Penn State Health and Human Development Building

State College, PA

Rendering Provided by BCJ

Christopher Graziani
Advisor: Craig Dubler
Construction Management

Penn State Health and Human Development Building

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Rendering Provided by BCJ

Existing Building Structure

Previous View From College Avenue

Future View From College Avenue

Rendering Provided by BCJ

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Multi-Use Spaces

Project Cost: $59 Million
Dates of Construction: February 2013 – June 2015
Occupancy Type: Office/ Lab/ Classroom

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Demolition Phase

Previous View From College Avenue

Future View From College Avenue

Rendering Provided by BCJ

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Multi-Use Spaces

Project Cost: $59 Million
Dates of Construction: February 2013 – June 2015
Occupancy Type: Office/ Lab/ Classroom

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New Construction

Previous View From
College Avenue

Future View From
College Avenue

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Multi-Use Spaces

Project Cost: $59 Million
Dates of Construction: February 2013 – June 2015
Occupancy Type: Office/ Lab/ Classroom

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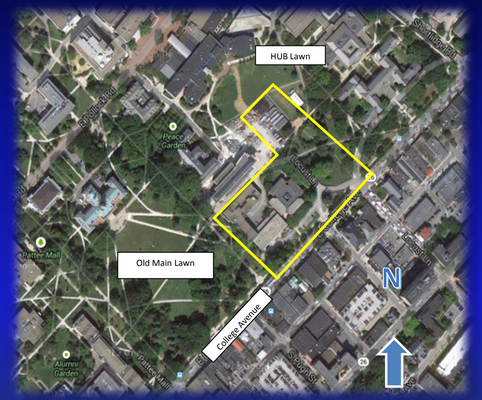
Project Overview

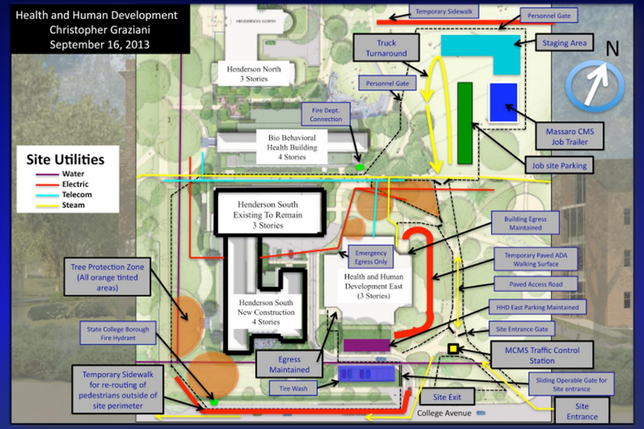
Penn State

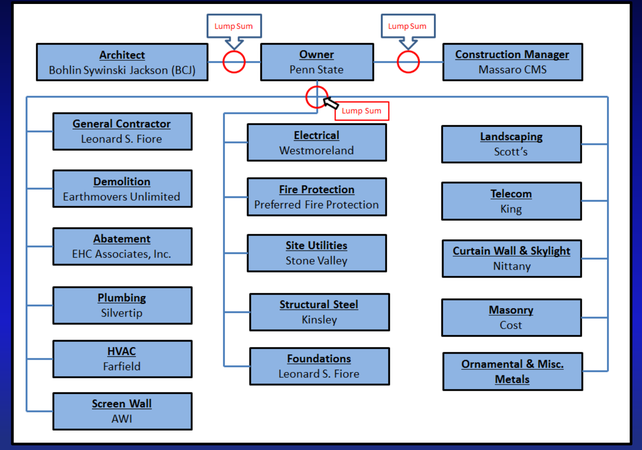
Massaro CM SERVICES, LLC

Bohlin Cywinski Jackson
Architecture Planning Interior Design



View Taken from Google Maps





Project Features

Project Features

- Building Renovation
- Large Atrium Space
- Architectural Screen Wall
- Pursuing LEED Certified
- Soil Nail Wall

Rendering Provided by BCJ

Architectural Screen Wall In Atrium

Soil Nail Wall Installation

Analysis 1 – Stair Tower Redesign

Problem Statement:

Concrete stair tower acting as a shear wall caused significant delays to the project schedule and provided a low quality product at project turnover

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Problem Identification & Overview

