Technical Report #1

Structural Concepts & Existing Conditions Report

Indiana Regional Medical Center

Indiana, PA

Cody A. Scheller

The Pennsylvania State University

Architectural Engineering

Structural Option

Faculty Adviser: Dr. Linda Hanagan

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Executive Summary

The Indiana Regional Medical Center's existing conditions and structural system was analyzed for this technical report. Gravity loads and lateral loads were evaluated throughout the typical portions of the structure using design and thesis codes.

Indiana Regional Medical Center is a full service healthcare facility that resides in Indiana, Pennsylvania. It is made up of 6 separate buildings, but is mostly one seven story 146 ft high building that lies in the core of the other five. The entire structure has an orange brick façade and is used mostly as a hospital for the public. It is a constructed moment frame made mostly of steel with metal deck and lightweight concrete.

Gravity loads for calculations in this assignment were discovered from ASCE 7-10. All calculations were compared to the actual loads on the plans used during the initial erection of the building. Winds loads were also calculated using ASCE 7-10 along with a beginning analysis of seismic loads.

Spot checks were done on a typical bay within the building. A composite beam and girder were both analyzed and the results showed that they meet all design standards. Both an exterior and interior column were spot checked along the entire height of the building. These were then compared to the actual design forces given.

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Introduction

Indiana Regional Medical Center (IRMC) is a 130,000 square foot hospital that resides in the heart of western Pennsylvania. It was first introduced to the public in November of 1914 and has seen many renovations and additions throughout its years. It is now the only full service health facility in its county. An elevation can be seen in figure 1 and an aerial view in figure 2.

Figure 1 – Current Entrance to IRMC

This technical report collects and analyzes the existing structural conditions of the Indiana Regional Medical Center in Indiana, Pennsylvania. An analysis of gravity loads, lateral loads, and the overall structural system of this building have been included with this report along with visual aids to help with the understanding of each concept.

Figure 2 – Site of Indiana Regional Medical Center

Framing & Lateral Loading

The hospital consists of one large seven story building with five smaller buildings branching off from all sides. Each building is rectangular in shape with a brick façade and has a flat roof. The largest building stands 146 feet in the air and has a rigid frame skeleton of steel. Along its North-South length, the hospital consists of 5 typical bays made up of W10, W14, and W16 steel. Moment frames allow more flexibility with the floor plan and awareness of moment connections throughout the structure. A sketch of the moment frame can be seen in figure 3.
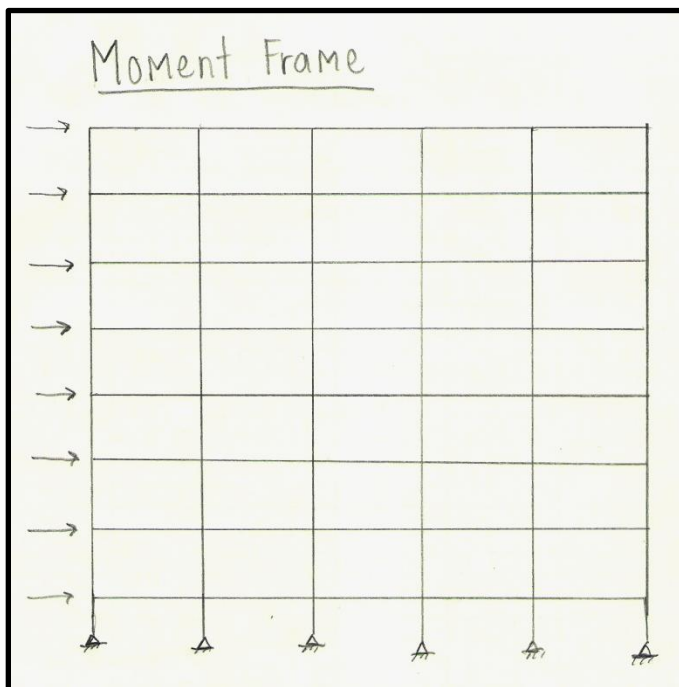

Figure 3 – Moment Frame Sketch

Other Structural Elements

Minor and secondary structural elements are not needed to be analyzed at this phase, but have to be recognized for their importance. Wind pressures and lateral soil pressures on existing walls do affect the overall loading on the building and should be taken into account. The fact that the building has had several renovations over the past 70 years should not be ignored and should always be involved when doing an analysis.

