

The School District of Philadelphia Administration Headquarters

Shell and Core Renovations

440 North Broad Street

Philadelphia, PA

Jayme Antolik
Architectural Engineering
Mechanical Option
Senior Thesis 2006





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Presentation Outline

Building Introduction

Mechanical Analysis

Structural Considerations

Constructability

Conclusions

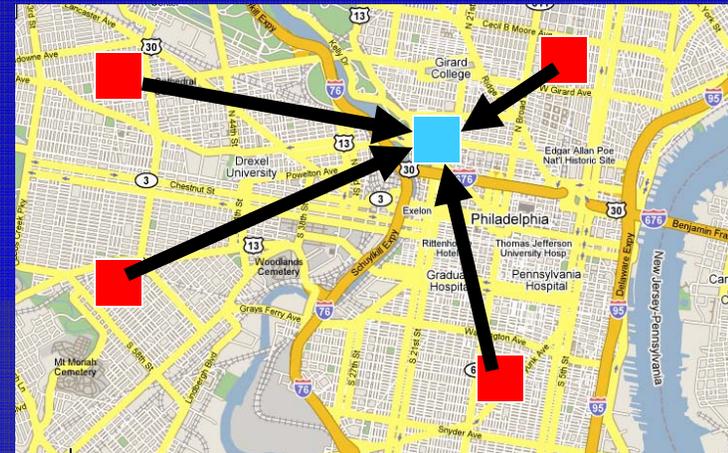


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Administration Headquarters
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Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Reason for Renovations

- School District Administration Relocation
 - Previous to move
 - Originally in 4 offices in different locations throughout Philadelphia
 - Working environment
 - Public accessibility
 - After move
 - One centrally located site
 - Better working environment
 - Easier public accessibility





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Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Building Site



- X-Axis: Broad and Market Streets
 - Nearly all of Philadelphia's commercial office space
 - 42% of center city's jobs
 - 7 colleges draw 34,000 students
 - 21% of downtown's jobs

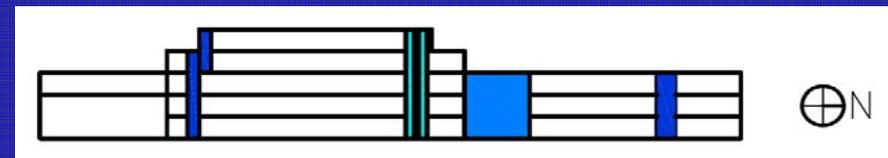
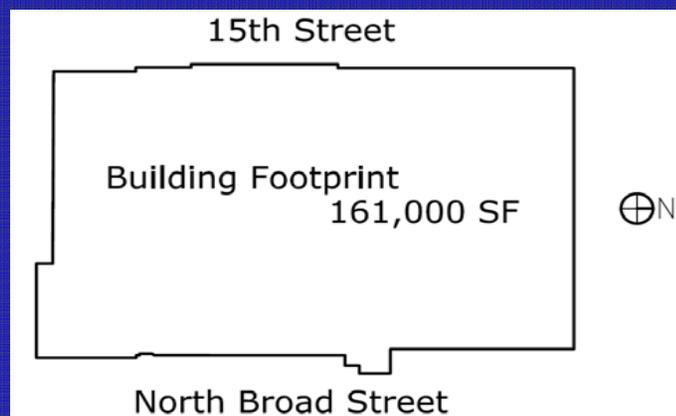


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Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Building History

- Existing printing facility for the *Inquirer and Daily News*
- 848,000 square feet with a 161,000 SF building footprint
- 5 stories above ground
- Large floor-to-floor heights
- Large live load structural capacity





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Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Design Team

- Architect: Hooper Shiles Architects, Wayne, PA
 - Mechanical Engineers: Cannon Design, NY, NY
 - Structural Engineers: Thornton Tomasetti Group, Newark, NJ
 - CM: Turner Construction Company, Philadelphia, PA
-
- Construction Dates: December 2004 – April 2006



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Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

New Architectural Features

- 3 story atrium
- Broad Street and 15th Street entrances
- New passenger and freight elevators





**The School District of Philadelphia
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440 North Broad Street
Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Existing Mechanical System

