Northside Piers – Brooklyn, NY
Structural System Redesign

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AE 482 – 5th Year Senior Thesis
Structural Option
April 15th, 2008

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Presentation Outline

- Intro
- Building Overview
- Redesign Goals
- Slab Design
- Shear Wall Design
- Construction Management
- Conclusions
- Acknowledgements
- Questions???

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Building Background – Location

Northside Piers - 4 North 5th Street, Brooklyn, NY

Manhattan

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Building Background - Architecture

- 29 Story Condominium Tower
- 176 units
- Two typical floor plans (7500SF and 6200SF)

- Glass Cladding System that allows for floor to ceiling views
- No drop ceiling over living spaces

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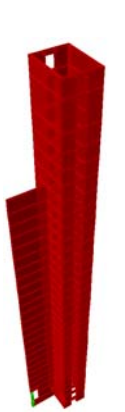
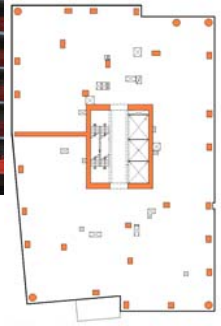
Building Background – Structural System





- Flat plate two-way mild reinforced slab
- Irregular Column Scheme
- Shear Walls around central core with additional wall

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Redesign Goals

Redesign Goals

- Make structure more cost effective
- Meet or improve serviceability of structure

Structural Elements Studied

- Floor Slab System - Mild reinforced vs. Post-Tensioned?
- Shear Wall System - More optimal layout?

Other Disciplines Considered

- Construction Management
- Acoustics
- Mechanical Exhaust Risers

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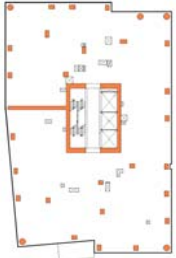
26^{rn}–Roof



3rd–25th Floor

Slab Design - Introduction

Slab Redesign Goals

- Make slab more cost effective
- Meet or improve serviceability of structure

Why Post-Tensioned System?

- No room for beams
- Tendons improve slab efficiency
- Tendons reduce deflections

Design Method

- RAM Concept with Post-Tensioned spreadsheets
- Must meet ACI318-05

Design Loads (Floor)

- 40psf Live
- 30psf Super

Design Loads (Balconies)

- 60psf Live
- 15psf Super

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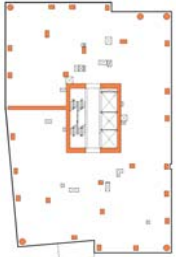
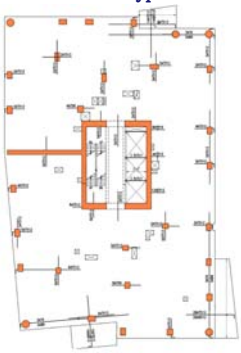


3rd–25th Floor

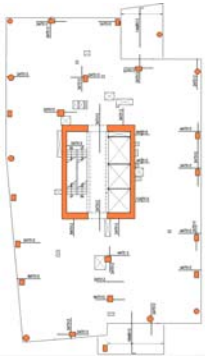
26rn–Roof

Slab Design – Current System

3rd–25th Floor Typical Slab



26th-Roof Typical Slab



- 8” Slabs with #5’s @ 12” o/c on Top and Bottom going both ways
- Additional bars added as shown on plan

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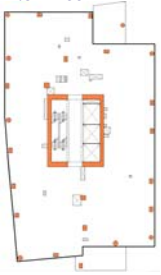
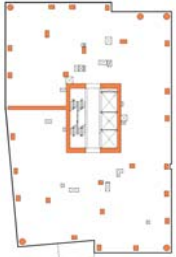


