Abstract

Journeyman International is a non-profit organization that pairs graduating seniors in the fields of architecture, architectural engineering, and construction management with professional mentors to provide practical services for humanitarian projects that seek their aid. The particular project of interest is economical housing for Habitat for Humanity in Huntington (West Virginia). The project aims to provide structural calculations and drawings for three different building layouts which the client would be able to submit as construction documents to the local authority having jurisdiction. This report includes the background of the project, the organizations involved, challenges faced by the sole architectural engineering student involved, structural design and calculations for the project.

Introduction

Habitat for Humanity (HFH) is a nonprofit organization that works all across the United States to build affordable housing in communities of need. They build houses with the sweat equity of volunteers, staff, and the recipients of these homes. The beneficiary of those efforts are allowed to purchase the home with a subsidized mortgage loan provided by HFH; eligibility criteria includes current housing insecurity or inadequacy, steady income, good credit, and sweat equity. For years, HFH of Huntington, West Virginia has been able to apply for building permits without traditional construction documents based on the good will of the local building department. Partnering with Journeyman International, this project aims to provide HFH a full set of construction documents that HFH could submit to their building department. Anything
not covered by the scope of this project would fall in the hands of a design professional registered in that jurisdiction.

Journeyman International (JI) is another nonprofit design-build organization founded by fellow Cal Poly San Luis Obispo alum Daniel Wiens. Their mission statement is to foster the next generation of humanitarian designers. By partnering graduating seniors with licensed mentors, the students get training and exposure to humanitarian work in the field of their passion. Even if the thesis project doesn’t get built or used in its entirety, the hope is that the student designer will continue to do humanitarian design work.

Project

The client furnished existing architectural and electrical plans (on 8.5x11) that they have been using to submit as construction documents to the local building department. The HFH chapter that reached out to JI is specifically for Huntington, West Virginia. For other jurisdictions, this would not be sufficient as construction documents. Luckily for HFH, the local (Huntington, WV) building department has an unspoken agreement to look the other way for the sake of fighting poverty. The past workmanship of the homes constructed by HFH have demonstrated proper construction methods and adequate designs.

Since the building that is to be designed has been constructed many times before with slight variations between them, there were very few design choices that need to be made. The primary intent was to create adequate structural drawings and calculations to go with them, so that they would be able to submit the more professional set of construction documents to the building department. In addition to that, the new set of construction documents will be used as
fundraising material; a full construction set that is drafted using modern computer-aided design (CAD) looks much more convincing than a xerox of penciled plans drawn on standard printer paper.

Deliverables

Because the different floor plan layouts generally share the same structural design criteria, the calculations were based off of the largest of the floor plans (resulting in the greatest base shear to design for). The largest floor plan is a 24’x60’ detached single-family dwelling with 5 bedrooms and 2 bathrooms. The building also includes a front porch that extends roughly 5 feet beyond the front of the house. Both the main structure and the front porch will likely be raised due to local conditions/preferences in Huntington, WV.

For personal exploration and enrichment, additional design methodologies were investigated for the design of this project. Based on the official building code adopted by the city of Huntington, WV (International Building Code, 2015, IBC), typical residential construction falls within the scope of the International Residential Code (IRC). The IRC and the IBC both allow a design method that is not mentioned in our curriculum: prescriptive design. As long as the building falls within the design limitations outlined by each prescriptive design method (IBC/IRC/Wood Frame Construction Manual), the amount of analysis required to produce a code-compliant structure is reduced. Most of the design proposed by the existing architectural drawings fell within the scope of both prescriptive methods. The parts of the current design that fell outside the scope are the porch at the front of the house and the raised floor (more precisely the girders); these must be designed by the accepted engineered method.
The analyses are separated into two modules: traditional engineered design and prescriptive design based on the Wood Frame Construction Manual (WFCM) published by the American Wood Council. The prescriptions given by the WFCM are explicitly permitted in the 2015 IBC in §2301.2 and in the 2015 IRC in §R301.1. While collating the results of the different analyses, it became evident that the limitations that permit for prescriptive design were very carefully shaped. The buildings that are permitted to be designed prescriptively must be similar enough that the prescriptions are sufficient for all the variations that may still occur within those bounds. The results for a typical roof rafter (gravity calculation) and for the length of braced wall required (lateral calculation) were essentially at parity. The tangible differences between the design methods are the detailing requirements and the code classifications of braced wall methods.

**Challenges**

Because the focus of the project was to compare prescriptive design methods versus engineered design, difficulties arise when parts of the project fall outside the permitted scope of prescriptive design. The juxtapositions stopped there so that no apples were compared to oranges. There were two discrete parts of the house that had to be engineered: the front porch (posts supporting the beams and the floor framing) and the desired floor framing layout (have to do stem walls instead of piers). The beams at the porch supporting the roof framing didn’t explicitly fall within a prescription but it was possible to finagle a table for load bearing headers to achieve the same loading and design criteria. Ideally, the prescriptive design methods would have permitted a floor framing system with intermediate beam (instead of load-bearing walls);
instead, to create a foundation and floor framing layout that is prescriptive compliant, a separate layout had to be calculated and drawn with stem walls instead of a joist and beam configuration.

Impact

The global impact of this senior thesis project is limited. As of 2019, there are still efforts to push prescriptive light frame construction into other regions and nations. Unifying building codes in developing nations with tried and true construction methods would ideally ensure more safe buildings for everyone governed by those codes. Even though compliance is relatively costly compared to ignoring building codes, including a prescriptive design method in said building code would be a good compromise that promotes safer building standards.

The social impacts of this project are will be felt by the residents of the communities that Habitat for Humanity in Huntington West Virginia serves. By helping fight housing insecurity by being a non-predatory lender and builder, the effect of HFH’s work should alleviate the largest worry of families living paycheck to paycheck. Based on Maslow’s Hierarchy of Needs, by helping fulfill basic physiological and security needs (shelter in this case) one is free to pursue personal development and growth. A byproduct of the “modernized” plans is any resistance that the building department may put up in the future regarding these homes should be mitigated.

The economic impact will be felt by the recipients of these low-income housing ventures. Ideally, this design package consisting of revamped construction documents will serve as a fundraising tool that allows them to bring in more donation revenue. Any additional
donations that may occur from this project would help finance the construction of more homes for the underserved.

The cultural impact of the project will hopefully be the continued flourishing of Habitat for Humanity. Not only would the design package help them be more successful in their particular venture in Huntington, WV, the lessons learned from the prescriptive design exploration should help them produce more code compliant plans for other jurisdictions and localities. Since the need of a “stamp” is evaluated on a state-by-state basis, the designs can be easily extrapolated within the state to all municipalities that adopt the IBC.

The environment influenced the project in a design sense. Because of the location of the project, it affects the types of wood that could be reasonably specified. Different species have different capacities (and even the loss of adjustment factors). Projects in West Virginia would have difficulty sourcing the Douglas Fir that we are familiar with in our curriculum; the design package is prepared with Southern Pine. If the client ever communicates that Spruce Pine Fir or another species of wood is more desirable or practical, the prescriptive methods will allow for quick adjustments to be made within minutes.

