S.T.E.P.S. Building

Joseph Murray
Structural Option
Senior Thesis Presentation
The Pennsylvania State University
Advisor: Linda Hanagan

Building Statistics

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth

- S.T.E.P.S.: Science, Technology, Environment, and Policy Building
- Education, laboratory, and research
- Owner: Lehigh University
- Location: Bethlehem, PA
- 5 story, 135,000 s.f. project
- 80’ to roofline of Wing C
- Cost: $62 million
- Construction: Aug. 2008 – Aug. 2010

Building Statistics

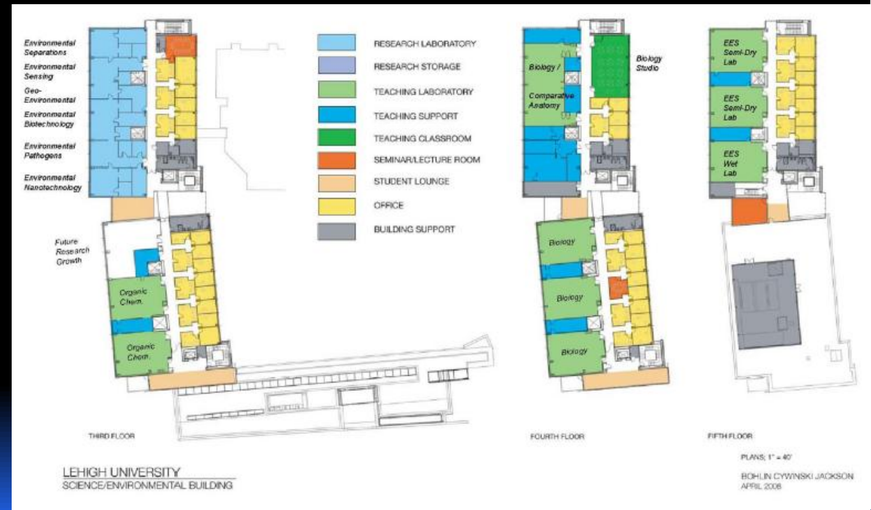
- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth

Project Team:

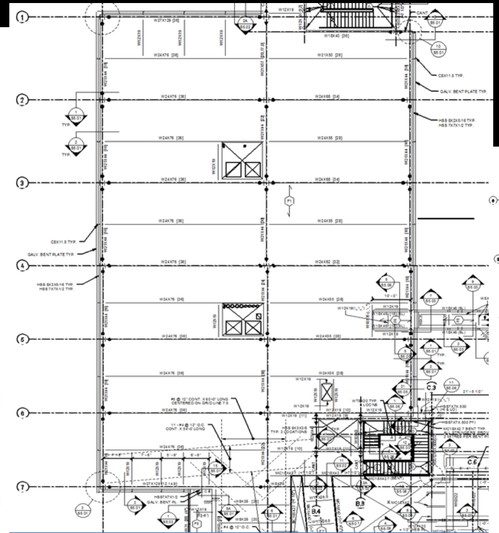
CM:	Alvin H. Butz	Allentown, PA
Architect:	BCJ Architects	Philadelphia
Structural:	CVM Structures	Oaks, PA
Civil:	Barry Isett & Assoc.	Trexlertown, PA
MEP/Fire:	Flack & Kurtz	New York, NY
Landscape:	Lager Raabe Skafte	Philadelphia

Existing Floor Plans

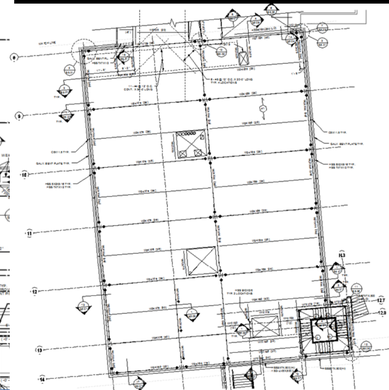
- Building Statistics
  - Existing Floor Plans
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth



Wing C

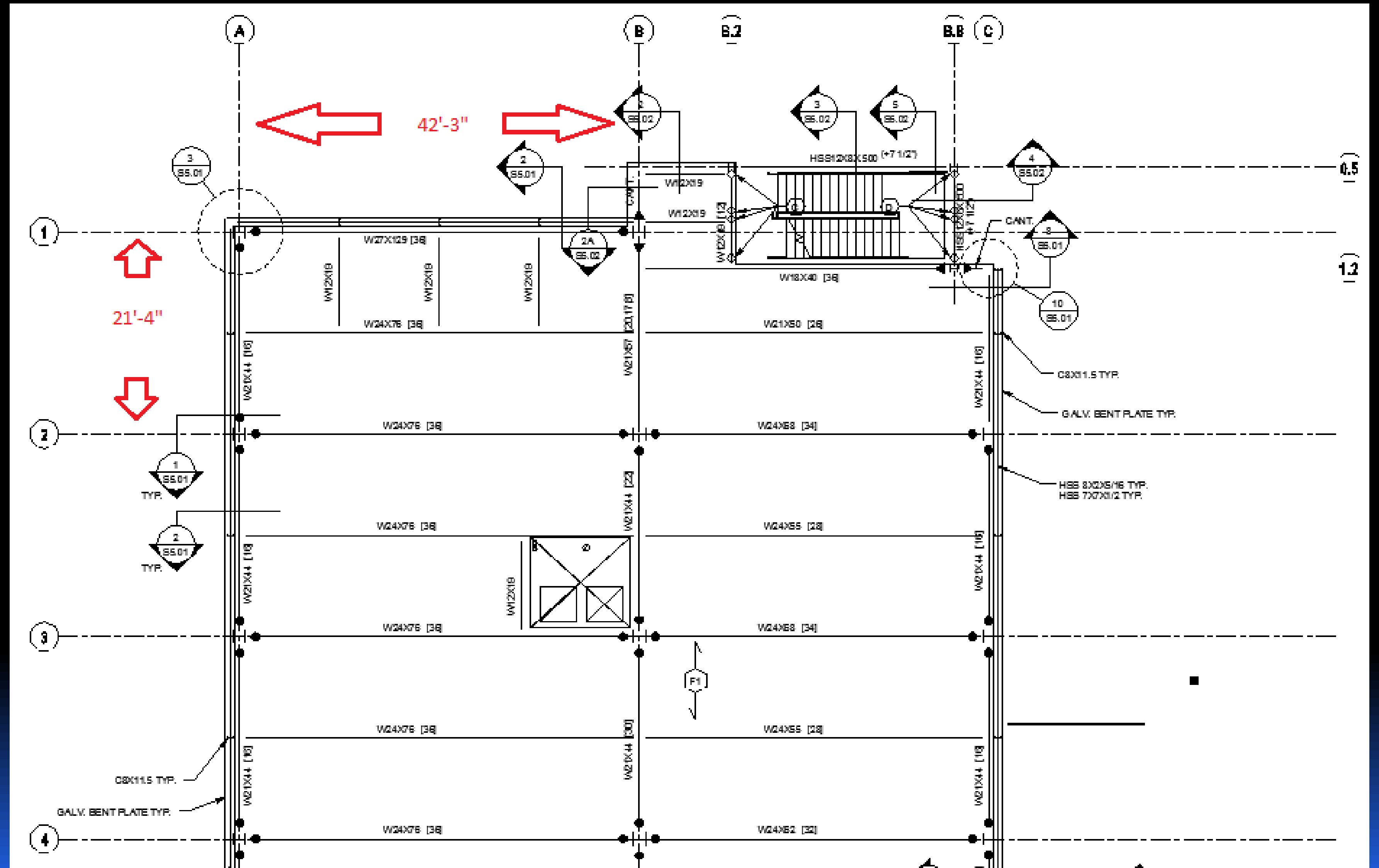


Wing B



Existing Structural System

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth



- 3” roof deck with varying topping
- 3” composite floor deck with 4.5” topping
- W24 beams framing into W21 girders
- Beam spacing: 10’-8” on center
- Beam span: 42’-3”
- Girder span: 21’-4”
- LFRD: semi-rigid wind clips
- Columns: W14x90 up to W14x192
- Foundation: square footings

Depth Proposal

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth

Project Goals

- 1. Analyze the existing floor system for vibration resistance with AISC Design Guide 11
- 2. Redesign the floor to allow for 400x microscopes at moderate walking speeds
- 3. Redesign the lateral system with full moment frames and braced frames
- 4. Design a typical moment connection in detail
- 5. Design a typical braced connection in detail

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth

Floor Design

- Floor vibration criteria were incorporated in design
- Laboratory and research sections designed for sensitive equipment
- Establish what equipment exist in the laboratories
- Design the floor for specific equipment

