Ryan T. Blatz
Structural Option

Thesis Consultant: Dr. Hanagan
November 16th, 2011

Orange Regional Medical Center
Middletown, NY
# Table of Contents

Executive Summary ......................................................................................................................... 3  
Introduction .................................................................................................................................. 4 
  Building Introduction .................................................................................................................. 4 
  Framing System ......................................................................................................................... 5 
  Lateral Load Resisting Elements ............................................................................................... 6 
  Floor System ............................................................................................................................... 6 
  Foundations ................................................................................................................................. 7 
General Structural Information ...................................................................................................... 7 
Load Determination ....................................................................................................................... 7 
  Gravity Loads ............................................................................................................................. 7 
  Wind Loads ................................................................................................................................. 8 
  Seismic Loads ............................................................................................................................. 11 
System Evaluation ......................................................................................................................... 12 
  Typical Floor System ................................................................................................................. 12 
  Typical Beam and Girder .......................................................................................................... 12 
  Typical Columns ....................................................................................................................... 12 
Lateral Systems ............................................................................................................................ 12 
  Lateral Load Distribution ......................................................................................................... 12 
Lateral Load Analysis ................................................................................................................... 13 
  Computer Model ........................................................................................................................ 13 
  Lateral Loads ............................................................................................................................. 15 
  Story Drifts ................................................................................................................................. 16 
  Overturning Moments ............................................................................................................... 17 
Alternate Systems .......................................................................................................................... 18 
  Existing One-Way Composite Concrete Slab ........................................................................... 20 
  One-Way Precast Hollow Core Planks on Steel Frame ............................................................. 20 
  One-Way Non-Composite Concrete Slab on Steel Frame ......................................................... 21 
  Two-Way Flat Slab with Drop Panels ....................................................................................... 23 
  Systems Summary ...................................................................................................................... 24 
Conclusions .................................................................................................................................... 25
# TABLE OF CONTENTS

Appendices ................................................................. 26  
  Appendix A: Snow Load and Drift Calculations ......................... 26  
  Appendix B: Wind Calculations ......................................... 27  
  Appendix C: Seismic Calculations ....................................... 30  
  Appendix D: Spot Checks ............................................... 32  
  Appendix E: Precast Plank System ..................................... 38  
  Appendix F: Non-Composite System .................................... 41  
  Appendix G: Two-Way Flat Slab ....................................... 43  
  Appendix H: Lateral Stiffness ......................................... 45  
  Appendix I: Lateral Loadings .......................................... 47  
  Appendix J: Torsional Shear ............................................ 49  
  Appendix K: Lateral Spot Checks ...................................... 50  
  Appendix L: Sample Calculations ...................................... 51
EXECUTIVE SUMMARY

When we peel away the brick façade, the artwork, the landscaping of this six story building, what are we left with? We’re left with the intricate structural system of Orange Regional Medical Center, a 600,000 SF hospital in Middletown, NY. This report explores that structural system to determine how the many systems work in unison to defy gravity and lateral forces.

The latest codes were applied to analyze this steel frame, including ASCE7-10 and AISC 14th Edition. An analysis of the lateral forces from seismic and wind revealed that seismic controls in both shear and overturning moment. A seismic 2803.6 kip base shear proves greater than wind’s 899.6 kips in the North/South and its 1008.7 kips in the East/West. Wind creates a moment of 49172 ft-kips East and West and 44393 ft-kips North and South. However, 295197 ft-kip tells us that seismic will be the condition to check when analyzing the eccentrically braced frame and concrete shear walls of this hospital. The geometry of this building has created different results than expected. The change in square footage at the third floor increases the gust factor while dropping seismic story shears.

Our spot checks of the composite deck with light weight concrete, beams, girders, and columns all checked out. In quite a few cases, however, the existing systems were over-designed in relation to the analysis methods from this report. We can only make educated guesses to explain these differences now, but these will become areas of interest in the future.

In the second part of this report, the lateral frames of the existing structure were analyzed. The distribution of lateral story forces was determined through relative stiffness and torsional shear calculations. The results proved that the existing structure is adequate to carry these loads, but the calculations produce lower member sizes than that of the existing frames. This may be due to the deliberate addition of redundancy, seeing that seismic loading in the East and West direction was the predominant lateral load at every story. The existing frame sizes allowed for story drifts to fall within the acceptable limits for wind and seismic, as well.

Continuing analysis on the effects of gravity loads, three alternative floor systems were explored in addition to the existing system. These four systems are the existing one-way composite, one-way precast hollow core planks, one-way non-composite, and two-way flat slab with drop plates. Through some quick preliminary calculations it was determined that both the precast planking system and non-composite system were not viable for this application. The 4’ module size of the planks pushed for limited bay sizes and less plenum space, and the weight of the planks puts much more stress on the foundations. The non-composite system proved slightly more expensive than the existing system for about 3.5” more plenum space and no other notable benefits, so it didn’t seem to be a better option. The alternative that does grant further research is the flat slab system. For a longer construction
This report explores the structural make-up of Orange Regional Medical Center. Through calculation and research, we will develop a greater understanding of the skeleton of this building, including the framing system, floor slab system, lateral resistance elements, and foundation. By carrying out an analysis of these systems and comparing it to the design of the project engineers, areas of discrepancy will become areas of interest, or perhaps a future thesis proposal. In order to understand these areas of discrepancy, we must understand how the structural system works as a whole, but let us first start with a building overview.

Building Introduction
The first hospital built in New York State in the last twenty-five years, Orange Regional Medical Center, can be found right off of Interstate 17 in the town of Middletown. This giant is 600,000 square feet spread over seven floors (six above grade and one below) and was designed anticipating future additions. As we can see in Figure 1, this structure follows a pod design, allowing for future additions to be constructed in the voids on the fifth and sixth floor roofs. We find this feature appearing in several areas throughout the building. For example, this hospital features a removable, full glass façade in multiple locations where future additions may be constructed. Later in this report, we will also see how the structure has been sized to account for these future loads.

When it comes to the building site, the original design had to be rotated 90 degrees to best fit the site. Although the design works better with the site grading, this change also moved the Emergency Room entrance to the back corner, on the opposite side from the street entrance (See Figure 2). This may be taken as an architectural drawback, but this can only be paired with a number of architectural...
innovations in the healthcare field. Since the hospital’s opening in August, patients have enjoyed rooms that rival that of hotels (See Figure 3). Carpeted hallways are also among some architectural features aimed at creating a quick recovery by creating comfortable, quiet spaces. Staying on the topic of architecture, this building has essentially been divided into two buildings: a healthcare building and a business administration building, each following a separate set of codes, as we will see later in this report. This separation is not so apparent in the façade, however. Tan brick with red soldier brick accents wrap completely around the building, leaving the EIFS façade of the lobby to stand apart as shown in Figure 4. The floor plan is also rather consistent from the second floor up. Each floor is in the shape of a Greek cross with the individual healthcare units branching off of the central elevator core, as seen in Figure 5. This not only allows for a uniform structural system, but it also allows first time visitors to be able to navigate the building with ease.

**Framing System**

The steel frame of this structure comes in a variety of sizes. On the first floor alone, there are a total of twelve different wide flange beams used, but in general, W16x26’s and W16x31’s serve as the primary joists throughout the building with an average spacing of about 7 feet and an average span of about 26 feet. W18x35’s and W21x44’s are the most common choice for girders with spans ranging between 14’ 8” and 27’ 1”. Following the load path to the columns, we find just as much dispersion. A majority of the columns are W12’s with a small grouping of
W10’s and W8’s. As mentioned earlier, structural columns for the future additions are also shown on the column schedule (Detail shown in Figure 6). Traveling up the building, the columns continue to carry less of the building load and therefore, reduce in size. Typically, each column has two splices occurring just above the second and fourth floors. However, there are special cases where splices occur on the third and fifth floors instead. The structural notes specify that all splice connections must be slip critical connections. Looking further into the frame connections, the structural notes also tell us to “detail steel beam connections as simple span beams, unless noted otherwise.” There are only a handful of moment frames specified throughout the building which must be considered as continuous beams.

**Lateral Load Resisting Elements**

In order to resist the lateral forces from wind and seismic activity, the structure utilizes concrete shear walls on the ground level. From the first floor and above, the lateral forces are then resisted by eccentrically braced steel frame as shown in *Figure 7*.

![Figure 7: Braced Frames Location](image)

**Floor System**

Out of the Vulcraft catalog, the floor system of ORMC consists primarily of 2VLI20 composite deck with 3¼” of lightweight concrete, making for a total floor thickness of 5¾”. The decking runs three spans, perpendicular to the joists, where typical spans are in the range of 7’4”. However, as mentioned earlier, the decking may see longer spans due to the lack of bay size uniformity.
Foundations
The foundations are determined by the recommendations of the geotechnical report by Melick-Tully and Associates. Square, concrete spread footings are set on with virgin soil or engineered, compacted soil with a bearing stress of 4000 psi.

General Structural Information
Throughout this report, the primary codes considered through the calculations were ASCE7-10 and AISC-14th Edition. ASCE was used for determining Live Loads and Lateral Loadings, where the Main Wind Force Resisting System (MWFRS) and Equivalent Lateral Force Method (ELF) were used for Wind and Earthquake analysis, respectively. It is important to note that the design team on this project had to follow the codes of New York State. This may contribute to discrepancy in values calculated for this report.

To better acquaint ourselves with the structural steel used throughout this report, refer to Figure 8 for grades of steel used for the particular structural elements.

<table>
<thead>
<tr>
<th>Material</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>W's and Wt's</td>
<td>ASTM A992</td>
</tr>
<tr>
<td>Plates &amp; other shapes</td>
<td>ASTM A36</td>
</tr>
<tr>
<td>HSS</td>
<td>ASTM A500, Grade B</td>
</tr>
<tr>
<td>Pipe</td>
<td>ASTM A53, Grade B</td>
</tr>
<tr>
<td>Bolts</td>
<td>ASTM A325, or F1852 where indicated, 3/4” diameter (min.), hex head in standard hole U.N.O.</td>
</tr>
<tr>
<td>Anchor Rods</td>
<td>ASTM F1554, Grade 36 with washers and heavy hex nuts U.N.O.</td>
</tr>
<tr>
<td>Threaded Rod</td>
<td>ASTM A36</td>
</tr>
<tr>
<td>Headed Studs</td>
<td>AWS D1.1, Type B</td>
</tr>
<tr>
<td>Electrodes</td>
<td>Matching strength, 70 ksi min.</td>
</tr>
</tbody>
</table>

Figure 8: Structural Materials

Load Determination
Gravity Loads
Most loadings used in this report come directly from the codes, such as the live loads. For the purpose of this report, only three live loads were used, all of which falling under the hospital category. The values shown in Table 2 are not quite as accurate as the live loads, but by making realistic assumptions for the dead load elements, we are able to design within a reasonable percent error to the actual values. To estimate the dead load contributed by beam self-weight, a random sample, found in Appendix C, was taken to determine the typical size beam in a very diverse structure. Through these efforts, a total building weight was able to be calculated, as shown in Table 2, and applied in the seismic and wind analysis to come later.
Gravity played an interesting role in the analysis of the building’s snow load. Although we arrived at a reasonable flat load value of 42 psf, the drift value seems a little high. Our issue stems from the large roof drop from the sixth floor to the second floor where there is also a large $l_1$ factor. Following the code, we arrive at 149.45 psf, but thinking about it realistically; any snow falling 52 ft will more than likely get blown about before it hits the lower roof. Therefore, to say that all snow will accumulate at the lower level seems unrealistic. Either way, drift loads should be accounted for in any snow load calculations, such as beam checks, since this increased loading will create a load imbalance, putting more stress on our structural system. For full snow load calculations, refer to Appendix A.

**Wind Loads**

Although wind applies a pressure to the building façade, the actual force is resisted internally once the force makes its way through the floor diaphragm and into the lateral elements. Therefore, since we will...
soon look to investigate lateral design further, it is important that we analyze wind’s effects in this report. To do this, the shape of Orange Regional Medical Center first had to be simplified. Figure 9 shows the simplified shape broken into and upper and lower section to better fit the building dimensions. This separation creates four different gust factors which all have a different effect on the building as we will see in the pressure diagram.

There was one discrepancy that emerged at the start of the wind analysis. The basic wind speed from ASCE7-10 for our design delivers a value of 120 mph, where the original drawings call for 90 mph. Since this is not calculation based, we can only assume that this difference comes from the difference in codes. New York State codes may allow a lower value for Middletown, NY. Despite this, the analysis still provided reasonable values as we can see in Tables 4 and 5 for the East/West and North/South directions. We arrived at the base shears and overturning moments shown in Table 6. The following figures (Figures 9 and 10) display how the pressures are distributed along the face of the building, and we can see how the change in the shape and gust factor creates different pressures along that face. For further wind calculations, see Appendix B.