Lifelong Learning

Because codes are very specific to the region in which the design is being done, familiarity with a particular code is secondary to being able to parse and navigate whatever is relevant. This project has taught me how to dive into codes that have grey areas and navigate dependencies. Sometimes two applicable codes (the IBC and the IRC) will have different requirements while stating that both must be fulfilled; a reasonable interpretation would be to
abide by the result that is more stringent and promoted the public health best. Essentially, this project introduced a new code and I needed to digest and extract all the relevant provisions. This is important training for being an adaptable engineer; it is paramount that they can constantly learn and improve themselves.

Personal Reflection

The work Journeyman International does seems very effective to me. Outside of the humanitarian aspect, the project was good practice on designing and drafting a small residential project. Furthermore, this project allowed me to practice self-reliance and taught me how to explore reference material on my own. I was able to dip my toes into humanitarian design through this project. I am now able to make an informed conclusion that I would love to continue down this path of humanitarian work. It has been gratifying taking the education that I have a passion for and putting it to work in a tangible way for those less fortunate than I. Aside from doing more humanitarian designing/engineering, I am confident I want to get involved with disaster relief volunteer work when my career progression permits it.
Structural Calculations for Low-Income Housing

In Huntington, West Virginia

With Habitat for Humanity and Journeyman International

BY

DAVID HSU

Contents

Engineered Analysis ........................................................................................................................................ 1

Prescriptive Analysis ..................................................................................................................................... 16
Engineered analysis:

Typical header 4x4 Southern Pine #1 or btr
Typical floor joist 2x6 southern Pine #2 or btr @ 24” cc
Typical floor girder (if occurs) (2)-2x8 Southern Pine #1 or btr
Typical ceiling joist 2x10 Southern Pine SS or btr @ 24” cc
Typical roof rafter 2x8 Southern Pine #1 or btr @ 24” cc
Shear wall 3/8” SP w/ 8d @ 6”, 6”, 12”

4’ in each braced wall line in both directions
w/ HD5B ea chord
use 3x chord in EW direction

Shear transfer H1 ea joist to top plate connection

1/2”Ø A.B. w/ 6” min embed spaced at 48” cc

Typical porch joist 2x6 Southern Pine #2 or btr @ 24” cc
Typical porch beam (2)-2x6 Southern Pine #1 or btr
Lateral analysis:

ASCE 7-16  Governing Load Combinations

(2.4.1)  2.  D + L  
3.  D + L  
4.  D + 0.75L + 0.75L  
5.  D + 0.6W  
6.  D + 0.75L + 0.75*0.6W + 0.75L  
7.  0.6D + 0.6W

Seismic Equivalent Lateral Force procedure from Chapter 12

\[ S_{DS} = 0.163 \]
\[ S_{D1} = 0.109 \]

(T1.5-2)  \[ I_e = 1.00 \]

(T12.2-1)  \[ R = 6.5 \text{ (A15)} \]

*see pg. ___ for unit loads*

<table>
<thead>
<tr>
<th></th>
<th>psf</th>
<th>Effective Area</th>
<th>Net Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>16</td>
<td>1560</td>
<td>24960</td>
</tr>
<tr>
<td>Floor</td>
<td>14</td>
<td>1560</td>
<td>21840</td>
</tr>
<tr>
<td>Interior Partitions</td>
<td>8</td>
<td>1680</td>
<td>13440</td>
</tr>
<tr>
<td>Exterior Partitions</td>
<td>12</td>
<td>1344</td>
<td>16128</td>
</tr>
</tbody>
</table>

\[ W = 76368 \text{ #} \]

(12.8-1)  \[ V = C_s W \]

(12.8-2)  \[ C_s = S_{DS} / (R/I_e) = 0.163 / (6.5/1.0) = 0.0251 \]

(T12.8-2)  \[ C_t = 0.02 \]

\[ x = 0.75 \]

(12.8.2)  \[ T = C_t h_n^x = 0.02 * 10^{0.75} = 0.112 \text{ s} \]

(12.8-3)  \[ C_{s,max} = S_{D1} / (T * R/I_e) = 0.109 / 0.112 / 6.5 / 1.00 = 0.150 > 0.0251 \]

(12.8-5)  \[ C_{s,min} = 0.044 S_{DS} I_e = 0.044 * 0.163 * 1.0 = 0.007 < 0.0251 \]

\[ V = 0.0251 * 76368 \text{ #} = 1917 \text{ #} \]

Seismic will not govern in either direction
Wind analysis per projected area approach from Chapter 28, Part 2, ASCE 7-16

$V = 106 \text{ mph} \rightarrow \text{take as 110 mph to use tables in ASCE 7-16}$

(26.7.3) Exposure C (see 26.7.4.2?)

(28.5-1) $p_s = \lambda k_{zt} p_{s30}$

(F28.5-1) $\lambda = 1.21$ (Mean roof height = 15’, exposure C)

(26.8.2) $k_{zt} = 1.0$

$\theta = \tan^{-1}(4/12) = 18.4^\circ \rightarrow \text{take as 20° to use tables}$

Note: In hind sight. Exposure should be B. Shears are roughly 20% larger than they should be. Resulting design is conservative.

Building Geometry (slightly simplified)
(F28.5-1) EW

<table>
<thead>
<tr>
<th></th>
<th>$p_{s30}$ @ exposure B</th>
<th>$p_s$ @ exposure C</th>
<th>Projected Area</th>
<th>Net Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>26.6</td>
<td>32.2</td>
<td>48</td>
<td>1546</td>
</tr>
<tr>
<td>B</td>
<td>-7.0</td>
<td>-8.5</td>
<td>24</td>
<td>-204</td>
</tr>
<tr>
<td>C</td>
<td>17.7</td>
<td>21.4</td>
<td>432</td>
<td>9245</td>
</tr>
<tr>
<td>D</td>
<td>-3.9</td>
<td>-4.7</td>
<td>236</td>
<td>-1109</td>
</tr>
</tbody>
</table>

$V_{wind,EW} = 9478 \#$

NS

<table>
<thead>
<tr>
<th></th>
<th>$p_{s30}$ @ exposure B</th>
<th>$p_s$ @ exposure C</th>
<th>Projected Area</th>
<th>Net Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>19.2</td>
<td>23.2</td>
<td>68</td>
<td>1578</td>
</tr>
<tr>
<td>C</td>
<td>12.7</td>
<td>15.4</td>
<td>172</td>
<td>2649</td>
</tr>
</tbody>
</table>

$V_{wind,NS} = 4227 \#$

EW (vs minimum design load per 28.5.4)

<table>
<thead>
<tr>
<th></th>
<th>Prescribed minimum $p_s$</th>
<th>Projected Area</th>
<th>Net Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>16</td>
<td>48</td>
<td>768</td>
</tr>
<tr>
<td>B</td>
<td>8</td>
<td>24</td>
<td>192</td>
</tr>
<tr>
<td>C</td>
<td>16</td>
<td>432</td>
<td>6912</td>
</tr>
<tr>
<td>D</td>
<td>8</td>
<td>236</td>
<td>1888</td>
</tr>
</tbody>
</table>