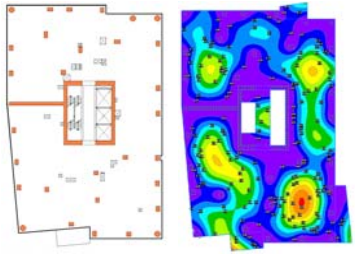
26rn–Roof



3rd–25th Floor

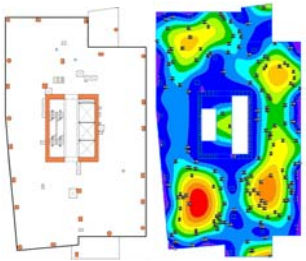
Slab Design – Current System

3rd–25th Floor Long-Term Deflection



Maximum Long-Term Deflection: 0.67”

26th-Roof Long-Term Deflection



Maximum Long-Term Deflection: 0.74”

ACI318 Limit (30’ Span): L/480 = 0.75”

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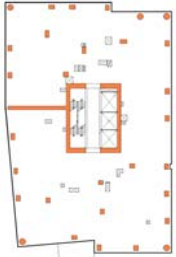
Slab Design – Post-Tensioned System

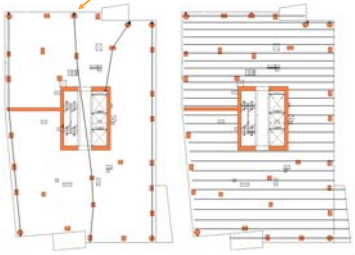
26^{rn}–Roof



3rd–25th Floor

3rd–25th Floor Tendon Plans

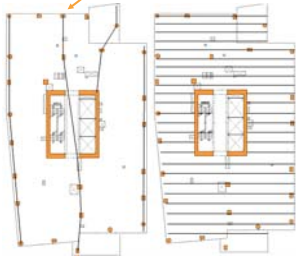
Column Shifted



Maximum Long-Term Deflection: 0.48”

26th-Roof Tendon Plans

Column Added



Maximum Long-Term Deflection: 0.49”

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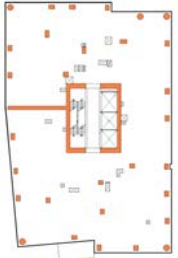
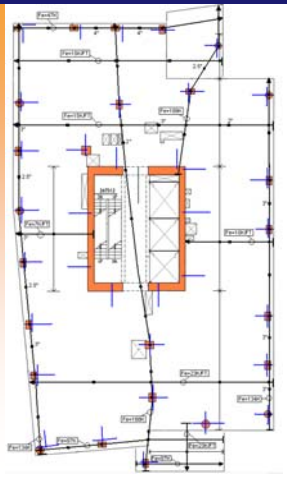


3rd–25th Floor

Slab Design – Post-Tensioned System



Tendon Stress

- 35% Banded tendon Load-Balancing Percentage
- 40% Uniform tendon Load-Balancing Percentage
- Maximum P/A of 320psi

Design Details

- 7” Slabs
- ½” Unbonded Tendons
- Typical Profile heights of 5.75” and 1.25”
- Typically #4 bars @ 24”o/c at bottom, both ways
- Top reinforcing at columns and walls

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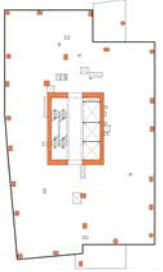
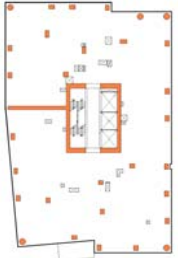


26th–Roof



3rd–25th Floor

Slab Design – Comparisons/Conclusions

Serviceability Comparison

- Maximum Long-Term Deflections reduced by about 30%
- Both slabs meet the IBC requirement for a 2-hr fire rating
- The difference in Sound Transmission Level is almost imperceptible (57-56)

Cost Comparison

Floor Slab Cost Comparison

	Original (3rd-25th)		PT (3rd-25th)		Original (26-Roof)		PT (26-Roof)	
	Amt.	Cost	Amt.	Cost	Amt.	Cost	Amt.	Cost
Concrete (CY)	185.2	$25,558	164	$22,632	153.1	$21,128	134	$18,492
Post-Tensioning (lbs)	0	$0	4,273	$6,367	0	$0	2,921	$4,352
Formwork (SFCA)	7,589	$33,088	7,589	$33,088	6,199	$27,028	6,199	$27,028
Formwork Edge (LF)	360	$839	360	$839	346	$806	346	$806
Mild Steel Reinforcing (ton)	17.85	$23,919	2.8	$3,752	14.94	$20,020	2.3	$3,082
Total		$83,404		$66,678		$68,982		$53,760
Cost/SF		$10.99		$8.79		$11.13		$8.67

