posed another risk to occupants, since the tiles could strike the occupant from above.
Modular House Restoration

The main focus of this senior project was to mitigate the immediate risks that afflicted the Modular House. Specific ways the problems were addressed include:

1. Fabrication and installation of main floor stairs.
2. Fabrication and installation of an additional railings.
3. Demolition of the existing roof and replacement with corrugated metal decking.

This construction will help increase the safety of the structure by covering existing openings in the floor with stairs to transition between floor levels and alleviate fall hazards. A handrail accompanies the larger staircase and an additional guardrail acts as a barrier between lines of elevation change. The demolition of the existing roof structure directly removes the tile ceiling hazard.
2.0 Stairs

Two staircases were designed and constructed to fill gaps in the slab and bridge the elevation changes. The first staircase (A,B) installed was near the entrance to the structure. The specific dimensions of the entry stairs are 31 in. wide, 24 in. deep and 24 in. tall with 8 in. risers and 12 in. treads. The plans from the 2017 renovations called for 36 in. long stairs, but that introduced a tripping hazard as the last step would extend into the entryway. The entryway staircase was fabricated as a whole unit.

The second staircase bridged the large 2 ft. by 8 ft. opening and was comprised of four segments (C,D,E,),(F,G,H), (I) & (J). (I) and (J) were fabricated for the Spring 2017 renovations to extend over the opening. This plan was expanded in this project to make an ‘L’ and fill an 8’x10’ corner, granting access to the lower elevation from two directions. Each segment varied in width, but all were 33 in. deep and 24 in. tall with 6 in. risers and 11 in. treads. (I) and (J) were constructed as whole units, but were well over 300 pounds. Knowing this would be an issue for handling in construction, (C,D,E) and (F,G,H) were fabricated as individual steps, that were later field welded together.

*Figure 1: New Modular House staircase*
2.1 Materials

- Steel Plates
  - 4’x8’x¼” sheet
  - 4’x8’x⅜” sheet
- 3/8 in. bolts

The 3/8 in. plate was chosen so the tread thickness of (C,D,E) and (F,G,H) would match the tread thickness of stairs (I) and (J). The 1/4 in. plate was used to make the risers and was chosen to reduce the overall weight of each step; compared to using 3/8 in. thick plate for everything. The remaining remaining plate material was used to make stiffener plates.

2.2 Fabrication

1. Cut pieces with plasma cutter in College of Agriculture, Food, and Environmental Sciences Support Shop
2. Prepared steel:
   a. Cleaned edges to be welded
   b. Drilled bolt holes
3. Welded riser and stiffeners to corresponding tread. To make modular step.
Figure 3: (Left) Using the Plasma Cutter to cut out all pieces for staircase. (Right) Shop welding the pieces of the staircases together.

Figure 4: Drilling bolt holes in stiffener plates and risers
2.3 Installation

2.3.1 STAIRCASE (A,B)
1. Clamp in place
2. Skip weld top and bottom to structural frame. Weld bottom riser to the columns.

*Figure 5: Plan view of entry stairs. Lowest step is flush with front face of column.*

*Figure 6: Field welding stair (A, B) to attach to structure*
2.3.2 STAIRCASE (C,D,E) & (F,G,H)

1. Clamp (E) and (H) in place to space out (I) and (J).
2. Install pieces (I) & (J), weld at top and bottom to structure.
3. Install (C) & (F), bolt (C) and (F) together and bolt to (I) and (J). Weld permanent supports underneath (C) and (F).
4. Install (D) and (G) using temporary supports, bolt (D) and (G) together and bolt to stairs (I) and (J). Weld at bottom to (C) and (F). Weld permanent support underneath (G).
5. Install (E) and (H) using temporary supports, bolt (E) and (H) together and bolt to stairs (I) and (J). Weld at bottom to (D) and (G) and weld at top to structure.
6. Remove temporary supports.

Figure 7: Staircase CAD drawings
Figure 8: The new steps were installed as individual pieces. Individual steps made handling the heavy steel easier.

Figure 9: Stiffener plates were used to reinforce the steps and to bolt the segments together.
3.0 Handrail

The larger “L” shaped staircase is 4 steps tall, so by the California Building Code, and code compliant handrail must be installed. The entry stair was only 3 steps tall, so the CBC did not require a handrail, and adding one was deemed unnecessary overall. The corner of the “L” shape is closest to the entrance, so this seemed like the most natural flow point to come down the stairs, especially those needing a handrail.