$V_{wind,EW} = 9760 \#$

NS (vs minimum design load per 28.5.4)

<table>
<thead>
<tr>
<th></th>
<th>$p_{s30}$ @ exposure B</th>
<th>$p_s$ @ exposure C</th>
<th>Projected Area</th>
<th>Net Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>19.2</td>
<td>16</td>
<td>68</td>
<td>1088</td>
</tr>
<tr>
<td>C</td>
<td>12.7</td>
<td>16</td>
<td>172</td>
<td>2752</td>
</tr>
</tbody>
</table>

$V_{wind,NS} = 3840 \#$

Wind governs in both directions (vs 1,917 # seismic base shear)

Uplift

<table>
<thead>
<tr>
<th></th>
<th>$p_{s30}$ @ exposure B</th>
<th>$p_s$ @ exposure C</th>
<th>Projected Area</th>
<th>Net Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>-23.1</td>
<td>-28.0</td>
<td>84</td>
<td>-2352</td>
</tr>
<tr>
<td>F</td>
<td>-16.0</td>
<td>-19.4</td>
<td>84</td>
<td>-1630</td>
</tr>
<tr>
<td>G</td>
<td>-16.0</td>
<td>-19.4</td>
<td>756</td>
<td>-14666</td>
</tr>
<tr>
<td>H</td>
<td>-12.2</td>
<td>-14.8</td>
<td>756</td>
<td>-11189</td>
</tr>
<tr>
<td>E_{OH}</td>
<td>-32.3</td>
<td>-39.1</td>
<td>70</td>
<td>-2737</td>
</tr>
<tr>
<td>G_{OH}</td>
<td>-25.3</td>
<td>-30.6</td>
<td>70</td>
<td>-2142</td>
</tr>
</tbody>
</table>

$F_{uplift} = -34716 \#$
Diaphragm analysis:

NDS SDPWS

2015 (T4.2C) \( v_n = 475 \text{ plf} \rightarrow v_{ASD} = \frac{475}{2} = 237 \text{ plf} > v_n = 0.6 \times 176 \text{ plf} = 106 \text{ plf} \)

5/16” sheathing w/ 6d @ 6”, 6”, 12” permitted \( (v_{ASD} = 237 \text{ plf}) \)

Aspect ratio check:

(4.2.4) \( L/W = 65/24 = 2.71 \); **unblocked** wood structural panels OK

\[
T = C = \frac{M_u}{\text{diaphragm depth}}
\]

\[
M_u = w_n L^2 / 8 = 0.6 w_n L^2 / 8
\]

\[
M_{u,EW} = 0.6 \times 150 \times 65^2 / 8 = 47531 \text{#} - ft
\]

\[
C_{EW} = 47531 \text{#} - ft / 24' = 1980 \text{#}
\]

\[
M_{u,NS} = 0.6 \times 176 \times 24^2 / 8 = 7603 \text{#} - ft
\]

\[
C_{NS} = 7603 \text{#} - ft / 65' = 117 \text{#}
\]

**Design chords running EW for 1980# axial force;**

negligible chord force running NS
Uplift anchorage:

\[ 0.6D + 06W \]

\[ F_u = 0.6 \times F_{uplift} = 0.6 \times 34716 \text{ #} = 20830 \text{ #} \]

see catalog use Simpson H1, uplift capacity: 480#/tie, shear capacity: 510#/tie

one tie at each end of rafters → 60 ties

\[ R_n = 480 \text{ #} \times 60 = 28800 \text{ #} > F_u = 20830 \text{ #} \text{ OK} \]

NDS 2018 \[ Z_\perp = 410 \text{ #} \]

(T12E) \[ Z'_\perp = Z_\perp \times C_D = 410 \times 1.6 = 656 \text{ #} \text{ for ea 1/2”Ø A.B. w/ 6” min. embed} \]

Bearing perimeter: 168’

\[ s = Z'_\perp / (F_u / \text{wall length}) = 656 / (20830 / 168) = 5.3' \rightarrow s = 4' \]

use Simpson H1 at each end of typical rafters

use 1/2”Ø A.B. w/ 6” min. embed @ 48” cc
Shear Wall analysis

\[ V = 106 \text{ mph} \rightarrow \text{take as 110 mph to use tables in ASCE 7-16} \]

3/8" sheathing w/ 8d @ 6", 6", 12" \( v_{ASD} = 730/2 = 365 \text{ plf} \)

Wall length required NS = 4227 * 0.6/365 = 6.9' \(\rightarrow (2) \text{ 4' panels NS} \)

Wall length required EW = 9760 * 0.6/365 = 16.0' \(\rightarrow (4) \text{ 4' panels EW} \)

**NS**

- 0.6 * 12 = 11.5 plf
- Use HD5B in both directions
- In NS, use 2x chord min.
- In EW, use 3x chord min.

**EW**

- 0.6 * 12 = 11.5 plf
- Use HD5B in both directions
- In NS, use 2x chord min.
- In EW, use 3x chord min.
Checking worst case of 4’ span

\[
DL = 16 \text{ psf}
\]

ASCE 7-16 4

\[
LL = 10 \text{ psf} \quad \text{uninhabited attic, irreducible}
\]

\[
LL_r = 20 \text{ psf} \quad \text{typical sloped roof, irreducible}
\]

Governing load combination: \( D + 0.75L + 0.75L_r \)

\[
w_u = (16 + 0.75(10 + 20)) \times 4' = 539 \text{ plf}
\]

\[
w_L = (20) \times 4' = 280 \text{ plf}
\]

\[
w_{0.5D+L} = (0.5 \times 16 + 20) \times 4' = 392 \text{ plf}
\]

\[
M_u = w_u L^2/8 = 539 \times 4^2/8 = 1078 \# - ft = 12936 \# - \text{in}
\]

Presume Southern Pine #2 \( E = 1400000 \text{ psi} \)

\[
\Delta_{L,\text{max}} = L/240 = 48/240 = 0.2''
\]

\[
\rightarrow I_{\text{req}} = 5 w_L L^4/(384 E \Delta_{\text{max}}) = 5.76 \text{ in}^4
\]

\[
\Delta_{0.5D+L,\text{max}} = L/180 = 48/180 = 0.267''
\]

\[
\rightarrow I_{\text{req}} = 5 w_{0.5D+L} L^4/(384 E \Delta_{\text{max}}) = 6.04 \text{ in}^4
\]

Presume 4x6 \( I_x = 48.53 \text{ in}^4 \)

(Table 4B)

\[
F'_b = F_b \times C_D = 1100 \text{ psi} \times 1.25 = 1375 \text{ psi}
\]

\[
f_b = M_u/S_x = 12936/17.65 = 733 \text{ psi} < F'_b = 1375 \text{ psi OK}
\]

Check Southern Pine #3 \( E = 1300000 \text{ psi} \)

\[
\Delta_{0.5D+L} = 5 w_{0.5D+L} L^4/(384 E I) = 0.035 \text{ in} < \Delta_{\text{max}} = 0.267'' \text{ OK}
\]

\[
F'_b = 650 \text{ psi} \times 1.25 = 813 \text{ psi} > f_b = 733 \text{ psi OK}
\]

\[
V_u = w_u L/2 = 539 \times 4/2 = 1078\# \rightarrow \text{bearing will be non-issue}
\]

