Phase I Construction - June 2017
Phase II Construction - December 2017
Modular House Project Narrative
Senior Project - Spring 2017

Completed by:
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Cameron Lober · Chris Martinez · Katie Mayer
February 24, 2017

Project Summary
The Modular House, located in Poly Canyon, has seen extensive damage since the last caretaker left nearly ten years ago. To prevent further damage and improve the safety and appeal of the structure, we are proposing a renovation of the existing building that removes the existing cladding and partitions. By the end of Spring Quarter 2017, the Modular House will have a guardrail system replacing the wood paneling on the walls and a new steel composite deck to replace the current flooring system. The structural steel framing system will remain as is.

Purpose
The Modular House has been subject to the most damage due to vandalism in Poly Canyon. After the last caretaker left in 2010, steps were taken to preserve the structures. The Modular House used to be a symbol of livelihood in the area and was once used as housing for the caretaker of the canyon. Now, it is a boarded up house. We hope to revive this structure by improving its structural and aesthetic qualities, thereby creating a safe and welcoming space for the Cal Poly community to utilize and enjoy.

Our focus is a remodel of the Modular House which emphasizes the unique structural and architectural aspects of the house. In terms of architectural design, what makes the house unique are the road signs that act as the building’s skin. In terms of structural design, the house was built using 8’0” cubes with a few forty-five degree offsets around the perimeter of the house. Our goal is to highlight the frames and utilize them in the design of a new guardrail system.

The new design will remove all of the walls from the structure, revealing the cubic modules, and will replace the perimeter walls with a guardrail that integrates the road signs into the design. This will effectively transform the structure from a closed off house into an open observation deck (overlooks a creek) to be used by the public.

Multi-Phase Project
**With this being such a large project to finish in 10 weeks, the construction will be split into two phases. We propose to complete Phase I, which will offer a new usable space, while Phase II will bring the addition of a 2nd level and the connecting stairs.**

Phase I: A complete demolition of the walls, roof, and floor will be performed. The new floor (LW concrete over steel decking) and guardrails for the first level will be installed.

Phase II: The second level guardrails and floor will be added, as well as the linking stairs and structural components necessary for the stairs (footings and columns). Since the design of the guardrails and floor will have been completed in Phase I, the design focus of Phase II will be the stairs.
**Scope of Work (Phase I)**

*Design*: This project will include the design of a new guardrail system, connections between the rails and the existing frame, and a new steel deck with concrete fill. The Modular House will have a new guardrail system surrounding every exterior side on both the lower and upper levels. We will be incorporating the existing road signs from the south wall of the structure into the design to maintain the unique charm they currently give to the Modular house. The guardrail will be made of steel for ease of connection to the frame through welds. These connections will be designed to ensure adequate strength. Additionally, a steel deck with concrete fill will be designed to replace the existing deck on both floors. A seismic analysis will be performed on the structure to ensure that the proposed solution will be adequate for the canyon. Analysis will also be performed on the existing structure to confirm that the structure is adequate for continuation of proposed design.

*Demolition/Construction*: For the repair and remodel for the Modular House, the following is a deconstruction and construction phase as proposed. The goal is to deconstruct the original modular house while maintaining the structural frame. For demolition, the interior and non-structural components (cabinets, furniture and other design aspects) are to be removed from the structure first. Following the removal of non-structural components will be the removal of the exterior walls whilst preserving the original signs. The signs will be reused for use of the handrail design. All waste will be disposed and removed from the premise to begin construction. The tentative construction phase proposal shall consist of the finalised design as described in the section above. All construction pertaining to the structural aspect of the building shall be completed first. Following the completion of the structural portion of construction will be the architectural finishes as proposed.

*Existing Repairs*: The floors will be removed and replaced with a new steel deck with concrete fill. Any decking that is damaged should also be replaced with new materials. For all other components of the Modular House, anything that is damaged, either by natural weathering or intentional mischief, shall be replaced and repaired. After all demolition is complete, a survey and analysis of the existing frame will be done, and then construction of the remodel will begin.

**Timeline**: The timeline below shows a tentative schedule of this project.

<table>
<thead>
<tr>
<th>Date</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late February 2017</td>
<td>Conduct Site Investigation</td>
</tr>
<tr>
<td>Mid March 2017</td>
<td>Complete Structural Analysis and Design</td>
</tr>
<tr>
<td>Late April 2017</td>
<td>Complete Permit to Send Off for Approval</td>
</tr>
<tr>
<td>Early May 2017</td>
<td>Begin Demolition</td>
</tr>
<tr>
<td>Late May 2017</td>
<td>Begin Panel Prefabrication</td>
</tr>
<tr>
<td>Early June 2017</td>
<td>Complete Phase I</td>
</tr>
</tbody>
</table>
NOTES:
1. ALL FOOTINGS AND COLUMNS CURRENTLY EXIST UNLESS LABELED (N)
2. (N) COLUMNS AND FOOTINGS ARE PART OF PHASE 2
3. ALL EXISTING FOOTINGS ARE 16.75" SQ. AND (N) FOOTINGS WILL BE MADE TO MATCH
4. ALL EXISTING COLUMNS ARE TS3x3x3/16 AND (N) COLUMNS WILL BE HSS3x3x3/16
5. TOP OF FOOTING ELEVATIONS VARY

---

**FOUNDATION PLAN**

H

E

G

F

A

B

C

D

1

1/4" = 1'-0"
NOTES:
1. TYP. ELEVATION: 0'-0" (ELEVATION DATUM IS TOP OF FIRST FLOOR)
2. ALL BEAMS & COLUMNS ARE EXISTING UNLESS LABELED (N)
3. ALL EXISTING COLUMNS ARE TS5x3x3/16
4. (N) FLOOR IS 1 1/2" LW CONCRETE FILL OVER 18 GAGE VERCO PLB FORMLOK DECK. SPAN DENOTES SPAN DIRECTION FOR METAL DECK.
5. TOP OF CONCRETE SLAB IS RELATIVE TO TYPICAL FLOOR ELEVATION
6. TYPICAL TOP OF STEEL ELEVATION IS (+0'-0") RELATIVE TO TOP OF CONCRETE ELEVATION
7. ALL STEPS AND STAIRS ARE 36" WIDE.

