# MONONGALIA GENERAL HOSPITAL

*1200 J.D. ANDERSON DRIVE, MORGANTOWN, WEST VIRGINIA*

# STRUCTURAL CONCEPTS AND EXISTING CONDITIONS REPORT

## TECH ONE

THE PENNSYLVANIA STATE UNIVERSITY
DEPARTMENT OF ARCHITECTURAL ENGINEERING
SENIOR THESIS 2008-2009

SUBMITTED: SEPTEMBER 29, 2008

HIROKI OTA
STRUCTURAL

DR. A. M. MEMARI

## Table of Contents

## Executive Summary

### *Purpose*

This Structural Concepts and Existing Conditions Report (Tech 1) contain the description of the existing physical conditions of the Monongalia General Hospital. This report includes information relative to the design and the design codes associated with the Hospital. Tech 1 will discuss these design codes and provide confirmation through structural analysis the Hospital's structural strength and stability against loads.

### *Building Description*

The Monongalia General Hospital is a 405,994 square feet hospital located in Morgantown, West Virginia. The building project includes a 280,000 square feet addition as well as a 60,000 square feet renovation to the existing structure. The building envelope is a brick façade tied to structural concrete walls with openings for punch windows and curtain wall systems. Aluminum curtain wall systems can be seen all around the Hospital, oriented around lobbies and other major openings on plan. The system consists of insulated tempered spandrel glass framed by aluminum mullions which is tied into the concrete structural system. The main structural system of the Hospital consists of two-way flat plate slabs supported by columns that follow a typical grid and edge beams located in the perimeter of each floor. The loads carried by the columns are transferred to the foundations. The lateral loads are resisted by twelve shear walls of varying height and width located in various portions of the building.

### *Structural Design*

The extent of Tech 1 provides analysis of an existing typical two-way slab, an edge beam, and a column against gravity loads with reference to IBC 2006, ASCE 7-05, and ACI 318-08. All of these members have proved more than adequate, through the calculations; to carry the gravity loads. One must keep in mind that the analyses conducted in Tech 1 neglects all other loads but gravity loads. For the succeeding technical reports, these members will be revisited to be analyzed under more detailed loadings and conditions.

The slab and beam were analyzed simultaneously as per ACI 318-08's section pertaining to two-way slab systems. Upon analysis, these two members have proved to be more than adequate to hold the loads. The slab provided much allowance for heavier load cases. The beam also provided allowance for heavier loads however the design was not as conservative as the slab's.

An exterior column was analyzed for its structural strength and too, provided enough strength to support the loads. The column was assumed to be a short column and analyzed at two different elevations, at the fifth and the first floor. The columns at these two locations were designed very conservatively.

The analysis results of Tech 1 provide further speculation for future reports when considering heavier load cases as well as secondary effects.

# Monongalia General Hospital

1200 J.D. Anderson Drive
Morgantown, WV

# Structural Concepts and Existing Conditions Report

## Introduction

The Structural Concepts and Existing Conditions Report (Tech 1) will describe the existing physical conditions of the Monongalia General Hospital. Tech 1 contains information on the different types of loads the Hospital is subjected to and will review and analyze the existing design against the calculated gravity loads to study the structural strength and serviceability of the Hospital. Tech 1 will also provide information on all of the structural components as well as the design codes that were referenced.

## The Monongalia General Hospital

The Monongalia General Hospital is located on 1200 J.D. Anderson Drive, West Virginia (Photograph 2 for aerial view). The current project the Hospital is going through is a 340,000 square foot expansion and renovation named the Hazel Ruby McQuain Tower, this new addition will provide more various facilities and departments to the Hospital. The construction started on June of 2006 and is scheduled to be completed on May of 2009 with a design-build contract with a guaranteed maximum price set at an estimated $69,000,000 by the Turner Construction Company. The Tower has been designed by Freeman White, Inc. from North Carolina and the structure designed by Atlantic Engineering Services from Pittsburgh. (See Appendix A for Project Team Directory)

The Monongalia General Hospital's plan can be divided into four different quads, A, B, C, and D (Figure 1). The first floor of the Monongalia General Hospital occupies 92,086 square feet and houses a boiler/chiller room, electrical rooms, doctors' offices, labs, nurse stations, storage spaces, and a dining space equipped with a food services kitchen. The second floor follows a similar layout but provides more space for examination rooms as well as a gift shop and café on the southern face of Quad A. The third floor mainly consists of patient rooms with the central part of the plan dedicated to operation rooms. The third floor has a reduced square footage compared to those of the floors below with an area of 80,882 square feet; the western section of Quad D does not continue up to the third floor as patient room spaces but provides housing for two air handling units. The fourth floor sees an even less square footage on plan at 53,833 square feet, with the western section of Quad D no longer existing at this elevation. This floor only houses private patient rooms, each equipped with a private toilet and shower. The square footage of the fourth floor continues up to the fifth, housing more private patient rooms as well as a Labor, Delivery, Recovery, and Postpartum (LDRP) rooms in Quad B and C. The sixth floor sees nearly a fifty percent reduction in square footage from the fifth floor with only Quads B and C serving rooms for private patients. The rooftop at Quad A is located at this elevation and houses five air handling units. Acoustic ceiling systems are utilized on each floor to provide acoustic insulation. The rooftop of the Monongalia General Hospital is used primarily to house mechanical equipment. Two different types of roof systems are utilized: an adhered roof system and a ballasted roof system. The ballasted roof system is only present on the rooftop of Quad A and all other roofs utilize the adhered roof system. (Refer to Figure 2 for building cross section)

The exterior façade of the Monongalia General Hospital is a brick façade tied to 8" structural concrete walls with openings for punch windows and curtain wall systems. Windows are typically aluminum punch window units and located where there are offices and patient rooms, located on the third floor and up. Aluminum curtain wall systems can be seen all around the Hospital, oriented around lobbies and other major openings on plan (Photograph 1 and 3). The system consists of insulated tempered spandrel glass framed by aluminum mullions which is tied into the concrete structural system. Two inch rigid insulation is provided all around the building for insulation.

## Structural System

### *Introduction*

The primary structural system of the Monongalia General Hospital is reinforced concrete with several composite floor systems present in parts of the building where appropriate (i.e. canopy/wall junctions, canopy fascia, etc.). The concrete used for the Hospital ranges from 3000 pounds per square inch (psi) to 5000 psi depending on its use. All concrete, as specified by ASTM C150; is normal weight concrete with a minimum weight of 144 pounds per cubic foot, and the reinforcement used are all ASTM A615 – Grade 60 steel reinforcement bars.

### *Foundation and Columns*

Concrete foundations are placed below every column located at a minimum depth of 3'-6" below grade and utilize 3000 psi cast in place concrete. The columns that transfer the loads to these foundations are all 24 inches by 24 inches utilizing 5000 psi cast in place concrete. A total of 100 columns are present in the structure ranging in height from 11'-6" (supports one floor) to the full height of the building 58'-5". There are six columns in the structure in which the column's material changes from concrete to steel. These columns support the canopy in Quad A as well as used as corner columns for the stair towers.

### *Slabs*

The slab on grades are 5" thick normal weight concrete and the slabs used in floors above are two-way flat plate slabs that utilizes 4000 psi normal weight concrete and are used as the primary floor system with the exception of a few in Quad C where an emergency energy plant is present: a composite concrete-steel floor system is used. The two way slab system is 8 inches thick and transfers its load to the columns and concrete edge beams present in the perimeter of each floor.

### *Beams*

The beams are all variable in size although the dominant cross section is an 18 inch by 24 inch beam usually spanning 27' from column to column. Like the columns, the concrete used for the beams are 5000 psi normal weight concrete framed in by the two way slabs. As mentioned earlier, beams in this Hospital are all edge beams with an exception around openings in plan for elevator shafts, stairs, as well as for the energy plant located in the northern part of Quad C.

### *Shear Walls*

There are twelve lateral force resisting shear walls present in the Hospital (Figure 3). All of these are variable sizes ranging in height and width, the most representative shear wall being a 52'-9-1/8" x 70' wall with two sets of eight #5 bars used at each floor level.