- Airside – Variable Air Volume with Parallel Fan Powered Boxes
 - 17 self contained packaged direct expansion (DX) air handling units located within the building core
 - 80 to 100 tons per unit
 - 25,000 to 32,000 CFM per unit
 - 68 kW reheat coil per unit
 - Parallel fan powered boxes utilize electric heating coils
 - 50 total at 19 kW per box
 - Ducted supply/Plenum return
 - Outdoor and return air mix within the core mechanical rooms



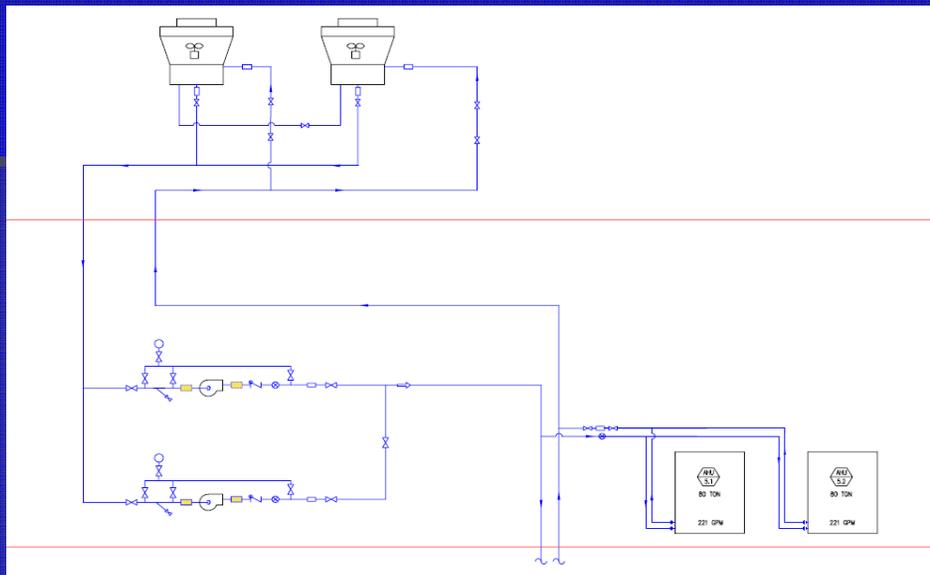


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Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Existing Mechanical System

- Waterside
 - 1500 ton 2-celled cooling tower serves the DX units with condenser water
 - 2 – 4370 GPM 250 HP condenser water pumps (one for back-up)





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Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Alternative Mechanical Systems

- Design focus
 - Office space
 - Floors 1, 2, 3, and 5
 - 425,000 SF
- Objectives
 - Save yearly energy consumption/cost
 - Reduce initial cost
 - Reduce emissions
 - Save lost rentable space





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Shell and Core Renovations
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Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Alternative Mechanical Systems

- **Airside Comparison**
 - Existing VAV system
 - Dedicated outdoor air system with parallel VAV system
 - Dedicated outdoor air system with parallel radiant system
- **Waterside Comparison**
 - Existing condenser water supply to DX units/Electric heating
 - Central Chilled Water and Central Hot Water Plant



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Administration Headquarters
Shell and Core Renovations
440 North Broad Street
Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Dedicated Outdoor Air System (DOAS)

- Purpose
 - Supply ventilation requirement (Standard 62.1)
 - Remove latent load from space
- Heat Recovery
 - Enthalpy wheel: Used to recover heat from the exhaust stream for conditioning of outdoor air
 - Summer: Hot outdoor air is cooled and dehumidified
 - Winter: Cold outdoor air is heated and humidified
- Benefits
 - Reduces equipment load

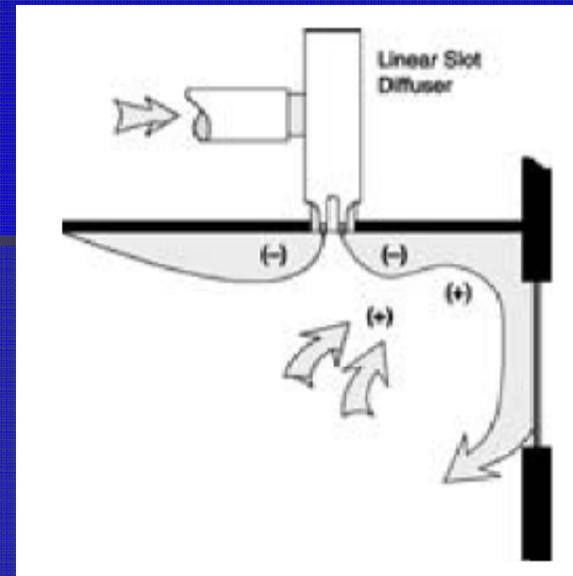


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Administration Headquarters
Shell and Core Renovations**
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Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