Check (2)-2x4 Southern Pine #2

\[
S_x \approx 6 \text{ in}^3 \rightarrow f_b = 12936/6 = 2156 \text{ psi} > 1375 \text{ psi NG}
\]

Check 4x4 Southern Pine #1

\[
S_x = 7.15 \text{ in}^3 \rightarrow f_b = 12936/7.15 = 1809 \text{ psi} > 1875 \text{ psi OK}
\]

**Use 4x4 Southern Pine #1 or btr**
Typical floor joist

\[ L = 8', s = 24'' \]
\[ DL = 14 \text{ psf} \]

**ASCE 7-16 4**  \( LL = 40 \text{ psf} \)  living areas or sleeping areas and partitions, irreducible

Governning load combination: \( D + L \)

\[ w_u = (14 + 40) \times 2' = 108 \text{ pfl} \]
\[ w_L = (40) \times 2' = 80 \text{ pfl} \]
\[ w_{0.5D+L} = (0.5 \times 14 + 40) \times 2' = 94 \text{ pfl} \]
\[ M_u = w_u \frac{L^2}{8} = 108 \times 8^2/8 = 864 \text{ ft} - \text{in} \]

presume Southern Pine \#2 \( E = 1400000 \text{ psi} \)

\[ \Delta_{L,max} = L/360 = 96/360 = 0.267'' \]

\[ \rightarrow I_{req} = 5 w_L \frac{L^4}{(384 E \Delta_{max})} = 19.72 \text{ in}^4 \]
\[ \Delta_{0.5D+L,max} = L/240 = 96/240 = 0.4'' \]

\[ \rightarrow I_{req} = 5 w_{0.5D+L} \frac{L^4}{(384 E \Delta_{max})} = 15.47 \text{ in}^4 \]

presume 2x6 \( I_x = 20.80 \text{ in}^4, S_x = 7.56 \text{ in}^3 \)

(\text{Table 4B})  \( F'_b = F_b \times C_D \times C_T = 1100 \text{ psi} \times 1.0 \times 1.15 = 1265 \text{ psi} \)
\[ f_b = \frac{M_u}{S_x} = 10368/7.56 = 1371 \text{ psi} < F'_b = 1265 \text{ psi NG} \]

Try Southern Pine \#1 \( E = 1600000 \text{ psi} \)

\[ F'_b = 1500 \text{ psi} \times 1.0 \times 1.15 = 1725 \text{ psi} > f_b = 1371 \text{ psi OK} \]

**use 2x6 Southern Pine \#1 or btr**
Typical floor girder

\[ L = 8', s = 96" \]

\[ DL = 14 \text{ psf} \]

**ASCE 7-16 4**

LL = 40 psf  
Living areas or sleeping areas and partitions, irreducible

Governing load combination: D + L

\[ w_u = (14 + 40) * 8' = 432 \text{ plf} \]

\[ w_L = (40) * 8' = 320 \text{ plf} \]

\[ w_{0.5D+L} = (0.5 * 14 + 40) * 8' = 376 \text{ plf} \]

\[ M_u = w_u L^2/8 = 376 * 8^2/8 = 3008 \# \mid \text{ ft} = 36096 \# \mid \text{ in} \]

Presume Southern Pine #2 \( E = 1400000 \text{ psi} \)

\[ \Delta_{L,\text{max}} = L/360 = 96/360 = 0.267" \]

\[ \rightarrow I_{\text{req}} = 5 w_L L^4/(384 E \Delta_{\text{max}}) = 78.99 \text{ in}^4 \]

\[ \Delta_{0.5D+L,\text{max}} = L/240 = 96/240 = 0.4" \]

\[ \rightarrow I_{\text{req}} = 5 w_{0.5D+L} L^4/(384 E \Delta_{\text{max}}) = 61.88 \text{ in}^4 \]

Presume (2)-2x8 \( I_x = 2 * 47.63 = 95.26 \text{ in}^4 \)

(Table 4B) \( F'_b = F_b \times C_D = 1100 \text{ psi} \times 1.0 = 1100 \text{ psi} \)

\[ f_b = M_u/S_x = 36096/(2 * 13.14) = 1374 \text{ psi} < F'_b = 1100 \text{ psi NG} \]

Try Southern Pine #1 \( E = 1600000 \text{ psi} \)

\[ F'_b = 1500 \text{ psi} \times 1.0 = 1500 \text{ psi} > f_b = 1374 \text{ psi OK} \]

**Use (2)-2x8 Southern Pine #1 or btr**

\[ V_u = w_u L/2 = 376 * 8/2 = 1504 \# \rightarrow \text{ bearing will be non-issue} \]
Typical ceiling joist

\[ L = 24', s = 24'' \]

\[ DL = 16 \text{ psf} \]

ASCE 7-16 4  \[ LL = 10 \text{ psf} \]  uninhabited attic, irreducible

Governing load combination: D + L

\[ w_u = (16 + 10) \times 2' = 52 \text{ plf} \]

\[ w_L = (10) \times 2' = 20 \text{ plf} \]

\[ w_{0.5D+L} = (0.5 \times 16 + 10) \times 2' = 36 \text{ plf} \]

\[ M_u = w_u L^2/8 = 52 \times 24^2/8 = 3744 \# - ft = 44928 \# - \text{in} \]

Presume Southern Pine SS \( E = 1800000 \text{ psi} \)

\[ \Delta_{L,max} = L/240 = 24 \times 12/240 = 1.2'' \]

\[ \rightarrow I_{req} = 5 w_L L^4/(384 E \Delta_{max}) = 69.1 \text{ in}^4 \]

\[ \Delta_{0.5D+L,max} = L/180 = 24 \times 12/180 = 1.6'' \]

\[ \rightarrow I_{req} = 5 w_{0.5D+L} L^4/(384 E \Delta_{max}) = 93 \text{ in}^4 \]

Presume 2x10 \( I_x = 98.93 \text{ in}^4, S_x = 21.39 \text{ in}^3 \)

(Table 4B) \[ F'_b = F_b \times C_D \times C_r = 2350 \text{ psi} \times 1.15 = 2703 \text{ psi} \]

\[ f_b = M_u/S_x = 44928/21.39 = 2100 \text{ psi} < F'_b = 2703 \text{ psi} \text{ OK} \]

**use 2x10 Southern Pine SS or btr**

\[ V_u = w_u L/2 = 52 \times 24/2 = 624 \# \]

\[ \rightarrow f_{c\perp} = V_u/A_{brg} = 624/(1.5 \times 3.5) = 119 \text{ psi} \]

\[ F'_{c\perp} = F_{c\perp} \times C_b = 565 \times C_b = 565 \times 1.25 = 706 \text{ psi} > f_{c\perp} = 119 \text{ psi} \]

\[ C_b = (l_b + 0.375)/l_b = (1.5 + 0.375)/1.5 = 1.25 \]
Typical roof rafter

\[ L = 14', s = 24'' \]

\[ DL = 16 \text{ psf} \]