- $36,000 will be saved if the story height is decreased by 1”

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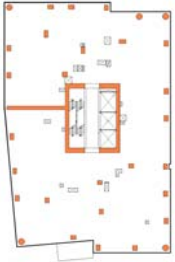
Original Shear Walls
Viewed from South West



3rd–25th Floor

Shear Wall Design - Introduction

Shearwall Redesign Goals

- Make shear walls more cost effective
- Meet or improve serviceability of structure

Design Method

- ETABS with shear wall spreadsheets
- Must meet ACI318-05

Lateral Loads

- Wind Loads were found from a wind tunnel test
- Wind produced base moments almost twice that of seismic

Serviceability Issues

- Story Drift must be less than L/600
- Building acceleration must be less than 15 milli-g

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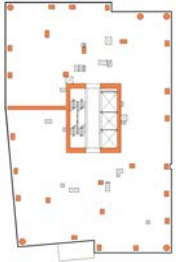
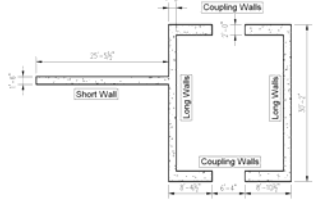


3rd–25th Floor

Shear Wall Design – Current Layout

Original Shear Walls
Viewed From South West

Original Shear Walls Plan



Design Information

- 8ksi concrete below 14th floor
- 6ksi concrete above 14th floor

Serviceability

- Total deflection: 3.80” (H/1004)
- Torsional deflection: 2.82 milli-rad
- Max story drift: H/759

Original Shear Walls
Viewed From North East

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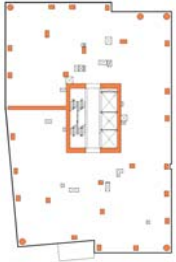
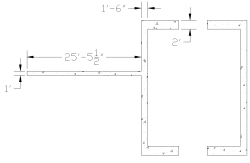


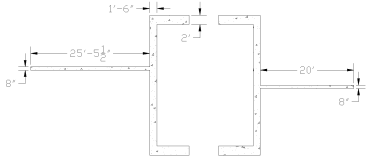
3rd–25th Floor

Shear Wall Design – Considered Layouts

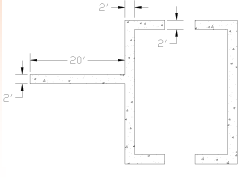
Modified Original



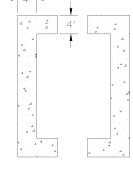
Additional Wall



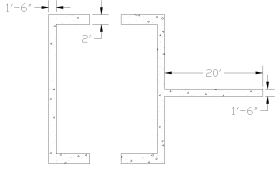
Shortened Wall



Core Only



Opposite Wall Only



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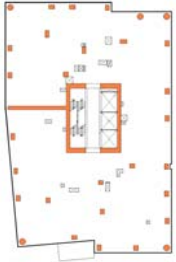

3rd–25th Floor

Shear Wall Design – Considered Layouts

Alternate Layouts Initial Estimate

	X Deflection (in)	Y Deflection (in)	Torsional Deflection (milli-rad)	Estimate Cost	Rank	Price Difference
Original	3.32	3.80	2.82	$24,463	4	$1,882
Modified Original	3.70	3.79	1.99	$23,555	2	$975
Core Only	3.29	2.08	1.54	$32,492	6	$9,911
Additional Wall	**3.37**	**3.82**	**2.83**	**$22,580**	**1**	**$0**
Shortened Wall	3.64	3.49	2.67	$27,661	5	$5,081
Opposite Wall Only	3.85	3.85	2.82	$24,070	3	$1,490