<table>
<thead>
<tr>
<th>Floor</th>
<th>$z$</th>
<th>$K_z$</th>
<th>$q_z$</th>
<th>$p_{\text{Windward (psf)}}$</th>
<th>$\text{WW (plf)}$</th>
<th>$\text{WW (k)}$</th>
<th>$q_h$</th>
<th>$p_{\text{Leeward (psf)}}$</th>
<th>$\text{LW (plf)}$</th>
<th>$\text{LW (k)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground</td>
<td>0</td>
<td>0.85</td>
<td>26.63</td>
<td>18.6</td>
<td>148.5</td>
<td>72.5</td>
<td>39.32</td>
<td>-16.1</td>
<td>-128.5</td>
<td>-62.7</td>
</tr>
<tr>
<td>1</td>
<td>16</td>
<td>0.86</td>
<td>26.95</td>
<td>18.8</td>
<td>300.4</td>
<td>146.6</td>
<td>39.32</td>
<td>-16.1</td>
<td>-257.0</td>
<td>-125.4</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>0.99</td>
<td>31.08</td>
<td>21.7</td>
<td>314.1</td>
<td>153.3</td>
<td>39.32</td>
<td>-16.1</td>
<td>-232.9</td>
<td>-113.7</td>
</tr>
<tr>
<td>3</td>
<td>45</td>
<td>1.07</td>
<td>33.37</td>
<td>23.3</td>
<td>302.3</td>
<td>108.5</td>
<td>39.32</td>
<td>-16.4</td>
<td>-213.7</td>
<td>-76.7</td>
</tr>
<tr>
<td>4</td>
<td>58</td>
<td>1.12</td>
<td>35.16</td>
<td>24.5</td>
<td>318.5</td>
<td>114.3</td>
<td>39.32</td>
<td>-16.4</td>
<td>-213.7</td>
<td>-76.7</td>
</tr>
<tr>
<td>5</td>
<td>71</td>
<td>1.17</td>
<td>36.79</td>
<td>25.6</td>
<td>333.2</td>
<td>119.6</td>
<td>39.32</td>
<td>-16.4</td>
<td>-213.7</td>
<td>-76.7</td>
</tr>
<tr>
<td>6</td>
<td>84</td>
<td>1.22</td>
<td>38.29</td>
<td>26.7</td>
<td>353.5</td>
<td>126.9</td>
<td>39.32</td>
<td>-16.4</td>
<td>-217.8</td>
<td>-78.2</td>
</tr>
<tr>
<td>Roof</td>
<td>97.5</td>
<td>1.26</td>
<td>39.32</td>
<td>27.4</td>
<td>185.0</td>
<td>66.4</td>
<td>39.32</td>
<td>-16.4</td>
<td>-111.0</td>
<td>-39.8</td>
</tr>
</tbody>
</table>

Table 4: North/South Wind Pressures
Wind Pressures - East/West

<table>
<thead>
<tr>
<th>Floor</th>
<th>z</th>
<th>K_z</th>
<th>q_z</th>
<th>p_Windward (psf)</th>
<th>WW (plf)</th>
<th>WW (k)</th>
<th>q_h</th>
<th>p_Leeward (psf)</th>
<th>LW (plf)</th>
<th>LW (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>0.86</td>
<td>26.95</td>
<td>18.6</td>
<td>298.4</td>
<td>170.5</td>
<td>39.32</td>
<td>-16.5</td>
<td>-264.6</td>
<td>-151.2</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>0.99</td>
<td>31.08</td>
<td>21.5</td>
<td>311.9</td>
<td>178.2</td>
<td>39.32</td>
<td>-16.5</td>
<td>-239.8</td>
<td>-137.0</td>
</tr>
<tr>
<td>3</td>
<td>45</td>
<td>1.07</td>
<td>33.37</td>
<td>23.1</td>
<td>300.2</td>
<td>119.0</td>
<td>39.32</td>
<td>-17.0</td>
<td>-221.1</td>
<td>-87.7</td>
</tr>
<tr>
<td>4</td>
<td>58</td>
<td>1.12</td>
<td>35.16</td>
<td>24.3</td>
<td>316.3</td>
<td>125.4</td>
<td>39.32</td>
<td>-17.0</td>
<td>-221.1</td>
<td>-87.7</td>
</tr>
<tr>
<td>5</td>
<td>71</td>
<td>1.17</td>
<td>36.79</td>
<td>25.5</td>
<td>330.9</td>
<td>131.2</td>
<td>39.32</td>
<td>-17.0</td>
<td>-221.1</td>
<td>-87.7</td>
</tr>
<tr>
<td>6</td>
<td>84</td>
<td>1.22</td>
<td>38.29</td>
<td>26.5</td>
<td>351.1</td>
<td>139.2</td>
<td>39.32</td>
<td>-17.0</td>
<td>-225.4</td>
<td>-89.4</td>
</tr>
<tr>
<td>Roof</td>
<td>97.5</td>
<td>1.26</td>
<td>39.32</td>
<td>27.2</td>
<td>183.7</td>
<td>72.8</td>
<td>39.32</td>
<td>-17.0</td>
<td>-114.8</td>
<td>-45.5</td>
</tr>
</tbody>
</table>

Table 5: East/West Wind Pressure

Shear   Moment
North/South

<table>
<thead>
<tr>
<th>Shear</th>
<th>Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>70.8</td>
<td>0</td>
</tr>
<tr>
<td>143.2</td>
<td>2345.783</td>
</tr>
<tr>
<td>149.7</td>
<td>4904.322</td>
</tr>
<tr>
<td>108.5</td>
<td>4883.48</td>
</tr>
<tr>
<td>114.3</td>
<td>6631.14</td>
</tr>
<tr>
<td>119.6</td>
<td>8493.638</td>
</tr>
<tr>
<td>126.9</td>
<td>10660.81</td>
</tr>
<tr>
<td>66.4</td>
<td>6474.051</td>
</tr>
<tr>
<td>899.6</td>
<td>44393.23</td>
</tr>
</tbody>
</table>

East/West

<table>
<thead>
<tr>
<th>Shear</th>
<th>Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>81.9</td>
<td>0</td>
</tr>
<tr>
<td>165.8</td>
<td>2728.237</td>
</tr>
<tr>
<td>173.3</td>
<td>5703.919</td>
</tr>
<tr>
<td>119.0</td>
<td>5356.439</td>
</tr>
<tr>
<td>125.4</td>
<td>7273.356</td>
</tr>
<tr>
<td>131.2</td>
<td>9316.236</td>
</tr>
<tr>
<td>139.2</td>
<td>11693.3</td>
</tr>
<tr>
<td>72.8</td>
<td>7101.053</td>
</tr>
<tr>
<td>1008.7</td>
<td>49172.54</td>
</tr>
</tbody>
</table>

Table 6: Wind Base Shear/Overturning Moment

Figure 9: North/South Wind Pressure

Figure 10: East/West Wind Pressure
Seismic Loads
Equivalent Lateral Force Method was used to determine the seismic forces, from the individual story forces, to the base shear, to the overturning moment. The analysis in this report follows right along with the results from the structural drawings. The only discrepancy was arriving at category A for the seismic design category. However, this was paired with class C derived from table 11.6-2, so we chose the higher category, C, to be more conservative. So much of the seismic forces are dependent on building weight, so as we mentioned earlier, these values were determined using actual values and educated approximations. In fact, floor weights may be the answer to the discrepancies in Figure 11, which shows the seismic story forces. In most cases, we expect to see a nice curving story force as we climb the building, but from the analysis in this report, we find jumps between stories. Since story forces are proportional to story height and weight, these jumps must be credited to the fact that changes in floor geometry create floors of varying weights. In the end, we determined that ORMC has a base shear of 2,803.6 kips and an overturning moment of 176,281.7 ft-kips, which seems reasonable. Table 7 shows how we arrived at these values, but for further calculations, check Appendix C.

<table>
<thead>
<tr>
<th>Floor</th>
<th>Weight (k)</th>
<th>Height (ft)</th>
<th>(w_i h_i^k)</th>
<th>(C_{vx})</th>
<th>(F_x) (k)</th>
<th>(V_x) (k)</th>
<th>M (ft-k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>3366</td>
<td>97.5</td>
<td>899001</td>
<td>0.159</td>
<td>744</td>
<td>744</td>
<td>72574</td>
</tr>
<tr>
<td>6</td>
<td>4857</td>
<td>84</td>
<td>1081310</td>
<td>0.192</td>
<td>895</td>
<td>1640</td>
<td>75205</td>
</tr>
<tr>
<td>5</td>
<td>4937</td>
<td>71</td>
<td>895419</td>
<td>0.159</td>
<td>741</td>
<td>2381</td>
<td>52638</td>
</tr>
<tr>
<td>4</td>
<td>6661</td>
<td>58</td>
<td>943957</td>
<td>0.167</td>
<td>782</td>
<td>3163</td>
<td>45331</td>
</tr>
<tr>
<td>3</td>
<td>6661</td>
<td>45</td>
<td>692611</td>
<td>0.123</td>
<td>573</td>
<td>3736</td>
<td>25806</td>
</tr>
<tr>
<td>2</td>
<td>9528</td>
<td>32</td>
<td>653571</td>
<td>0.116</td>
<td>541</td>
<td>4277</td>
<td>17316</td>
</tr>
<tr>
<td>1</td>
<td>16218</td>
<td>16</td>
<td>477555</td>
<td>0.085</td>
<td>395</td>
<td>4673</td>
<td>6326</td>
</tr>
<tr>
<td>Ground</td>
<td>5643425</td>
<td></td>
<td></td>
<td></td>
<td>4673</td>
<td></td>
<td>295197</td>
</tr>
</tbody>
</table>

Table 7: Seismic Calculations

Figure 11: Seismic Story Forces
System Evaluation

Typical Floor System
All checks in this report worked for the floor system. However, the floor deck is significantly over designed. This could be due to one of three things: this deck was chosen to achieve the 2 hour fire rating, regardless of loading, for constructability purposes where there may be longer spans, or this deck was chosen for serviceability reasons. At a hospital where patients are being rolled back and forth in stretchers all day, it probably is a good idea to design for vibration. Therefore, the deck may be oversized to account for vibrational dampening. To view the check calculations, refer to Appendix D.

Typical Beam and Girder
Values for the check came relatively close to actual values. The beam checks out okay and is reasonably close, where the girder also checks out but is a little over-designed. Again, I am claiming this is for serviceability reasons in an attempt to dampen vibrations.

Typical Columns
Both columns pass the spot check, with the interior column coming pretty close to the actual value. However, as with the other structural members, one is always a little over-designed. The exterior column may be accounting for the future additions, but I am unsure why we would see a greater difference in the exterior than the interior.

Lateral Systems

Lateral Load Distribution
The stiffest members will take the most lateral load. Loading first starts as a pressure transferred from the building façade into the floor diaphragms. Both wind and seismic loading is then transferred through the diaphragm into the lateral braced frames. Again, the stiffest members will take a majority of this load since force follows stiffness. A majority of the frames in this structure take the lateral loading to the sub-grade shear walls where it is then transferred into the foundation. Other frames do not have ground floor shear walls and instead, transfer the shear force right into the footings. After modeling all lateral frames, the relative stiffness was computed at two locations since a majority of the exterior frames only extend up through the second floor, where there building footprint steps back. A 100 kip lateral load was applied to the rigid diaphragm at the top of the frames at the second floor and roof levels. Finding the shear in the frames at these levels allowed for stiffness to be calculated, using the constant story deflection across the diaphragm. Figure 12 illustrates the location of the braced frames, with full height braced frames shown in red and two-story frames shown in blue. The actual and relative stiffness of all frames at the two vertical heights can be found in Appendix H with a sample hand calculation shown in Appendix L. Later in this report, the distribution of torsional shear will also be illustrated in the lateral spot checks section of this report.
Lateral Load Analysis

Computer Model
Given the size and complexity of Orange Regional Medical Center, a computer model was used to efficiently analyze the structural response to lateral loading. Only the eccentrically braced frames, shear walls, and foundation walls were modeled in ETABS since these systems resist the loads from wind and seismic. Figures 13 and 14 show the model with rigid diaphragms, which distribute the load to the lateral elements. Figure 15 shows just the lateral frames mentioned earlier. In each of these figures, one will notice the varying base levels and heights of the braced frames. The ground floor is partially below grade, so some of the northern frames have pinned supports starting at the first floor. Additionally, this model accounts for the future additions above the fifth floor since this is how the lateral loading would have accurately been handled by the design team.

Figure 12: Braced Frames Location
Figure 13: ETABS Model Looking Southeast

Figure 14: ETABS Model Looking Northeast
Lateral Loads
Load combinations from ASCE7-10 give wind and seismic a 1.0 load factor. Essentially, this means that the same lateral load can be applied to check strength and serviceability. Wind however, is given a factor for MWFRS in the different cases from ASCE7-10, as shown in Figure 16. Each of these load cases were evaluated to determine the worst case loading. Only cases in which the torsional moment would be additive were considered. This concept is illustrated in Appendix I, along with sample calculations in Appendix L. Plugging these loadings for wind and seismic into ETABS produced results showing earthquake as the predominant load on every story. In particular, earthquake in the North and South direction yielded the largest story shears and deflections.
Story Drifts

ETABS was used on numerous occasions throughout this report to gain a better understanding of the existing structure. One place this model was employed was to output story drifts that could be checked against the accepted values. For wind, drift values should be less than L/400, and for seismic drift, the values for occupancy category IV should fall underneath 0.01h_s x 0.39. Tables 8 and 9 show the model story drifts compared to the accepted values. All drifts for both wind and seismic fall within the acceptable limits for this structure. For sample calculations from the tables below, refer to Appendix L.