Foundation

IRMC rests on a shallow layer of bedrock so the foundation of the overall building is very shallow. The current level of grade is actually higher than initially since the foundation could not be placed deep into the ground. Concrete footings and columns make up the entire base of the
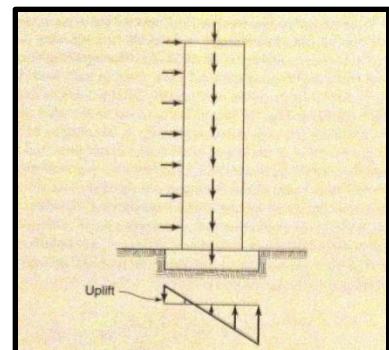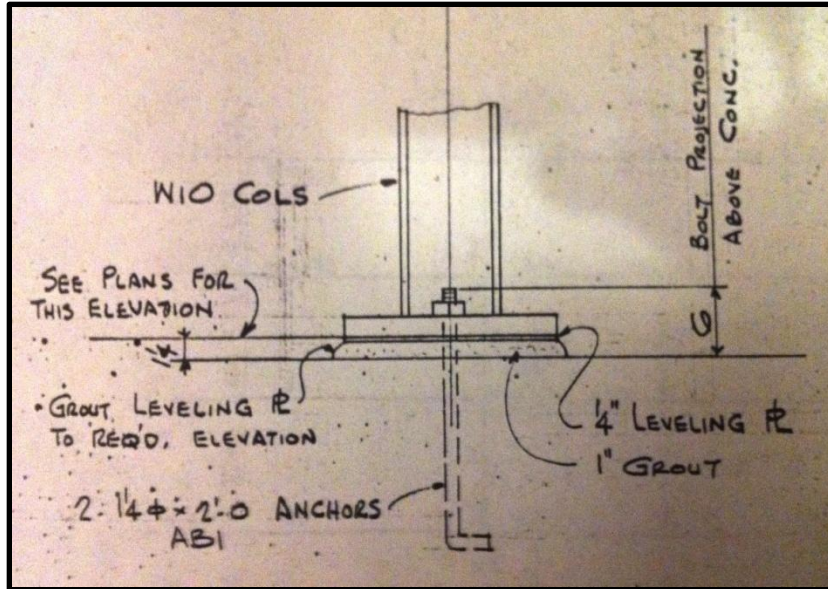

Figure 4 – Concrete Footing

Figure 5 – Anchor Bolt

building and our attached to the upper steel skeleton by anchor bolts as seen in figure 4 and figure 5. Since the building rests on a shallow foundation it is very important to check load impact and load transfer. This foundation makes the building very vulnerable and could be easily affected by wind and seismic loadings. It may also be relevant to check the current foundation for any damages since this building has been renovated several times in the past.

General Structural Information

The following codes were used throughout the entire technical report for the identification of loads, wind load calculations, seismic load calculations, spot checking, and overall accuracy of research.

Design Codes

1. AISC Manual of Steel Construction Ninth Edition (ASD)
2. AISC Manual of Steel Construction Load and Resistance Factor Design Second Edition
3. ASCE 7-98 Minimum Design Loads for Buildings and Other Structures
4. International Building Code 2003

Thesis Codes

1. AISC Manual of Steel Construction Thirteenth Editioin
2. American Society of Civil Engineers, AISC 7-10
3. International Building Code 2010

Determination of Loads

Gravity Loads

Location	Design (IBC 2003)	Thesis (ASCE 7-10)
Office	50 psf	50 psf
Restaurants	100 psf	100 psf
Retail	100 psf	100 psf
Mechanical Rooms	200 psf	-
Hospitals		
Operating rooms/Laboratories	60 psf	60 psf
Patient Rooms	40 psf	40 psf
Corridors Above First Floor	80 psf	80 psf
Roof	30 psf	20 psf
Stairs & Lobby	100 psf	100 psf
Corridors	80 psf	80 psf

Floor Dead Loads	
Composite Decking	44 psf
Superimposed Dead Load	30 psf
Total	74 psf

Snow Loads

Snow load criteria were obtained from section 7.3 of ASCE 7-10. It was found that P_f would be 17.325 lb/ft^2. Calculations can be seen below in figure 6.