## Building Design Loads

### *Gravity Loads*

For the structural analysis, gravity loads were determined as per ASCE 7-05, AISC 13th Edition, IBC 2006, and other relevant publications. The construction documents were also referenced to provide a better perception of code compliant loads. On the following page is a table listing the loads by type and material.

| **Floor Loads** | | | |
|---|---|---|---|
| *Type* | *Material/Occupancy* | *Load* | *Reference* |
| **Dead Load** | Normal Weight Concrete | 145 PCF | Drawing G1-2 |
| | Steel | Per shape | AISC 13th Edition |
| | Brick Masonry | 40 PSF | MSJC |
| | Partitions | 20 PSF | Drawing G1-2 |
| | Superimposed | 10 PSF | * |
| **Live Load** | Public Areas | 100 PSF | IBC 2006 |
| | Lobbies | 100 PSF | IBC 2006 |
| | Corridors (1st Floor) | 100 PSF | IBC 2006 |
| | Corridors (Above 1F) | 80 PSF | IBC 2006 |
| | Operation Rooms | 60 PSF | Drawing G1-2 |
| | Patient Rooms | 40 PSF | Drawing G1-2 |
| | Mechanical | 150 PSF | Drawing G1-2 |
| | Stairs | 100 PSF | Drawing G1-2 |
| **Roof Loads** | | | |
| **Dead Load** | Normal Weight Concrete | 145 PCF | Drawing G1-2 |
| | Steel | Per shape | AISC 13th Edition |
| | Brick Masonry | 40 PSF | MSJC |
| | Superimposed | 10 PSF | ** |
| **Live Load** | Roof Live Load | 20 PSF | Drawing G1-2 |
| | Mechanical | 150 PSF | Drawing G1-2 |
| **Snow Load** | Flat Roof Load | 24 PSF | ASCE 7-08 |
| **Rain Load** | Rain Load | 21 PSF | ASCE 7-08 |

*Includes electrical and telecommunications wiring, ductwork, drop ceiling
**Includes ballasting, waterproofing, insulation

Snow drift loads were to be considered as a loading condition as per ASCE 7-08 however this type of loading was determined to be beyond the scope of this report and therefore neglected and will be discussed in future reports.

### *Lateral Loads*

Lateral loads were calculated as per ASCE 7-08. Although the building is only six stories high, these loads must be considered as a design issue. The wind loads were calculated by referencing parameters from ASCE 7-08, IBC 2006, and the United States Geological Service under the analytical method:

| | |
|---|---|
| - Basic Wind Speed | 90 mph |
| - Direction Factor | 0.85 |
| - Occupancy Category | IV |
| - Importance Factor | 1.15 |

|  |  |
|---|---|
| - Exposure Category | B |
| - Topographic Factor | 1 |
| - Gust Effect Factor | 0.85 |
| - Fundamental Frequency | 6.43 (Rigid Structure) |
| - Peak Factor | 3.4 |
| - Enclosure | Enclosed |

The above listed parameters were used to calculate the wind load in pounds per square feet for the different surfaces of the Hospital:

| **Wind Loads** |  |  |  |  |
|---|---|---|---|---|
|  | ***North to South Wind Pressure*** |  | ***East to West Wind Pressure*** |  |
|  | *Height (ft)* | *Pressure (PSF)* | *Height* | *Pressure (PSF)* |
| **Windward** | 0-15 | 7.9 | 0-15 | 7.9 |
|  | 20 | 8.5 | 20 | 8.5 |
|  | 25 | 8.9 | 25 | 8.9 |
|  | 30 | 9.6 | 30 | 9.6 |
|  | 40 | 10.5 | 40 | 10.5 |
|  | 50 | 11.2 | 50 | 11.2 |
|  | 60 | 11.3 | 60 | 11.3 |
|  | 70 | 11.3 | 70 | 11.3 |
| **Leeward** | All | -8.3 | All | -7.9 |
|  | *Base Shear (kips)* | **362.3** | *Base Shear* | **362.3** |
|  | *Overturning Moment (k-ft)* | **47875.4** | *Overturning Moment (k-ft)* | **47875.4** |
| **Roof** | Windward to 90° | -12.7 | Windward to 90° | -12.7 |
|  | 90°-180° | -7.0 | 90°-180° | -7.0 |
|  | 180° to Leeward | -4.2 | 180° to Leeward | -4.2 |

(Refer to Figure 6 and 7 for Wind Loading Diagram)

The seismic loads were also calculated in a similar fashion, by referencing the aforementioned publications, the following parameters were used:

|  |  |
|---|---|
| - Occupancy Category | IV |
| - Importance Factor | 1.5 |
| - Seismic Category | A |
| - Site Class | C |
| - Spectral Acceleration, Short Period | 0.133 |
| - Spectral Acceleration, 1 Second | 0.052 |
| - Site Coefficient, $F_a$ | 1.2 |
| - Site Coefficient, $F_v$ | 1.7 |
| - R-Factor | 5.0 |

These parameters were used under the equivalent lateral force procedure to calculate the base shear of the building as well as the force acting at each floor level:

| **Seismic Loads** | | |
|---|---|---|
| *Floor* | *Height (ft)* | *$F_x$ (kips)* |
| 1 | 0 | 314.83 |
| 2 | 12 | 340.39 |
| 3 | 24 | 389.23 |
| 4 | 35.5 | 278.90 |
| 5 | 47 | 367.52 |
| 6 | 58.5 | 455.63 |
| Roof | 70 | 314.83 |
| *Seismic Base Shear (kips)* | | **1543.78** |
| *Overturning Moment (k-ft)* | | **33854.8** |

(Refer to Figure 8 for Seismic Loading Diagram)

Upon analyzing the two lateral load types, the wind load will be the critical load in the design process. (See Appendix E for details)

## Structural Design

Please refer to the calculations in Appendix F.
Please refer to Figures 4 and 5 for the plan.

### *Beams*

For the beam analysis, Beam FB601 was taken and studied. This beam is an edge beam supporting a slab on the sixth floor. The existing design was a 24” x 18” reinforced concrete beam with #7 bars as reinforcement. A frame analysis as per ACI 318-08 was conducted for the slab and the beam to calculate the required moment. Through the computations, the existing beam design proved to be more than adequate to resist the loads.

### *Slabs*

The analysis of the slab was done simultaneously with beam FB601 (Figures 4, 5) as per ACI 318-08. The slab is an 8 inch thick slab with dimensions of 30’-4” x 30’-4” and proved more than adequate to carry the required moment.

### *Columns*

Column S8 was analyzed for its structural stability (Figure 4). This column, like many others in the Hospital is a typical 24” x 24” column. During this analysis, a simple assumption was made: a short column. For the analysis, the column was analyzed in two different floors. First on the fifth floor holding up the roof, and another time on the first floor holding up 4 floors above it. Through both of these analyses, the column proved to be adequate to hold the loads.

### *Others*

Structural systems such as the shear walls and the roof were neglected from the analyses due to the interest of Tech 1 but will be visited in the future reports for analysis. Other structural systems such as the composite floor system will be another topic of interest. Further analysis is required for all systems in this report by taking into account lateral loads and secondary effects.

## Conclusion

The Monongalia General Hospital follows a simple plan and structural system. The structural system is primarily reinforced concrete beams, columns, and two-way slabs. The 100 columns are responsible for holding the weights of the floors. The active lateral load resisting system consists of 12 shear walls of varying size. Through the gravity load analysis, the beam, slab, and column were analyzed and proved more than adequate to carry the loads.

The beam and the slab proved to be designed, within the scope of this report; very conservatively providing much more than enough capacity against the required gravity loads it must resist.

A column was analyzed at two floors under the assumption that it was a short column. When analyzed at the fifth floor, the column proved to be too large for the amount of load that it was required to carry. When analyzed at the first floor, the column capacity was reasonable for the loads coming from the floors above.

However consideration must be made that the members were only analyzed against gravity loads and nothing else. In the future reports these members will be revisited and analyzed under more detailed loadings. Shear walls were also neglected from the analysis and these too, will be analyzed in future reports.

