Redland Tech Center

Rockville, MD

Shawn Pepple • Construction Management • April 14, 2009

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Presentation Outline

- Project Overview
- Chilled Beam HVAC System (MAE) (Mechanical)
- NEC Wire Sizing (Electrical)
- Parking Garage Sequencing
- Conclusion and Recommendations
- Questions and Acknowledgements

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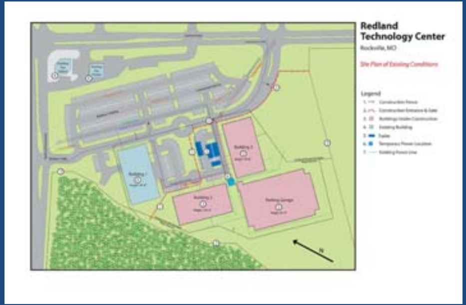
Project Overview

- Two office buildings with stand alone parking garage
- Building II: 9 levels; 210,240 SF
- Building III: 6 levels; 136,430 SF
- Parking Garage: 6 levels; 310,600 SF
- January 2008 – June 2009 Construction
- $52,800,000 Negotiated GMP
- Design-Bid-Build



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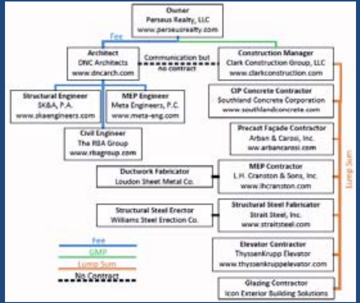
Project Overview

- Structural steel office buildings
- Precast façade with curtain wall and ribbon windows
- Self-contained air conditioning units with VAVs
- Precast parking garage
- LEED Silver Certification



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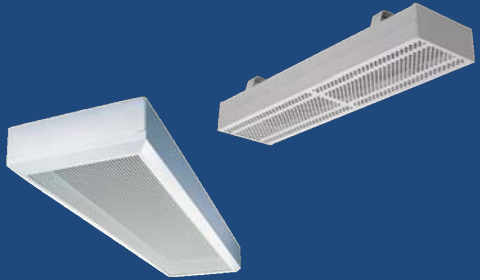
Critical Industry Research: Chilled Beams

- Energy efficiency becoming more important
- Water more efficient energy transporter
- Reduce ductwork, fans, AHUs, VAVs, plenum space
- Increase piping, pumping
- Two types: Passive and Active
- Used in Europe and Australia for several decades



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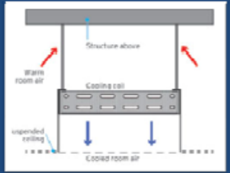
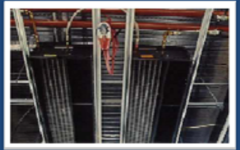
Passive Chilled Beams

- Use natural convection to cool air
- Only provide sensible cooling
- Cannot be used for heating
- Requires separate system for latent loads and ventilation
- 200-650BTUH sensible heat per ft of beam
- Exposed or recessed type





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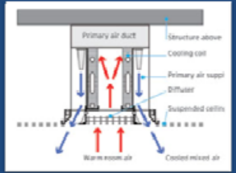
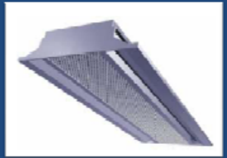
Active Chilled Beams

- Forced air induction
- Primary air and secondary cooling
- Used for cooling and heating
- 1,100 BTUH sensible heat per ft of beam
- Typically used with dedicated outdoor air system (DOAS)
- Several varieties to suit building requirements





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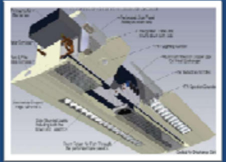
Multi-service Chilled Beams

- Prefabricated unit
- Incorporates other building systems
- Both passive and active types



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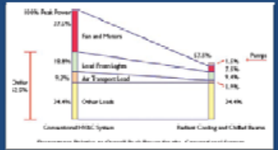
Chilled Beam Advantages

- Reduce primary air by 75-85%
- 20-40% savings in energy consumption
- Reduced ductwork size
- Low maintenance
- Increased room comfort; quiet
- Payback less than 5 years typical



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Chilled Beam Disadvantages

- Initial cost higher
- Not familiar in United States
- Cannot be used in areas with high or unpredictable humidity levels