Snow Load

#7.3 Flat Roof Snow Load

$$P_f = 0.7 \, C_e \, C_t \, I_s \, P_g$$

where $C_e = 0.9$
$C_t = 1.0$
$I_s = 1.1$
$P_g = 25$

$$P_f = (0.7)(0.9)(1.0)(1.1)(25) = \boxed{17.325 \, ^{lb}/_{ft^2}}$$

Figure 6 – Snow Load Calculation

Wind Loads

ASCE 7-10 was used when determining the wind load analysis for the Indiana Regional Medical Center. Chapter 27 of this design code is the enclosed and partially enclosed section and aided in the calculations. An analysis was done for both North-South and East-West directions.

To begin, it needed to be decided if the IRMC was calculated under a rigid structure or flexible structure. The calculations for this result are located in Appendix A and proved that this specific building should be calculated as a rigid structure.

When the actual calculations for the wind loads were being ran, only the 146 ft tower of the hospital was taken into account. From figure 7 shown below, it is evident that East-West direction produces the strongest wind forces of 668.74 psf due to larger surface area.

Figure 7 – TOP: North-South Direction, BOTTOM: East-West Direction   ← 668. 74 psf
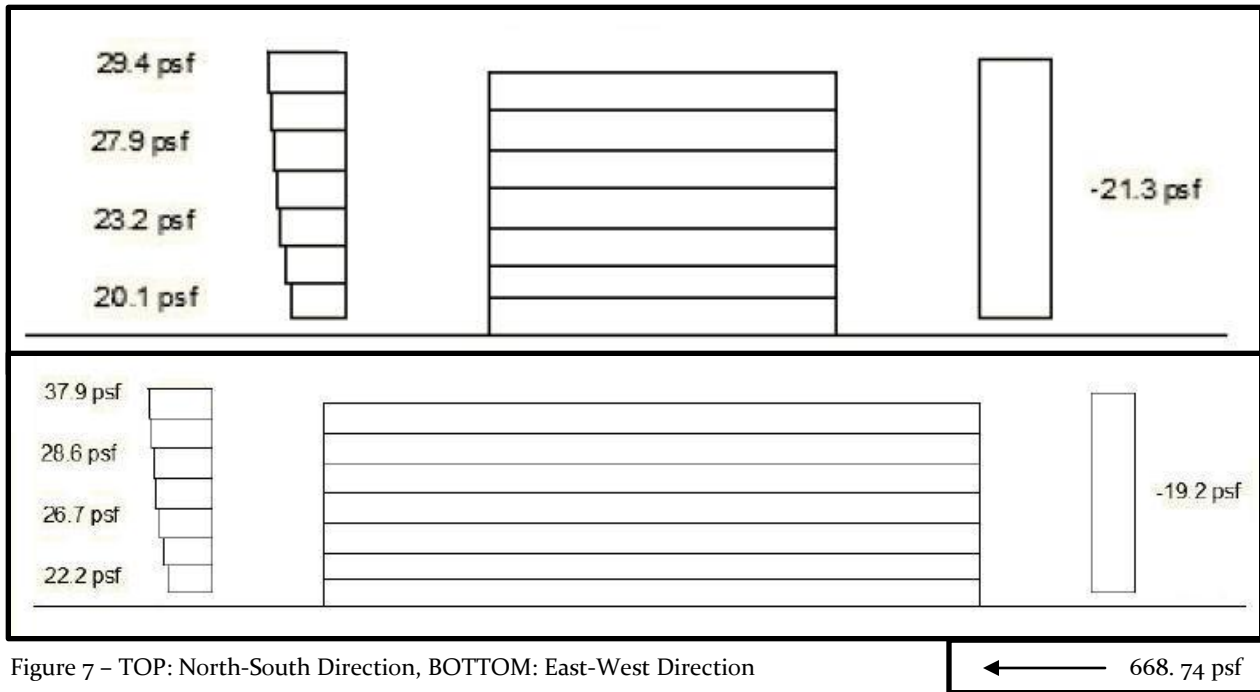
In Appendix A there is a set of hand calculations showing the analysis of base shear and overturning moment. Governing lateral force can be determined by comparing these values to the seismic calculations.