# MONONGALIA GENERAL HOSPITAL

## STRUCTURAL CONCEPTS AND EXISTING CONDITIONS REPORT

# APPENDIX A

## PROJECT TEAM

| | | |
|---|---|---|
| **Owner** | **Monongalia General Hospital**<br>1200 J.D. Anderson Dr.<br>Morgantown, WV 26505 | Phone: 304-598-7690<br>Fax: 304-598-7693<br>Website: http://www.monhealthsys.org/ |
| **Architect and Interiors** | **Freeman White, Inc.**<br>8025 Arrowbridge Blvd.<br>Charlotte, NC 28273-5665 | Phone: 704-523-2230<br>Fax: 704-523-2235<br>Website: http://www.freemanwhite.com/ |
| **Civil Engineer** | **Alpha Associates, Inc.**<br>209 Prairie Ave.<br>Morgantown, WV 26502 | Phone: 304-296-8216<br>Fax: 304-296-8216<br>Website: http://www.alphaaec.com/ |
| **Construction Manager** | **Turner Construction Company**<br>Two PNC Plaza, 620 Liberty Ave., 27th Floor<br>Pittsburgh, PA 15222-2719 | Phone: 412-255-5400<br>Fax: 412-255-0249<br>Website: http://www.turnerconstruction.com/ |
| **Geotechnical and Environmental Consultant** | **Potesta Engineers and Environmental Consultants**<br>125 Lakeview Drive<br>Morgantown, WV 26508 | Phone: 304-225-2245<br>Fax: 304-225-2246<br>Website: http://www.potesta.com/ |
| **Mechanical, Electrical, and Plumbing** | **Freeman White, Inc.**<br>2300 Rexwoods Dr., Suite 300<br>Raleigh, NC 27607 | Phone: 919-782-0699<br>Fax: 919-783-0139<br>Website: http://www.freemanwhite.com/ |
| **Structural Engineer** | **Atlantic Engineering Services**<br>650 Smithfield St., Suite 1200<br>Pittsburgh, PA 15222 | Phone: 412-338-9000<br>Fax: 412-338-0051<br>Website: http://www.aespj.com/ |

# MONONGALIA GENERAL HOSPITAL

## STRUCTURAL CONCEPTS AND EXISTING CONDITIONS REPORT

# APPENDIX B

## FIGURES

Figure 1: Hospital Divided in Four Quads

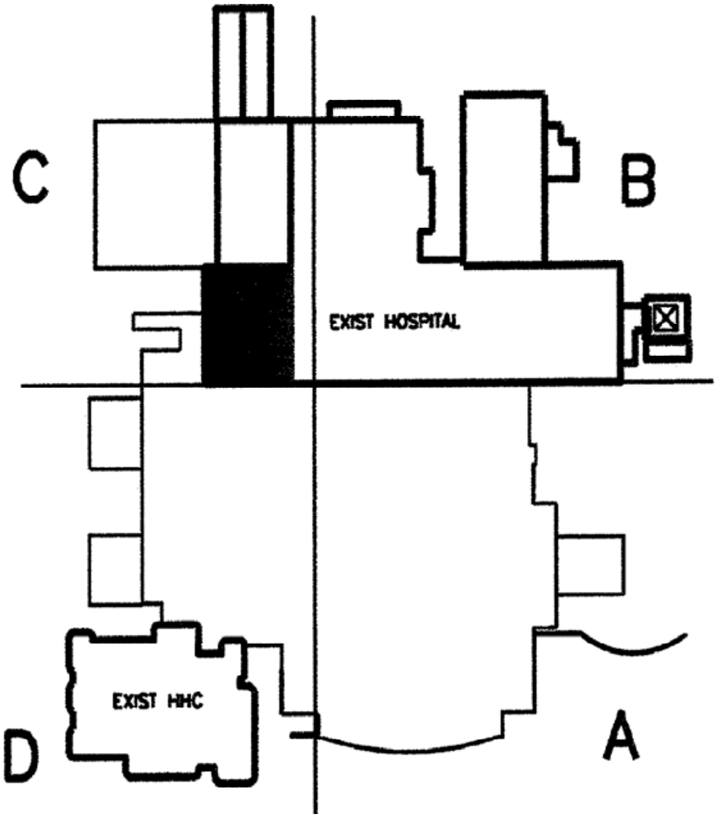
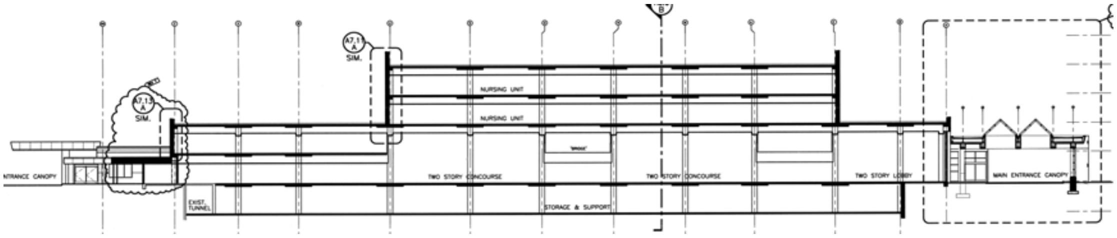
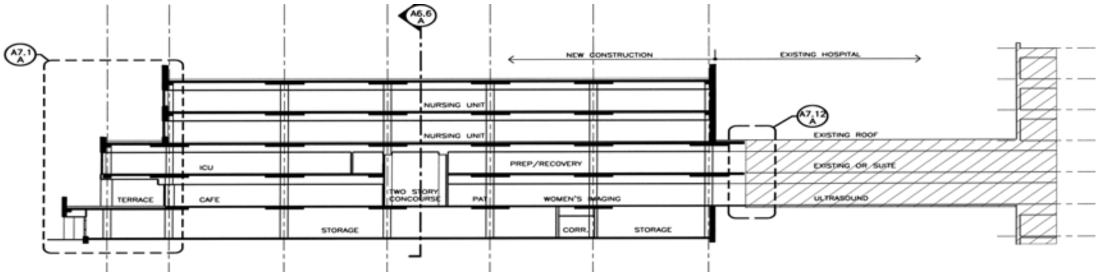


Figure 2: Cross Section of the Monongalia General Hospital



West Section



South Section

Figure 3: Location of Shear Walls (Colored in blue)

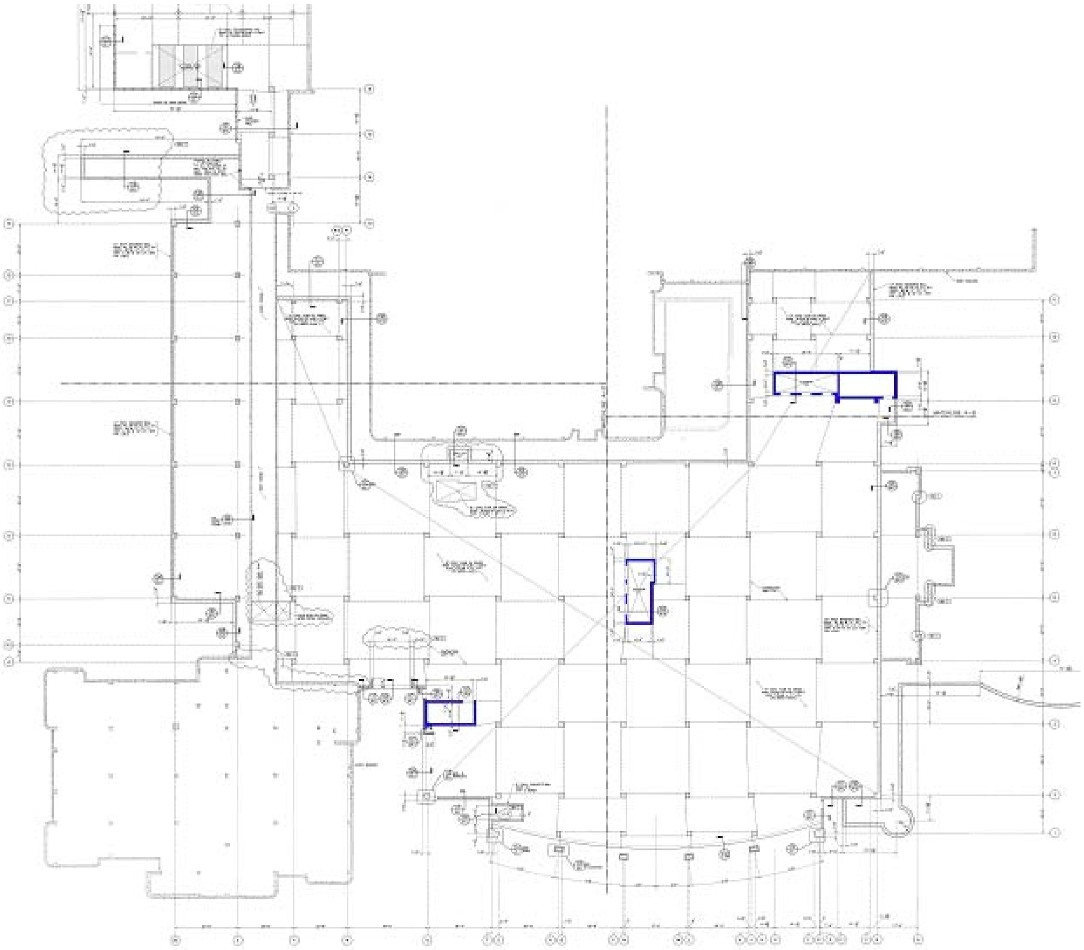


Figure 4: Typical Framing Plan (Taken from Quad A)

