GEISINGER GRAY'S WOODS AMBULATORY CARE CAMPUS - PHASE II

**Rendering of front view supplied by Alexander Building Construction with Owner Permission

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Penn State AE Senior Capstone Project

George M. Andonie

Construction Option

Advisor: Rob Leicht

April 16th, 2014

INTRODUCTION

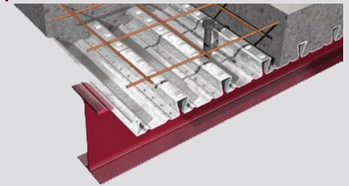
PRESENTATION OUTLINE:

PROJECT OVERVIEW

ANALYSIS 1 | VIRTUAL MOCKUP IMPLEMENTATION

ANALYSIS 2 | BRICK FAÇADE PREFABRICATION

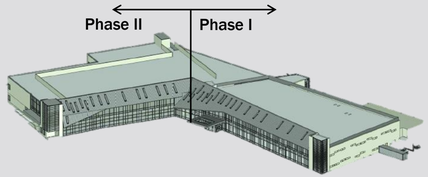
ANALYSIS 3 | RE-VALUATING COMPOSITE SLAB



PROJECT BACKGROUND

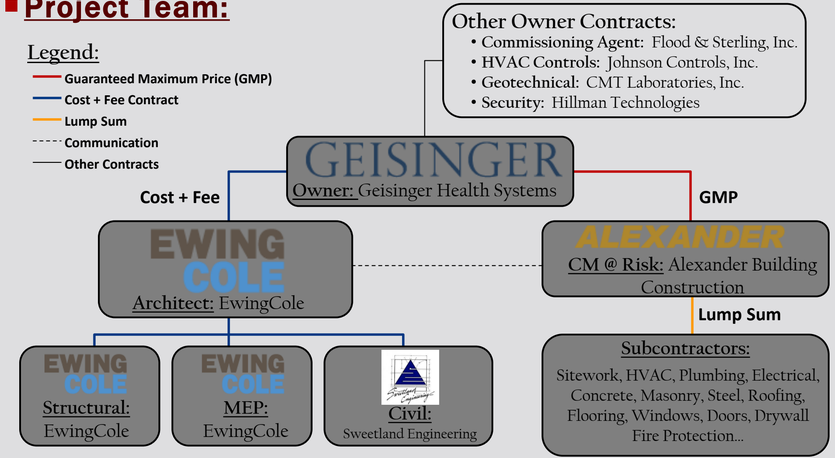
Building Functions:

- Outpatient Surgery Center
- Houses 70 Exam Rooms, 4 Operating Rooms, 4 Endoscopy Suites & 2 Main Therapy Rooms
- Phase 1: 2007-2008
- Phase 2 :2012-2014



General Building Information	
Building Name	Grays Woods Ambulatory Care Campus
Location	Port Matilda, PA
Function	Outpatient Surgery Center
Size	77,560 GSF
Height	2 Stories (48' Total Height)
Cost	$26.3 Million GMP
Construction	July '12 - February '14
Delivery	Design-Bid-Build
LEED	LEED Certified

Project Team:



Analysis #1

Implementing Virtual Mockups on Operating & Endoscopy Rooms

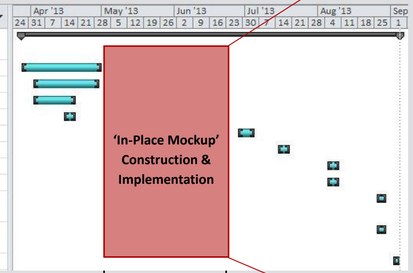
IN-PLACE MOCKUP PROCESS

Problem Identification:

- 8-week Mock-Up Process
- Low Level of Detail (LOD)
- Waste Generation
- Costly & Time Consuming Process
- Obstruction to Schedule
- Risk of Delays

Current Schedule:

	Task Name	Duration	Start	Finish
1	**Interior Work for Operating/Endoscopy Rooms**	**115 days**	**Thu 3/28/13**	**Wed 9/4/13**
2	Partition Framing	24 days	Thu 3/28/13	Tue 4/30/13
3	MEP Rough-in	20 days	Tue 4/2/13	Mon 4/29/13
4	O.R. Light/Boom Support Steel	14 days	Tue 4/2/13	Fri 4/19/13
5	Sheetrock Installation, Finish, Paint	5 days	Mon 4/15/13	Fri 4/19/13
6	Drywall Ceiling	5 days	Fri 6/28/13	Thu 7/4/13
7	Install & Hookup Surgical Scrub/Sinks	5 days	Mon 7/15/13	Fri 7/19/13
8	Light Fixtures	5 days	Mon 8/5/13	Fri 8/9/13
9	Install Grills/Registrers/Diffusers	5 days	Mon 8/5/13	Fri 8/9/13
10	Pull Wire/Terminate - Branch Power & Lighting	4 days	Mon 8/26/13	Thu 8/29/13
11	Device Installation - Fire Alarm, Nurse Call, PA, CATV, V&D	4 days	Mon 8/26/13	Thu 8/29/13
12	MEP Trim-Out	3 days	Mon 9/2/13	Wed 9/4/13



Proposed Solution:

- Virtual Mockups for Design Reviews

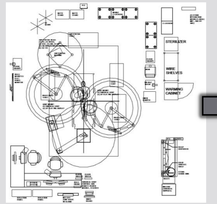
Research Goal:

- Develop Virtual Mockup for Operating & Endoscopy Rooms
- Capture Efforts, Criteria & Workflow
- Schedule Analysis Implementation

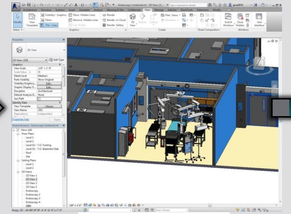
VIRTUAL MOCKUP DEVELOPMENT

Development Process:

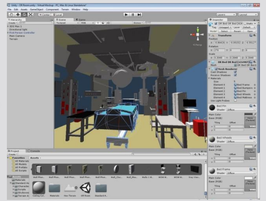
1. Autodesk Revit:
   - Model Building Space
   - Model MEP Systems
   - Model Equipment & Casework
   - Populate & Arrange
2. 3ds Max:
   - Material Placement
   - Scale Adjustment
3. Unity Game Engine:
   - Scripting Model Interaction



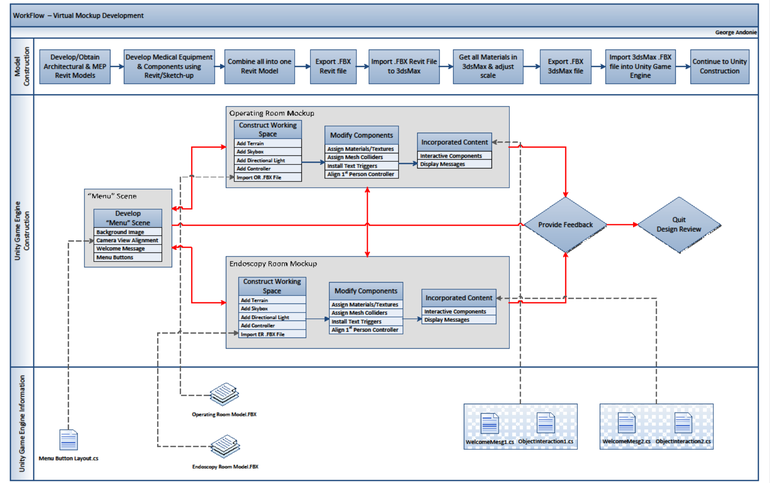
EWING COLE



AUTODESK REVIT



unity



VIRTUAL MODEL APPLICATION

PRESENTATION OUTLINE:

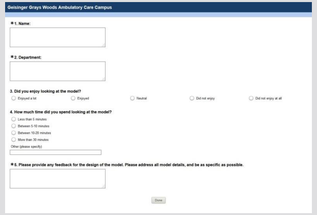
Model Application:

1. Model Walkthrough:
   - First Person Controller (FPC)
   - Computer/Iconn Lab
2. Design Review:
   - Functionality & Room Layout
     - Check Clearances
     - Equipment/Casework Location
     - Mounting heights
     - General Appearance
3. Provide Feedback:
   - Online Survey Completion

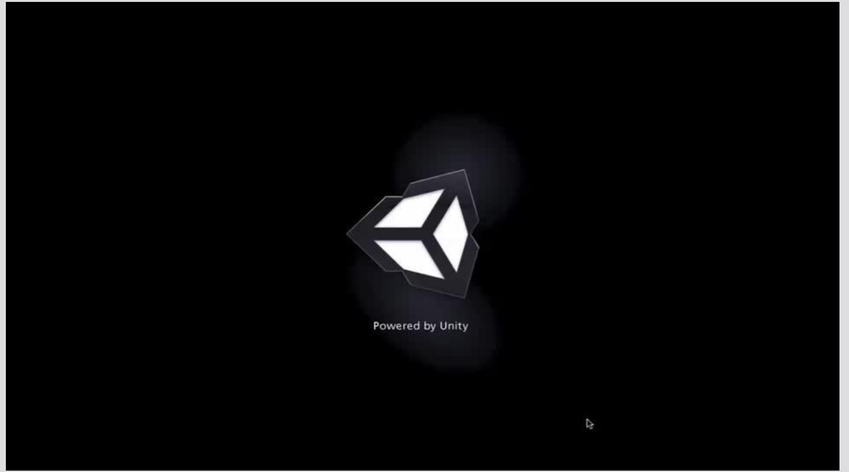
Welcome Menu:

Operating Room Design Review:

Feedback Survey



Endoscopy Room Design Review:



VIRTUAL MOCKUP IMPLEMENTATION

Time Requirements:

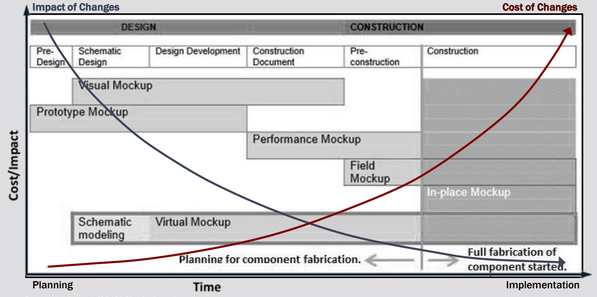
Time Requirement	
Step Description	**Duration (Hrs.)**
1. Obtained Existing Revit Model	-
2. Combine Architectural & MEP Revit Models	2
3. Strip Out Revit Model	0.5
4. Model all Owner Furnished Equipment	8
5. Export Model to 3Ds Max	1
6. Export Model to Unity	1
7. Develop Scripting and Textures in Unity	8
Total	**20.5 Hrs**