DOAS/Parallel System

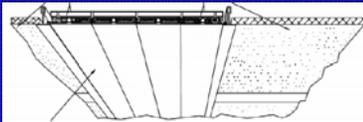
- 2 DOAS Air Handlers
 - Supply low temperature air (45F) via high induction diffusers
 - North DOAS
 - 76 tons
 - 16200 CFM
 - South DOAS
 - 125 tons
 - 26500 CFM
- Parallel System
 - VAV or Radiant
 - 749 tons





**The School District of Philadelphia
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Shell and Core Renovations
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Philadelphia, PA**

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions



Radiant Parallel System

Sterling



- Radiant Cooling Panels
 - Absorption capacity per panel: 292 Btu/hr
 - Room DBT – Mean Water Temp
 - 17 panels per circuit
 - Flow per circuit: 2 GPM
 - Absorption capacity per circuit: 5000 Btu/hr
 - Flow rate
 - Assumed temperature rise
 - 23.8' PD per circuit
 - 110 circuits per space
- Radiant Baseboard Heating
 - Perimeter heating load: 3241 MBH
 - 125 MBH per space



**The School District of Philadelphia
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Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Airside Results – VAV vs. DOAS/Parallel

Floor	Space Load [Btu/hr]		Cooling Coil Load		Percent Reduction
	Sensible	Latent	VAV	DOAS/Parallel	
1	3031029	100000	382.9	277.6	27.49%
2	2785496	80000	351.8	254.5	27.66%
3	3542547	100000	447.5	323.2	27.77%
5	1011878	40000	127.8	94.3	26.20%

- Equipment load reduction – 27.5%
 - VAV system – 1310 tons
 - DOAS/Parallel system – 950 tons



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Shell and Core Renovations
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Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Central Chilled Water Plant

- Purpose
 - Supply chilled water to cooling coils in air handling units
 - Supply chilled water to radiant cooling panels
- Equipment
 - 2 - electric two-stage centrifugal water-cooled chillers
 - Piped in parallel
 - Variable-primary
 - 2 chilled water pumps
 - 1 to head each chiller
- Benefits
 - Reduces total cooling energy consumption



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Shell and Core Renovations
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Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Central Hot Water Plant

- Purpose
 - Supply hot water to heating coils in air handling units
 - Supply hot water to heating coils in VAV boxes
 - Supply hot water to radiant baseboard heaters
- Equipment
 - 1 gas-fired hot water boiler
 - Efficiency: 83.3%
 - Load: 7000 MBH
 - Capacity: 8400 MBH
- Benefits
 - Reduces total heating energy consumption
 - Existing gas service at Buttonwood Street