LEVEL 1 FRAMING
1/4" = 1'-0"

1ST FLOOR PLAN
NOTES:
1. SECOND FLOOR SLAB AND STAIRS ARE PART OF PHASE 2
2. TYP. ELEVATION: 8'-4" (TOP OF FLOOR)
3. ALL BEAMS & COLUMNS ARE EXISTING UNLESS LABELED (N)
4. SEE SHEET NOTES ON DWG S.3.2 FOR ADDITIONAL INFORMATION
NOTES:
1. TYP. ELEVATION: 16'-8" (TOP OF BEAM)
2. TYPICAL TOP OF STEEL IS (+0'-0") RELATIVE TO TYP. ELEVATION. UNLESS NOTED OTHERWISE.

1. \text{TYP. ELEVATION: 16'-8" (TOP OF BEAM)\text{.}}
2. \text{TYPICAL TOP OF STEEL IS (+0'-0") RELATIVE TO TYP. ELEVATION, UNLESS NOTED OTHERWISE.\text{.}}
GUARD RAIL INTERIOR TYP.

\[ \frac{3}{4}" = 1'-0" \]
1 PANEL TO GUARD RAIL - TOP

1 1/2" = 1'-0"

2 PANEL CONNECTION - TOP

3" = 1'-0"

3 PANEL TO GUARD RAIL - BOTTOM

1 1/2" = 1'-0"

4 PANEL CONNECTION - BOTTOM

3" = 1'-0"
1. **Upper Rail to Column Connection**

   1 1/2" typ.

   - (N) C3x5x0'-1.25"
   - (N) HSS3x2x3/16 Guard Rail

   2. **Rail to Column - Top & Bottom**

   - (N) HSS3x2x3/16
   - (E) TS3x3x3/16

   3. **Rail to Angled Column - Top & Bottom**

   - (N) HSS3x2x3/16
   - (E) TS3x3x3/16

   1/8" WHERE OCCURS

   1/2" WHERE OCCURS

   3" = 1'-0"
1. **Panel Connection TYP.**

   - STOP SIGN: GUARDRAIL IN-FILL
   - L1-1/2x1-1/2x1/8
   - 1/8" TYP.
   - 1/8
   - 1/8

2. **Sign Connection**

   - STOP SIGN: GUARDRAIL IN-FILL
   - L1-1/2x1-1/2x1/8
   - 1/4" DIAM. BOLT
   - 1/2"
   - % ANGLE

**DRAWING TITLE:** TYPICAL GUARD RAIL DETAILS

**DRAWN BY:** RYAN LEFEBVRE

**DRAWN:** 5/2/17

**DRAWING NUMBER:** SHEET NUMBER: S.3.14
GUARD RAIL EXTERIOR 5'-10 3/4"

3/4" = 1'-0"
1. DECKING CONNECTION

3" = 1'-0"

- JOINT SEALANT
- 1/2" DIAM. BACKER ROD
- 4x4 - W2xW2 WWF
- 1/4" (N) 18G. VERCO PLB DECKING w/ LW CONC.
- 1/2" DIAM. SPOT WELD @ 12" OC
- (E) L2x2x3/16 w/ 3/4" PLUG WELD @ 2" OC
- (E) TS5x3x3/16

S.3.17
MONO-STRINGER STEPS

3" = 1'-0"

1/4" THICK PL

HILTI SLEEVE ANCHOR,
HLC-HX 5/16x1-5/8,
5/16" DIAM. HOLE, 1.38" DEPTH

3" CONCRETE FLOOR
TS5x3x3/16
1/4" THICK PL

1/2" PL
1/4" PL
HSS5x3x3/16

10" TYP.
6" TYP.
STEPS SECTION 1

1 1/2" = 1'-0"

1/2" THICK PL
PL 1/4"x4"x1'-1.25"
HSS 5x3x3/16

WHERE IN CONTACT
1 1/2"
1/8
1/8

HSS 5x3x3/16
1/4" THICK PL w/ (2)
3/8" DIAM. HOLES

HILTI SLEEVE ANCHOR,
HLC-HX 5/16"x1-5/8,
5/16" DIAM. HOLE, 1.38" DEPTH

STEPS SECTION 2

1 1/2" = 1'-0"

PL 1/4"x4"x1'-1.25"
TS 5x3x3/16
HSS 5x3x3/16

WHERE IN CONTACT
1 1/2"
1/8
1/8

STEPS SECTION 3

1 1/2" = 1'-0"

1/2" THICK PL
PL 1/4"x4"x1'-1.25"
HSS 5x3x3/16

WHERE IN CONTACT
1 1/2"
1/8
1/8
Project Description

This project will include the design of a new handrail system, connections between the rails and the existing frame, and a new steel deck with concrete fill. The Modular House will have a new handrail system surrounding every exterior side on both the lower and upper levels. The exact design of this handrail is yet to be determined. We will be incorporating the existing road signs from the south wall of the structure into the design to maintain the unique charm they currently give to the Modular house. The handrail will likely be made of steel for ease of connection to both the signs and the frame, either through welds or bolts. These connections will be designed to ensure adequate strength. Additionally, a steel deck with concrete fill will be designed to replace the existing deck on both floors. A seismic analysis will be performed on the structure to ensure that the proposed solution will be adequate for the canyon. Analysis will also be performed on the existing structure to confirm that the structure is adequate for continuation of proposed design.

