SOHO

HIGH RISE

CONDOMINIUMS

A STUDY OF LIGHTWEIGHT CONCRETE CONSTRUCTION

JOSEPH MUGFORD THESIS PRESENTATION SPRING 2007

PENNSTATE

Location and Architecture

LOCATION AND ARCHITECTURE

> “This is a way to live at this time, in the poetry of the neighborhood. The emotion of architecture is linked to this harmony, to this relationship.”
> Jean Nouvel, Architect

SOHO, NY,NY

- Trendy urban Neighborhood of Downtown Manhattan
- Simple geometric shapes create areas of transparency, light and shadow
- Sleek horizontal and vertical lines provide a rigid architectural grid for the building façade, a combination of colored and transparent glass

LOCATION AND ARCHITECTURE

15 Story Condominium Complex

Height: 175′

Base: 70′ X 200′

Tower: 33′ X 170′

Sub-Cellar Parking

Cellar Fitness and Spa

1st Floor Retail

10,000 SF

2-5: 27 Residential Units

11,800 SF/Floor

6-12: 13 Residential Units

4,650 SF/Floor

12-13: 2 Penthouse Units

6th Floor Roof Terrace

Project Team

Owner: WXIV/Broadway Grand

Architect of Record: SLCE Architects

Design Architect: AJN Ateliers Jean Nouvel

Structural Engineers: Gilsanz.Murray.Steficek.LLP

MEP Engineers: Cosentini Associates

Curtain Wall Consultants: Gilsanz.Murray.Steficek.LLP

Landscape Architect: Thomas Balsley Associates

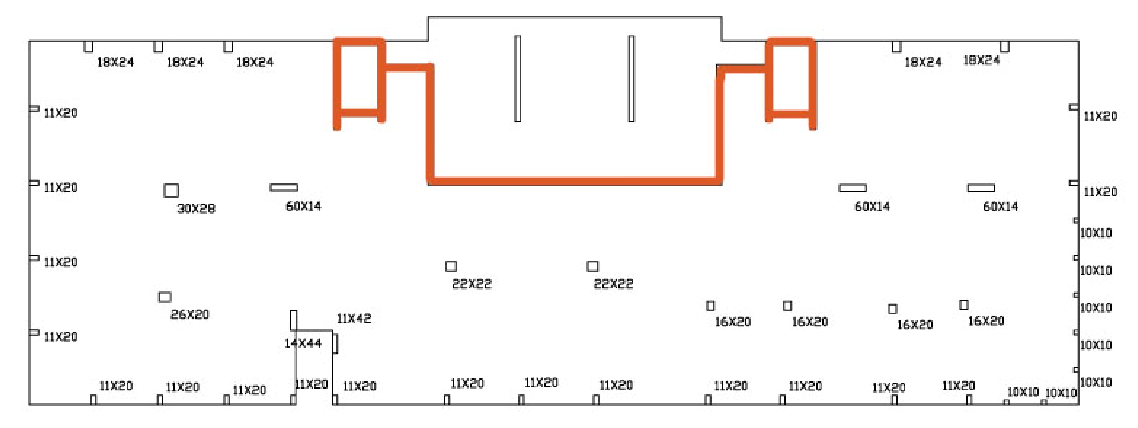
Lighting Consultant: Johnson Schwinghammer Inc.

General Contractor: Pavarini Construction Co. Inc.

Existing Structure

EXISTING STRUCTURE

Floor Plans



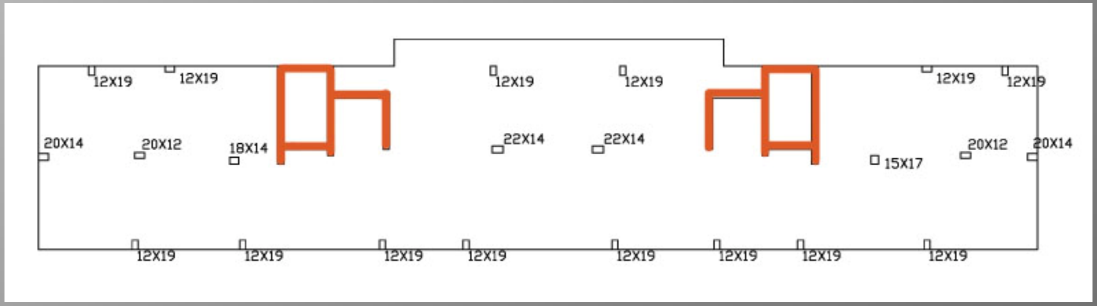
10 ½" Flat Plate

Uniform Steel

#4 @12" o.c. bot. ea. way

#5@16" o.c. top ea. Way

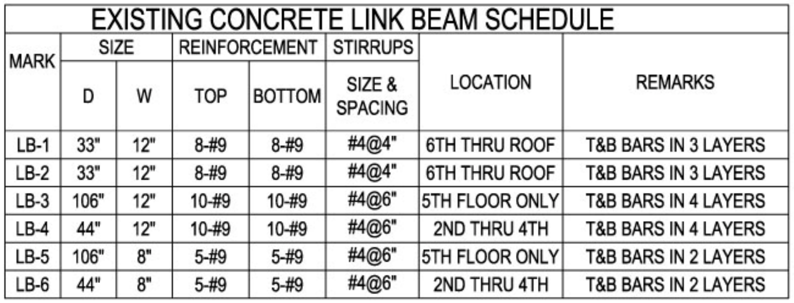
Significant additional steel at column locations