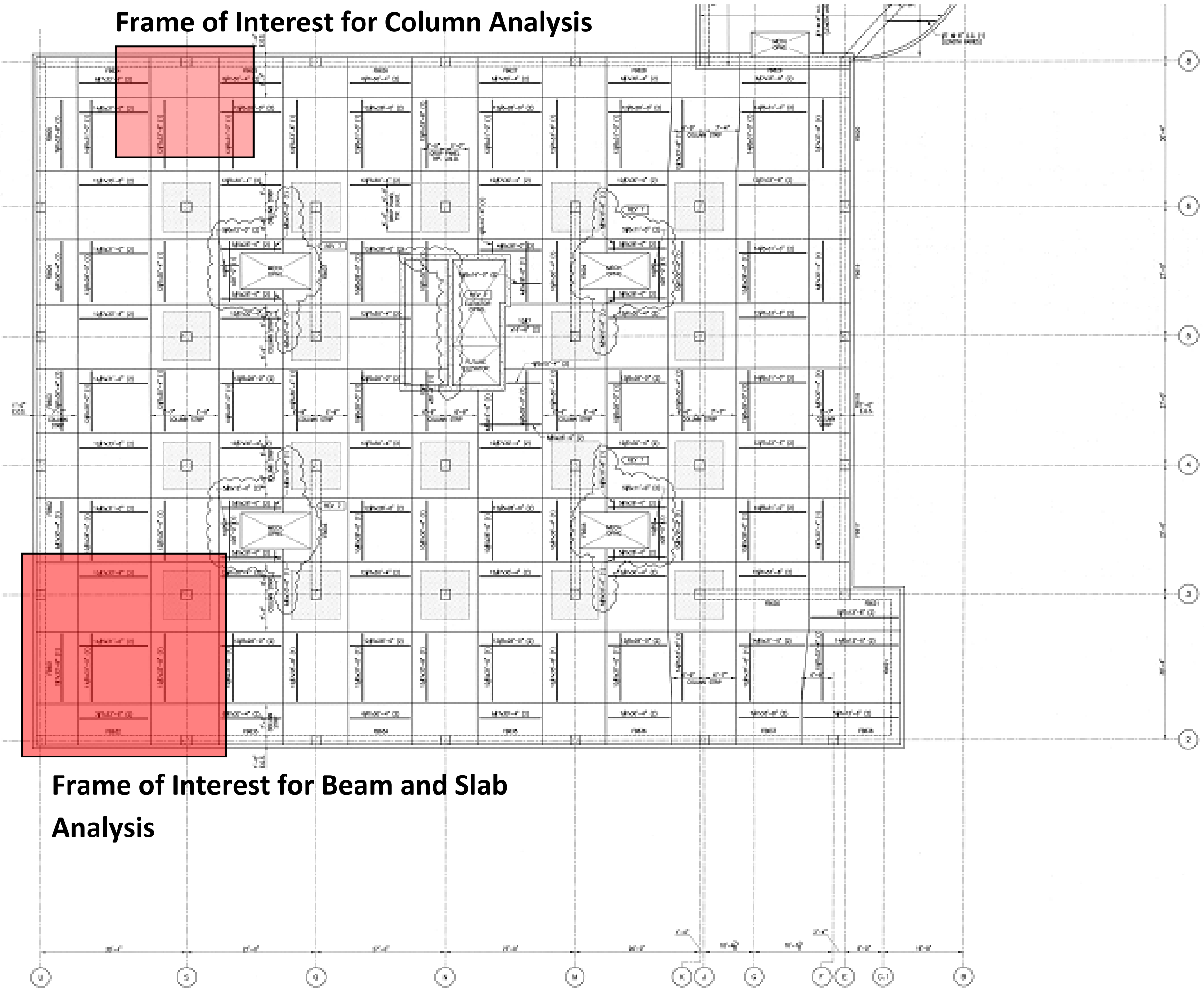
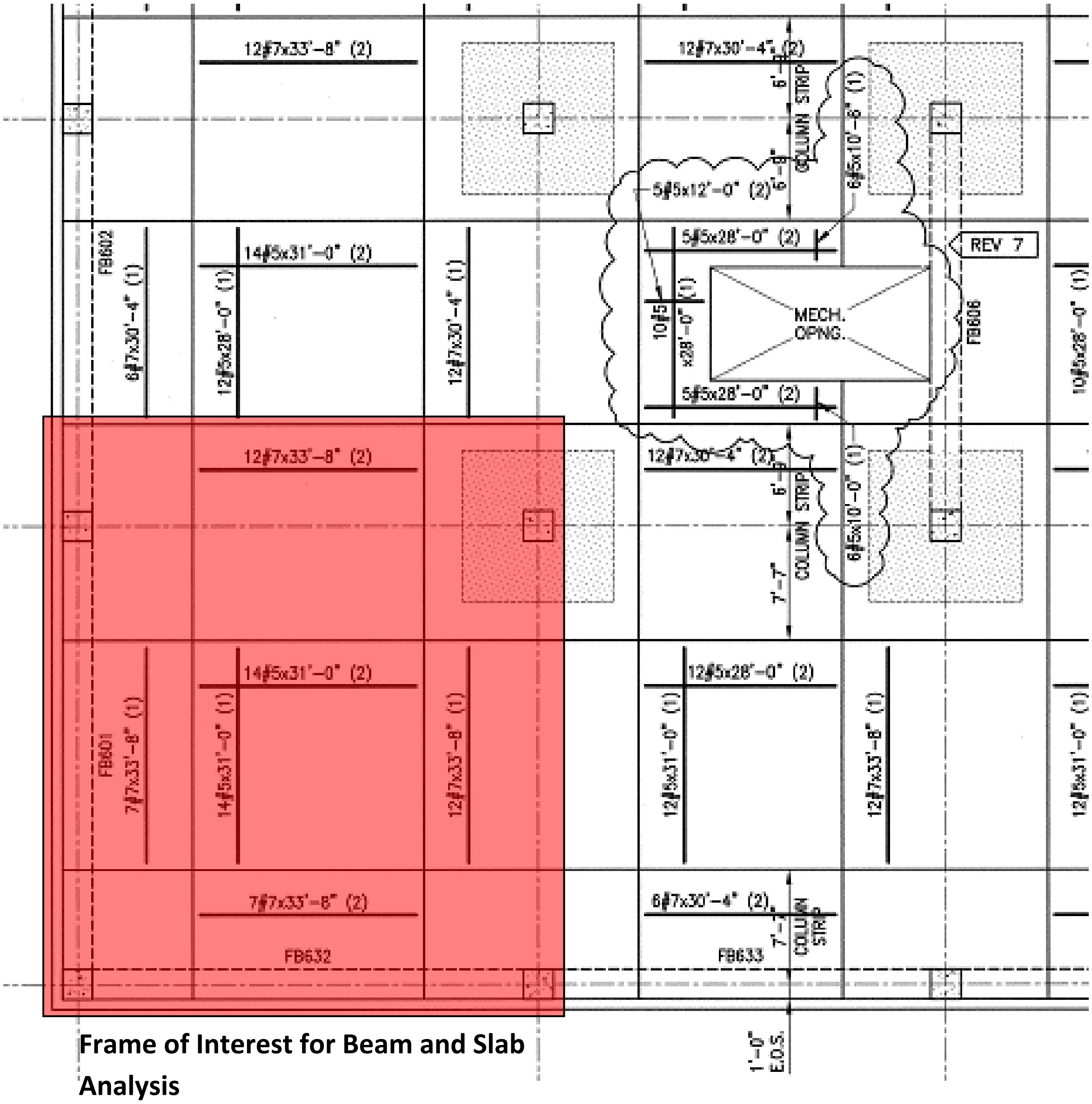


Figure 5: Typical Framing Plan (Taken from Quad A)