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Chilled Beam Applications

- Best for projects with high sensible loads
- Retrofit and renovation projects
- Projects with building heightt restrictions
- Projects with ultimate sustainability goals

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Chilled Beams at RTC Building II

- Analysis uses active chilled beams
- Used chilled beams only in open office space
- Maximized energy efficiency by matching primary air to ventilation air requirements
- Analysis assumptions:
  - 100 ft^2/person
  - Current design used 72°F room air, 55°F supply air
  - Latent load = 200 BTUH/person

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Floor	Description	Area (SF)	Population	VAV CFM	Sensible Load (BTUH)	Latent Load (BTUH)	Outdoor Air Requirement (CFM)
1	Open Office	11,380	114	9,500	174,420	22,760	1,565
2	Open Office	19,862	199	12,000	220,320	39,724	2,731
3	Open Office	20,534	205	12,000	220,320	41,068	2,823
4	Open Office	20,534	205	12,000	220,320	41,068	2,823
5	Open Office	20,534	205	12,000	220,320	41,068	2,823
6	Open Office	20,534	205	12,000	220,320	41,068	2,823
7	Open Office	20,534	205	12,000	220,320	41,068	2,823
8	Open Office	20,534	205	12,000	220,320	41,068	2,823
9	Open Office	20,534	205	12,000	220,320	41,068	2,823

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Number of Chilled Beams Required

- Room air: 72°F/50% relative humidity (0.00836lb_w/lb_{da})
- Supply air: 55°F/58% relative humidity (0.00535lb_w/lb_{da})
- Analysis used 1,000 BTUH sensible heat per ft of beam
- Based on 6’ chilled beams

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Floor	Total Sensible Load (BTUH)	Primary Air Sensible Capacity (BTUH)	Primary Air Sensible % of Total	Secondary Sensible Capacity (BTUH)	Secondary Sensible % of Total
1	174,420	28,729	16.5%	145,691	83.5%
2	220,320	50,142	22.8%	170,178	77.2%
3	220,320	51,838	23.5%	168,482	76.5%
4	220,320	51,838	23.5%	168,482	76.5%
5	220,320	51,838	23.5%	168,482	76.5%
6	220,320	51,838	23.5%	168,482	76.5%
7	220,320	51,838	23.5%	168,482	76.5%
8	220,320	51,838	23.5%	168,482	76.5%
9	220,320	51,838	23.5%	168,482	76.5%

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- Analysis used 1,000 BTUH sensible heat per ft of beam
- Based on 6’ chilled beams

Floor	Secondary Sensible Capacity (BTUH)	Linear Feet of Chilled Beam Required	Number of 6' Chilled Beams
1	145,691	146	25
2	170,178	170	29
3	168,482	168	29
4	168,482	168	29
5	168,482	168	29
6	168,482	168	29
7	168,482	168	29
8	168,482	168	29
9	168,482	168	29
		Total Number of 6’ Beams	**257**

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Chilled Beam Costs

- Material cost for chilled beams is $140 per linear foot
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- Each 6’ beam will cost $1,680 installed

Floor	Number of 6' Chilled Beams	Material Cost	Labor Cost	Total Cost
1	25	$21,000	$21,000	$42,000
2	29	$24,360	$24,360	$48,720
3	29	$24,360	$24,360	$48,720
4	29	$24,360	$24,360	$48,720
5	29	$24,360	$24,360	$48,720
6	29	$24,360	$24,360	$48,720
7	29	$24,360	$24,360	$48,720
8	29	$24,360	$24,360	$48,720
9	29	$24,360	$24,360	$48,720
		Total Chilled Beam Cost		$431,760
		Chilled Beam Cost per SF		$2.47

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Description	Material	Labor	Total	% of Total
Chilled Water Piping	$116,601	$66,159	$182,760	7.6%
Mechanical Insulation	$58,998	$76,002	$135,000	5.6%
Pumps	$20,004	$3,558	$23,562	1.0%
Cooling Towers	$205,775	$16,325	$222,100	9.2%
VAVs	$37,088	$8,212	$45,300	1.9%
Fans	$79,100	$7,413	$86,513	3.6%
Self Contained AHUs	$790,242	$38,183	$828,425	34.5%
Ductwork	$97,290	$607,710	$705,000	29.3%
Controls	$86,670	$48,330	$135,000	5.6%
Condensate Piping	$9,412	$13,488	$22,900	1.0%
Testing and Balancing	$0	$18,000	$18,000	0.7%
Totals	**$1,501,178**	**$903,382**	**$2,404,560**	**100.0%**
VAV Mechanical System Cost per SF = $11.44				

