# MONONGALIA GENERAL HOSPITAL

## BLAST AND PROGRESSIVE
## COLLAPSE ANALYSIS

# 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:<br>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:<br>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:<br>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:<br>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:<br>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 Website:<br>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:<br>http://www.aespj.com/ |

# MONONGALIA GENERAL HOSPITAL

## BLAST AND PROGRESSIVE COLLAPSE ANALYSIS

# APPENDIX B

## FIGURES

Figure B 1: Hospital Divided in Four Quads

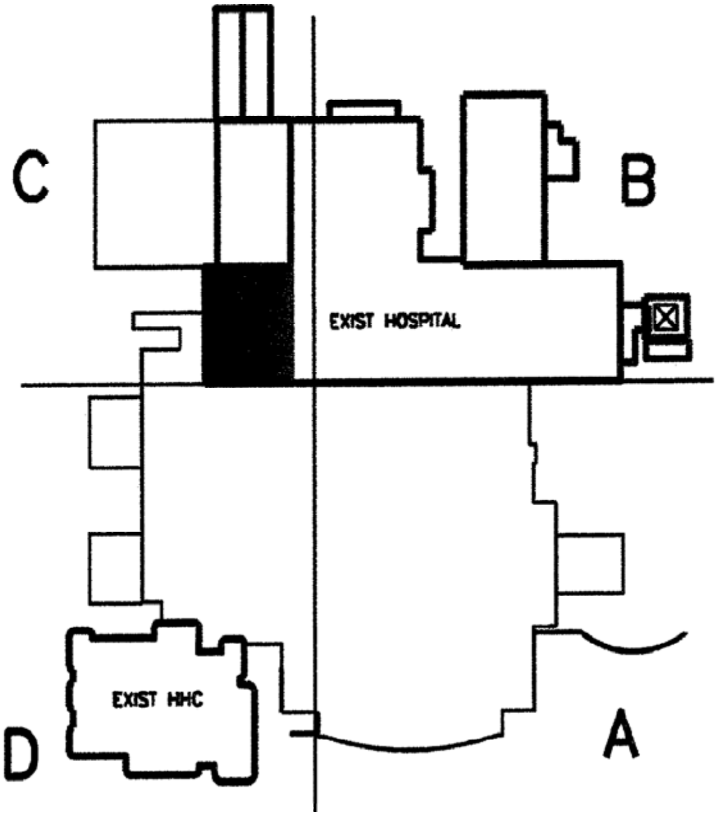
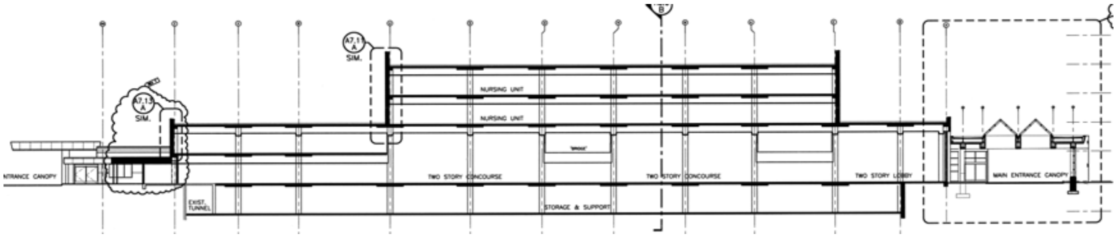
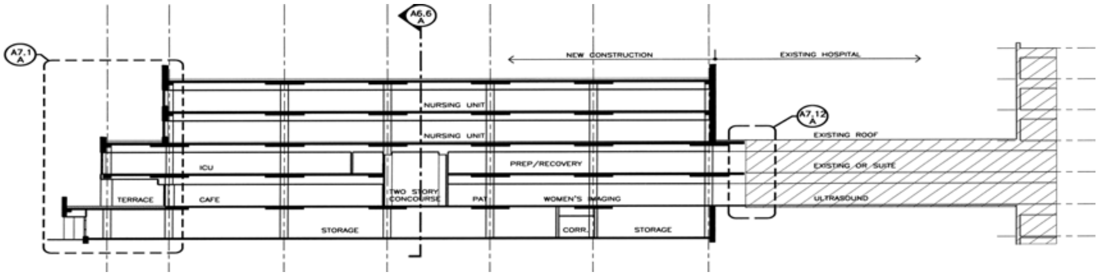


Figure B 2: Cross Section of the Monongalia General Hospital



West Section



South Section

Figure B 3: East Elevation of the Monongalia General Hospital

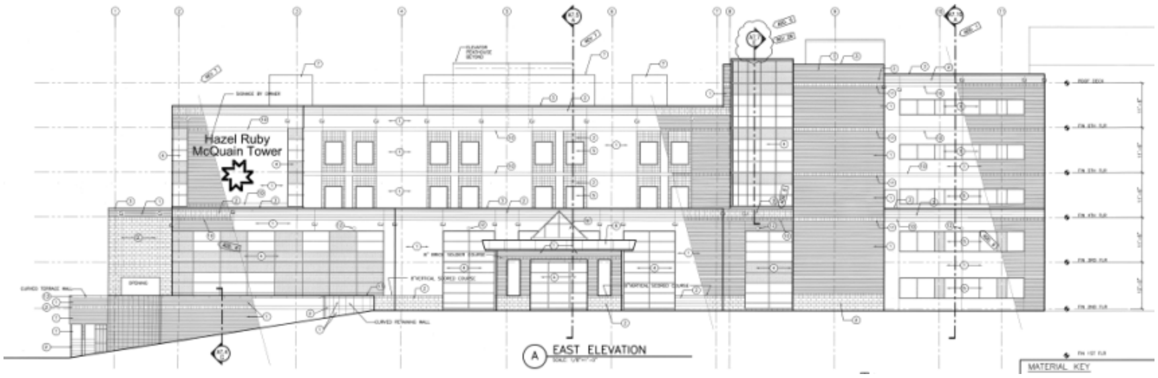


Figure B 4: South Elevation of the Monongalia General Hospital

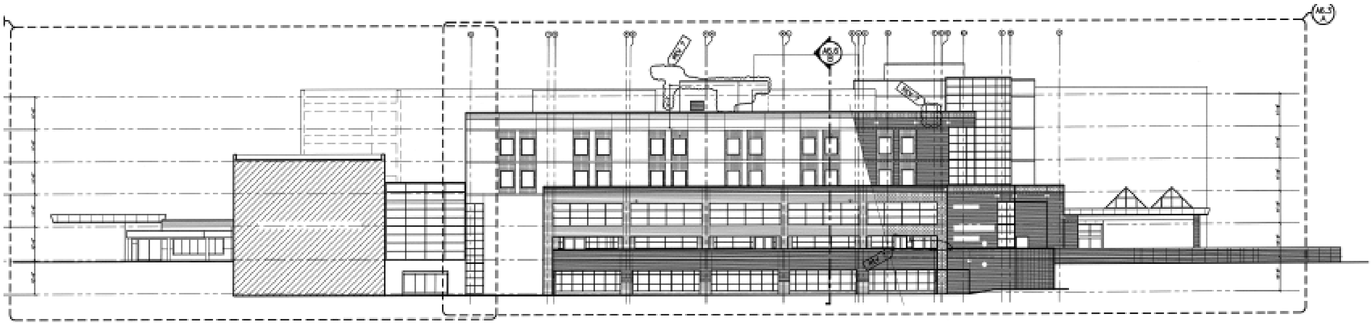


Figure B 5: Location of Shear Walls (Colored in blue) and Blast (Colored in Red)