Design Criteria

Design Code: IBC 2012
ASCE 7-10
AISC Steel 314
AISC Seismic

Building Type: Construction Type: Type I
No hour fire rating
Occupancy Group: Assembly Area A-5 (Assembly Area for viewing outside activities)

Wind Criteria: N/A, Due to open nature of the structure

Seismic Criteria: $S_0 = 0.789g$
$S_1 = 0.450g$
$C_s = .2254$

Foundation Criteria: Use existing Foundation

Allowable loads: Live Loads: Floor 100 psf
Dead Loads: Floor (Fill and Decking) 26.1 psf

Controlling Deflections: Depth of beam shall be great than L/240

GFRS: HSS Tubing (Beam and Column), Steel Decking and Fill

LFRS: HSS Tubing Moment Frames

References

System: Project Summary

The existing weight of the Modular House is 25.7 kips. After all modifications and renovations are complete the building is going to weigh only 17 kips. The renovated building will be 34% lighter than the original building.

Force is defined by mass multiplied by the acceleration. The design acceleration will not change. Therefore a decrease of mass by 34% means that the force the building needs to resist will also be decreased by 34%. The original lateral system was strong enough to resist the original forces with a heavier mass so the lateral system will remain unchanged and will be strong enough to resist the smaller forces that it may experience.

In addition, by getting rid of the complexity of the multiple materials and changing the flooring system will no longer have a mass irregularity caused by the change from wood flooring to tile.
### Existing Load Takeoff

<table>
<thead>
<tr>
<th>References</th>
<th>System: Existing Load Takeoff</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td><strong>ROOF</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STRESSED SKIN PANEL</td>
<td>10 psf</td>
<td></td>
</tr>
<tr>
<td>PARTITION</td>
<td>10 psf</td>
<td></td>
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<tr>
<td>AREA</td>
<td>427.5 sf</td>
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</tr>
<tr>
<td>Load</td>
<td>8.55 k</td>
<td></td>
</tr>
<tr>
<td><strong>2ND FLOOR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2&quot; PLYWOOD SHEATHING - FLOOR</td>
<td>1.6 psf</td>
<td></td>
</tr>
<tr>
<td>3/8&quot; PLYWOOD SHEATHING - CEILING</td>
<td>1.2 psf</td>
<td></td>
</tr>
<tr>
<td>CERAMIC TILE - FLOORING</td>
<td>10 psf</td>
<td></td>
</tr>
<tr>
<td>CLADDING</td>
<td>10 psf</td>
<td></td>
</tr>
<tr>
<td>PARTITION</td>
<td>10 psf</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>22.8 psf</td>
<td></td>
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<tr>
<td>AREA</td>
<td>153 sf</td>
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<tr>
<td>LOAD</td>
<td>3.5 k</td>
<td></td>
</tr>
<tr>
<td><strong>1ST FLOOR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2&quot; PLYWOOD SHEATHING - FLOOR</td>
<td>1.6 psf</td>
<td></td>
</tr>
<tr>
<td>3/8&quot; PLYWOOD SHEATHING - CEILING</td>
<td>1.2 psf</td>
<td></td>
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<tr>
<td>CERAMIC TILE - FLOORING</td>
<td>10 psf</td>
<td></td>
</tr>
<tr>
<td>CLADDING</td>
<td>10 psf</td>
<td></td>
</tr>
<tr>
<td>PARTITION</td>
<td>10 psf</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>22.8 psf</td>
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</tr>
<tr>
<td>AREA</td>
<td>479.5 sf</td>
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<tr>
<td>LOAD</td>
<td>10.9 k</td>
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<tr>
<td><strong>TUNING</strong></td>
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</tr>
<tr>
<td>ROOF</td>
<td>1 k</td>
<td></td>
</tr>
<tr>
<td>2ND FLOOR RISE</td>
<td>0.22 k</td>
<td></td>
</tr>
<tr>
<td>2ND FLOOR</td>
<td>0.38 k</td>
<td></td>
</tr>
<tr>
<td>1ST FLOOR RISE</td>
<td>0.22 k</td>
<td></td>
</tr>
<tr>
<td>1ST FLOOR</td>
<td>0.71 k</td>
<td></td>
</tr>
<tr>
<td>1ST FLOOR DROP</td>
<td>0.22 k</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>3 k</td>
<td></td>
</tr>
<tr>
<td>TOTAL BUILDING WEIGHT</td>
<td>25.7 k</td>
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</tbody>
</table>
### References

<table>
<thead>
<tr>
<th>System</th>
<th>Seismic Analysis Cont. / Decking</th>
</tr>
</thead>
</table>

### Decking Requirements
- Minimum 20 Grade
- No Sanding
- Limit Weight, No Ice Damage

### Deck Material
- Nominal 18 Gauge 3 in LW Conc.
- Single Span 8' - 0', No Smoking Req'd
- Assumed Super Lumber = 100 psf

### Deck Load Take-Off

<table>
<thead>
<tr>
<th>Floor</th>
<th>Decking</th>
<th>Tonnage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>22.2 + 2.9 psf</td>
<td>(4'x8') x 2.0 psf</td>
</tr>
<tr>
<td>2nd</td>
<td>26.1 psf</td>
<td>(4'x8') x 2.5 psf</td>
</tr>
<tr>
<td>3rd</td>
<td>26.1 psf</td>
<td>(4'x8') x 2.5 psf</td>
</tr>
<tr>
<td>4th</td>
<td>26.1 psf</td>
<td>(4'x8') x 2.5 psf</td>
</tr>
</tbody>
</table>