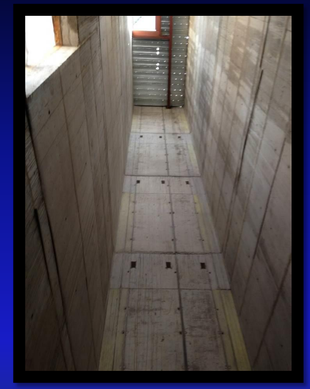
Desired Benefits

Faster Installation Time

Higher Quality of Finish

Improved Coordination of Trades

Concrete Stair Tower Installation



Tower Twisting and Interior Finish

Worker Safety

Christopher Graziani | AE Senior Thesis | Construction Management Option

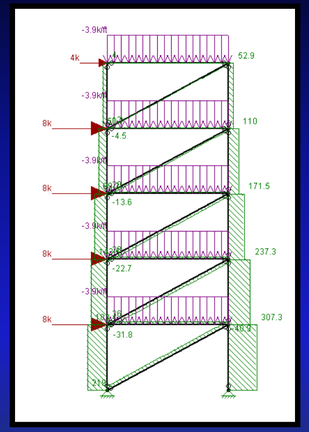
Structural Breadth

Purpose:

Change the concrete stair tower to a steel braced frame with drywall infill

Parameters

- Wind Loads
- RISA Program for Calculations
- Fireproofing
- Wall Partition Fill



RISA Program Showing Axial Loads

Maximum Axial Forces
Column = 307.3 Kips
Horizontal Beams = 36 Kips

Steel Design Summary

Size	Quantity	Length (ft)
HSS 4-1/2 x 4-1/2 x 3/8	10	19.8
HSS 6 x 6 x 1/4	10	29.5
W14x90	8	28
W14x90	4	14
W10x30	10	26
W10x17	10	14

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Cost and Schedule Impact Analysis

Interior Finish of Concrete Stair Tower

Photo Taken by David Walenga

Stud Framing Infill of Steel Braced Frame System

Summary for Current Design	
Material	$ 147,031.50
Equipment	$ 40,750.00
Manpower	$ 57,029.20
	$ 244,810.70
Schedule	5 weeks (25 Days)

Summary for New Design	
Item	Cost
Steel	$ 75,955.44
Fireproofing	$ 7,939.27
Fill (Framed Drywall)	$ 39,517.70
	$ 123,412.41

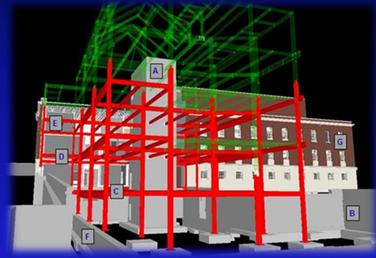
Schedule Summary	
Item	Duration (Days)
Steel Members	1.16
Fireproofing	4.34
6" GWB Partition	20

Cost Savings from Steel Design

- Current Design = $244,180.70
- Proposed Design = $123,412.41
  - **Savings = $121,398.29**

Schedule Savings from Steel Design

- Current Design = 25 Days
- Proposed Design = 25 Days
  - Savings = 0 Total Days
- **Critical Time Savings = 24 Days**



Stair Tower Construction Compared to BIM Model

Analysis 2 – Return Air Plenum

Problem Statement:

Tight ceiling spaces cause added schedule time and heavy coordination of trades is required

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System Research

Massaro CM SERVICES, LLC

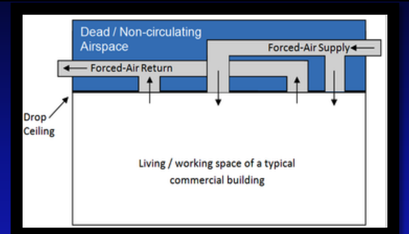
Bohlin Cywinski Jackson
Architecture Planning Interior Design

Purpose:

Utilize a Return Air Plenum System as Opposed to the Return Air Ductwork

Parameters

- Return Air Ductwork Removal
- Fire Damper Requirements
- Plenum Rating Materials
- System Requirements



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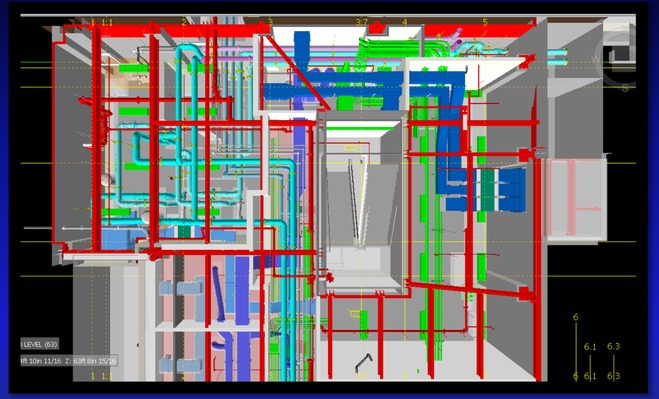