Seismic Loads

Seismic calculations are not required by the location in which Indiana Regional Medical Center resides. Necessary information to analyze the seismic loads on the building have been requested to the architects and engineers that were responsible for the resurrection of this building. Once this information is obtained it will be used in all necessary seismic calculations and compared to the wind pressures on the building.

Other Loads

There may be other loads that affect the overall structure of the building as well. Snow drift may be something to worry about considering there are lower level buildings surrounding the main 146 ft core building. Anti-terrorism loading is not something to ignore either since this building is a public health facility. These additions will be evaluated at a later time.

Evaluation of Systems

Floor System for Typical Bay

Spot checks were done to determine the result of gravity loads on the structure. A typical bay from the second floor of the building was used and can be seen in figure 8. Detailed hand calculations for this bay are located in Appendix B. The 1st spot check was that of the composite slab. The slab used throughout the building is
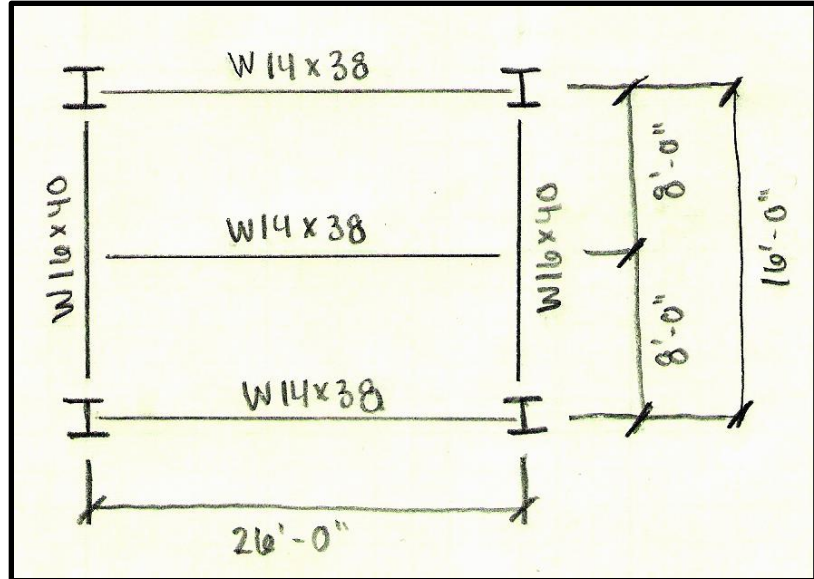

Figure 8 – Typical Bay

a Composite Steel Deck with 3 ½'' of lightweight 3000 psi concrete fill netting and a total thickness of 5 ½'' as seen in Appendix C. Vulcraft Decking Catalog was used to check the values of the decking. After all necessary calculations were completed; it was found that the composite decking used met all standard requirements.

Two more spot checks were done next. One was evaluating a W14x38 composite beam and the other was evaluating a W16x40 composite girder. The calculations in Appendix B show that the beam is more than adequate for the specific loads it needs to carry. When checking the shear stud requirements it was found that the calculated number was slightly less than what was used in the plans. This could come from conservative reasoning or manufacturer changes. The beam also met deflection checks for both live and wet concrete. Results from the composite girder checked yielded positive results as well. They were not as conservative as the beam's numbers were, but it was still adequate for the loading.