### Beam Shear Capacity

<table>
<thead>
<tr>
<th>Beam Shear Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vy = 0.6 Fy A_u C_u</td>
</tr>
<tr>
<td>Fy = 46 kips</td>
</tr>
<tr>
<td>A_u = 0.65</td>
</tr>
<tr>
<td>C_u = 0.65</td>
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</tbody>
</table>

### Beam Fireproof Capacity

<table>
<thead>
<tr>
<th>Beam Fireproof Capacity</th>
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<tbody>
<tr>
<td>Vy = 0.6 Fy A_u C_u</td>
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<tr>
<td>Fy = 46 kips</td>
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<tr>
<td>A_u = 0.65</td>
</tr>
<tr>
<td>C_u = 0.65</td>
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</table>

### Design Criteria 3

Design Criteria 2

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**MODULAR HOUSE SENIOR PROJECT**
**ARCE 453/460**
**Building 21-122E. Cal Poly San Luis Obispo, California 93410**

**Code: A00 7-10**
**Date: 04/20/2012**
**By: SD Sheet 5 of 81**

**MODULAR HOUSE SENIOR PROJECT**
**ARCE 453/460**
**Building 21-122E. Cal Poly San Luis Obispo, California 93410**

**Code: A00 7-10**
**Date: 04/20/2012**
**By: SD Sheet 6 of 81**
### References

**System:** Frame Analysis

### Comments

**Design Criteria 4**

#### Allowable Beam Deflection

\[
D + L = \frac{6L}{120} = 8\times12\frac{1}{12} = 8\times10 = 1.4\]

**Column Slenderness Ratio**

\[
K = 0.61 \left( \frac{b h}{l} \right) = 0.61 \left( \frac{1.81}{16} \right) = 0.61 < 2.0 \checkmark
\]

### References

**System:** Frame Analysis

#### Compression Strength Column

\[
\begin{align*}
E_3 - 1 & \quad P_{nl} = A_{nl} f_{nl} \\
& \quad A_{nl} f_{nl} = 1.89 \text{ in}^2
\end{align*}
\]

\[
\begin{align*}
P_{nl} & = \frac{6 \times 2.52 \times 10^{6}}{2} \\
& = 1.89 \times 10^{6} \\text{N}
\end{align*}
\]

---

**Design Criteria 5**

#### Shear Strength Column

\[
\begin{align*}
\text{Section G9} & \quad P_{nl} = A_{nl} f_{nl} + \frac{V_{nl}}{C_{y}}
\end{align*}
\]

\[
\begin{align*}
A_{nl} & = \frac{9.257}{16} \\
& = 0.57 \\
V_{nl} & = 0.6 \times f_{nl} \times A_{nl}
\end{align*}
\]

\[
\begin{align*}
C_{y} & = 0.59 \left( \frac{b h}{l} \right) \\
& = 0.59 \left( \frac{1.81}{16} \right) = 0.59 \times 10^2 \checkmark
\end{align*}
\]

\[
\begin{align*}
G2 - 3 & \quad V_{nl} = 0.6 \left( \frac{b h}{l} \right) \left( \frac{V_{nl}}{C_{y}} \right) \left( 1.0 \right) \\
& = 26.6 \text{ kN}
\end{align*}
\]

\[
\begin{align*}
\phi & = 0.9 \\
\phi & = 23\%
\end{align*}
\]
**Design Criteria 6**

**References**

<table>
<thead>
<tr>
<th>System: FRAME ANALYSIS</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Weld Connection</td>
<td></td>
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<tr>
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</tbody>
</table>

- **Welded Shear**
  - $P_{w} = \frac{1}{2} \left( F_{w} \text{, Att} + U_{w} \text{, Att} \right)$
  - $F_{w} = 0.75 F_{y}$
  - $U_{w} = 0.5 (0.3)$
  - $A_{w} = 1.0$
  - $P_{w} = 2.56 + 1.67$
  - $= 32.24$

- **Moment Connection**
  - $W_{w} = W_{w}$
  - $V_{w} = V_{w}$
  - $B = \frac{B_{w}}{B_{w}} = 3in/\text{in} = 1.00$

- **K3-10**
  - $B > 0.85$
  - $N_{w} = F_{w} (b - 0.1) (A_{w} / A_{w})$
  - $F_{w} = 4.5 F_{y}$
  - $b = 2in$
  - $A_{w} = 0.5 (0.34) (0.5 + 0.34)$
  - $= 1.25$ in
  - $= 11.1 k\cdot ft$

**Design Criteria 7**

**References**

<table>
<thead>
<tr>
<th>System: FRAME ANALYSIS</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>Beam Connection</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Column**
  - **Flanges:** $7.34 k$
  - **Connection:** $63.5 k$
  - **Shear:** $23 k$
  - **Shear Ratio:** $< 2.00$

- **Beam**
  - **Flanges:** $14.34 k$
  - **Shear:** $13.5 k$
  - **Deflection:** $0.4$

- **Connection**
  - **Weld:** $65.25$
  - **Nom. Conn:** $11 X 6$

**Design Summary**

- **N+8 = 8”** (Framing Member)
  - $m = 8 - 0.8 (2) = 2.8$ in

<table>
<thead>
<tr>
<th>Plate Thickness</th>
<th>0.25 in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate Location</td>
<td>3/8 in</td>
</tr>
<tr>
<td>Anchorage Wall Housing</td>
<td>3/8 in</td>
</tr>
</tbody>
</table>

- **Plate Capacity**
  - **Shear:** $0.6 F_{y}$
  - $F_{y} = 35 k / l$
  - $A_{w} = 0.6 (2) (0.34) (0.34)$
  - $= 3.84 k$
  - $= 1.00$
  - $f = 3.84 k$
### References

**System:** Frame Analysis

#### Base Plate Check

<table>
<thead>
<tr>
<th>Material</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin Steel</td>
<td></td>
</tr>
<tr>
<td>Table 12.2</td>
<td></td>
</tr>
</tbody>
</table>