EXISTING STRUCTURE

Lateral System

Base Thru 5th



EXISTING CONCRETE LINK BEAM SCHEDULE

MARK	SIZE		REINFORCEMENT		STIRRUPS	LOCATION	REMARKS
	D	W	TOP	BOTTOM	SIZE & SPACING		
LB-1	33"	12"	8-#9	8-#9	#4@4"	6TH THRU ROOF	T&B BARS IN 3 LAYERS
LB-2	33"	12"	8-#9	8-#9	#4@4"	6TH THRU ROOF	T&B BARS IN 3 LAYERS
LB-3	106"	12"	10-#9	10-#9	#4@6"	5TH FLOOR ONLY	T&B BARS IN 4 LAYERS
LB-4	44"	12"	10-#9	10-#9	#4@6"	2ND THRU 4TH	T&B BARS IN 4 LAYERS
LB-5	106"	8"	5-#9	5-#9	#4@6"	5TH FLOOR ONLY	T&B BARS IN 2 LAYERS
LB-6	44"	8"	5-#9	5-#9	#4@6"	2ND THRU 4TH	T&B BARS IN 2 LAYERS

6th Thru 13th

Structural Depth

STRUCTURAL DEPTH

LWC FLAT PLATE DESIGN GOALS & STRATEGY

Minimize usage of structural materials to offset the premium of LWC

Reduce Slab Thickness

1. Deflection equations derived by R.I. Gilbert
2. Add edge beams at building corners to support reduced slab

Re-Design Shear Wall Core

1. Elements that are more efficient in bending
   - Offset reduced gravity loads
2. Uniform Cross section throughout height of building
   - Consistent formwork
   - Efficient load path with limited number of vertical discontinuities

STRUCTURAL DEPTH

Materials

	Existing System	New System
Floor Slabs		
	4 ksi NWC	4 ksi LWC
Shear Walls		
	5 ksi NWC	5 ksi NWC

Structural Depth

Flat Plate

STRUCTURAL DEPTH

LWC vs. NWC

BENEFITS

- Better acoustical performance
- Better thermal properties
- Higher fire resistance
- Reduced autogeneous shrinkage
- Improved contact zone between aggregate and concrete matrix
- less micro-cracking as a result of better elastic compatibility
- Higher blast resistance
- Recycled additatives (fly ash, etc.)
- SIGNIFICANT WEIGHT REDUCTION

-"Structural Lightweight Concrete"
Expanded Shale Clay and Slate Institute

COSTS

- $20-30/ Cu. YD premium
- compressive strengths exceeding 4 ksi not available
- Alternative design and detailing to NWC

STRUCTURAL DEPTH

DEFLECTION RESEARCH AND APPLICATION

Gilbert-85

- Modification of Branson Beam Equation

*sustained loading
includes 50% live load

$$\frac{l}{d} \le \overset{1.3}{K_1}\overset{1.0}{K_2}\overset{1.0}{K_3}\left[\frac{\Delta}{l}\left(\frac{\overset{15\sqrt{\rho n}}{\alpha} b_{eff} E_c}{k\left(w_v + \underset{2.0-1.2A_s'/A_s}{c} w_s\right)}\right)\right]^{0.33}$$

= 9” Slab Depth

K_1 = Support Factor
K_2 = Shape Factor
K_3 = Slab System Factor
Δ = Maximum Deflection
α = Effect of ρ and n

b_{eff} = Effective Width
E_c = Modulus of Elasticity
k = Load Fraction Carried by Equivalent Beam
w_v = Variable Load
w_s = Sustained Load
c = Long Term Deflection Modification

STRUCTURAL DEPTH

DEFLECTION RESEARCH AND APPLICATION

Gilbert-99

- Modification of current ACI deflection equation
  - β accounts for tension cracking resulting from shrinkage and long term loading
  - Computed deflection multiplied by λ per ACI 318 *(2.0 for long term loading)*

$$I_e = \beta\left(\frac{M_{cr}}{M_a}\right)^3 I_g + \left[1-\beta\left(\frac{M_{cr}}{M_a}\right)^3\right] I_{cr} \le I_g$$

0.4 (long term loading)