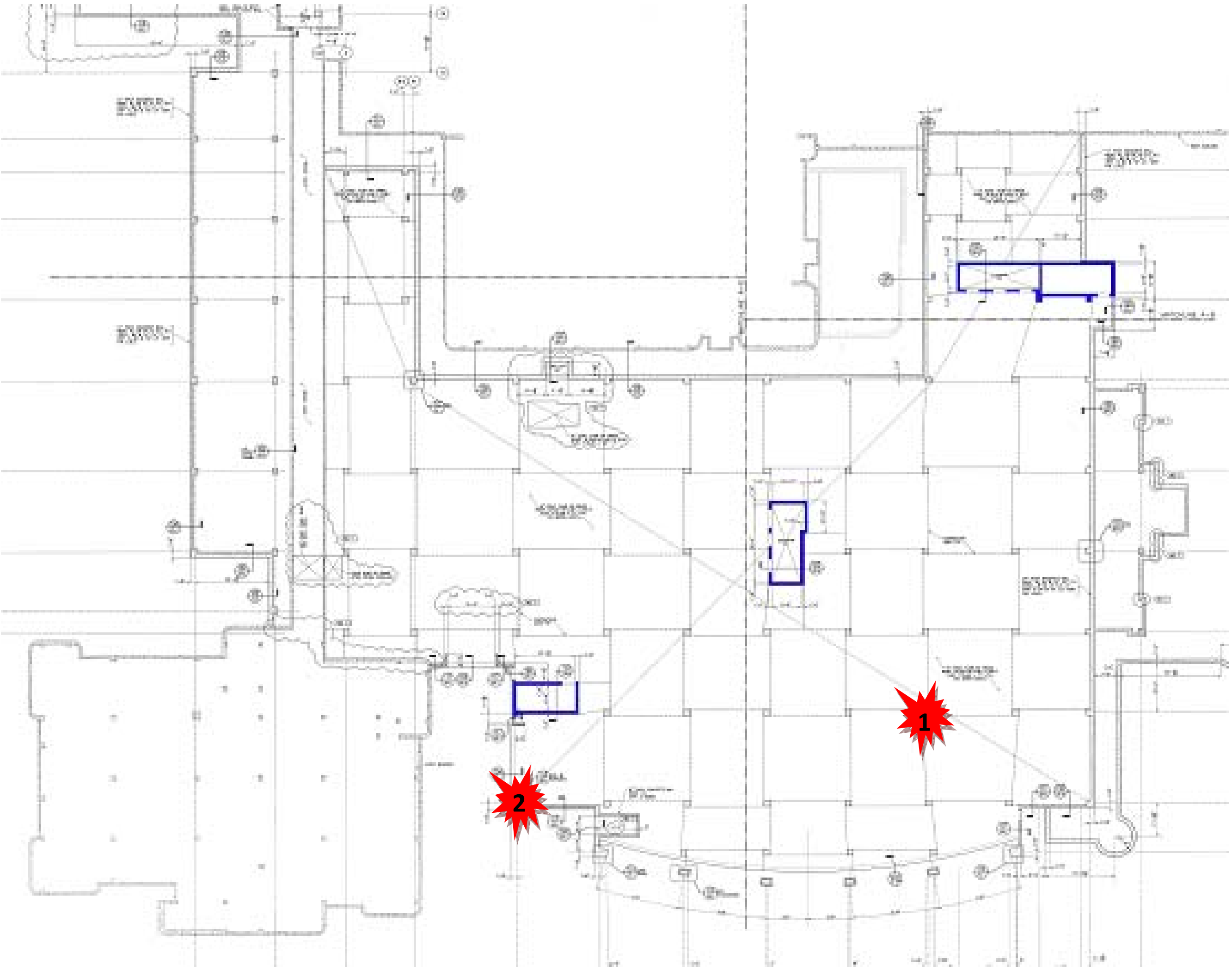


Figure B 6: ETABS Model of the Monongalia General Hospital

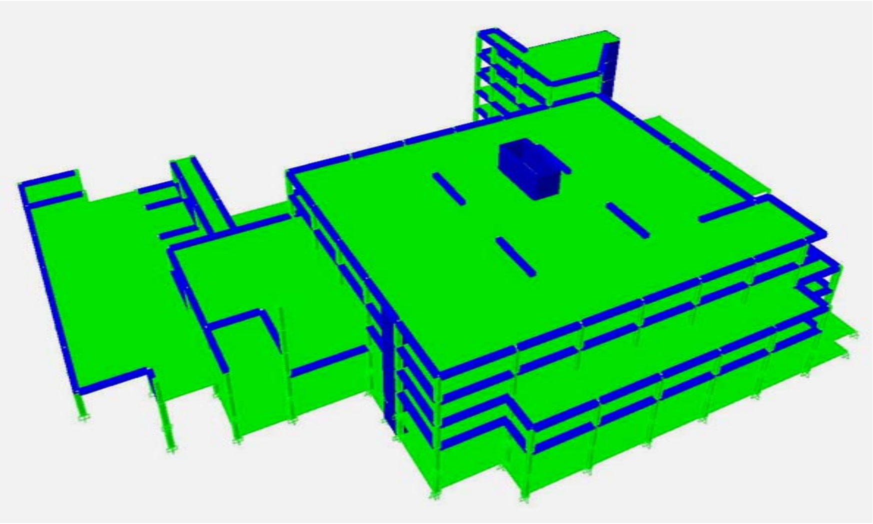


Figure B 7: ETABS Model of the Monongalia General Hospital

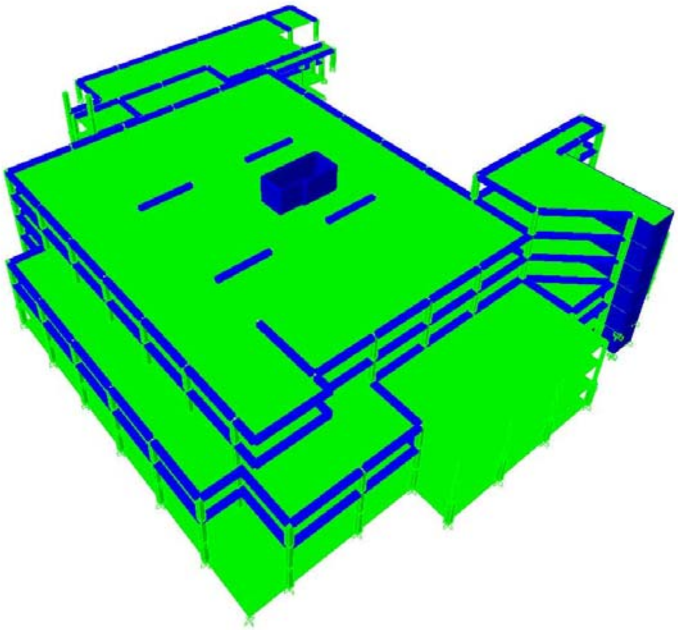


Figure B 8: SAP 2000 Model of the Monongalia General Hospital

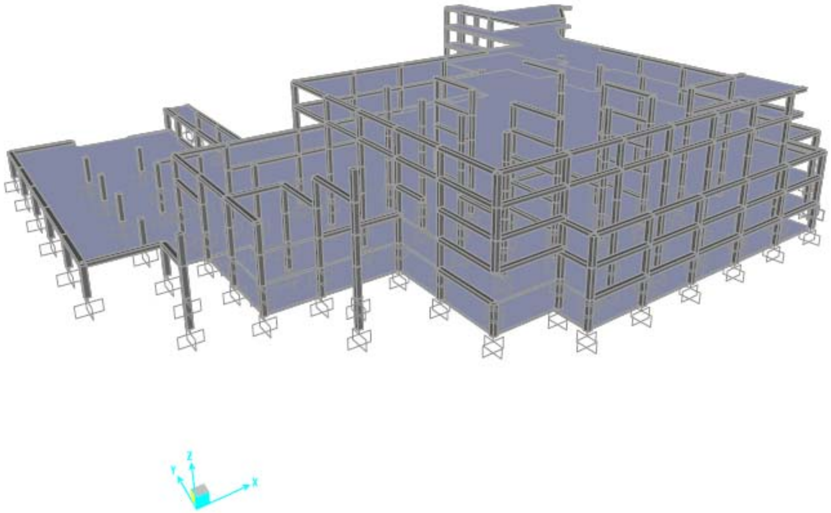


Figure B 9: SAP 2000 Model of the Monongalia General Hospital

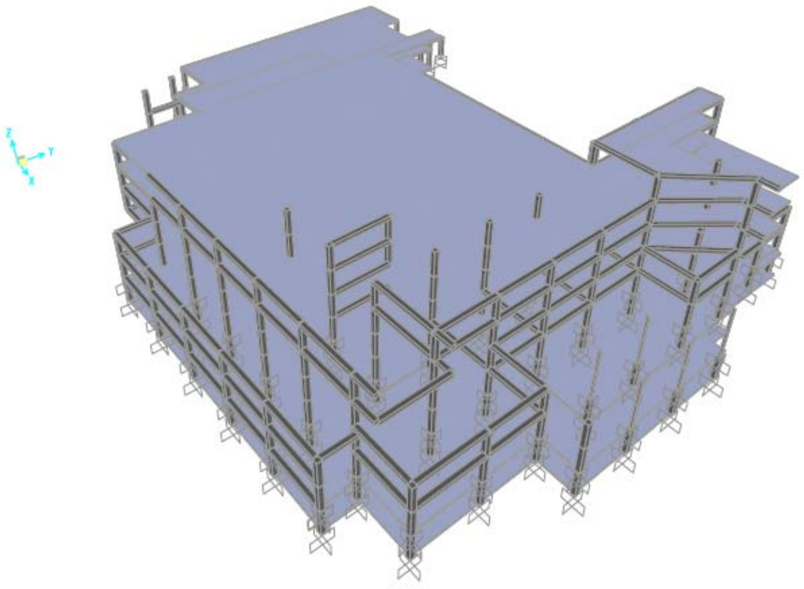


Figure B 10: Division of Areas by Construction Phases

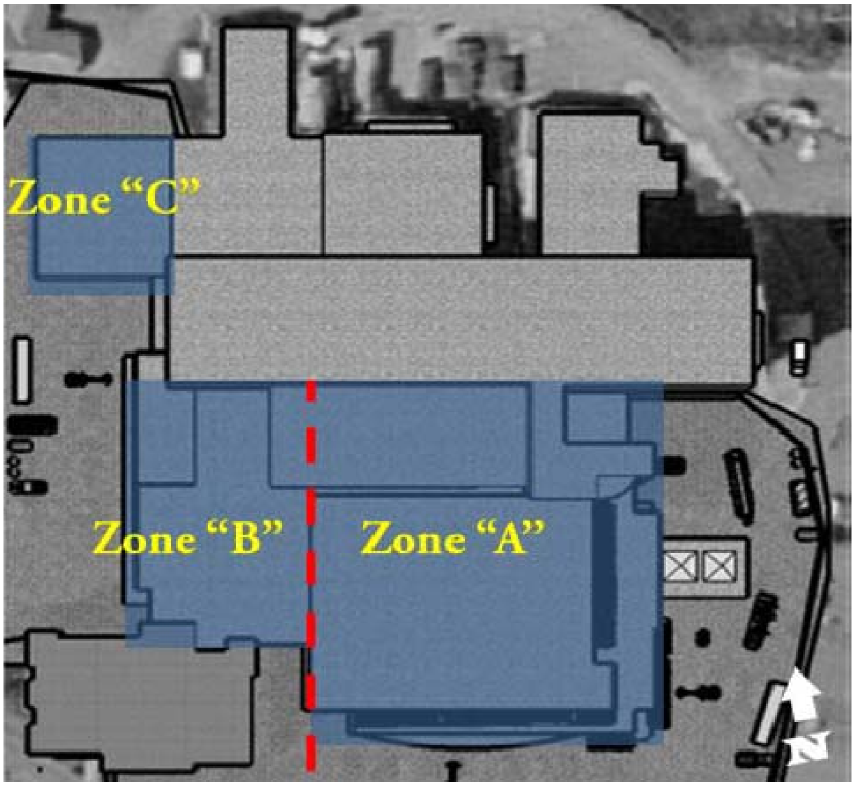
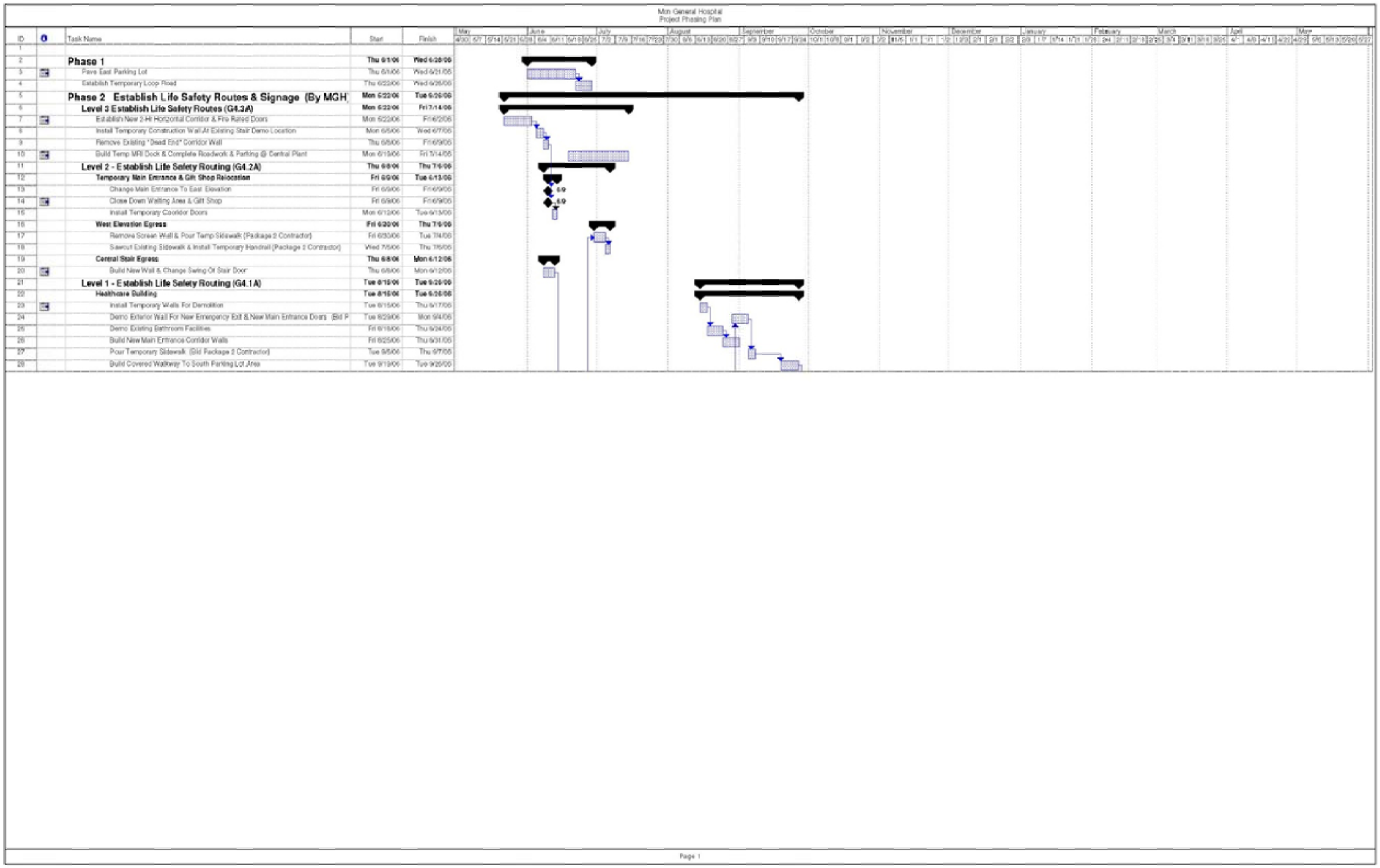


Figure B 11: Monongalia General Hospital Phasing Plan

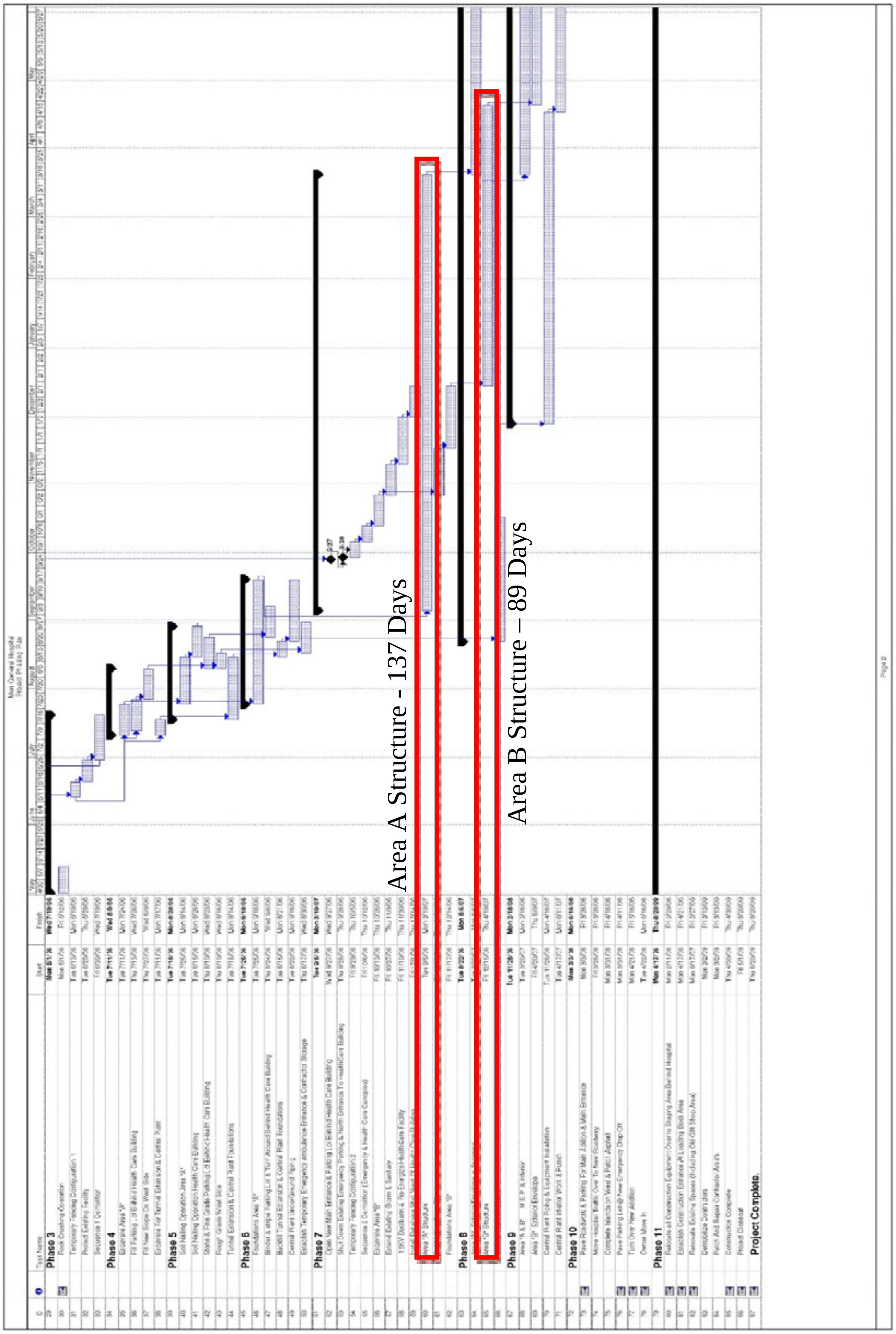
See the following pages

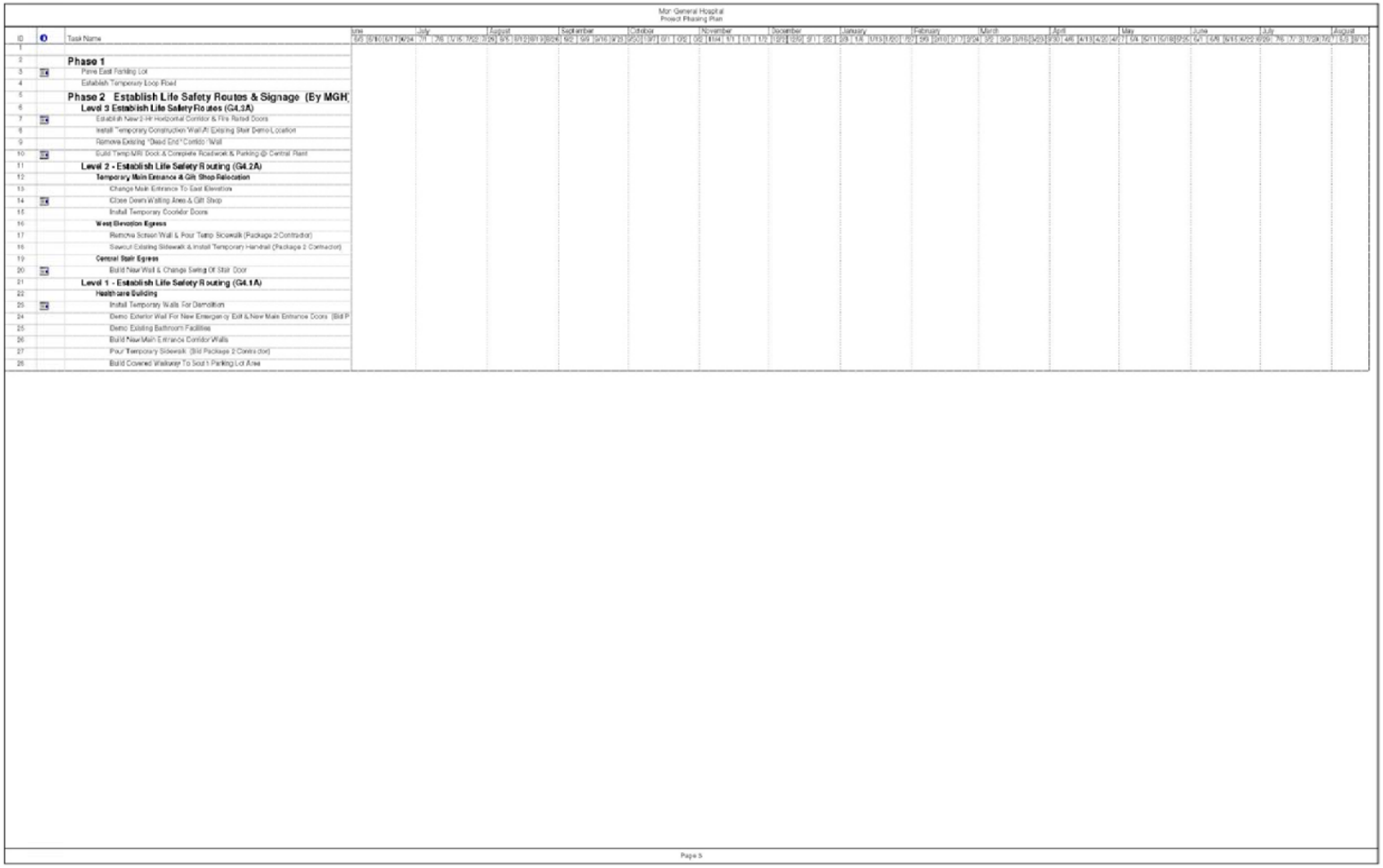
Mon General Hospital
Project Phasing Plan