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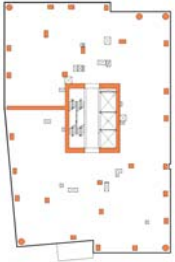
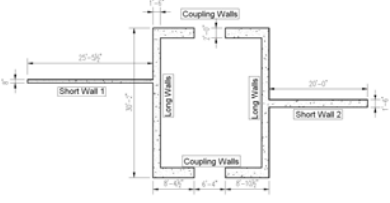


3rd–25th Floor

Shear Wall Design – Alternate Layout

Original Shear Walls
Viewed From South West

Original Shear Walls Plan



Serviceability

- Total deflection: 3.81” (H/1002)
- Torsional deflection: 2.49 milli-rad

Original Shear Walls
Viewed From North East

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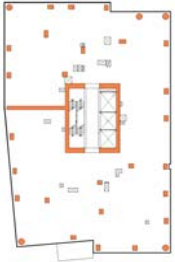

3rd–25th Floor

Shear Wall Design – Comparison/Conclusions

Serviceability Comparison

- New layout reduced torsional deflections by 12%
- Both layouts have equivalent total deflections and story drifts

Cost Comparison

Shear Wall Cost Comparison				
	Original Design		New Design	
	Amt.	Cost	Amt.	Cost
Total Rebar (ton)	126	$182,248	106	$151,369
Total Concrete (CY)	2183	$334,858	2113	$328,170
Total Formwork (SFCA)	62155	$121,202	66675	$130,016
Total		$638,308		$609,555

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Construction Management – Schedule Comparison

Schedule Comparison

Floor Schedule

	3rd-25th Floors		26th-Roof	
	Mild Reinforced	Post-Tensioned	Mild Reinforced	Post-Tensioned
Estimated Time Per Floor	22 Days	20 Days	18 Days	16 Days

Shear Wall Schedule

	Original Layout	New Layout
Estimated Total Time	110 days	107 days

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Construction Management – Schedule Comparison

Schedule Comparison

Shear Wall Schedule By Floor						
	Bottom Floor		12th Floor		Top Floor	
	Original	New	Original	New	Original	New
Estimated Time Per Floor	4 days	5 days	3 days	3 days	2 days	2 days

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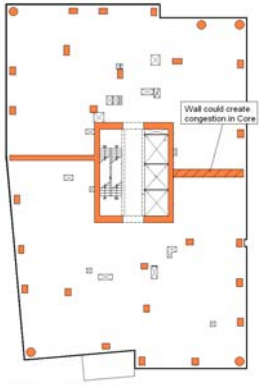
Construction Management – Construction Issues

Typical Floor Plan (Ground-11th Floor)



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- ❖ **Overall Conclusions**
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Overall Conclusions

	Serviceability Exceeded?		More Cost Effective?	
Post-Tensioned Slab	✓	30% less long term deflection	✓	20% Cheaper
New Shear Wall Layout	✓	12% less torsional deflection	✓	5% Cheaper

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Acknowledgements

Thanks to:

McLaren Engineering

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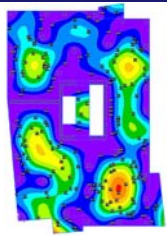
The entire AE Department Faculty and Staff

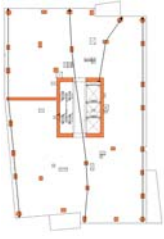
All of the practitioners who participated in the discussion boards