$= \ell\,/390$

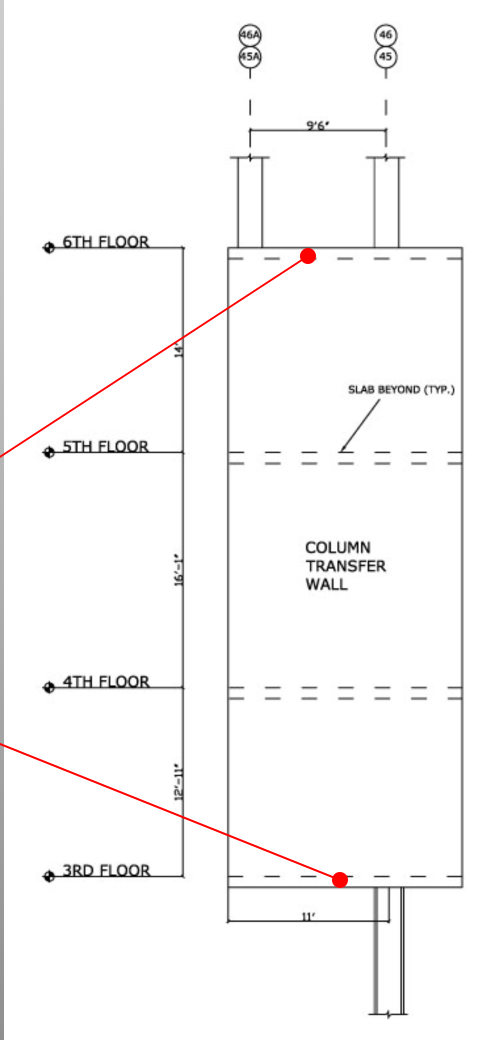
STRUCTURAL DEPTH

COLUMN TRANSFER

Transfer Forces

Moment=$5434'^{k}$

Shear=253^{k}



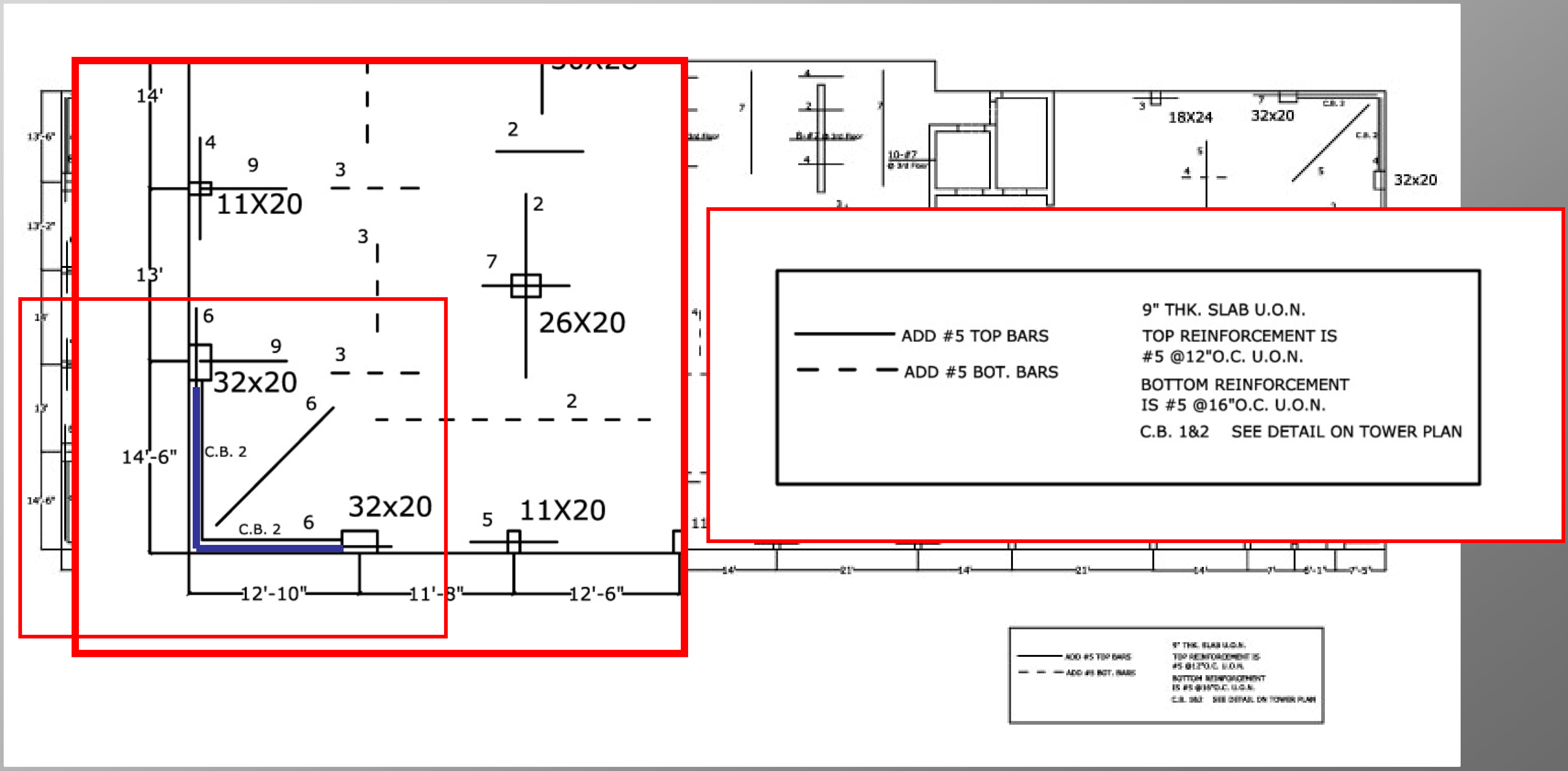
Shear Transfer Reinforcement

8-#7 @ Transfer walls

10-#7 @ Shear walls

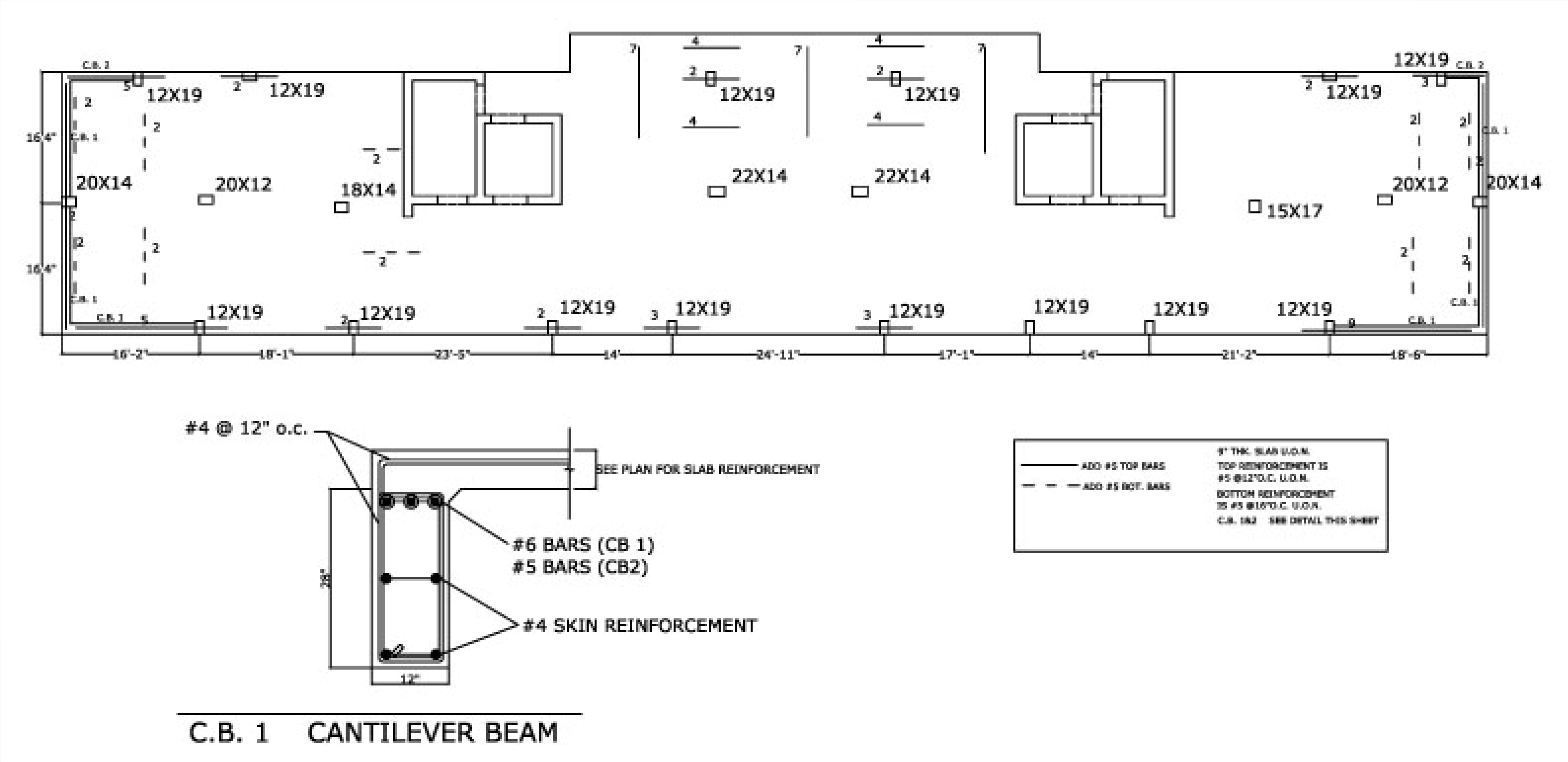
STRUCTURAL DEPTH

LWC FLAT PLATE DESIGN



STRUCTURAL DEPTH

LWC FLAT PLATE DESIGN



C.B. 1 CANTILEVER BEAM

STRUCTURAL DEPTH

LWC FLAT PLATE DESIGN

Equivalent Frame Method

Design Slab depth=9”

Uniform Reinforcement

#5@16” o.c. bottom ea. way

#5@12” o.c. top ea. way

Cantilever Beams

12X28 cantilever beams at building corners
Corner columns increase to 20 x 32 @ Base