| ID | ⓘ | Task Name | Start | Finish |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | **Phase 1** | **Thu 6/1/06** | **Wed 6/28/06** |
| 3 | ▤ | Pave East Parking Lot | Thu 6/1/06 | Wed 6/21/06 |
| 4 | | Establish Temporary Loop Road | Thu 6/22/06 | Wed 6/28/06 |
| 5 | | **Phase 2 Establish Life Safety Routes & Signage (By MGH)** | **Mon 5/22/06** | **Tue 9/26/06** |
| 6 | | **Level 3 Establish Life Safety Routes (G4.3A)** | **Mon 5/22/06** | **Fri 7/14/06** |
| 7 | ▤ | Establish New 2-Hr Horizontal Corridor & Fire Rated Doors | Mon 5/22/06 | Fri 6/2/06 |
| 8 | | Install Temporary Construction Wall At Existing Stair Demo Location | Mon 6/5/06 | Wed 6/7/06 |
| 9 | | Remove Existing "Dead End" Corridor Wall | Thu 6/8/06 | Fri 6/9/06 |
| 10 | ▤ | Build Temp MRI Dock & Complete Roadwork & Parking @ Central Plant | Mon 6/19/06 | Fri 7/14/06 |
| 11 | | **Level 2 - Establish Life Safety Routing (G4.2A)** | **Thu 6/8/06** | **Thu 7/6/06** |
| 12 | | **Temporary Main Entrance & Gift Shop Relocation** | **Fri 6/9/06** | **Tue 6/13/06** |
| 13 | | Change Main Entrance To East Elevation | Fri 6/9/06 | Fri 6/9/06 |
| 14 | ▤ | Close Down Waiting Area & Gift Shop | Fri 6/9/06 | Fri 6/9/06 |
| 15 | | Install Temporary Coorldor Doors | Mon 6/12/06 | Tue 6/13/06 |
| 16 | | **West Elevation Egress** | **Fri 6/30/06** | **Thu 7/6/06** |
| 17 | | Remove Screen Wall & Pour Temp Sidewalk (Package 2 Contractor) | Fri 6/30/06 | Tue 7/4/06 |
| 18 | | Sawcut Existing Sidewalk & Install Temporary Handrail (Package 2 Contractor) | Wed 7/5/06 | Thu 7/6/06 |
| 19 | | **Central Stair Egress** | **Thu 6/8/06** | **Mon 6/12/06** |
| 20 | ▤ | Build New Wall & Change Swing Of Stair Door | Thu 6/8/06 | Mon 6/12/06 |
| 21 | | **Level 1 - Establish Life Safety Routing (G4.1A)** | **Tue 8/15/06** | **Tue 9/26/06** |
| 22 | | **Healthcare Building** | **Tue 8/15/06** | **Tue 9/26/06** |
| 23 | ▤ | Install Temporary Walls For Demolition | Tue 8/15/06 | Thu 8/17/06 |
| 24 | | Demo Exterior Wall For New Emergency Exit & New Main Entrance Doors (Bid P | Tue 8/29/06 | Mon 9/4/06 |
| 25 | | Demo Existing Bathroom Facilities | Fri 8/18/06 | Thu 8/24/06 |
| 26 | | Build New Main Entrance Corridor Walls | Fri 8/25/06 | Thu 8/31/06 |
| 27 | | Pour Temporary Sidewalk (Bid Package 2 Contractor) | Tue 9/5/06 | Thu 9/7/06 |
| 28 | | Build Covered Walkway To South Parking Lot Area | Tue 9/19/06 | Tue 9/26/06 |

Page 1

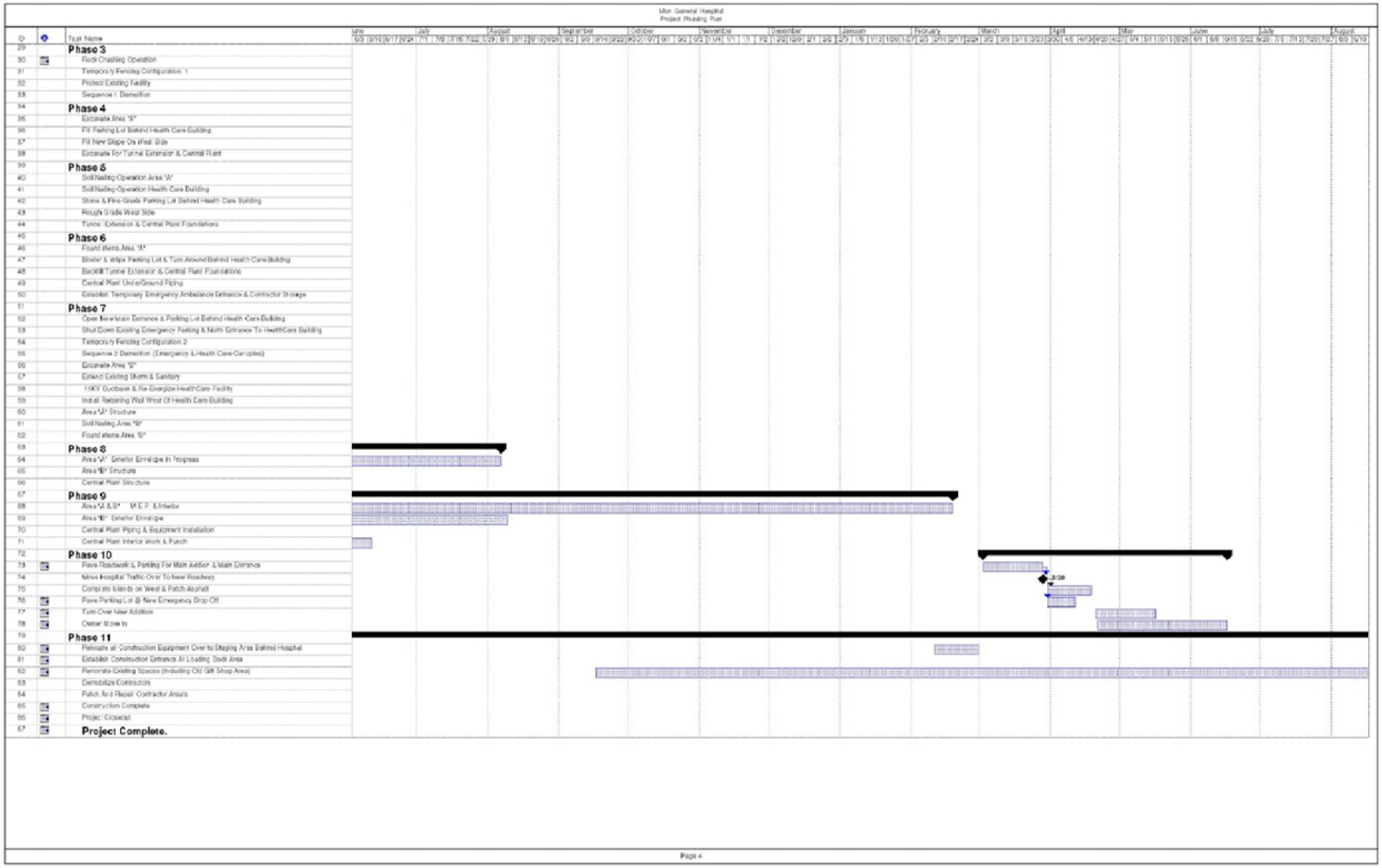

Area A Structure - 137 Days
Area B Structure – 89 Days

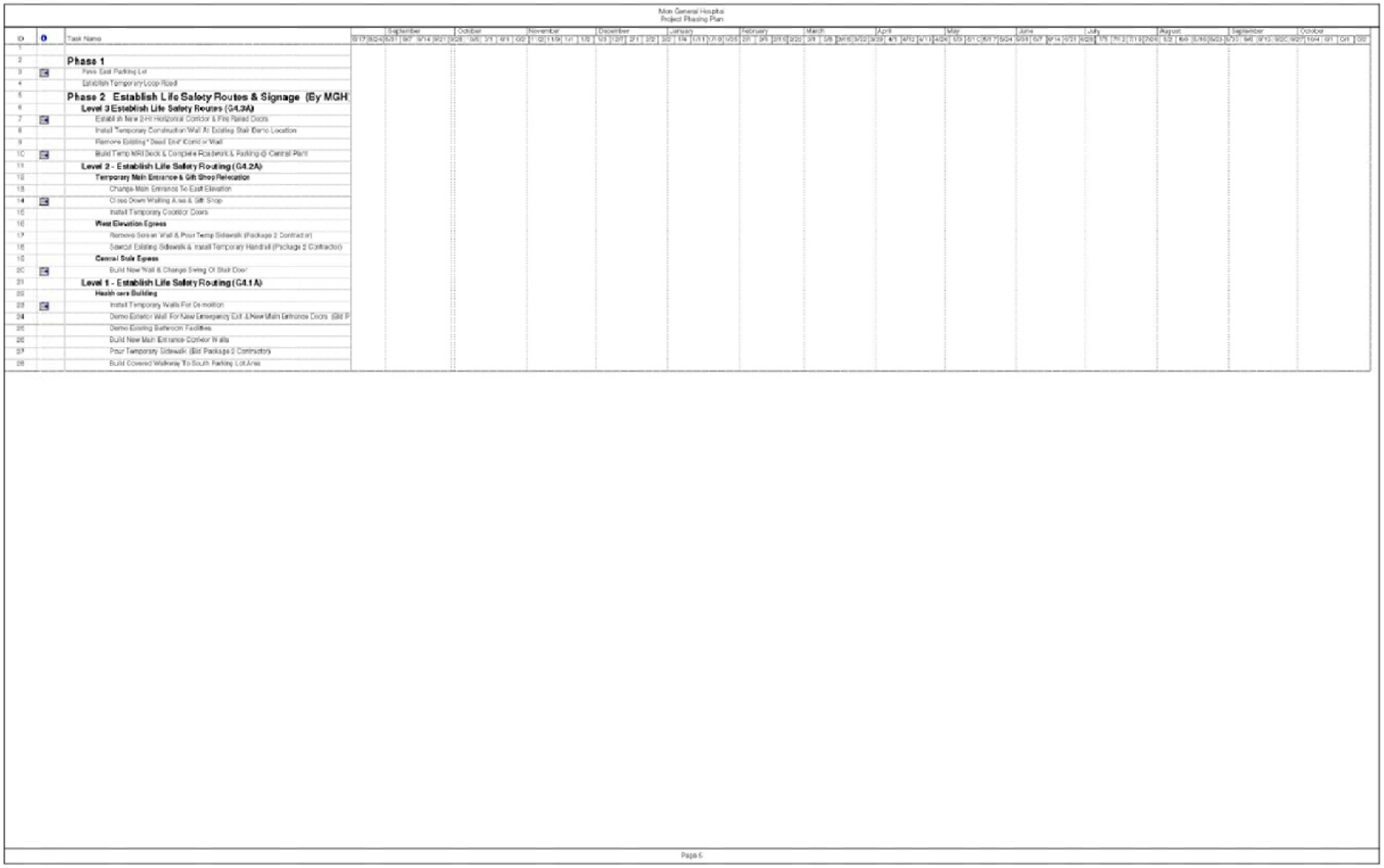


Mon General Hospital
Project Phasing Plan

| ID | | Task Name |
|---|---|---|
| 1 | | |
| 2 | | **Phase 1** |
| 3 | ▦ | Pave East Parking Lot |
| 4 | | Establish Temporary Loop Road |
| 5 | | **Phase 2 Establish Life Safety Routes & Signage (By MGH)** |
| 6 | | **Level 3 Establish Life Safety Routes (G4.3A)** |
| 7 | ▦ | Establish New 2-Hr Horizontal Corridor & Fire Rated Doors |
| 8 | | Install Temporary Construction Wall At Existing Stair Demo Location |
| 9 | | Remove Existing "Dead End" Corridor Wall |
| 10 | ▦ | Build Temp MRI Dock & Complete Roadwork & Parking @ Central Plant |
| 11 | | **Level 2 - Establish Life Safety Routing (G4.2A)** |
| 12 | | **Temporary Main Entrance & Gift Shop Relocation** |
| 13 | | Change Main Entrance To East Elevation |
| 14 | ▦ | Close Down Waiting Area & Gift Shop |
| 15 | | Install Temporary Corridor Doors |
| 16 | | **West Elevation Egress** |
| 17 | | Remove Screen Wall & Pour Temp Sidewalk (Package 2 Contractor) |
| 18 | | Sawcut Existing Sidewalk & Install Temporary Handrail (Package 2 Contractor) |
| 19 | | **Central Stair Egress** |
| 20 | ▦ | Build New Wall & Change Swing Of Stair Door |
| 21 | | **Level 1 - Establish Life Safety Routing (G4.1A)** |
| 22 | | **Healthcare Building** |
| 23 | ▦ | Install Temporary Walls For Demolition |
| 24 | | Demo Exterior Wall For New Emergency Exit & New Main Entrance Doors (Bid P |
| 25 | | Demo Existing Bathroom Facilities |
| 26 | | Build New Main Entrance Corridor Walls |
| 27 | | Pour Temporary Sidewalk (Bid Package 2 Contractor) |
| 28 | | Build Covered Walkway To South Parking Lot Area |