<table>
<thead>
<tr>
<th>STORY</th>
<th>ETABS Drift E/W</th>
<th>ETABS Drift N/S</th>
<th>DRIFT (in)</th>
<th>ALLOWABLE</th>
<th>PASS?</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0.000278</td>
<td>0.045</td>
<td>0.045</td>
<td>0.405</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>0.000365</td>
<td>0.059</td>
<td>0.059</td>
<td>0.405</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>0.000378</td>
<td>0.059</td>
<td>0.059</td>
<td>0.39</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>0.000495</td>
<td>0.077</td>
<td>0.077</td>
<td>0.39</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>0.000466</td>
<td>0.073</td>
<td>0.073</td>
<td>0.39</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>0.000607</td>
<td>0.095</td>
<td>0.095</td>
<td>0.39</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>0.000519</td>
<td>0.081</td>
<td>0.081</td>
<td>0.39</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>0.000687</td>
<td>0.107</td>
<td>0.107</td>
<td>0.39</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>0.000615</td>
<td>0.096</td>
<td>0.096</td>
<td>0.39</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>0.000655</td>
<td>0.102</td>
<td>0.102</td>
<td>0.39</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>0.000577</td>
<td>0.111</td>
<td>0.111</td>
<td>0.48</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>0.000565</td>
<td>0.108</td>
<td>0.108</td>
<td>0.48</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 8: Actual Wind Story Drifts vs. Accepted
SEISMIC STORY DRIFTS

<table>
<thead>
<tr>
<th>STORY</th>
<th>ETABS DriftX</th>
<th>ETABS DriftY</th>
<th>DRIFT (in)</th>
<th>ALLOWABLE</th>
<th>PASS?</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0.001366</td>
<td>0.001984</td>
<td>0.443</td>
<td>1.62</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.001739</td>
<td>0.002514</td>
<td>0.543</td>
<td>1.56</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.002005</td>
<td>0.002882</td>
<td>0.671</td>
<td>1.56</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.00215</td>
<td>0.003149</td>
<td>0.982</td>
<td>1.56</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.002341</td>
<td>0.002801</td>
<td>0.730</td>
<td>1.56</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.001904</td>
<td>0.002132</td>
<td>0.731</td>
<td>1.92</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9: Actual Seismic Story Drifts vs. Accepted

Overturning Moments

As mentioned earlier, once the lateral members take the wind or seismic load, the forces are then carried down to the foundation. It is crucial that these foundations can handle the moment forces developed by the lateral forces. Again, earthquake controls for overturning moment with 295,197 ft-kips acting on the soil. From the geotechnical report, the soil is capable of withstanding 4,000 psi, so they footings must be properly designed to spread out the load. Table 10 gives the overturning moment for wind and seismic in kip-ft.

<table>
<thead>
<tr>
<th>Floor</th>
<th>Earthquake</th>
<th>Wind E/W</th>
<th>Wind N/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>72574</td>
<td>7101</td>
<td>6474</td>
</tr>
<tr>
<td>6</td>
<td>75205</td>
<td>11693</td>
<td>10661</td>
</tr>
<tr>
<td>5</td>
<td>52638</td>
<td>9316</td>
<td>8494</td>
</tr>
<tr>
<td>4</td>
<td>45331</td>
<td>7273</td>
<td>6631</td>
</tr>
<tr>
<td>3</td>
<td>25806</td>
<td>5356</td>
<td>4883</td>
</tr>
<tr>
<td>2</td>
<td>17316</td>
<td>5704</td>
<td>4904</td>
</tr>
<tr>
<td>1</td>
<td>6326</td>
<td>2728</td>
<td>2346</td>
</tr>
<tr>
<td>Ground</td>
<td>295197</td>
<td>49173</td>
<td>44393</td>
</tr>
</tbody>
</table>

Table 10: Overturning Moment from Wind and Earthquake

Lateral Spot Checks

Although analysis using a computer model often times seems advantageous, there is also much room for human error. Therefore, to confirm the ETABS model and to confirm the adequacy of the lateral elements to withstand load, several spot checks were run. Appendix K is the spot check of a typical
brace and column at the second floor level. The second floor was chosen for checks because this is the level where the shorter lateral frames drop out and the taller frames must now carry that extra lateral load. Therefore, a check was necessary at this point of interest to confirm the elements’ strength. The calculations shown in Appendix K confirm that both the brace and column are adequate to carry the required loading. However, the calculated values are much smaller than the required strength for both the column and brace. This difference can most likely be credited to the application of redundancy in the lateral system. Since seismic loading was the predominant load in this structure, it is good practice to include redundancy to increase the over strength of a structure. This way, appropriate strength will be available in the extreme case earthquake. Torsional shear was also calculated by hand in the East and West direction to confirm the results of the ETABS model. The table for all torsional shears in East/West running lateral frames can be found in Appendix J. Overall, the combination of direct and torsional shear from hand calculations were comparable to the shears from ETABS. The values were within a couple kips with the hand calculations being consistently larger than the model. Since these values are so close, it is tough to say where the error comes from. The most likely option is either rounding errors or a missed frame somewhere in calculation. A sample calculation for torsion can be found in Appendix L.

Alternate Systems

Multiple floor systems are analyzed in the remainder of this report. Exploring three preliminary alternative floor systems, and comparing them with the existing system, allows for the pros and cons to transpire. What effects does this system have on the other disciplines of the building? Is this cost effective? Are the results comparable to or better than the existing system? These are some of the questions that will be answered as the following systems are examined:

- Existing one-way composite concrete slab
- One-way precast hollow core planks on steel frame
- One-way non-composite concrete slab on steel frame
- Two-way flat slab with drop panels

All floor systems are designed in relation to the typical bay shown in Figure 12. This allows for close comparisons to be made in order to determine which alternate systems may be viable. Of course, the existing system likely fits the needs of this building quite well, which is why the project team chose the system in the first place. However, there is a multitude of floor combinations that a structural engineer may choose from, so chances are, this report may stumble upon other viable systems which will warrant further investigation.
Figure 12: Typical Bay
Existing One-Way Composite Concrete Slab

Making use of composite action, the existing steel frame uses 2VLI20 composite deck with 3¾" of lightweight concrete, running in the 22'-1" direction of the 26'-0" x 22'-1" typical bay. The decking rests on W16x26 beams, typically spaced at 7'-4 3/8" with 18 shear studs a piece. These then frame into W18x35 girders, which span the 22'-1" direction and have 24 shear studs a piece. In total, the cost of the existing floor system can be estimated by RS Cost Works to be about $11,380,000. This system, like the other system in this comparison study, is subjected to the loads mentioned earlier in this report, and further calculations for these loadings can be found in Appendix D. These loadings, as well as self-weight, put a 305 psi pressure on the soil from the footings. Also, refer back to Figure 12 for the bay layout of this system.

Advantages

By putting the concrete in compression and placing the steel beam in tension, composite systems are very efficient systems. This enables the designer to use a smaller beam or girder and therefore reduce the structural depth. The composite floor system is also fairly light, being the second lightest system studied in this report. This allows for smaller footings and therefore, less concrete. A third advantage is the ease of constructability since the metal composite decking serves as the formwork for the concrete. Lastly, the estimated system cost is comparable to the other systems in this report, meaning that it is not too expensive to take advantage of the composite action.

Disadvantages

A lighter system such as this could have potential vibration issues, which would need to be investigated. Additionally, although it is structurally efficient to use composite action, installation and inspection of the shear stubs could prove time consuming and costly. Fireproofing may also be a concern in this system with all the exposed steel. In order to achieve the two hour fire rating, the beams, girders, and underside of the decking will need to be fireproofed, which again, is time consuming and adds cost. Despite these disadvantages though, the existing floor system still fits the needs of this building fairly well, which is why it was chosen by the designers as a viable system.

One-Way Precast Hollow Core Planks on Steel Frame

From the Nitterhouse specifications, untopped 10” x 4’-0” hollow core planks with 6-1/2” diameter strand pattern were chosen to withstand the typical floor loading. Starting with the typical bay size of 26’-0” x 22’-1”, the 4 ft width planks were assessed for the best fit. It was determined that planks spanning the long direction (26’-0”), had the smallest effect on the architectural floor plan. However, this 4 ft module size meant that the short direction had to be changed to either 24’-0” or 20’-0”. Table 8 gives the load capacity for the 26 ft span. These precast planks are supported by a steel frame which was determined by the AISC manual to be W18x86 girders.
All of this can be seen in Figure 13 of the typical bay. For further calculations, refer to Appendix E.

![Table 8: Plank Loading Specs](image)

**Advantages**

Precast planks offer quite a few advantages, some of which, the existing composite system can’t offer. For one, hollow core planks allow for easy construction since everything is cast off-site and can simply be put in place once they arrive on site. Additionally, since a majority of the flooring throughout the hospital is carpet, a leveling top coat isn’t necessary for the planks. The joints can simply be feathered with a latex cement or grout. This all allows for the construction schedule to move along quicker and deliver the building earlier. A second advantage is the 2 hour fire rating that the planks provide, meaning that only the steel support girders would need to be fireproofed, rather than the entire system. This is also the second cheapest system being evaluated in this report at about $10 million. This is about $1 million less than the existing system.

**Disadvantages**

As mentioned earlier, in order to accommodate the 4 ft module width of the planks, the bay sizes had to be adjusted in the plan E-W direction. Luckily, in most locations on the typical floor plan, the columns fall in the center of a wall and may be moved east or west with little impact on the architectural layout. However, there are areas where adjustments will not be so easy and would need to be coordinated with the architect. In order to withstand the typical floor loading with this system, the structural depth had to be increased from that of the existing composite system. At 28.4”, this system is just short of 5.5” deeper, which translates to larger floor-to-floor heights or smaller plenum space for the other disciplines to work with. A larger story height would consequently add cost to this project from the expanded façade around the perimeter of the building. Additional costs may be accrued up front, considering transportation costs and the additional cranes that would be required to hoist the precast planks to the constructed floors. This system also adds a lot of weight to the foundation at 415 psi on the soil. This is over 100 psi more than the existing structure. The connection to the lateral system would also have to be reworked. Overall, the disadvantages outweigh the advantages of this system. Difficulty with the module bay sizes along with added weight and structural depth makes this system tough to justify.

**One-Way Non-Composite Concrete Slab on Steel Frame**

Using form deck rather than the composite decking, it was found that 2C20 deck, from the Vulcraft Catalog, could adequately withstand the floor loading. For comparison purposes, lightweight concrete was used, which requires a topping thickness of 3¾”. For the slab to hold these loads, the concrete had to be paired with 6x6 – w2.9 x w2.9 welded wire fabric. All other criteria such as unshored clear span and deflections checked out, as can be found in Appendix F. The decking then transfers the floor load to
W14x48 beams, as determined by the AISC Steel Manual, which span the 26’-0” direction. Loading is then transferred to W14x68 girders, spanning the 22’-1” direction, which frame nicely with the W14 beams. This framing is illustrated in the bay of Figure 14. Calculations for required moment and moment of inertia, used in determining these framing sizes, can also be found in Appendix F. The appendix also shows calculations for the system weight which was slightly larger than the composite system at a 343 psi soil pressure.

![Figure 14: Typical Bay](Image)

**Advantages**
As mentioned with the composite system, installing shear studs can be costly and time consuming, but since a non-composite system does not use shear studs, construction may move along quicker than a composite system. Again, as with the composite system, construction may also move along quicker due to the form deck serving as the concrete formwork. In terms of structural depth, this system is about 3.5” less than the existing, which would leave more room for other disciplines to install their equipment.

**Disadvantages**
Because part of the steel beam will be in compression with the non-composite system, members with larger flexural strength will have to be chosen. This translates to a heavier system and heavier foundation loads. This system puts roughly 40 psi more on the soil than the composite system, and the site soils will have to be analyzed for that. In some cases, the cost of shear studs may be more than the cost of larger beams. This is not the case for this structure, however. According to RS Means Cost Works, this system totaled $11.5 million (the most expensive system evaluated), which is about $200,000 more than the existing structure. These results were also confirmed in Appendix F on a material load basis. With shear studs counting for roughly ten pounds a piece, the proportion shows that non-composite is much heavier, and therefore more expensive in material costs. Lastly, as mentioned with the existing floor, all exposed steel would still need to be fireproofed. This shows that the only thing to really gain from non-composite is 3.5” of plenum space and slightly shorter construction schedule. These benefits do not seem to make up for the added costs and weight, and can therefore be ruled out as a viable option.
Two-Way Flat Slab with Drop Panels

Switching over to concrete framing, a flat slab with drop panels was evaluated for the typical bay, given the appropriate spans, as shown in Figure 15, and its popular use in hospitals. The CRSI Handbook was used for preliminary design to arrive at a 9" slab with drop panels 8.67' wide and 6.25" in depth. The handbook mentioned that for rectangular bays with \( \frac{l_2}{l_1} \) close to 1.0, to use the longer span for design and reinforcement. Therefore, the design bay size is 26'-0" x 26'-0", but the actual bay size is still 26'-0" x 22'-1". Reinforcement and dimensions can be found in the bay layout in Figure 16, but for additional calculations and the CRSI design table, refer to Appendix G.