Column Transfer

Additional 8-#7 @Gravity Wall
Additional 10-#7 @Shear Wall

Structural Depth

Lateral System

STRUCTURAL DEPTH

SHEAR WALL DESIGN CRITERIA

Lateral forces

Wind

ASCE 7-05 Method 2

Earthquake

ASCE 7-05 Equivalent Lateral Force Procedure (ELF)

Dynamic analysis (ETABS)

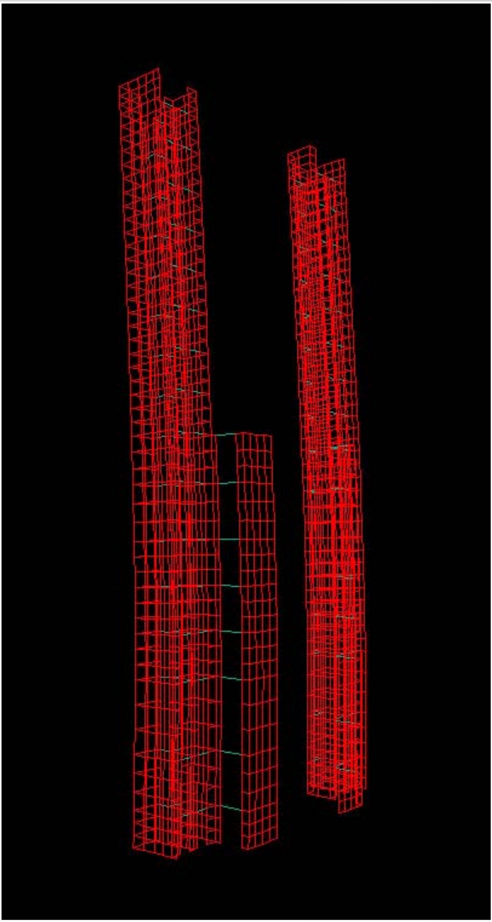
Shear From Column Transfer

Deflection

Total Building Drift H/500 (Wind)

Total Building Drift H/400 (Seismic)

STRUCTURAL DEPTH



N-S Wind Controls

Level	Load (k)		Shear (k)		Moment (ft-k)	
	N/S	E/W	N/S	E/W	N/S	E/W
Roof	26	5	0	0	4,348	846
12	48	9	26	5	7,455	1,443
11	45	9	75	15	6,382	1,235
10	44	9	120	23	5,712	1,101
9	43	8	165	32	5,038	965
8	43	8	208	40	4,521	866
7	42	8	251	48	3,890	740
6	64	10	293	56	5,200	840
5	79	25	357	67	5,426	1,736
4	79	25	436	92	4,354	1,384
3	61	19	515	117	2,381	745
2	59	18	577	136	1,524	471
1	66	20	636	155	853	256
Totals	702	174	702	174	57,083	12,626

STRUCTURAL DEPTH

E-W Seismic Controls

Modal (Dynamic) Analysis

- Response Spectrum

IBC 2000 Function scaled to NYC S_{DS} &S_{D1}

- Base Shear=386 K (ELF)
- R=4 (Normally Reinforced Shear Walls)

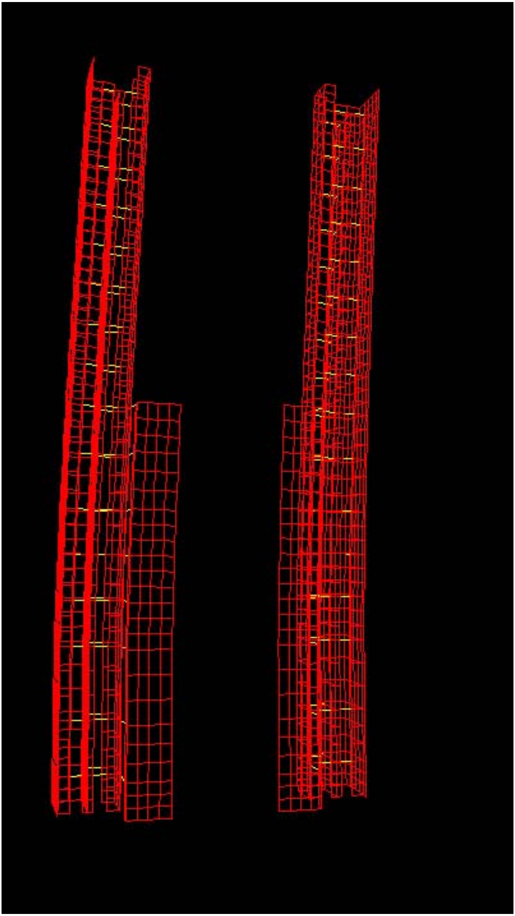
Element Stiffness

modified to account for cracking of concrete and force distribution

Walls=0.7Ig (uncracked)