Cost Implications:

Cost Summary			
Item Description	**Mhrs**	**Hourly Wage**	**Total Cost**
Develop & Modify Model	23	$35/hr	$805
Design-Review Meetings (GC)	50	$65/hr	$3,250
Total		**$4,055**	

*Costs taken from RS Means 2013

Schedule Implications:



Source: Maing, M. (2012) *Physical or Virtual*

- Design Phase: Implement Early
  - Design-Review meetings between project participants & end users
  - Changes can be costly to implement later in the project lifecycle
- Construction Phase: Visual communication of built space

Recommendation:

- Implement Virtual Mockups for Operating & Endoscopy Rooms

Potential Value Added:

- Streamlining the design and construction process
- Subcontractor & end user feedback
- Reduce project waste (time & cost)
- Strong visualization/communication tool
- Ensuring the end product meets owner's needs
- No disturbance to project schedule

Analysis #2

Brick Façade Prefabrication

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FAÇADE COMPARISON

GEISINGER GRAYS WOODS
AMBULATORY CARE CAMPUS – PHASE II

PRESENTATION OUTLINE:

Opportunity Identification:

- Time & Labor Intensive
- Site Congestion
- Weather Delays
- Critical Path

Research Goals:

- Identify alternative panel
- Reduce schedule & cost
- Reduce site congestion & trade coordination on site

Original Façade:

- 4” Brick on Metal Stud
- $674,000
- 178 Day Construction Duration

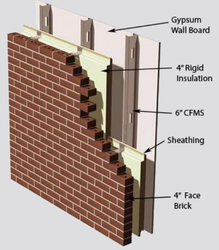


*Image Courtesy of www.veneerbricks.com

Proposed Facade:

- 9” Insulated Precast Panel
- Embedded Thin Brick
- Cost = $25/SF
- Erection = 16 panels/ day

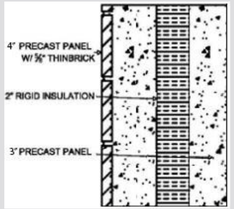
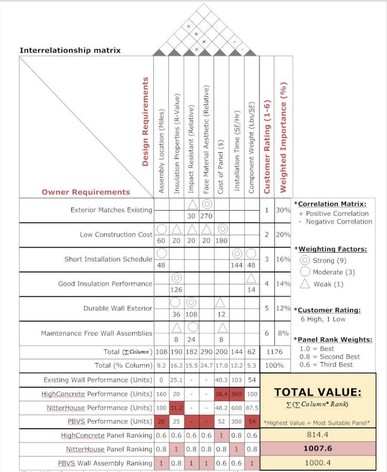


*Image Courtesy of Nitterhouse Concrete

House of Quality:

Customer's Needs	Design Requirements
Façade Aesthetics	Face Material Type
Low Cost	Assembly Location
Short Schedule	Erection Time
Good Thermal Performance	Component Weight
Durability	Insulation Properties
Maintenance	Cost of Panel



PANEL DESIGN

Panel Design:

- Consistency & transportation
- Span Building Height (40')
- Maximum width 12'
- Total 74 precast panels
  - 14 different panel widths

Panel Installation Durations			
Façade Orientation	Panel Qty.	Calculated Duration	Adjusted Duration
East Façade	19	1.27 Days	2 Days
South Façade	25	1.67 Days	2 Days
West Façade	22	1.47 Days	2 Days
North Façade	8	0.53 Days	1 Day
Total	**74**	**4.93 Days**	**7 Days**

*Durations taken from Precast Panel Takeoff, and assume productivity of 16 Panels/Day.

East Elevation:

North Elevation:

South Elevation:

West Elevation:

MECHANICAL BREADTH

PRESENTATION OUTLINE:

Mechanical Analysis:

- Evaluate Thermal Performance
  - Thermal Property Comparison
  - Energy Performance

Heat Transfer Rate:

$$Q = (\text{U-Value}) * (\text{Area}) * (\Delta T)$$

Annual Heating Fuel Consumption:

$$AHFC = \frac{24 * Q * HDD}{\Delta T_w * HV * HEE}$$

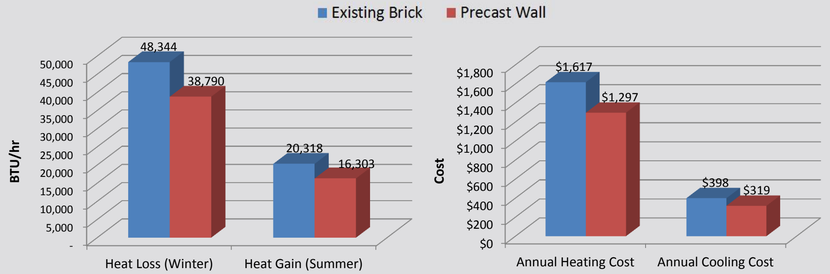
Annual Cooling Energy Consumption:

$$ACEC = \frac{24 * Q * CDD}{\Delta T_s * CV}$$

Heat Loss & Heat Gain Calculations

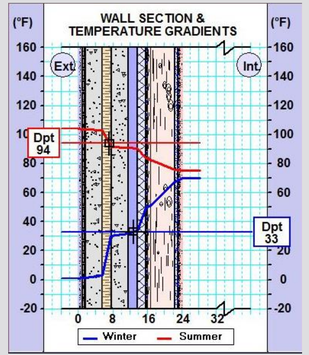
Wall Assembly	R - Value	U-Value	Area (SF)	Heat Loss (Winter)		Heat Gain (Summer)	
				ΔT (°F)	BTU/Hr	ΔT (°F)	BTU/Hr
Existing Brick Assembly	25.05	0.03992	17,551	69	48,344	29	20,318
Precast Wall Assembly	31.22	0.03203	17,551	69	38,790	29	16,303
Difference	**6.17**	**0.00789**	**-**	**9,554 BTU/hr**		**4,015 BTU/hr**	

*R-Values taken from Nitterhouse Manufacturer



Breadth Conclusions:

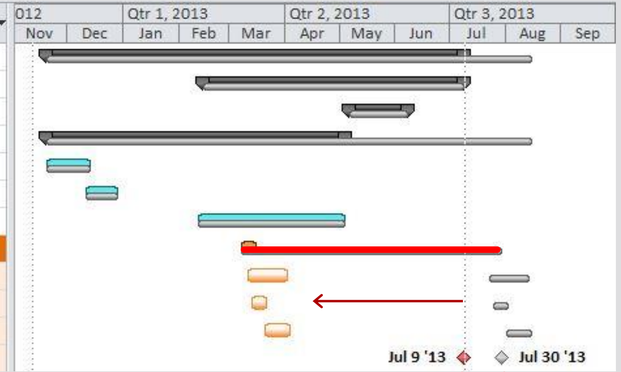
- Improved Thermal Performance (By 20%)
  - Heat Gain/Loss Reduction
  - Reduced Heating/Cooling Costs
- No condensation in systems
- Potentially Downsize Mechanical System



PANEL IMPLEMENTATION

Schedule Implications:

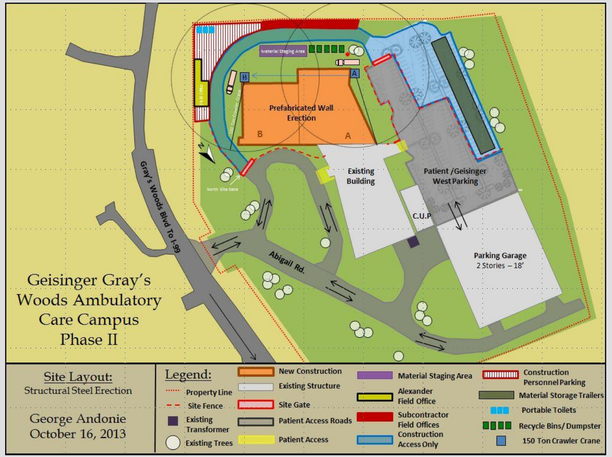
	Task Name	Duratic	Start	Finish
1	Building Envelope	166 days	Mon 11/19/12	Tue 7/9/13
2	Roofing	103 days	Thu 2/14/13	Mon 7/8/13
4	Curtain Wall	25 days	Mon 5/6/13	Fri 6/7/13
6	Exterior Wall	120 days	Mon 11/19/12	Fri 5/3/13
7	Exterior Wall Framing	19 days	Mon 11/19/12	Thu 12/13/12
8	Exterior Wall Sheathing	14 days	Tue 12/11/12	Fri 12/28/12
9	Air Vapor Barrier & Insulation	60 days	Mon 2/11/13	Fri 5/3/13
10	Brick Veneer/Flashing	7 days	Thu 3/7/13	Fri 3/15/13
11	Install Windows/Doors	16 days	Mon 3/11/13	Mon 4/1/13
12	Exterior Painting	7 days	Wed 3/13/13	Thu 3/21/13
13	Façade Joint Sealant	11 days	Wed 3/20/13	Wed 4/3/13
14	Building Dried-in & Conditioned	0 days	Tue 7/9/13	Tue 7/9/13



Shorten Brick Installation by 96 Days!