Advantages

At 15.25", the flat slab system is 7.7" inches less in structural depth than the existing system. This leaves much more room for plenum space, which is always needed in a hospital for the other disciplines to work with. Also, this 7.7" could be used to drop the floor to floor height and save money on the façade. The concrete system is also the lightest out of those analyzed in this report, despite using normal weight concrete, giving a soil pressure of 225 psi. This takes a huge weight off of the foundation, allowing for smaller footings. Now, because Orange Regional Medical Center is only six stories, it is not expected that this lighter structural weight will cause any issues with overturning moment, but it may be an area worth checking for reassurance. In addition to the lighter structure, the flat slab system is also the cheapest of those analyzed, totaling in at roughly $9.77 million (about $1.5 million less than the existing structure). A flat slab system also does not need any additional fireproofing. The nine inches of slab is sufficient to provide a two hour fire rating, and since no fireproofing is needed, a flat slab still appears aesthetically pleasing and may be painted as is and used as the finished ceiling.
Disadvantages

The biggest disadvantage with a concrete structure is the increased construction time to allow for formwork placement and concrete curing. Construction may also be slowed down for rebar placement and inspections. This system also produces larger columns than that of the steel frames. The existing structure used W12’s where this system calls for 19” square columns. This may put a strain on the architectural layout, and would need to be coordinated with the architect. It would also be difficult to tie into the existing lateral steel braced frames. This would have to be explored to find effective lateral resistance in a concrete frame by either using shear walls or some other means. One final drawback is the possibility of vibrational problems with such a light system, but in the end, the advantages definitely outweigh the disadvantages. The designer may be able to pitch $1.5 million in savings to the owner in exchange for the longer construction schedule. Therefore, the two-way flat slab system with drop plates is still a viable alternative.

Systems Summary

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Existing</th>
<th>Alternative Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One-Way Composite</td>
<td>Precast Planks</td>
</tr>
<tr>
<td>Cost</td>
<td>$11.4 million</td>
<td>$11.5 million</td>
</tr>
<tr>
<td>Weight Ratio</td>
<td>1.0</td>
<td>1.36</td>
</tr>
<tr>
<td>Vibration Dampening</td>
<td>Unknown</td>
<td>Fine</td>
</tr>
<tr>
<td>Structural Depth</td>
<td>22.95”</td>
<td>28.4”</td>
</tr>
<tr>
<td>Bay Size Flexibility</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Lateral System Altered</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Constructability</td>
<td>Moderate</td>
<td>Easy</td>
</tr>
<tr>
<td>Additional Fireproofing</td>
<td>Yes</td>
<td>Some</td>
</tr>
<tr>
<td>Viable Option</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 9: Pros and Cons Summary
Conclusions

From the calculations performed in this report, we have achieved a greater understanding of Orange Regional Medical Center and its structural components. Although the actual building was designed to a different set of codes, by using ASCE7-10 and AISC we were able to find areas of discrepancy and determine if these differences were substantial or not.

We saw a difference in numbers for the composite floor deck, the girder, and exterior column. At this point, we can assume this is either for serviceability or this is compensating for future loads. As we continue our work with these buildings, we will begin to understand the true differences and perhaps explore them as a thesis proposal. At this point, vibrations may be one of those areas.

The lateral system was explored in the second piece of this report. From the use of an ETABS model and hand calculations, it was determined that story drifts were acceptable in both wind and seismic. Additionally, spot checks of a column and brace at a critical location showed that these elements were more than adequate to withstand the loading. The difference in load capacity was credited to the desire for redundancy in seismic loading. After all, seismic loading in the North and South direction proved to be the dominant load at every story level. Now, that greater knowledge of the lateral system and its load distribution has been achieved, exploration of alternative lateral resistance may be an area of interest for a spring proposal.

In the third part of this report, preliminary calculations showed that changes in floor system can have a rather dramatic effect on the structure. Each system had its set of advantages and disadvantages, but it was how those offset each other that really determined whether a system was a viable alternative. In the end, the two-way flat slab with drop panels was the only viable alternative to the existing system. For a much cheaper cost, the flat slab system offers a lighter, shallower design that requires no additional fireproofing. Construction timeline may be extended, but this may be something worth considering, given the benefits. At this point, because this was only a preliminary design, further investigation into this system will be required in order to determine if this is a realistic option. For example, little is known about its vibration characteristics and how the lateral system will work. Additionally, the cost comparison in this report is a very rough estimate and would need to be calculated. However, this system has definitely become a point of interest and may be explored as a thesis proposal in the future.
Appendix A: Snow Calculations

DESIGN CRITERIA - ASCE 7-10

- $C_e = 1.0$ (Table 7-2)
- $C_o = 1.0$ (Table 7-2)
- $C_f = 1.0$ (Table 7-3)
- $I_s = 1.20$ (Table 1.5-2)

- $R_0^3 = 0.5$ (Figure 7-1)
- $p_d = 50$ psf (from drawings)

$c_f = 0.7(1.0)(1.0)(1.20)(50) = 42$ psf

SNOW DRIFTS

- $7^* = 0.13(50)+14 \leq 30$
- $7^* = 20.5$ psf $= 30^*$

- DRIFT ONTO FIFTH FLOOR ROOF

- $I_u = 117^\circ$
- $h_d = 13.5^\circ$
- $p_d = (4.55)(20.5) = 92.18$ psf

- DRIFT ONTO SECOND FLOOR ROOF - NORTH/SOUTH

- $I_u = 39^\circ 7^\prime 4^\prime$
- $h_d = 0.43 \sqrt[3]{117^\circ/50+10} - 1.5 = 4.35$
- $w = 4h_d = 4(4.35) = 17.4$
- $p_d = (4.35)(20.5) = 89.18$ psf

- DRIFT ONTO SECOND FLOOR ROOF - EAST/WEST

- $I_u = 215^\circ 4^\prime$
- $h_d = 0.43 \sqrt[3]{215^\circ/50+10} - 1.5 = 5.65$
- $w = 4h_d = 4(5.65) = 22.6$
- $p_d = (5.65)(20.5) = 115.54$ psf
Appendix B: Wind Calculations

Design Criteria - ASCE7-10

Basic Wind Speed (Figure 26.5-18): \( V = 120 \) mph

Risk Factor (Table 15.1): IV Essential Facility

Wind Directionality Factor (Table 26.6-1): \( K_d = 0.65 \)

Exposure Category (Section 26.9.3): Exposure C

Topographic Factor (Section 26.8): Does not apply, \( K_t = 1.0 \)

Gust Factor: See attached calculations

* RIGIDITY CALCULATION

\[
L_{eff} = \frac{16(485) + 32(355) + 45(355) + 56(357) + 71(297) + 89(145) + 99.5(145)}{16 + 32 + 45 + 56 + 71 + 89 + 99.5 + 99.5}
\]

\[
L_{eff} = 248.5'(4) > 99.4' \rightarrow \text{CALCULATE } h \text{ USING SECTION 26.7.3}
\]

\[
\eta = \frac{75/18}{79/79.5} = 0.769 < 1.0 \rightarrow \text{STRUCTURE NOT CONSIDERED RIGID}
\]

\[
g_a = 3.4 \quad g_r = 3.4 \quad g = \sqrt{2.3 \ln(3600(769.7)) + \frac{0.577}{2.1 \ln(3600(769.7))}}
\]

\[
g_a = 4.13
\]

1) Gust Calculation - East/West Bottom Section

\[
\frac{L}{Z} = 0.65 \quad \frac{h}{Z} = 0.15 \cdot 0.15 = 0.0225
\]

\[
\frac{L}{Z} = 0.65 \quad \frac{h}{Z} = 0.15 \cdot 0.15 = 0.0225
\]

\[
L = 500 \text{ ft} \quad \frac{h}{Z} = \frac{1}{6.6} = 0.064
\]

\[
\eta_1 = \frac{4.47}{(1 + 10.3(3.45))^{0.5}} = 0.064
\]

\[
N = 9.76(560.66) = 3.45
\]

\[
\frac{P_h}{L} = \frac{1}{2.96} - \frac{1}{2(2.76)} \cdot (1 - e^{-2(0.76)}) = 0.297
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\frac{P_h}{L} = \frac{1}{10.15} - \frac{1}{2(10.15)}(1 - e^{-20(0.76)}) = 0.060
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]

\[
\eta_6 = 4.6(1.764)(57.15) = 16.18
\]

\[
\eta_4 = 4.6(1.764)(12) = 0.76
\]
Appendix B: Wind Calculations

2) Gust Calculation - East/West Top Section

- All calculations not shown are the same as previous section

- $P_{0} = \frac{1}{11.23} \cdot \frac{1}{1 - e^{-\frac{1}{11.23}}} = 0.086$

- $P_{\infty} = \frac{1}{34.03} \cdot \frac{1}{1 - e^{-\frac{1}{34.03}}} = 0.027$

- $P_{i} = \sqrt{\frac{1}{1 + 1.7(1.182)\sqrt[4]{0.085(0.55 + 0.47(0.027))}}} = 0.276$

- $Q = \frac{1}{1 + 5.6(0.767)^{2} \cdot (0.43)^{2}} = 0.1775$

- $C_{r} = 0.725 \cdot \frac{1 + 1.7(1.82)}{1 + 1.7(3.4)(1.82)} = 0.845$

3) Gust Calculation - North/South Bottom Section

- $P_{b} = \frac{1}{13.82} \cdot \frac{1}{1 - e^{-\frac{1}{13.82}}} = 0.079$

- $P_{\infty} = \frac{1}{54.17} \cdot \frac{1}{1 - e^{-\frac{1}{54.17}}} = 0.018$

- $P_{i} = \sqrt{\frac{1}{0.064(0.297)(0.65 + 0.47(0.018))}} = 0.268$

- $Q = \frac{1}{1 + 1.7(0.81)\sqrt[4]{0.064(0.297)^{2} \cdot (0.43)^{2}}} = 0.1779$

- $C_{r} = 0.725 \cdot \frac{1 + 1.7(1.182)\sqrt[4]{0.085(0.55 + 0.47(0.027))^{2}}}{1 + 1.7(3.4)(1.82)} = 0.851$
# Appendix B: Wind Calculations

## Wind Calculations

### 4) Gust Calculation - North/South Top Section

| P_a | \( \frac{1}{10.17} \left( 1 - e^{2(0.07)} \right) \) | 0.093 |
| P_L | \( \frac{1}{37.57} \left( 1 - e^{2(0.07)} \right) \) | 0.026 |
| \( \bar{P} \) | \( \sqrt{\left( \frac{P_a}{P_L} \right) \left( 1.15 \right) \left( 0.07 \right) \left( 0.35 \right) \left( 0.49 \right) \left( 0.020 \right)} \) | 0.310 |

\[ Q = \frac{1}{1 + 0.63 \left( \frac{33.9 + 22.6}{50.6} \right) + 0.36} = 0.802 \]

\[ C_{T1} = 0.125 \left( 1 + 1.7 \left( \frac{1}{1.18} \right) \sqrt{\left( 0.29 \right)^2 + \left( 0.13 \right)^2} \right) = 0.871 \]

**Main Wind Force Resisting System (MWFRS) - Directional Procedure**

- **Enclosure Classification:** Enclosed, \( C_{en} = 0.18 \) - Do not need
- **Windward Wall:** \( C_f \) = 0.8
- **Leeward Wall:** \( C_f \) = 0.5 - East/West
- **Side Wall:** \( C_f \) = 0.7

*The remainder is calculated using an Excel spreadsheet: see attached
Appendix C: Seismic Calculations

Design Criteria: ASCE 7-10

Site Class: C (from geotechnical report)

RISK CATEGORY (Table 15.1): IV ESSENTIAL FACILITY

Importance Factor (Table 15.2): $I_e = 1.50$

$S_x = 0.20$ (Figure 22.1) $S_y = 0.06$ (Figure 22.2)

$F_a = 1.2$ (Table 11.4.1) $F_v = 1.9$ (Table 11.4.2)

$S_m = (1.3)(0.20) = 0.24$ $S_m = (1.7)(0.06) = 0.102$

$S_{ps} = \frac{2}{3}h_{ps} + \frac{2}{3}(0.24) = 0.16$ $S_p = \frac{3}{4}S_m + \frac{1}{4}(0.102) = 0.068$

Seismic Design Category: A (Table 11.6.1) or C (Table 11.6.2) - USE HIGHER CATEGORY

Response Modification Coefficient (Table 12.2.1): $R = 3$

*Steel and concrete composite ordinary shear walls

Equivalent Lateral Force Method (ELF)

$T_a = C_v h_v = (0.03)(97.5) = 0.731$ $C_v = 0.03$ (Table 12.3.2)

$C_s = 0.16 = 0.08$ (3/15)

