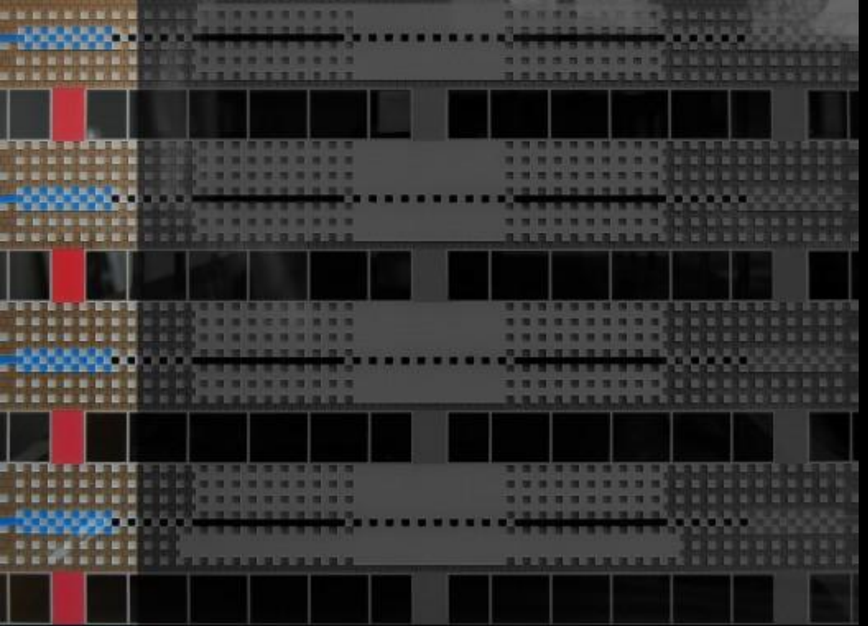


Photo Property of: Mr. Nuno Cruz

THE URBN CENTER & ANNEX

Philadelphia, PA

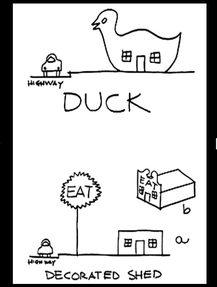
Penn State AE Senior Thesis Project

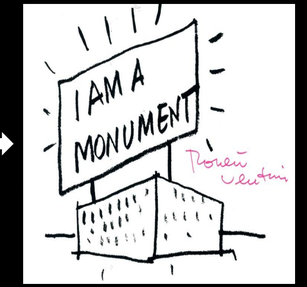
Ghaith Yacoub | Construction Management

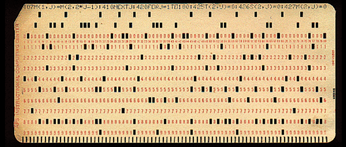
Dr. Robert Leicht | CM Advisor

Project Location:

Building's History:







Project Background

Project Volume: $31 Million

Size: 145917 SF

Construction Duration: URBN Center: 10/11-9/12
Annex: 12/11-10/12

Delivery Method: Design-Bid-Build. Lump-Sum Contract

Renovation Scope: Demo of core
New Mezzanine levels
Curtain walls
MEP replacement

Turner

Drexel

Ghaith Yacoub I Construction Management

Building Layout:

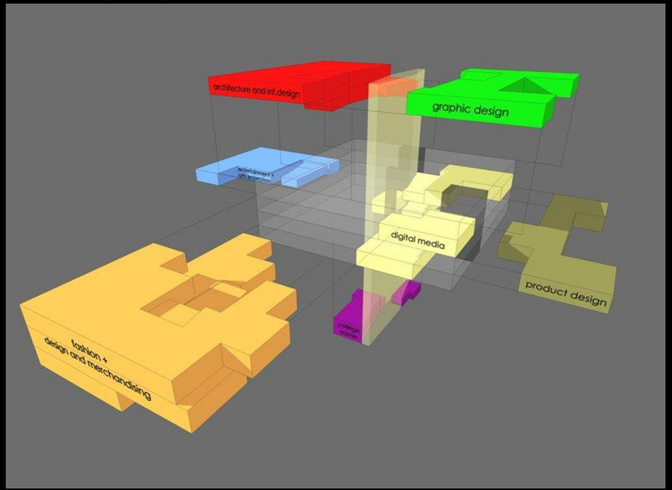


Photo Property of: MS&R LTD.

Construction Depths:

Analysis # 1: Demolition Alternatives for the Building's Core.

Analysis # 2: SIP Scheduling for the Steel Erection

Analysis # 3: Prefabrication of the Curtain Walls

Analysis # 4: Supply Chain Research of the Mechanical System

Breadth Topics:

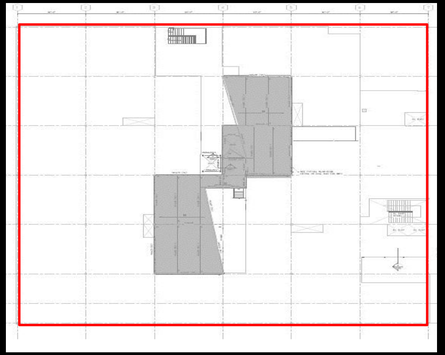
Structural Breadth #1: Steel Beam Sizing (Related to Analysis #1)

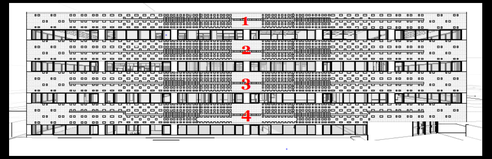
Mechanical Breadth #2: Energy Comparison Between Chilled Beams and VAV System (Related to Analysis #4)

ANALYSIS I

Demolition Alternatives for the Building's Core

Concern: Columns are un-braced for more than 14'





Solution: Maintain critical existing beams during demolition.