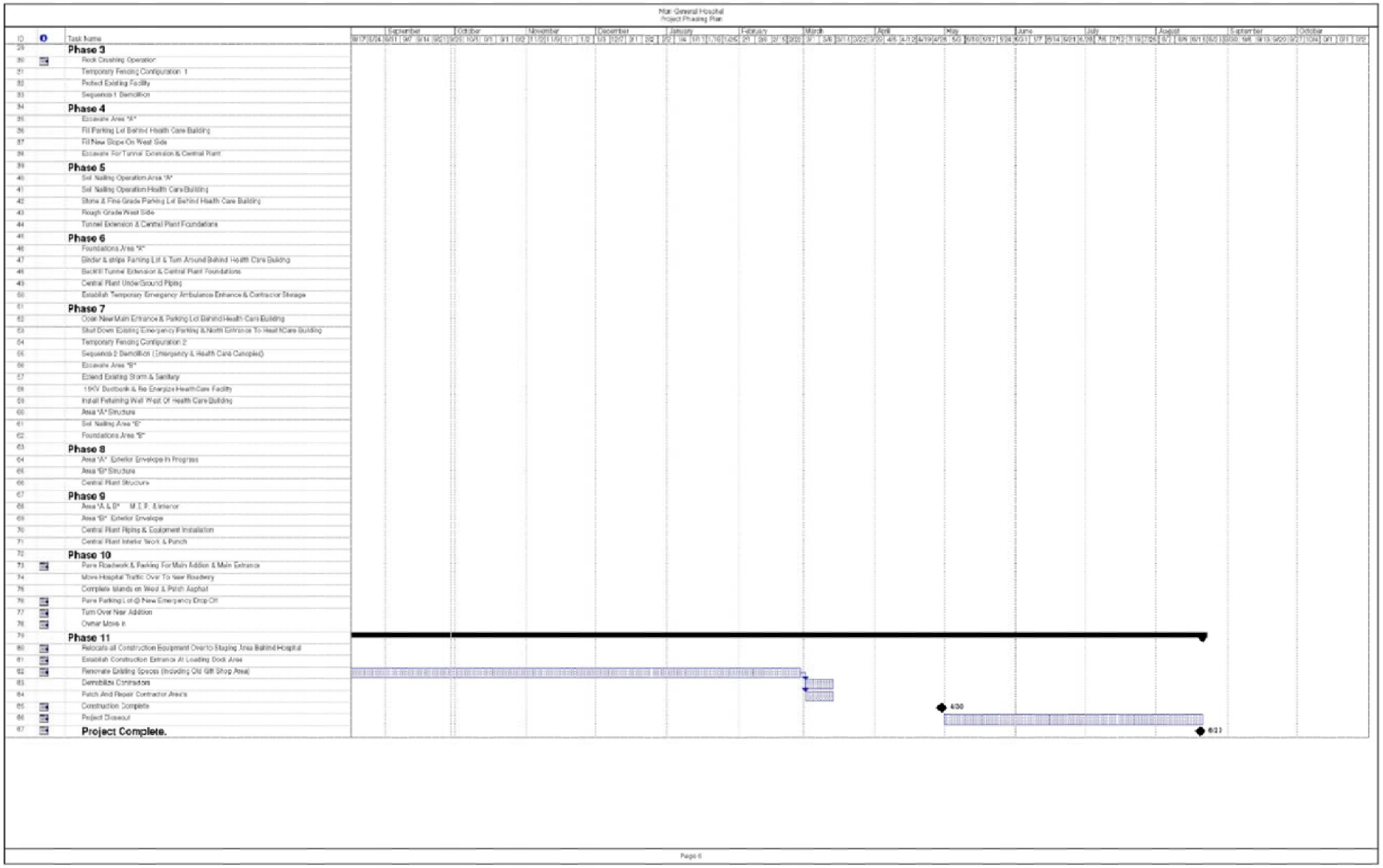
Page 5


Mon General Hospital
Project Phasing Plan
ID
Task Name
June
July
August
September
October
November
December
January
February
March
April
May
June
July
August
29 Phase 3
30 Rock Crushing Operation
31 Temporary Fencing Configuration 1
32 Protect Existing Facility
33 Sequence 1 Demolition
34 Phase 4
35 Excavate Area "A"
36 Fill Parking Lot Behind Health Care Building
37 Fill New Slope On West Side
38 Excavate For Tunnel Extension & Central Plant
39 Phase 5
40 Soil Nailing Operation Area "A"
41 Soil Nailing Operation Health Care Building
42 Stone & Fine Grade Parking Lot Behind Health Care Building
43 Rough Grade West Side
44 Tunnel Extension & Central Plant Foundations
45 Phase 6
46 Foundations Area "A"
47 Binder & stripe Parking Lot & Turn Around Behind Health Care Building
48 Backfill Tunnel Extension & Central Plant Foundations
49 Central Plant UnderGround Piping
50 Establish Temporary Emergency Ambulance Entrance & Contractor Storage
51 Phase 7
52 Open New Main Entrance & Parking Lot Behind Health Care Building
53 Shut Down Existing Emergency Parking & North Entrance To HealthCare Building
54 Temporary Fencing Configuration 2
55 Sequence 2 Demolition (Emergency & Health Care Canopies)
56 Excavate Area "B"
57 Extend Existing Storm & Sanitary
58 15KV Ductbank & Re-Energize HealthCare Facility
59 Install Retaining Wall West Of Health Care Building
60 Area "A" Structure
61 Soil Nailing Area "B"
62 Foundations Area "B"
63 Phase 8
64 Area "A" Exterior Envelope In Progress
65 Area "B" Structure
66 Central Plant Structure
67 Phase 9
68 Area "A & B" M.E.P. & Interior
69 Area "B" Exterior Envelope
70 Central Plant Piping & Equipment Installation
71 Central Plant Interior Work & Punch
72 Phase 10
73 Pave Roadwork & Parking For Main Addition & Main Entrance
74 Move Hospital Traffic Over To New Roadway
75 Complete Islands on West & Patch Asphalt
76 Pave Parking Lot @ New Emergency Drop-Off
77 Turn Over New Addition
78 Owner Move In
79 Phase 11
80 Relocate all Construction Equipment Over to Staging Area Behind Hospital
81 Establish Construction Entrance At Loading Dock Area
82 Renovate Existing Spaces (Including Old Gift Shop Area)
83 Demobilize Contractors
84 Patch And Repair Contractor Areas
85 Construction Complete
86 Project Closeout
87 Project Complete.
3/28
Page 4



Mon General Hospital
Project Phasing Plan

| ID | ℹ | Task Name |
|---|---|---|
| 1 | | |
| 2 | | **Phase 1** |
| 3 | ▣ | Pave East Parking Lot |
| 4 | | Establish Temporary Loop Road |
| 5 | | **Phase 2 Establish Life Safety Routes & Signage (By MGH** |
| 6 | | **Level 3 Establish Life Safety Routes (G4.3A)** |
| 7 | ▣ | Establish New 2-Hr Horizontal Corridor & Fire Rated Doors |
| 8 | | Install Temporary Construction Wall At Existing Stair Demo Location |
| 9 | | Remove Existing "Dead End" Corridor Wall |
| 10 | ▣ | Build Temp MRI Dock & Complete Roadwork & Parking @ Central Plant |
| 11 | | **Level 2 - Establish Life Safety Routing (G4.2A)** |
| 12 | | **Temporary Main Entrance & Gift Shop Relocation** |
| 13 | | Change Main Entrance To East Elevation |
| 14 | ▣ | Close Down Waiting Area & Gift Shop |
| 15 | | Install Temporary Corridor Doors |
| 16 | | **West Elevation Egress** |
| 17 | | Remove Screen Wall & Pour Temp Sidewalk (Package 2 Contractor) |
| 18 | | Sawcut Existing Sidewalk & Install Temporary Handrail (Package 2 Contractor) |
| 19 | | **Central Stair Egress** |
| 20 | ▣ | Build New Wall & Change Swing Of Stair Door |
| 21 | | **Level 1 - Establish Life Safety Routing (G4.1A)** |
| 22 | | **Health care Building** |
| 23 | ▣ | Install Temporary Walls For Demolition |
| 24 | | Demo Exterior Wall For New Emergency Exit & New Main Entrance Doors (Bid P |
| 25 | | Demo Existing Bathroom Facilities |
| 26 | | Build New Main Entrance Corridor Walls |
| 27 | | Pour Temporary Sidewalk (Bid Package 2 Contractor) |
| 28 | | Build Covered Walkway To South Parking Lot Area |



Mon General Hospital
Project Phasing Plan

| ID | Task Name |
|---|---|
| 29 | **Phase 3** |
| 30 | Rock Crushing Operation |
| 31 | Temporary Fencing Configuration 1 |
| 32 | Protect Existing Facility |
| 33 | Sequence 1 Demolition |
| 34 | **Phase 4** |
| 35 | Excavate Area "A" |
| 36 | Fill Parking Lot Behind Health Care Building |
| 37 | Fill New Slope On West Side |
| 38 | Excavate For Tunnel Extension & Central Plant |
| 39 | **Phase 5** |
| 40 | Soil Nailing Operation Area "A" |
| 41 | Soil Nailing Operation Health Care Building |
| 42 | Stone & Fine Grade Parking Lot Behind Health Care Building |
| 43 | Rough Grade West Side |
| 44 | Tunnel Extension & Central Plant Foundations |
| 45 | **Phase 6** |
| 46 | Foundations Area "A" |
| 47 | Binder & stripe Parking Lot & Turn Around Behind Health Care Building |
| 48 | Backfill Tunnel Extension & Central Plant Foundations |
| 49 | Central Plant UnderGround Piping |
| 50 | Establish Temporary Emergency Ambulance Entrance & Contractor Storage |
| 51 | **Phase 7** |
| 52 | Open New Main Entrance & Parking Lot Behind Health Care Building |
| 53 | Shut Down Existing Emergency Parking & North Entrance To HealthCare Building |
| 54 | Temporary Fencing Configuration 2 |
| 55 | Sequence 2 Demolition (Emergency & Health Care Canopies) |
| 56 | Excavate Area "B" |
| 57 | Extend Existing Storm & Sanitary |
| 58 | 15KV Ductbank & Re Energize HealthCare Facility |
| 59 | Install Retaining Wall West Of Health Care Building |
| 60 | Area "A" Structure |
| 61 | Soil Nailing Area "B" |
| 62 | Foundations Area "B" |
| 63 | **Phase 8** |
| 64 | Area "A" Exterior Envelope In Progress |
| 65 | Area "B" Structure |
| 66 | Central Plant Structure |
| 67 | **Phase 9** |
| 68 | Area "A & B" M.E.P. & Interior |
| 69 | Area "B" Exterior Envelope |
| 70 | Central Plant Piping & Equipment Installation |
| 71 | Central Plant Interior Work & Punch |
| 72 | **Phase 10** |
| 73 | Pave Roadwork & Parking For Main Addition & Main Entrance |
| 74 | Move Hospital Traffic Over To New Roadway |
| 75 | Complete Islands on West & Patch Asphalt |
| 76 | Pave Parking Lot @ New Emergency Drop Off |
| 77 | Turn Over New Addition |
| 78 | Owner Move in |
| 79 | **Phase 11** |
| 80 | Relocate all Construction Equipment Over to Staging Area Behind Hospital |
| 81 | Establish Construction Entrance At Loading Dock Area |
| 82 | Renovate Existing Spaces (Including Old Gift Shop Area) |
| 83 | Demobilize Contractors |
| 84 | Patch And Repair Contractor Area's |
| 85 | Construction Complete |
| 86 | Project Closeout |
| 87 | **Project Complete.** |

# MONONGALIA GENERAL HOSPITAL

## BLAST AND PROGRESSIVE
## COLLAPSE ANALYSIS

# APPENDIX C

## PHOTOGRAPHS

Photograph C 1: View from South-East

Photograph C 2: Aerial Photo of the Monongalia General Hospital

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

# MONONGALIA GENERAL HOSPITAL

## BLAST AND PROGRESSIVE COLLAPSE ANALYSIS

# APPENDIX D

## CODES AND STANDARDS

*Building Design 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.

*Miscellaneous Codes and Standards*

American Concrete Institute Committee 318, Building Code Requirements for Structural Concrete, 2008

American Society of Civil Engineers Standard 7, Minimum Design Loads for Building and Other Structures, 2005

American Society of Testing Materials, Standard Practice for Determining Load Resistance of Glass in Buildings, E 1300-04, 2006

Department of Defense, UFC 4-023-03, Design of Buildings to Resist Progressive Collapse

# MONONGALIA GENERAL HOSPITAL

## BLAST AND PROGRESSIVE COLLAPSE ANALYSIS

# APPENDIX E

## BUILDING DESIGN LOADS

*Gravity Loads*

| **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 |

See Figure E 1 and E 2 for wind loading diagram:

Figure E 1: Wind Loading – North to South

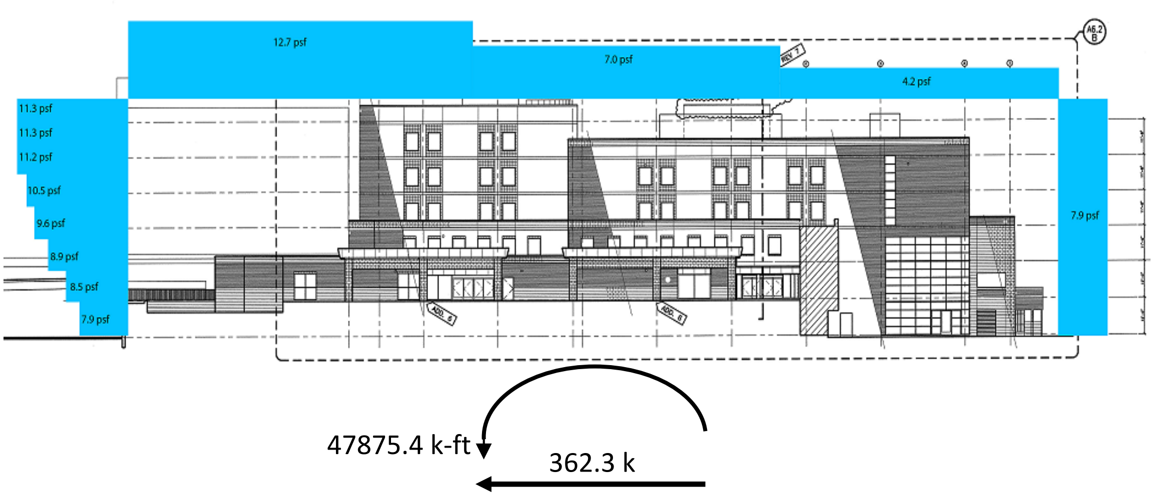
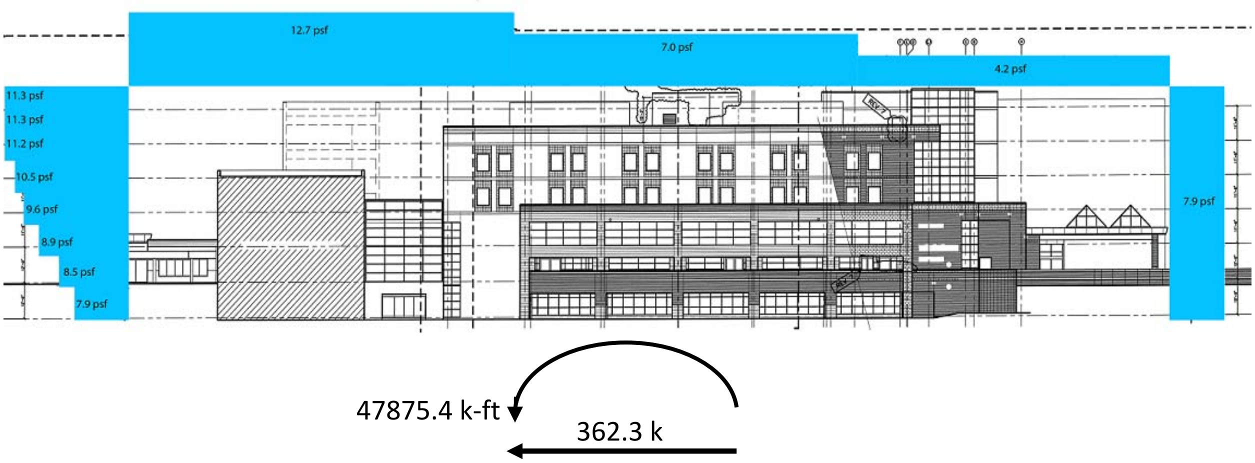


Figure E 2: Wind Loading – East to West



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

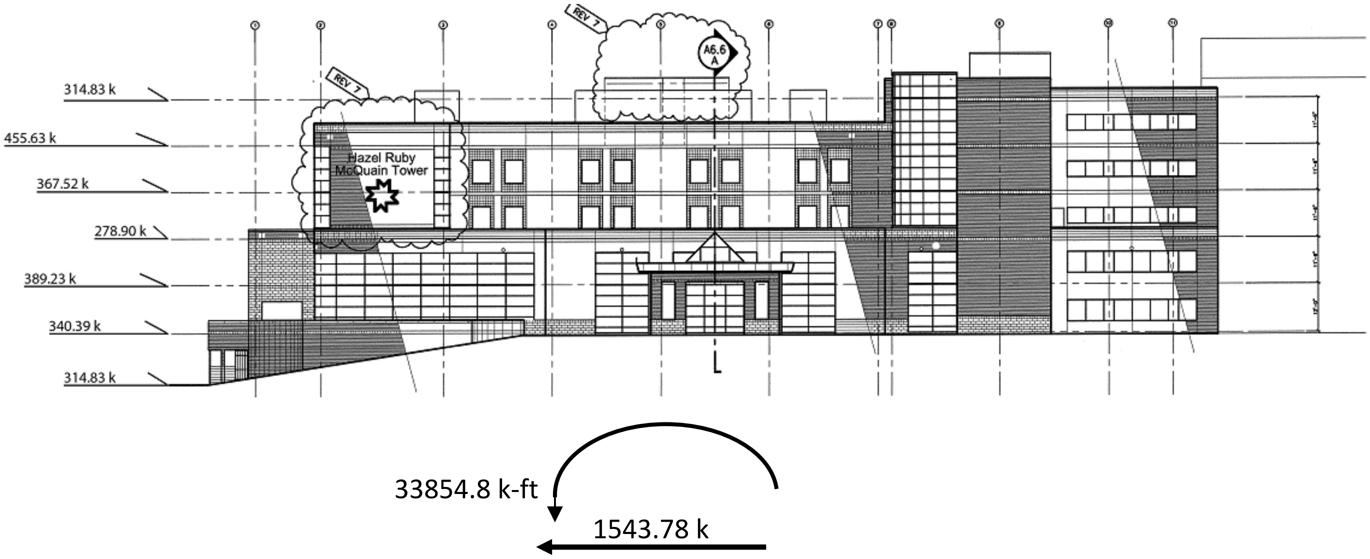
| | |
|---|---|
| - Occupancy Category | IV |
| - Importance Factor | 1.5 |
| - Seismic Category | A |
| - Site Class | C |
| - Spectral Acceleration, Short Period | 0.133 |
| - Spectral Acceleration, 1 Second | 0.052 |
| - Site Coefficient, $F_a$ | 1.2 |
| - Site Coefficient, $F_v$ | 1.7 |
| - R-Factor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