BIM Model Showing Ceiling Space Systems

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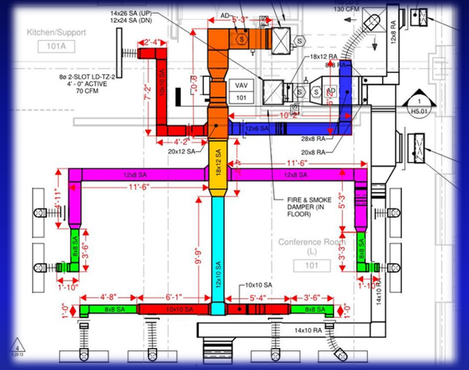
Cost and Schedule Comparisons



Supply Air Takeoff for Area Analyzed

Current Design	
Item	**Cost**
Ductwork	$ 2,085.70
Fire Dampers (1)	$ 350.00
	$ 2,435.70
PLENUM DESIGN	
Item	**Additional Cost**
Ductwork Insulation Wrap	$ 948.10

Savings in Area	SF of Area	Savings/SF
$ 1,487.61	1250	$ 1.19
Total Area of Building	**Savings/SF**	**Total Savings**
150000	$ 1.19	$ 178,512.94

Cost Savings from Plenum Design

- Current Design = $2,435.70
- Proposed Design = $948.10
- **Savings = $1,487.61**

Cost Savings from Plenum Design

- Savings per SF of Area = $1.19
- Total Area of Building = 150,000
- **Total Potential Savings = $178,512.94**

Schedule Information For Current Design	
Activity	**Duration**
Prefabrication	2 hours
Raise and Hang	195 minutes
Install Piece that Penetrates Wall	30 minutes
Seal Duct Flange Between Pieces	13 minutes
Insulate Ductwork	63 minutes
Install Fire/Smoke Damper	10 minutes
Total	7 hours

Insulation Wrap = 1 Hour

Savings in Area (Hours)	SF of Area	Savings/SF
6	1250	0.0048
Total Area of Building	**Savings/SF**	**Total Savings**
150000	0.0048	720.00

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Mechanical Breadth and Conclusions

Massaro CM SERVICES, LLC

Bohlin Cywinski Jackson
Architecture Planning Interior Design

Noise Criteria	Air Velocity at Supply Register (fpm)	Air Velocity at Return Grille (fpm)
NC-15 to NC-20	250 to 300	300 to 360
NC-20 to NC-25	300 to 350	360 to 420
NC-25 to NC-30	350 to 425	420 to 510
NC-30 to NC-35	425 to 500	510 to 600
NC-35 to NC-40	500 to 575	600 to 690
NC-40 to NC-45	575 to 650	690 to 780

	ACF 8	
Level	Supply Air Provided (CFM)	Return Air (CFM)
3	2700	3000
3.1	1440	1440
3.2	740	740
3.3	960	960
3.4	1390	1390
	7230	7530

Air	Airflow (CFM)	Duct Size (in.)	Velocity (FPM)	Friction (in. wg/100')
	1440	21	600	0.0245
	680 (l/s)	*533 (mm)*	*3.05 (m/s)*	*0.2 (Pa/m)*

Equivalent Duct Sizes	
Round (in.)	21ø
Rect, most square (1:1 ratio) (in.)	20X20
Rect, flattest (4:1 ratio) (in.)	34X12
Rect, enter one side (in.)	
Rect, duct size (in.)	
Oval, balanced (2:1 ratio) (in.)	ov 30X14
Oval, flattest (4:1 ratio) (in.)	ov 34X12
Oval, enter one side (in.)	
Oval, duct size (in.)	