Typical Columns

The final two checks were that of an interior and an exterior column. Column F3 was selected to be spot checked as an interior column and Column F2 was selected for an exterior column as seen in figure 9. Tri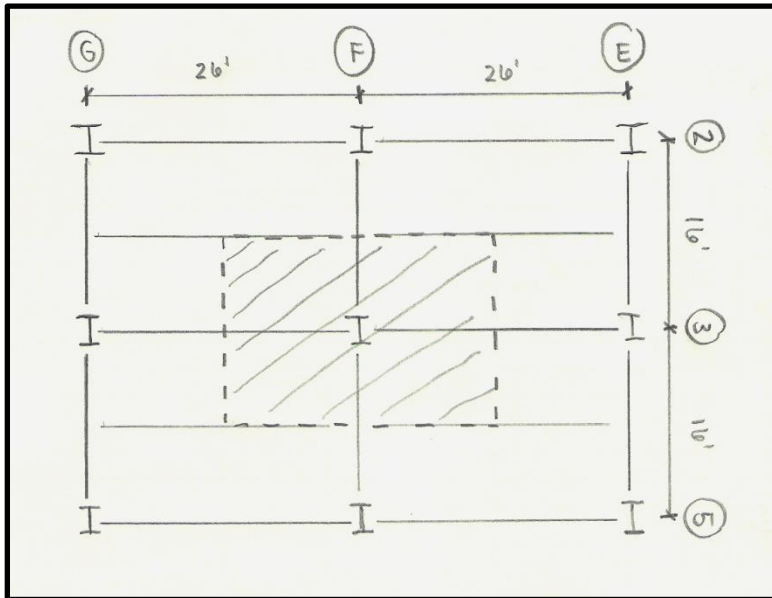butary Area calculations for these spot checks are located in Appendix D. The live load selected for each floor was 80 to be conservative and the dead load consisted of 44 psf for the slab and 30 psf for superimposed load. Self weight of each column was taken into account as well as the 24' splice length that is used throughout the building.

Figure 9 – Tributary Area for Interior Column

Figure 10 and figure 11 below show the resultant forces on these specific columns.

Figure 10 – Interior Column Check

Interior Column						
Column Check						
Floor	Area	DL	LL	Column Size	Splice	Pu
3	416	74	80	95	24	92468.8
4	416	74	80	95	24	92468.8
5	416	74	80	87	24	92276.8
6	416	74	80	87	24	92276.8
7	416	74	80	87	24	92276.8
Roof	416	74	20		24	50252.8
Total =						512.02 kips

Figure 11 – Exterior Column Check

Exterior Column						
Column Check						
Floor	Area	DL	LL	Column Size	Splice	Pu
3	208	74	80	95	24	47374.4
4	208	74	80	95	24	47374.4
5	208	74	80	87	24	47182.4
6	208	74	80	87	24	47182.4
7	208	74	80	87	24	47182.4
Roof	208	74	20		24	25126.4
Total =						261.42 kips

Conclusion

From the analysis of the Indiana Regional Medical Center, it is safe to conclude that it can withstand all applied loads. All typical layouts of the structural system were spot checked: including a composite slab, composite girder, interior column, and exterior column. All beams and girders have also met deflection standards

The lateral forces due to wind and seismic were also analyzed throughout the report. It was shown that the East-West direction had the strongest wind pressures due to large surface area. The seismic calculations are not needed for this specific location and there was not an adequate amount of information obtained from the engineer to calculate the minimum ground acceleration, but it has been requested and will be compared to the wind calculations when the information is acquired.

 The loads used in the actual design of the building were not significantly different then the loads discovered in ASCE 7-10. In comparing the results, it is easy to see that some characteristics seemed to be over designed, but this error could be related to documents that were not included on the actual floor and structural plans.

Appendix

Appendix A: Wind Load Calculations

Tech. #1 Calc.

Wind Loads

Risk Category: III

Directionality Factor: $k_d = 0.85$

Exposure Category: B

Topographic Factor: $k_{zt} = 1.0$

Wind Speed: 120 mph

Section 26.9.5

$$g_Q = 3.4 \qquad g_v = 3.4$$

$$g_R = \sqrt{2\ln(3600 n_1)} + \frac{0.577}{\sqrt{2\ln(3600 n_1)}}, \text{ where } n_1 = \frac{1}{T_a}$$

$$T_a = \text{natural period}$$

Section 12.8.2.1

$$T_a = C_t h_n^x \rightarrow C_t = 0.02 \quad \& \quad x = 0.75$$

$$T_a = (0.02)(146)^{0.75} \qquad h_n = \text{main roof height} = 146'$$

$$T_a = 0.84$$

$$n_1 = \frac{1}{0.84} = 1.19$$

↳ greater than one → ∴ rigid
structure.