Frame of Interest for Beam and Slab Analysis

Figure 6: Wind Loading – North to South

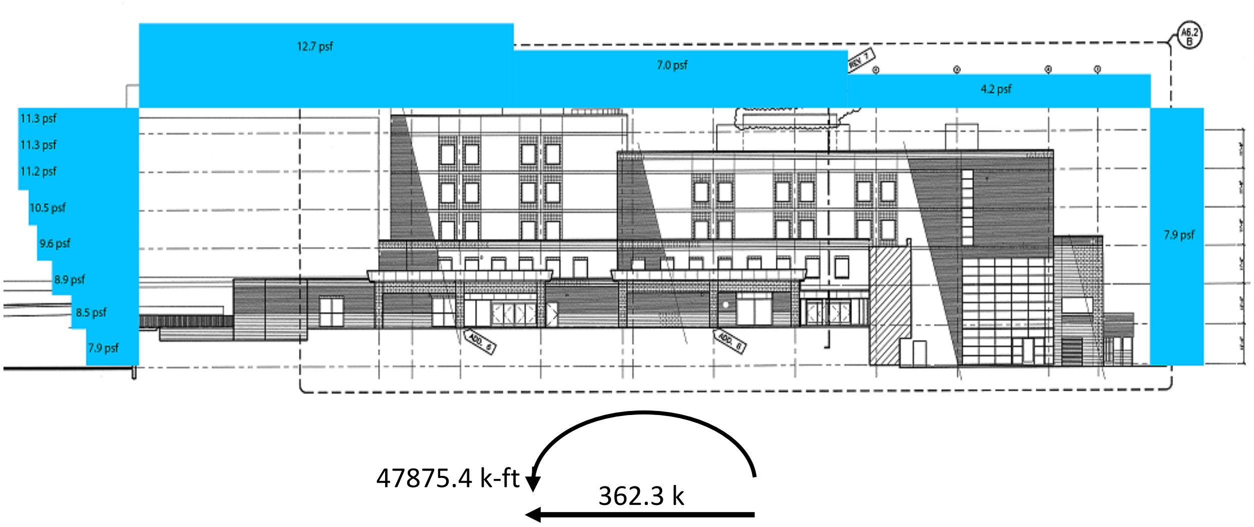


Figure 7: Wind Loading – East to West

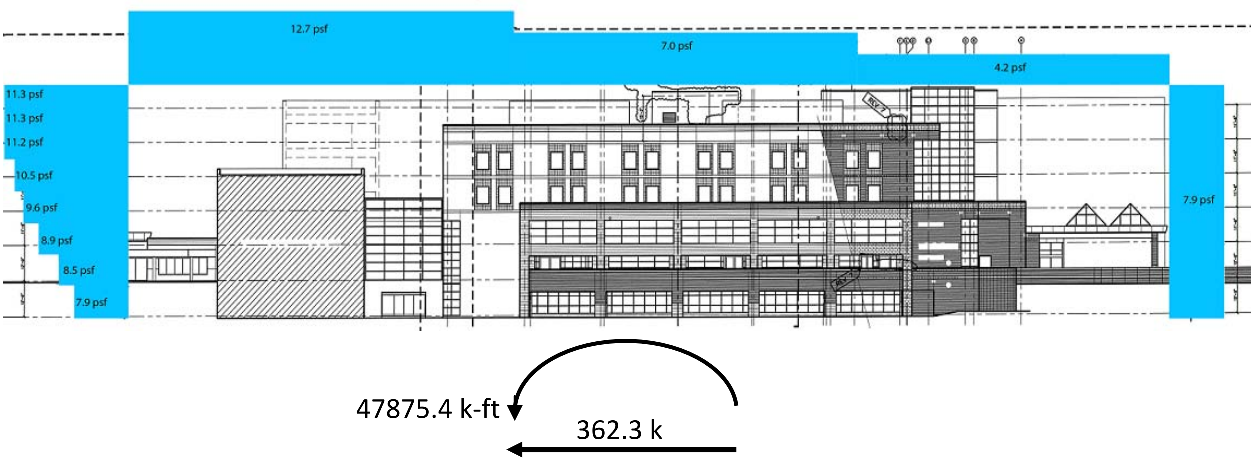
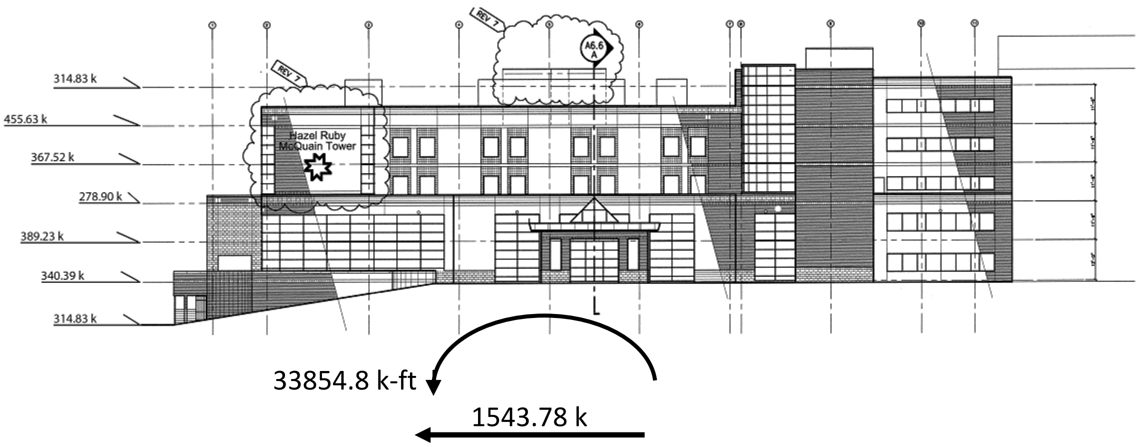


Figure 8: Seismic Loading



# MONONGALIA GENERAL HOSPITAL

## STRUCTURAL CONCEPTS AND EXISTING CONDITIONS REPORT

# APPENDIX C

## PHOTOGRAPHS

Photograph 1: View from South-East

Photograph 2: Aerial Photo of the Monongalia General Hospital

Photograph 3: View from South-East showing the brick façade and curtain walls

# MONONGALIA GENERAL HOSPITAL

## STRUCTURAL CONCEPTS AND EXISTING CONDITIONS REPORT

# APPENDIX D

## CODES

| **Type** | **Designed with** | **Analyzed with** |
|---|---|---|
| Building | IBC 2000 | IBC 2006 |
| Structural | IBC 2003 | IBC 2006 |
| Plumbing | IPC 2000 | - |
| Mechanical | IMC 2000 | - |
| Electrical | NFPA 1999 | - |
| Fire Safety | WV Fire Code 2002 | - |
| Accessibility | ADA 1994 | - |
| Energy | IEGC 2000 | - |
| Fuel Gas | IFGC 2000 | - |
| Sprinkler | NFPA 13 | - |

Construction Type: 1-A

Primary Occupancy: Institutional I-2

At the point of the project design phase, the building codes that were effective in Morgantown, WV are the ones listed above under the “Designed with” column. Today, the city of Morgantown has adopted the latest codes and ordinances.

# MONONGALIA GENERAL HOSPITAL

## STRUCTURAL CONCEPTS AND EXISTING CONDITIONS REPORT

# APPENDIX E

## LATERAL LOADS

## Wind Load

| Wind Load Criteria | |
|---|---|
| Wind Speed (mph) | 90 |
| Direction Factor | .85 |
| Occupancy Category | IV |
| Importance Factor | 1.15 |
| Exposure Category | B |
| Topographic Factor | 1.0 |
| Gust Effect Factor | 0.85 |
| Fundamental Frequency | 6.430 (Rigid) |
| Peak Factor | 3.4 |
| Peak Factor – Resonant Response | 4.61 |
| c | 0.3 |
| l | 320 |
| ε | 0.33 |
| b | 0.45 |
| α | 0.25 |
| β | 1 |
| L (ft) | 550 |
| B (ft) | 550 |

| Wind Load-East to West | | | | |
|---|---|---|---|---|
| **Location** | **Height (ft)** | **$K_z$** | **$q_z$** | **$p_z$ (psf)** |
| Windward | 15 | 0.57 | 11.6 | 7.9 |
| | 20 | 0.62 | 12.6 | 8.5 |
| | 30 | 0.7 | 14.2 | 9.6 |
| | 40 | 0.76 | 15.4 | 10.5 |
| | 50 | 0.81 | 16.4 | 11.2 |
| | 60 | 0.818 | 16.6 | 11.3 |
| | 70 | 0.818 | 16.6 | 11.3 |
| Leeward | all | 0.96 | 19.5 | -8.3 |
| Roof | 58 | - | 16.6 | -12.7 |
| | 58 | - | 16.6 | -7.0 |
| | 58 | - | 16.6 | -4.2 |

| **Wind Load-East to West (Story Force, Shear, and Overturning Moment)** | | | |
|---|---|---|---|
| *Floor* | *Story Force (k)* | *Story Shear (k)* | *Overturning Moment (k-ft)* |
| 1 | 45.5 | **362.3** | **47875.36** |
| 2 | 47.5 | 316.9 | 42471.99 |
| 3 | 50.7 | 269.4 | 36158.79 |
| 4 | 53.0 | 218.7 | 28097.39 |
| 5 | 55.0 | 165.7 | 19351.64 |
| 6 | 55.3 | 110.7 | 6640.292 |
| Roof | 55.3 | 55.3 | 3873.504 |