#### Plate Flange Check

- $M_{pl} = 0.5 \times 8'' \times (1.8'' - 0.25'') = 3.6 \text{ kip''}^2$
- $N_{pl} = 18 \text{ kip''}$
- $W_{pl} = 16 \text{ kip''}$

#### Bearing Strength on Concrete

- $P_c = 0.25 \times 4000 = 1000 \text{ kips}$
- $0.80 \times 4000 = 3200 \text{ kips}$

### Comments

#### Frame on Grid

*Modified* \( \theta \)-\( \epsilon \) diagram

#### Design Criteria

- $P_{fl} = 7.69 \times 10^{-6} \times 5 \times 3 \text{ COL}$
- $P_{fl} = 1.62 \times 10^{-6} \times 5 \times 3 \text{ BMS}$

#### RISA Gravity Analysis

- 12 of 81
RISA Gravity Analysis 2

MODULAR HOUSE SENIOR PROJECT
ARCE 453/460
Building 21- 122E. Cal Poly
San Luis Obispo, California 93410

CODE: ________________________ DATE: ________________________
BY: ________________________ SHEET N: ________________________

RISA Gravity Analysis 3

MODULAR HOUSE SENIOR PROJECT
ARCE 453/460
Building 21- 122E. Cal Poly
San Luis Obispo, California 93410

CODE: ________________________ DATE: ________________________
BY: ________________________ SHEET N: ________________________
MODULAR HOUSE SENIOR PROJECT
ARCE 453/460
Building 21- 122E. Cal Poly
San Luis Obispo, California 93410

CODE: ______________
DATE: ______________
BY: ______________

RISA Gravity Analysis 4

RISA Gravity Analysis 5
Max Moment = 8.498 k·ft

Note: Due to moment combination, amount to columns is minimal.
MODULAR HOUSE SENIOR PROJECT
ARCE 453/460
Building 21-122E, Cal Poly
San Luis Obispo, California 93410
Gridline 3 - Gravity

CODE: ____________ DATE: ____________

(IBC 2012) SHEET No. 19 of 81

NOTE: $M_{calc} = 7.6\, \text{ft-lb}$

RISA Gravity Analysis 8

MODULAR HOUSE SENIOR PROJECT
ARCE 453/460
Building 21-122E, Cal Poly
San Luis Obispo, California 93410

CODE: ____________ DATE: ____________

(IBC 2012) SHEET No. 20 of 81

RISA Gravity Analysis 9
**GRAVITY**

Dead Load = 26.1 PSF

Live Load = 100 PSF

Total Load (w/ load combo) = 191 PSF

**RISA Gravity Analysis 10**
RISA Gravity Analysis 16

Moments

Max Moment = 6.42 k-ft

RISA Gravity Analysis 17

<table>
<thead>
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<th>Joint Label</th>
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<tr>
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<th>Design Criteria</th>
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<tr>
<td></td>
<td>Lateral Acceleration: $a_g$</td>
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<td>Module Weight: $2k$</td>
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Frame on Gridline (0)

Rigid Diaphragm

Flexible Diaphragm

Lateral Forces

Beams: HSS 3x3x3/16

Columns: HSS 6x8x3/16

Joint Deflections

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</tr>
<tr>
<td>N14</td>
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</table>

MAX STORY DRIFT: $17''$

*Conservative, since modeled with a pin & base.

RISA Analysis - Lateral 1

RISA Analysis - Lateral 2
**Deflected Shape**

**RISA Analysis - Lateral 3**

---

**Deflected Shape**

**RISA Analysis - Lateral 4**

---

**Deflected Shape**

**RISA Analysis - Lateral 3**

---

**Deflected Shape**

**RISA Analysis - Lateral 4**
Shear:
V_{\text{max}} = 0.856k

Moment:
M_{\text{max}} = 1.474k-ftk
Shear:
\[ V_{\text{max}} = 0.698 \text{k} \]

Moment:
\[ M_{\text{max}} = 1.393 \text{k-ft} \]

RISA Analysis - Lateral 7

RISA Analysis - Lateral 8
RISA Analysis - Lateral 9

RISA Analysis - Lateral 10
References
System: GRID 4 RISA 2D CHECK

FLEXIBLE DIAPHRAGM

Axial

Shear

Moment

Deflection

Max Moment: 1.66'
Max Shear: 0.64
RIGID DIAPHRAGM

Axial
Shear
Moment
Deflection

Max Moment: 2.03 k
Max Shear: 0.74

References: GRID 4 RISA 2D CHECK
Comments:

RISA Analysis - Lateral 13
RISA Analysis - Lateral 15

References | System: | Comments
---|---|---

FLEXIBLE DIAPHRAGM

RIGID DIAPHRAGM

FIRST FLOOR PLAN

SECOND FLOOR PLAN

Equivalent force:

\[ x = \left( \frac{2(8.38') \times 5(1.82')}{11.7k} \right) = 3.73' \]

Center of rigidity:

\[ c_y = 2(k)(8.38') - 5(k)(0') = 3.47' \]

Torsional moment:

\[ 1.11k \times (3.73' - 3.47') = 24.6\text{k}\text{in} \]

\[ F_x = 0.24\text{k} \]

\[ F_y = 0.24\text{k} \]

RISA Analysis - Lateral 16

References | System: | Comments
---|---|---

RIGID DIAPHRAGM

SECOND FLOOR PLAN

RISE

Equivalent force:

\[ x = \left( \frac{2(8.38') \times 5(1.82')}{11.7k} \right) = 3.73' \]

Center of rigidity:

\[ c_y = 2(k)(8.38') - 5(k)(0') = 3.47' \]