Floor Design

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth

Owner	Building	Material	Criteria	Opening
Cornell	Nanotechnology Laboratory	RC	1000 $\mu in^2/s$	Fall 2003
Harvard	Institute of Medicine	SS	2000 $\mu in^2/s$	Summer 2005
MIT	Brain and Cognitive Science Center	SS	2000 $\mu in^2/s$	Spring 2005
Duke	Science Center	RC	2000 $\mu in^2/s$	Fall 2006
U. Chicago	Interdivisional Research Center	SS	750 $\mu in^2/s$	Summer 2005
U. Mass Worcester	Research Institute	SS	2000 $\mu in^2/s$	Fall 2000

Table 6.1
Vibration Criteria for Sensitive Equipment

Facility Equipment or Use	Vibrational Velocity*	
	(μ in./sec)	(μm/sec)
Computer systems; Operating Rooms**; Surgery; Bench microscopes at up to 100x magnification;	8,000	200
Laboratory robots	4,000	100
Bench microscopes at up to 400x magnification; Optical and other precision balances; Coordinate measuring machines; Metrology laboratories; Optical comparators; Microelectronics manufacturing equipment—Class A***	2,000	50
Micro surgery, eye surgery, neuro surgery; Bench microscopes at magnification greater than 400x; Optical equipment on isolation tables; Microelectronics manufacturing equipment—Class B***	1,000	25

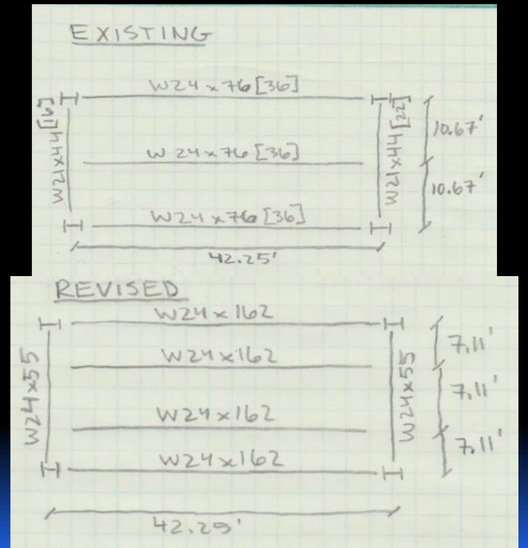
Upper image courtesy of E.M. Hines, Tufts University

Means & Methods

- AISC Design Guide 11: Floor Vibrations Due to Human Activity
- Chapter 6: Sensitive Equipment
- Based on natural frequency of floor
- Current floor allows for 100x magnitude microscopes at “slow walking”
- 2000 microinches/second was chosen as the design criterion at “moderate walking” pace

Floor Design

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth

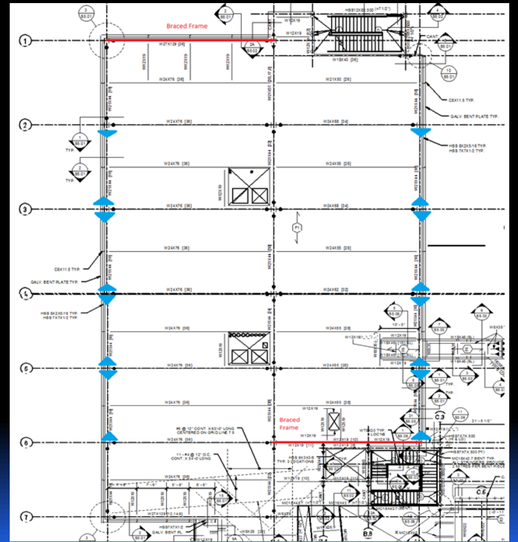


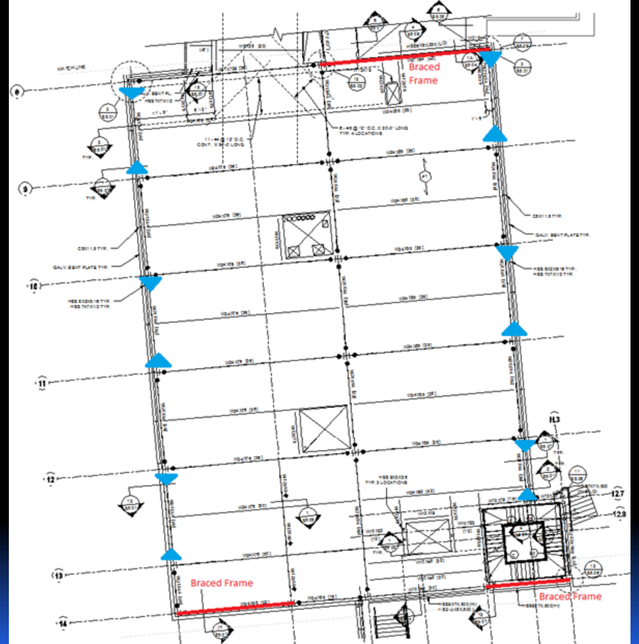
Impact of Redesign

- Beam spacing decreased from 10’-8” to 7’-11” on center
- Bay frequency rose from 3.7 to 5.3 Hz
  - Allows use of different equation
- Bay floor weight increased by 21 psf
  - Only in sensitive laboratories
- Floor depth could be increased
  - Move labs to one floor
- Columns could be moved to decrease span