Tech. #1 Calc.

Wind Loads

<u>Section 27</u>

$$g_R = \sqrt{2\ln[(3600)(1.19)]} + \frac{0.577}{\sqrt{2\ln[(3600)(1.19)]}} =$$

$$g_R = 4.0897 + 0.1411 = \underline{4.231}$$

$$I_z = C\left(\frac{33}{\bar{z}}\right)^{1/6}$$

$z = 0.6 \,(\text{height}) = 0.6\,(146')$

$z = 87.6'$

$C = 0.30$

$$I_z = (0.30)\left(\frac{33}{87.6}\right)^{1/6} = \underline{0.255}$$

$$L_z = \ell\left(\frac{\bar{z}}{33}\right)^{\bar{\epsilon}}$$

$\ell = 320$

$\epsilon = 1/3$

$$L_z = (320)\left(\frac{87.6}{33}\right)^{1/3} = \underline{443.08}$$

$$Q = \sqrt{\frac{1}{1+0.63\left(\frac{B+h}{L_z}\right)^{0.63}}} = \sqrt{\frac{1}{1+0.63\left(\frac{226'+146'}{443.08}\right)^{0.63}}}$$

$$\underline{Q = 0.7996}$$

Tech. #1 Calc.

Wind Loads

$$R = \sqrt{\frac{1}{\beta} R_n R_h R_B (0.53 + 0.47 R_L)}$$

$$R_n = \frac{7.47 N_1}{(1 + 10.3 N_1)^{5/3}} \quad , \quad N_1 = \frac{n_1 L_{\bar{z}}}{\bar{V}_{\bar{z}}} \quad , \quad \bar{V}_{\bar{z}} = \bar{b}\left(\frac{\bar{z}}{33}\right)^{\bar{a}}\left(\frac{88}{66}\right) \cdot V$$

→ Solve $\bar{V}_{\bar{z}}$: $\bar{a} = 1/4$ $\bar{b} = 0.45$

$$\bar{V}_{\bar{z}} = 0.45\left(\frac{87.6}{33}\right)^{1/4}\left(\frac{88}{66}\right)(120) = 91.9$$

→ Solve $N_1 = \dfrac{(1.19)(443.08)}{91.9} = 5.737$

→ Solve $R_n = \dfrac{(7.47)(5.737)}{[1 + 10.3(5.737)]^{5/3}} = \dfrac{42.855}{921.8995} = 0.04649$

R_L: $n = 15.4 n_1 L / \bar{V}_{\bar{z}} = 15.4(1.19)(92)/(91.9) = 18.35$

$$R_L = \frac{1}{18.35} - \frac{1}{2(18.35)^2}\left(1 - e^{-2(18.35)}\right) = \underline{0.05301}$$

R_B: $n = 4.6 n_1 B / \bar{V}_{\bar{z}} = 4.6(1.19)(226)/(91.9) = 13.46$

$$R_B = \frac{1}{13.46} - \frac{1}{2(13.46)^2}\left(1 - e^{-2(13.46)}\right) = \underline{0.0715}$$

R_h: $n = 4.6 n_1 h / \bar{V}_{\bar{z}} = 4.6(1.19)(146)/(91.9) = 8.696$

$$R_h = \frac{1}{8.696} - \frac{1}{2(8.696)^2}\left(1 - e^{-2(8.696)}\right) = \underline{0.1084}$$

→ $\beta = 1.5\%$ for steel and concrete buildings

$$R = \sqrt{\frac{1}{0.015}(0.04649)(0.1084)(0.0715)\left[0.53 + 0.47(0.05301)\right]}$$
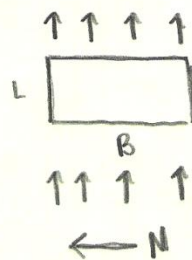
$$R = \underline{0.1155}$$

Tech. #1 Calc.