ASCE 7-16 4 \( LL_r = 20 \text{ psf} \) typical sloped roof, irreducible

Governing load combination: \( D + Lr \)

\[ w_{u} = (16 + 20) \times 2' = 72 \text{ plf} \]

\[ w_{L} = (20) \times 2' = 40 \text{ plf} \]

\[ w_{0.5D+L} = (0.5 \times 16 + 20) \times 2' = 56 \text{ plf} \]

\[ M_u = w_{u} L^2/8 = 72 \times 14^2/8 = 1764\# \quad ft = 21168\# \quad in \]

Presume Southern Pine #2 \( E = 1400000 \text{ psi} \)

\[ \Delta_{L,\text{max}} = L/240 = 14 \times 12/240 = 0.7'' \]

\[ \rightarrow I_{eq} = 5 w_{L} L^4/(384 E \Delta_{\text{max}}) = 35.3 \text{ in}^4 \]

\[ \Delta_{0.5D+L,\text{max}} = L/180 = 14 \times 12/180 = 0.9'' \]

\[ \rightarrow I_{eq} = 5 w_{0.5D+L} L^4/(384 E \Delta_{\text{max}}) = 38.4 \text{ in}^4 \]

Presume 2x8 \( I_x = 47.63 \text{ in}^4, S_x = 13.14 \text{ in}^3 \)

(Table 4B) \[ F'_b = F_b \times C_D \times C_r = 1100 \text{ psi} \times 1.25 \times 1.15 = 1581 \text{ psi} \]

\[ f_b = M_u/S_x = 21168/13.14 = 1611 \text{ psi} > F'_b = 1581 \text{ psi NG} \]

Try #1 \( E = 1600000 \text{ psi} \)

\[ F'_b = 1500 \times C_D \times C_r = 1500 \text{ psi} \times 1.25 \times 1.15 = 2156 \text{ psi} > f_b = 1611 \text{ psi OK} \]

**Use 2x8 Southern Pine #1 or btr**

\[ V_u = w_u L/2 = 72 \times 14/2 = 504\# \]
Typical porch joist

\[ L = 4.75', s = 24'' \]

DL = 10 psf

**ASCE 7-16 4**  
LL = 60 psf  
1.5 x occupancy served

Governing load combination: D + L

\[ w_u = (10 + 60) \times 2' = 140 \text{ plf} \]
\[ w_L = (60) \times 2' = 120 \text{ plf} \]
\[ w_{0.5D+L} = (0.5 \times 10 + 60) \times 2' = 130 \text{ plf} \]
\[ M_u = w_u \frac{L^2}{8} = 140 \times 4.75^2/8 = 395.8 \# \times \text{ft} = 4738 \# - \text{in} \]

Presume Southern Pine #2  
\[ E = 1400000 \text{ psi} \]

\[ \Delta_{L,max} = L/360 = 4.75 \times 12/360 = 0.158'' \]
\[ \rightarrow I_{req} = 5 w_L \frac{L^4}{384 E \Delta_{max}} = 6.21 \text{ in}^4 \]

\[ \Delta_{0.5D+L,max} = L/240 = 4.75 \times 12/240 = 0.238'' \]
\[ \rightarrow I_{req} = 5 w_{0.5D+L} \frac{L^4}{384 E \Delta_{max}} = 4.67 \text{ in}^4 \]

Presume 2×6  
\[ I_x = 20.80 \text{ in}^4, S_x = 7.56 \text{ in}^3 \]

(Table 4B)  
\[ F'_b = F_b \times C_D \times C_r = 1100 \text{ psi} \times 1.0 \times 1.15 = 1265 \text{ psi} \]
\[ f_b = \frac{M_u}{S_x} = 13440/13.14 = 627 \text{ psi} < F'_b = 1265 \text{ psi OK} \]

**Use 2x6 Southern Pine #2 or btr @ 24” cc**

\[ V_u = w_u L/2 = 140 \times 8/2 = 560 \# \rightarrow \text{bearing will be non-issue} \]
Typical porch beam

\[ L = 8', s = 2.375' \]

\[ DL = 10 \text{ psf} \]

ASCE 7-16 4  LL = 60 psf  1.5 x occupancy served

Governing load combination: D + L

\[ w_u = (10 + 60) \times 2.375' = 166 \text{ plf} \]
\[ w_L = (60) \times 2.375' = 143 \text{ plf} \]
\[ w_{0.5D+L} = (0.5 \times 10 + 60) \times 2.375' = 154 \text{ plf} \]
\[ M_u = w_u L^2/8 = 166 \times 8^2/8 = 1328 \# - ft = 15936 \# - \text{in} \]

Presume Southern Pine #2  \( E = 1400000 \text{ psi} \)

\[ \Delta_{L,\text{max}} = L/360 = 96/360 = 0.267'' \]

\[ \rightarrow I_{\text{req}} = 5 w_L L^4/(384 E \Delta_{\text{max}}) = 35.3 \text{ in}^4 \]

\[ \Delta_{0.5D+L,\text{max}} = L/240 = 96/240 = 0.4'' \]

\[ \rightarrow I_{\text{req}} = 5 w_{0.5D+L} L^4/(384 E \Delta_{\text{max}}) = 25.3 \text{ in}^4 \]

Presume 2x8 \( I_x = 47.63 \text{ in}^4, S_x = 13.14 \text{ in}^3 \)

(Table 4B)  \( F'_b = F_b \times C_D = 1100 \text{ psi} \times 1.0 = 1100 \text{ psi} \)

\[ f_b = M_u/S_x = 15936/13.14 = 1213 \text{ psi} > F'_b = 1100 \text{ psi NG} \]

Try #1  \( E = 1600000 \text{ psi} \)

\[ F'_b = 1500 \times C_D = 1500 \text{ psi} \times 1.25 = 1875 \text{ psi} > f_b = 1213 \text{ psi OK} \]

\[ V_u = w_u L/2 = 140 \times 8/2 = 560 \# \rightarrow \text{bearing will be non-issue} \]

Check (2)-2x6 Southern Pine #1

\[ S_x \approx 15 \text{ in}^3 \rightarrow f_b = 15936/15 = 1062 \text{ psi} < F'_b = 1875 \text{ psi OK} \]

**Use (2)-2x6 Southern Pine #1 or btr**
Double top plate check

\[ P = 1980 \, \# \]

check 2x4 Southern Pine #3 \( A = 5.25 \, in^2, F_{c\|} = 850 \, psi \)

\[ F_{c\|}' = F_{c\|} \times C_D = 850 \times 1.6 = 1360 \, psi \]

\[ f_{c\|} = \frac{P}{A} = \frac{1980 \, \#}{5.25 \, in^2} = 377 \, psi < F_{c\|}' = 1360 \, psi \, OK \]

**use 2x4 Southern Pine #3 or btr**
Light-framed wood construction prescriptions:

Typical header 2x8 Southern Pine #2 or btr
Typical floor joist 2x6 Southern Pine #1 or btr @ 24” cc
Typical ceiling joist 2x10 Southern Pine SS @ 24” cc
Typical roof rafter 2x8 Southern Pine #1 or btr @ 24” cc
w/ (8)-16d ea heel joint
w/ (2)-8d ea end of ridge strap