Settings	
Duct Sizing Increment	2 in.
Rounding	Round Up
Duct Material	Galvanized
Absolute Roughness Factor (ε)	0.0005
Air Temperature (deg. F)	70
Altitude (ft.)	0
Air Density (pcf)	0.075

Duct Calculator Results Provided by KLING STUBBINS

- Amount of Space in the Plenum = 31-3/4”
- Most Square Piece Necessary = 20”x20”
- Flattest Piece Necessary = 34”x12”

Analysis Summary

↓	**Schedule Time**	6 hours in Area
↓	Cost	$1,497.61
↑	**Coordination**	

Analysis 3 – Alternative Excavation Options

Problem Statement:

Soil is made of dolomite rock so rock excavation techniques are required

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Blasting vs. Rock Hammering

Purpose:

Compare the Cost and Schedule Implications of Rock Excavation Techniques and Research Additional Tactics

Parameters

- Personnel Requirements
- Equipment Necessary
- Soil Classification
- Noise Levels
- Safety

Image Taken from Google Image Search

Image Taken from Google Image Search

Traditional Rock Hammering

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Blasting vs. Rock Hammering

Massaro CM SERVICES, LLC

Bohlin Cywinski Jackson
Architecture Planning Interior Design

Purpose:

Compare the Cost and Schedule Implications of Rock Excavation Techniques and Research Additional Tactics

Parameters

- Personnel Requirements
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- Noise Levels
- Safety

Image Taken from Google Image Search

Traditional Rock Hammering

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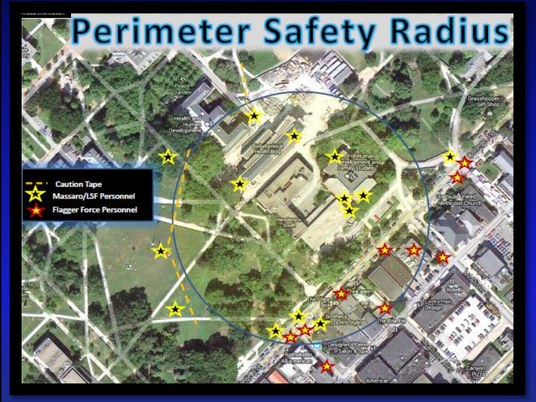
Cost and Schedule Comparisons



Traditional Excavation Takeoff	
Unrippable Soil	
Cost/CY	**Cost**
$ 50.00	$186,825.00
Rippable Soil	
Cost/Cy	Cost
$ 25.00	$ 93,412.50
Total	$280,237.50
Additional Costs	
General Conditions	$ 5,000.00
Subtotal	$285,237.50
Shoring Requirements	$400,000.00
Total	$685,237.50

Blasting Totals	
Blasting Estimate	$ 95,000.00
Manpower Takeoffs	$ 74,954.96
Excavation	$186,825.00
	$356,779.96

Cost Savings from Blasting

$328,457.54

Blasting Schedule Time

- Blasting = 14 Days
- Excavation = 8 Days
- Total Time = 22 Days

Traditional Schedule Time

- Unrippable Soil = 12 Days
- Rippable Soil = 15 Days
- Total Time = 27 Days

Time Savings From Blasting

5 Days

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Research and Conclusions

Blasting		Traditional
✓	Schedule	
✓	Cost	
	Safety	✓
✓	Noise	

Image Taken from Google Image Search

Royex Technology

- Minimal Fly Rock
- Minimal Rock Vibrations
- Lower Noise Levels
- Faster
- Minimal Personnel Required
- Safer to Transport
- Cost Savings

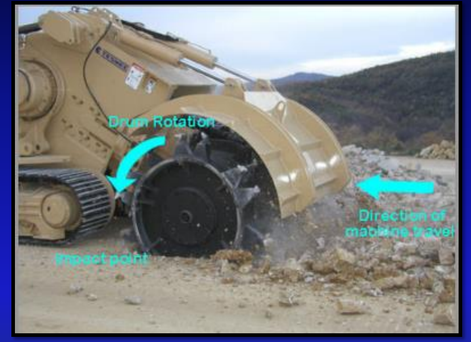

Image Taken from Google Image Search

Rock Hawg

- 110 ton, 630 hp Machine
- Top-Down Cutting Technology
- Material Recycled for Backfill

Image Taken from Google Image Search

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Conclusions & Recommendations

- Improves Quality
- Accelerates Schedule
- Improves Safety

Analysis 1 – Stair Tower Redesign

- Potential cost savings of $121,398.29
- Critical schedule savings of 24 days
- Improved quality and safety
- More logical to use steel braced frame on future projects

Analysis 2 – Return Air Plenum

- Potential cost savings of $1,497.61 in area
- Schedule savings of 6 hours in area
- Reduce amount of coordination necessary in ceiling space
- Industry standard to plenum rate materials → return air plenum is more logical

Analysis 3 – Alternative Excavation Options

- Blasting was cheaper due to lack of shoring necessary
- Blasting saved an estimated 5 days of schedule time
- Traditional rock hammering is a major noise disruption
- If the schedule allows, blasting is preferred