$V = C_s W = (0.16)(58407.49) = 4672.6$ kips

$F_x = C_{ax}V$ computed in Table

$C_{ax} = \frac{V_a h_a}{F_{ax} h_a}$

$K = 1.22$ (Section 12.8.3)
### Appendix C: Seismic Calculations

#### Beam Sample - From 16,267.2 SF Sample Area

<table>
<thead>
<tr>
<th>Beam Type</th>
<th>Unit Weight</th>
<th># of linear feet</th>
<th>Weight (kips)</th>
<th># of Beams</th>
</tr>
</thead>
<tbody>
<tr>
<td>W12x19</td>
<td>19 plf</td>
<td>42.2</td>
<td>0.8018</td>
<td>2</td>
</tr>
<tr>
<td>W14x22</td>
<td>22 plf</td>
<td>16</td>
<td>0.352</td>
<td>1</td>
</tr>
<tr>
<td>W14x30</td>
<td>30 plf</td>
<td>42.2</td>
<td>1.266</td>
<td>2</td>
</tr>
<tr>
<td>W16x26</td>
<td>26 plf</td>
<td>1413.8</td>
<td>36.7588</td>
<td>56</td>
</tr>
<tr>
<td>W16x31</td>
<td>31 plf</td>
<td>683.9</td>
<td>21.2009</td>
<td>26</td>
</tr>
<tr>
<td>W16x36</td>
<td>36 plf</td>
<td>52.8</td>
<td>1.9008</td>
<td>2</td>
</tr>
<tr>
<td>W18x35</td>
<td>35 plf</td>
<td>293.5</td>
<td>10.2725</td>
<td>14</td>
</tr>
<tr>
<td>W21x44</td>
<td>44 plf</td>
<td>54.4</td>
<td>2.3936</td>
<td>2</td>
</tr>
<tr>
<td>W21x50</td>
<td>50 plf</td>
<td>31</td>
<td>1.55</td>
<td>1</td>
</tr>
<tr>
<td>W24x55</td>
<td>55 plf</td>
<td>154.1</td>
<td>8.4755</td>
<td>6</td>
</tr>
<tr>
<td>W24x62</td>
<td>62 plf</td>
<td>28</td>
<td>1.736</td>
<td>1</td>
</tr>
<tr>
<td>W24x76</td>
<td>76 plf</td>
<td>150.5</td>
<td>11.438</td>
<td>5</td>
</tr>
<tr>
<td><strong>SUM:</strong></td>
<td></td>
<td></td>
<td><strong>98.1459</strong></td>
<td><strong>118</strong></td>
</tr>
</tbody>
</table>

**BEAM WEIGHT CONTRIBUTION:** \( \frac{98,145.9 \text{ lbs}}{16,267.2 \text{ SF}} = 6.0 \text{ psf} \)
Appendix D: Spot Check – Decking

NOTE: THERE ARE NOT MANY BAYS WITH THE SAME DIMENSIONS AND SPACING BUT THESE SPOT CHECK CALCULATIONS USE THE MOST TYPICAL BAY.

FLOOR & FLOOR CONSTRUCTION
• 2” COMPOSITE DECK (20 GAUGE)
• 5/4” LWT, 3000 psf CONCRETE
• t TOTAL = 5/4”

TYPICAL FLOOR LOADING
• LL = 50 psf (CORRIDOR ABOVE 1ST FLOOR)
• DL = 20 psf (REP AND MISC.)
• 100 psf

FROM VULCRAFT CATALOG FOR 2VL120

UNSHORED CLEAR SPAN (5 SPAN) = 10'-0" > 7'-4 3/8" OK /

SUPERIMPOSED LL AT 7'-6" CLEAR SPAN = 203 psf > 100 psf OK

Orange Regional Medical Center
Appendix D: Spot Check - Beams

Composite Beam W16 x 26 (12):

\[ F_g = 50 \text{ kip}, \quad A = 9.68 \text{ in}^2, \quad I_x = 301 \text{ in}^4 \]

Typical Beam Loading:

- LL = 60 psf (Corridor Above 1st Floor)
- DL = 20 psf (MEP and Misc.)
- W = 70 psf (Composite Deck W/ LW Concrete)
- Self WT = 26 plf

\[ \omega = 1.2 \left( 20 \times 50.7 \times (7.36) + 26 \right) + 1.6 \left( 80 \times (7.36) \right) = 1.6 \text{ kip} \]

**General Notes from Drawing Call for Pin Connections**

- \( V_{\text{v}} = \frac{(1/2)(26)}{2} = 20.8 \text{ kips} \)
- \( M_{\text{v}} = \frac{(1/2)(26)^2}{8} = 155.2 \text{ ft-kips} \)

Check Composite Action:

- \( v_{\text{eff}} = \frac{2c}{4} = 6.5 \text{ in} \rightarrow \text{controls} \)
- \( a = \frac{2c}{6} = 0.41 \leq 1.0 \rightarrow \text{controls} \)
- \( \gamma = 0.85(5)(0.5)(2) \)
- \( \gamma = 5.95 - 1/2 = 4.75 \)
- \( \phi \gamma < 135.2 \text{ ft-kips} \rightarrow \text{ok} \)

Check Deflection:

- \( \Delta_{\text{ll}} = \frac{5wn^4}{384EI} < \frac{1}{360} \)
- \( wn^4 = 4125 \text{ ft-lb}^3, \quad 26(12) \)
- \( 384(7700)(945) = 360 \)
- \( 0.324 < 0.867 \rightarrow \text{ok} \)

Technical Assignment III

Ryan T. Blatz | Structural

Orange Regional Medical Center
**Appendix D: Spot Check - Beams**

<table>
<thead>
<tr>
<th>APPENDIX D</th>
<th>SPOT CHECK - BEAMS 2</th>
<th>RYAN BLATZ</th>
</tr>
</thead>
</table>

**FIND $I_{req}$ FOR WET CONCRETE DEFLECTION**

\[
\Delta_{max} = \frac{(26)(12)}{240} = 1.3 \text{ in} \]

\[
\omega = \frac{(59.7(0.36) + 26)}{1000} \text{ kip} \]

\[
I_{req} = \frac{5 \cdot w \cdot l^2}{384 \cdot E \cdot I_{req}} = \frac{(0.4)(26)(12)^4}{384(21000) \cdot I_{req}} \]

\[
I_{req} = 107.1 \text{ in}^4 \geq 301 \text{ in}^4 \quad \text{ok} / \]

Orange Regional Medical Center
Appendix D: Spot Check - Girder

CHECKED AGAINST AISI STEEL MANUAL - 14th EDITION

Composite Girder: W18 x 35 (24): \( F_g = 50 \text{ ksf} \), \( A = 10.3 \text{ in}^2 \), \( I_{y} = 510 \text{ in}^4 \)

Typical Girder Loading:
- \( P = 41.6 \text{ kips (from joists)} \)
- \( w = 19(35) = 0.062 \text{ kif (self weight)} \)

Check Composite Action

\[ b_{	ext{eff}} = \frac{22H/4}{26} = 5.53 \text{ in} \]

\[ \Sigma Q_n = 137 \text{ kips (Table 3-1)} \]

\[ a = \frac{127}{(0.85)^3(5.53)} = 0.76 < 1.0 \text{ - controls} \]

\[ \gamma_a = 3.2 \text{ in}^4 \text{ kif} < 306.7 \text{ ft-k in } \text{ - ok} \]

Check Deflection

\[ \Delta_{\text{all}} = \frac{6Pl^4}{384EI} < \frac{f}{L^2} \]

\[ 0 + \frac{5.2(22.1)^4(128)}{48(2x10^6)(832)} < \frac{22.1(12)}{360} \]

\[ 0.23 \text{ in} < 0.737 \text{ in} \text{ - ok} \]

Find \( I_{\text{req}} \) for wet concrete deflection

\[ \Delta_{\text{max}} = 22.1(12) = 1.1 \text{ in} \]

\[ P = (0.4x26) = 10.4 \]

\[ I_{\text{req}} = \frac{5(0.053x22.1)^4(128)}{384(2x10^6)(1.1)} + \frac{(10.4)(22.1)^4(128)}{48(2x10^6)(1.1)} \]

\[ I_{\text{req}} = 259.3 \text{ in}^4 < 510 \text{ in}^4 \text{ - ok} \]

\[ Q_n = 127 \text{ kips} \geq 7.5 \text{ kips for half length} \]

16 studs < 24 studs ok
APPENDIX D  SPOT CHECK - COLUMN

COLUMN AB34: W12 x 87 ANALYZED AT GROUND FLOOR

INTERIOR COLUMN
\[ A_e = 582.4 \text{ ft}^2 \]
\[ A_i = 2321.8 \text{ ft}^2 > 400 \text{ ft}^2 : \text{ REDUCIBLE} \]
\[ DL = (68.65 \text{ ksf})(582.4)(6 \text{ floors}) \]
\[ (24 \text{ ksf})(582.4) = 324.4 \text{ kips} \]
\[ S = (42 \text{ ksf})(582.4) = 24.5 \text{ kips} \]
\[ *\text{ NO DRIFT ON UPPER FLOOR} \]
\[ LL = (100 \text{ ksf})(582.4) + (44.9 \text{ ksf})(582.4)(5) \]
\[ = 189.0 \text{ kips} \]
\[ *\text{ CORRIDOR THROUGH DAY HT EACH FLOOR} \]

\[ L = 80 \left( \frac{0.25 + 15}{\sqrt{2321.8}} \right) \]
\[ L = 44.56 > 0.4L_0 \]

\[ DL \times COL: WT = 324.4 + 55(37.2) + 56(46) = 328.0 \text{ kips} \]

LOAD COMBINATIONS
\[ 1.4D \times 1.4(328.0) = 459.2 \text{ kips} \]
\[ 1.2D \times 1.4L + 0.5 = 1.2(328.0) + 1.6(187) + 0.5(24.5) = 708.3 \text{ kips} \]
\[ AT: KL = 16 \text{ ft}, \quad \Delta P_n = 865 \text{ kips} \]
\[ L = 708.3 \quad \text{OK} / \]

SYSTEM WEIGHT CALCULATION
\[ A_e = (24)(22.1) = 537.7 \text{ kips} \]
\[ DL e w/unc. = 1.17 + (10.1/72) = 51.76 \text{ ksf} \]
\[ 1.2 \left[ (L)(1.75 + 20)(537.7) + (L/2)(22.1) + 26(24)(4) \right] + 1.6 \left[ 100(537.7) + 46(537.7)(5) \right] \]

WEIGHT ON FOOTING: 537.7 kips + 305 psi on soil < 4,000 psi

FROM GEOTECHNICAL REPORT:
FOUNDATION RATED FOR 4,000 PSI
\[ L = 80 \left( \frac{0.26 + 15}{\sqrt{2321.8}} \right) \]
\[ L = 45 \text{ psf} \]

A FOOTING = 1764 in²
Appendix D: Spot Check - Column

COLUMN 243: W12x53 ANALYZED AT FIRST FLOOR

Exterior Column

\[ A_4 = (16.2 + 12.9)(10.5 + 11.0) = 316.1 \text{ ft}^2 \]

\[ A_1 = (20.9)(43) + \frac{2}{3}(12)(11.2) = 1266.7 \text{ ft}^2 \]

\[ D_L = (68.65)(316.1)(S) + (24)(316.1) + (58)(21.5)(73.5) = 208.0 \text{ kips} \]

\[ S = (42)(316.1) = 13.5 \text{ kips} \]

\[ L_L = (24.9)(316.1) + (46.3)(316.1) = 57.5 \text{ kips} \]

Brick Façade: 36 psf

- 2nd, 4th, 5th, 6th floors - Operating Rooms

\[ L_2 = 40 \left( 0.25 + \frac{15}{1266.7} \right) \]

\[ L_2 = 40.3 \text{ psf} > 0.41 \text{k} \]

\[ D_L + \text{Col. WT} = 208 + 40(37.5) + 45(25) \]

\[ D_L + \text{Col. WT} = 510.8 \text{ kips} \]

- 3rd Floor - Patient Rooms

\[ L_3 = 40 \left( 0.25 + \frac{15}{1266.7} \right) \]

\[ L_3 = 28.7 \text{ psf} > 0.41 \text{k} \]

Load Combinations

\[ 1.4D + 1.4(210.8) = 295.1 \text{ kips} \]

\[ 1.2D + 1.6L + 0.55 = 1.2(210.8) + 1.6(59.5) + 0.5(15.3) = 354.8 \text{ kips} \]

At \[ KL = 13 \text{ ft} \], \[ \gamma P_n = 526 \text{ kips} > 254.8 \text{ kips} \] ok
Appendix E: Precast Plank System

APPENDIX E

PRECAST HOLLOWCORE PLANK

RYAN BLATZ

PLANK SIZING

USE 10' x 4' HOLLOW CORE PLANK (UNTOTTED)

* TO ACHIEVE 2 HOUR FIRE RATING

LOADING

* LL = 80 psf (corridor above first floor)
* DL = 20 psf (MEP and Misc.)

1.2D + 1.6L = 1.2(20) + 1.6(80) = 152 psf

ACCORDING TO NITTERHOUSE HOLLOW CORE SPEC SHEET (SEE NEXT PAGE) FOR A 26'-0" SPAN:

10' x 4' UNTOTTED HOLLOW CORE PLANK WITH 0.75" STRAND PATTERN

176 psf (from tables) > 152 psf

NOTE: 4 ft. widths will either push bay sizes to be 1' - 11" longer or 2' - 1" shorter in the plan east and west directions.