Schedule Savings = 3 weeks

Site Layout:



PANEL IMPLEMENTATION

Cost Implications:

- Implement = Additional $10/SF
- Interior Components Same
  - Vapor Barrier, Sheathing & Backup
- Cost Changes
  - 2” vs. 4” Insulation
  - Caulking Panel Joints
- General Conditions Savings
  - 21 Days = $43,663

Building Enclosure Construction Cost Comparison

Material Description	Total	Unit	Prefabricated Panels		Traditional Brick	
			Cost/SF	Total Cost	Cost/SF	Total Cost
Exterior Face Wall	17,551	SF	$25.00	$438,775	$16.10	$282,571
Interior Component	17,551	SF	$19.63	$344,485	$19.63	$344,485
Insulation (2" or 4")	17,551	SF	$1.37	$24,045	$2.68	$47,037
Caulking	3,360	LF	$2.16	$7,258	-	-
Transportation	-	-	Included	Included	-	-
Erection Equipment (Scaffolding or Crane)	-	-	Included	Included	-	$47,037
Total			**$48.2**	**$814,563**	**$38.4**	**$721,130**

Costs provided by Nitterhouse Concrete, RS Means 2013, and Actual Project Costs

Building Enclosure Cost Comparison Summary

Item Description	Prefabricated Panels Total Cost	Existing Brick Total Cost
Cost of Assembly	$814,562.69	$721,130
General Conditions Cost	$742,260.05	$785,922
Total	**$1,556,823**	**$1,507,052**

**Estimated Assembly costs based on RS Means 2013, Nitterhouse Concrete, and Actual Project Costs

Final Conclusions:

- 74 Architectural Precast Panels
- Improve Thermal Performance by 20%
- Schedule Reduction = 21 Days
- Implementation Cost = $50,000

Recommendation:

- Not in owner’s best interest to pursue
  - Increased cost and planning for implementation outweigh savings in schedule and building performance

Analysis #3

Re-evaluation of Structural Composite Slab

EXISTING CONDITIONS

Opportunity Identification:

- Vale Engineering on Structural System (20% of Building Costs)
  - Reduce Overall Building Costs

Proposed Solution:

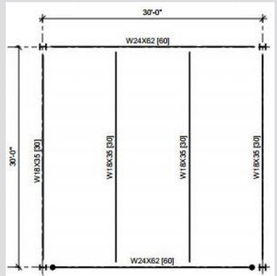
- Change Lightweight Composite Deck to Normal Concrete
  - NW = Lower Material Cost

Research Goal:

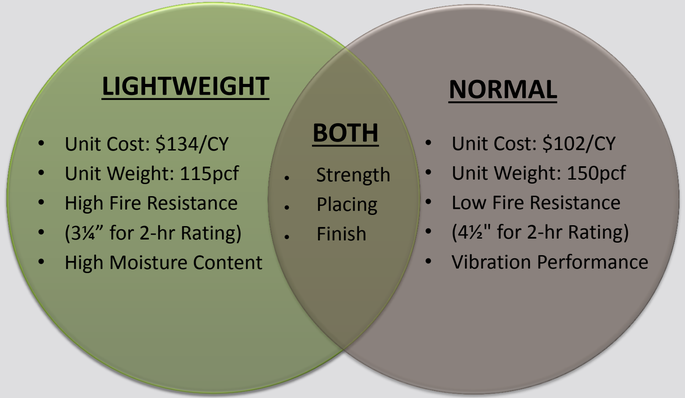
- Reduce building costs
- Improve building performance

Existing Conditions:

- 38,000 SF of Composite Floor
- 3 ¼” Lightweight Concrete
- 2” Composite Metal Decking (18-Gauge)
- Typical 30’ x 30’ Bays (40)



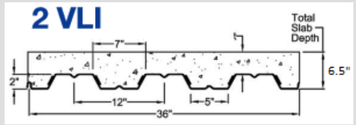
Current Typical Bay (LW Concrete)



STRUCTURAL BREADTH

Structural Calculations:

- Determine NW Deck Assembly
- Check Beam Sizing
- Check Girder Sizing
- Check Column Sizing
- Check Footing Sizing



Source: Vulcraft Decking Catalog

CURRENT TYPICAL BAY (LIGHTWEIGHT CONCRETE)

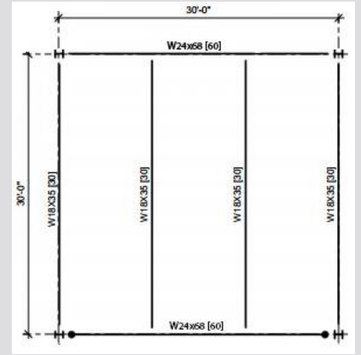
Existing LW Design	
Item Description	**Size**
LW Concrete Material	3.25"
Concrete Placing	<6"
Concrete Reinforcing	6x6 W1.4xW1.4
Floor Decking	2VLI18
Shear Studs	½" Diameter
Steel Beams (4)	W18x35
Steel Girders (2)	W24x62
Steel Columns (2)	W10x49
Additional Fireproofing	-

PROPOSED TYPICAL BAY DESIGN (NORMAL CONCRETE)

Proposed NW Design	
Item Description	**Size**
NW Concrete Material	4.5"
Concrete Placing	<6"
Concrete Reinforcing	6x6 W2.1xW2.1
Floor Decking	2VLI18
Shear Studs	½" Diameter
Steel Beams (4)	W18x35
Steel Girders (2)	W24x68
Steel Columns (2)	W10x49
Additional Fireproofing	-

Breadth Conclusions:

- 4 ½" NW Composite Deck
  - Increase Reinforcement
- Beam Spacing and Size
- Girder Sizes Increase to W24x68
  - 360lbs of Steel/Bay
- Column and Footing Sizes Acceptable
- Member Quantity Constant
- No Additional Fireproofing



Proposed Typical Bay (NW Concrete)

PROJECT IMPACTS

Construction Implications:

1. Floor-to-floor height:
   - Loose 1.25” per floor
   - Absorbed by ceiling plenum
2. Beam Deflections:
   - Impact on building’s serviceability
   - Addressed in Structural Analysis
3. Improved Quality Control:
   - Moisture Content
   - Fireproofing

Cost Implications:

Overall Cost Comparison			
Item Description	System A: Proposed NW	System B: Existing LW	Cost Ratio (A/B)
Concrete Material & Placing	$85,068.00	$80,643.60	1.05
Concrete Reinforcing	$15,480.00	$12,960.00	1.19
Composite Metal Decking	$136,440.00	$136,440.00	1.00
Headed Shear Stud Connectors	$22,080.00	$22,080.00	1.00
Structural Steel Framing	$713,904.00	$693,504.00	1.03
Additional Fireproofing	-	-	-
TOTAL	$972,972	$945,627	1.03

Costs taken from 30x30' Typical Bay Detailed Estimate (Assuming 40 Bays)

- Implementing change increases system cost by 3%
  - Concrete costs still increased
  - Largest % Increase = Reinforcement
  - Metal Decking & Studs Constant

Final Conclusions:

- Initial Goal = Reduce Project Costs
  - Escalate Costs by $27,344
  - Upsize Girders (Additional 7.2 Tons of Steel)
- Revised Goal = Improve Building Performance
  - Vibration, Moisture, & Fireproofing

Recommend Change:

- Improved Quality Control
- Reduce Risks of Escalating Project Cost & Schedule
  - Could have saved project over $100,000

FINAL RECOMMENDATIONS

- IMPROVE EFFICIENCY ✓
- INCREASED COLLABORATION ✓
- STREAMLINE PROCESS ✓
- REDUCE RISK ✓ ✓
- REDUCE COST ✗
- REDUCE SCHEDULE ✗
- IMPROVE QUALITY CONTROL ✓

ANALYSIS 1 | VIRTUAL MOCKUP IMPLEMENTATION:

- Implement Virtual Mockups for the facility's Operating & Endoscopy Rooms
  - Save Cost
  - Save Time
  - Reduce Risk
  - Solve Constructability Issues

ANALYSIS 2 | BRICK FAÇADE PREFABRICATION

- Would not recommend the prefabrication of the building's facade
  - Increased Cost & Planning
  - Reduced Schedule & Building Performance

ANALYSIS 3 | REEVALUATING COMPOSITE SLAB

- Recommend Changing from LW to NW Composite Slab
  - Increased Cost
  - Improved Quality Control (Reduce Risk)

ACKNOWLEDGEMENTS

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PENNSTATE
PENNSTATE Department of Architectural Engineering

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George Burnley – High Concrete Group
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Questions & Comments

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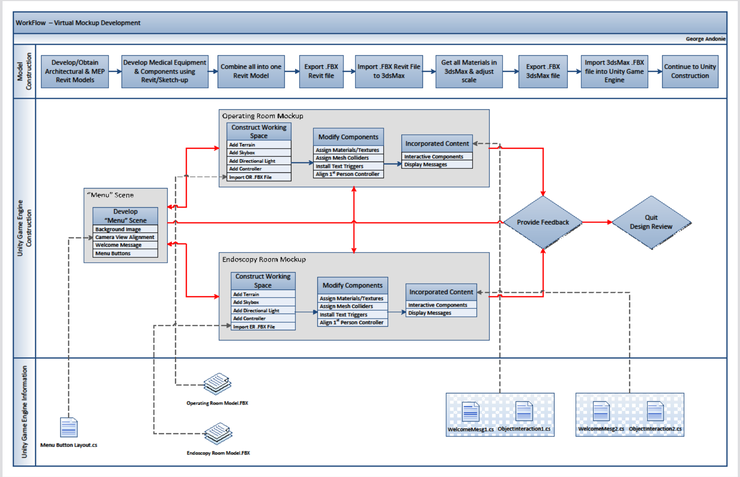
APPENDIX 1A


WorkFlow – Virtual Mockup Development
George Andonie
Model Construction
Develop/Obtain Architectural & MEP Revit Models
Develop Medical Equipment & Components using Revit/Sketch-up
Combine all into one Revit Model
Export .FBX Revit file
Import .FBX Revit File to 3dsMax
Get all Materials in 3dsMax & adjust scale
Export .FBX 3dsMax file
Import 3dsMax .FBX file into Unity Game Engine
Continue to Unity Construction
Unity Game Engine Construction
Operating Room Mockup
Construct Working Space
Add Terrain
Add Skybox
Add Directional Light
Add Controller
Import OR .FBX File
Modify Components
Assign Materials/Textures
Assign Mesh Colliders
Install Text Triggers
Align 1st Person Controller
Incorporated Content
Interactive Components
Display Messages
"Menu" Scene
Develop "Menu" Scene
Background Image
Camera View Alignment
Welcome Message
Menu Buttons
Provide Feedback
Quit Design Review
Endoscopy Room Mockup
Construct Working Space
Add Terrain
Add Skybox
Add Directional Light
Add Controller
Import ER .FBX File
Modify Components
Assign Materials/Textures
Assign Mesh Colliders
Install Text Triggers
Align 1st Person Controller
Incorporated Content
Interactive Components
Display Messages
Unity Game Engine Information
Operating Room Model.FBX
Endoscopy Room Model.FBX
Menu Button Layout.cs
WelcomeMesg1.cs
ObjectInteraction1.cs
WelcomeMesg2.cs
ObjectInteraction2.cs

APPENDIX 2A

Interrelationship matrix

Owner Requirements	Assembly Location (Miles)	Insulation Properties (R-Value)	Impact Resistant (Relative)	Face Material Aesthetic (Relative)	Cost of Panel ($)	Installation Time (SF/Hr)	Component Weight (Lbs/SF)	Customer Rating (1-6)	Weighted Importance (%)
Exterior Matches Existing								1	30%
Low Construction Cost		30	270					2	20%
Short Installation Schedule	60	20	20	20	180			3	16%
Good Insulation Performance	-48					144	48	4	14%
Durable Wall Exterior		126					14	5	12%
Maintenance Free Wall Assemblies		36	108		12			6	8%
Total (ΣColumn)	108	190	182	290	200	144	62	1176	
Total (% Column)	9.2	16.2	15.5	24.7	17.0	12.2	5.3	100%	
Existing Wall Performance (Units)	0	25.1	-	-	40.3	103	54		
HighConcrete Performance (Units)	160	20	-	-	38.4	960	100		
NitterHouse Performance (Units)	100	32	-	-	48.2	600	87.5		
PBVS Performance (Units)	50	25	52	52	52	300	54		
HighConcrete Panel Ranking	0.6	0.6	0.6	0.6	1	0.8	0.6	814.4	
NitterHouse Panel Ranking	0.8	1	0.8	0.8	0.8	1	0.8	1007.6	
PBVS Wall Assembly Ranking	1	0.8	1	1	0.6	0.6	1	1000.4	

*Note: Values for panel costs, duration, and weight are relative and are used for performance comparison purposes only.