Wind Loads

$$G_F = 0.925 \left(\frac{1 + 1.7 I_{\bar{z}} \sqrt{9 Q^2 Q^2 + 9_R^2 R^2}}{1 + 1.7 g_v I_z} \right) =$$

$$G_F = (0.925) \left(\frac{2.197419}{2.4739} \right) = 0.822$$

→ Enclosure Classification → Enclosed

↳ $GC_{pi} = \pm 0.18$

$L/B = {}^{92}/_{226} = 0.407$

Windward Wall → 0.8
Leeward Wall → -0.5

←N

$$p = q \, G_F \, C_p - q_i (GC_{pi}) \qquad k_z = 1.3728$$

$$q = 0.00256 (1.3728)(1.0)(0.85)(120)^2 = 43.0159$$

windward: $p = 28.78 - 28.78(-0.18) = 33.96$ psf

leeward: $p = -14.39 - 28.78(0.18) = -19.57$ psf

→ Wind Loads calculated for the
parts of the building over
two stories.

Appendix B: Floor System Calculations

Tech. #1 Calc.

Typical Bay with Typical Floor

Composite Slab

2" x 18 G.A. Steel Deck   → Use Vulcraft
3½" Lightweight Concrete   Decking Catalog
3000 psi Fill

↳ use 2VLI18 → Max. unshored clear span
                    ↳ 2 span = 10'-4"

Actual Bay Clear Span = 8'0" < 10'4" ∴ ok ✓
Superimposed Live Load = 8'-0" span = 306 psf
Loading ASCE 7-10: Operating Rooms = 60 psf
                   Patient Rooms = 40 psf
                   Corridors: 80 psf
                   S.I. Dead Load: 30 psf
                   ─────────────────────
                   Total   = 210 psf

210 psf < 306 psf → ∴ ok ✓

↳ The decking designed is ok. It is over
  designed for this loading, but it is not the
  controlling load factor.

Tech. #1 Calc.

Composite Beam → W14×38

$A_g = 11.2$ $LL = 80$ - not reduced for conservation

$I_x = 428$ $DL = 44 \, psf$ $SW = 44 \, plf$

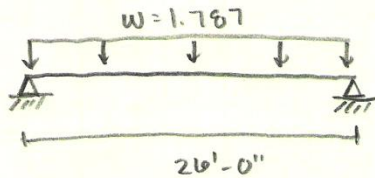$F_y = 50 \, ksi$ $SDL = 30 \, psf$

$W_u = 1.2D + 1.6L$

Dead $= (44+30)(8') + 44 = 636 \, plf$

Live $= 30(8) = 640 \, plf$

$W_u = 1.2(636) + 1.6(640) = 1787.2 \, plf = 1.787 \, k/ft$

$w = 1.787$

$26'-0''$

$V_u = 1.787(26)\left(\frac{1}{2}\right) = 23.23^k$

$M_u = 1.787(26)^2\left(\frac{1}{8}\right) = 151^{'k}$

$\text{span}/4 = 6.5 \rightarrow$ controls

$\phi V_n = 131 \, k > 23.23^k$
∴ ok ✓

$b_{eff} = \min \begin{cases} \\ \text{spacing} = 8' \end{cases}$

$PNA = 7$ $\Sigma Q_n = 140$ $a = \dfrac{\Sigma Q_n}{0.85(f'c)(b_{eff})} = \dfrac{140}{0.85(3)(6.5 \times 12)}$

$a = 0.704 < 1$
→ treat $a = 1$

$Y_2 = \text{thickness}_{slab} - \dfrac{a}{2} = 5.5 - \dfrac{1}{2} = 5$

$\phi M_n = 231^k \rightarrow$ greater than $151^{'k}$ ∴ ok

$Q_n = \dfrac{140}{17.2} = 8.14 \rightarrow$ 9 studs required
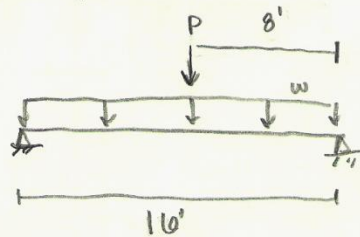
Deflection