Coupling Beams=0.35Ig

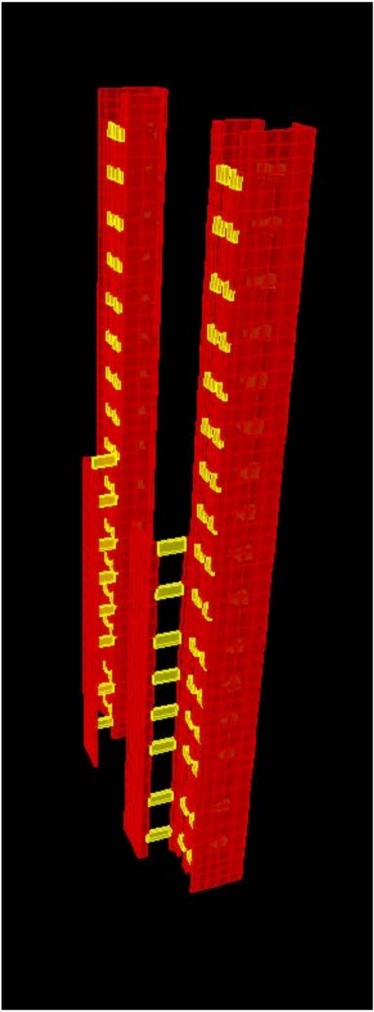
T=2.06s



STRUCTURAL DEPTH

Story Displacements

Story	Load	ΔX	ΔY
BH 2	WINDX	0.75	0.00
BH 2	Quake X	3.03	0.13
BH 2	WINDY	0.08	4.04
BH 2	QUAKE Y	0.07	3.50
BH 1	WINDX	0.75	-0.01
BH 1	Quake X	3.03	-0.16
BH 1	WINDY	0.08	3.48
BH 1	QUAKE Y	0.07	2.98
ROOF	WINDX	0.71	0.00
ROOF	Quake X	2.84	0.02
ROOF	WINDY	0.02	3.60
ROOF	QUAKE Y	0.02	3.10
STORY 13	WINDX	0.66	0.00
STORY 13	Quake X	2.62	0.00
STORY 13	WINDY	0.02	3.25
STORY 13	QUAKE Y	0.02	2.79
STORY 12	WINDX	0.60	0.00
STORY 12	Quake X	2.36	0.00
STORY 12	WINDY	0.02	2.90
STORY 12	QUAKE Y	0.01	2.47
STORY 11	WINDX	0.54	0.00
STORY 11	Quake X	2.12	0.00
STORY 11	WINDY	0.01	2.57
STORY 11	QUAKE Y	0.01	2.17
STORY10	WINDX	0.49	0.00
STORY10	Quake X	1.87	0.00
STORY10	WINDY	0.01	2.25
STORY10	QUAKE Y	0.01	1.88
STORY 9	WINDX	0.43	0.00
STORY 9	Quake X	1.62	0.00
STORY 9	WINDY	0.01	1.93
STORY 9	QUAKE Y	0.01	1.60
STORY 8	WINDX	0.37	0.00
STORY 8	Quake X	1.37	0.00
STORY 8	WINDY	0.01	1.62
STORY 8	QUAKE Y	0.01	1.32
STORY 7	WINDX	0.32	0.00
STORY 7	Quake X	1.14	0.00
STORY 7	WINDY	0.01	1.32
STORY 7	QUAKE Y	0.01	1.07
STORY 6	WINDX	0.26	0.00
STORY 6	Quake X	0.89	0.00
STORY 6	WINDY	-0.04	1.04
STORY 6	QUAKE Y	-0.03	0.83
STORY 5	WINDX	0.20	0.00
STORY 5	Quake X	0.65	0.00
STORY 5	WINDY	-0.03	0.74
STORY 5	QUAKE Y	-0.02	0.59
STORY 4	WINDX	0.13	0.00
STORY 4	Quake X	0.40	0.00
STORY 4	WINDY	-0.02	0.45
STORY 4	QUAKE Y	-0.01	0.35
STORY 3	WINDX	0.07	0.00
STORY 3	Quake X	0.23	0.00
STORY 3	WINDY	-0.01	0.25
STORY 3	QUAKE Y	-0.01	0.19
STORY 2	WINDX	0.03	0.00
STORY 2	Quake X	0.09	0.00
STORY 2	WINDY	0.00	0.10
STORY 2	QUAKE Y	0.00	0.07