Lateral System

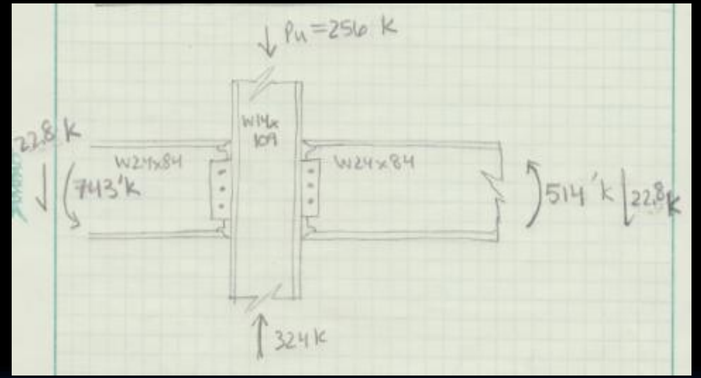
- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth





Moment Connection

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth

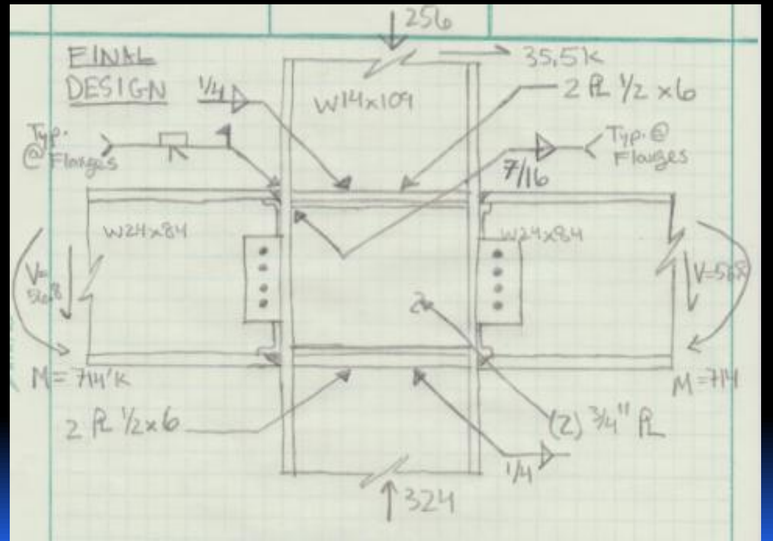


Means & Methods

- Wind clips in N/S direction replaced with full moment connections
- AISC 14th Edition and AE 534 notes
- 2 rows of 7 moment frames
- 1.2D + .5L + .5S + 1.6W
- Portal method to distribute loads
- Frame analyzed for lowest story

Moment Connection

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth

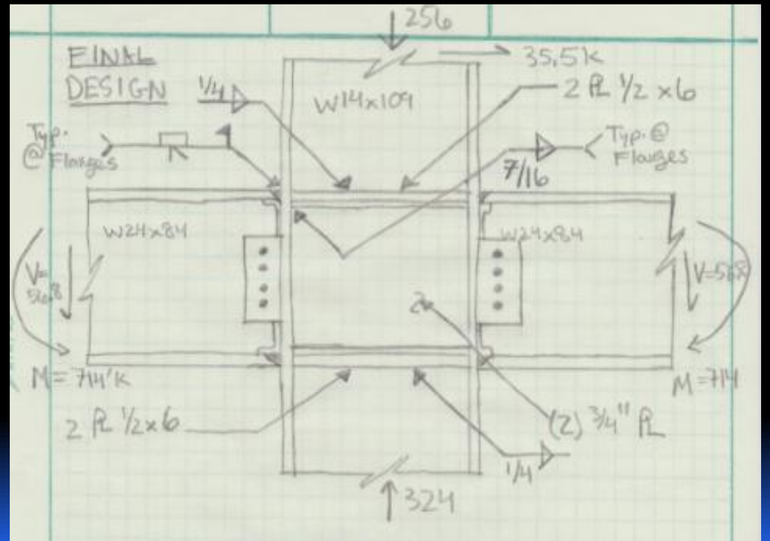


Details

- Flange Welded/ Web Bolted
- Flange Connection
  - Full penetration welds with backers
- Web Connection
  - 5/16” plate with (4) 3/4” A325-N bolts
- Column Reinforcement
  - Full depth 1/2” stiffeners required
  - (2) 3/4” doubler plates required