NEW BAY SIZES: 26'-0" x 24'-0" OR 26'-0" x 20'-0"

STEEL GIRDERS SIZING

USE WORST CASE BAY: 26'-0" x 24'-0"

LOADING:

LL = 80 psf
DL = 20 psf

PLANK = 63.0 psf

144.0 psf

1.2D + 1.6L = 1.2(88.0) + 1.6(80) = 233.6 psf

Vu = (233.6)(26) = 6.07 kip

2

CHECK DEFLECTION

Pl = (0.07)(24) = 137.0 ft

8

ΔLL = (24)(12) = 0.08

5 (208)(24)(720) 384(24000)

I ΔL = 0.013 in

ΔTL = (24)(12) = 0.08

5 (607)(24)(720) 384(24000)

I ΔL = 0.013 in
Appendix E: Precast Plank System

According to Table 3-10 and Table 1-1,

USE A W18 x 86

WITH $I_m = 1500 \text{ in}^4 > 1382.1 \text{ in}^4$ OK

$P_m = 474 \text{ kips} > 487.0 \text{ kips}$ OK

@ USL = 24" O.C.

Change in Total Structural Depth

EXISTING: 5'4" Conc. w/ Deck

17.9" Girder

22.95"

PLANK SYSTEM: 10" Plank

18.4" Girder

38.4"

System Weight Calculations

\[ A_t = (52)(24) = 1248 \text{ ft}^2 \]

Planks: 60 psf

A \approx (24)(2)(24)(2) = 2496 \text{ ft}^2

1.2 \left[ \frac{(6)(68)(20)(24)}{(6)(86)(24)} \right] = 1.6 \left[ \frac{100(624) + 4(124)(5)}{1764} \right]

Weight on Footing: \frac{729.7 \text{ psi}}{1764 \text{ in}^2} = 415 \text{ psi}

L = 60 \left( \frac{0.25}{12496} \right)

L = 44 \text{ psi}
Appendix E: Precast Plank System

Prestressed Concrete
10"x4'-0" Hollow Core Plank
2 Hour Fire Resistance Rating (Untopped)

<table>
<thead>
<tr>
<th>PHYSICAL PROPERTIES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Precast</td>
<td></td>
</tr>
<tr>
<td>A = 262 in.²</td>
<td>bₚ = 13.13 in.</td>
</tr>
<tr>
<td>l = 3198 in.³</td>
<td>Sₚ = 640 in.³</td>
</tr>
<tr>
<td>γₚ = 4.99 in.</td>
<td>S₁ = 638 in.³</td>
</tr>
<tr>
<td>Y = 5.01 in.</td>
<td>W₁ = 272 PLF</td>
</tr>
<tr>
<td>e = 3.24 in.</td>
<td>W₁ = 68.00 PSF</td>
</tr>
</tbody>
</table>

DESIGN DATA
1. Precast Strength @ 28 days = 6000 PSI
2. Precast Strength @ release = 3500 PSI
3. Precast Density = 150 PCF
4. Strand = 1/2"Ø and 0.6"Ø 270K L0-Relaxation,
5. Strand Height = 1.75 in.
6. Ultimate moment capacity (when fully developed),
   6-1/2"Ø, 270K = 142.3 k-ft at 60% jacking force
   7-1/2"Ø, 270K = 163.4 k-ft at 60% jacking force
7. Maximum bottom tensile stress is 10√fₚ = 775 PSI
8. All superimposed load is treated as live load in the strength analysis of flexure and shear.
9. Flexural strength capacity is based on stress/strain strand relationships.
10. Deflection limits were not considered when determining allowable loads in this table.
11. Load values to the left of the solid line are controlled by ultimate shear strength.
12. Load values to the right are controlled by ultimate flexural strength or structural fire endurance.
13. Load values may be different for IBC 2000 & ACI 318-05. Load tables are available upon request.
14. Camber is inherent in all precast hollow core slabs and is a function of the amount of eccentric prestressing force needed to carry the superimposed design loads along with a number of other variables. Because prediction of camber is based on empirical formulas it is at best an estimate, with the actual camber usually higher than calculated values.

SAFE SUPERIMPOSED SERVICE LOADS

<table>
<thead>
<tr>
<th>Strand Pattern</th>
<th>SPAN (FEET)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 - 1/2&quot;LOAD (PSF)</td>
<td>26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44</td>
</tr>
<tr>
<td>214 194 175 159 144 130 118 107 97 87 79 71 64 57 51 45 40</td>
<td></td>
</tr>
</tbody>
</table>

NITTERHOUSE
CONCRETE PRODUCTS

2655 Molly Pitcher Hwy, South, Box N
Chambersburg, PA 17202-9203
717-287-4505  Fax 717-287-4518

Orange Regional Medical Center
Appendix F: Non-Composite System

Typical Floor Loading:
- LL = 80 psf (corridor above first floor)
- DL = 20 psf (MEP and MISC)
- Use LW concrete for comparison purposes

Size Decking (using Vulcraft Floor Decking Catalog)
Use 2020 Form Deck with 6x6, 2.7x2.7 WNF and 3/8" of LW concrete

Unshored clear span (5 span) = y"-1" > y"-4.92" OK
Allowable uniform load for all deflections = 111 psf > 100 psf OK
Reinforced concrete allowable load = 113 psf > 100 psf OK

Beam Sizing (using AISC Steel Manual, 14th Edition)

Loading:
- LL = 80 psf
- DL = 20 psf
- 43 psf (Decking w/ LW Conc.)
- 5 psf (Self wt allowance)
- 148 psf

1.2D + 1.6L = 1.2(68) + 1.6(80) = 207.6 psf (7.36") = 1.54 klf

\[ V_0 = \frac{(1.54)(26)}{2} \]
\[ M_0 = \frac{(1.54)(26)^2}{8} \]

Check Deflection
\[ \Delta_{LL} = \frac{(26)(12)}{360} \times \frac{5(0.325)(26)^2}{(122)} \times \frac{384}{(2100)} \times I \]
\[ \Delta_{DL} = \frac{(26)(12)}{360} \times \frac{5(0.34)(26)^2}{(122)} \times \frac{384}{(2100)} \times I \]

From Tables 3&10 and 1-1, use A W11 x 48 with \( I_x = 484 \text{ in}^4 \), \( I_y = 490 \text{ in}^4 \), \( w = 190 \text{ lb/ft} \), \( S = 315 \text{ lb/ft} \), \( D = 280 \text{ lb} \), \( D_y = 260 \text{ lb} \)

Check actual self wt (65 psf)
\[ W_0 = 211.4 \text{ psf (2.56")} \times 1.56 \text{ klf} \]
\[ M_0 = 131.8 \text{ ft-lb} < 140 \text{ ok} \]
\[ I_{req} = 425.5 \text{ in}^4 > 484 \text{ in}^4 \text{ ok} \]
Appendix F: Non-Composite System

**Girder Sizing**

**Loading:**
\[ P = 40.04 \text{ kips} \]
\[ W = 1.2 \times (0.221) = 0.265 \text{ kips} \]
\[ V_0 = 40.04 + (1.2 \times 0.221) = 42.4 \text{ kips} \]
\[ M_0 = 40.04 \times (0.221)^2 = 9.716 \text{ ft-kips} \]

**Check Deflection**

\[ \Delta_{LL} = \frac{(221)(0.221)^2}{360} \times \frac{19.5(0.221)^4}{(1728)} \]
\[ I_{req} = 278.3 \text{ in}^4 \]

\[ \Delta_{TL} = \frac{(221)(0.221)^2}{240} \times \frac{384(0.221)^4}{(1728)} \]
\[ I_{req} = 521.0 \text{ in}^4 \]

From Tables 3-10 and 1-1, use a W14×48 with \( I_{x} = 7.22 \text{ in}^4 > 521.0 \text{ in}^4 \) ok.

**Cost Comparison**

**Existing:**
W14×26 (4) = 2.1 kips
W18×36 (2) = 1.55 kips
122.51/05 (0.5% FS) = 1.22 kips
5.44 kips

**Non-Composite:**
W14×48 (9) = 4.97 kips
W14×62.5 (22) = 3.01 kips
8.0 kips

Based solely on material costs, the non-composite system will cost more.

**System Weight Calculations**

Deck w/conc = 43 psf
\[ A_L = \frac{1.6 \times (5.742 \times 0.5742)}{100 (5.742 \times 0.5742)} = 1.6 \times \frac{100 (5.742 \times 0.5742)}{100 (5.742 \times 0.5742)} \]

Weight on footing = 695.8 kips on soil
### Appendix G: Two-Way Flat Slab

#### TWO-WAY CONC. FLAT SLAB

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span (26'-0&quot;)</td>
<td>(Page 10-1)</td>
</tr>
<tr>
<td>Loading</td>
<td></td>
</tr>
<tr>
<td>LL</td>
<td>50 psf (corridor above first floor)</td>
</tr>
<tr>
<td>DL</td>
<td>80 psf (MEP and Misc.)</td>
</tr>
<tr>
<td>1.2D</td>
<td>1.5L</td>
</tr>
<tr>
<td>1.2(20) + 1.5(20)</td>
<td>152 psf</td>
</tr>
</tbody>
</table>

**From Tables:**
- H: 1.9" at 26'-0" span and 200 psf (conservatively)

#### DROP PANEL
- Width: 8.67 ft
- Depth: 4.25 in

#### COLUMN SIZE
- 19" x 19"

#### REINFORCING: COLUMN STRIP
- Top: (12) #6's
- Bottom: (21) #4's

#### MIDDLE STRIP
- Top: (16) #4's
- Bottom: (9) #6's

#### CHANGE IN STRUCTURAL DEPTH
- Existing: 32.75" (from Appendix B)
- Flat slab: 9" + 0.25" + 15.25"

#### SYSTEM WEIGHT CALCULATION
- \( A = 5794.2 \text{ ft}^2 \)

\[
1.2 \left[ 594.2 \left( \frac{710}{72} + 3.49 \left( \frac{625}{72} \right) \right) + 1.6 \left( 100 \left( 594.2 \right) + 45 \left( 594.2/3 \right) \right) \right]
\]

**Weight on Footing:**
- \( 394.7 \text{ kips} \) on soil
- 1954 kips

---

Orange Regional Medical Center
<table>
<thead>
<tr>
<th>SPAN (ft)</th>
<th>Factored Nominal Load (psf)</th>
<th>Square Column Depth (in)</th>
<th>Width (ft)</th>
<th>% Square Column</th>
<th>REINFORCING BARS (E. W.)</th>
<th>MOMENTS</th>
<th>Factored Nominal Load (psf)</th>
<th>REINFORCING BARS (E. W.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>100</td>
<td>4.25</td>
<td>7.67</td>
<td>12</td>
<td>0.583</td>
<td>10-44 2</td>
<td>10-45</td>
<td>8-45</td>
</tr>
<tr>
<td>23</td>
<td>200</td>
<td>4.25</td>
<td>7.67</td>
<td>15</td>
<td>0.742</td>
<td>10-46 2</td>
<td>10-46</td>
<td>8-46</td>
</tr>
<tr>
<td>330</td>
<td>300</td>
<td>6.25</td>
<td>7.67</td>
<td>18</td>
<td>0.629</td>
<td>12-44 2</td>
<td>10-44</td>
<td>8-44</td>
</tr>
<tr>
<td>23</td>
<td>200</td>
<td>4.25</td>
<td>7.67</td>
<td>19</td>
<td>0.701</td>
<td>15-44 4</td>
<td>9-49</td>
<td>8-49</td>
</tr>
<tr>
<td>23</td>
<td>200</td>
<td>4.25</td>
<td>7.67</td>
<td>22</td>
<td>0.628</td>
<td>12-48 2</td>
<td>12-48</td>
<td>8-48</td>
</tr>
<tr>
<td>23</td>
<td>200</td>
<td>4.25</td>
<td>7.67</td>
<td>22</td>
<td>0.646</td>
<td>18-44 2</td>
<td>15-48</td>
<td>10-48</td>
</tr>
<tr>
<td>23</td>
<td>200</td>
<td>4.25</td>
<td>7.67</td>
<td>21</td>
<td>0.646</td>
<td>18-44 2</td>
<td>17-47</td>
<td>13-45</td>
</tr>
<tr>
<td>23</td>
<td>200</td>
<td>4.25</td>
<td>7.67</td>
<td>20</td>
<td>0.629</td>
<td>15-44 3</td>
<td>11-47</td>
<td>10-47</td>
</tr>
<tr>
<td>23</td>
<td>200</td>
<td>4.25</td>
<td>7.67</td>
<td>20</td>
<td>0.629</td>
<td>15-44 3</td>
<td>11-47</td>
<td>10-47</td>
</tr>
<tr>
<td>23</td>
<td>200</td>
<td>4.25</td>
<td>7.67</td>
<td>20</td>
<td>0.629</td>
<td>15-44 3</td>
<td>11-47</td>
<td>10-47</td>
</tr>
<tr>
<td>23</td>
<td>200</td>
<td>4.25</td>
<td>7.67</td>
<td>21</td>
<td>0.646</td>
<td>18-44 2</td>
<td>17-47</td>
<td>13-45</td>
</tr>
<tr>
<td>23</td>
<td>200</td>
<td>4.25</td>
<td>7.67</td>
<td>20</td>
<td>0.629</td>
<td>15-44 3</td>
<td>11-47</td>
<td>10-47</td>
</tr>
</tbody>
</table>
## Appendix H: Lateral Stiffness