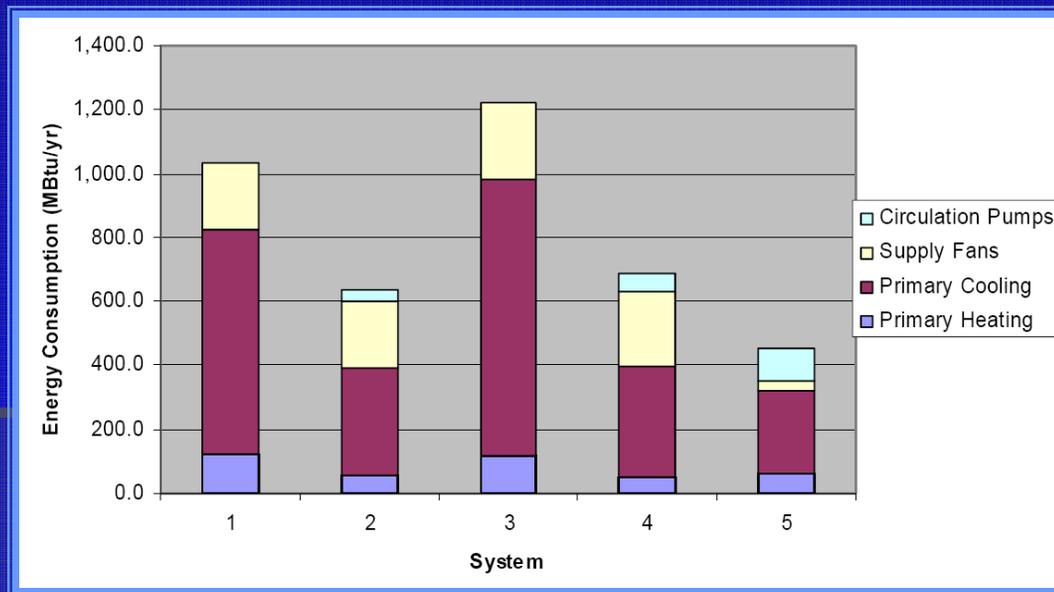




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Shell and Core Renovations
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Philadelphia, PA**

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Energy Consumption Results



- System 1: Existing VAV – DX & electric coils
- System 2: VAV system – CHW & HW
- System 3: DOAS and parallel VAV – DX & electric coils
- System 4: DOAS and parallel VAV – CHW & HW
- System 5: DOAS/Radiant – CHW & HW



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Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Yearly Operating Cost

	1	2	3	4	5
Electric	\$1,697,433	\$1,463,243	\$1,793,130	\$1,495,847	\$1,180,379
Gas	\$0	\$37,455	\$0	\$34,661	\$41,100
Water	\$152,379	\$140,887	\$170,704	\$145,723	\$107,851
Total	\$1,849,812	\$1,641,585	\$1,963,834	\$1,676,231	\$1,329,330

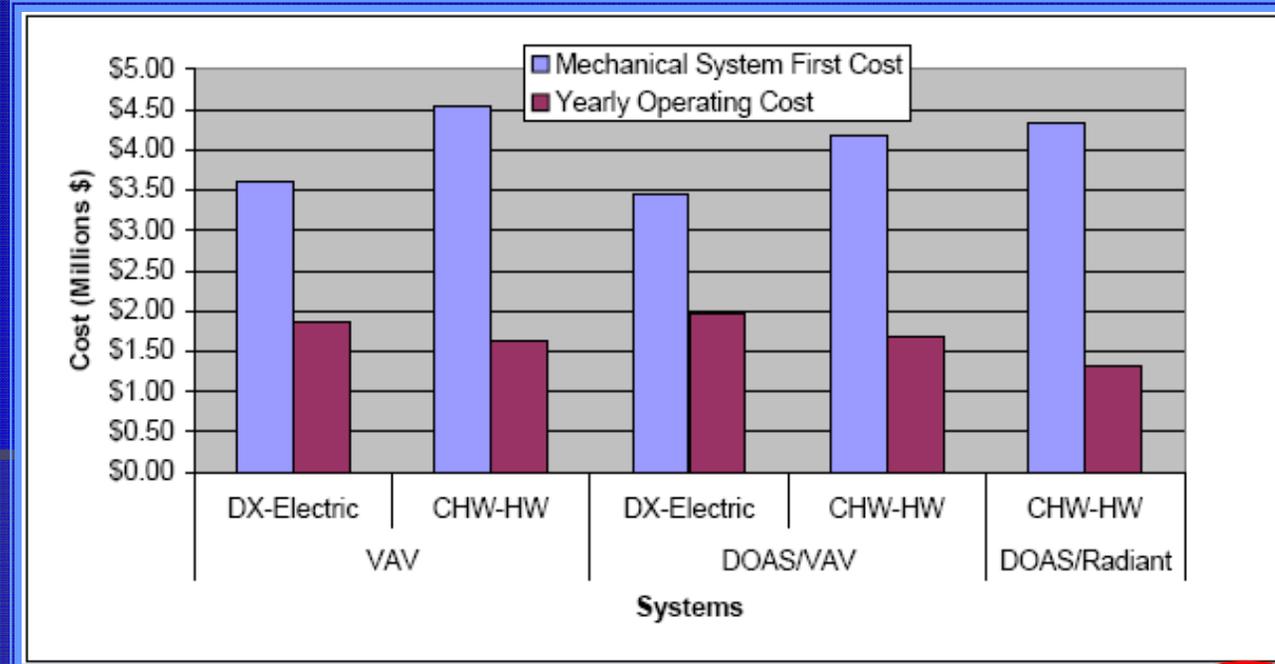
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- System 2: VAV system – CHW & HW
- System 3: DOAS and parallel VAV – DX & electric coils
- System 4: DOAS and parallel VAV – CHW & HW
- System 5: DOAS/Radiant – CHW & HW