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Chilled Beam Component Costs

- Chilled water piping
  - Material: $8.94/lf *1,300lf/floor*9floors = $104,598
  - Labor: $5.06/lf *1,300lf/floor*9floors = $59,202
  - Total Additional Cost: **$163,800**
- Mechanical Insulation
  - No change

- Pumps
  - Material: $20,004*2 = $40,008
  - Labor: $3,558*2 = $7,116
  - Total Additional Cost: **$47,124**
- Cooling Tower
  - No change

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Chilled Beam Component Costs

- VAVs
  - Material: 72VAVs*$442/VAV = $31,824
  - Labor: 72VAVs*$442/VAV = $31,824
  - Total Savings: **$38,808**
- Fans
  - Material: 0.7*0.92*$79,100 = $50,940
  - Labor: 0.7*0.92*$7,413 = $4,774
  - Total Savings: **$55,714**

- SCUs
  - Material: $790,242
  - Labor: $38,183
  - Total Savings: **$828,425**
- Electric Heating Coils
  - Material: 257coils*$620/coil = $159,340
  - Labor: 257coils*$59/coil = $15,163
  - Total Additional Cost: **$174,503**

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Chilled Beam Component Costs

- Wiring and Conduit for Heating Coils
  - Material: 3-wires*$0.81/LF*650LF/floor*9floors = $14,217
  - Labor: $2.47/LF*650LF/floor*9floors = $14,450
  - Total Additional Cost: **$28,667**
- Centrifugal Chillers
  - Material: $384,160
  - Labor: $384,160
  - Total Additional Cost: **$402,192**
- AHUs
  - Material: $46,592
  - Labor: $7,056
  - Total Additional Cost: **$53,648**
- Ductwork
  - Material: 0.45*0.92*$97,290 = $40,278
  - Labor: 0.25*0.92*$607,710 = $137,773
  - Total Savings: **$178,051**

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Chilled Beam Component Costs

- Controls
  - Material: 0.92*$86,670 = $79,736
  - Labor: 0.92*$48,330 = $44,464
  - Total Savings: **$124,200**
- Condensate Piping
  - No change

- Testing and Balancing
  - Material: $0
  - Labor: **$124,200**
  - Total Savings: **$16,560**

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Chilled Beams	$215,880	$215,880	$431,760	17.4%
Chilled Water Piping	$221,199	$125,361	$346,560	14.0%
Mechanical Insulation	$58,998	$76,002	$135,000	5.4%
Pumps	$60,012	$10,674	$70,686	2.9%
Cooling Towers	$205,775	$16,325	$222,100	9.0%
VAVs	$5,264	$1,228	$6,492	0.3%
Fans	$28,160	$2,639	$30,799	1.2%
Self Contained AHUs	$0	$0	$0	0.0%
Electric Heating Coils	$159,340	$15,163	$174,503	7.0%
Wiring and Conduit for Heating Coils	$14,217	$14,450	$28,667	1.2%
Centrifugal Chiller	$384,160	$18,032	$402,192	16.2%
AHUs	$46,592	$7,056	$53,648	2.2%
Ductwork	$57,012	$469,937	$526,949	21.3%
Controls	$6,934	$3,866	$10,800	0.4%
Condensate Piping	$9,412	$13,488	$22,900	0.9%
Testing and Balancing	$0	$16,560	$16,560	0.7%
Totals	**$1,472,954**	**$1,006,662**	**$2,479,616**	**100%**
Chilled Beam Mechanical System Cost per SF = $11.79				

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VAV Cost	Chilled Beam Cost	Cost Increase	% Increase
$2,404,560	$2,479,616	$75,056	1.03

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Additional Office Space w/ Chilled Beams

- Removed SCUs add office space for floors 2-7
- 360SF/floor
- 2,160SF additional office space
- Office space will lease for $12/SF/month
- Additional leasing income of $25,290/month