Schedule Effects: 10 Mondays.
Recovered with overtime/2nd shift

URBN Center's Existing Demolition Schedule					Notes
Item	Level	Start	Finish	Duration (days)	
Concrete Slab	4	12/27/2012	12/30/2012	4	N/A
	3	1/3/2012	1/6/2012	4	
	2	1/9/2012	1/12/2012	4	
Deck and Initial Beams	4	1/10/2012	1/14/2012	4	15 Beams
	3	1/16/2012	1/19/2012	4	0 beams
	2	1/20/2012	1/25/2012	4	15 Beams
Remaining Beams	4	3/26/2012	3/27/2012	2	5 beams
	3	3/28/2012	3/29/2012	2	2 Beams
	2	3/26/2012	3/27/2012	2	5 Beams

Analysis # 1: Demolition Alternatives

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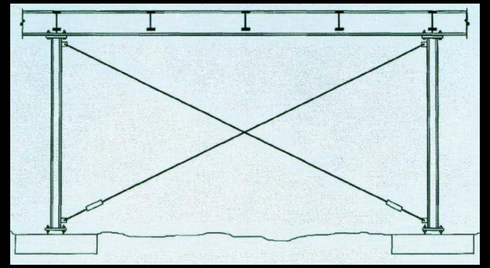
[Using AISC Guide: Erection Bracing of Low-Rise Structural Steel Buildings

Proposed Plan: Remove all steel in 1phase and implement Temporary bracing through either

A) Cross Cable Bracing



B) Temporary Beam Placement

Cost of Cable Bracing:

Item	Quantity	Unit	Cost per Unit ($)	Total cost ($)	Source
½" wire rope	5600	LF	1.33	7448	ACE Industries Inc
U-Bolt Clip	40	EA	0.88	35.2	ACE Industries Inc
Angles	40	EA	0.98	39.2	ACE Industries Inc
Total Cost ($)				7523	

Schedule Changes:

URBN Center's Proposed Demolition Schedule					Notes
Item	Level	Start	Finish	Duration (days)	
Concrete Slab	4	12/27/2012	12/30/2012	4	N/A
	3	1/3/2012	1/6/2012	4	
	2	1/9/2012	1/12/2012	4	
Deck and Beams	4	1/10/2012	1/17/2012	6	20 Beams
	3	1/18/2012	1/23/2012	4	2 beams
	2	1/20/2012	1/25/2012	4	20 Beams
Cable Installation	4	1/10/2012	1/10/2012	1	N/A
	3	1/18/2012	1/18/2012	1	
	2	1/20/2012	1/20/2012	1	

Comparison Factors:

Additional cost

Effects on next critical path item [Steel erection]

Method	Advantages	Disadvantages
Existing demolition method	• Limits additional labor • Does not interfere with the steel erection • Does not add additional cost to the project	• Need of demolition during the construction phase of the project. • Demo. Sub. Needs to come back to finish the scope.
Cable Cross Bracing	• Fast and easy installation • Allows for demolition of steel in one phase • cheap	• Additional Labor • Disrupts the steel erection
Temporary Beams	• NA	• Labor intensive • Availability of steel is questionable • Expensive

Analysis # 1: Demolition Alternatives

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Existing demolition plan is most effective due to having no additional cost and no effect on the steel erection.

Time taken to develop demo plan [10 Days] allows for schedule Acceleration Opportunities

Demolition Photos:

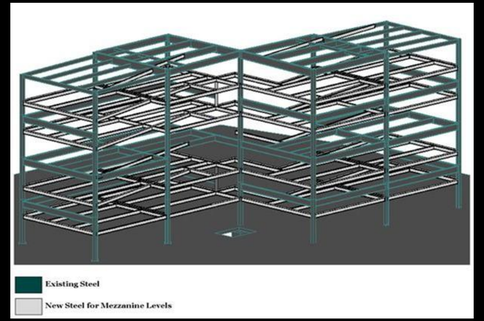
ANALYSIS II

SIP Scheduling for Mezzanine Levels

Why?

Highly repetitive activities in mezzanine levels

Potential acceleration of critical path items



Structural Framing and Slab on Metal Deck Durations		
	Structural Framing	Slab on Metal Deck
Level	Duration (Days)	Duration (Days)
1A	8	1.5
2A	8	1.5
3A	8	1.5
4A	8	1.5

[38 DAYS TOTAL]

Structural Steel	Welding clip angles to existing steel
	Steel erection
	Installing safety cables
	Detail Welding
Slab on Metal Deck	Decking
	Installing Bent plates
	Slab prep
	Slab pouring

[STEEL ERECTION IS MOST CRITICAL]

Labor:

- 1 foreman
- 2 erectors
- 1 crane operator
- 2 welders
- 1 Apprentice

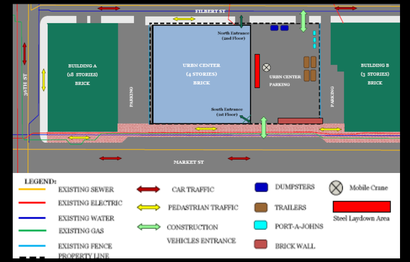
Equipment:

- 26 Ton Mobile Crane
- Propane Powered Mini Crane
- Chain Falls
- Trolleys

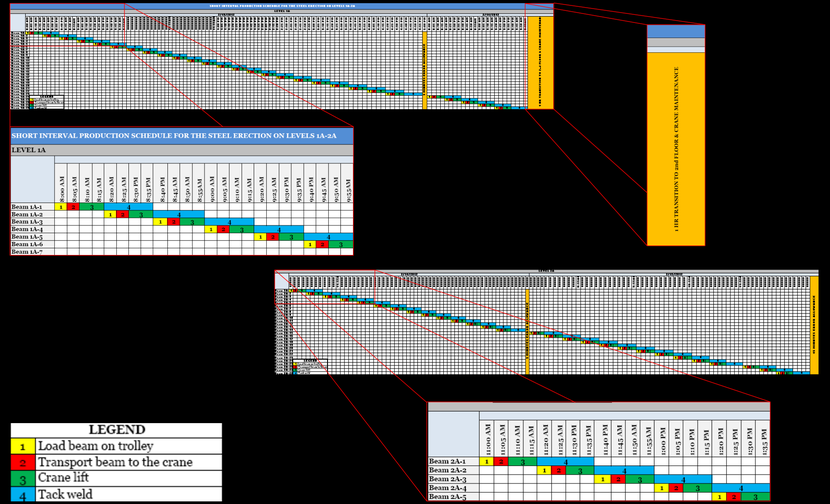
Levels 1A-2A Sequence:

Load beam on trolley..... 4 Mins
Transport beam inside the building..4 Mins
Crane lift.....8 Mins
Tack (initial) welding..... 20 Mins

Total member duration: 36 Mins
Total of 28 members on each level



LEVEL	Duration	Total hours (hrs)
1A	2/13/2012 (8AM-5PM)	8
	2/14/2012 (8AM-10AM)	2
Crane transition period		1
2A	2/14/2012 (11AM-5PM)	5
	2/15/2012 (8AM-2 :15 PM)	5.25
Error Allowance		0.75
Total Duration (hrs)		22
Total Duration (work Days)		2.75



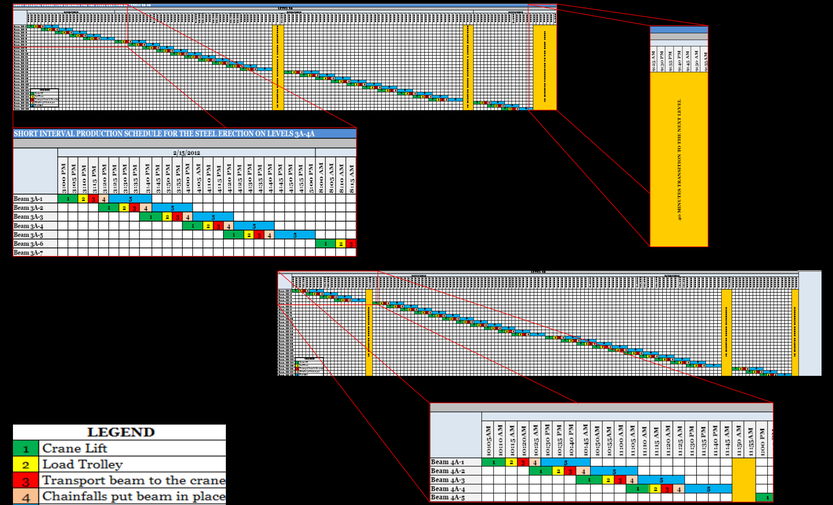
LEGEND	
1	Load beam on trolley
2	Transport beam to the crane
3	Crane lift
4	Tack weld

Levels 3A-4A Sequence:

Crane lift……..…8mins
Beam placement on trolley from window opening……..…4mins
Transporting the beam to center of the building……..……..4mins
Using chain falls to move the beam into place……...4mins
Tack welding……..……..…20mins

Total member duration: 40 Mins
Total of 28 members on each level

LEVEL	Duration	Total hours (hrs)
3A	2/15/2012 (3PM-5PM)	2
	2/16/2012 (8AM-5PM)	8
	2/17/2012 (8AM-9:20AM)	1.33
Transition to the next floor		0.66
4A	2/17/2012 (10AM-5PM)	6
	2/20/2012 (8AM-3:20 PM)	6.25
Error Allowance		.25
Total Duration (hrs)		25
Total Duration (work Days)		3.13



Activity	Duration (Days)
Welding clip angles to existing steel	4
Steel erection	5.88
Safety cables	4
Detail Welding	8
Decking and bent plates	8
Slab prep	4
Slab Pour	2
Total days	**35.88**

Total Savings: **2.12 Work Days**

General Conditions Cost/Day: **$6,031**

General Conditions Savings: **$12,800**

Labor	Hourly Rate ($/hr)	Hours	Cost ($)
Forman	52.05	17	885
Steel Worker (x2)	50.05	17	851
Crane Operator	48.80	17	830
Welder (x2)	50.05	17	851
Apprentice	33.05	17	562
Total Cost			**$3,980**

[TOTAL SAVINGS = $16,780]

Schedule acceleration is possible

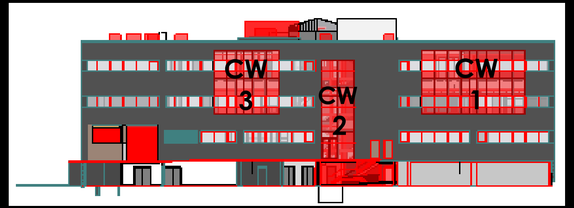
With the commitment from all parties involved.