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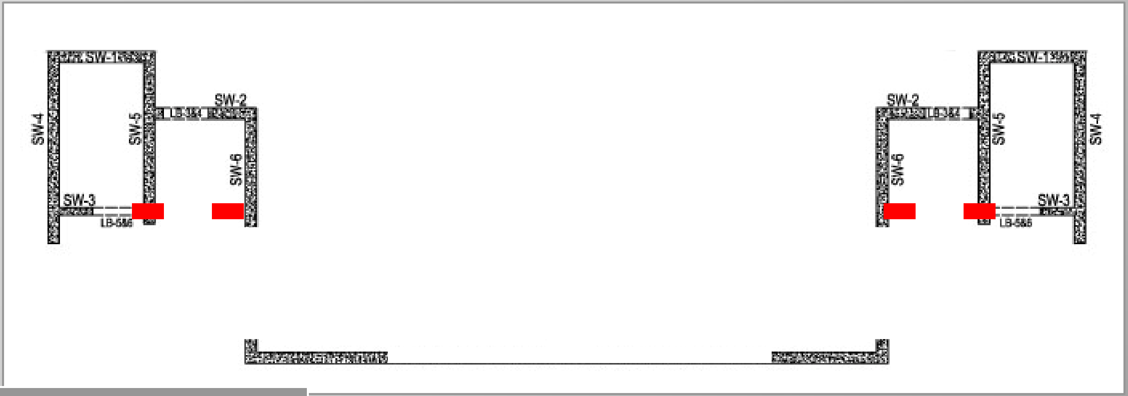
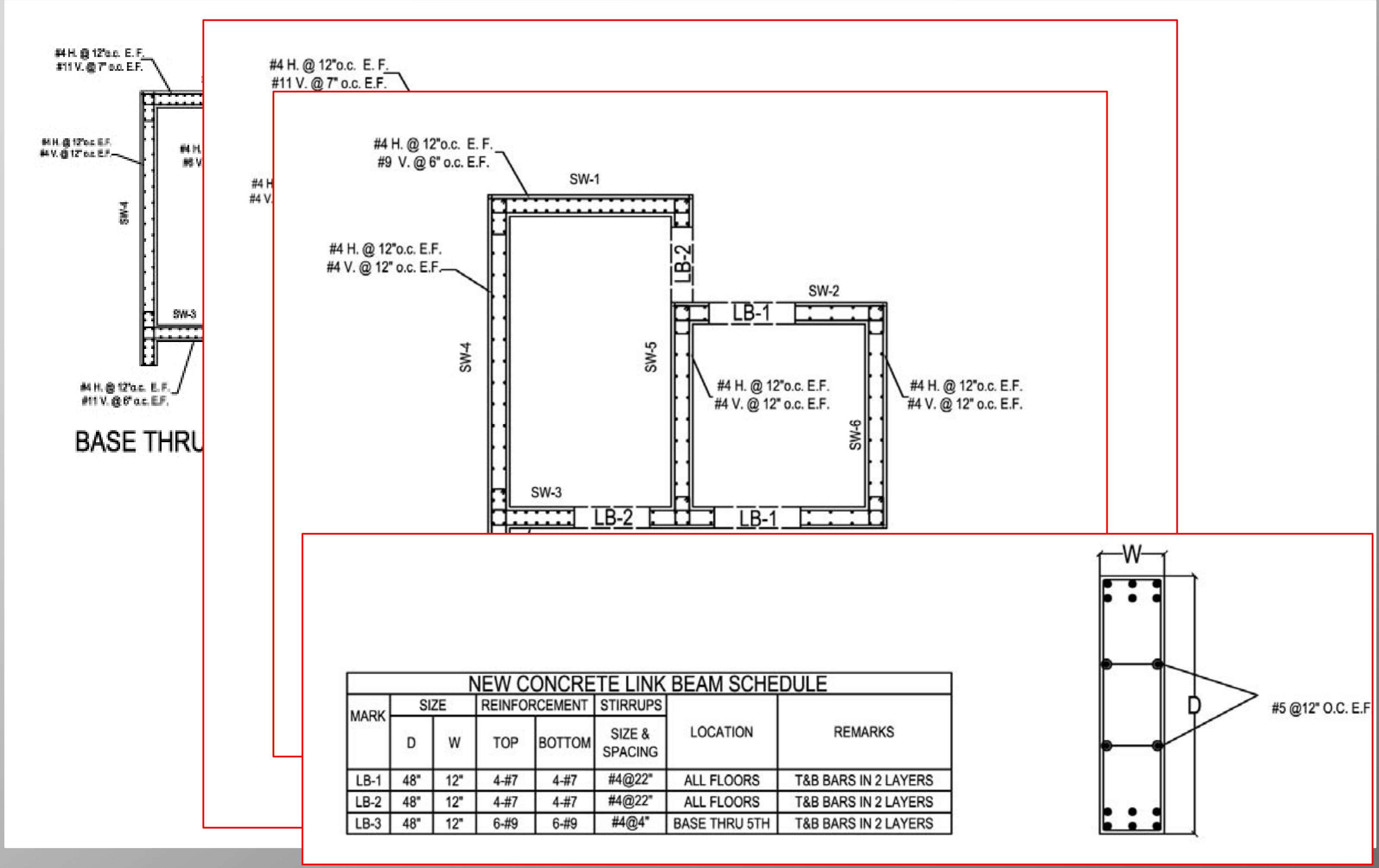


Base Thru 5th

Lateral
System
Modification

6th Thru 13th

STRUCTURAL DEPTH



NEW CONCRETE LINK BEAM SCHEDULE

MARK	SIZE		REINFORCEMENT		STIRRUPS	LOCATION	REMARKS
	D	W	TOP	BOTTOM	SIZE & SPACING		
LB-1	48"	12"	4-#7	4-#7	#4@22"	ALL FLOORS	T&B BARS IN 2 LAYERS
LB-2	48"	12"	4-#7	4-#7	#4@22"	ALL FLOORS	T&B BARS IN 2 LAYERS
LB-3	48"	12"	6-#9	6-#9	#4@4"	BASE THRU 5TH	T&B BARS IN 2 LAYERS