(See Figure 6 for Wind Loading Diagram)

| **Wind Load-North to South** | | | | |
|---|---|---|---|---|
| **Location** | **Height (ft)** | **$K_z$** | **$q_z$** | **$p_z$ (psf)** |
| Windward | 15 | 0.57 | 11.6 | 7.9 |
| | 20 | 0.62 | 12.6 | 8.5 |
| | 30 | 0.7 | 14.2 | 9.6 |
| | 40 | 0.76 | 15.4 | 10.5 |
| | 50 | 0.81 | 16.4 | 11.2 |
| | 60 | 0.818 | 16.6 | 11.3 |
| | 70 | 0.818 | 16.6 | 11.3 |
| Leeward | all | 0.96 | 19.5 | -7.9 |
| Roof | 58 | - | 16.6 | -12.7 |
| | 58 | - | 16.6 | -7.0 |
| | 58 | - | 16.6 | -4.2 |

| **Wind Load-North to South (Story Force, Shear, and Overturning Moment)** | | | |
|---|---|---|---|
| *Floor* | *Story Force (k)* | *Story Shear (k)* | *Overturning Moment (k-ft)* |
| 1 | 45.5 | **362.3** | **47875.36** |
| 2 | 47.5 | 316.9 | 42471.99 |
| 3 | 50.7 | 269.4 | 36158.79 |
| 4 | 53.0 | 218.7 | 28097.39 |
| 5 | 55.0 | 165.7 | 19351.64 |
| 6 | 55.3 | 110.7 | 6640.292 |
| Roof | 55.3 | 55.3 | 3873.504 |

(See Figure 7 for Wind Loading Diagram)

## Seismic Load

| **Seismic Criteria** | |
|---|---|
| Occupancy Category | IV |
| Importance Factor | 1.500 |
| Seismic Category | A |
| Site Class | C |
| Spectral Acceleration for Short Periods (Ss) | 0.133 |
| Spectral Acceleration for 1 Second Periods (S1) | 0.052 |
| Site Coefficient, Fa | 1.200 |
| Site Coefficient, Fv | 1.700 |
| Seismic Design Category | |
| R Factor | 5.000 |
| $S_{MS}$ | 0.160 |
| $S_{M1}$ | 0.088 |
| $S_{DS}$ | 0.106 |
| $S_{D1}$ | 0.059 |
| Cs | 0.032 |
| Total Dead Load per Floor (psf) | 80 |
| Snow Load (psf) | 24 (< 30, Neglect) |
| Wall Load (psf) | 47 |
| Area ($ft^2$) | 92,086 (1st Floor) |
| | 97,102 (2nd Floor) |
| | 80,882 (3rd Floor) |
| | 53,833 (4th Floor) |
| | 53,554 (5th Floor) |
| | 53,554 (6th Floor) |
| | 28,538 (Roof) |
| Perimeter (ft) | 1900 |

| **Seismic Loads Distributed per Floor** | | | | |
|---|---|---|---|---|
| *Floor* | *Height (ft.)* | *Weight (Kips)* | *Cvx* | *Fx (kips)* |
| Roof | 70 | 1115.96 | 0.20 | 314.83 |
| 6 | 58.5 | 5924.01 | 0.30 | 455.63 |
| 5 | 47.0 | 5947.62 | 0.24 | 367.52 |
| 4 | 35.5 | 5975.52 | 0.18 | 278.90 |
| 3 | 24.0 | 8694.82 | 0.25 | 389.23 |
| 2 | 12 | 10609.08 | 0.22 | 340.39 |
| 1 | 0 | 10097.11 | 0.20 | 314.83 |
| Total Weight | | **48364.124** | Total Shear | **483.64124** |
| Overturning Moment (k-ft) | | **33854.8** | Base Shear | **1543.78** |

(See Figure 8 for Loading Diagram)

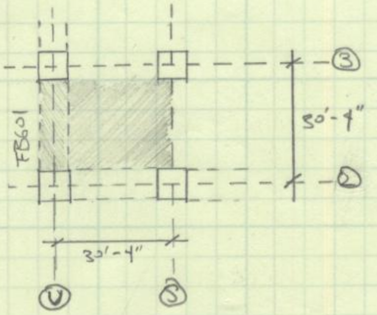
# MONONGALIA GENERAL HOSPITAL

## STRUCTURAL CONCEPTS AND EXISTING CONDITIONS REPORT

# APPENDIX F

## SPOT CHECKS

BEAM AND SLAB ANALYSIS, FRAME ANALYSIS.



$f'_c$ = 5000 psi
$f_y$ = 60000 psi

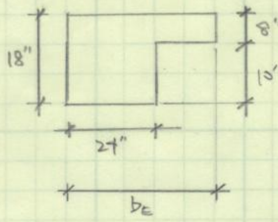
- FIND $M_o$, TOTAL FACTORED MOMENT.

$$M_o = \frac{w_u l_2 l_n^2}{8}$$

$$\Rightarrow w_u = 1.2\left[\left(\frac{8''}{12''/ft}\right)(145PCF) + 20PSF\right] + 1.6(80PSF) = 268\ PSF$$

$$M_o = \frac{(0.268KSF)\left(\frac{30.333'}{2}\right)(30.333' - 2')^2}{8} = 407.86\ k\cdot ft$$

- DETERMINE FLEXURAL STIFFNESS RATIO, $\alpha$.



$$b_E = b_w + h_w < b_w + 4t$$

$$= 24'' + 10'' < 24'' + 4(8'')$$

$$= 34'' < 56'' \quad (USE\ b_E = 34'')$$

$$K = \frac{1 + (b_E/b_w - 1)(t/h)\left[4 - 6(t/h) + 4(t/h)^2 + (b_E/b_w - 1)(t/h)^3\right]}{1 + (b_E/b_w - 1)(t/h)}$$

$$\Rightarrow \frac{b_E}{b_w} = \frac{34''}{24''} = 1.417$$

$$\frac{t}{h} = \frac{8''}{18''} = 0.444$$

→ CONT'D

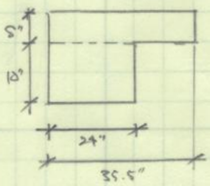
$$k = \frac{1+(1.417-1)(0.444)\left[4-6(0.444)+4(0.444)^2+(1.417-1)(0.444)^3\right]}{1+(1.417-1)(0.444)} = 1.18$$

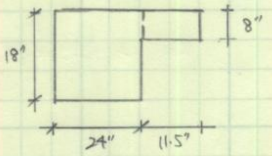
$$I_B = \frac{k \cdot b_w \cdot h^3}{12} = \frac{(1.18)(24'')(18'')^3}{12} = 13763.5 in^4$$

$$I_s = \frac{l_2 \cdot t^3}{12} = \frac{(\frac{30.355'}{2})(12''/ft)(8'')^3}{12} = 7765.25 in^4$$

$$\alpha = \frac{I_B}{I_s} = \frac{13763.5 in^4}{7765.25 in^4} = 1.77.$$

- DETERMINE TORSION CONSTANT, C.





$$C = \Sigma\left(1-0.63\frac{x}{y}\right)\left(\frac{x^3 y}{3}\right) \; ; \; x<y.$$

$$C_1 = \left(1-0.63\frac{8''}{35.5''}\right)\left(\frac{(8'')^3(35.5'')}{3}\right) + \left(1-0.63\frac{10''}{24''}\right)\left(\frac{(10'')^3(24'')}{3}\right)$$

$$= 11098.5 in^4$$

$$C_2 = \left(1-0.63\frac{18''}{24''}\right)\left(\frac{(18'')^3(24'')}{3}\right) + \left(1-0.63\frac{8''}{11.5''}\right)\left(\frac{(8'')^3(11.5'')}{3}\right)$$

$$= 25713.5 in^4 \; *$$

$\therefore$ $C = 25713.5 in^4$

- DISTRIBUTION OF MOMENTS
  - LONGITUDINAL DISTRIBUTION, (AS PER ACI318-08, SECTION 13.6.3.3)

$$M^-_{EXT} = 0.16(407.86 k \cdot ft) = 65 k \cdot ft$$

$$M^+_{EXT} = 0.57(407.86 k \cdot ft) = 232.48 k \cdot ft$$

$$M^-_{INT} = 0.7(407.86 k \cdot ft) = 285.5 k \cdot ft.$$

  - TRANSVERSE DISTRIBUTION (AS PER ACI318-08, SECTION 13.6.4)

$$\beta_t = \frac{C}{2 I_s} = \frac{25713 in^4}{2(7765.25 in^4)} = 1.655$$

→ CONT'D.

$\alpha \cdot \frac{l_2}{l_1} = 1.77\left(\frac{30.333'}{30.333'}\right) = 1.77 > 1.0 \Rightarrow$ 85% OF MOMENT GOES TO BEAM.