Mezzanine Photo:

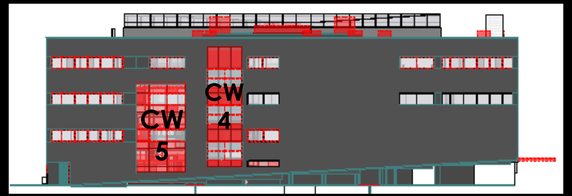
ANALYSIS III

Prefabrication of the Curtain Walls

North Elevation:



East Elevation:



Curtain Wall Label	Curtain Wall Dimensions (ft)	Area (SF)
CW 1	40 x 25	1000
CW2	40 x 15	600
CW3	25 x 25	625
CW4	45 x 15	675
CW5	35 x 20	700
Total Area:		**3600 SF**

Curtain Wall	Duration	Start	Finish
CW1	7	4/26/12	5/4/12
CW2	5	5/5/12	5/11/12
CW3	5	5/12/12	5/16/12
CW4	5	5/19/12	5/23/12
CW5	4	5/25/12	5/29/12
Total	**26**	**4/26/12**	**5/29/12**

RS Means Code	Item	Quantity	Unit	Daily Labor				Bare Cost				Total
				Crew	Output	Hrs	Units	Material	Labor	Equip.	Total	Inc O& P
08 44 13 10	Glazed C-Wall	3600	SF	H1	205	0.156	SF	34	7.2		41.2	49.5
Total Cost	$											178,200.00

Analysis # 3: Prefabrication of the Curtain Wall System

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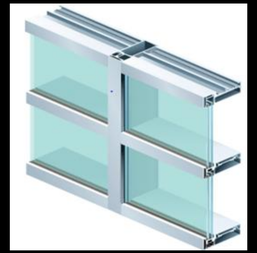
Benefits:
- Quality Control
- Safety
- Reduction of field labor

Technique:
- System is spliced in Panels:
  - width= 4 or 5ft
  - Height= 5 or 10 ft
- Most labor preformed in factory environment
- 20-40 panels per day

Construction Considerations:
Delivery ≈ 45 panels/truck
Stored on East Parking lot



Curtain Wall	Number of Panels
CW1	20
CW2	12
CW3	15
CW4	15
CW5	15
Total	80

Materials				
Item	Quantity	Unit	Cost/Unit ($/SF)	Total Cost ($)
Prefab C-Wall	3600	SF	55	198,000
Labor				
	Total hrs	Rate/hr ($/Hr)		Total Cost ($)
Glazier	24	43.30		1039
Glazier	24	43.30		1039
Helper	24	33.75		810
Total Cost				$200,888

Schedule Acceleration:

23 Days of installation time

Item	Cost ($)		Cost Savings ($)
	Stick Built	Prefabricated	
Material	122,400	198,000	**-75,600**
General Conditions	156806	18093	**+138713**
On-Site Labor	25,030	2,888	**+22140**
Total Savings ($)			**+85,253**

[Cumulative savings≈ **$102,000**]

Begin Prefabrication process very early in the design

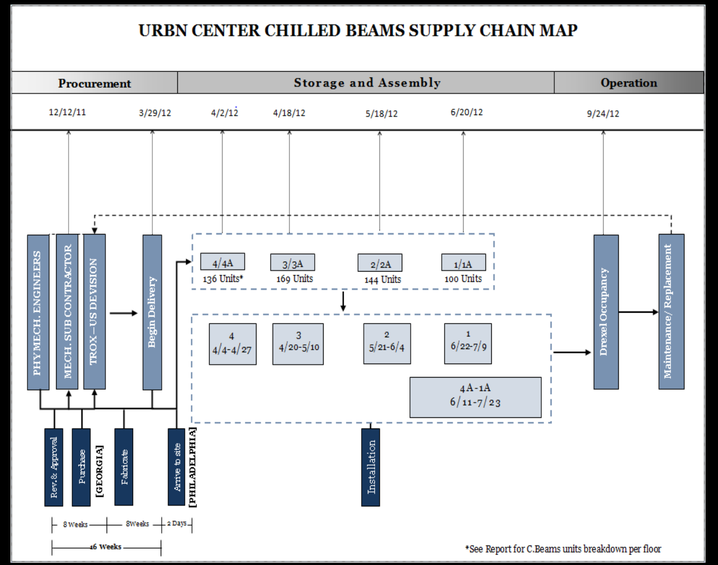
Avoid Customization

Design for Prefabrication

Curtain Walls Photos:

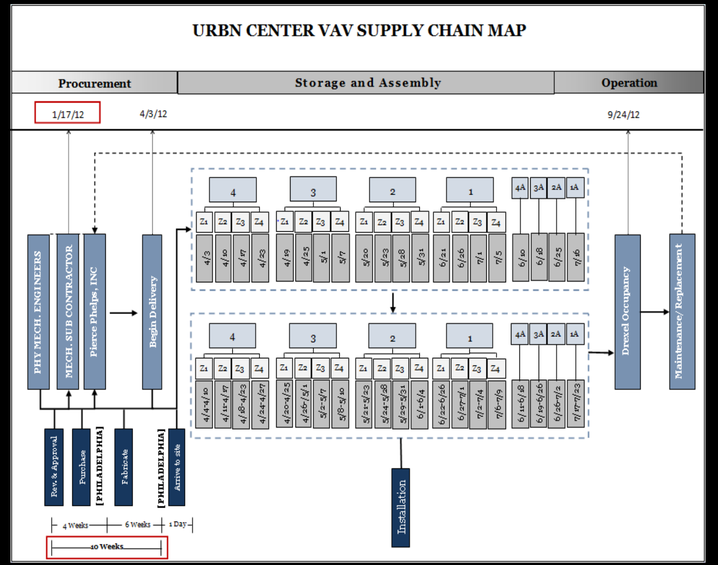
ANALYSIS IV

Supply Chain of the Mechanical System

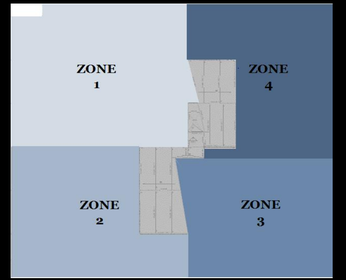


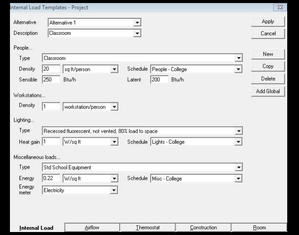
- 16 Week Procurement
- Limited Suppliers
- Delivery relevant to construction sequence