Moment Connection

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth

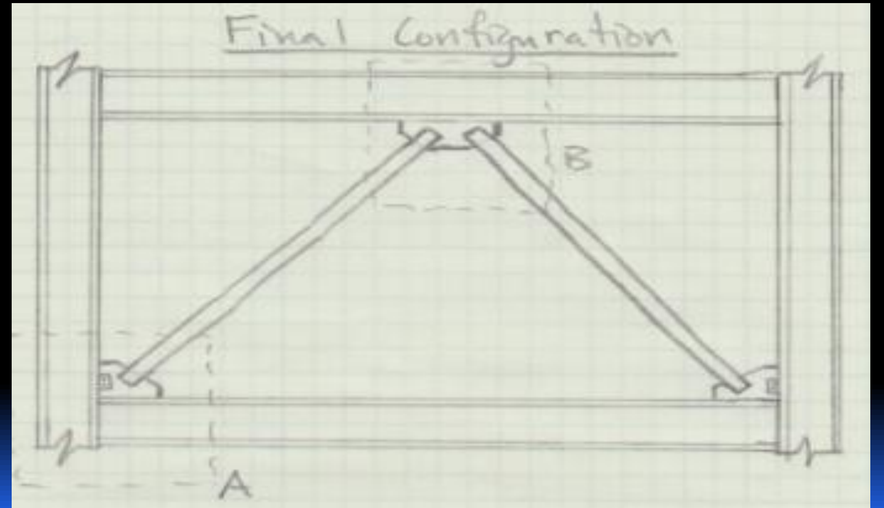


Impact of Redesign

- Number of moment connections reduced
- Field welds limited in connection
- Column stiffening can be prefabricated
- A stronger column could eliminate stiffeners and doubler plates

Braced Connection

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth

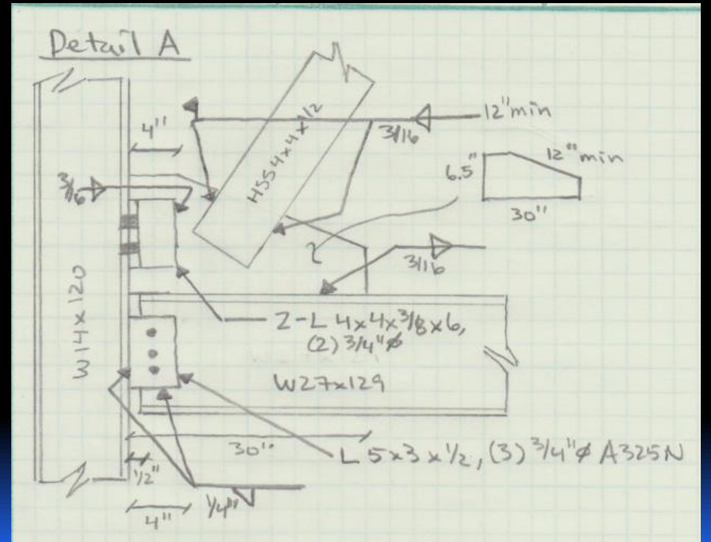


Means & Methods

- Wind clips in E/W direction to be replaced with 5 braced frames
- AISC 14th Edition and AE 534 notes
- 1.2D + .5L + .5S + 1.6W
- Concentric braces initially selected
- Eccentric braces chosen due to span
- HSS 4x4x1/2 selected as brace

Braced Connection

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth

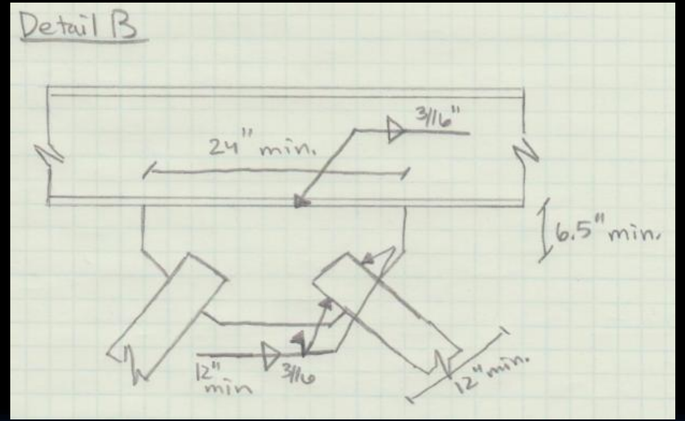


Corner Brace Connection

- 1/2” gusset plate with 30x6.5x12 dimensions
- HSS to Gusset: 3/16” field welds
- Gusset to Column: 2-L 4x4x3/8x6
  - 3/16” fillet welds to gusset
  - (2) 3/4” bolts to column
- Gusset to Beam: 3/16” fillet welds
- Beam to Column: L 5x3x1/2
  - 1/4” fillet weld to column
  - (3) 3/4” bolts to beam