See Figure E 3 for seismic loading diagram:

Figure E 3: Seismic Loading



# MONONGALIA GENERAL HOSPITAL

## BLAST AND PROGRESSIVE COLLAPSE ANALYSIS

# APPENDIX F

## CALCULATIONS

## INDIRECT METHOD - TIE FORCES

- PERIPHERAL TIES

$$F_t \leq \begin{cases} 4.5 + 0.9 n_0 & ; n_0 = 6 \text{ STORIES} \\ 13.5 k/ft. \end{cases}$$

$$F_t \leq \begin{cases} 4.5 + 0.9(6 \text{ STORIES}) = 9.9 k/ft \text{ * CRITICAL} \\ 13.5 k/ft \end{cases}$$

$$F_t = \Omega \phi f_y A_s \quad ; \Omega = 1.25 \quad \phi = 0.75$$

$$\Rightarrow A_s = \frac{F_i}{\Omega \phi f_y} = \frac{9.9 k/ft}{(0.75)(1.25)(60ksi)} = 0.176 in^2$$

$$A_{s,PROVIDED} = (3) \#5 = 0.93 in^2 > A_s = 0.176 in^2 \quad (\text{GOOD})$$

- INTERNAL TIES (EAST - WEST)

$$R_u \geq \begin{cases} \frac{D+L}{156.6} \; \frac{L_r}{16.4} \; \frac{F_t}{3.3} \\ \frac{F_t}{3.3} \end{cases}$$

$$\Rightarrow D = 20PSF + 90PSF = 110 PSF$$
$$L = 40 PSF$$
$$L_r = 34.33'$$

$$R_u \geq \begin{cases} \frac{110PSF + 40PSF}{156.6} \cdot \frac{34.33'}{16.4} \cdot \frac{9.9k/ft}{3.3} = 6.02 k/ft \text{ * CRITICAL} \\ \frac{9.9k/ft}{3.3} = 3k/ft \end{cases}$$

$$\Rightarrow A_s = \frac{6.02 k/ft}{(0.75)(1.25)(60ksi)} = 0.107 in^2$$

$$A_{s\,PROVIDED} = 1.067 in^2/ft > A_s = 0.107 in^2 \quad (\text{GOOD})$$

- INTERNAL TIES (NORTH - SOUTH)

$$R_u \geq \begin{cases} \frac{110PSF + 40PSF}{156.6} \cdot \frac{30.33'}{16.4} \cdot \frac{9.9k/ft}{3.3} = 5.314 k/ft \text{ * CRITICAL} \\ 3 k/ft \end{cases}$$

→ CONT'D.

## INDIRECT METHOD – TIE FORCES

- INTERNAL TIES (NORTH-SOUTH) CONT'D.

$$\Rightarrow A_s = \frac{5.314\,k/ft}{(0.75)(1.25)(60ksi)} = 0.0945\,in^2/ft$$

$$A_{s\,PROVIDED} = 0.408\,in^2/ft > A_s = 0.0945\,in^2/ft \quad (GOOD)$$

- HORIZONTAL TIE TO COLUMNS

$$R_u \geq \begin{cases} 0.03[4(D+L)]A_T = 0.03[4(110psf + 40psf)](28.67')^2 = 14.8k \text{ *CRITICAL} \\ R_u' \leq \begin{cases} 2.0F_t = 2.0(9.9k/ft) = 19.8k \\ \frac{l_s}{8.2}F_t = \frac{11.5'}{8.2}(9.9k/ft) = 13.9k. \end{cases} \end{cases}$$

$$\Rightarrow A_s = \frac{14.8k}{(0.75)(1.25)(60ksi)} = 0.263\,in^2$$

$$A_{s\,PROVIDED} = 0.33\,in^2 > A_s = 0.263\,in^2 \quad (GOOD)$$

- VERTICAL COLUMN TIES

$$R_v = A_T(D+L) = (28.67')(14.33')(110psf + 40psf) = 123.3k.$$

$$\Rightarrow A_s = \frac{123.3k}{(0.75)(1.25)(60ksi)} = 2.19\,in^2$$

$$A_{s\,PROVIDED} = 6\,in^2 > A_s = 2.19\,in^2 \quad (GOOD)$$

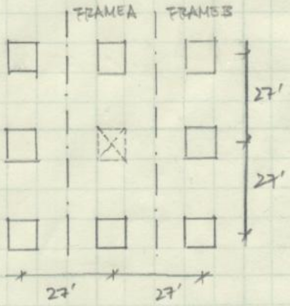
- CORNER COLUMN TIES

$$R_u \geq \begin{cases} 0.03[4(D+L)_{VERT}]A_{T\,VERT} = 0.03[4(500psf)](28.67')(70.5') = 121.3k \text{ *CRITICAL} \\ R_u' \leq \begin{cases} 2.0F_t = 19.8k \\ \frac{l_s}{8.2}F_t = 13.9k \end{cases} \end{cases}$$

$$\Rightarrow A_s = \frac{121.3k}{(0.75)(1.25)(60ksi)} = 2.16\,in^2$$

$$A_{s\,PROVIDED} = 6\,in^2 > A_s = 2.16\,in^2 \quad (GOOD)$$

SLAB DESIGN: 2 WAY (INT)



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

NORMAL WEIGHT CONCRETE

24 x 24 COLUMNS (TYPICAL)

INTERIOR SLAB.

- SLAB THICKNESS CHECK.

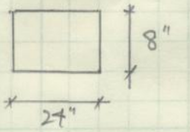
$$t_{MIN} = \frac{l_n}{30}$$

$$\Rightarrow l_n = 27' - 24''/12''/ft = 25'$$

$$t_{MIN} = \frac{(25')(12''/ft)}{30} = 10'' > t_{EXIST} = 8''$$

$$\Rightarrow \text{ACI 318-08 § 9.5.3.2(b)}: t_{MIN} = 4'' < 8'' \therefore \text{USE } t = 8''$$

- TORSIONAL CONSTANT



$$C = \sum \left(1 - 0.63\frac{x}{y}\right)\left(\frac{x^3 y}{3}\right)$$

$$= \left[1 - 0.63\left(\frac{8''}{24''}\right)\right]\left[\frac{(8'')^3(24'')}{3}\right]$$

$$\therefore C = 3235.84 in^3$$

- PARAMETERS

- FRAME A.

$$I_s^{\beta t} = \frac{(25')(12''/ft)(8'')^3}{12} = 12800 in^4$$

$$\beta_t = \frac{C}{2 I_s^{\beta t}} = \frac{3235.84 in^3}{2(12800 in^4)} = 0.126.$$

→ CONT'D.

## SLAB DESIGN: 2 WAY (CONT)

- PARAMETERS CONT'D
  - FRAME A

$\alpha = 0$ (NO BEAMS)

$$\frac{l_2}{l_1} = \frac{27'}{2(27')} = 0.5$$

$$\alpha\frac{l_2}{l_1} = 0.$$

  - FRAME B

$$I_s^{\beta t} = 17800\,in^4$$

$$\beta_t = 0.126$$

$$\alpha = 0.$$

$$\frac{l_2}{l_1} = 1.0$$

$$\alpha\frac{l_2}{l_1} = 0.$$

- TOTAL FACTORED MOMENTS AND REDISTRIBUTIONS.
  - FRAME A.

$$M_o = \frac{w_u l_2 l_1^2 \left(1 - {}^{2c}/_{3l_1}\right)^2}{8}$$

$$= \frac{(152\,PSF)(27')(54')^2\left(1 - {}^{2(24")}/_{3(54')(12"/ft)}\right)^2}{8}$$

$\therefore M_o = 1423\,k\cdot ft$

$\Rightarrow M^+ = 0.35M_o = 498\,k\cdot ft$

$M^- = 0.65M_o = 925\,k\cdot ft$

  - FRAME B

$$M_o = \frac{(152\,PSF)(27')(27')^3\left(1 - {}^{2(24")}/_{3(27')(12"/ft)}\right)^2}{8}$$

$\therefore M_o = 338\,k\cdot ft$

→ CONT'D.

SLAB DESIGN: 2 WAY (INT)

- TOTAL FACTORED MOMENTS AND REDISTRIBUTIONS. CONT'D.
  - FRAME B

    $\Rightarrow M^{+} = 0.35M_o = 118\,k\cdot ft$

    $M^{-} = 0.65M_o = 220\,k\cdot ft.$

- DISTRIBUTION OF MOMENTS
  - FRAME A.
    - INTERIOR NEGATIVE MOMENTS

| | $l_2/l_1 = 0.5$ |
|---|---|
| $\alpha\, l_2/l_1 = 0$ | 75%. |

$925\,k\cdot ft \rightarrow$ 75% TO CS ($693.8\,k\cdot ft$)

$925\,k\cdot ft \rightarrow$ 25% TO MS ($231.3\,k\cdot ft$)

- POSITIVE MOMENTS

| | $l_2/l_1 = 0.5$ |
|---|---|
| $\alpha\, l_2/l_1 = 0$ | 60%. |

$498\,k\cdot ft \rightarrow$ 60% TO CS ($299\,k\cdot ft$)

$498\,k\cdot ft \rightarrow$ 40% TO MS ($199\,k\cdot ft$)

- FRAME B
  - INTERIOR NEGATIVE MOMENTS

| | $l_2/l_1 = 1.0$ |
|---|---|
| $\alpha\, l_2/l_1 = 0$ | 75% |

$220\,k\cdot ft \rightarrow$ 75% TO CS ($165\,k\cdot ft$)

$220\,k\cdot ft \rightarrow$ 25% TO MS ($55\,k\cdot ft$)

→ CONT'D.

SLAB DESIGN: 2 WAY (INT)

- DISTRIBUTION OF MOMENTS CONT'D
  - FRAME B
    - POSITIVE MOMENTS

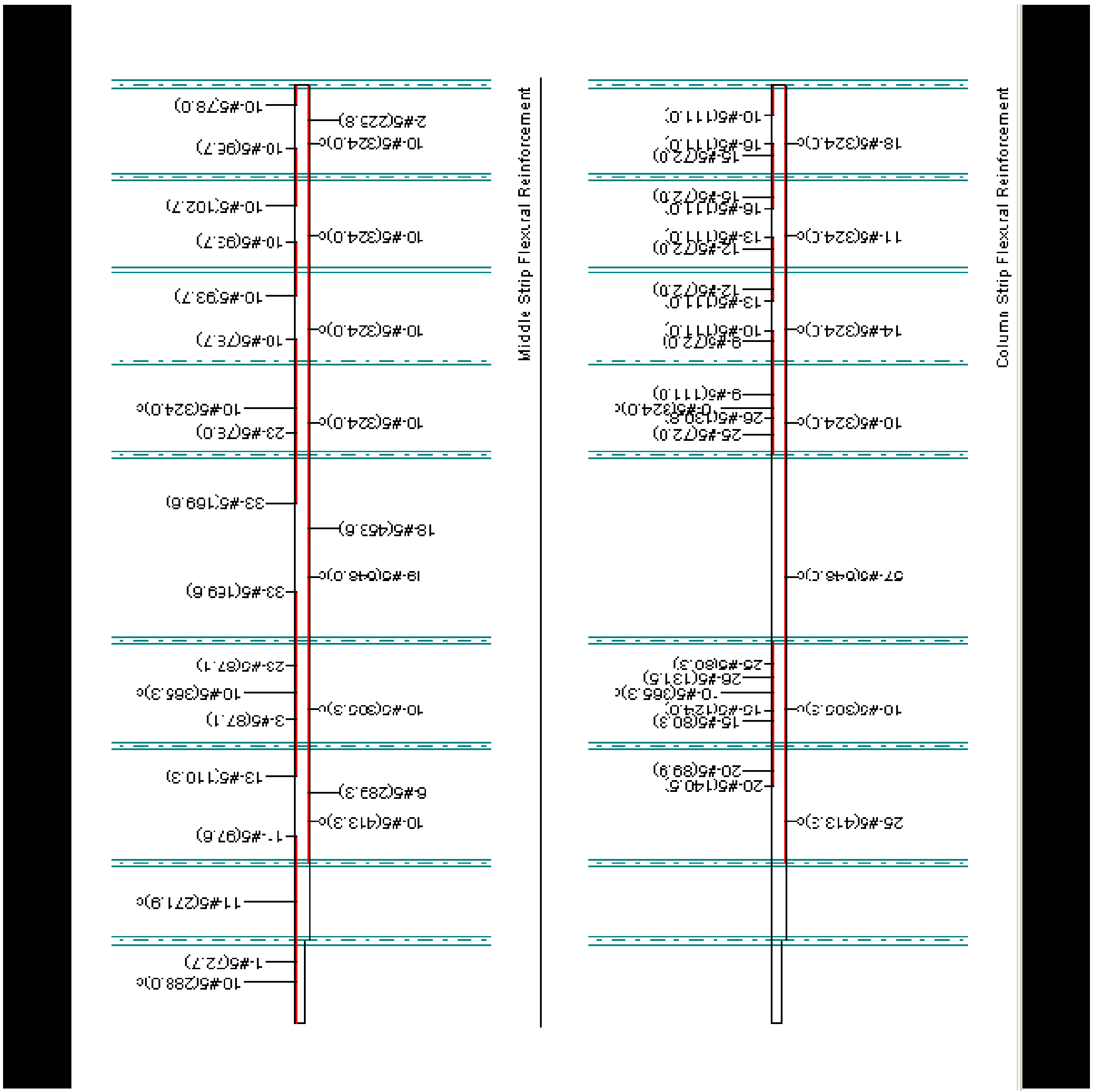
|  | $l_2/l_1 = 1.0$ |
|---|---|
| $\alpha\, l_2/l_1 = 0$ | 60% |

118 k·ft → 60% TO CS (71 k·ft)

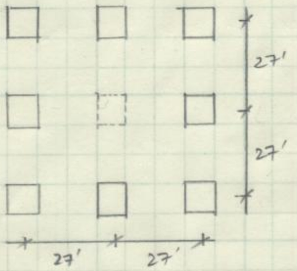
↘ 40% TO MS (47 k·ft)

- DESIGN
  - SEE FOLLOWING SPREADSHEET.