***Correlation Matrix:**
+ Positive Correlation
- Negative Correlation

***Weighting Factors:**
Strong (9)
Moderate (3)
Weak (1)

***Customer Rating:**
6 High, 1 Low

***Panel Rank Weights:**
1.0 = Best
0.8 = Second Best
0.6 = Third Best

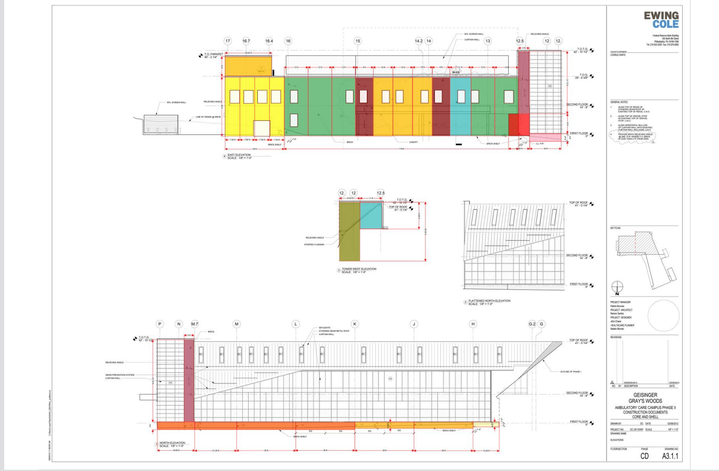
TOTAL VALUE:
$\Sigma(\Sigma Column * Rank)$
Highest Value = Most Suitable Panel

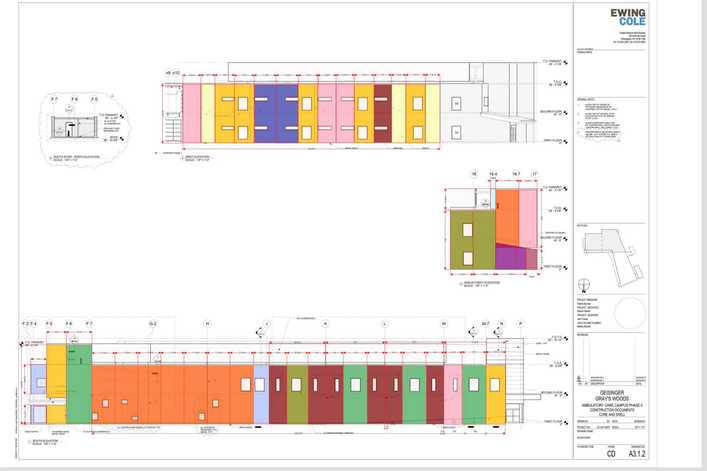
Precast Panel Takeoffs

Panel Orientation	Panel Designation	Panel Width (ft.)	Panel Height (ft.)	Openings (Qty. & Type)	Total Opening Area (SF)	Joint Sealant (LF)	East Façade	South Façade	West Façade	North Façade	Total Quantity	Total Panel Area (SF)	Average Cost/SF	Total Cost
VERTICAL	A-1	2.5	10.5	1	8	26	-	-	1	-	1	26.25	$25.00	$656.25
	B-1	5	31.72	-	0	73.44	1	-	-	-	1	158.6	$25.00	$3,965.00
	B-2	5	41.7	-	0	93.4	-	-	-	1	1	208.5	$25.00	$5,212.50
	C-1	7.25	30	-	0	74.5	-	-	3	-	3	652.5	$25.00	$16,312.50
	D-1	7.5	30	1 x W5	33	75	3	-	-	-	3	576	$25.00	$14,400.00
	D-2	7.5	21.85	1 x W5	33	58.7	1	-	-	-	1	130.875	$25.00	$3,271.88
	E-1	8	15	1 x W4	20.5	46	-	1	-	-	1	99.5	$25.00	$2,487.50
	E-2	8	9.77	1 x W1	55.66	35.54	1	-	-	-	1	22.5	$25.00	$562.50
	E-3	8	30	1 x W5	33	76	-	1	-	-	1	207	$25.00	$5,175.00
	F-1	9	30	1 x W6	26	78	2	-	-	-	2	488	$25.00	$12,200.00
	F-2	9	30	2 x W1	25.6	78	-	-	-	1	1	244.4	$25.00	$6,110.00
	F-3	9	30	1 x W7	14	78	-	6	-	-	6	1536	$25.00	$38,400.00
	G-1	9.25	30	-	0	78.5	-	-	2	-	2	555	$25.00	$13,875.00
	G-2	9.25	30	2 x W1	25.6	78.5	-	-	2	-	2	503.8	$25.00	$12,595.00
	G-3	9.25	30	1 x W7	14	78.5	1	-	-	-	1	263.5	$25.00	$6,587.50
	H-1	10	30	2 x W1	25.6	80	-	-	1	-	1	274.4	$25.00	$6,860.00
	H-2	10	30	2 x W5	66	80	-	-	3	-	3	702	$25.00	$17,550.00
	H-3	10	30	1 x W5	33	80	-	1	-	-	1	267	$25.00	$6,675.00
	H-4	10	30	1 x W6	26	80	3	-	-	-	3	822	$25.00	$20,550.00
	H-5	10	27	-	0	74	-	1	-	-	1	270	$25.00	$6,750.00
	H-6	10	9.77	-	0	39.54	-	1	-	-	1	97.7	$25.00	$2,442.50
	I-1	10.5	30	-	0	81	-	-	1	-	1	315	$25.00	$7,875.00
	I-2	10.5	30	1 x W5	33	81	-	1	-	-	1	282	$25.00	$7,050.00
	J-1	11	13.6	-	0	49.2	-	-	1	-	1	149.6	$25.00	$3,740.00
	J-2	11	30	1 x W6	26	82	-	1	-	-	1	304	$25.00	$7,600.00
	K-1	11.2	30	2 x W1	25.6	82.4	-	-	2	-	2	620.8	$25.00	$15,520.00
	L-1	11.5	30	-	0	83	-	-	1	-	1	345	$25.00	$8,625.00
	L-2	11.5	30	2 x W5	66	83	-	-	1	-	1	279	$25.00	$6,975.00
	M-1	11.7	30	-	0	83.4	-	2	1	-	3	1053	$25.00	$26,325.00
	M-2	11.7	30	L1 , L2	22	83.4	-	1	-	-	1	329	$25.00	$8,225.00
	M-3	11.7	30	L3, L4	12	83.4	-	1	-	-	1	339	$25.00	$8,475.00
	M-4	11.7	30	L+L5	11	83.4	-	2	-	-	2	680	$25.00	$17,000.00
	M-5	11.7	30	1 x W1	12.8	83.4	-	1	-	-	1	338.2	$25.00	$8,455.00
	N-1	12	30	-	0	84	1	-	-	-	1	360	$25.00	$9,000.00
	N-2	12	30	2 x W3	51.2	84	1	-	-	-	1	308.8	$25.00	$7,720.00
	N-3	12	30	1 x W5	33	84	1	3	-	-	4	1308	$25.00	$32,700.00
	N-4	12	30	1 x W6	26	84	2	-	-	-	2	668	$25.00	$16,700.00
	N-5	12	30	-	0	108	-	1	-	-	1	480	$25.00	$12,000.00
HORIZONTAL	O-1	13.3	2.5	-	0	31.6	-	-	-	1	1	33.25	$25.00	$831.25
	P-1	30	3.25	-	0	66.5	-	-	-	2	2	195	$25.00	$4,875.00
	Q-1	16	4	-	0	40	1	-	-	-	1	64	$25.00	$1,600.00
	R-1	19	4	-	0	46	-	-	-	1	1	76	$25.00	$1,900.00
	S-1	21.25	4	-	0	50.5	-	-	-	1	1	85	$25.00	$2,125.00
	T-1	30	4	-	0	68	-	-	-	2	2	240	$25.00	$6,000.00
	U-1	23.62	10	-	0	67.24	1	-	-	-	1	236.2	$25.00	$5,905.00
	V-1	10.65	10	-	0	41.3	1	-	-	-	1	106.5	$25.00	$2,662.50
	W-1	5.54	-	-	0	32.9	-	-	1	-	1	57.9	$25.00	$1,447.50
	X-1	15.56	-	-	0	56.1	-	-	1	-	1	192.5	$25.00	$4,812.50
	TOTAL					3,360 LF	19	25	23	8	74	17,551 SF	$25.00	$438,782
	*Anticipated Schedule Durations (Days)						1.19	1.56	1.38	0.50	4.63			

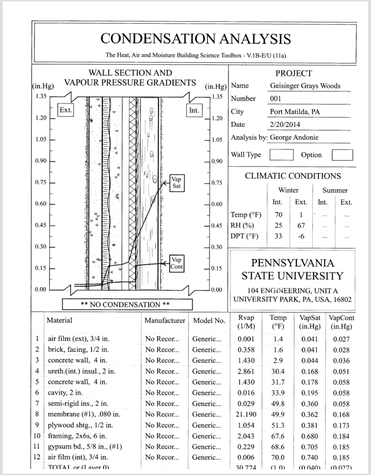
- Costs and Productivity Rates provided by NitterHouse Concrete
- Quantity Takeoffs taken from
- *Assuming Productivity of 15 Panels/Day

Opening	D1	W1	W3	W4	W5	W6	W7	L1 & L2	L3 & L4	L5
Area (SF)	55.66	12.8	25.6	20.5	33	26	14	11	6	11