### STORY 2 RELATIVE STIFFNESS

**EAST/WEST 100k APPLIED @ CR W/ DEFL OF 0.0064**

<table>
<thead>
<tr>
<th>Frame</th>
<th>Shear</th>
<th>Stiffness</th>
<th>Relative Stiffness</th>
</tr>
</thead>
<tbody>
<tr>
<td>VB-28</td>
<td>2.88</td>
<td>449.3</td>
<td>0.029</td>
</tr>
<tr>
<td>VB-29</td>
<td>2.91</td>
<td>454.2</td>
<td>0.029</td>
</tr>
<tr>
<td>VB-14</td>
<td>10.79</td>
<td>1685.2</td>
<td>0.109</td>
</tr>
<tr>
<td>VB-13</td>
<td>3.02</td>
<td>472.2</td>
<td>0.031</td>
</tr>
<tr>
<td>VB-17</td>
<td>10.74</td>
<td>1678.7</td>
<td>0.109</td>
</tr>
<tr>
<td>VB-18</td>
<td>9.29</td>
<td>1452.0</td>
<td>0.094</td>
</tr>
<tr>
<td>VB-22</td>
<td>4.31</td>
<td>673.1</td>
<td>0.044</td>
</tr>
<tr>
<td>VB-21</td>
<td>4.60</td>
<td>718.7</td>
<td>0.047</td>
</tr>
<tr>
<td>VB-23</td>
<td>3.02</td>
<td>472.4</td>
<td>0.031</td>
</tr>
<tr>
<td>VB-24</td>
<td>2.74</td>
<td>427.3</td>
<td>0.028</td>
</tr>
<tr>
<td>VB-25</td>
<td>3.00</td>
<td>468.4</td>
<td>0.030</td>
</tr>
<tr>
<td>VB-26</td>
<td>2.86</td>
<td>446.2</td>
<td>0.029</td>
</tr>
<tr>
<td>VB-27</td>
<td>2.85</td>
<td>446.0</td>
<td>0.029</td>
</tr>
<tr>
<td>VB-38</td>
<td>2.51</td>
<td>392.5</td>
<td>0.025</td>
</tr>
<tr>
<td>VB-39</td>
<td>3.26</td>
<td>510.0</td>
<td>0.033</td>
</tr>
<tr>
<td>VB-40</td>
<td>1.91</td>
<td>298.7</td>
<td>0.019</td>
</tr>
<tr>
<td>VB-41</td>
<td>0.04</td>
<td>6.2</td>
<td>0.000</td>
</tr>
<tr>
<td>VB-43</td>
<td>4.69</td>
<td>732.5</td>
<td>0.047</td>
</tr>
<tr>
<td>VB-44</td>
<td>5.52</td>
<td>862.2</td>
<td>0.056</td>
</tr>
<tr>
<td>VB-49</td>
<td>5.95</td>
<td>929.1</td>
<td>0.060</td>
</tr>
<tr>
<td>VB-50</td>
<td>5.02</td>
<td>784.6</td>
<td>0.051</td>
</tr>
<tr>
<td>VB-36</td>
<td>6.86</td>
<td>1072.5</td>
<td>0.070</td>
</tr>
</tbody>
</table>

**Sum = 15432.0**

### NORTH/SOUTH 100k APPLIED @ CR W/ DEFL OF 0.0085

<table>
<thead>
<tr>
<th>Frame</th>
<th>Shear</th>
<th>Stiffness</th>
<th>Relative Stiffness</th>
</tr>
</thead>
<tbody>
<tr>
<td>VB-1</td>
<td>0.20</td>
<td>23.7</td>
<td>0.002</td>
</tr>
<tr>
<td>VB-2</td>
<td>0.18</td>
<td>21.2</td>
<td>0.002</td>
</tr>
<tr>
<td>VB-3</td>
<td>5.33</td>
<td>626.9</td>
<td>0.054</td>
</tr>
<tr>
<td>VB-4</td>
<td>5.35</td>
<td>629.6</td>
<td>0.054</td>
</tr>
<tr>
<td>VB-5</td>
<td>5.05</td>
<td>594.4</td>
<td>0.051</td>
</tr>
<tr>
<td>VB-6</td>
<td>6.33</td>
<td>745.1</td>
<td>0.064</td>
</tr>
<tr>
<td>VB-8</td>
<td>10.25</td>
<td>1205.6</td>
<td>0.104</td>
</tr>
<tr>
<td>VB-9</td>
<td>5.34</td>
<td>627.7</td>
<td>0.054</td>
</tr>
<tr>
<td>VB-10</td>
<td>6.21</td>
<td>730.7</td>
<td>0.063</td>
</tr>
<tr>
<td>VB-11</td>
<td>4.39</td>
<td>516.5</td>
<td>0.045</td>
</tr>
<tr>
<td>VB-12</td>
<td>4.50</td>
<td>529.8</td>
<td>0.046</td>
</tr>
<tr>
<td>VB-30</td>
<td>4.58</td>
<td>538.5</td>
<td>0.047</td>
</tr>
<tr>
<td>VB-31</td>
<td>4.58</td>
<td>538.4</td>
<td>0.047</td>
</tr>
<tr>
<td>VB-33</td>
<td>9.16</td>
<td>1077.4</td>
<td>0.093</td>
</tr>
<tr>
<td>VB-34</td>
<td>5.05</td>
<td>594.4</td>
<td>0.051</td>
</tr>
<tr>
<td>VB-35</td>
<td>4.68</td>
<td>551.1</td>
<td>0.048</td>
</tr>
<tr>
<td>VB-48</td>
<td>3.70</td>
<td>435.6</td>
<td>0.038</td>
</tr>
<tr>
<td>VB-46</td>
<td>3.70</td>
<td>435.5</td>
<td>0.038</td>
</tr>
<tr>
<td>VB-45</td>
<td>3.68</td>
<td>432.4</td>
<td>0.037</td>
</tr>
<tr>
<td>VB-42</td>
<td>2.28</td>
<td>268.1</td>
<td>0.023</td>
</tr>
<tr>
<td>VB-47</td>
<td>3.68</td>
<td>432.5</td>
<td>0.037</td>
</tr>
</tbody>
</table>

**Sum = 11554.86**
## Appendix H: Lateral Stiffness

### Story 7 Relative Stiffness

**EAST/WEST 100k APPLIED @ CR W/ DEFL OF 0.071**

<table>
<thead>
<tr>
<th>Frame</th>
<th>Shear</th>
<th>Stiffness</th>
<th>Relative Stiffness</th>
</tr>
</thead>
<tbody>
<tr>
<td>VB-28</td>
<td>4.16</td>
<td>58.6</td>
<td>0.042</td>
</tr>
<tr>
<td>VB-29</td>
<td>4.39</td>
<td>61.8</td>
<td>0.044</td>
</tr>
<tr>
<td>VB-14</td>
<td>20.71</td>
<td>291.8</td>
<td>0.207</td>
</tr>
<tr>
<td>VB-13</td>
<td>3.28</td>
<td>46.2</td>
<td>0.033</td>
</tr>
<tr>
<td>VB-16</td>
<td>19.95</td>
<td>280.9</td>
<td>0.199</td>
</tr>
<tr>
<td>VB-18</td>
<td>14.05</td>
<td>197.9</td>
<td>0.141</td>
</tr>
<tr>
<td>VB-22</td>
<td>7.06</td>
<td>99.5</td>
<td>0.071</td>
</tr>
<tr>
<td>VB-21</td>
<td>7.03</td>
<td>99.0</td>
<td>0.070</td>
</tr>
<tr>
<td>VB-23</td>
<td>4.30</td>
<td>60.5</td>
<td>0.043</td>
</tr>
<tr>
<td>VB-24</td>
<td>3.84</td>
<td>54.1</td>
<td>0.038</td>
</tr>
<tr>
<td>VB-25</td>
<td>3.78</td>
<td>53.2</td>
<td>0.038</td>
</tr>
<tr>
<td>VB-26</td>
<td>3.68</td>
<td>51.9</td>
<td>0.037</td>
</tr>
<tr>
<td>VB-27</td>
<td>3.76</td>
<td>52.9</td>
<td>0.038</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td></td>
<td><strong>1408.2</strong></td>
<td></td>
</tr>
</tbody>
</table>

**NORTH/SOUTH 100k APPLIED @ CR W/ DEFL OF 0.1023**

<table>
<thead>
<tr>
<th>Frame</th>
<th>Shear</th>
<th>Stiffness</th>
<th>Relative Stiffness</th>
</tr>
</thead>
<tbody>
<tr>
<td>VB-1</td>
<td>6.24</td>
<td>61.0</td>
<td>0.062</td>
</tr>
<tr>
<td>VB-2</td>
<td>6.24</td>
<td>61.0</td>
<td>0.062</td>
</tr>
<tr>
<td>VB-3</td>
<td>8.19</td>
<td>80.1</td>
<td>0.082</td>
</tr>
<tr>
<td>VB-4</td>
<td>9.29</td>
<td>90.8</td>
<td>0.093</td>
</tr>
<tr>
<td>VB-5</td>
<td>7.91</td>
<td>77.3</td>
<td>0.079</td>
</tr>
<tr>
<td>VB-6</td>
<td>8.37</td>
<td>81.8</td>
<td>0.084</td>
</tr>
<tr>
<td>VB-8</td>
<td>22.79</td>
<td>222.7</td>
<td>0.228</td>
</tr>
<tr>
<td>VB-9</td>
<td>8.83</td>
<td>86.3</td>
<td>0.088</td>
</tr>
<tr>
<td>VB-10</td>
<td>9.47</td>
<td>92.5</td>
<td>0.095</td>
</tr>
<tr>
<td>VB-11</td>
<td>6.26</td>
<td>61.2</td>
<td>0.063</td>
</tr>
<tr>
<td>VB-12</td>
<td>6.30</td>
<td>61.6</td>
<td>0.063</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td></td>
<td><strong>976.3</strong></td>
<td></td>
</tr>
</tbody>
</table>
## Appendix I: Lateral Loadings

### Case I \((P_{wx} + P_{lx})\)

<table>
<thead>
<tr>
<th>Story</th>
<th>Load</th>
<th>UX</th>
<th>UY</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROOF</td>
<td></td>
<td>0.4117</td>
<td>-0.0032</td>
</tr>
<tr>
<td>STORY 6</td>
<td></td>
<td>0.3724</td>
<td>-0.0019</td>
</tr>
<tr>
<td>STORY 5</td>
<td></td>
<td>0.0112</td>
<td>0.4628</td>
</tr>
<tr>
<td>STORY 4</td>
<td></td>
<td>0.3189</td>
<td>-0.0007</td>
</tr>
<tr>
<td>STORY 3</td>
<td></td>
<td>0.0023</td>
<td>0.3899</td>
</tr>
<tr>
<td>STORY 2</td>
<td></td>
<td>0.2514</td>
<td>0.0004</td>
</tr>
<tr>
<td>STORY 1</td>
<td></td>
<td>0.0034</td>
<td>0.3</td>
</tr>
<tr>
<td>STORY 0</td>
<td></td>
<td>0.1664</td>
<td>0.0009</td>
</tr>
<tr>
<td>STORY 1</td>
<td></td>
<td>-0.0025</td>
<td>0.1977</td>
</tr>
<tr>
<td>STORY 2</td>
<td></td>
<td>0.0936</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

### Case II \((0.75(P_{wx} + P_{lx})B_{x}(\pm 0.15B_{x}))\)

<table>
<thead>
<tr>
<th>Story</th>
<th>Load</th>
<th>UX</th>
<th>UY</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROOF</td>
<td></td>
<td>0.0059</td>
<td>0.3955</td>
</tr>
<tr>
<td>STORY 6</td>
<td></td>
<td>0.3103</td>
<td>0.0005</td>
</tr>
<tr>
<td>STORY 5</td>
<td></td>
<td>0.0078</td>
<td>0.3532</td>
</tr>
<tr>
<td>STORY 4</td>
<td></td>
<td>0.2812</td>
<td>0.0012</td>
</tr>
<tr>
<td>STORY 3</td>
<td></td>
<td>0.0096</td>
<td>0.2976</td>
</tr>
<tr>
<td>STORY 2</td>
<td></td>
<td>0.2415</td>
<td>0.0017</td>
</tr>
<tr>
<td>STORY 1</td>
<td></td>
<td>0.0112</td>
<td>0.2292</td>
</tr>
<tr>
<td>STORY 0</td>
<td></td>
<td>0.1914</td>
<td>0.002</td>
</tr>
<tr>
<td>STORY 1</td>
<td></td>
<td>-0.0063</td>
<td>0.1507</td>
</tr>
<tr>
<td>STORY 2</td>
<td></td>
<td>0.1231</td>
<td>0.0015</td>
</tr>
<tr>
<td>STORY 2</td>
<td></td>
<td>0.0026</td>
<td>0.0786</td>
</tr>
</tbody>
</table>