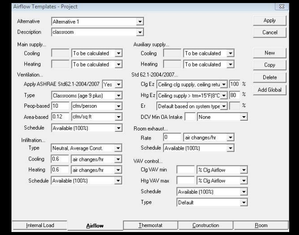
CHILLED BEAMS QUANTITIES PER LEVEL		
Level	Quantity	Shipment
1	110	1
1A	26	
2	149	2
2A	20	
3	118	3
3A	26	
4	82	4
4A	18	

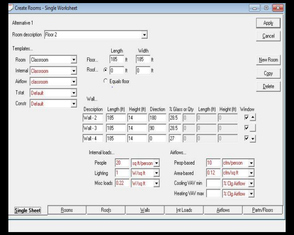


- 10 Week procurement
- Availability of local vendors
- Same day delivery option
- Avoiding a congested site

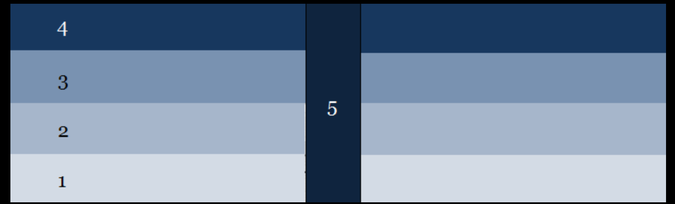








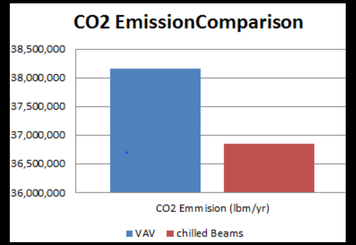
- Model based on two space types:
  - Classroom
  - Atrium (lobby)



Breadth II: Energy Comparison

------- Monthly Energy Consumption -------													
Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
VAV System													
Electric													
On-Pk Cons. (kWh)	39,658	34,822	49,528	54,571	77,301	89,457	101,969	96,920	70,189	60,631	50,620	41,765	**767,432**
On-Pk Demand (kW)	280	279	291	324	392	492	564	494	428	337	313	284	564
Chilled Beam System													
Electric													
On-Pk Cons. (kWh)	40,730	36,837	43,424	40,670	72,909	96,112	113,808	104,830	65,126	47,567	40,241	38,986	**741,239**
On-Pk Demand (kW)	185	185	352	366	446	507	562	506	452	366	362	185	562

Chilled Beams use 26193 KWH less/year



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Year	Cost ($/KWh)	Savings/yr	Coumlative Savings
1	0.156	4086.11	4086.11
2	0.157	4112.30	8198.41
3	0.158	4138.49	12336.90
4	0.159	4164.69	16501.59
5	0.16	4190.88	20692.47
6	0.161	4217.07	24909.54
7	0.162	4243.27	29152.81
8	0.163	4269.46	33422.27
9	0.164	4295.65	37717.92
10	0.165	4321.85	42039.77
11	0.166	4348.04	46387.80
12	0.167	4374.23	50762.03
13	0.168	4400.42	55162.46
14	0.169	4426.62	59589.08
15	0.17	4452.81	64041.89
16	0.171	4479.00	68520.89
17	0.172	4505.20	73026.08
18	0.173	4531.39	77557.47
19	0.174	4557.58	82115.06
20	0.175	4583.78	86698.83
21	0.176	4609.97	91308.80
22	0.177	4636.16	95944.96
23	0.178	4662.35	100607.31
24	0.179	4688.55	105295.86
25	0.18	4714.74	110010.60
26	0.181	4740.93	114751.53
27	0.182	4767.13	119518.66
28	0.183	4793.32	124311.98
29	0.184	4819.51	129131.49
30	0.185	4845.71	133977.20
Total Savings		**133977.20**	

Cost Return During 30 year life cycle ≈ **$140,000**

Analysis # 4: Supply Chain of the Mechanical System

Ghaith Yacoub I Construction Management

VAV has more benefits in terms of Supply Chain

Chilled Beams provide cost savings through out the life cycle

Chilled Beams Photos:

Analysis I: Demo Alt

- Existing Method is most efficient
  - No additional Cost
  - Minimum effect on the critical path

Analysis II: Steel Erection SIP

- Schedule Savings: 2.12 Days
- Cost Savings: $16,780

Analysis III: Curtain Walls Prefab.