Image Taken from Google Image Search

Acknowledgements

Academic Acknowledgements

Penn State Architectural Engineering Faculty
Craig Dubler – CM Advisor
Moses Ling – Mechanical Advisor

Industrial Acknowledgements

Massaro CM SERVICES, LLC

Bohlin Cywinski Jackson
Architecture Planning Interior Design

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Kevin Nestor – Massaro Senior Project Manager
Keith Smith – Massaro Site Manager
Dan Kiefer – Massaro Senior Estimator
David Walenga – Ruby + Associates
Geoff Measel – G.E.M. Construction
Family and Friends

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Questions?

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Analysis 4 – Re-Sequencing of Atrium Systems

1

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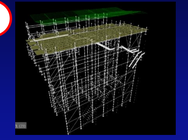

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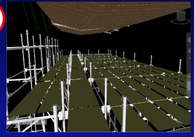

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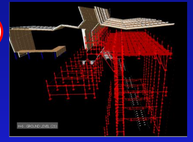

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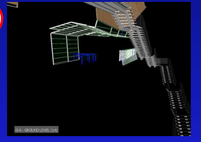

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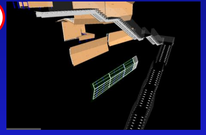

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Appendix

Current Stair Tower Design

STAIR A: LEVEL 1 - TOP OF STRUCTURE						Unit	$ per unit	Total $
			12	" THICK	4,690	SF		
	CONCRETE - BUY				182	CY	125.00	$22,799
	REBAR		50	#/CY	9,119	LBS	2.00	$18,239
	FORMING				9,380	SF	10.00	$93,800
	RUBBING				9,380	SF	1.30	$12,194
	Stair A		- COST PER CUBIC YARD			$806	/CY	
	Stair A		- COST PER SQUARE FOOT			$31	/SF	
CIP WALL @ STAIR A			-SUBTOTAL		$147,032			

Manpower Takeoff for Current Design

Type of laborer	Number of Workers	Hours Per Worker Per Level	# of Levels	Total Number of Hours	Cost/Hour	Total Cost
Iron Workers	2	12	5	120	$ 49.63	$ 5,955.60
Carpenter	3	40	5	600	$ 38.60	$ 23,160.00
Laborer	3	40	5	600	$ 29.14	$ 17,484.00
Crane Operator	1	40	5	200	$ 43.54	$ 8,708.00
Pump Operator	1	8	5	40	$ 43.04	$ 1,721.60
						$ 57,029.20

Equipment Takeoff for Current Design

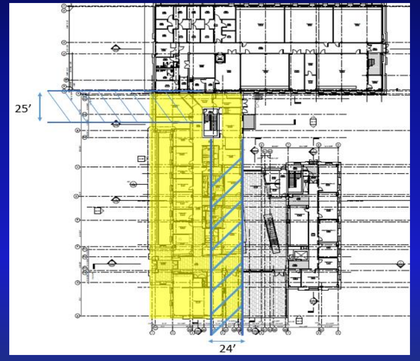
Type of Equipment	Days/Level	# of Levels	Total Number of Days	Cost/Day	Total Cost
Crane	5	5	25	$ 1,250.00	$ 31,250.00
Lift	5	5	25	$ 180.00	$ 4,500.00
Pump Truck	1	5	5	$ 1,000.00	$ 5,000.00
					$ 40,750.00

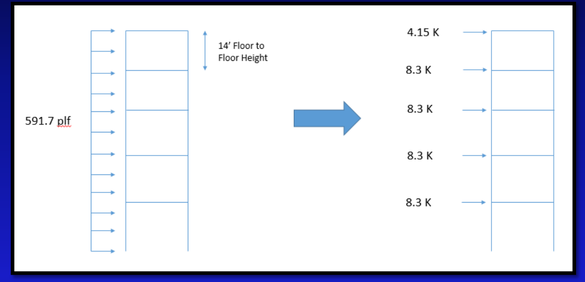
Summary for Current Design

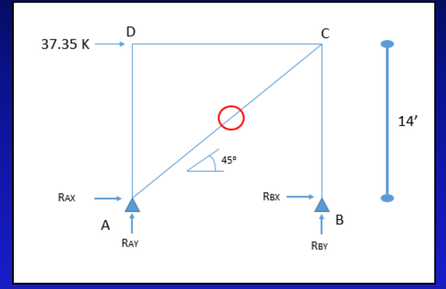
Material	$ 147,031.50
Equipment	$ 40,750.00
Manpower	$ 57,029.20
Total	$ 244,810.70
Schedule Time	5 Weeks