| **FRAME A** | **CS** | | | | **FRAME B** | **CS** | | |
|---|---|---|---|---|---|---|---|---|
| *Item* | *Description* | *Interior Span* | | | *Item* | *Description* | *Interior Span* | |
| | | $M^-$ | $M^+$ | | | | $M^-$ | $M^+$ |
| 1 | $M_n$ | 693.75 | 299 | | 1 | $M_n$ | 165 | 71 |
| 2 | $b_{CS}$ | 162 | 162 | | 2 | $b_{CS}$ | 81 | 81 |
| 3 | $d_{eff}$ | 6.31 | 6.31 | | 3 | $d_{eff}$ | 6.31 | 6.31 |
| 4 | $M_u = M_n/\varphi$ | 991.0714 | 427.1429 | | 4 | $M_u = M_n/\varphi$ | 235.7143 | 101.4286 |
| 5 | $M_n(12/b)$ | 51.38889 | 22.14815 | | 5 | $M_n(12/b)$ | 24.44444 | 10.51852 |
| 6 | $R = M_u/bd^2$ | 1843.794 | 794.6587 | | 6 | $R = M_u/bd^2$ | 877.0481 | 377.3965 |
| 7 | $\rho$ | 0.02 | 0.0146 | | 7 | $\rho$ | 0.0163 | 0.0066 |
| 8 | $A_{steel} = \rho bd$ | 20.4444 | 14.92441 | | 8 | $A_{steel} = \rho bd$ | 8.331093 | 3.373326 |
| 9 | $A_{s,min} = 0.002bt$ | 2.592 | 2.592 | | 9 | $A_{s,min} = 0.002bt$ | 1.296 | 1.296 |
| 10 | $N = A_s/A$ | 33 | 19 | | 10 | $N = A_s/A$ | 33 | 18 |
| 11 | $N_{min} = w_{strip}/2t$ | 10 | 10 | | 11 | $N_{min} = w_{strip}/2t$ | 5 | 5 |
| | | | | | | | | |
| **FRAME A** | **MS** | | | | **FRAME B** | **MS** | | |
| *Item* | *Description* | *Interior Span* | | | *Item* | *Description* | *Interior Span* | |
| | | $M^-$ | $M^+$ | | | | $M^-$ | $M^+$ |
| 1 | $M_n$ | 231 | 199 | | 1 | $M_n$ | 55 | 47 |
| 2 | $b_{CS}$ | 81 | 81 | | 2 | $b_{CS}$ | 40.5 | 40.5 |
| 3 | $d_{eff}$ | 6.93 | 6.93 | | 3 | $d_{eff}$ | 6.93 | 6.93 |
| 4 | $M_u = M_n/\varphi$ | 330 | 284.2857 | | 4 | $M_u = M_n/\varphi$ | 78.57143 | 67.14286 |
| 5 | $M_n(12/b)$ | 34.22222 | 29.48148 | | 5 | $M_n(12/b)$ | 16.2963 | 13.92593 |
| 6 | $R = M_u/bd^2$ | 1017.99 | 876.9701 | | 6 | $R = M_u/bd^2$ | 484.7574 | 414.2472 |
| 7 | $\rho$ | 0.0197 | 0.0162 | | 7 | $\rho$ | 0.0085 | 0.0073 |
| 8 | $A_{steel} = \rho bd$ | 11.0582 | 9.093546 | | 8 | $A_{steel} = \rho bd$ | 2.385653 | 2.048855 |
| 9 | $A_{s,min} = 0.002bt$ | 1.296 | 1.296 | | 9 | $A_{s,min} = 0.002bt$ | 0.648 | 0.648 |
| 10 | $N = A_s/A$ | 57 | 25 | | 10 | $N = A_s/A$ | 25 | 10 |
| 11 | $N_{min} = w_{strip}/2t$ | 5 | 5 | | 11 | $N_{min} = w_{strip}/2t$ | 3 | 3 |


Middle Strip Flexural Reinforcement
10-#5(78.0)
2-#5(23.8)
10-#5(324.0)c
10-#5(96.7)
10-#5(102.7)
10-#5(324.0)c
10-#5(96.7)
10-#5(93.7)
10-#5(324.0)c
10-#5(73.7)
10-#5(324.0)c
10-#5(324.0)c
23-#5(73.0)
33-#5(169.6)
18-#5(453.6)
19-#5(648.0)c
33-#5(169.6)
23-#5(87.1)
10-#5(365.3)c
10-#5(305.3)c
3-#5(87.1)
13-#5(110.3)
6-#5(283.3)
10-#5(413.3)c
11-#5(97.6)
11-#5(271.9)c
1-#5(72.7)
10-#5(288.0)c
Column Strip Flexural Reinforcement
10-#5(111.0)
18-#5(324.0)c
16-#5(111.0)
15-#5(72.0)
16-#5(72.0)
16-#5(111.0)
13-#5(111.0)
11-#5(324.0)c
12-#5(72.0)
12-#5(72.0)
13-#5(111.0)
10-#5(111.0)
14-#5(324.0)c
9-#5(72.0)
9-#5(111.0)
26-#5(130.5)
0-#5(324.0)c
10-#5(324.0)c
25-#5(72.0)
57-#5(648.0)c
25-#5(80.3)
26-#5(131.5)
0-#5(365.3)c
15-#5(124.0)
10-#5(305.3)c
15-#5(80.3)
20-#5(89.9)
20-#5(140.5)
25-#5(413.3)c

# SLAB DESIGN : PT SLAB (INT)



$f'_c = 5000\text{psi}$ $f'_{ci} = 3000\text{psi}$

$f_y = 60000\text{psi}$ $1/2''\phi$ 7 WIRE STRANDS $f_{pu} = 270\text{ksi}$

24 × 24 COLUMN (TYPICAL)

- POST-TENSIONING

ESTIMATED PRE-STRESS LOSSES = 15ksi

$f_{SE} = 0.7 f_{pu} - \text{LOSSES}$

$= 0.7(270\text{ksi}) - 15\text{ksi}$

$\therefore f_{SE} = 174\text{ksi}$

$P_{EFF} = A_p \times f_{se}$

$= (0.153\text{in}^2)(174\text{ksi})$

$\therefore P_{EFF} = 26.6\text{k/TENDON}$.

- PRIMARY SLAB THICKNESS

ASSUME 10"

- SECTION PROPERTIES

$A_c = b \times h$

$= (54')(12''/\text{ft})(10'')$

$\therefore A_c = 6480\text{in}^2$

$S = \dfrac{bh^2}{6}$

$= \dfrac{(6480\text{in}^2)(10'')}{6}$

$\therefore S = 10800\text{in}^3$

→ CONT'D.

## SLAB DESIGN: PT SLAB (INT)

- DESIGN PARAMETERS

ASSUMING CLASS U

- JACKING

$f'_{ci} = 3000\ psi$

COMPRESSION $= 0.6 f'_{ci} = 0.6(3000\ psi) = 1800\ psi$

TENSION $= 3\sqrt{f'_{ci}} = 3\sqrt{3000\ psi} = 164\ psi$

- SERVICE

$f'_c = 5000 psi$

COMPRESSION $= 0.45 f'_c = 0.45(5000 psi) = 2250 psi$

TENSION $= 6\sqrt{f'_c} = 6\sqrt{5000 psi} = 424\ psi$

- TARGET LOAD BALANCE

$0.75\, w_{DL} = 0.75(110 PSF) = 82.5 psf$

- TENDON PROFILE

$a_{INT} = 9''$

$a_{END} = 5.25''$

- PRESTRESS FORCE REQUIRED

$$w_B = 0.75\, w_{DL,S} = \frac{(0.75)(145 PCF)(10'')(54')}{12''/ft} = 4.9 k/ft.$$

$$P = \frac{w_B l^2}{8\, a_{END}}$$

$$= \frac{(4.9 k/ft)(54')^2}{(8)(5.25''/12''/ft)}$$

$\therefore P = 1020 K.$

→ CONT'D.

## SLAB DESIGN: PT SLAB (INT)

- PRECOMPRESSION ALLOWANCE
  - NUMBER OF TENDONS

$$\frac{1020k}{26.6k/\text{TENDON}} = 38.3 \text{ TENDONS} \Rightarrow \text{USE } 39 \text{ TENDONS.}$$

  - ACTUAL FORCE FOR BONDED TENDONS

$$P_{ACT} = (39 \text{ TENDONS})(26.6k/\text{TENDON}) = 1037k$$

  - BALANCED LOAD

$$W_{BAL} = \frac{1037k}{1020k}(4.9k/ft)$$

$$\therefore W_{BAL} = 5k/ft.$$

  - ACTUAL PRECOMPRESSION STRESS

$$\frac{P_{ACT}}{A_c} = \frac{1037k}{6480in^2} = 160 psi > 125 psi \text{ (GOOD)}$$

$$< 300 psi \text{ (GOOD)}$$

- INTERIOR SPAN FORCE

$$P = \frac{(4.9k/ft)(54')^2}{8(5.25''/12''/ft)}$$

$$\therefore P = 4082.4k.$$

$$W_B = \frac{(4082.4k)8(5.25'')}{(54')^2(12''/ft)}$$

$$\therefore W_B = 4.89k/ft.$$

$$\frac{W_B}{W_{DL}} = \frac{4.89k/ft}{6.5k/ft} = 74\% < 100\% \text{ (ACCEPTABLE)}$$

$$\therefore P_{EFF} = 4082.4k.$$

→CONT'D.

## SLAB DESIGN: PT SLAB (INT)

- SLAB STRESSES. (ASSUME SIMPLY SUPPORTED ; 54').
  - DEAD LOAD

$$M = \frac{(3k/ft)(54')^2}{8}$$

$\therefore M = 1094\,k\cdot ft.$

  - LIVE LOAD

$$M = \frac{(2.16k/ft)(54')^2}{8}$$

$\therefore M = 787\,k\cdot ft$

  - BALANCED LOAD

$$M = \frac{(2.58k/ft)(54')^2}{8}$$

$\therefore M = -940\,k\cdot ft.$

- STRESSES AT TRANSFER

$$f_{TOP} = \left(\frac{-1094k\cdot ft + 940k\cdot ft}{10800\,in^3}\right)(12''/ft)(1000lb/k) - 160psi = -331psi < 1800psi \text{ (GOOD)}$$

$$f_{BOT} = \left(\frac{1094k\cdot ft - 940k\cdot ft}{10800\,in^3}\right)(12''/ft)(1000lb/k) - 160psi = 11psi < 164psi \text{ (GOOD)}$$

- STRESSES AT SERVICE.

$$f_{TOP} = \left(\frac{-1094k\cdot ft - 787k\cdot ft + 940k\cdot ft}{10800\,in^3}\right)(12''/ft)(1000lb/k) - 160psi = -1205psi < 2250psi \text{ (GOOD)}$$

$$f_{BOT} = \left(\frac{1094k\cdot ft + 787k\cdot ft - 940k\cdot ft}{10800\,in^3}\right)(12''/ft)(1000lb/k) - 160psi = 430psi > 424psi$$

(WITHIN 5%
GOOD)

→CONT'D.

## SLAB DESIGN: PT SLAB (INT)

- ULTIMATE STRENGTH DESIGN
  - INTERIOR SPAN

$$f_t = 430\text{psi} > 2\sqrt{f'c} = 2\sqrt{5000\text{psi}} = 141\text{ psi} \quad (\text{REINFORCEMENT REQUIRED})$$

- MINIMUM POSITIVE MOMENT REINFORCEMENT REQUIRED.

$$y = \left(\frac{430\text{psi}}{430\text{psi} + 1205\text{psi}}\right)(8")$$

$$\therefore y = 2.6"$$

$$N_c = \left[\frac{(1094\text{k}\cdot\text{ft} + 787\text{ k}\cdot\text{ft})(12"/\text{ft})}{10800\text{ in}^3}\right]\left(\tfrac{1}{2}\right)(2.6")(54')(12"/\text{ft})$$

$$\therefore N_c = 1761\text{ k.}$$

$$As_{MIN} = \frac{1761\text{k}}{(0.5)(60\text{ksi})}$$

$$\therefore As_{MIN} = 58\text{ in}^2$$

$$\Rightarrow As_{MIN} = \frac{58\text{ in}^2}{54'}$$

$$\therefore As_{MIN} = 1.09\text{ in}^2/\text{ft.}$$

$\Rightarrow$ USE # 10 @ 12" O.C.

- CHECK MINIMUM REINFORCEMENT.

$$A_{ps} = (0.153\text{in}^2)(39\text{ TENDONS}) = 5.97\text{ in}^2$$

$$f_{ps} = 174000\text{ psi} + 10000 + \frac{(5000\text{psi})(54')(12"/\text{ft})(10")}{300(5.97\text{in}^2)}$$

$$\therefore f_{ps} = 202\text{ ksi}$$

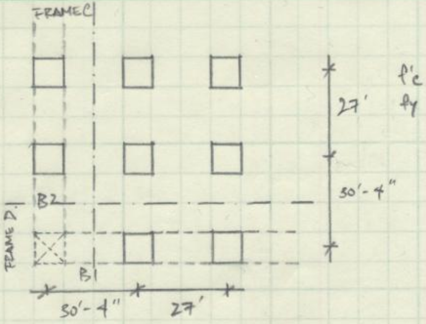
$$a = \frac{(58\text{in}^2)(60\text{ksi}) + (5.97\text{in}^2)(202\text{ksi})}{0.85(5\text{ksi})(54')(12"/\text{ft})}$$

$$\therefore a = 1.7"$$

$$\phi M_n = [(58\text{in}^2)(60\text{ksi}) + (5.97\text{in}^2)(202\text{ksi})]\left(10" - \frac{1.7"}{2}\right)(0.9)$$

$$\therefore \phi M_n = 3215\text{ k}\cdot\text{ft} > 1881\text{ k}\cdot\text{ft} \quad (\text{GOOD})$$

## BEAM DESIGN/SLAB DESIGN.



$f'_c = 5000\,psi$ EDGE BEAMS: 24" × 18" (TYPICAL)
$f_y = 60000\,psi$ COLUMNS: 24" × 24" (TYPICAL)

- FROM SAP 2000:

$M_{B1} = 555\,k\cdot ft$

$M_{B2} = 315\,k\cdot ft.$

⇒ THESE MOMENTS WILL BE USED TO DESIGN THE SLAB AND THE BEAM. THE GREATER MOMENT WILL CONTROL AND USED FOR ANALYSIS.

- CHECK BEAM B1

$$\rho_{MAX\phi} = 0.85\beta_1 \frac{f'_c}{f_y} \cdot \frac{\varepsilon_u}{\varepsilon_u + 0.005}$$

$$= 0.85(0.85)\frac{5000psi}{60000psi} \cdot \frac{0.003}{0.003+0.005}$$

$$\therefore \rho_{MAX\phi} = 0.0226.$$

$$\Rightarrow A_{s1} = 0.226(24'')(14') = 7.59\,in^2$$

$$a = \frac{A_s f_y}{0.85 f'_c b}$$

$$= \frac{(7.59\,in^2)(60ksi)}{0.85(5ksi)(24'')}$$

$$\therefore a = 4.46''$$

$$c = \frac{a}{\beta_1}$$

$$= \frac{4.46''}{0.85}$$

$$\therefore c = 5.25''$$

→ CONT'D.

## BEAM DESIGN/ SLAB DESIGN

- CHECK BEAM B1 CONT'D.