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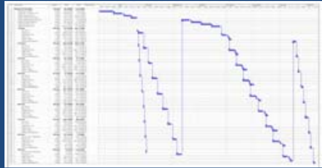
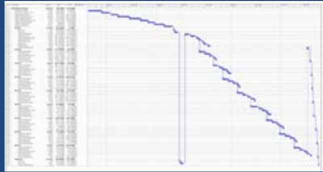
Chilled Beam Schedule Impacts

- Original Schedule:
  - June 9, 2009 – February 10, 2009
  - 246 days
- Chilled Beam Schedule:
  - June 9, 2009 – March 19, 2009
  - 283 days
- Overall Project Schedule:
  - No change



Original VAV Schedule



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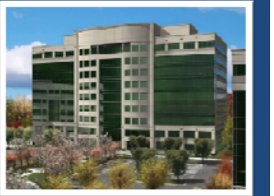

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Energy Savings

- EPA estimates annual HVAC energy cost/SF for Mid-Atlantic area office building to be $1.59/SF
- Annual HAVC Cost = $1.59/SF*210,240SF = $334,282 per year

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Energy Reduction	HVAC Energy Costs per Year	Savings per Year
20%	$267,426	$66,856
30%	$233,997	$100,285
40%	$200,569	$133,713

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Payback Period

- Additional cost of $75,056 (1.03% increase)
- Savings between $66,856 and $133,713 in energy costs
- Additional $311,040/year in office leasing revenue
- Less than 1 year payback

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Conclusion

- Initial cost increase of $75,056 (1.03%)
- VAV system cost = $2,404,560 = $11.44/SF
- Chilled beam system cost = $2,479,616 = $11.79/SF
- Lower operating costs, higher revenues offset higher initial cost with less than 1 year payback
- Chilled beams increased HVAC construction duration by 37 days
- Overall project schedule not affected
- Chilled beams unfamiliar to industry professionals in United States

Recommendation

- Chilled beams should be pursued on more projects in US
- Would be appropriate to use for RTC project

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NEC Wire Sizing

- Upsizing wire conductors has the potential to the improve the energy efficiency of buildings
- Wire conductors have resistance which creates voltage drops and uses energy
- Larger conductors have lower resistance than smaller wires
- Analysis determines the feasibility of upsizing wires one size larger than NEC code minimum to reduce energy usage

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Calculations

- Circuit No. 12 on lighting panel LP-H
- Powers 2'x4' parabolic troffer luminaires
- 277V
- Connected load = 4,400 VA
- 2-#12 AWG - #12 Ground
- Luminaires are approximately 100' from panelboard

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Calculations

- Current in wires = 4,400VA/277V = 15.9 amps
- The first step is to calculate the resistance of #12 wire:
  - For #12 THHN @ 75°C (From NEC Chapter 9, Table 9):

    R = 2Ω/kFT
  - To correct resistance to 30°C, use NEC Table 8 footnote:

    R_2 = 2 [1+0.00323(30-75)] = 1.71 Ω/kFT
- The second step is to calculate the power loss for #12 wire:

  Power Loss = $I^2 * R = (15.9)^2 * 1.71 * 0.1$ = 43.0 W

- The third step is to calculate energy loss per year for #12 wire:

  Energy Loss = 43.0 W / 1000W/kW * 12hrs/day * 365days/year = 188 kWh/yr
- Repeat steps for #10wire

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Calculations

- Resistance of #10 wire:
  - For #10 THHN @ 75°C (From NEC Chapter 9, Table 9):

    R = 1.2Ω/kFT
  - To correct resistance to 30°C, use NEC Table 8 footnote:

    R_2 = 1.2 [1+0.00323(30-75)] = 1.03 Ω/kFT
- Power loss for #10 wire:

  Power Loss = $I^2*R = (15.9)^2 * 1.03 * 0.1 = 26.0$ W

- Energy loss per year for #10 wire:

  Energy Loss = 26.0 W / 1000W/kW * 12hrs/day * 365days/year = 113 kWh/yr
- Savings due to upsizing wire:

  188-113 = 75 kWh/yr
- Dollar savings at $0.09 per kWh:

  $6.75/yr
- Dollar savings at $0.09 per kWh:

  $6.75/yr
- Initial cost increase:

  Cost of #12 wire and conduit = $2.85LF*100’ = $285

  Cost of #10 wire and conduit = $3.03LF*100’ = $303

  Cost difference = $18

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Discounted Payback Period

- Assume MARR = 15%

Period	Cash Flow	Cost of Funds (15%)	Cumulative Cash Flow
0	($18)	$0	($18)
1	$6.75	($2.70)	($13.95)
2	$6.75	($2.09)	($9.29)
3	$6.75	($1.39)	($3.93)
4	$6.75	($0.59)	$2.23

$0.09/kWh – 4 year payback

Period	Cash Flow	Cost of Funds (15%)	Cumulative Cash Flow
0	($18)	$0	($18)
1	$10.50	($2.70)	($10.20)
2	$10.50	($1.53)	($1.23)
3	$10.50	($0.18)	$9.09

$0.14/kWh – 3 year payback

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Other Findings

- Payback shows wire upsizing is feasible
- Most circuits do not operate at design
- Penn State Campus buildings design capacities typically 3 to 4 times average load
- Wires already upsized several times

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Possible Uses of Wire Upsizing

- Locations with constant high loads
- Data center equipment
- Large constant speed motors
- HVAC chillers

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Conclusion

- Wire upsizing feasible
- Savings not drastic
- Payback typically within a few years
- Best uses would be areas with constant high loads
- Data center equipment, large constant speed motors, HVAC chillers

Recommendation

- Apply principle only in areas of building projects with high constant loads

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Actual Construction Sequence

- February 6, 2008 – April 1, 2009; 420 days
- Constructed in 2 phases
- 46 day gap in precast member erection

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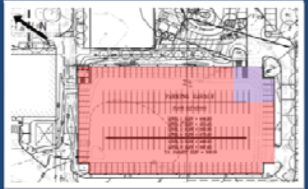

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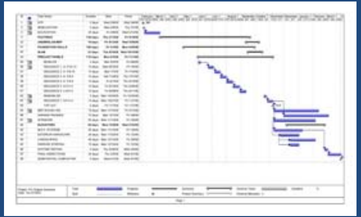

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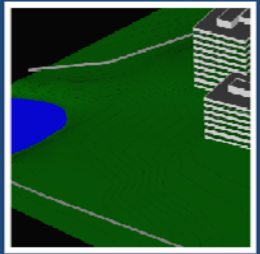

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Actual Construction Sequence

- No remobilization fees were paid to the Precast Erectors, Inc. because only 1 mobilization charge was stated in contract with Clark Construction
- Precast Erectors PM estimated second mobilization costs were $70,000
- Precast Erectors absorbed second mobilization costs

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Proposed Construction Sequence

- Erect majority of building in same manner as the actual sequence except leave out south non-load bearing foundation wall instead of corner
- Erect members from inside the building
- Move crane from basement to outside foundation wall through opening in wall and erect last sequence

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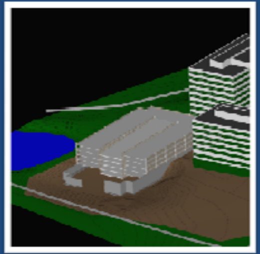

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Proposed Construction Sequence

- Erect majority of building in same manner as the actual sequence except leave out south non-load bearing foundation wall instead of corner
- Erect members from inside the building
- Move crane from basement to outside foundation wall through opening in wall and erect last sequence
- February 6, 2008-February 17, 2009; 377 days
- Saves 43 days in construction duration

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Cost Impacts

- GCs are reduced
- Precast Erectors would save $70,000 for the second mobilization costs
- Project cost is not affected

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Conclusion

- Proposed sequence saves 43 days in construction duration
- Saves Precast Erectors $70,000 in second mobilization costs
- Does not reduce cost to owner
- Allows Clark Construction to better manage risks

Recommendation

- Use proposed sequence to reduce construction duration, minimize risks on project, allow site work to finish earlier, and save Precast Erectors second mobilization costs
- Would make project more of a success for everyone involved

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Conclusion

- Chilled beams are a new HVAC technology which has the potential to drastically improve a building's energy efficiency
- Chilled beams can be implemented at RTC BII for $75,056 with payback period less than 1 year and no schedule impact
- Wire upsizing has the potential to save energy
- Implement in areas with constant high loads
- Proposed sequence for the parking garage saves 43 days on the schedule; costs are not reduced

Recommendation

- All three analysis topics should be used for project

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Questions?

Shawn Pepple • Construction Management • April 14, 2009

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