Braced Connection

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth

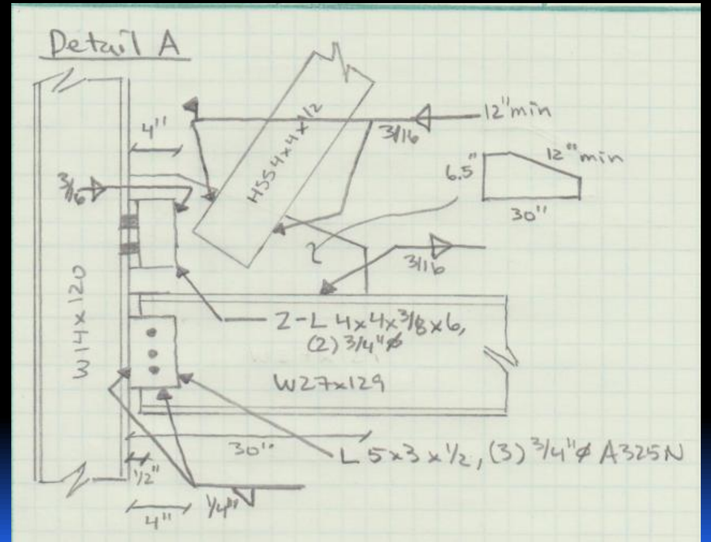


Center of Beam Connection

- 1/2” gusset plate with 24x6.5x12 dimensions on both sides
- HSS to Gusset: 3/16” field welds
  - 12” minimum length
- Gusset to Beam: 3/16” fillet welds
  - 24” minimum length

Braced Connection

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth

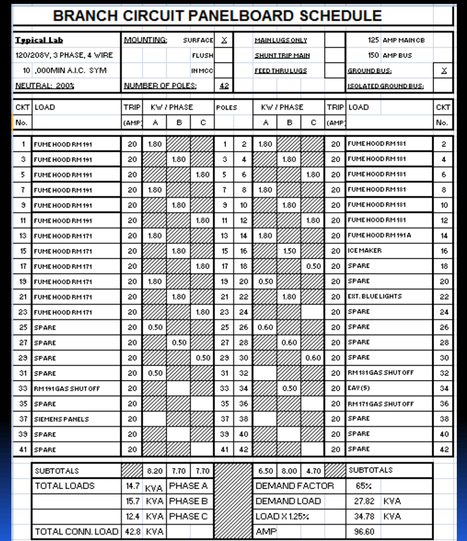


Impact of Redesign

- Wind clips were eliminated in the E/W direction of the building
- Field welds limited in connection
- Shorter brace spans could create more efficient braces
  - Would require adjusting interior columns
- Impact on lateral loads seen by foundations in these frames