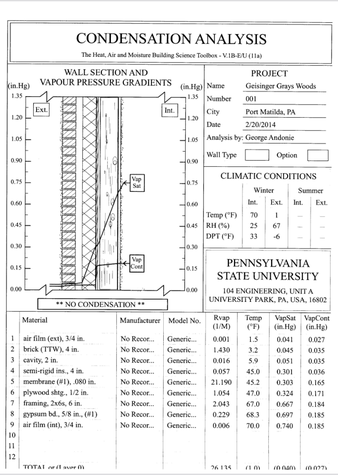




APPENDIX 2B



	Material	Manufacturer	Model No.	Rvap (I/M)	Temp (°F)	VapSat (in.Hg)	VapCont (in.Hg)
1	air film (ext), 3/4 in.	No Recor...	Generic...	0.001	1.4	0.041	0.027
2	brick, facing, 1/2 in.	No Recor...	Generic...	0.358	1.6	0.041	0.028
3	concrete wall, 4 in.	No Recor...	Generic...	1.430	2.9	0.044	0.036
4	ureth.(int.) insul., 2 in.	No Recor...	Generic...	2.861	30.4	0.168	0.051
5	concrete wall, 4 in.	No Recor...	Generic...	1.430	31.7	0.178	0.058
6	cavity, 2 in.	No Recor...	Generic...	0.016	33.9	0.195	0.058
7	semi-rigid ins., 2 in.	No Recor...	Generic...	0.029	49.8	0.360	0.058
8	membrane (#1), .080 in.	No Recor...	Generic...	21.190	49.9	0.362	0.168
9	plywood shtg., 1/2 in.	No Recor...	Generic...	1.054	51.3	0.381	0.173
10	framing, 2x6s, 6 in.	No Recor...	Generic...	2.043	67.6	0.680	0.184
11	gypsum bd., 5/8 in., (#1)	No Recor...	Generic...	0.229	68.6	0.705	0.185
12	air film (int), 3/4 in.	No Recor...	Generic...	0.006	70.0	0.740	0.185
	TOTAL or (Last over 0)			30.274	(1.0)	(0.040)	(0.027)



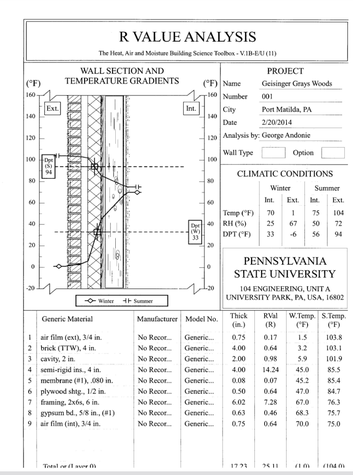
	Material	Manufacturer	Model No.	Rvap (I/M)	Temp (°F)	VapSat (in.Hg)	VapCont (in.Hg)
1	air film (ext), 3/4 in.	No Recor...	Generic...	0.001	1.5	0.041	0.027
2	brick (TTW), 4 in.	No Recor...	Generic...	1.430	3.2	0.045	0.035
3	cavity, 2 in.	No Recor...	Generic...	0.016	5.9	0.051	0.035
4	semi-rigid ins., 4 in.	No Recor...	Generic...	0.057	45.0	0.301	0.036
5	membrane (#1), .080 in.	No Recor...	Generic...	21.190	45.2	0.303	0.165
6	plywood shtg., 1/2 in.	No Recor...	Generic...	1.054	47.0	0.324	0.171
7	framing, 2x6s, 6 in.	No Recor...	Generic...	2.043	67.0	0.667	0.184
8	gypsum bd., 5/8 in., (#1)	No Recor...	Generic...	0.229	68.3	0.697	0.185
9	air film (int), 3/4 in.	No Recor...	Generic...	0.006	70.0	0.740	0.185
10							
11							
12							
	TOTAL or (Last over 0)			26.135	(1.0)	(0.040)	(0.027)

Prefabricated Brick Wall R-Value			
	Material Component	Thick.	R-Value
R_0	Outside Air Film	-	0.17
R_1	Exterior Face Thin Brick	5/8"	0.12
R_2	Exterior Concrete Wythe	3-3/8"	0.58
R_3	Insulation (Polyisocyanurate)	2"	13
R_4	Interior Concrete Wythe	3"	0.23
R_5	Air Cavity	1-1/2"	0.98
R_6	Semi-Rigid Insulation	2"	7.12
R_7	Air Vapor Barrier	-	Negligible
R_8	Sheathing	1/2"	0.64
R_9	Cold Formed Metal Stud	6"	7.28
R_{10}	Gypsum Wall Board	5/8"	0.46
R_{11}	Inside Air Film	-	0.64
	Total	**1' 7-5/8"**	**31.22**
		U-Value	**0.032031**

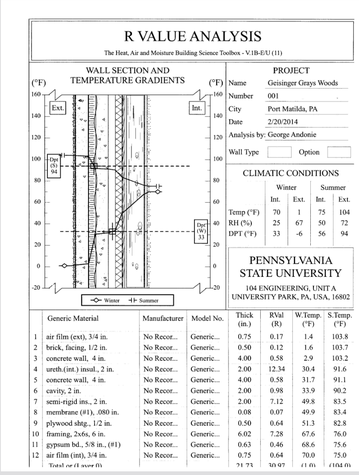
*R-Values taken from Nitterhouse Concrete Manufacturer

Existing Brick Wall R-Value			
	Material Component	Thick.	R-Value
R_0	Outside Air Film	-	0.17
R_1	Exterior Face Brick	3-5/8"	0.64
R_2	Air Cavity	1-1/2"	0.98
R_3	Semi-Rigid Insulation	4"	14.24
R_4	Air Vapor Barrier	-	Negligible
R_5	Sheathing	1/2"	0.64
R_6	Cold Formed Metal Stud	6"	7.28
R_7	Gypsum Wall Board	5/8"	0.46
R_8	Inside Air Film	-	0.64
	Total	**1' 4-1/4"**	**25.05**
		U-Value	**0.03992**

*R-Values taken from ASHRAE 2009 Fundamentals (Tables 4 & 7)



	Generic Material	Manufacturer	Model No.	Thick (in.)	RVal (R)	W.Temp. (°F)	S.Temp. (°F)
1	air film (ext), 3/4 in.	No Recor...	Generic...	0.75	0.17	1.5	103.8
2	brick (TTW), 4 in.	No Recor...	Generic...	4.00	0.64	3.2	103.1
3	cavity, 2 in.	No Recor...	Generic...	2.00	0.98	5.9	101.9
4	semi-rigid ins., 4 in.	No Recor...	Generic...	4.00	14.24	45.0	85.5
5	membrane (#1), .080 in.	No Recor...	Generic...	0.08	0.07	45.2	85.4
6	plywood shtg., 1/2 in.	No Recor...	Generic...	0.50	0.64	47.0	84.7
7	framing, 2x6s, 6 in.	No Recor...	Generic...	6.02	7.28	67.0	76.3
8	gypsum bd., 5/8 in., (#1)	No Recor...	Generic...	0.63	0.46	68.3	75.7
9	air film (int), 3/4 in.	No Recor...	Generic...	0.75	0.64	70.0	75.0
	Total or (Last over 0)			17.73	25.11	(1.0)	(104.0)



	Generic Material	Manufacturer	Model No.	Thick (in.)	RVal (R)	W.Temp. (°F)	S.Temp. (°F)
1	air film (ext), 3/4 in.	No Recor...	Generic...	0.75	0.17	1.4	103.8
2	brick, facing, 1/2 in.	No Recor...	Generic...	0.50	0.12	1.6	103.7
3	concrete wall, 4 in.	No Recor...	Generic...	4.00	0.58	2.9	103.2
4	ureth.(int.) insul., 2 in.	No Recor...	Generic...	2.00	12.34	30.4	91.6
5	concrete wall, 4 in.	No Recor...	Generic...	4.00	0.58	31.7	91.1
6	cavity, 2 in.	No Recor...	Generic...	2.00	0.98	33.9	90.2
7	semi-rigid ins., 2 in.	No Recor...	Generic...	2.00	7.12	49.8	83.5
8	membrane (#1), .080 in.	No Recor...	Generic...	0.08	0.07	49.9	83.4
9	plywood shtg., 1/2 in.	No Recor...	Generic...	0.50	0.64	51.3	82.8
10	framing, 2x6s, 6 in.	No Recor...	Generic...	6.02	7.28	67.6	76.0
11	gypsum bd., 5/8 in., (#1)	No Recor...	Generic...	0.63	0.46	68.6	75.6
12	air film (int), 3/4 in.	No Recor...	Generic...	0.75	0.64	70.0	75.0
	Total or (Last over 0)			21.73	30.97	(1.0)	(104.0)

APPENDIX 2C

Annual Heating Fuel Consumption (Winter)			
Variable	Unit	Existing Brick Assembly	Precast Panel Assembly
Heat Loss (Q)	BTU/hr	48,344	38,790
Annual Heating Degree Days (HDD)	°F * # Days	6087	6087
Winter Temperature Difference (ΔT)	°F	69	69
Heating Value of Natural Gas (HV)	BTU/ft^3	1027	1027
Heating Efficiency of Equipment (HEE)	%/100	0.8	0.8
Annual Heating Fuel Consumption	Cubic Feet	124,579	99,959
Average Cost of Natural Gas (PA)	$ / 1000ft^3	11.67	11.67
Annual Heating Cost ($)		$1,617	$1,297

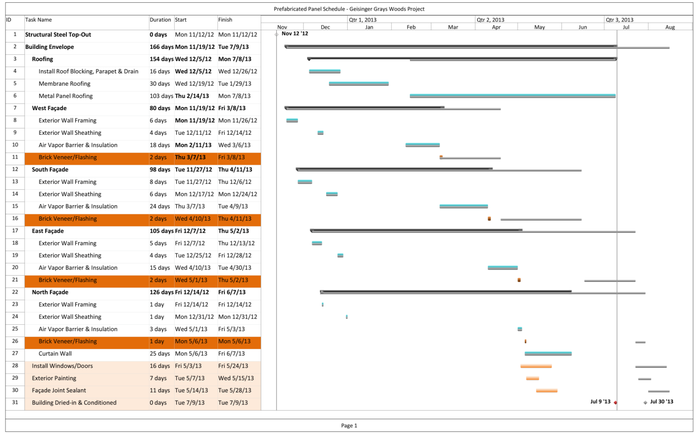
*Pennsylvania's Average Price of Natural Gas Cost taken from U.S. Energy Information Administration

$$\text{Annual Heating Fuel Consumption (AHFC)} = \frac{24 * Q * HDD}{\Delta T_w * HV * HEE}$$