3.1 Materials

- 1 ½” x 1 ½” x ⅛” tube steel
- ¾” Bolts
- 5” x 5” x ⅜” steel base plate
- (2)1 ¾” closure plates

3.2 Fabrication

1. Cut long member of handrail with 90 degree cutoffs.
2. Cut post lengths with 21 degree cutoffs. Use complimentary cutoff pieces to cut handrail extensions.
3. Weld handrail extensions to long handrail member, then weld full handrail to post while verifying post are plumb.
4. Drill 7/16 in. bolt holes into base plate and weld base plate to bottom of higher post.
5. Drill 7/16 in. bolt holes into base of lower post.
6. Cut (2) 1 ¾” plates and weld to ends of the handrail to seal tubes.
7. Smooth out all connections and joints with grinder for a consistent grip surface.

3.3 Installation

1. Drill bolts holes into tread of step for the higher post and into rister of step for lower post.
2. Insert and tighten bolts.
Figure 10: Railing is bolted through the post at the bottom and bolted through a base plate at the higher post.

Figure 11: Finished railing installed
4.0 Guardrail

One extension of the large “L” shaped staircase runs into the edge of the structure. The other extension is followed by another 4 ft. of floor space with a 2 ft. change in elevation between floor levels. While two feet does not mandate further action by code standards, it was deemed best to add a guardrail across this length. The guardrail prevents stumbles that can arise from not seeing the drop off. The guardrail also accentuates the difference in floor elevations and the draw for a staircase.

The guardrail matches the design of the perimeter guardrails made in the 2017 renovations. It is a frame suspended above and below by two tubes welded into the structure. The frame is infilled with recycled street signs donated by the local Public Works department. The street signs pay homage to the Modular House prior to the Spring 2017 renovations, where the signs were used for cladding.

4.1 Materials

- 1½"x1½"x1/8" Angle
- Recycled street signs
- 3/16” Rivets
- ⅜” x 4” Bolts
- 2” x 3” x 3/16” HSS tube

4.2 Fabrication

1. Cut angle
2. Weld infill frame (26 in. by 45 in.)
3. Drill holes for bolts and rivets, (1½ in. bolt holes in from edges)
4. Assemble sign infill
5. Rivet signs to frame
6. Bolt frame to rails
Figure 12: Railing frame fabrication

Figure 13: Railing field installation
4.3 Installation

1. Temporarily support top rail and frame with saw horses.
2. Weld HSS top and bottom rail to existing frame.

*Figure 14: Guardrail installed (sign infill still to be installed)*
5.0 Roof

The existing roof consisted of 2x4 joists supporting plywood sheathing, rigid insulation, and acoustic tiles. The insulation and joists were exposed on top as the roof had previously been abated for asbestos. Upon this discovery of the exposed conditions while working, this posed another threat to safety because the exposed wood was already starting to suffer wood rot. The new roof design is W3 18 gauge Verco Decking secured to steel angle ledgers connected to the structural frame. The decking is sloped for drainage to shed rain water.

Demolition and installation of the roof required greater measures for construction safety. Anyone on the work site was required to wear safety glasses, hard hats and gloves. Furthermore, anyone on the roof had to be tied off with safety harnesses as a fall prevention measure. Two people acted as the demolition personnel and a third was used for spotting. All other persons were cleared from the structure during demolition.

The whole demolition and installation process occurred in conjunction. To maintain a working platform, each bay was demolished and rebuilt before moving onto the next bay. Work was started at the farthest point from our roof access point and finished at the roof access point. This was because the existing roof, which was determined to still be strong enough to hold the workers, was easier to walk and maneuver around then the ridged decking.

5.1 Materials

- W3 18 ga Verco Decking (8’x3’ Sections)
- 100’ of 1½”-2” x ⅛” Steel Angle
- Teks Roofing Screws
- Adhesive Sealant
5.2 Demolition of Existing Roof

1. First, the existing 8 ft. by 8 ft. wood roof modules were unscrewed from the existing steel angle ledgers using an extension ladder to access from below.

2. Then, two people worked from above. They were tied off to the structure and constantly changed their anchor points and lead rope lengths to safely accommodate to their working position. Crowbars were used to lift up the full lumber, plywood and insulation module and then pulled it off its supporting ledger, and allowed it to fall to the ground.

3. The grounded modules were then dismantled and the remains properly disposed of with facilities.

Figure 15: (Left) Roof demolition from above. (Right) Collapsed roof pieces after dropping a roof module.
5.3 Installation of New Roof

1. Steel angle ledgers were precut at 7 ft.-11 in. long with 6 screw holes at 16 in. on center (o.c.).
2. Adhesive sealant was applied to the back of the ledger around screw holes to protect the HSS steel from possible water intrusion.
3. Ledger was clamped in place.
4. Holes drilled and ledger screwed to HSS frame using #12 x 1 in. Hex-Washer-Head Drill Point Roofing Screws.
5. Ledger unclamped
6. Verco decking section placed on top of ledgers with equidistant purchase on either end to ledgers.
7. Decking screwed to ledgers at 12 in. o.c.