Torsional moment:

\[ 1.11k \times (3.73' - 3.47') = 24.6\text{k}\text{in} \]

\[ F_x = 0.24\text{k} \]

\[ F_y = 0.24\text{k} \]
Gridline A - Flexible Diaphragm

Axial

Moment

Max moment: 5.1 kip
Max axial: 1.3 k
Max shear: 1.4 k

Shear

Deflected Shape

Gridline A - Rigid Diaphragm

Axial

Moment

Max moment: 3.2 kip
Max axial: 1.4 k
Max shear: 1.5 k

Shear

Deflected Shape

Joint Deflections

RISA Analysis - Lateral 17

RISA Analysis - Lateral 18
References

System: Modular House Grid B Flexible Diaphragm

Loads Applied

Deflections

Moments

Shear

RISA Analysis - Lateral 19

RISA Analysis - Lateral 20
References

System: Modular House Grid B Rigid Diaphragm

Moments

Shear

Axial

RISA Analysis - Lateral 23

RISA Analysis - Lateral 24
References | System: | Comments
--- | --- | ---
Line "C" RISA Analysis – Stiffness

Deflected Shape

Shear:
V_{max} = 0.476k

Moment:
M_{max} = 0.953k-ft
Elevation on Line 1

LEVEL | Displacement (inches)
-------|----------------------
Roof Rise | 0.340
Roof Framing | 0.340
Level 2 Rise | 0.331
Level 2 Framing | 0.316
Level 1 Rise | 0.195
Level 1 Framing | 0.176
Level 1 Drop | 0.000

ETABS Comparison - Lateral 1

MAX (+) | MIN (-)
Shear | 0.87 kips
Moment | 1.18 k-ft 1.25 k-ft

ETABS Comparison - Lateral 2
Elevation of Line 2

### Shear

<table>
<thead>
<tr>
<th>Level</th>
<th>Displacement (inches)</th>
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<tr>
<td>Roof Rise</td>
<td>0.340</td>
</tr>
<tr>
<td>Roof Framing</td>
<td>0.340</td>
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<tr>
<td>Level 2 Rise</td>
<td>0.331</td>
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<tr>
<td>Level 2 Framing</td>
<td>0.316</td>
</tr>
<tr>
<td>Level 1 Rise</td>
<td>0.195</td>
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<tr>
<td>Level 1 Framing</td>
<td>0.176</td>
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<tr>
<td>Level 1 Drop</td>
<td>0.000</td>
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</tbody>
</table>

### Moment

- **MAX (+):** 1.18 k-ft
- **MIN (-):** 1.18 k-ft
Elevation of Line 3

**Elevation**

**Deformed Shape**

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>Displacement (inches)</th>
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<tbody>
<tr>
<td>Roof Rise</td>
<td>---</td>
</tr>
<tr>
<td>Roof Framing</td>
<td>0.367</td>
</tr>
<tr>
<td>Level 2 Rise</td>
<td>---</td>
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<tr>
<td>Level 2 Framing</td>
<td>0.355</td>
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<tr>
<td>Level 1 Rise</td>
<td>---</td>
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<tr>
<td>Level 1 Framing</td>
<td>0.168</td>
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<tr>
<td>Level 1 Drop</td>
<td>0.057</td>
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</table>

**ETABS Comparison - Lateral 5**

**ETABS Comparison - Lateral 6**

- **MAX (+)**
  - Shear: 1.22 kips
  - Moment: 1.70 k-ft

- **MIN (-)**
  - Shear: 1.14 kips
  - Moment: 1.74 k-ft
Elevation of Line 4

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>Displacement (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof Rise</td>
<td></td>
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<tr>
<td>Roof Framing</td>
<td>0.378</td>
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<tr>
<td>Level 2 Rise</td>
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<tr>
<td>Level 2 Framing</td>
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<td>Level 1 Rise</td>
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<tr>
<td>Level 1 Framing</td>
<td>0.163</td>
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<tr>
<td>Level 1 Drop</td>
<td>0.037</td>
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ETABS Comparison - Lateral 7

Shear

<table>
<thead>
<tr>
<th>MAX (+)</th>
<th>MIN (-)</th>
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<tbody>
<tr>
<td>Shear</td>
<td>0.83 kips</td>
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<tr>
<td>Moment</td>
<td>1.03 k-ft</td>
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</table>
Elevation of Line A

Deformed Shape

<table>
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<tr>
<th>LEVEL</th>
<th>Displacement (inches)</th>
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<tbody>
<tr>
<td>Roof Rise</td>
<td>0.412</td>
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<tr>
<td>Roof Framing</td>
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<td>Level 2 Framing</td>
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<td>Level 1 Rise</td>
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<tr>
<td>Level 1 Framing</td>
<td>0.199</td>
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<tr>
<td>Level 1 Drop</td>
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</tbody>
</table>

Shear

- MAX (+) MIN (-)
  - Shear: 1.10 kips
  - Moment: 1.43 k-ft, -1.49 k-ft
Elevation on Line B

**LEVEL** | **Displacement (inches)**
--- | ---
Roof Rise | 0.324
Roof Framing | 0.324
Level 2 Rise | 0.320
Level 2 Framing | 0.310
Level 1 Rise | 0.185
Level 1 Framing | 0.162
Level 1 Drop | 0.042

**Max (+) Min (-)**

- **Shear:** 1.10 kips
- **Moment:** 1.40 k-ft, 1.18 k-ft
### References

<table>
<thead>
<tr>
<th>System: Panel Connections (capacities)</th>
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<td>References</td>
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#### Guard Rail and Connection Calcs 1

1. **HSS - a C 3.5 x 2**: A36
   - $a = 10''$
   - $w_{min} = 6/''$
   - 60 electrode - 60 hr