Electrical Breadth

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth



BRANCH CIRCUIT PANELBOARD SCHEDULE

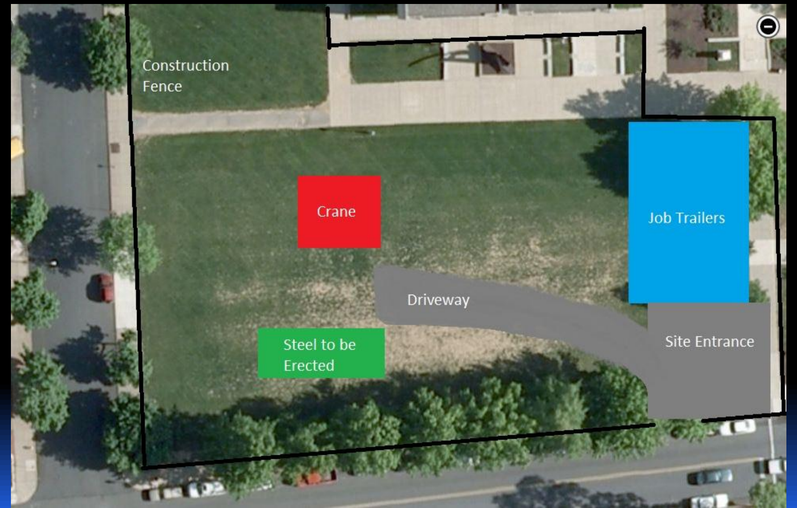
Typical Lab		MOUNTING:	SURFACE	X		MAIN LUGS ONLY			125 AMP MAIN CB										
120/208V, 3 PHASE, 4 WIRE			FLUSH			SHUNT TRIP MAIN			150 AMP BUS										
10 ,000MIN A.I.C. SYM			IN HOO			FEED THRU LUGS			GROUND BUS:			X							
NEUTRAL: 200%		NUMBER OF POLES:		42					ISOLATED GROUND BUS:										
CKT No.	LOAD	TRIP (AMP)	KW / PHASE A	B	C	POLES		KW / PHASE A	B	C	TRIP (AMP)	LOAD	CKT No.						
1	FUME HOOD RM 191	20	1.80			1	2	1.80			20	FUME HOOD RM 181	2						
3	FUME HOOD RM 191	20		1.80		3	4		1.80		20	FUME HOOD RM 181	4						
5	FUME HOOD RM 191	20			1.80	5	6			1.80	20	FUME HOOD RM 181	6						
7	FUME HOOD RM 191	20	1.80			7	8	1.80			20	FUME HOOD RM 181	8						
9	FUME HOOD RM 191	20		1.80		9	10		1.80		20	FUME HOOD RM 181	10						
11	FUME HOOD RM 191	20			1.80	11	12			1.80	20	FUME HOOD RM 181	12						
13	FUME HOOD RM 171	20	1.80			13	14	1.80			20	FUME HOOD RM 191A	14						
15	FUME HOOD RM 171	20		1.80		15	16		1.50		20	ICE MAKER	16						
17	FUME HOOD RM 171	20			1.80	17	18			0.50	20	SPARE	18						
19	FUME HOOD RM 171	20	1.80			19	20	0.50			20	SPARE	20						
21	FUME HOOD RM 171	20		1.80		21	22		1.80		20	EXT. BLUE LIGHTS	22						
23	FUME HOOD RM 171	20			1.80	23	24				20	SPARE	24						
25	SPARE	20	0.50			25	26	0.60			20	SPARE	26						
27	SPARE	20		0.50		27	28		0.60		20	SPARE	28						
29	SPARE	20			0.50	29	30			0.60	20	SPARE	30						
31	SPARE	20	0.50			31	32				20	RM 191 GAS SHUT OFF	32						
33	RM 191 GAS SHUT OFF	20				33	34		0.50		20	EAV (S)	34						
35	SPARE	20				35	36				20	RM 171 GAS SHUT OFF	36						
37	SIEMENS PANELS	20				37	38				20	SPARE	38						
39	SPARE	20				39	40				20	SPARE	40						
41	SPARE	20				41	42				20	SPARE	42						
	SUBTOTALS		8.20	7.70	7.70			6.50	6.00	4.70		SUBTOTALS							
	TOTAL LOADS	14.7	KVA	PHASE A				DEMAND FACTOR			65%								
		15.7	KVA	PHASE B				DEMAND LOAD			27.82	KVA							
		12.4	KVA	PHASE C				LOAD X 1.25%			34.78	KVA							
	TOTAL CONN. LOAD	42.8	KVA					AMP			96.60								

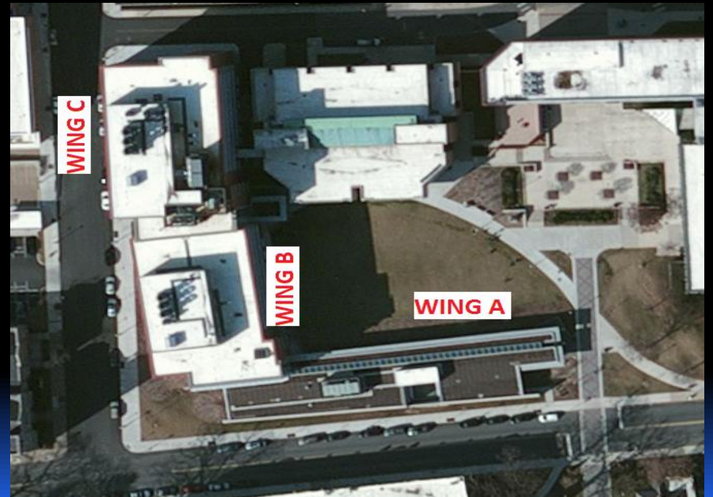
Electrical System Details

- 1500 KVA Service Transformer
- 480 / 277V 3-Phase 4-Wire Secondary Feed to 3000-amp Distribution Panel
- 2 - 150 KVA Emergency Generators
- 277V T8, T5 and Compact Fluorescent Light Sources with Ballasts