- INTERIOR NEGATIVE MOMENT. (AS PER ACI 318-08, SECTION 13.6.4.1)

- 285 k·ft
  - 75% TO CS (-213.75 k·ft)
    - 85% TO BEAM (-181.69 k·ft)
    - 15% TO SLAB (-32.1 k·ft)
  - 25% TO MS (-71.25 k·ft)

- EXTERIOR NEGATIVE MOMENT (AS PER ACI 318-08, SECTION 13.6.4.2)

$\beta_t = 1.665 \Rightarrow$ INTERPOLATE

| | $l_2/l_1$ | 1.0 |
|---|---|---|
| | $\beta_t = 0$ | 100 |
| $\alpha\frac{l_2}{l_1} \geq 1.0$ | $\beta_t = 1.665$ | $\boxed{x}$ |
| | $\beta_t = 2.0$ | 75 |

$$\Rightarrow \frac{1.665 - 0}{2.0 - 0} = \frac{x - 100}{75 - 100}$$

$x = 83.45\%$.

- 65 k·ft
  - 83.45% TO CS (-54.24 k·ft)
    - 85% TO BEAM (-46.10 k·ft)
    - 15% TO SLAB (-8.14 k·ft)
  - 16.55% TO MS (-10.76 k·ft)

- POSITIVE FACTORED MOMENT (AS PER ACI 318-08, SECTION 13.6.4.4)

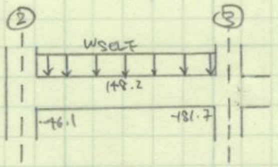
+ 232 k·ft
  - 75% TO CS (174.36 k·ft)
    - 85% TO BEAM (148.2 k·ft)
    - 15% TO SLAB (26.16 k·ft)
  - 25% TO MS (58.12 k·ft)

- SUMMARY

| | $M^-_{EXT}$ | $M^+_{EXT}$ | $M^-_{INT}$ |
|---|---|---|---|
| TOTAL | -65 | 232. | -285 |
| BEAM | -46.1 | 148.2 | -181.69 |
| CS | -8.14 | 26.16 | -32.1 |
| MS | -10.76 | 58.12 | -71.25 |

*END OF FRAME ANALYSIS*

ANALYSIS OF BEAM.



$f'_c = 5000\,psi$

$f_y = 60000\,psi$

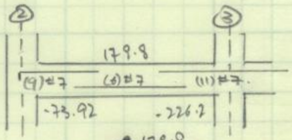
$$W_{SELF} = \left(\frac{18" \times 24"}{144\,in^2/ft^2}\right)(145\,PCF) = 462\,PLF.$$

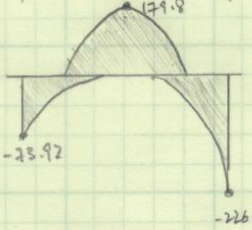
- MOMENTS ON BEAM

$$M^{-\prime}_{EXT} = -46.1\,k\cdot ft + (1.2)\frac{(0.462\,KLF)(30.333' - 2')^2}{-16} = -73.92\,k\cdot ft$$

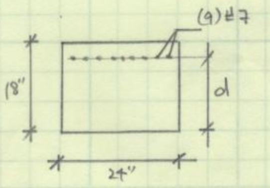
$$M^{+\prime}_{EXT} = 148.2\,k\cdot ft + (1.2)\frac{(0.462\,KLF)(30.333' - 2')^2}{+14} = 179.8\,k\cdot ft$$

$$M^{-\prime}_{INT} = 181.7\,k\cdot ft + (1.2)\frac{(0.462\,KLF)(30.333' - 2')^2}{-10} = 226.2\,k\cdot ft.$$





- CHECK SECTION AT ②



$$d = 18" - 1.5" - \tfrac{3}{8}" - 7/8"/2 = 15.69"$$

$$A_S = (9)(0.6\,in^2) = 5.4\,in^2$$

- CHECK $A_{S,MIN}$ AND $A_{S,MAX}$.

$$A_{S,MIN} \geq \begin{cases} \dfrac{3\sqrt{f'_c}\cdot b\cdot d}{f_y} = \dfrac{3\sqrt{5000\,psi}\,(24")(15.69")}{60000\,psi} = 1.53\,in^2 \;* \\[2ex] \dfrac{200\,b\cdot d}{f_y} = \dfrac{200(24")(15.69")}{60000\,psi} = 1.26\,in^2 \end{cases}$$

$A_S > A_{S,MIN}$ (ok)

→ CONT'D.

$$\rho_{MAX} = 0.85\beta_1 \frac{f'_c}{f_y} \cdot \frac{\varepsilon_u}{\varepsilon_u + 0.004} = (0.85)(0.85)\frac{5ksi}{60ksi} \cdot \frac{0.003}{0.003+0.004} = 0.0258$$

$A_{S,MAX} = \rho_{MAX}\, bd = (0.0258)(24'')(15.69'') = 9.72in^2$

$A_S < A_{S,MAX}$ (ok)

- DETERMINE $M_n$ (ASSUME $f_s \geq f_y$)

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{(5.4in^2)(60ksi)}{0.85(5ksi)(24'')} = 3.17''$$

$$c = \frac{a}{\beta_1} = \frac{3.17''}{0.85} = 3.73''$$

- CHECK $\varepsilon_s > \varepsilon_y$

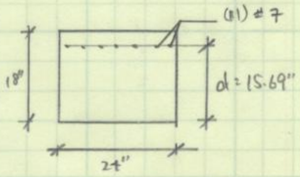
$$\varepsilon_s = \frac{\varepsilon_u}{c}(d-c) = \frac{0.003}{3.73''}(15.69'' - 3.73'') = 0.0096 > \varepsilon_y$$

$\Rightarrow \varepsilon_t > 0.005$, $\phi = 0.9$

$$\phi M_n = \phi A_s f_y (d - \frac{a}{2}) = 0.9(5.4in^2)(60ksi)(15.69in^2 - \frac{3.17''}{2}) = 4113.02k \cdot in.$$

$\therefore \phi M_n = 342.8k \cdot ft > 73.92 k \cdot ft$ (GOOD)

- CHECK SECTION AT ③



$A_S = 6.61n^2.$

- CHECK AS,MIN AND AS,MAX.

$A_{S,MIN} < A_S$ (ok)

$A_{S,MAX} > A_S$ (ok)

- DETERMINE $M_n$ (ASSUME $f_s \geq f_y$)

$$a = \frac{(6.61n^2)(60ksi)}{0.85(5ksi)(24'')} = 3.88''$$

$$c = \frac{3.88''}{0.85} = 4.57''$$

→ CONT'D.

- CHECK $\varepsilon_s > \varepsilon_y$

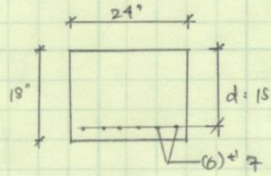
$\varepsilon_s = \frac{0.003}{4.57''}(15.69'' - 4.57'') = 0.0073 > \varepsilon_y$

$\Rightarrow \varepsilon_T > 0.005,\ \phi = 0.9$

$\phi M_n = 0.9(6.6\,in^2)(60ksi)(15.69'' - \frac{3.88''}{2}) = 4901\,k \cdot in.$

$\therefore \phi M_n = 408.4\,k \cdot ft > 226.2\,k \cdot ft$ (GOOD)

- CHECK SECTION AT MIDSPAN (ASSUME $f_s \geq f_y$)



$A_s = 3.6\,in^2$

- CHECK $A_{s,MIN}$ AND $A_{s,MAX}$

$A_{s,MIN} < A_s$ (OK)

$A_{s,MAX} > A_s$ (OK)

- DETERMINE $M_n$ (ASSUME $f_s \geq f_y$)

$a = \frac{(3.6\,in^2)(60ksi)}{0.85(5ksi)(24'')} = 2.12''$

$c = \frac{2.12''}{0.85} = 2.49''$

- CHECK $\varepsilon_s > \varepsilon_y$

$\varepsilon_s = \frac{0.003}{2.49''}(15.69'' - 2.49'') = 0.0161 > \varepsilon_y$

$\Rightarrow \varepsilon_T > 0.005,\ \phi = 0.9$

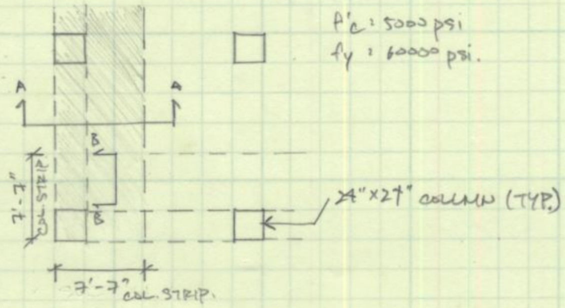
$\phi M_n = 0.9(3.6\,in^2)(60ksi)(15.69'' - \frac{2.12''}{2}) = 2709.9\,k \cdot in$

$\therefore \phi M_n = 225.8\,k \cdot ft > 179.8\,k \cdot ft$ (GOOD)

*END OF BEAM ANALYSIS*

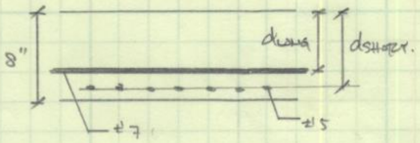
ANALYSIS of SLAB: COLUMN STRIP.