   **Shear strength, weld metal**
   - $R_{th} = 0.75(0.4)(60hr)(0.707)(4/10'' = 24 kips -< 60 kips
   - $R_{th} = 0.9(0.4)(60hr)(4/10'' = 37.5 kips

2. **C 3.5 x 2 L 2 1/2 x 1 1/2 x 1/8**:  
   - 2 1/2 x 1 1/2 x 1/8  
   - $A = 0.725$

   **Shear:** $R_{th} = 0.75(0.4)(60hr)(0.707)(4/10'' = 24 kips -< 60 kips
   - **Shear yielding:** $R_n = 0.60F_a$  
   - $R_n = 0.0(0.6)(60hr)(0.75)(4/10'' = 24 kips -< 60 kips

3. **Shear rupture:** $R_n = 0.60F_a$  
   - $R_n = 0.75(0.6)(60hr)(0.75)(4/10'' = 24 kips -< 60 kips

4. **Truss yielding:** $R_n = 5.4$  
   - $R_n = 0.5(0.4)(60hr)(0.75)(4/10'' = 24 kips -< 60 kips

#### Guard Rail and Connection Calcs 2

- **Black shear:***  
  - $(0.75)(0.6)(60hr)(0.75)(4/10'' = 24 kips -< 60 kips

- **Base cover weld:***  
  - $R_n = 0.75(0.6)(60hr)(0.707)(4/10'' = 24 kips -< 60 kips

- **Base weld:**  
  - $R_n = 0.75(0.6)(60hr)(0.707)(4/10'' = 24 kips -< 60 kips

- **Base shears:**  
  - $R_n = 0.60F_a$  
  - $A_e \times R_n = (2.5)(4/10'' = 24 kips -< 60 kips

- **Base shears:**  
  - $R_n = 0.60F_a$  
  - $A_e \times R_n = (2.5)(4/10'' = 24 kips -< 60 kips

- **Base shears:**  
  - $R_n = 0.60F_a$  
  - $A_e \times R_n = (2.5)(4/10'' = 24 kips -< 60 kips
Guard Rail and Connection Calculations

**References**

- System: Guard Rail Deflection

**Comments**

- HSS 3" x 2" x 3/16
  
  \[ L = 100\text{in} \]
  
  \[ \Delta_{\text{max}} = \frac{P L^2}{4EI} \text{ or } \Delta_{\text{max}} = \frac{S_{\text{weld}}}{S_{\text{BEET}}} \]
  
  \[ J_x = 1.77\text{in}^3 \]
  
  \[ I_y = 0.933\text{in}^4 \]
  
  \[ \Delta_{\text{max}} = \left( \frac{20.2\text{in}^2}{21\text{in}^2} \right) \left( \frac{0.0011}{180,000,000\text{in}^6} \right) = 0.0011\text{in} \]
  
  \[ \Delta_{\text{max}} = \left( \frac{0.01\text{in}^2}{21\text{in}^2} \right) \left( \frac{0.05}{180,000,000\text{in}^6} \right) = 0.0021\text{in} \]
  
  \[ \Delta_{\text{max}} = \frac{0.05\times0.77}{0.932} = 0.096\text{in} \]

---

**References**

- System: Guard Rail Connections

**Comments**

- HSS 3" x 2" x 3/16
  
  \[ A_{\text{BEET}} = 600\text{in}^2 \]
  
  \[ L = 10\text{in} \]
  
  \[ \text{min weld: } 1/8\text{in} \]
  
  \[ \text{weld metal shear strength: } \]
  
  \[ \text{P} = 0.75 (0.6\times600\text{in}^2) (1.77\text{in}) (1.77\text{in}) = 24\text{kips} \]
  
  \[ \text{Base metal: } \]
  
  \[ \text{P} = 0.9 (0.4\times36\text{in}^2) (1.77\text{in}) (1.77\text{in}) = 32.5\text{kips} \]
### References

<table>
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<tr>
<th>System:</th>
<th>Beam Analysis</th>
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</table>

### Load Combination

#### 1st Floor

- **Axial Load on Columns:**
  - **TA:** 3(4x4) = 48 kips
  - **P_e = 12.5 kips
  - **P_L = 4.8 kips**

- **Beam Loading (Dead + Live):**
  - **W_0 = 26.1 psf (4') = 2.1 kips**
  - **W_L = 100 psf (8') = 8.0 kips**

- **M = W_0 L / 12**
  - **M_L = 112 kips**

- **V = W_0 / 4**
  - **V_L = 3.2 kips**

#### 2nd Floor

- **W_0 = 26.1 psf (4') = 104.4 kips**
  - **W_L = 100 psf (4') = 400 kips**

#### Earthquake Load

- **Shear = 1.20 L = 144 kips**

#### Limit States

- **Shear = 1.2 L = 144 kips (Earthquake) /
  - **6.13 < 144 kips (Beam)**
  - **< 61 kips (Connect)**

---

### Limit States 1

- **Beam:**
  - **V_b = 2.15 kips**
  - **P_e = 2.15 kips**

- **Column:**
  - **P_e = 2.15 kips**

- **Lateral:**
  - **Max Shear = 1.6 kips**
  - **Max Moment = 2.6 kips**

---

### Limit States 2

- **Beam:**
  - **V_b = 2.15 kips**
  - **P_e = 2.15 kips**

- **Column:**
  - **P_e = 2.15 kips**

- **Lateral:**
  - **Max Shear = 1.6 kips**
  - **Max Moment = 2.6 kips**

---

### Comments

- **Axial Force (Lateral):**
  - **Max Shear = 1.6 kips**
  - **Max Moment = 2.6 kips**

- **Beam Loading (Dead + Live):**
  - **W_0 = 26.1 psf (4') = 2.1 kips**
  - **W_L = 100 psf (8') = 8.0 kips**