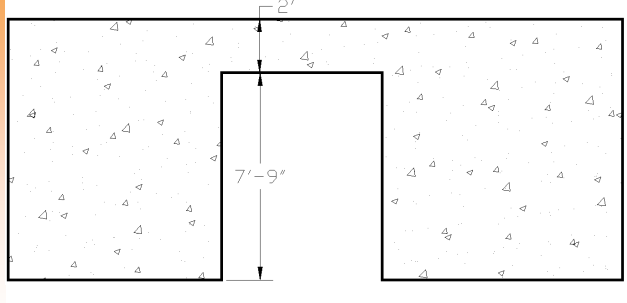
All my friends and family

The Class of 2008

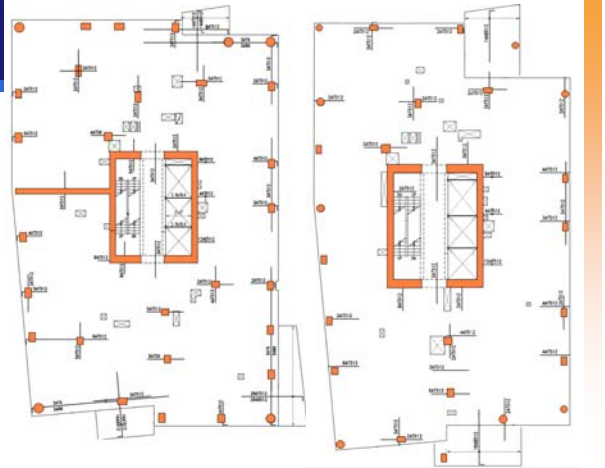


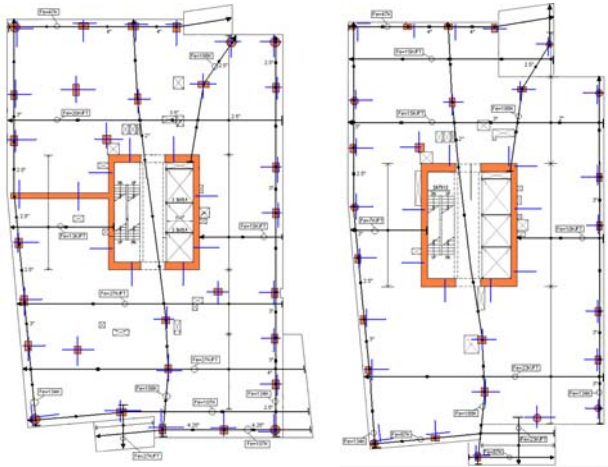
Any Questions???

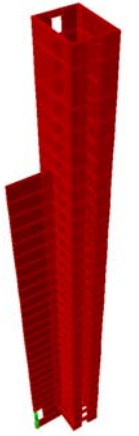




Existing Ceiling Link Beam Height:	7'-9"
Reduction due to thinner slab:	1"
Reduction for shear walls:	3"
Potential New Ceiling Link Beam Height:	7'-5"
New York City Limit:	7'-0" (Gives 5" for finishes)





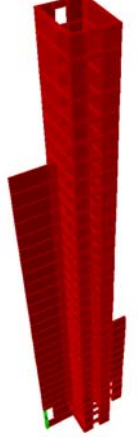


Original Wind Deflections

Floor	Floor Height (ft)	Story X Deflection (in)	Story Y Deflection (in)	Story Torsional Deflection (milli-rad)
Building Top	318	0.115	0.151	0.010
EMR FLOOR	304	0.210	0.271	0.020
ROOF	294	0.130	0.166	0.020
29	282	0.126	0.158	0.020
28	272	0.128	0.158	0.030
27	261	0.129	0.151	0.030
26	251	0.128	0.152	0.040
25	240	0.118	0.146	0.040
24	231	0.118	0.145	0.050
23	221	0.118	0.145	0.050
22	211	0.118	0.143	0.060
21	201	0.118	0.142	0.070
20	192	0.117	0.140	0.080
19	182	0.116	0.137	0.100
18	172	0.115	0.135	0.110
17	162	0.114	0.131	0.120
16	153	0.112	0.128	0.120
15	143	0.110	0.123	0.140
14	132	0.106	0.119	0.120
13	123	0.103	0.114	0.120
12	113	0.100	0.109	0.120
11	103	0.097	0.104	0.130
10	93	0.093	0.098	0.130
9	83	0.089	0.091	0.120
8	74	0.084	0.084	0.130
7	64	0.079	0.077	0.130
6	54	0.073	0.069	0.120
5	45	0.067	0.060	0.120
4	35	0.060	0.049	0.120
3	25	0.059	0.044	0.130
2	14	0.054	0.041	0.160
LOBBY	0	0.011	0.011	0.060
BASEMENT	-10			
Max Story Deflection		H/571	H/444	
Total Deflection		3.32"	3.80"	2.82 milli-rad
Total Deflection		H/1149	H/1004	