$M_{N_1} = A_s f_y (d - \frac{a}{2})$

$= (7.59_{in^2})(60ksi)(14'' - \frac{4.46''}{2})$

$\therefore M_{N_1} = 446 k \cdot ft.$

$M_{N_2} = \frac{M_U}{\phi} - M_{N_1}$

$= \frac{555 k \cdot ft}{0.9} - 446 k \cdot ft$

$\therefore M_{N_2} = 170 k \cdot ft$

$A_{S_2} = \frac{M_{N_2}}{f_y(d - d')}$

$= \frac{(170k \cdot ft)(12''/ft)}{(60ksi)(14'' - 4'')}$

$\therefore A_{S_2} = 3.4_{in^2}$

$A_S = A_{S_1} + A_{S_2}$

$= 7.59_{in^2} + 3.4_{in^2}$

$\therefore A_S = 10.99_{in^2}$

$f'_s = \varepsilon_u \frac{c - d'}{c} E_s.$

$= 0.003 \left(\frac{5.25'' - 4''}{5.25''}\right) 29000ksi$

$\therefore f'_s = 20.7ksi.$

$A'_s = A_{S_2} \frac{f_y}{f'_s}$

$= (3.4_{in^2})\left(\frac{60ksi}{20.7ksi}\right)$

$\therefore A'_s = 9.89_{in^2}$

$\therefore A_s = (9)\#10 \quad (11.43_{in^2})$
$A'_s = (10)\#9 \quad (10_{in^2})$

→CONT'D.

BEAM DESIGN / SLAB DESIGN

- CHECK YIELDING AND DESIGN MOMENT CAPACITY:

$$\rho_{cy} = 0.85(0.85)\left(\frac{5\text{ksi}}{60\text{ksi}}\right)\left(\frac{4''}{14''}\right)\left(\frac{0.003}{0.001}\right) = 5.16\%$$

$$\rho = \frac{11.43\text{in}^2}{(24'')(18'')} = 2.65\% < \rho_{cy} = 5.16\% \Rightarrow \text{DOES NOT YIELD : CASE II}$$

$\Rightarrow$ ASSUME $f_s > f_y$ ; $C = T$.

$$0.85 f'_c b \beta_1 c + A'_s f'_s = A_s f_y.$$

$$0.85(5\text{ksi})(0.85)c^2 + (10\text{in}^2)(0.003)(29000\text{ksi})c - (10\text{in}^2)(0.003)(29000\text{ksi})(4'') = (11.43\text{in}^2)(60\text{ksi})c$$

$$\therefore c = 14.7''$$

$$a = \beta_1 c$$

$$= (0.85)(14.7'')$$

$$\therefore a = 12.5''$$

$$\varepsilon'_s = \frac{0.003}{14.7''}(14.7'' - 4'') = 0.0021 < \varepsilon_y \quad \text{(GOOD)}$$

$$\varepsilon_s = \frac{0.003}{14.7''}(14.7'' - 14'') = 0.0014$$

$$M_n = (10\text{in}^2)(0.0021)(29000\text{ksi})(14'' - 4'') + 0.85(5\text{ksi})(24'')(12.5'')\left(14'' - \frac{12.5''}{2}\right)$$

$$\therefore M_n = 1533\text{k}\cdot\text{ft}$$

$$\phi M_n = (0.9)(1533\text{k}\cdot\text{ft})$$

$$\therefore \phi M_n = 1380\text{k}\cdot\text{ft} > 555\text{k}\cdot\text{ft} \quad \text{(GOOD)}$$

## BEAM DESIGN/SLAB DESIGN

- FROM SAP 2000:

$M_{o_C} = 1436\ k\cdot ft$

$M_{o_D} = 2530\ k\cdot ft$

=> THESE MOMENTS WILL BE USED TO DESIGN THE 2WAY SLAB.

- DISTRIBUTION OF MOMENTS
  - FRAME C

$M_o = 1436\ k\cdot ft$

$M^-_{EXT} = 0.3M_o = 430.1\ k\cdot ft$

$M^+_{INT} = 0.5M_o = 718\ k\cdot ft$

$M^-_{INT} = 0.7M_o = 1005\ k\cdot ft.$

  - FRAME D

$M_o = 2530\ k\cdot ft$

$M^-_{EXT} = 0.3M_o = 759\ k\cdot ft$

$M^+_{INT} = 0.5M_o = 1265\ k\cdot ft$

$M^-_{INT} = 0.7M_o = 1771\ k\cdot ft$

- FRAME PARAMETERS (VALUES TAKEN FROM TECH 2)

$I_s^{\beta_t} = 7762.25\ in^4$

$\beta_t = 1.4.$

$\alpha = 1.77$

$\frac{l_2}{l_1} = 1.0$

$\alpha \frac{l_2}{l_1} = 1.77$

→ CONT'D.

BEAM DESIGN/SLAB DESIGN

- DISTRIBUTION OF MOMENTS
  - EXTERIOR NEGATIVE MOMENTS

| | $l_2/l_1$ | 1.0 |
|---|---|---|
| $\alpha\, l_2/l_1 > 1.0$ | $\beta = 0$ | 100 |
| | $\beta = 1.4$ | $x$ |
| | $\beta = 2.5$ | 75 |

$\Rightarrow$ INTERPOLATING : $x = 86\%$

- FRAME C

430.1 k·ft → 86% TO CS (370.5 k·ft)
→ 14% TO MS (60 k·ft)

- FRAME D

759 k·ft → 86% TO CS (653 k·ft)
→ 14% TO MS (106 k·ft)

- INTERIOR POSITIVE MOMENTS.

| | $l_2/l_1 = 1.0$ |
|---|---|
| $\alpha\, l_2/l_1 > 1.0$ | 75%. |

- FRAME C

718 k·ft → 75% TO CS (538.5 k·ft)
→ 25% TO MS (179.5 k·ft)

- FRAME D

1265 k·ft → 75% TO CS (948.8 k·ft)
→ 25% TO MS (316 k·ft)

→ CONT'D.

BEAM DESIGN/SLAB DESIGN

- DISTRIBUTION OF MOMENTS CONT'D.
  - INTERIOR NEGATIVE MOMENTS

|  | $l_2/l_1 = 1.0$ |
|---|---|
| $\alpha\, l_2/l_1 > 1.0$ | 75% |

  - FRAME C

1005 k·ft → 75% TO CS (753.8 k·ft)
1005 k·ft → 25% TO MS (251.3 k·ft)

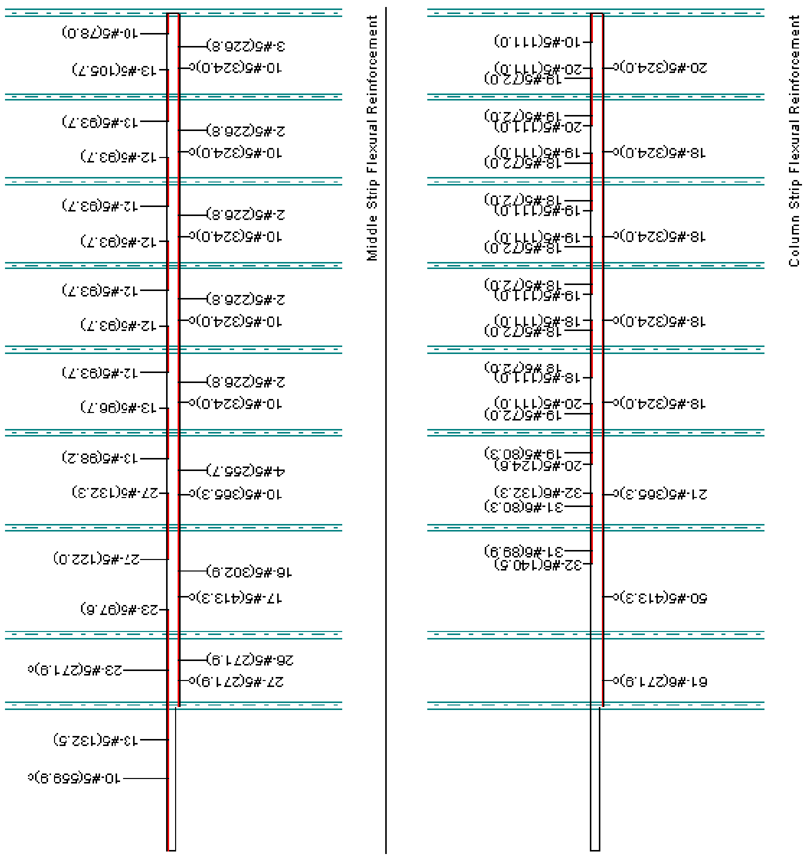
  - FRAME D

1771 k·ft → 75% TO CS (1328 k·ft)
1771 k·ft → 25% TO MS (442.8 k·ft)

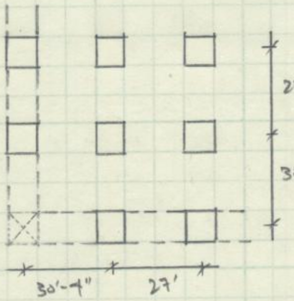
- DESIGN
  - SEE FOLLOWING SPREADSHEET.

| **FRAME C** | **CS** | | | |
|---|---|---|---|---|
| *Item* | *Description* | *Exterior Span* | | |
| | | $M^-_{EXT}$ | $M^+_{INT}$ | $M^-_{INT}$ |
| 1 | $M_n$ | 370.5 | 538.5 | 753.75 |
| 2 | $b_{CS}$ | 91 | 91 | 91 |
| 3 | $d_{eff}$ | 6.31 | 6.31 | 6.31 |
| 4 | $M_u = M_n/\varphi$ | 529.285714 | 769.28571 | 1076.7857 |
| 5 | $M_n(12/b)$ | 48.8571429 | 71.010989 | 99.395604 |
| 6 | $R = M_u/bd^2$ | 1752.95718 | 2547.8204 | 3566.2388 |
| 7 | $\rho$ | 0.02 | 0.02 | 0.02 |
| 8 | $A_{steel} = \rho bd$ | 11.4842 | 11.4842 | 11.4842 |
| 9 | $A_{s,min} = 0.002bt$ | 1.456 | 1.456 | 1.456 |
| 10 | $N = A_s/A$ | 32 | 50 | 61 |
| 11 | $N_{min} = w_{strip}/2t$ | 6 | 6 | 6 |
| | | | | |
| **FRAME C** | **MS** | | | |
| *Item* | *Description* | *Exterior Span* | | |
| | | $M^-_{EXT}$ | $M^+_{INT}$ | $M^-_{INT}$ |
| 1 | $M_n$ | 370.5 | 538.5 | 753.75 |
| 2 | $b_{CS}$ | 45.5 | 45.5 | 45.5 |
| 3 | $d_{eff}$ | 6.93 | 6.93 | 6.93 |
| 4 | $M_u = M_n/\varphi$ | 529.285714 | 769.28571 | 1076.7857 |
| 5 | $M_n(12/b)$ | 97.7142857 | 142.02198 | 198.79121 |
| 6 | $R = M_u/bd^2$ | 2906.65544 | 4224.653 | 5913.3375 |
| 7 | $\rho$ | 0.02 | 0.02 | 0.02 |
| 8 | $A_{steel} = \rho bd$ | 6.3063 | 6.3063 | 6.3063 |
| 9 | $A_{s,min} = 0.002bt$ | 0.728 | 0.728 | 0.728 |
| 10 | $N = A_s/A$ | 10 | 13 | 27 |
| 11 | $N_{min} = w_{strip}/2t$ | 3 | 3 | 3 |

| **FRAME D** | **CS** | | | |
|---|---|---|---|---|
| Item | Description | Exterior Span | | |
| | | $M^{-}_{EXT}$ | $M^{+}_{INT}$ | $M^{-}_{INT}$ |
| 1 | $M_n$ | 653 | 948 | 1328 |
| 2 | $b_{CS}$ | 91 | 91 | 91 |
| 3 | $d_{eff}$ | 6.31 | 6.31 | 6.31 |
| 4 | $M_u = M_n/\varphi$ | 932.85714 | 1354.2857 | 1897.1429 |
| 5 | $M_n(12/b)$ | 86.10989 | 125.01099 | 175.12088 |
| 6 | $R = M_u/bd^2$ | 3089.5575 | 4485.2993 | 6283.2041 |
| 7 | $\rho$ | 0.02 | 0.02 | 0.02 |
| 8 | $A_{steel} = \rho bd$ | 11.4842 | 11.4842 | 11.4842 |
| 9 | $A_{s,min} = 0.002bt$ | 1.456 | 1.456 | 1.456 |
| 10 | $N = A_s/A$ | 31 | 31 | 20 |
| 11 | $N_{min} = w_{strip}/2t$ | 6 | 6 | 6 |
| | | | | |
| **FRAME D** | **MS** | | | |
| *Item* | *Description* | *Exterior Span* | | |
| | | $M^{-}_{EXT}$ | $M^{+}_{INT}$ | $M^{-}_{INT}$ |
| 1 | $M_n$ | 106 | 316.25 | 442.75 |
| 2 | $b_{CS}$ | 45.5 | 45.5 | 45.5 |
| 3 | $d_{eff}$ | 6.93 | 6.93 | 6.93 |
| 4 | $M_u = M_n/\varphi$ | 151.42857 | 451.78571 | 632.5 |
| 5 | $M_n(12/b)$ | 27.956044 | 83.406593 | 116.76923 |
| 6 | $R = M_u/bd^2$ | 831.59373 | 2481.052 | 3473.4729 |
| 7 | $\rho$ | 0.02 | 0.02 | 0.02 |
| 8 | $A_{steel} = \rho bd$ | 6.3063 | 6.3063 | 6.3063 |
| 9 | $A_{s,min} = 0.002bt$ | 0.728 | 0.728 | 0.728 |
| 10 | $N = A_s/A$ | 23 | 27 | 16 |
| 11 | $N_{min} = w_{strip}/2t$ | 3 | 3 | 3 |


Middle Strip Flexural Reinforcement
Column Strip Flexural Reinforcement

SLAB DESIGN: PT SLAB (EXT)



$f'_c = 5000$ psi $\quad f'_{ci} = 3000$ psi

$f_y = 60000$ psi $\quad$ 1/2 ϕ 7 WIRE STRANDS

$f_{pu} = 270$ ksi

24" x 24" COLUMN (TYPICAL)

- POST-TENSIONING

ESTIMATED PRE-STRESS LOSSES = 15ksi

$f_{SE} = 174$ ksi

$P_{EFF} = 26.6$k/TENDON.

- THICKNESS

ASSUME 10"

- SECTION PROPERTIES

$A = 3458 \text{ in}^2$

$S = 5763 \text{ in}^3$

- DESIGN PARAMETERS

SEE SLAB DESIGN: PT (INT)

- TARGET LOAD BALANCE

$0.75 w_{DL} = 82.5$ psf.

- TENDON PROFILE

$a_{INT} = 9"$

$a_{END} = 5.25"$

- PRESTRESS FORCE REQUIRED.

$$w_B = 0.75 w_{DLS} = \frac{(0.75)(145\text{PCF})(10")(30.33')}{12"/\text{ft}} = 2.75\text{k/ft}$$

→ CONT'D.