- Schedule Savings: 23 Days
- Cost Savings: $85,253

Analysis IV: C-Beams VS. VAV

- VAV: More efficient supply chain
- C-Beams: Cost savings over lifecycle≈$140,000

Total Schedule Savings: 25.12 Days
Total Cost Savings: $102,000

Acknowledgments

Industry Acknowledgments:

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Mr. Christopher Renshaw—Turner

Ethan Marchant—MS&R LTD

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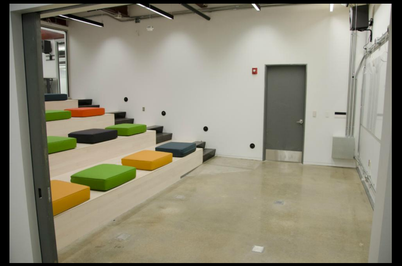
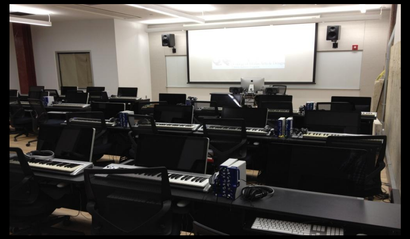
Mr. Logan Gray—AE graduate

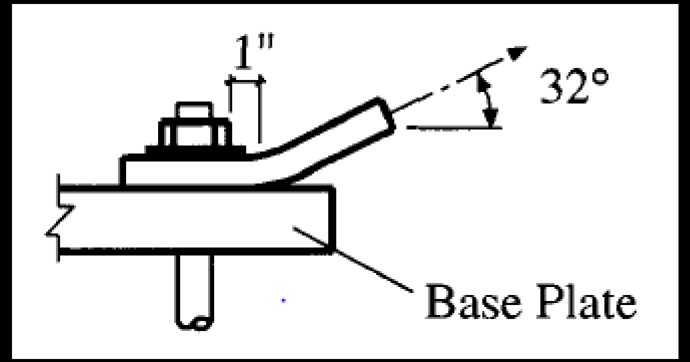




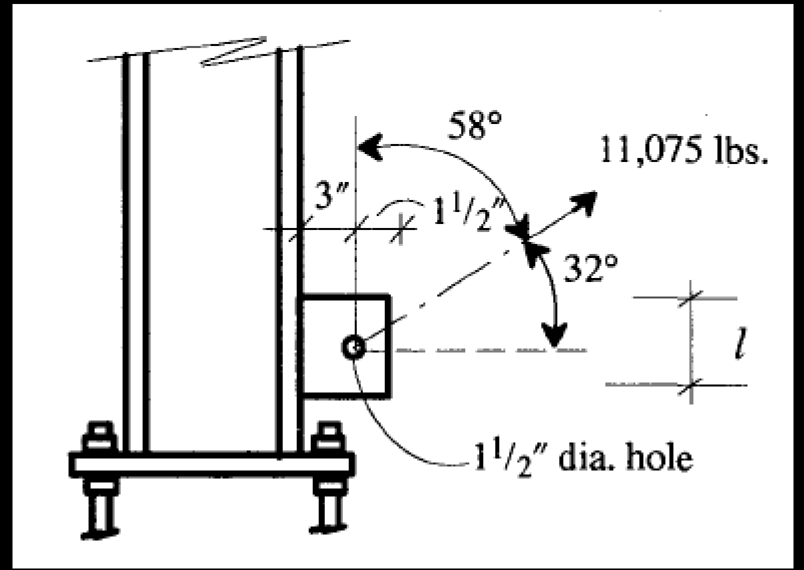
Questions?

Cable Bracing:

(from AISC Design Guide: Erection Bracing of Low-Rise Structural Steel Frames

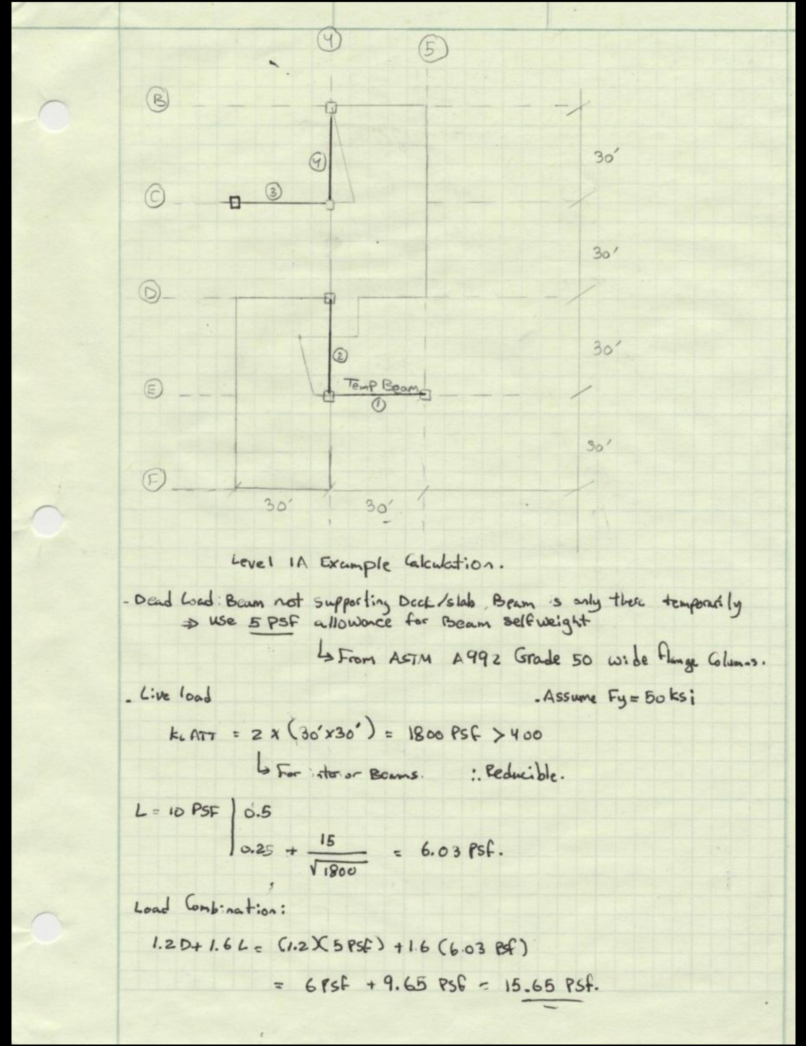


Option A



Option B

Temp. Beam Calculation



Level 1A Example Calculation.