Appendix

Structural Breadth Calculations

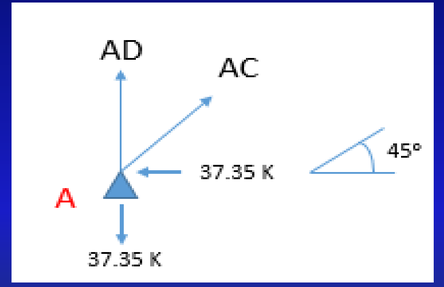


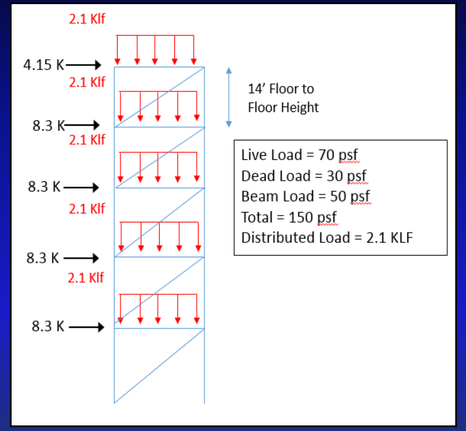


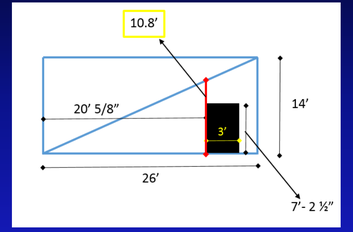


Appendix

Structural Breadth Calculations







Appendix

Steel Design Summary

Size	Quantity	Length (ft)	Sum of Lengths	LB/LF	Lbs	Tons	Material Cost/LF	Labor Cost/ LF	Equipment Cost/ LF	Total/ LF	Cost/Ton	Total Cost
HSS 4-1/2 x 4-1/2 x 3/8	10	19.8	198	19.82	3924.36	1.96					$ 3,000.00	$ 5,886.54
HSS 6 x 6 x 1/4	10	29.5	295	19.02	5610.9	2.81					$ 3,000.00	$ 8,416.35
W14x90	8	28	224	90	20160	10.08	$ 172.00	$ 2.86	1.59	$ 176.45		$ 39,524.80
W14x90	4	14	56	90	5040	2.52	$ 172.00	$ 2.86	1.59	$ 176.45		$ 9,881.20
W10x30	10	26	260	30	7800	3.9	$ 47.00	$ 4.99	2.77	$ 54.76		$ 14,237.60
W10x17	10	14	140	17	2380	1.19	$ 31.50	$ 4.58	2.54	$ 38.62		$ 5,406.80
												$ 69,050.40
											Add 10%	$ 6,905.04
												$ 75,955.44

Fireproofing

Size	Quantity	Length (ft)	Sum of Lengths	Surface Length	Square Footage	Material	Labor	Equipment	Total	Inches	Total Cost
HSS 4-1/2 x 4-1/2 x 3/8	10	19.8	198	1.5	297	$ 0.53	$ 0.60	$ 0.09	$ 1.22	2.00	$ 724.68
HSS 6 x 6 x 1/4	10	29.5	295	2	590	$ 0.53	$ 0.60	$ 0.09	$ 1.22	2.00	$ 1,439.60
W14x90	8	28	224	4.8	1065.49	$ 0.53	$ 0.60	$ 0.09	$ 1.22	2.00	$ 2,599.80
W14x90	4	14	56	4.8	266.37	$ 0.53	$ 0.60	$ 0.09	$ 1.22	2.00	$ 649.95
W10x30	10	26	260	2.7	705.47	$ 0.53	$ 0.60	$ 0.09	$ 1.22	2.00	$ 1,721.34
W10x17	10	14	140	2.4	329.47	$ 0.53	$ 0.60	$ 0.09	$ 1.22	2.00	$ 803.90
											$ 7,939.27

Material

Description	Quantity	Unit	Material Unit Cost	Total Cost
6" Studs @ 16" O.C.	400	LF	30	$ 12,000.00
5/8" Drywall - Taped and Finsihed	11200	SF	1.52	$ 17,024.00
Joint Sealant	400	LF	0.3	$ 120.00
Sound Attenuation Blanket	4000	SF	0.44	$ 1,760.00
				$ 30,904.00