Braced wall requirements 3/8” SP w/ 8d @ 6”, 6”, 12”
8’ in each braced wall line in EW direction
4’ in each braced wall line in NS direction
w/ HD5B at ea chord

Shear transfer (3)-8d ea joist to top plate connection
5/8” Ø A.B. w/ 6” min embed spaced at 48” cc

WFCM/IBC/IRC prescriptive approach does not cover design of porch
Floor system:

Floor joists

DL = 20 psf

LL = 40 psf living areas or sleeping areas + partitions

Deflection limited to L/360

T3.18B use 2x6 Southern Pine #1 @ 24” cc

or 2x8 Southern Pine #2 @ 24” cc

or 2x10 Southern Pine #3 @ 24” cc

3.3.1.4 no additional lateral bracing required

Roof System:

Rafter (with ceiling not attached to rafter)

DL = 20 psf

LL = 20 psf

Deflection limited to L/180

T3.26A use 2x8 Southern Pine #1 or btr @ 24” cc

or 2x10 Southern Pine #2 or btr @ 24” cc

3.3.1.4 no additional lateral bracing required

TA-3.6 w/ (2)-8d common nails in each end of 1-1/4” strap as ridge strap

Ceiling joist

Deflection limited to L/240 for flexible finishes

LL = 10 psf uninhabitable attics without storage

T3.25A1 use 2x10 Southern Pine SS @ 24” cc

T3.25A2 brittle finishes (L/360) all noncompliant for Southern Pine @ 24” cc

3.3.1.4 both edges of member shall be sheathed (“held in line for their entire length”)
Rafter/ceiling joist heel joint connection

**T3.9A**  
*use (8)-16d common nails per connection*

Joist to top plate connection

**T3.4A**  
*use (3)-8d common nails per connection*

Roof sheathing  
110 mph wind speed  
Exposure B  
Rafters spaced at 24” cc  

**T3.12CA**  
*use 3/8” minimum Sheathing grade WSP*  
**T3.10**  
*w/ 8d common nails @ 6”, 6”, 12”*  
or 10d box nails @ 6”, 6”, 12”

Lateral System:

Shear Walls  
Exposure B, 110 mph  

**T3.4B**  
*use 7/16” OSB or 15/32” plywood w/ 8d common nails @ 3”, 6”, 12”*  

\[ NS \rightarrow 3.6' \times 0.50 \text{ (roof pitch reduc)} = 1.8'' \text{ ea wall line} \]  
\[ EW \rightarrow 9.1' \times 0.50 \text{ (roof pitch reduc)} = 4.6'' \text{ ea wall line} \]  
braced wall segment lengths based on minimums in IBC/IRC

Hold-downs  

**T3.17D**  
3488#/ per holdown / 1.61 = 2167# req per hold – down  

**T3.17F**  
*use HD5B at each shear wall chord* (2405# capacity)
Anchorage to foundation

T3.2A  *use 5/8” Ø A.B. w/ 6” min embed spaced at 48” cc max in both NS and EW*

T3.2B  can use 1/2”Ø A.B. as alternative but maximum spacing permitted is 31” cc

T3.2C

Wall System:

Typical Header (dropped exterior)

T3.22A  *use 2x8 Southern Pine #2 or btr*

no flat configurations permitted

T3.22F  **supported by (1)-2x jack stud**
Floor Framing Plan

1. For panel framing, see S2.3B

2. For floor framing, see S2.2A

Habitat for Humanity Huntington, WV

SHEET INFORMATION
DATE: 12.31.2019
JOB NUMBER: 3BR2BA
DRAWN: DHH
CHECKED: DHH
APPROVED: DHH

DRAWING ISSUE / REVISIONS
NO DATE DESCRIPTION
ORIGINAL 12.31.2019 3BR/2BA Habitat for Humanity Huntington, WV

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

Roof Framing Notes:
- Cut-out joist must be 2x12 Southern Pine Structural Select or Better.

Sheet Information:
- Date: 12.31.2019
- Job Number: 3BR2BA
- Habitat for Humanity Huntington, WV

Drawing Issue / Revisions:
- No
- Date: 12.31.2019

Roof Framing Plan
A Look At Prescriptive “Design”

Presented by
David Hsu
Do you need a stamp?

- Huntington West Virginia Municipal Code 1711.01.a
  - Adopts the IBC as the official building code of the city
- IBC 2015 101.2
  - Explicitly points towards IRC for construction of detached one- and two-family dwellings and townhouses less than three stories tall.
- IRC 2015 105.1, 106.1
  - Construction documents must be prepared by a “registered design professional”
- West Virginia Legislature §30-12-12
  - A detached single family dwelling is an exception to needing a professional license

1711.01 - ADOPTION.

(a) The International Building Code 2015 adopted as the Official Building Code of the State of West Virginia, as promulgated by the State Fire Commission pursuant to W. Va. Code §§ 26-3-15b, 8-12-13, and 7-1-3o, as amended, together with any amendments and modifications thereto as may hereafter be adopted and promulgated from time to time by the Commission, is hereby adopted as the Official Building Code of the City.

(b) The City of Huntington does not adopt any of the additional appendices authorized pursuant to the W. Va. legislative rule identified in § 87-4-1, et seq., and specifically authorized in §§ 87-4-117-3.

(c) The City of Huntington does adopt the provisions of the national codes with respect to the penalty for imprisonment, but the penalty for any violation shall be limited to a maximum of $500 and/or 30 days imprisonment for any single violation.

(d) The City of Huntington does not reject the International Property Maintenance Code and hereby incorporates said Code in its adoption of the Official Building Code.

(Ord. of 11-27-04; Ord. of 6-20-10(1); Ord. of 10-15-13(1); Ord. of 9-12-16(2))
Do you need a stamp?

- Huntington West Virginia Municipal Code 1711.01.a
  - Adopts the IBC as the official building code of the city
- IBC 2015 101.2
  - Explicitly points towards IRC for construction of detached one- and two-family dwellings and townhouses less than three stories tall.
- IRC 2015 105.1, 106.1
  - Construction documents must be prepared by a “registered design professional”
- West Virginia Legislature §30-12-12
  - A detached single family dwelling is an exception to needing a professional license
Do you need a stamp?

- Huntington West Virginia Municipal Code 1711.01.a
  - Adopts the IBC as the official building code of the city

- IBC 2015 101.2
  - Explicitly points towards IRC for construction of detached one- and two-family dwellings and townhouses less than three stories tall.

- IRC 2015 105.1, 106.1
  - Construction documents must be prepared by a “registered design professional”

- West Virginia Legislature §30-12-12
  - A detached single family dwelling is an exception to needing a professional license

R305.1 Required

Any owner or owner’s authorized agent who intends to construct, enlarge, alter, repair, move, demolish or change the occupancy of a building or structure, or to erect, install, enlarge, alter, repair, remove, convert or replace any electrical, gas, mechanical or plumbing system, the installation of which is regulated by this code, or to cause any such work to be performed, shall first make application to the building official and obtain the required permit.