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Philadelphia, PA**

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Cost Summary



	VAV		DOAS/VAV		DOAS/Radiant
	DX-Electric	CHW-HW	DX-Electric	CHW-HW	CHW-HW
Mechanical System First Cost	\$3.61	\$4.53	\$3.46	\$4.17	\$4.33
Yearly Operating Cost	\$1.85	\$1.64	\$1.96	\$1.67	\$1.33



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Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Structural Study – Central Water Plant

- Existing structural system
 - 5 inch concrete slab on metal deck
 - Steel girders and columns
 - Designed for a live load of 125 PSF
- Existing modifications
 - Column extensions to carry weight of cooling tower for existing VAV-DX system – 45,000 lbs
- New modifications
 - Column extensions to carry weight of new central water plant – 140,000 lbs
 - Designed live load: 100 PSF (corridors)
 - Designed dead load: 75 PSF

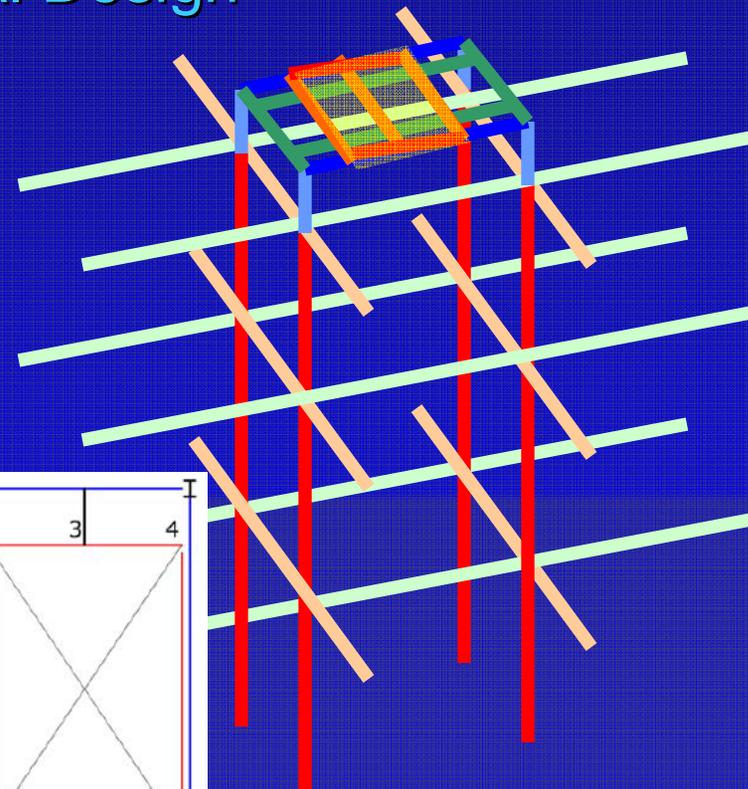
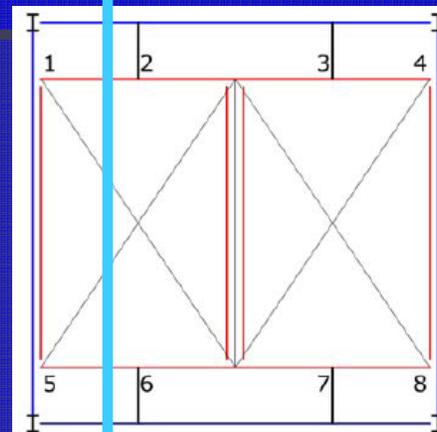


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Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Structural Design

- Original Columns
- Column Extensions
 - W 12 x 40
- Frame for Columns
 - HSS 20 & HSS 12
- Frame for Equipment
 - HSS 20 & HSS 18
- Mechanical Equipment
 - Chillers & Boiler