Labor

Type of Manpower	Quantity	Unit	Cost per Unit	Total Cost
Carpenter & Taper	20	MD	357.04	$ 7,143.02
Laborer	3.3	MD	273.12	$ 910.68
Laborer (stocking)	11200	SF	0.05	$ 560.00
				$ 8,613.70

Schedule

Steel Members

Size	Quantity	Length (ft)	Sum of Lengths	Tons	Tons/Day	Daily Output/LF	Days
HSS 4-1/2 x 4-1/2 x 3/8	10	19.8	198	1.96	30		0.07
HSS 6 x 6 x 1/4	10	29.5	295	2.81	30		0.09
W14x90	8	28	224	10.08		960	0.23
W14x90	4	14	56	2.52		960	0.06
W10x30	10	26	260	3.9		550	0.47
W10x17	10	14	140	1.19		600	0.23
							1.16

Fireproofing

Daily Output/SF	Total SF	Total Days
1500	3253.8	4.34

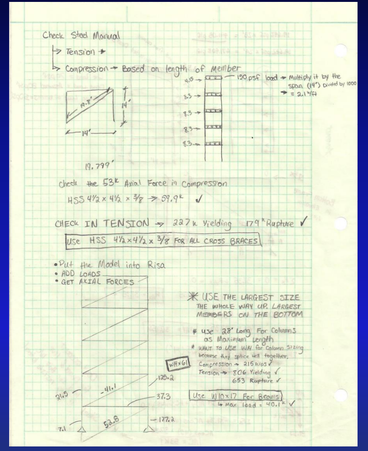
6" GWB Partition Material

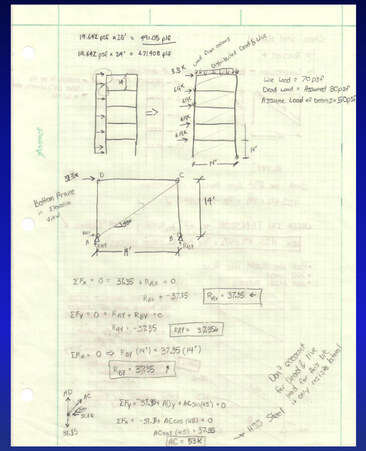
Description	Quantity	Unit	Production Rate Per day	Unit	Total Time Needed (Days)
6" Studs @ 16" O.C.	400	LF	100	LF	4
5/8" Drywall - Taped and Finsihed	11200	SF	965	SF	11.61
Joint Sealant	400	LF	1000	LF	0.4
Sound Attenuation Blanket	4000	SF	1000	SF	4
					20

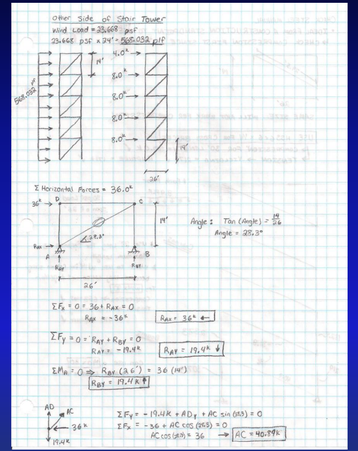
Penn State Health and Human Development Building

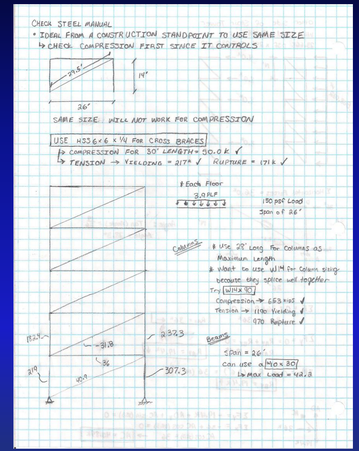
State College, PA

Appendix









Appendix

RA Ductwork Takeoffs

Size	Sum of the two sides	Max Dimension	Gage	lb/ft	Length (ft)	Pounds	SF	Cost/pound	Cost
18x12	30	18 -> 30	24	6.5	3	19.50	13.86913	$ 8.50	$ 117.89
28x8	36	28 -> 30	24	7.8	7	54.60	38.83357	$ 8.50	$ 330.09
8X8	16	8 -> 30	24	3.4	3	10.20	7.254623	$ 8.50	$ 61.66
12X8	20	12 -> 30	24	4.3	7	30.10	21.40825	$ 8.50	$ 181.97
16X6	22	16 -> 30	24	4.7	2	9.40	6.685633	$ 8.50	$ 56.83
20X8	28	20 -> 30	24	6	10	60.00	42.67425	$ 8.50	$ 362.73
14X10	24	14 -> 30	24	5.2	31	161.20	114.6515	$ 8.50	$ 974.54
		TOTALS				345.00	245.377		$ 2,085.70