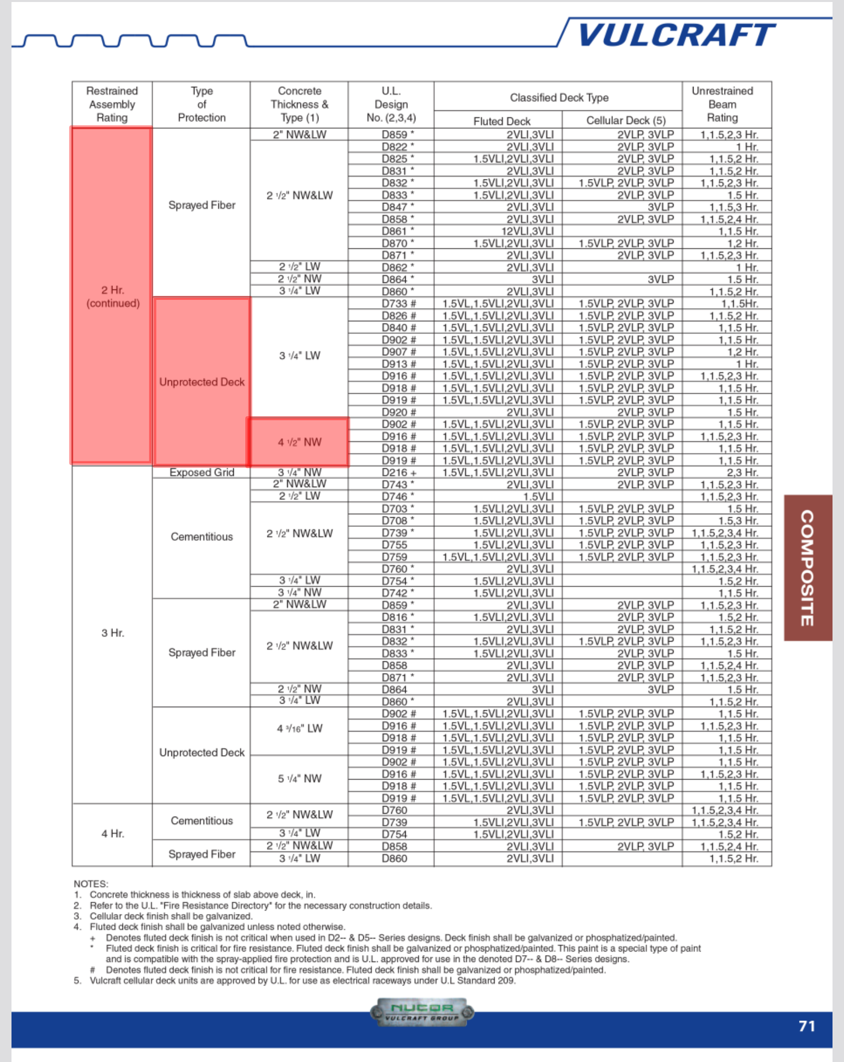
Annual Cooling Energy Consumption (Summer)			
Variable	Unit	Existing Brick Assembly	Precast Panel Assembly
Heat Gain (Q)	BTU/hr	20,318	16,303
Annual Cooling Degree Days (HDD)	°F * # Days	622	622
Winter Temperature Difference (ΔT)	°F	29	29
Cooling Value (CV)	BTU/KWh	3415	3415
Annual Cooling Energy Consumption	KWh	3,063	2,457
Average Electricity Cost (PA)	$/KWh	0.0921	0.0921
Annual Cooling Cost ($)		$398	$319

*Pennsylvania's Average Electricity Costs taken from U.S. Energy Information Administration

$$\text{Annual Cooling Energy Consumption (ACEC)} = \frac{24 * Q * CDD}{\Delta T_s * CV}$$

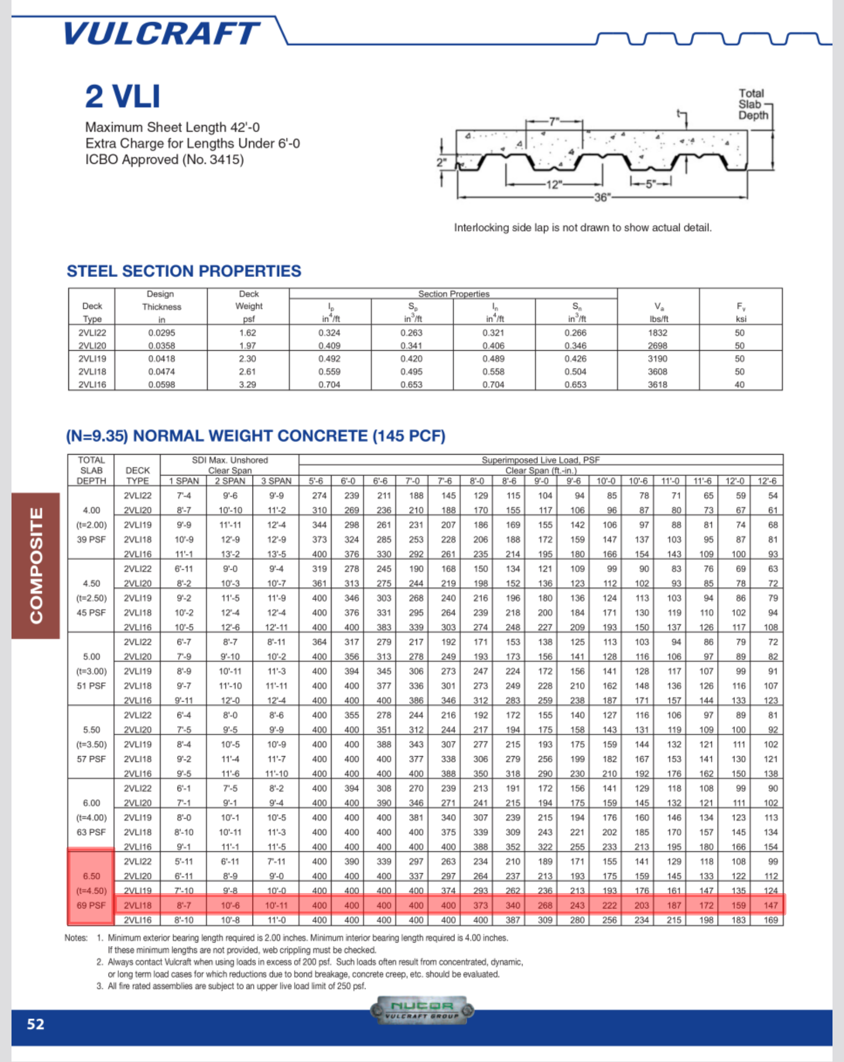


APPENDIX 3A


VULCRAFT

COMPOSITE

71


VULCRAFT

2 VLI

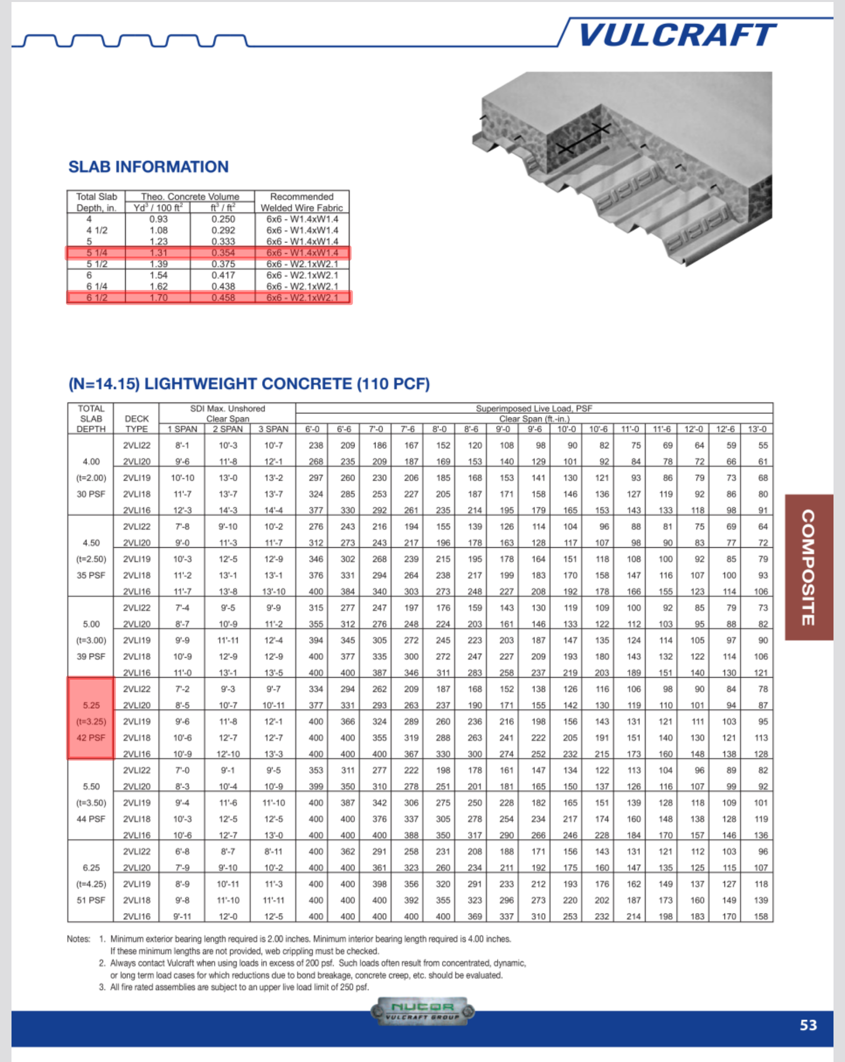
Maximum Sheet Length 42'-0
Extra Charge for Lengths Under 6'-0
ICBO Approved (No. 3415)

STEEL SECTION PROPERTIES

(N=9.35) NORMAL WEIGHT CONCRETE (145 PCF)