$\Delta_{LL} = \dfrac{\ell}{360} = \dfrac{26(12)}{360} = 0.867 \, in \rightarrow$ max deflection

$\Delta_{LL} = \dfrac{5 w_{LL} \ell^4}{384 E I} = \dfrac{5(0.64)(26)^4}{384(29000)(428)}(1728) = 0.53 \, in$

$0.53 \, in < 0.867 \, in$
∴ ok.

Tech. #1 Calc.

Deflection of wet concrete:

$$\Delta_{max} = \frac{\ell}{240} = \frac{26(12)}{240} = 1.3 \text{ in}$$

$$I_{req} = \frac{5w\ell^4}{384 \, \Delta_{max} E} \qquad w = \frac{(44 \times 8) + 44}{1000} = 0.396$$

$$= \frac{5(0.396)(26)^4}{384(1.3)(29000)}(1728) = 108 \text{ in}^4.$$

$$108 \text{ in}^4 < 385 \text{ in}^4 \quad \therefore \text{ ok } \checkmark.$$

Composite Girder = W16×40

→ assume pin supports

→ assume load: $p = 38^k$

$W_U = \frac{80}{1000} = 0.08 \, klf$

$V_U = \frac{38}{2} + \frac{0.08(16)}{2} = 19.64^k$

$M_U = \frac{0.08(16)^2}{8} + 38(8) = 306.56^{'k}$

PNA = 7 $\Sigma Q_n = 147$

$b_{eff} = \begin{cases} 16/4 = 4 \rightarrow controls. \\ spacing = 8 \end{cases}$

$a = \frac{147}{0.85(3)(4)(12)} = 1.2$

↳ use a = 1.2

$Y_2 = 5.5 - 0.5 = 5$

$\emptyset M_n = 309^{'k} > 306.56^{'k}$

$\emptyset V_n = 146^k > 19.64^k$ ⟩ ∴ ok.

Appendix C: Floor System
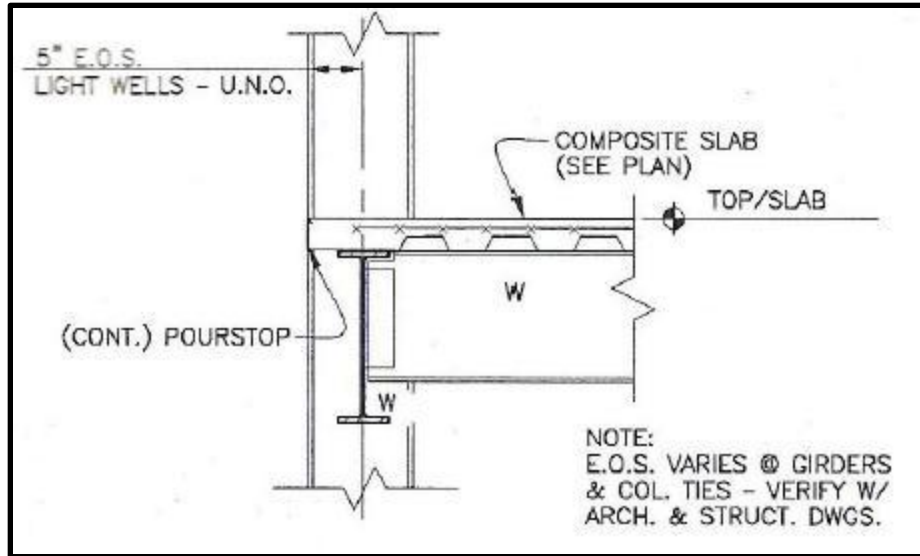
Appendix D: Column Check

Tech. #1 Calc.
Columns

→ Looking at column F3

Tributary Area

$$(16')(26') = 416 \text{ ft}^2$$

LL: Floors = 80 psf