Construction Breadth

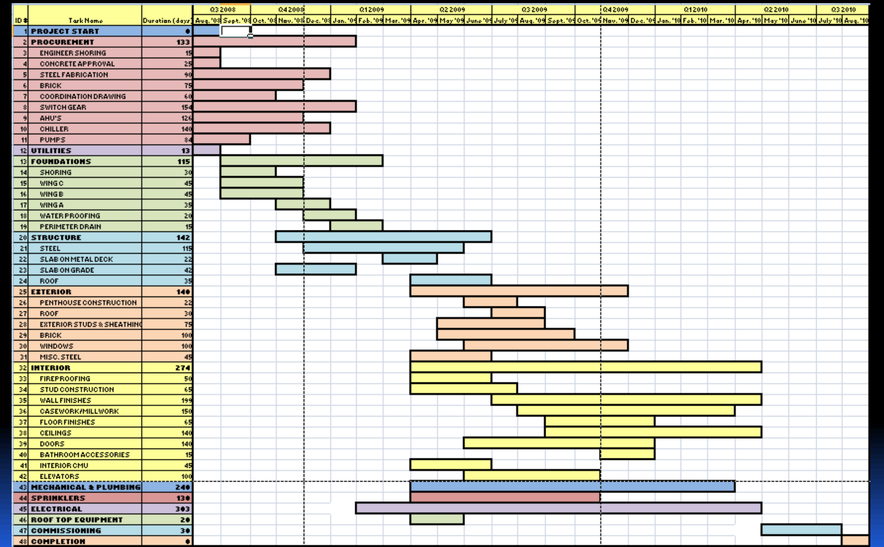
- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth





Construction Breadth

- Building Statistics
- Structural System
- Depth Proposal
  - Floor Design
  - Lateral System
  - Moment Connections
  - Braced Connections
- Electrical Breadth
- Construction Breadth



ID	Task Name	Duration (days)
1	PROJECT START	0
2	PROCUREMENT	133
3	ENGINEER SHORING	15
4	CONCRETE APPROVAL	28
5	STEEL FABRICATION	90
6	BRICK	75
7	COORDINATION DRAWING	60
8	SWITCH GEAR	154
9	AHU'S	126
10	CHILLER	140
11	PUMP'S	84
12	UTILITIES	13
13	FOUNDATIONS	115
14	SHORING	30
15	WING C	45
16	WING B	45
17	WING A	30
18	WATER PROOFING	20
19	PERIMETER DRAIN	15
20	STRUCTURE	142
21	STEEL	115
22	SLAB ON METAL DECK	22
23	SLAB ON GRADE	42
24	ROOF	35
25	EXTERIOR	148
26	PENTHOUSE CONSTRUCTION	22
27	ROOF	30
28	EXTERIOR STUDS & SHEATHIN	75
29	BRICK	100
30	WINDOWS	100
31	MISC. STEEL	45
32	INTERIOR	274
33	FIREPROOFING	50
34	STUD CONSTRUCTION	65
35	WALL FINISHES	199
36	CASEWORK/MILLWORK	150
37	FLOOR FINISHES	65
38	CEILINGS	140
39	DOORS	140
40	BATHROOM ACCESSORIES	15
41	INTERIOR CMU	45
42	ELEVATORS	100
43	MECHANICAL & PLUMBING	240
44	SPRINKLERS	130
45	ELECTRICAL	303
46	ROOF TOP EQUIPMENT	20
47	COMMISSIONING	30
48	COMPLETION	0

	Start	Finish
Project Start:	8/2008	
Utilities:	8/2008	8/2008
Foundations:	9/2008	2/2009
Superstructure:	11/2008	6/2009
Exterior:	4/2009	11/2009
Interior:	4/2009	4/2010
Mech./Plumbing:	4/2009	3/2010
Electrical:	1/2009	5/2010
Commissioning:	5/2010	7/2010
Completion:	8/2010	

Acknowledgements

- Advisors:
  - Dr. Linda Hanagan
  - Dr. Kevin Parfitt
- Contacts:
  - Ms. Patricia Chase – Lehigh University
  - Jeff Pritchford – CVM Engineering
  - Eric Holland – Alvin Butz
- Family: Father, Mother, and Sisters