COMPOSITE

52

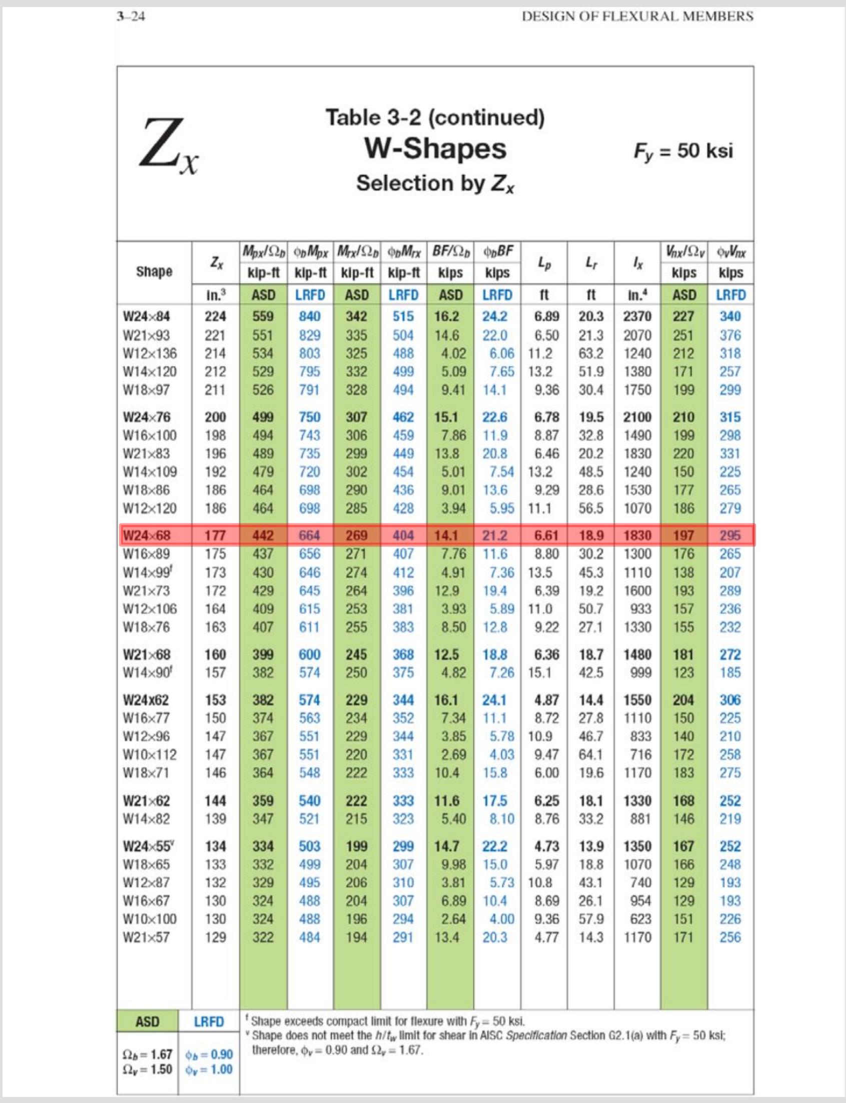

VULCRAFT

SLAB INFORMATION

(N=14.15) LIGHTWEIGHT CONCRETE (110 PCF)

COMPOSITE

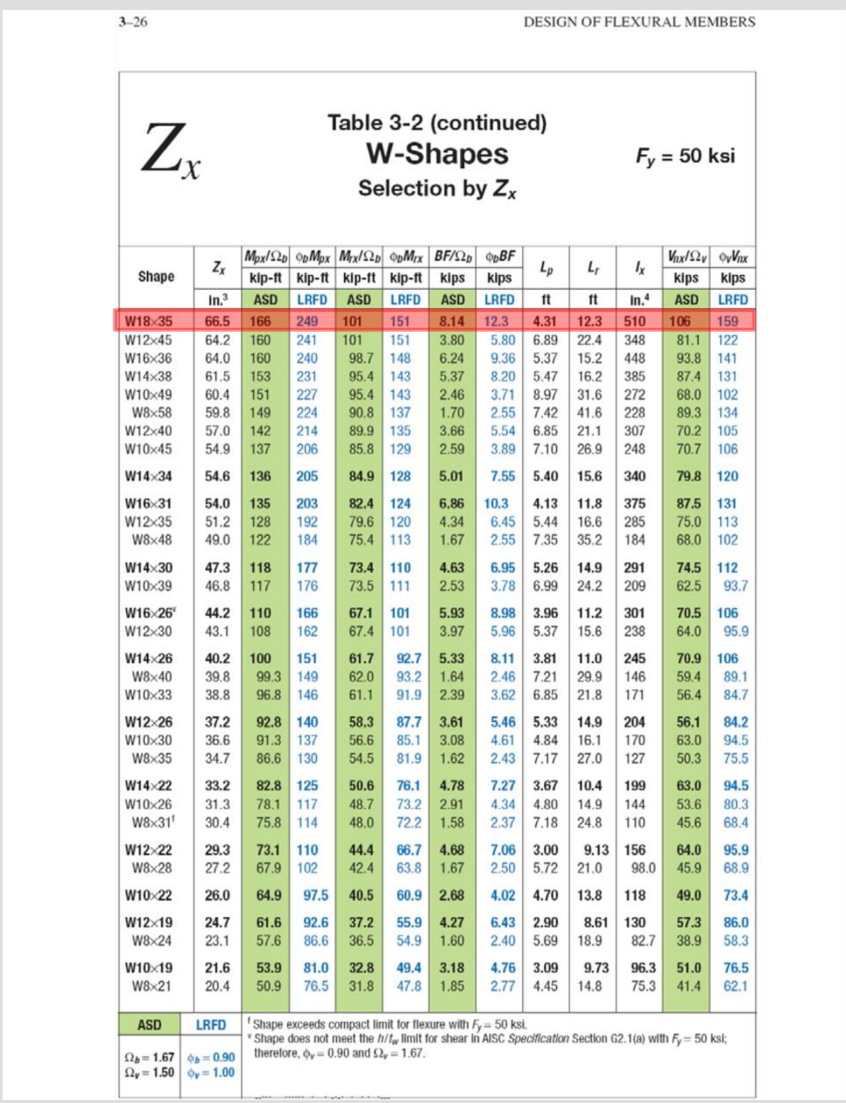
53


3–24 DESIGN OF FLEXURAL MEMBERS

Z_x

Table 3-2 (continued)
W-Shapes
Selection by Z_x

F_y = 50 ksi


3–26 DESIGN OF FLEXURAL MEMBERS

Z_x

Table 3-2 (continued)
W-Shapes
Selection by Z_x

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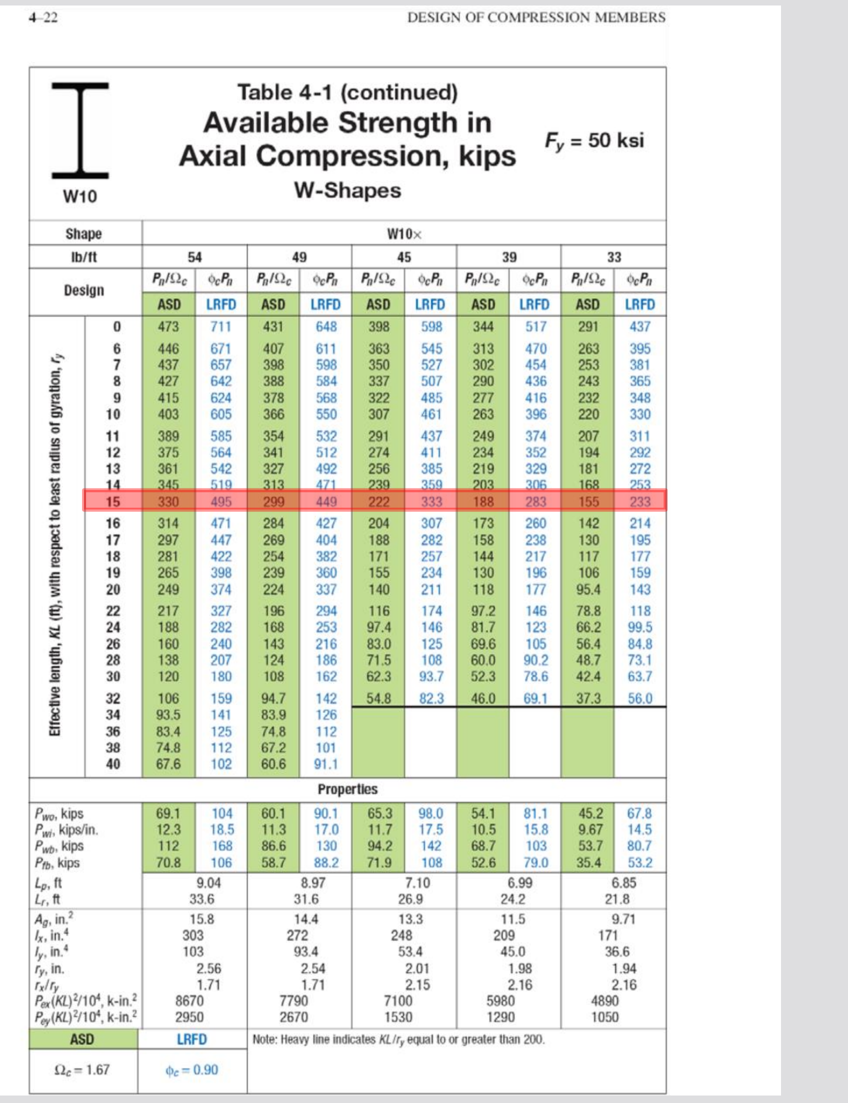

4–22 DESIGN OF COMPRESSION MEMBERS

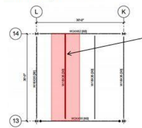
W10

Table 4-1 (continued)
Available Strength in
Axial Compression, kips
W-Shapes

F_y = 50 ksi

APPENDIX 3B

Calculating Beam Size:



Assumptions:

Tributary Width:
$W_T = 10'$

Influence Area:
$K_{LL}\,A_T = 20' \times 30'$
$K_{LL}\,A_T = 600SF$
$600SF \geq 400SF$ ∴ Reducible LL

Live Loads:
Hospital = 60psf
Wall Partitions = 20psf

Calculations:

$LL_R = 80psf + \left(0.25 + \frac{15}{\sqrt{600}}\right)$

$LL_R = 80psf + 0.86$

$LL_R = 67psf$

$DL = (Comp.\ Deck) + (Super.) + (Beam)$

$DL = 69psf + 10psf + 5psf$

$DL = 84psf$

$W_u = 1.2D + 1.6L$

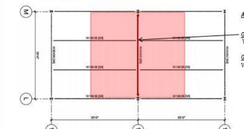
$W_u = 1.2(84) + 1.6(51.6)$

$W_u = 211.1lbf/sf$

Graphs:

Check W18x35: $\phi M_n = 249^{ft\text{-}k} \geq 237.5^{ft\text{-}k}$ ∴ Ok
$\phi V_n = 159^{k} \geq 31.67^{k}$ ∴ Ok
$\Delta = \frac{5wL^4}{384EI} \leq \frac{L/360}{1in} \rightarrow .631'' \leq .042''$ ∴ Ok