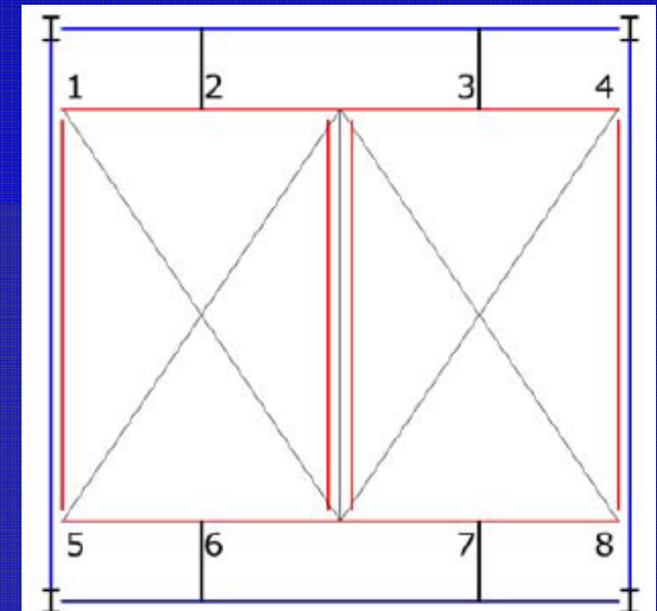
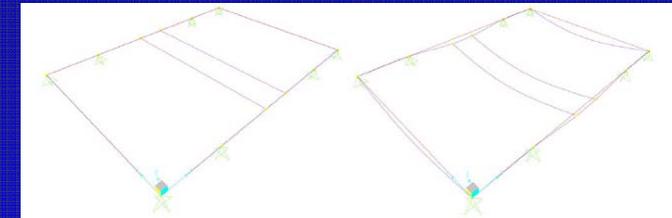
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Philadelphia, PA**

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Structural Model

- Top Frame – SAP model
 - Point loads 2, 3, 6, 7: 1 KIP
 - Point loads 1, 4, 5, 8: 136 KIP
- Bottom Frame – RAM model
 - Line load: 15 KIP/LF
- Existing top column – 12 x 40
 - Passes
- Existing bottom column – 12 x 72
 - Passes

→ No major structural modifications





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Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Constructability – Sequence Schedule Interior Equipment Installation

- Similar sized spaces – 25,000 SF
 - Plenty of crew work space
- Equal amounts of material installed in each space
- Adequate laydown area
- Sufficient freight elevator capacity – 20,000 lbs



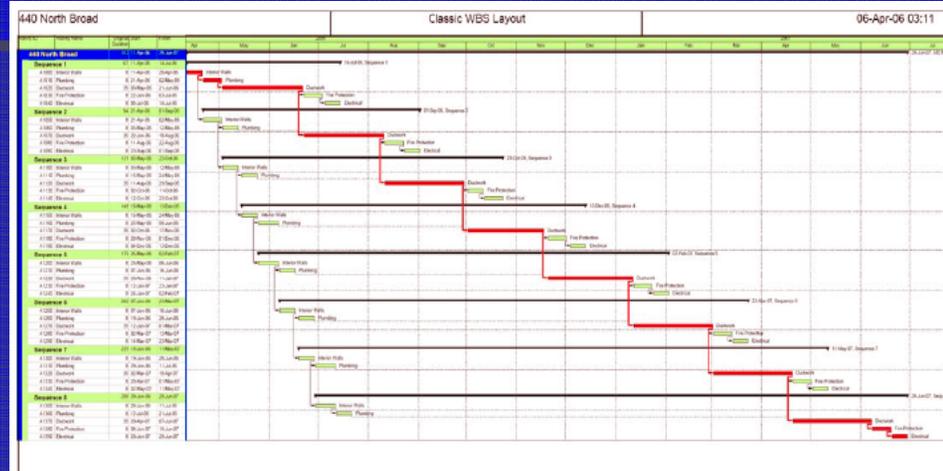


**The School District of Philadelphia
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Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Constructability – Sequence Schedule Interior Equipment Installation

- VAV
 - Critical activity: Ductwork
 - Weight: 500,000 lbs
 - Daily output: 14250 lbs
 - Installation time: 35 days
- DOAS/Radiant
 - Critical activity: Radiant Panels
 - Pipe length: 80000 ft
 - Daily output: 5250 ft
 - Installation time: 15 days