Original Rebar Plans

Floor	Short Wall	Long Walls	Coupled Walls
Building Top			
EMR FLOOR		#5	#6
ROOF		"	"
29		"	"
28		"	"
27		"	"
26		"	"
25	#5	"	"
24	"	"	"
23	"	"	"
22	"	"	"
21	"	"	"
20	"	"	"
19	"	"	"
18	"	"	"
17	"	"	#7
16	"	"	"
15	"	"	"
14	"	"	"
13	"	#6	"
12	"	"	"
11	"	"	"
10	#7	"	#9
9	"	#8	"
8	"	"	"
7	"	"	"
6	"	"	"
5	#9	"	#10
4	"	#10	"
3	"	"	"
2	#10	"	#11
LOBBY	"	"	"
	"	"	"
Shear Rebar	#5	#7	#6
Total Rebar (ft^3)	77	286	150
Total Concrete (ft^3)	9,750	27,825	24,110
Total Formwork (ft^2)	13,000	37,100	12,055



New Wind Deflections

Floor	Floor Height (ft)	Story X Deflection (in)	Story Y Deflection (in)	Story Torsional Deflection (milli-rad)
Building Top	318	0.116	0.151	0.000
EMR FLOOR	304	0.212	0.272	0.020
ROOF	294	0.131	0.166	0.010
29	282	0.127	0.159	0.020
28	272	0.128	0.159	0.020
27	261	0.129	0.155	0.030
26	251	0.129	0.155	0.030
25	240	0.119	0.146	0.040
24	231	0.119	0.146	0.040
23	221	0.119	0.145	0.040
22	211	0.118	0.143	0.050
21	201	0.118	0.142	0.060
20	192	0.117	0.140	0.070
19	182	0.116	0.137	0.090
18	172	0.114	0.135	0.100
17	162	0.111	0.132	0.100
16	153	0.108	0.128	0.110
15	143	0.112	0.133	0.120
14	132	0.099	0.119	0.110
13	123	0.094	0.114	0.110
12	113	0.089	0.111	0.110
11	103	0.077	0.105	0.110
10	93	0.072	0.097	0.110
9	83	0.069	0.091	0.110
8	74	0.066	0.084	0.110
7	64	0.062	0.076	0.110
6	54	0.057	0.068	0.120
5	45	0.052	0.059	0.100
4	35	0.046	0.049	0.110
3	25	0.045	0.042	0.120
2	14	0.048	0.041	0.150
LOBBY	0	0.012	0.011	0.060
Max Story Deflection		L/566	L/441	
Total Deflection		3.13"	3.81"	2.49 milli-rad
Total Deflection		L/1218	L/1002	

New Rebar Plans

Floor	Short Wall 1	Short Wall 2	Long Walls	Coupled Walls
Building Top				
EMR FLOOR			#5	#5
ROOF			"	"
29			"	"
28			"	"
27			"	"
26			"	"
25	#5		"	"
24	"		"	"
23	"		"	"
22	"		"	"
21	"		"	"
20	"		"	"
19	"		"	"
18	"		"	"
17	"		"	"
16	"		"	#7
15	"		"	"
14	#7		"	"
13	"		"	"
12	"		"	"
11	"	#6	"	"
10	"	"	"	#9
9	"	#8	"	"
8	"	"	"	"
7	"	#11	"	"
6	"	"	"	"
5	#9	"	"	#10
4	"	"	"	"
3	"	#14	"	"
2	#11	"	#7	#11
LOBBY	"	"	"	"
	-	-	-	-
Shear Rebar	#5	#5	#7	#6
Total Rebar (ft^3)	43	69	179	150
Total Concrete (ft^3)	4,333	3,390	27,825	24,290
Total Formwork (ft^2)	13,000	4,520	37,100	12,055