R305.1 Submittal Documents

Submit all documents consisting of construction documents, and other data shall be submitted in two or more sets with each application for a permit. The construction documents shall be prepared by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed. Where special conditions exist, the building official is authorized to require additional construction documents to be prepared by a registered design professional.
Do you need a stamp?

- Huntington West Virginia Municipal Code 1711.01.a
  - Adopts the IBC as the official building code of the city
- IBC 2015 101.2
  - Explicitly points towards IRC for construction of detached one- and two-family dwellings and townhouses less than three stories tall.
- IRC 2015 105.1, 106.1
  - Construction documents must be prepared by a “registered design professional”
- West Virginia Legislature §30-12-12
  - A detached single family dwelling is an exception to needing a professional license

§30-12-12. Exceptions.

Nothing in this article may be construed to prohibit:

[a] Any of the activities that, apart from this exemption, would constitute the practice of architecture, if performed in connection with any of the following:

[1] A detached single family dwelling and any shed, storage building and garages incidental thereto;

[2] A multifamily residential structure not in excess of three stories excluding any basement area;

[3] Farm buildings, including barns, silos, sheds, or housing for farm equipment and machinery.
Prescriptive Design

2301.2 General design requirements.

The design of structural elements or systems, constructed partially or wholly of wood or wood-based products, shall be in accordance with one of the following methods:

1. Allowable stress design in accordance with Sections 2304, 2305, and 2306.
2. Load and resistance factor design in accordance with Sections 2304, 2305, 2307.
3. Conventional light-frame construction in accordance with Sections 2304 and 2308.
4. WFCM in accordance with Section 2309.
5. The design and construction of log structures in accordance with the provisions of ICC 400.

R300.3 Alternative provisions.

As an alternative to the requirements in Section R300.1, the following standards are permitted subject to the limitations of this code and the limitations therein. Where engineered design is used in conjunction with these standards, the design shall comply with the International Building Code.

1. AFRSA Wood Frame Construction Manual (WFCM).
2. ASI Standard for Cold-Formed Steel Framing – Prescriptive Method for One- and Two-Family Dwellings (ASI 5230).
### Prescriptive Criteria Check

#### Table 3 Prescriptive Design Limitations

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Limitation</th>
<th>Sentence</th>
<th>Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof Type</td>
<td>Flat</td>
<td>3.1.11</td>
<td>-</td>
</tr>
<tr>
<td>Number of Stories</td>
<td>3</td>
<td>3.1.12</td>
<td>-</td>
</tr>
<tr>
<td>Building Height Limitation</td>
<td>37</td>
<td>3.1.13</td>
<td>-</td>
</tr>
<tr>
<td>Building Height Multiplier</td>
<td>1.0</td>
<td>3.1.14</td>
<td>-</td>
</tr>
<tr>
<td><strong>FLOOR SYSTEMS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumber Joists</td>
<td>Rod 25</td>
<td>3.1.3</td>
<td>-</td>
</tr>
<tr>
<td>Roof Framing</td>
<td>24'- 6&quot;</td>
<td>3.1.15</td>
<td>-</td>
</tr>
<tr>
<td>Airplane - Supporting loadbearing wall</td>
<td>3</td>
<td>3.1.16</td>
<td>-</td>
</tr>
<tr>
<td>Rafters - loadbearing wall</td>
<td>3</td>
<td>3.1.17</td>
<td>-</td>
</tr>
<tr>
<td><strong>Diaphragms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor</td>
<td>Tables 3.108 and 3.156</td>
<td>3.1.18</td>
<td>-</td>
</tr>
<tr>
<td>Wall</td>
<td>Less than 1/8&quot; thick</td>
<td>3.1.19</td>
<td>-</td>
</tr>
<tr>
<td>Wall</td>
<td>1.0</td>
<td>3.1.20</td>
<td>-</td>
</tr>
<tr>
<td>Shear Wall</td>
<td>1.0</td>
<td>3.1.21</td>
<td>-</td>
</tr>
<tr>
<td>Shear Wall (Sideways)</td>
<td>1.0</td>
<td>3.1.22</td>
<td>-</td>
</tr>
<tr>
<td>Shear Wall (Diagonal)</td>
<td>1.0</td>
<td>3.1.23</td>
<td>-</td>
</tr>
<tr>
<td><strong>DIP SYSTEMS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumber Shear Spans (Horizontal)</td>
<td>30</td>
<td>3.1.24</td>
<td>-</td>
</tr>
<tr>
<td>Shear Spans (Vertical)</td>
<td>24'- 6&quot;</td>
<td>3.1.25</td>
<td>-</td>
</tr>
<tr>
<td>Floor Shear Spans (Horizontal)</td>
<td>1.0</td>
<td>3.1.26</td>
<td>-</td>
</tr>
<tr>
<td>Roof Shear Spans (Horizontal)</td>
<td>1.0</td>
<td>3.1.27</td>
<td>-</td>
</tr>
<tr>
<td><strong>Diaphragms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor</td>
<td>Tables 3.10A and 3.156</td>
<td>3.1.28</td>
<td>-</td>
</tr>
<tr>
<td>Wall</td>
<td>1.0</td>
<td>3.1.29</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Section 2008.2 Limitations

Buildings are permitted to be constructed in accordance with the provisions of conventional light-frame construction, subject to the limitations in Sections 2008.2.1 through 2008.2.5.

#### Table 2008.2.1 Allowable Story Height

<table>
<thead>
<tr>
<th>Seismic Design Category</th>
<th>Allowable Story Height Above Grade Plane</th>
</tr>
</thead>
<tbody>
<tr>
<td>A and B</td>
<td>Three stories</td>
</tr>
<tr>
<td>C</td>
<td>Two stories</td>
</tr>
<tr>
<td>D and E*</td>
<td>One story</td>
</tr>
</tbody>
</table>

---

*For the purposes of this section, buildings assigned to Seismic Design Category 3 or E shall be considered as a story unless the story height and roof pitch are such as to prevent wind loads from causing damage.*

**Allowable Floor-to-Floor Height**

Maximum floor-to-floor height shall not exceed 11 feet, 6 inches US 1351 millimeter. Exterior bearing wall and interior braced wall heights shall not exceed a height of 10 feet (3050 millimeters).
Typical Rafter

Design assumptions: use Southern Pine, simplified 14’ span
Typical roof rafter

\[ L = 14, f = 24\]°

\[ DL = 16\] psf

LL = 20 psf  typical sloped roof, invariable

Governing load combination: D + L

\[ w_d = (16 + 20) \times 2 = 72\] psf

\[ w_L = 16 \times 2 = 32\] psf

\[ w_{d+L} = (16 + 20 + 2) \times 2 = 56\] psf

\[ \frac{w_{d+L}}{f} = 56 / 24 = 2.34 \times \frac{14}{8} = 1764 \# \rightarrow f_{D+L} = 2168 \# - in\]

presume Southern Pine #2 E = 1400000 psf

\[ D_{\text{req}} = L 	imes 240 = 16 \times 240 = 3.7^2\]

\[ \frac{D_{\text{req}}}{f} = 3.7^2 \times 2.34 \times 1400000 \times \frac{1}{8} = 13.3^2\]

\[ D_{\text{req}} = L 	imes 240 = 16 \times 240 = 3.87^2\]

\[ \frac{D_{\text{req}}}{f} = 3.87^2 \times 2.34 \times 1400000 \times \frac{1}{8} = 13.4^2\]

presume 2x8, \( r = 47.63 \times 10^3, d_{\text{req}} = 13.4^2 \)