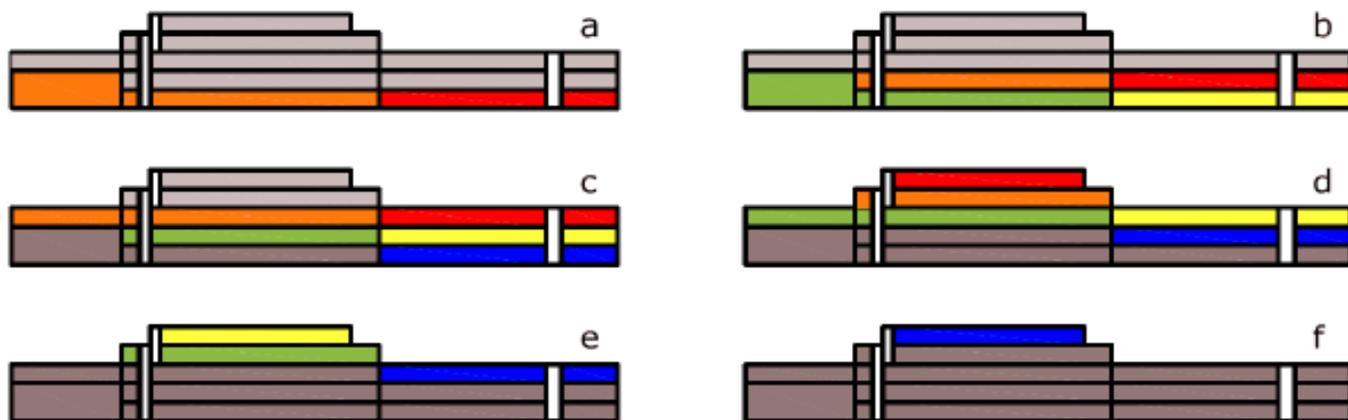
**The School District of Philadelphia
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Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Constructability – Sequence Schedule Interior Equipment Installation

5 Activities

1. Interior Walls
2. Plumbing
3. Ductwork/Radiant Panels
4. Fire Protection
5. Electrical



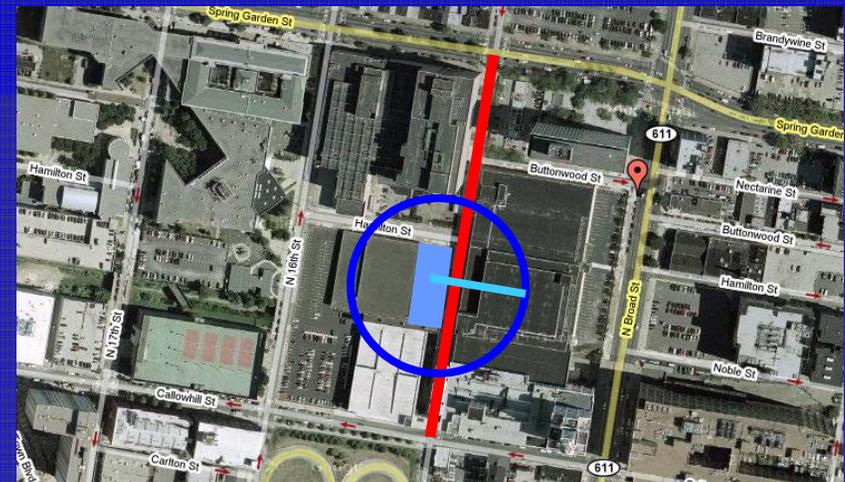


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Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Constructability – Sequence Schedule Outdoor Equipment Installation

- Structural Modifications
 - New roof column extensions → No major construction issues
 - New roof framing
- Mechanical Equipment – Chillers & Boiler
 - Location: Roof
- Required Construction Equipment – Crane
 - Location: Turner Construction parking lot
 - Neighborhood nuisance?
 - 15th Street closed for 1 - 2 days
 - Commuter traffic rerouted





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Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Conclusions

- IF an owner chooses chilled water plant
 - **Choose DOAS/Radiant System**
 - Lowest energy consumption
 - Smallest operating cost
 - Lowest emissions
 - Decrease in mechanical room space
 - No major structural modifications
 - No major construction issues



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Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Thank You

- Penn State Architectural Engineering Mechanical Faculty
 - Especially my advisor: Jae-Weon Jeong
- Classmates
 - Especially Evan, Jess, Jenny, Yulien, Lourdes, Bryan
- Mike Rush at Cannon Design
- Bill Harrington at Turner Construction



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Philadelphia, PA

Building Introduction
Mechanical Analysis
Structural Considerations
Constructability
Conclusions

Questions?