Figure 16: Decking attachment detail.

Figure 17: Pre-drilled holes are prepped for installation with an adhesive sealant.
Figure 18: Installing ledger to structural framing while temporarily clamped.

Figure 19: Roof after all decking is installed.
6.0 Reflections

This section consists of the reflections from each individual team member and experiences gleaned from the project.

6.1 Reflection: Michael Blanchard

This project meant a lot to me. First of all because of the impact it is going to play. I lead several tours of the structures in Poly Canyon, and there was always a sense of alert leading people through the Modular House. In one sense, it is great that it is opened up to the public at all, but there are still hazardous condition lurking around. While there is more to do to clean up the structure, there are no more large dangers that pose a threat to tourists.

There was a lot learned about the communication between field conditions, engineering design, and construction work. Knowing how the existing site lays out is critical for understanding how to design. It is also very important to admit that perfect knowledge of the site does not exist, so permitting construction tolerances is important. We had to take time to shave off even 1/8 in. in a few spots which cost a hefty amount of time in the field to correct.

Walking through the process of how everything is put together is also key to designing properly. A specific example is the bolt holes in the handrail post. We originally designed and pre-drilled through the post in the North-South direction. We were unable to drill into the staircase that direction because the stair had stiffener plates in the way. We were able to correct ourselves and drill into the post from the East-West direction, but even that direction we narrowly avoided another stiffener plate. A second example is we knew we were going to be drilling holes into many of the stiffener plates and risers, so we could have just cut out the holes with the plasma cutter if we had planned that step out ahead of time, instead of having to line everything up with a drill press. We cost ourselves a lot of time, and that means in the real world, we cost ourselves a lot of money.

The last stand out take away from this project that I did not think would have come to the forefront so often is workplace safety. We had to be cognizant of both the environment around us, and since we had volunteers helping with install, had to be proactive for the safety of others. General safety equipment for all personnel was required. That means glasses, hard hats, and sturdy gloves. Welding in the field meant fire hazard, so we put one volunteer on fire watch duty while I welded or someone was using a grinder. Climbing gear was used to harness workers on the roof. The biggest safety tool was communication. The work place is a dynamic environment and the only way to maintain safety is to communicate through what is going on.
6.2 Reflection: Abby Lentz

I learned valuable construction lessons throughout the duration of this project. Such as the importance of construction tolerance, to be over prepared with supplies, and do as much shop prefabrication as possible. I think if we had allowed for large construction tolerances with respect to the staircase it would have saved us half of the time and effort we spent on field installation. We designed the stairs right up to the edge of the frame and forgot to add some wiggle room. An inch or two of wiggle room would have saved an hour or two of grinding and made it easier to fit all the pieces together instead of forcing them into place. I think of the six days we worked on installation in the Canyon we had to go back to the shop at least four times because we forgot a drill bit, cutting tool, or some other necessary item which ate up our available work time. It was easy to see how projects get off schedule because without fail some unforeseen circumstance or problem occurs and it’s best to be over prepared and equipped to handle them by bringing backups and making lists. I learned how helpful a drill press is in preparing steel as opposed to using a hand drill in the field and the magnitude of difficulty that is increased by the thickness of material and size of hole.

I am grateful for the opportunity I had to work in the Canyon and to help revitalize a small part of it. I am pleased to know that the work we did will be in place for many years to come and aid in keeping the Canyon a place where people can explore old structures and engage with various spaces created by CAED students who have gone before them. I hope to continue making improvements to other Poly Canyon structures next year.

7.0 References

8.0 Appendix

This section includes sample calculations used to perform the experiment and categorize the data into tables.

Appendix A: Railing Calculations
## Appendix B: Verco Decking Catalog Page

### PLW3™ or W3 FORMLOK™
- Without Concrete Fill

### Allowable Uniform Loads (psf)

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See footnotes on page 65.
STAIRCASE (C,D,E) & (F,G,H) PLAN
STAIRCASE (A,B) PLAN

STAIR STEPS

Project: Modular House Restoration
Issue Date: 05/26/2018
Scale: NTS
Sketch Title: Staircase plan 2
Sketch No. 2.02
1. Staircase C,D,E & F,G,H

2. Staircase C,D,E & F,G,H
EXISTING FRAMING

(N) 2X3X3/16" TOP & BTM RAIL

(N) STEEL ANGLE FRAME

3/8" BOLT

RAILING
NEW HANDRAIL

HANDRAIL PLAN

STAIRS

Project: Modular House Restoration
Issue Date: 06/18/2018
Scale: NTS
Sketch Title: Handrail Plan

Sketch No. 2.06
DECKING TO ROOF