### DEFLECTIONS

<table>
<thead>
<tr>
<th>Story</th>
<th>Load</th>
<th>UX</th>
<th>UY</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROOF</td>
<td></td>
<td>0.4117</td>
<td>-0.0032</td>
</tr>
<tr>
<td>STORY 6</td>
<td></td>
<td>0.3724</td>
<td>-0.0019</td>
</tr>
<tr>
<td>STORY 5</td>
<td></td>
<td>0.0112</td>
<td>0.4628</td>
</tr>
<tr>
<td>STORY 4</td>
<td></td>
<td>0.3189</td>
<td>-0.0007</td>
</tr>
<tr>
<td>STORY 3</td>
<td></td>
<td>0.0023</td>
<td>0.3899</td>
</tr>
<tr>
<td>STORY 2</td>
<td></td>
<td>0.2514</td>
<td>0.0004</td>
</tr>
<tr>
<td>STORY 1</td>
<td></td>
<td>0.0034</td>
<td>0.3</td>
</tr>
<tr>
<td>STORY 0</td>
<td></td>
<td>0.1664</td>
<td>0.0009</td>
</tr>
<tr>
<td>STORY 1</td>
<td></td>
<td>-0.0025</td>
<td>0.1977</td>
</tr>
<tr>
<td>STORY 2</td>
<td></td>
<td>0.0936</td>
<td>0.0001</td>
</tr>
<tr>
<td>STORY 2</td>
<td></td>
<td>0.0007</td>
<td>0.1046</td>
</tr>
</tbody>
</table>
### Appendix I: Lateral Loadings

#### CASE III (75PWX + .75PLX)

<table>
<thead>
<tr>
<th>Story</th>
<th>Load</th>
<th>UX</th>
<th>UY</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROOF</td>
<td>CASE3</td>
<td>0.3088</td>
<td>0.3861</td>
</tr>
<tr>
<td>ROOF</td>
<td>CASE3</td>
<td>0.2802</td>
<td>0.3457</td>
</tr>
<tr>
<td>STORY5</td>
<td>CASE3</td>
<td>0.2409</td>
<td>0.2919</td>
</tr>
<tr>
<td>STORY4</td>
<td>CASE3</td>
<td>0.191</td>
<td>0.2253</td>
</tr>
<tr>
<td>STORY3</td>
<td>CASE3</td>
<td>0.1229</td>
<td>0.149</td>
</tr>
<tr>
<td>STORY2</td>
<td>CASE3</td>
<td>0.0708</td>
<td>0.0785</td>
</tr>
</tbody>
</table>

#### CASE IV

<table>
<thead>
<tr>
<th>Story</th>
<th>Load</th>
<th>UX</th>
<th>UY</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROOF</td>
<td>CASE4</td>
<td>0.2377</td>
<td>0.1302</td>
</tr>
<tr>
<td>STORY6</td>
<td>CASE4</td>
<td>0.2167</td>
<td>0.1295</td>
</tr>
<tr>
<td>STORY5</td>
<td>CASE4</td>
<td>0.1879</td>
<td>0.1152</td>
</tr>
<tr>
<td>STORY4</td>
<td>CASE4</td>
<td>0.1511</td>
<td>0.0881</td>
</tr>
<tr>
<td>STORY3</td>
<td>CASE4</td>
<td>0.0884</td>
<td>0.0514</td>
</tr>
<tr>
<td>STORY2</td>
<td>CASE4</td>
<td>0.0553</td>
<td>0.0288</td>
</tr>
</tbody>
</table>

#### EARTHQUAKE

<table>
<thead>
<tr>
<th>Story</th>
<th>Load</th>
<th>UX</th>
<th>UY</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROOF</td>
<td>EWQUAKE</td>
<td>1.6427</td>
<td>-0.0259</td>
</tr>
<tr>
<td>ROOF</td>
<td>NSYQUAKE</td>
<td>0.0001</td>
<td>2.3692</td>
</tr>
<tr>
<td>STORY6</td>
<td>EWQUAKE</td>
<td>1.4456</td>
<td>-0.018</td>
</tr>
<tr>
<td>STORY6</td>
<td>NSYQUAKE</td>
<td>0.0382</td>
<td>2.0666</td>
</tr>
<tr>
<td>STORY5</td>
<td>EWQUAKE</td>
<td>1.1968</td>
<td>-0.0105</td>
</tr>
<tr>
<td>STORY5</td>
<td>NSYQUAKE</td>
<td>0.0159</td>
<td>1.6939</td>
</tr>
<tr>
<td>STORY4</td>
<td>EWQUAKE</td>
<td>0.9043</td>
<td>0.0035</td>
</tr>
<tr>
<td>STORY4</td>
<td>NSYQUAKE</td>
<td>0.0236</td>
<td>1.2654</td>
</tr>
<tr>
<td>STORY3</td>
<td>EWQUAKE</td>
<td>0.5614</td>
<td>0.0014</td>
</tr>
<tr>
<td>STORY3</td>
<td>NSYQUAKE</td>
<td>0.0158</td>
<td>0.7939</td>
</tr>
<tr>
<td>STORY2</td>
<td>EWQUAKE</td>
<td>0.2962</td>
<td>0.0004</td>
</tr>
<tr>
<td>STORY2</td>
<td>NSYQUAKE</td>
<td>0.0043</td>
<td>0.3928</td>
</tr>
</tbody>
</table>
## Appendix J: Torsional Shear

### Torsional Shear on 2nd Story Frames

<table>
<thead>
<tr>
<th>Frame</th>
<th>R</th>
<th>d1</th>
<th>d2</th>
<th>Rdi2</th>
<th>k*d</th>
<th>Seismic V&lt;sub&gt;TORSION&lt;/sub&gt;</th>
<th>Seismic V&lt;sub&gt;DIRECT&lt;/sub&gt;</th>
<th>Total Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>VB-28</td>
<td>0.015494</td>
<td>105.854</td>
<td>11205.069</td>
<td>173.612165</td>
<td>2</td>
<td>0.001 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>0.27</td>
<td>15.75</td>
</tr>
<tr>
<td>VB-29</td>
<td>0.015663</td>
<td>738.854</td>
<td>54590.23</td>
<td>8550.652499</td>
<td>12</td>
<td>0.004 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>1.92</td>
<td>15.92</td>
</tr>
<tr>
<td>VB-14</td>
<td>0.05811</td>
<td>1315.896</td>
<td>1731582.3</td>
<td>100623.0301</td>
<td>76</td>
<td>0.023 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>12.69</td>
<td>59.08</td>
</tr>
<tr>
<td>VB-13</td>
<td>0.016283</td>
<td>2811.396</td>
<td>7903947.5</td>
<td>128698.9205</td>
<td>46</td>
<td>0.014 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>7.60</td>
<td>16.55</td>
</tr>
<tr>
<td>VB-17</td>
<td>0.057885</td>
<td>1315.896</td>
<td>1731582.3</td>
<td>100233.0509</td>
<td>76</td>
<td>0.023 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>12.64</td>
<td>58.85</td>
</tr>
<tr>
<td>VB-18</td>
<td>0.050067</td>
<td>179.354</td>
<td>32167.857</td>
<td>746.6374598</td>
<td>4</td>
<td>0.001 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>0.69</td>
<td>23.60</td>
</tr>
<tr>
<td>VB-22</td>
<td>0.023211</td>
<td>179.354</td>
<td>32167.857</td>
<td>746.6374598</td>
<td>4</td>
<td>0.001 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>0.69</td>
<td>23.60</td>
</tr>
<tr>
<td>VB-21</td>
<td>0.024781</td>
<td>179.354</td>
<td>32167.857</td>
<td>797.1597141</td>
<td>4</td>
<td>0.001 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>0.74</td>
<td>25.19</td>
</tr>
<tr>
<td>VB-23</td>
<td>0.016291</td>
<td>1683.854</td>
<td>1731582.3</td>
<td>100623.0301</td>
<td>76</td>
<td>0.023 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>12.69</td>
<td>59.08</td>
</tr>
<tr>
<td>VB-24</td>
<td>0.016151</td>
<td>952.271</td>
<td>906820.06</td>
<td>14646.41426</td>
<td>15</td>
<td>0.005 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>2.55</td>
<td>16.42</td>
</tr>
<tr>
<td>VB-26</td>
<td>0.015387</td>
<td>736.271</td>
<td>542094.99</td>
<td>8341.428173</td>
<td>11</td>
<td>0.001 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>1.49</td>
<td>50.90</td>
</tr>
<tr>
<td>VB-27</td>
<td>0.015378</td>
<td>736.271</td>
<td>542094.99</td>
<td>8341.428173</td>
<td>11</td>
<td>0.001 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>1.49</td>
<td>50.90</td>
</tr>
<tr>
<td>VB-38</td>
<td>0.013533</td>
<td>3098.396</td>
<td>9600057.8</td>
<td>129916.2991</td>
<td>42</td>
<td>0.013 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>6.96</td>
<td>13.76</td>
</tr>
<tr>
<td>VB-39</td>
<td>0.017588</td>
<td>1683.854</td>
<td>2835364.3</td>
<td>49867.88611</td>
<td>30</td>
<td>0.009 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>4.91</td>
<td>17.88</td>
</tr>
<tr>
<td>VB-40</td>
<td>0.010301</td>
<td>1683.854</td>
<td>2835364.3</td>
<td>29206.08543</td>
<td>17</td>
<td>0.005 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>2.88</td>
<td>10.47</td>
</tr>
<tr>
<td>VB-41</td>
<td>0.000212</td>
<td>1055.354</td>
<td>1113772.1</td>
<td>236.4365268</td>
<td>0</td>
<td>0.000 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td>VB-43</td>
<td>0.025259</td>
<td>3722.854</td>
<td>13859642</td>
<td>350075.4378</td>
<td>94</td>
<td>0.029 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>15.60</td>
<td>25.68</td>
</tr>
<tr>
<td>VB-44</td>
<td>0.02973</td>
<td>3722.854</td>
<td>13859642</td>
<td>412040.5825</td>
<td>111</td>
<td>0.034 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>18.36</td>
<td>30.22</td>
</tr>
<tr>
<td>VB-49</td>
<td>0.032037</td>
<td>1827.854</td>
<td>3341050.2</td>
<td>107036.017</td>
<td>59</td>
<td>0.018 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>9.72</td>
<td>32.57</td>
</tr>
<tr>
<td>VB-50</td>
<td>0.027054</td>
<td>1708.854</td>
<td>2920182</td>
<td>79003.82459</td>
<td>46</td>
<td>0.014 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>7.67</td>
<td>27.51</td>
</tr>
<tr>
<td>VB-36</td>
<td>0.036984</td>
<td>3098.396</td>
<td>9600057.8</td>
<td>355052.1367</td>
<td>115</td>
<td>0.035 F&lt;sub&gt;s&lt;/sub&gt;</td>
<td>19.01</td>
<td>37.60</td>
</tr>
</tbody>
</table>

**SUM R= 0.532136**  
**J = 1961115.117**
**Appendix K: Lateral Spot Checks**

**COLUMN CHECK: FRAME VB-8**

- $P = \frac{1}{1670}$
- $b_x = \frac{3}{(1)(438)} = 0.00132$
- $P_r = 0.1224 \times 425.16 = 0.225 > 0.2$

**FRAME CHECK: FRAME VB-8**

- In tension: $\sigma P_a = \frac{F}{A} \leq (0.1)(425)(17.2) = 712.08$ kN > 227.06 kN, OK
- In compression: $P_c = \frac{\pi^2 E I}{L^2} = \frac{\pi^2 (2800)(256)}{306.5^2} = 1713.3$ kN

\[ \sigma_p = (0.1)(1713.3) = 154.2 \leq 227.06 \text{ kN, OK} \]
Appendix L: Sample Calculations

Relative Stiffness

\[ F \cdot KA \]
\[ (2.86) \cdot K (0.0064) \]
\[ K = 445.3 \text{ kips/in} \]

\[ \text{Krel} \cdot K_i = 445.3 \cdot 0.029 \text{ for VB-27 @} \]
\[ \Sigma K_i = 15432 \text{ story 2 in E/W dir.} \]

Story Drift

Wind: ETABS OUTPUT
\[ 0.000278 \cdot h_{x} > \frac{L}{400} \]
\[ = (2.78 \cdot 10^{-4})(13.5 \cdot 12) > (13.5 \cdot 12)/400 \]
\[ = 0.045 > 0.040 \text{ ok} \]

Seismic: ETABS OUTPUT
\[ 0.001366 \cdot \frac{h_{x}}{I} < 0.01h_{x} \]
\[ I = (1.366E-3) \cdot (162)^{2} < 0.01(162) \]
\[ 1.5 \]
\[ 0.443 < 1.62 \text{ ok} \]

Wind Shear

Case 4:
\[ M_{x} = 0.663 (P_{w} \cdot P_{r}) \cdot b_{x} \cdot c_{x} + 0.563 (P_{w} \cdot P_{r}) \cdot b_{y} \cdot c_{y} \]
\[ = 0.663 (166.56)(1375.625)(-15) + 0.563 (186.237)(1375.625)(-15) \]
\[ = -3206.54 \text{ kips-in} \]

* Use with East blowing wind and South blowing wind for worst case

\[ E = 1.15 b_{x} \]

Torsional Shear

Frame VB-27
\[ R \cdot K/E = 445.3/27000 > 0.0155 \]
\[ F_x = \frac{R_{dia} \cdot F_x (601.44)(10155)(400.27)}{196115.12} = 0.002 F_x \]

From torsion:
\[ 0.002 F_x \cdot 0.002 (541) \cdot 1.02^2 \]

From direct:
\[ 0.029 F_x \cdot 0.029 (541) \cdot 15.63^2 \]

Total: 16.66° compared to 15.39° from ETABS