Items in the Ceiling	Does it need to be Plenum Rated?	Is it already Plenum Rated?
Steel	No	-
Electrical Conduit	Yes	Yes
Cables	Yes	Yes
SA Ductwork	Insulation needs wrapped	-
Sprinkler System	no	-

Supply Air Takeoff

Size	Sum of the two sides	Max Dimension	Gage	lb/ft	Length (ft)	Pounds	SF
20x12	32	20 --> 30	24	6.9	14	98.3	85.1
10x10	20	10 --> 30	24	4.3	25	107.9	93.3
12x6	18	12 --> 30	24	3.9	16	63.7	55.1
18x12	30	18 --> 30	24	6.5	5	30.9	26.7
12x8	20	12 --> 30	24	4.3	33	142.6	123.4
8x8	16	8 --> 30	24	3.4	21	70.0	60.5
12x10	22	12 --> 30	24	4.7	10	45.8	39.6
							483.7

* Requirements say that the insulation wrap needs to be 1/2 inch thick						
According to Subcontractor	Cost per SF	SF	Total Cost	Minutes/SF	Minutes	
1" Vapor Barrier Wrap	1.96	484	$ 948.10	0.15	73	

SCHEDULE INFORMATION							
PREFABRICATION - 1 hr labor per 200 lbs of sheetmetal							
2	hrs total						
15 MINUTES TO RAISE AND HANG ONE RECTANGULAR PIECE OF DUCTWORK							
13	Pieces	15	minutes/piece		195		
ADD 15 MINUTES OF INSTALL TIME FOR EACH PIECE OF DUCT WHICH PENETRATES A WALL							
2	Pieces that Penetrate	15	minutes/piece		30		
1 MINUTE TO SEAL 24 LINEAR INCHES OF DUCT FLANGE BETWEEN PIECES							
13	Areas to sea	1	Minute/seal		13		
10 MINUTES TO INSULATE 10 LINEAR FEET OF DUCTWORK							
63	LF	10	Minutes/10 LF		63		
					404.5	6.7	Hours

Appendix

Blasting Estimate	
Blasting	$55,000.00
Pre Blast Survey	$20,000.00
Monitors	$ 6,000.00
Blasting Mats	$ 6,000.00
Stone	$ 1,000.00
Mobilization	$ 7,000.00
Total	$95,000.00

Manpower Takeoffs

Type of Personnel	Hours/day	Number of days	Total Number of Hours	Cost per Hour	Total Cost
Project Manager	2	14	28	$ 95.00	$ 2,660.00
Site Managers (3)	6	14	84	$ 85.00	$ 7,140.00
Superintendent	2	14	28	$ 100.00	$ 2,800.00
Senior PM	2	14	28	$ 100.00	$ 2,800.00
Intern (2)	4	14	56	$ 35.00	$ 1,960.00
Project Engineer (3)	6	14	84	$ 75.00	$ 6,300.00
LSF Laborers (6)	12	14	168	$ 29.14	$ 4,895.52
Douglas Blaster In Charge	8	14	112	$ 45.19	$ 5,061.28
Douglas Personnel	8	14	112	$ 45.19	$ 5,061.28
Flagger Force (10)	45	14	630	$ 39.00	$ 24,570.00
Excavation Operators (2)	16	17	272	$ 43.04	$ 11,706.88
					$ 74,954.96

Excavation Takeoff For Blasting		
CY needed to be Excavated	Cost/ CY	Total Cost
7473	$ 25.00	$186,825.00

Appendix

Traditional Excavation Takeoff			
Assumed half unrippable material and half rippable because dolemite rock works like a sin graph			
Unrippable Soil			
Cost/CY	**Cost**	**cy/day**	**Days**
$ 50.00	$ 186,825.00	315	12
Rippable Soil			
Cost/Cy	Cost	CY/Day	Days
25	$ 93,412.50	500	15
Total	$ 280,237.50		27
Additional Costs			
General Conditions	$ 5,000.00		
Subtotal	$ 285,237.50		
Shoring Requirements	$ 400,000.00		
Total	$ 685,237.50		