Calculating Girder Size:



Assumptions:

Girder Tributary Width:
$W_T = 30'$

Girder Self-Weight:
$W_G = 5psf$

Calculations:

$P_C = 2 \times 31.67$

$P_{2,3} = P_{C,D} = 63.34^{kips}$

$w_u = W_u \times A_T$

$w_u = 2^{psf} \times 30'$

$w_u = 60^{plf} = .06^{klf}$

$P_{B,2} = w_u \times W_T$

$P_{B,2} = .06^{klf} \times 30' = 1.8^{kips}$

$\sum M = 0$

$0 = 1.8 \times (-P_{B,2}) + 15' \times (-P_{C,2}) + 20' \times (-P_{C,3}) + 30' \times V_1$

$0 = 1.8 \times (63.34^{k}) + 15' (1.8^{k}) + 20' (63.34^{k}) + 30' \times V_1$

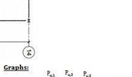
$V_1 = V_3 = 64.24^{kips}$

$M_{1.8kips} = (V_1 \times 15') - \frac{1}{2}(1.8 \times 15 \times 0.5)$

$M_{1.8kips} = (64.24^{k} \times 15') - \frac{1}{2}(\ldots)$

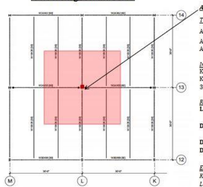
$M_{1.8kips} = 639.4^{ft\text{-}kips}$

Graphs:



Check W24x68: $\phi M_n = 664^{k} \geq 639.4^{k}$ ∴ Ok
$\phi V_n = 292^{k} \geq 64.24^{k}$ ∴ Ok
$\Delta = \frac{5wL^4}{384EI} = .911'' \leq \frac{L/360}{1in} = 1.0''$ ∴ Ok

Calculating Column Size:



Assumptions:

Tributary Area:
$A_T = \frac{(30' + 30')}{2} \times \frac{(30' + 30')}{2}$
$A_T = 30' \times 30'$
$A_T = 900SF$

Influence Area:
$K_{LL}\,A_T = 60' \times 60'$
$K_{LL}\,A_T = 3.600SF$
$3.600SF \geq 400SF$ ∴ Reducible LL

Roof Loads:
$LL = SL = 30psf$

$DL = (Roof) + (Deck) + (FP) + (Super.) + (Beams)$
$DL = 30psf + 3psf + 3psf + 10psf + 5psf + 2psf$
$DL = 53psf$

Effective Column Length (KL):
K=1 (Pin-Pin Connection)
L= 15'
KL = 15'

Calculations:

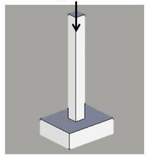
a) First Floor:
$P_{u,a} = (2 \times V_{u,Girder}) + (2 \times V_{u,Beam})$
$P_{u,a} = (2 \times 64.2^{kips}) + (2 \times 21.67^{kips})$
$P_{u,a} = (128.4^{kips}) + (63.34^{kips})$
$P_{u,a} = 191.74^{kips}$

b) Roof:
$P_{u,b} = [1.2D + 1.6S]$
$P_u = [1.2(53^{k}) + 1.6(30^{k})]$
$P_u = [63.6^{k} + 48^{k}]$
$P_{u,b} = 111.6^{kips}$

$\sum P_u = 191.74^{k} + 111.6^{k} = 303.34^{k}$

Check W10x49: $\phi P_n = 449^{k} \geq 303.34^{k}$ ∴ Ok

Calculating Footing Size:



Assumptions:

Column 12x12 Size:

Width = 9'
Length = 9'

Allowable Bearing Capacity:
$q_a = 4.000^{psf} = 4^{ksf}$

Calculations:

$q_u = \frac{P_u}{Area} = \frac{262.34^{k}}{9' \times 9'} = \frac{262.34^{k}}{81ft^2} = 3.238^{ksf}$

Check 9'x9' Footing:

$q_u \leq q_{allowable}$

$3.238^{ksf} < 4^{ksf}$ ∴ Ok

EQUATIONS

LIVE LOAD REDUCTION:

$$L_r = L_o \left[.25 + \frac{15}{\sqrt{K_{LL} A_t}} \right]$$

FACTORED DISTRIBUTED LOAD:

$$W = (1.2)(D_L) + (1.6)(L_R)$$

$$w_u = (W)(Tributary\ Area)$$

FACTORED BENDING MOMENT:

$$M_u = \frac{(w_u)(l^2)}{8}$$

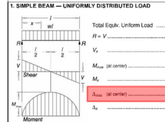
FACTORED SHEAR:

$$V_u = \frac{w_u \times Length}{2}$$

BEAM DIAGRAMS AND FORMULAS 3–213

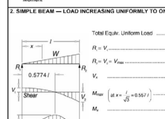
Table 3-23
Shears, Moments and Deflections

1. SIMPLE BEAM — UNIFORMLY DISTRIBUTED LOAD



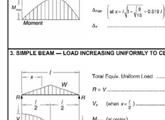
Total Equiv. Uniform Load ..... $= wl$
$R = V ..... = \frac{wl}{2}$
$V_x ..... = w\left(\frac{l}{2} - x\right)$
M_{max} (at center) ..... $= \frac{wl^2}{8}$
$M_x ..... = \frac{wx}{2}(l - x)$
Δ_{max} (at center) ..... $= \frac{5wl^4}{384EI}$
$\Delta_x ..... = \frac{wx}{24EI}(l^3 - 2lx^2 + x^3)$

2. SIMPLE BEAM — LOAD INCREASING UNIFORMLY TO ONE END



Total Equiv. Uniform Load ..... $= \frac{1}{2}W = 1.03\,W$
$R = V ..... = \frac{W}{2}$
$R_1 = V_1 = V_{max} ..... = \frac{0.577W}{2}$
$V_x ..... = \frac{W}{2} - \frac{Wx^2}{l^2}$
M_{max} (at $x = \frac{l}{\sqrt{3}} = 0.5617$) ..... $= \frac{0.577W}{9.49} = 0.128\,Wl$
$M_x ..... = \frac{Wx}{15.59}(l^2 - x^2)$
Δ_{max} (at $x = \sqrt{\frac{8}{15}} = 0.5219$) ..... $= 0.0130\frac{Wl^3}{El}$
$\Delta_x ..... = \frac{Wx}{180\,lEl}(3x^4 - 10l^2x^2 + 7l^4)$

3. SIMPLE BEAM — LOAD INCREASING UNIFORMLY TO CENTER



Total Equiv. Uniform Load ..... $= \frac{1}{2}W = 1.03\,W$
$R = V ..... = \frac{W}{2}$
V_x (when $x \leq \frac{l}{2}$) ..... $= \frac{W}{2}\left(\frac{l^2}{2} - x^2\right)$
M_{max} (at center) ..... $= \frac{Wl}{8}$
M_x (when $x \leq \frac{l}{2}$) ..... $= \frac{Wx}{6}\left(\frac{3}{2} - \frac{2x^2}{l^2}\right)$
Δ_{max} (at center) ..... $= \frac{Wl^3}{60EI}$
Δ_x (when $x \leq \frac{l}{2}$) ..... $= \frac{Wx}{480\,EI}(5l^2 - 4x^2)$

TABLE 4-1 MINIMUM UNIFORMLY DISTRIBUTED LIVE LOADS, L_o, AND MINIMUM CONCENTRATED LIVE LOADS

Occupancy or Use	Uniform psf (kN/m²)	Conc. lb (kN)
Apartments (see *Residential*)		
Access floor systems		
Office use	50 (2.4)	2,000 (8.9)
Computer use	100 (4.79)	2,000 (8.9)
Armories and drill rooms	150 (7.18)	
Assembly areas and theaters		
Fixed seats (fastened to floor)	60 (2.87)	
Lobbies	100 (4.79)	
Movable seats	100 (4.79)	
Platforms (assembly)	100 (4.79)	
Stage floors	150 (7.18)	
Balconies (exterior)	100 (4.79)	
	60 (2.87)	
Bowling alleys, poolrooms, and similar recreational areas	75 (3.59)	
Catwalks for maintenance access	40 (1.92)	300 (1.33)
Corridors		
First floor	100 (4.79)	
Other floors, same as occupancy served except as indicated		
Dance halls and ballrooms	100 (4.79)	
Decks (patio and roof)		
Same as area served, or for the type of occupancy accommodated		
Dining rooms and restaurants	100 (4.79)	
Dwellings (see *Residential*)		
Elevator machine room grating (on area of 4 in.² (2,580 mm²))		300 (1.33)
Finish light floor plate construction (on area of 1 in.² (645 mm²))		200 (0.89)
Fire escapes	100 (4.79)	
	40 (1.92)	
Fixed ladders	See Section 4.4	
Garages (passenger vehicles only)	40 (1.92)[a,b]	
Trucks and buses		
Grandstands (see *Stadiums and arenas, Bleachers*)		
Gymnasiums—main floors and balconies	100 (4.79)	
Handrails, guardrails, and grab bars	See Section 4.4	
Hospitals		
Operating rooms, laboratories	60 (2.87)	1,000 (4.45)
Patient rooms	40 (1.92)	1,000 (4.45)
Corridors above first floor	80 (3.83)	1,000 (4.45)
Hotels (see *Residential*)		
Libraries		
Reading rooms	60 (2.87)	1,000 (4.45)
Stack rooms	150 (7.18)[f]	1,000 (4.45)
Corridors above first floor	80 (3.83)	1,000 (4.45)
Manufacturing		
Heavy	125 (6.00)	2,000 (8.90)
Light	250 (11.97)	3,000 (13.40)
Marquees	75 (3.59)	
Office Buildings		
File and computer rooms shall be designed for heavier loads based on anticipated occupancy		
Lobbies and first floor corridors	100 (4.79)	2,000 (8.90)
Offices	50 (2.40)	2,000 (8.90)
Corridors above first floor	80 (3.83)	2,000 (8.90)
Penal Institutions		
Cell blocks	40 (1.92)	
Corridors	100 (4.79)	
Residential		
Dwellings (one- and two-family)		
Uninhabitable attics with storage	10 (0.48)	
Uninhabitable attics without storage	20 (0.96)	
Habitable attics and sleeping areas	30 (1.44)	
All other areas except stairs and balconies	40 (1.92)	
Hotels and multifamily houses		
Private rooms and corridors serving them	40 (1.92)	
Public rooms and corridors serving them	100 (4.79)	
Reviewing stands, grandstands, and bleachers	100 (4.79)[f]	

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