LEED Breadth

LEED Breadth

> *"A green building is one whose construction and lifetime of operation assure the healthiest possible environment while representing the most efficient and least disruptive use of land, water, energy and resources. The optimum design solution is one that effectively emulates all of the natural systems and conditions of the pre-developed site – after development is complete."*
>
> *-Zeigler*

Design Goal

Gain LEED Certification of the SOHO High Rise (Implement 26/69 LEED Criteria):

- Acknowledge criteria already met
- Identify additional suitable criteria and associated costs

LEED Breadth

Water Efficiency

Water Efficency Worksheet	Daily Uses	Flow Rate	Duration	Residents	Water Use
Flush Fixture		(GPF)	(Flushes)		(GPD)
Conventional Water Closet (M & F)	3	1.6	1	132	634
Low Flush Water Closet (M & F)	3	1	1	132	396
Flow Fixture		(GPM)	(Sec)		
Conventional Lavoratory	3	2.5	12	132	198
Conventional Kitchen Sink	1	2.5	12	132	66
Conventional Shower	1	2.5	180	132	990
Laminar Flow Lavoratory	3	1.8	12	132	143
Laminar Flow Kitchen Sink	1	1.8	12	132	48
Laminar Flow Shower	1	1.8	180	132	713
			Convemtional Water Use		1888
			Efficent Water Use		1299
Assumptions				%reduction	31
3 occupants per condominium					
44 Total Condominiums					

LEED BREADTH

Associated Costs

Credit	LEED Credits	Costs
Sustainable Site		
1-Site Selection	1	$0
2-Development Density	1	$0
4.1-Alternative Transportation- Public Transportation	1	$0
4.2-Alternative Transportation-Bicylce Storage	1	$505/rack
7.1-Heat Island Effect (Non-Roof)	1	$0
Water Efficency		
3.1-Reduced Water Usage- 20%	1	$0
3.2-Reduced Water Usage-30%	1	$1,500
Energy and Atmosphere		
1-Increase Energy Performance (15%)	1	$0
3-Additional Commissioning	1	1-5% Building
4-HCFC and Halon free	1	Significant
Materials and Resources		
2.1-Construction Waste Management, Divert 50% from Disposal	1	$25/TON
4.1-Recycled Content, 10% (post-consumer + ½ pre-consumer)	1	$0
5.1-Regional Materials, 20% Extracted, Processed & Manufactured Regionally	1	$0
7-Certified Wood	1	$0
Indoor Environmental Quality		
3.1-Construction IAQ Management Plan, During Construction	1	Varies
3.2-Construction IAQ Management Plan, Before Occupancy	1	Varies
4.1-Low-Emitting Materials, Adhesives & Sealants	1	$0
4.2-Low-Emitting Materials, Paints & Coatings	1	$0
4.3-Low-Emitting Materials, Carpet Systems	1	$0
4.4-Low-Emitting Materials, Composite Wood & Agrifiber Products	1	$0
5-Indoor Chemical & Pollutant Source Control	1	Minimal
7.1-Thermal Comfort, Design	1	$0
7.2-Thermal Comfort, Permanent monitoring system	1	$0
8.1-Daylight & Views, Daylight 75% of Spaces	1	$0
8.2-Daylight & Views, Views for 90% of Spaces	1	$0
LEED Certified Proffessional	1	
Credits Attained	26	

Conclusions and Recommendations

CONCLUSIONS AND RECOMMENDATIONS

			Existing Cost	Redesign Cost	Comparison
Flat Plate	Base	Concrete	$228,165	$232,875	$4,710
		Rebar	$283,700	$259,780	$23,921
		Cantilevers	$0	$33,198	$33,198
	Tower	Concrete	$140,175	$143,125	$2,950
		Rebar	$174,335	$159,615	$14,720
		Cantilevers	$0	$53,116	$53,116
Shear Walls					
	Walls	Concrete	$109,984	$121,072	$11,088
		Rebar	$64,455	$119,472	$55,016
	Coupling Beams				
			$92,039	$77,428	$14,611
		Cost Increase			$106,826

Structural

- 13-18% Reduction of Column Service Loads ~4500K
- 8-10% Reduction in Slab Reinforcement
- 19 ½" Total Height Reduction
- 25% Reduction of Seismic Base Shear
  - Applicable to high seismic regions
- Uniformity of shear wall system
  - Predictable lateral response
  - Consistent formwork

*Does not include possible column cross section reduction

Architectural

- Elimination of shear wall section provides for architecturally free floor plan
- Lower gravity loads may increase sellable floor area by reducing column cross sections

CONCLUSIONS AND RECOMMENDATIONS

LEED

It should be the goal of developers and designers to implement design solutions that not only provide low first cost, but also improve the world and environments we live in.

Implement additional LEED criteria that benefit occupants and meet allowable development budget

Certification carries significant cost and schedule implications

Notable social status symbol

Questions?

AE Faculty

GMS.LLP

SLCE ARCHITECTS

FAMILY & FRIENDS

THANK YOU