- Dead Load: Beam not supporting Deck/slab, Beam is only there temporarily
  ⇒ use 5 PSF allowance for Beam selfweight
  ↳ From ASTM A992 Grade 50 wide flange Columns.
- Live load
  . Assume $F_y = 50$ ksi

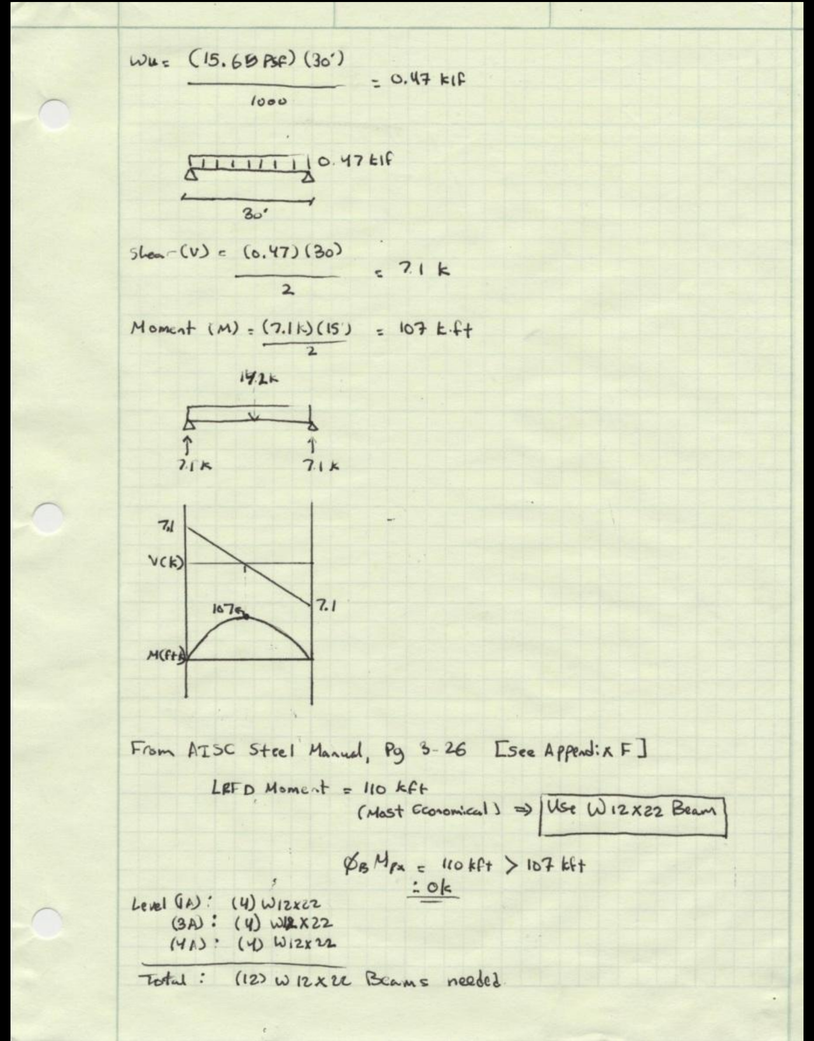
$K_{LL} A_T = 2 \times (30' \times 30') = 1800$ PSF > 400
↳ For interior Beams. ∴ Reducible.

$L = 10 \text{ PSF} \left| 0.5 \right.$; $0.25 + \frac{15}{\sqrt{1800}} = 6.03$ Psf.

Load Combination:

$1.2D + 1.6L = (1.2)(5 \text{ PSF}) + 1.6 (6.03 \text{ Psf})$

$= 6 \text{ PSF} + 9.65 \text{ PSF} = 15.65 \text{ PSF}.$



$W_u = \frac{(15.65 \text{ PSF})(30')}{1000} = 0.47$ klf

0.47 klf
30'

Shear (V) $= \frac{(0.47)(30)}{2} = 7.1$ k

Moment (M) $= \frac{(7.1k)(15')}{2} = 107$ k.ft

14.2k
7.1k 7.1k
7.1
V(k)
7.1
107
M(ft)

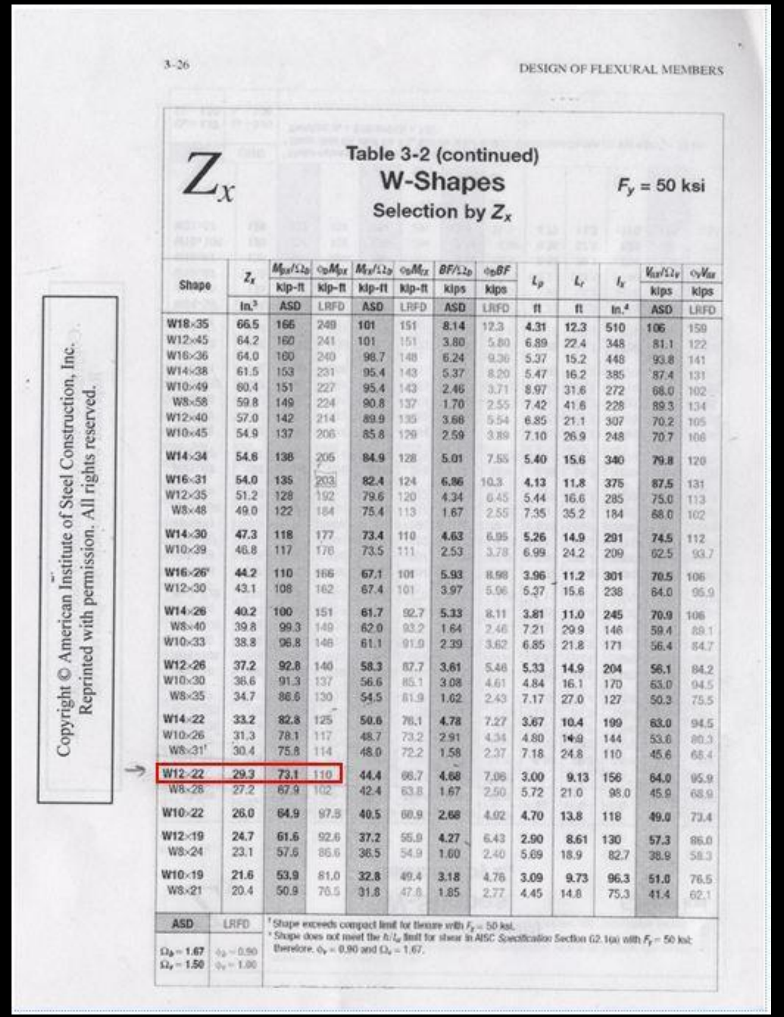
From AISC Steel Manual, Pg 3-26 [See Appendix F]