- **Load Combinations:**
  - **Shear = 1.20 L = 144 kips**
  - **6.13 < 144 kips (Beam)**
  - **< 61 kips (Connect)**
<table>
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<tr>
<th>References</th>
<th>System: Frame Analysis</th>
<th>Comments</th>
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<tr>
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</table>

**Moments (Kips)**

\[
M = 12(1.5L) + 12(1.5L) + 12(1.5L) + 12(1.5L) = 8.33k \cdot ft
\]

**Points of Interest**

\[W_1 = \text{psf (4')}\]

\[W_2 = \text{psf (4')}\]

\[W_3 = \text{psf (8')}\]

**End Moments**

**First Floor Ribs:**

\[D_{AB} = 0.56''\]

\[L_{AB} = 2.12''\]

**First Floor (left):**

\[D_{AB} = 0.56''\]

\[L_{AB} = 2.12''\]

**First Floor (right):**

\[D_{AB} = 1.11''\]

\[L_{AB} = 4.27''\]

---

**Limit States 3**

**References**

**System: Frame Analysis**

**Comments**

---

**Limit States 4**

**References**

**System: Frame Analysis**

**Comments**
<table>
<thead>
<tr>
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<th>System: Phase 2 Stairs Code Compliance</th>
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<tbody>
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<td>→ Stair shall not be more than a 2%</td>
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<tr>
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<td>→ Water shall not accumulate on landing</td>
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<td>1011.6</td>
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<td>→ Flight shall not be less than the stairs between Floor/ Landing</td>
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<td>1011.3</td>
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<td></td>
<td>→ Shall not be less than the stairs</td>
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</tr>
<tr>
<td></td>
<td>→ Where stairway has a straight run the depth need not exceed 48 in</td>
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<td>1011.5.2</td>
<td>Headroom</td>
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<td>→ Clearance not less than 80 in</td>
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<td>1014.3.2</td>
<td>Riser Height</td>
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<td></td>
<td>→ max: 7 in, min: 4 in</td>
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<tr>
<td>1014.2</td>
<td>Tread Run</td>
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</tr>
<tr>
<td></td>
<td>→ min: 11 in</td>
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</tr>
<tr>
<td>1015.2</td>
<td>Handrails</td>
<td></td>
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<tr>
<td></td>
<td>→ Section 1014</td>
<td></td>
</tr>
<tr>
<td></td>
<td>→ Height 34&quot; to 38&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>→ Graspibility: Type 2</td>
<td></td>
</tr>
<tr>
<td>1011.5.2</td>
<td>Guards</td>
<td></td>
</tr>
<tr>
<td></td>
<td>→ Continuity: Continuous (no exceptions)</td>
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</table>

### Phase 2 Stairs 1

- Construction → 0% SLOPE ON TREAD ✓
- Continuity → ✓
- Landing → IS LESS THAN 48" FOR STRAIGHT RUN ✓

### Phase 2 Stairs 2

- HATCH AREA SHOWING CONTINUOUS 36" WIDE PATH
- TOP OF LANDING: 5'-6"
ROOF RISE
18' - 8"

LEVEL 2 RISE
10' - 4"

STAIR LANDING
5' - 6"

LEVEL 1 FRAMING
0"

FLIGHT < 12' → 5' 6" < 12' ✓
TREAD = 11" ✓
RISE = 6 1/2" ✓

Phase 2 Stairs 3
<table>
<thead>
<tr>
<th>ID</th>
<th>Task Mode</th>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
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<tbody>
<tr>
<td>1</td>
<td></td>
<td>Modular House</td>
<td>47.88 days</td>
<td>Sun 3/19/17</td>
<td>Tue 6/13/17</td>
</tr>
<tr>
<td>2</td>
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<td>Preconstruction</td>
<td>32.88 days</td>
<td>Sun 3/19/17</td>
<td>Thu 5/18/17</td>
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<tr>
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<td>14.38 days</td>
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<td>2 days</td>
<td>Tue 4/18/17</td>
<td>Fri 4/21/17</td>
</tr>
<tr>
<td>5</td>
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<td>Complete structural analysis and design</td>
<td>5 days</td>
<td>Wed 4/19/17</td>
<td>Sun 4/30/17</td>
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<tr>
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<td>1 day</td>
<td>Sun 4/30/17</td>
<td>Thu 5/4/17</td>
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<td>Sat 5/13/17</td>
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<td>Sun 5/7/17</td>
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### Task Table

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<tr>
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<td>Signage Design</td>
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<td>Make Connections (Bolt / Weld)</td>
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<td>Sun 5/28/17</td>
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<td>Closeout</td>
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<td>Necessary Inspections</td>
<td>1 day</td>
<td>Thu 6/15/17</td>
<td>Fri 6/16/17</td>
</tr>
</tbody>
</table>

### Diagram

- **Signage Design**
- **Prefab Steel Guardrails**
- **Reinforce super structure**
- **Weld Plates at existing structure**
- **Erect Steel Guardrails**
- **Make Connections (Bolt / Weld)**
- **Finishes**
- **Paint layout, tape and surface prep**
- **Paint**
- **Paint Finish**
- **Post Construction**
- **Closeout**
- **As-Built Drawings**
- **Project Contact Sheet**
- **Necessary Inspections**

---

Project: Modular House Workin

Date: Wed 5/3/17

Duration: 5 days

Start: Sun 4/23/17

Finish: Tue 5/16/17

Critical Dates:
- Wed 5/3/17
- Wed 5/10/17
- Wed 5/17/17
- Wed 5/24/17
- Wed 5/31/17

Critical Milestones:
- Wed 5/3/17
- Wed 5/10/17
- Wed 5/17/17
- Wed 5/24/17
- Wed 5/31/17

External Milestones:
- Wed 5/17/17
- Wed 5/24/17
- Wed 5/31/17