$f'_c = 5000$ psi
$f_y = 60000$ psi.



- CHECK SECTION A-A.

$b = (7.58' \times 12"/ft) - 24" = 66.96"$



$d_{SHORT} = 8" - \frac{3}{4}" - \frac{1}{2}(\frac{5}{8}") = 6.94"$

$d_{LONG} = d_{eff} = d_{SHORT} - (\frac{5}{8})' = 6.32"$

- $\rho_{MAX}$

FROM TABLE A5.a (TEXT, DESIGN of CONCRETE STRUCTURES)

$\rho_{MAX} = 0.0243$

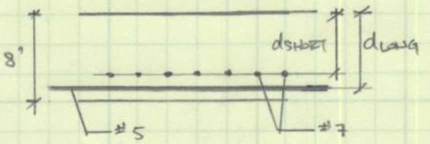
- DETERMINE $M_u$

$\phi M_n = \phi \rho f_y b d^2 (1 - 0.59 \frac{\rho f_y}{f'c})$

$= 0.9(0.0243)(60ksi)(66.96")(6.06")^2(1 - 0.59 \frac{(0.0243)(60ksi)}{5ksi}) = 2671.6 k \cdot in$

$\therefore \phi M_n = 222.6 k \cdot ft > M_{u_{MAX}} = 32.1 k \cdot ft$ (GOOD)

- CHECK SECTION B-B.



$d_{LONG} = d_{SHORT, A-A} = d_{eff} = 6.94"$

→ CONT'D.

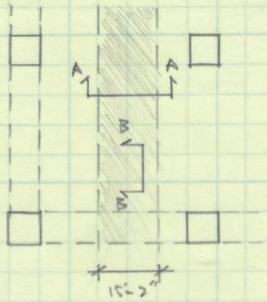
- DETERMINE $M_n$

$$\phi M_n = 0.9(0.0243)(60ksi)(66.96")(6.32")^2\left(1-0.59\frac{(0.0243)(60ksi)}{5ksi}\right) = 2905.7\ k\cdot in$$

$$\therefore \phi M_n = 242.1\ k\cdot ft > M_{u,MAX} = 82.1\ k\cdot ft\ (GOOD)$$

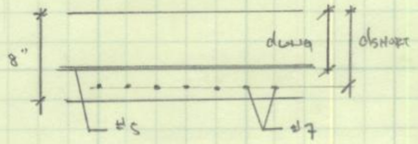
*END OF COLUMN STRIP ANALYSIS*

ANALYSIS OF SLAB: MIDDLE STRIP.



$f'_c = 5000$ psi
$f_y = 60000$ psi

- CHECK SECTION A-A.



$d_{SHORT} = 8'' - \frac{3}{4}'' - \frac{1}{2}\left(\frac{7}{8}''\right) = 6.8125''$

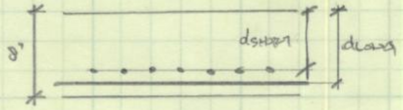
$d_{LONG} = d_{EFF} = d_{SHORT} - \left(\frac{7}{8}''\right) = 5.94''$

- DETERMINE $M_n$

$\phi M_n = 0.9(0.0243)(60ksi)(15.167' \times 12''/ft)(5.94'')^2(1 - 0.59\frac{(0.0243)(60ksi)}{5ksi}) = 6976.9k \cdot in$

$\therefore \phi M_n = 581.4k \cdot ft > M_{u,max} = 71.25k \cdot ft$ (GOOD)

- CHECK SECTION B-B



$d_{LONG} = d_{SHORT, A-A} = 6.8125''$

- DETERMINE $M_n$

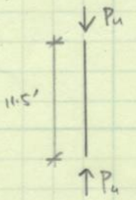
$\phi M_n = 0.9(0.0243)(60ksi)(15.167' \times 12''/ft)(6.8125'')^2(1 - 0.59\frac{(0.0243)(60ksi)}{5ksi}) = 9177 k \cdot in$

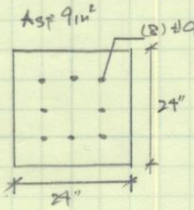
$\therefore \phi M_n = 764.8k \cdot ft > M_{u,max} = 71.25k \cdot ft$ (GOOD)

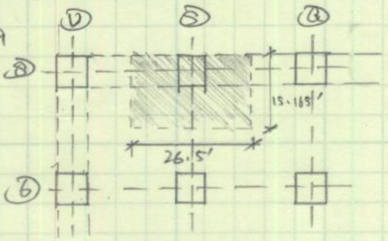
*END OF MIDDLE STRIP ANALYSIS*

ANALYSIS OF COLUMN

- COLUMN 38 ON 5TH FLOOR (ASSUMING SHORT COLUMN)







$f'_c$ = 5000 psi
$f_y$ = 60000 psi

- LOADS

$$L = (20\ \text{PSF}) + (150\ \text{PSF}) = 170\ \text{PSF} \Rightarrow > 100\ \text{PSF}, \text{NO REDUCTION.}$$

MECHANICAL
ROOF LIVE

$$D = 20\ \text{PSF}\ ,\quad S = 24\ \text{PSF}$$

$$P_u = \frac{[1.2(20\ \text{PSF}) + 1.6(170\ \text{PSF}) + 0.5(24\ \text{PSF})](26.5' \times 15.165')}{1000\ \text{lb/KIP.}} = 123.8\text{K.}$$

- DETERMINE $P_n$.

$$\phi P_n = 0.8\phi[0.85 f'_c(A_g - A_{ST}) + f_y A_{ST}]$$

$$= 0.8(0.65)[0.85(5\text{ksi})[(24'' \times 24'') - 8\text{in}^2] + (60\text{ksi})(8\text{in}^2)]$$

$\therefore \phi P_n = 1504.9\text{K} > P_u$ (GOOD)

- COLUMN 38 ON FIRST FLOOR (ASSUMING SHORT COLUMN)

- LOADS

$$L = 170\ \text{PSF} + 4(100\ \text{PSF} + 100\ \text{PSF} + 40\ \text{PSF}) = 1130\ \text{PSF.}$$

LOBBIES
PUBLIC AREA
PATIENT ROOMS

$$D = 5(20\ \text{PSF}) = 100\ \text{PSF}\ ,\quad S = 24\ \text{PSF}$$

$$P_u = \frac{[1.2(100\ \text{PSF}) + 1.6(1130\ \text{PSF}) + 0.5(24\ \text{PSF})](26.5' \times 15.165')}{1000\ \text{lb/K}} = 779.6\text{k.}$$

$\phi P_n = 1504.9\text{k} > P_u$ (GOOD)

* END OF COLUMN ANALYSIS *

# MONONGALIA GENERAL HOSPITAL

## STRUCTURAL CONCEPTS AND EXISTING CONDITIONS REPORT

# APPENDIX G

## REFERENCES

## References

The following resources were utilized or considered in the writing of this report.

*Construction Documents*

- Volume 1 – *Architecture, Interiors, Food Services* by Freeman White, Inc.
  - A6-1
  - G1-2
- Volume 2 – *Structures* by Atlantic Engineering Services
  - S2-0
  - S2-4AD Bottom
  - S2-4AD Top
  - S3-0
  - S3-1
  - S4-0
  - S4-1
  - S4-4
  - S8-0
- *Geotechnical Report* by Potesta Engineers and Environmental Consultants.

*Photographs*

- Photograph 1 and 3 taken by the Turner Construction Company.

*Publications*

- ACI 318-08, *Building Code Requirements for Structural Concrete* by the American Concrete Institute.
- AISC 13th Edition, *Steel Construction Manual* by the American Institute of Steel Construction.
- ASCE/SEI 7-05, *Minimum Design Loads for Buildings and Other Structures* by the American Society of Civil Engineers.
- *Design of Concrete Structures* 13th Edition, by Nilson, et. al.
- IBC 2006, by the International Code Committee.
- TMS 402/ACI 530/ASCE 5, *Building Code Requirements and Specification for Masonry Structures* by the Masonry Standards Joint Committee.

*Websites*

- Monongalia General Hospital, <http://www.monhealthsys.org>.
- United States Geological Services, <http://earthquake.usgs.gov/research/hazmaps/design/>.