SLAB DESIGN: PT SLAB (EXT)

- PRESTRESS FORCE REQUIRED CONT'D.

$$P = \frac{w_B l^2}{8\,a_{END}} = \frac{(2.75k/ft)(30.33')^2}{8\,(5.25''/12''/ft)} = 722.6k$$

- PRECOMPRESSION ALLOWANCE

  - NUMBER OF TENDONS

$$\frac{722.6k}{26.6k/TENDON} = 27 \text{ TENDONS} \Rightarrow \text{CONSERVATIVELY USE 30 TENDONS}$$

  - ACTUAL FORCE FOR BONDED TENDONS

$$P_{ACT} = (80 \text{ TENDONS})(26.6k/\text{TENDONS}) = 798k.$$

  - BALANCED LOAD

$$w_{BM} = \frac{798k}{722.6k}(2.75k/ft)$$

  - ACTUAL PRECOMPRESSION STRESS.

$$\frac{P_{ACT}}{A} = \frac{798k}{3458\,in^2} = 230\,psi > 125\,psi \text{ (GOOD)}$$

$$< 300\,psi \text{ (GOOD)}$$

- SPAN FORCE

$$P = \frac{(2.75k/ft)(30.33')^2}{8\,(5.25''/12''/ft)} = 722k$$

$$w_B = \frac{(722k)(8)(5.25'')}{(30.33')^2(12''/ft)} = 2.74\,k/ft$$

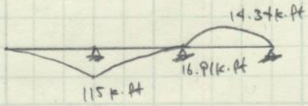
$$\frac{w_B}{w_{DL}} = \frac{2.74\,k/ft}{3.67k/ft} = 74\%.$$

$$\therefore P_{EFF} = 722.6k.$$

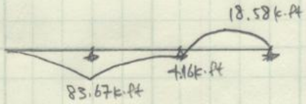
→CONT'D.

## SLAB DESIGN: PT SLAB (EXT)

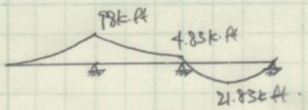
- SLAB STRESSES
  - DEAD LOAD



  - LIVE LOAD.



  - BALANCED LOAD



- STRESSES AT TRANSFER (CRITICAL MOMENTS CHECKED)

$$f_{TOP} = \left(\frac{-115k\cdot ft + 98k\cdot ft}{5763in^3}\right)(12"/ft)(1000lb/k) - 230psi = -265psi < 1800psi \text{ (GOOD)}$$

$$f_{BOT} = \left(\frac{115k\cdot ft - 98k\cdot ft}{5763in^3}\right)(12"/ft)(1000lb/k) - 230psi = -194.6psi < 1800psi \text{ (GOOD)}$$

- STRESSES AT SERVICE (CRITICAL MOMENTS CHECKED)

$$f_{TOP} = \left(\frac{-115k\cdot ft - 83.67k\cdot ft + 98k\cdot ft}{5763in^3}\right)(12"/ft)(1000lb/k) - 230psi = -439psi < 2250psi \text{ (GOOD)}$$

$$f_{BOT} = \left(\frac{115k\cdot ft + 83.67k\cdot ft - 98k\cdot ft}{5763in^3}\right)(12"/ft)(1000lb/k) - 230psi = -20.38psi < 2250psi \text{ (GOOD)}$$

- ULTIMATE STRENGTH DESIGN.

$f_T = -450psi < 2\sqrt{f'c} = 141psi$ (NO REINFORCEMENT REQUIRED)

## CURTAIN WALL DESIGN

- GLASS DETAILS (ONE PANEL)

1/4" THICK, HEAT STRENTHENED (GTF = 1.8); 1 LITE (LSF = 1.0)

$$\left.\begin{array}{l} w = 5.5' \ (1676.4\,mm) \\ h = 2.7' \ (822.3\,mm) \end{array}\right\} \Rightarrow NFL = 54.3\ PSF\ (2.6\,kPa)\ (ASTM\ E1300\text{-}04)$$

- DETERMINE 3-S EQUIVALENT DESIGN LOAD. AT 75' AND 100 $lb_{TNT}$

STANDOFF DISTANCE = 75' (23.5 m) (ASSUMED)

EQUIVALENT CHARGE = 100 $lb_{TNT}$ (45.3 $kg_{TNT}$) (ASSUMED)

3-S EQUIVALENT DESIGN LOAD = 98 PSF (4.5 kPa) (ASTM F2248-03 FIG. 3)

- DETERMINING LOAD RESISTANCE AT 75' AND 100 $lb_{TNT}$.

LR = NFL × ADJUSTMENT FACTORS

= NFL × GTF × LSF

= (54.3 PSF)(1.8)(1.0)

∴ LR = 98 PSF = 3-S EQUIVALENT DESIGN LOAD (OK)

=> THIS WILL CAUSE THE GLASS TO SHATTER, ALTERNATIVE GLASS TYPES MUST BE INSPECTED

=> ALTERNATIVES:

1) USE 2 LITE; GLASS WILL LOAD SHARE (LSF = 2.0)

LR = 195 PSF

2) USE FULLY TEMPERED GLASS (GTF = 4.0); 1 LITE

LR = 217.2 PSF

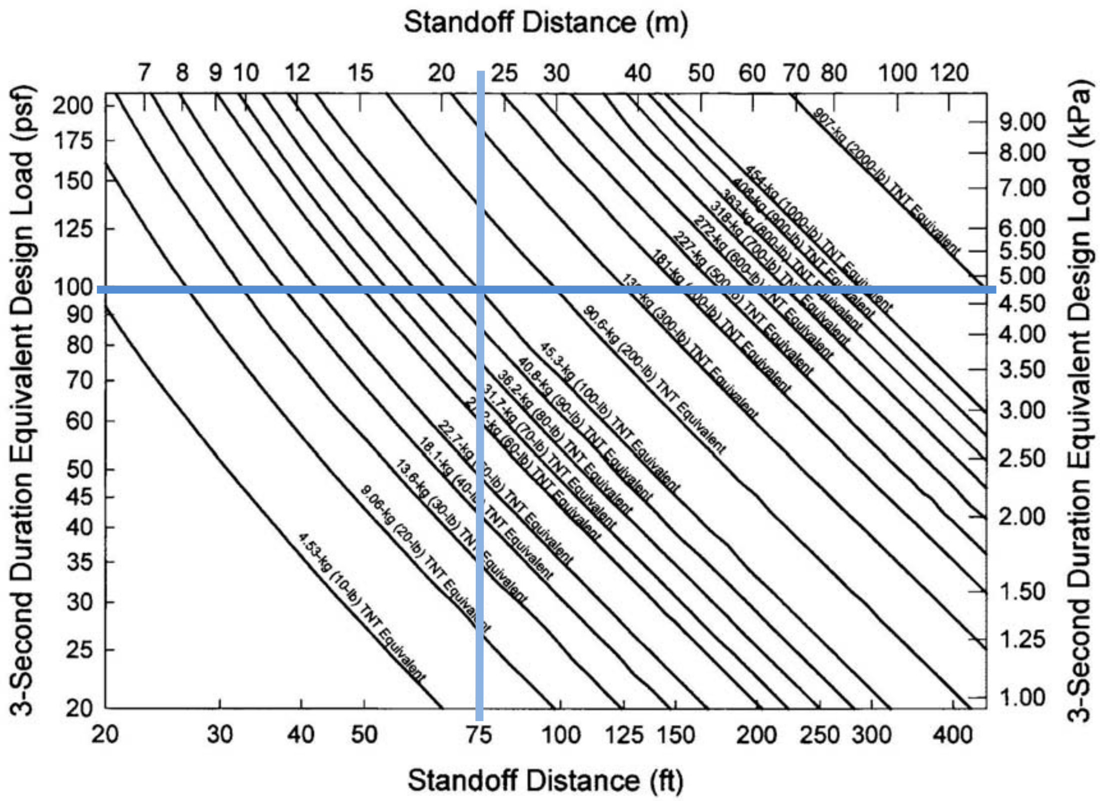
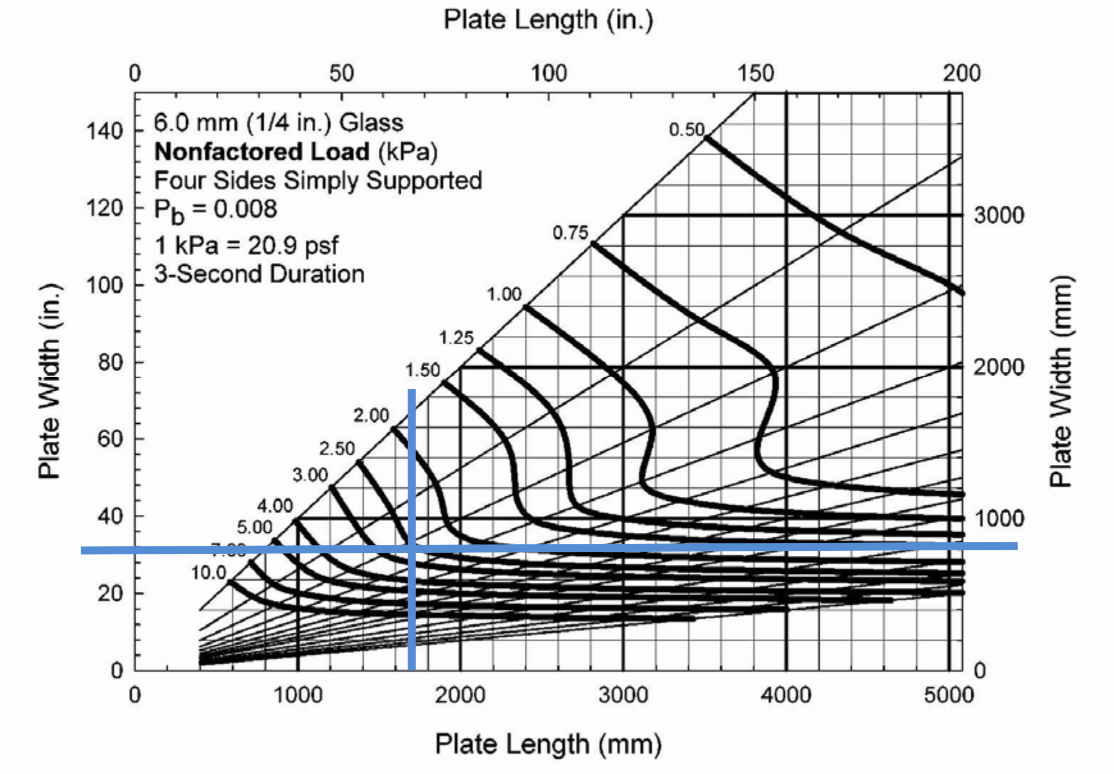


**Fig. 3.** Chart that relates standoff distance and charge size to equivalent 3-s duration equivalent design loading from ASTM F 2248 (Reprinted with permission from ASTM F 2248-03, copyright ASTM International, 100 Barr Harbor Dr., West Conshohocken, PA 19428.)



Conductive Properties of Heat Strengthened, 1 Lite Curtain Wall

| *Layer* | *Conductivity, k (W/m*K)* | *Thickness (m)* | *Thickness (in)* | *Conductance, C (W/m$^2$*K)* | | *Resistance, R (m$^2$*K/W)* | |
|---|---|---|---|---|---|---|---|
| | | | | *Summer* | *Winter* | *Summer* | *Winter* |
| Exterior Air Film | N/A | N/A | | 23.00 | 34.00 | 0.0435 | 0.0294 |
| Glass Lite 1 | 0.96 | 0.0064 | 0.25 | 151.18 | | 0.0066 | |
| Interior Air Film | N/A | N/A | | 8.30 | | 0.1205 | |

| | | |
|---|---|---|
| ∑$R_{SI}$ | 0.17 | 0.16 |
| ∑R (hr*ft$^2$*°F/BTU) | 0.97 | 0.89 |

| | | |
|---|---|---|
| U (BTU/hr*ft2*°F) | 1.03 | 1.13 |

Conductive Properties of Heat Strengthened, 2 Lite Curtain Wall

| *Layer* | *Conductivity, k (W/m*K)* | *Thickness (m)* | *Thickness (in)* | *Conductance, C (W/m$^2$*K)* | | *Resistance, R (m$^2$*K/W)* | |
|---|---|---|---|---|---|---|---|
| | | | | *Summer* | *Winter* | *Summer* | *Winter* |
| Exterior Air Film | N/A | N/A | | 23.00 | 34.00 | 0.0435 | 0.0294 |
| Glass Lite 1 | 0.96 | 0.0064 | 0.25 | 151.18 | | 0.0066 | |
| Air Space | N/A | 0.0127 | 0.5 | 7.14 | 5.00 | 0.1401 | 0.2000 |
| Glass Lite 2 | 0.96 | 0.0064 | 0.25 | 151.18 | | 0.0066 | |
| Interior Air Film | N/A | N/A | | 8.30 | | 0.1205 | |

| | | |
|---|---|---|
| ∑$R_{SI}$ | 0.32 | 0.36 |
| ∑R (hr*ft$^2$*°F/BTU) | 1.80 | 2.06 |

| | | |
|---|---|---|
| U (BTU/hr*ft2*°F) | 0.56 | 0.49 |

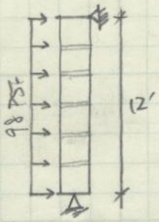
Conductive Properties of Fully Tempered, 1 Lite Curtain Wall

| *Layer* | *Conductivity, k (W/m*K)* | *Thickness (m)* | *Thickness (in)* | *Conductance, C (W/m$^2$*K)* | | *Resistance, R (m$^2$*K/W)* | |
|---|---|---|---|---|---|---|---|
| | | | | *Summer* | *Winter* | *Summer* | *Winter* |
| Exterior Air Film | N/A | N/A | | 23.00 | 34.00 | 0.0435 | 0.0294 |
| Glass Lite 1 | 0.96 | 0.0064 | 0.25 | 151.18 | | 0.6164 | |
| Interior Air Film | N/A | N/A | | 8.30 | | 0.1205 | |

| | | |
|---|---|---|
| $\sum R_{SI}$ | 0.78 | 0.77 |
| $\sum R$ (hr*ft$^2$*°F/BTU) | 4.43 | 4.35 |

| | | |
|---|---|---|
| U (BTU/hr*ft2*°F) | 0.23 | 0.23 |

## BRICK VENEER ANALYSIS



$A = 43.6\,in^2/ft_{WALL}$
$I = 47.8\,in^4/ft_{WALL}$

$f'_m = 1500\,psi$

- MID-HEIGHT STRESSES, AXIAL LOAD

$P_{MH} = (27\,psf)(6') = 162\,lb/ft_{WALL}$

$$f_a = \frac{P}{A} = \frac{162\,lb/ft_{WALL}}{43.6\,in^2/f_{WALL}}$$

$\therefore f_a = 3.72\,psi$

$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{47.8\,in^4/ft_{WALL}}{43.6\,in^2/ft_{WALL}}}$$

$\therefore r = 1.05''$

$$\frac{h}{r} = \frac{(12')(12''/ft)}{1.05''} = 137 > 99$$

$$\Rightarrow F_a = 0.25f'_m\left(\frac{70}{h/r}\right)^2$$

$$= 0.25(1500\,psi)\left(\frac{70}{137}\right)^2$$

$\therefore F_a = 101\,psi$

- MID-HEIGHT STRESSES, BLAST LOAD

$$M_{MH} = \frac{(98\,psf)(12')^2(12''/ft)}{8} = 21168\,lb \cdot in$$

$$f_b = \frac{Mc}{I} = \frac{(21168\,lb \cdot in)(7.63''/2)}{47.8\,in^4}$$

$\therefore f_b = 1689.4\,psi$

$F_b = \frac{1}{3} f'_m$

$\therefore F_b = 500\,psi$

$\rightarrow$ CONT'D.

BRICK VENEER ANALYSIS.

- CHECK UNITY

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} < 1.0$$

$$\frac{3.72\text{psi}}{101\text{psi}} + \frac{1689.4\text{psi}}{500\text{psi}} = 3.41 \gg 1.0$$ (NO GOOD)

# MONONGALIA GENERAL HOSPITAL

## BLAST AND PROGRESSIVE COLLAPSE ANALYSIS

# APPENDIX G

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