(Table 4)

\[ P = f_{D+L} + C = 1100 \text{ psf} \times 1.25 + 1.55 = 1581 \text{ psf}\]

\[ f_{D+L} = 2168 \text{ psf, } c = 1314 \text{ psf, } c_{\text{req}} = 1381 \text{ psf, } c_{\text{req}} > c_{\text{req}} = 300 \text{ psf}\]

try #4 E = 1400000 psf

\[ P = 1500 + C + C = 1500 \text{ psf} + 1.25 + 1.15 = 2156 \text{ psf} > f_{\text{req}} = 1611 \text{ psf}\]

see 2nd Southern Pine #4 or #8
<table>
<thead>
<tr>
<th>Type</th>
<th>Material Details</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineered</td>
<td>2x8 Southern Pine #1</td>
<td></td>
</tr>
<tr>
<td>IBC</td>
<td>2x8 Southern Pine #1</td>
<td>2308.7.2(1)</td>
</tr>
<tr>
<td></td>
<td>2x10 Southern Pine #2</td>
<td></td>
</tr>
<tr>
<td>IRC</td>
<td>2x8 Southern Pine #1</td>
<td>R802.5.1(1)</td>
</tr>
<tr>
<td></td>
<td>2x10 Southern Pine #2</td>
<td></td>
</tr>
<tr>
<td>WFCM</td>
<td>2x8 Southern Pine #1</td>
<td>T3.26A</td>
</tr>
<tr>
<td></td>
<td>2x10 Southern Pine #2</td>
<td></td>
</tr>
</tbody>
</table>
Shear Walls (WSP)

Design assumptions: 110 mph wind speed, Exposure B
R602.12 Simplified wall bracing.
Buildings meeting all of the conditions listed below shall be permitted to be braced in accordance with this section as an alternate to the requirements of Section R602.10. The entire building shall be braced in accordance with this section; the use of other bracing provisions of Section R602.10, except as specified herein, shall not be permitted.
1. There shall be not more than three stories above the top of a concrete or masonry foundation or basement wall. Permanent wood foundations shall not be permitted.
2. Floors shall not cantilever more than 24 inches (607 mm) beyond the foundation or bearing wall below.
3. Wall height shall not be greater than 10 feet (3048 mm).
4. The building shall have a roof eave-to-ridge height of 15 feet (4572 mm) or less.
5. Exterior walls shall have gypsum board with a minimum thickness of 1/2 inch (12.7 mm) installed on the interior side fastened in accordance with Table R702.3.5.
6. The structure shall be located where the ultimate design wind speed is less than or equal to 130 mph (58 m/s), and the exposure category is B or C.
7. The structure shall be located in Seismic Design Category A, B or C for detached one- and two-family dwellings or Seismic Design Category A or B for townhouses.

R602.12.3 Bracing unit.
A bracing unit shall be a full-height sheathed segment of the exterior wall without openings or vertical or horizontal offsets and a minimum length as specified herein. Interior walls shall not contribute toward the amount of required bracing. Mixing of Items 1 and 2 is prohibited on the same story.
1. Where all framed portions of all exterior walls are sheathed in accordance with Section R602.12.2, including wall areas between bracing units, above and below openings and on gable end walls, the minimum length of a bracing unit shall be 3 feet (914 mm).
2. Where the exterior walls are braced with sheathing panels in accordance with Section R602.12.2 and areas between bracing units are covered with other materials, the minimum length of a bracing unit shall be 4 feet (1219 mm).
<table>
<thead>
<tr>
<th>ULTIMATE DESIGN WIND SPEED (mph)</th>
<th>STORY LEVEL</th>
<th>EAVE-TO-RIDGE HEIGHT (feet)</th>
<th>MINIMUM NUMBER OF BRACING UNITS ON EACH LONG SIDE(^a, d)</th>
<th>MINIMUM NUMBER OF BRACING UNITS ON EACH SHORT SIDE(^b, d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>115</td>
<td>10</td>
<td>Length of short side (feet)(^e)</td>
<td>Length of long side (feet)(^e)</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>1 2 2 2 3 3 1 2 2 2 3 3</td>
<td>1 2 2 2 3 3 1 2 2 2 3 3</td>
<td>1 2 2 2 3 3 1 2 2 2 3 3</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>2 3 3 4 5 6 2 3 3 4 5 6</td>
<td>2 3 3 4 5 6 2 3 3 4 5 6</td>
<td>2 3 3 4 5 6 2 3 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>2 3 4 6 7 8 2 3 4 6 7 8</td>
<td>2 3 4 6 7 8 2 3 4 6 7 8</td>
<td>2 3 4 6 7 8 2 3 4 6 7 8</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>1 2 3 3 4 4 1 2 3 3 4 4</td>
<td>1 2 3 3 4 4 1 2 3 3 4 4</td>
<td>1 2 3 3 4 4 1 2 3 3 4 4</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>2 3 4 5 6 7 2 3 4 5 6 7</td>
<td>2 3 4 5 6 7 2 3 4 5 6 7</td>
<td>2 3 4 5 6 7 2 3 4 5 6 7</td>
</tr>
</tbody>
</table>

\(a, d\) \(b, d\) \(e\)
<table>
<thead>
<tr>
<th>Shear Walls 4 ways (EW direction)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Engineered</strong></td>
</tr>
<tr>
<td>3/8” WSP w/ 8d @ 6”, 6”, 12”</td>
</tr>
<tr>
<td>16’ required of shear wall required</td>
</tr>
<tr>
<td>= 8’ required <em>per braced wall line</em></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>IBC</strong></td>
</tr>
<tr>
<td>3/8” WSP w/ 8d @ 6”, 6”, 12”</td>
</tr>
<tr>
<td>“Each end and ≤ 25’-0” o.c.”</td>
</tr>
<tr>
<td>= 8’ required <em>per braced wall line</em></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>IRC</strong></td>
</tr>
<tr>
<td>3/8” WSP w/ 8d @ 6”, 6”, 12”</td>
</tr>
<tr>
<td>3 bracing units</td>
</tr>
<tr>
<td>= 9’ required <em>per braced wall line</em></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>WFCM</strong></td>
</tr>
<tr>
<td>7/16” OSB or 15/32” plywood</td>
</tr>
<tr>
<td>9.1’ required <em>per shear wall line</em></td>
</tr>
</tbody>
</table>
Cookbook OK?

- Prescriptive/tabulated approach meets rigor and intent of code
- Sometimes overstressed (e.g. holdowns)
- Sometimes limiting (e.g. headers, joists)
What good is it?

- Allows an entrepreneurial homeowner/builder (or a dropout) to do much of the “structural” work on typical residential homes without an engineer
- Can produce a design without design analysis or load calculations