LRFD Moment = 110 kft
(Most Economical) ⇒ Use W12X22 Beam

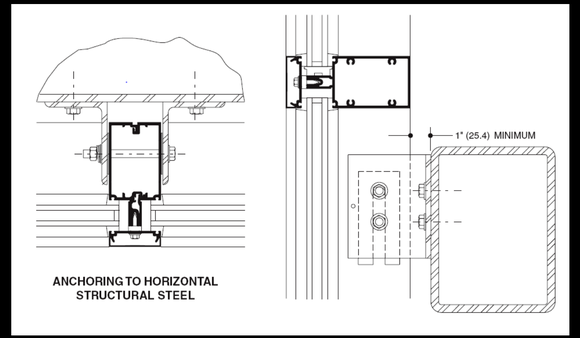
$\phi_B M_{px} = 110 \text{ kft} > 107 \text{ kft}$
∴ ok

Level (1A): (4) W12x22
(3A): (4) W12X22
(4A): (4) W12x22

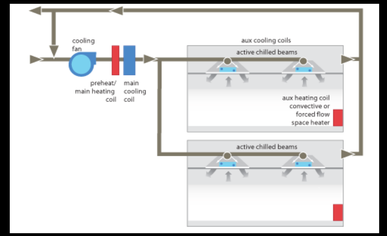
Total: (12) W12X22 Beams needed



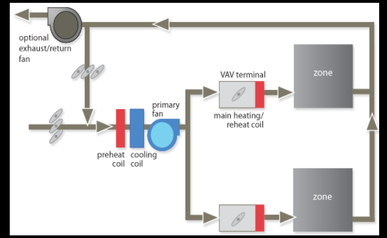
Curtain Wall Connection:



Chilled Beam System Schematic:



VAV System Schematic:



SYSTEM SUMMARY

DESIGN COOLING CAPACITIES

By Ghaith Yacoub

VAV System

Building Airside Systems and Plant Capacities

	Peak Plant Loads									Block Plant Loads							
	Main	Aux	Opt	Misc	Stg 1 Desic	Stg 2 Desic	Base	Peak	Tim Of	Main	Aux	Opt	Misc	Stg 1 Desic	Stg 2 Desi	Base	Block
	Coil	Coil	Coil	Load	Cond	Cond	Utility	Total	Peak	Coil	Coil	Coil	Load	Cond	Cond	Utility	Total
Plant Syste	ton	ton	ton	ton	ton	ton	ton	ton	mo/	ton	ton	ton	ton	ton	ton	ton	ton
Cooling plant - 001	680.1	0.0	0.0	0.0	0.0	0.0	0.0	680.1	7/16	672.0	0.0	0.0	0.0	0.0	0.0	0.0	672.0
System - 001	680.1	0.0	0.0	0.0	0.0	0.0	0.0	680.1	7/16	672.0	0.0	0.0	0.0	0.0	0.0	0.0	672.0
Building totals	680.1	0.0	0.0	0.0	0.0	0.0	0.0	680.1		672.0	0.0	0.0	0.0	0.0	0.0	0.0	672.0

Building peak load is 680.1 tons.

Building maximum block load of 672.0 tons occurs in July at hour 16 based on system simulation.

Chilled-Beam System

Building Airside Systems and Plant Capacities

	Peak Plant Loads									Block Plant Loads							
	Main	Aux	Opt	Misc	Stg 1 Desic	Stg 2 Desic	Base	Peak	Tim Of	Main	Aux	Opt	Misc	Stg 1 Desic	Stg 2 Desi	Base	Block
	Coil	Coil	Coil	Load	Cond	Cond	Utility	Total	Peak	Coil	Coil	Coil	Load	Cond	Cond	Utility	Total
Plant Syste	ton	ton	ton	ton	ton	ton	ton	ton	mo/	ton	ton	ton	ton	ton	ton	ton	ton
Cooling plant - 001	740.4	289.6	0.0	0.0	0.0	0.0	0.0	1,030.0	7/16	537.5	74.1	0.0	0.0	0.0	0.0	0.0	611.7
System - 001	740.4	289.6	0.0	0.0	0.0	0.0	0.0	1,030.0	7/16	537.5	74.1	0.0	0.0	0.0	0.0	0.0	611.7
Building totals	740.4	289.6	0.0	0.0	0.0	0.0	0.0	1,030.0		537.5	74.1	0.0	0.0	0.0	0.0	0.0	611.7

Building peak load is 1,030.0 tons.

Building maximum block load of 611.7 tons occurs in July at hour 16 based on system simulation.