### Northside Piers – Brooklyn, NY Structural System Redesign



Jeremiah Ergas AE 482 – 5<sup>th</sup> Year Senior Thesis Structural Option April 15<sup>th</sup>, 2008

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#### Intro

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





### **Building Background - Location**

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



### Manhattan





### **Building Background - Architecture**

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- Glass Cladding System that allows for floor to ceiling views

- No drop ceiling over living spaces

- 29 Story Condominium Tower

- 176 units
- Two typical floor plans (7500SF and 6200SF)





### **Building Background – Structural System**

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





### **Redesign Goals**

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### **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



26<sup>tn</sup>-Roof

#### **Slab Design - Introduction**

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#### **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





### Slab Design – Current System



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#### 26<sup>th</sup>-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



26<sup>tn</sup>-Roof

### Slab Design – Current System

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#### 26<sup>th</sup>-Roof Long-Term Deflection



Maximum Long-Term Deflection: 0.67"

Maximum Long-Term Deflection: 0.74"

### ACI318 Limit (30' Span): L/480 = 0.75"



### Slab Design - Post-Tensioned System



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#### 26<sup>th</sup>-Roof Tendon Plans

Column Added



Maximum Long-Term Deflection: 0.49"



Intro.

### **Presentation Outline**

### 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



### 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 Con	nparison							
	Origina Amt.	I (3rd-25th)	PT (3r Amt.	d-25th) Cost	Original Amt.	(26-Roof) Cost	PT (20 Amt.	G-Roof)
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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3rd-25th Floor



#### **Shear Wall Design - Introduction**

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#### **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



### Shear Wall Design - Current Layout

Coupling Walls

Coupling Walls

 $8'-49_2^{**}$   $6'-4^{*}$   $8'-109_2^{**}$ 

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#### **Original Shear Walls** Viewed From South West



#### **Original Shear Walls** Viewed From North East



- 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



### Shear Wall Design - Considered Layouts

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Original Shear Walls Viewed from South West





Additional Wall



Core Only

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#### **Opposite Wall Only**





### Shear Wall Design - Considered Layouts

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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		



### Shear Wall Design - Alternate Layout

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### 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**

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3rd-25th Floor

Shear Wall Cost C	Shear Wall Cost Comparison							
	Origin Amt.	Original Design Amt. Cost		sign <u>Cost</u>				
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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#### **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				



### Construction Management - Schedule Comparison

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#### **Schedule Comparison**

Shear Wall Schedule By Floor									
	Bottom F	ottom 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			



### **Construction Management - Construction Issues**

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#### Typical Floor Plan (Ground-11<sup>th</sup> Floor)





### **Overall Conclusions**

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### Overall Conclusions

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	Serv Exc	viceability eeded?	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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### Thanks to: McL

McLaren Engineering Toll Brother's Inc. FxFowle Architects Dr. Ali Memari 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: Reduction for shear walls:	1" 3"
Potential New Ceiling Link Beam Height:	7'-5"

New York City Limit:

7'-0" (Gives 5" for finishes)













Image         Story X	0	Drigin	al Win	d Defle	ctions	Origina	al Reba	Plans
Defension         2010         0.115         0.101         0.0101 </th <th>Floor</th> <th>Floer Height (R)</th> <th>Story X Deflection (in)</th> <th>Story Y Deflection (in)</th> <th>Story Torsianal Deflection (milli cad)</th> <th>Short Wall</th> <th>Long Walls</th> <th>Coupled Walls</th>	Floor	Floer Height (R)	Story X Deflection (in)	Story Y Deflection (in)	Story Torsianal Deflection (milli cad)	Short Wall	Long Walls	Coupled Walls
DMR FLOOR         243         0.271         0.020         #5         #6           DOOF         243         0.131         0.162         0.020         -	<b>Building Top</b>	318	0.115	0.151	0.010			
BOOF         244         0.356         0.956         0.0200         -	EMR FLOOR	304	0.210	0.271	0.020		#5	#6
29         20         0.1%         0.1%         0.000         0 <th0< th=""> <!--</td--><td>ROOF</td><td>294</td><td>0.130</td><td>0.166</td><td>0.020</td><td></td><td></td><td></td></th0<>	ROOF	294	0.130	0.166	0.020			
20         272         0.193         0.193         0.000         0 <th0< th=""> <th0< th=""> <th0< th="">         &lt;</th0<></th0<></th0<>	29	202	0.126	0.158	0.020	1.000	•	
27         381         0.191         0.000         1         0           28         340         0.191         0.451         0.000         45         -	20	272	0.128	0.158	0.030		•	
20         251         0.173         0.160         47         7         5         47         7         5         7         7         25         201         0.173         0.160         47         1 </td <td>27</td> <td>261</td> <td>0.129</td> <td>0.151</td> <td>0.030</td> <td></td> <td></td> <td></td>	27	261	0.129	0.151	0.030			
Sc         241         0118         0.146         0.000         #5         1         -           25         211         0118         0.145         0.000         - <td< td=""><td>26</td><td>251</td><td>0.129</td><td>0.152</td><td>0.040</td><td></td><td></td><td></td></td<>	26	251	0.129	0.152	0.040			
24         271         0.118         0.465         0.000         -         -         -         -           22         21         0.118         0.45         0.000         -	25	243	0.118	0.146	0.040	#5	1.00	
22         221         0118         0.145         0.000         1         1         1           23         21         0118         0.145         0.000         -	24	231	0.118	0.145	0.050			
22         211         0.118         0.403         0.000               22         201         0.118         0.424         0.000 </td <td>23</td> <td>221</td> <td>0.118</td> <td>0.145</td> <td>0.050</td> <td></td> <td>1</td> <td></td>	23	221	0.118	0.145	0.050		1	
21         207         0.118         0.442         0.070         0         1         1         1           30         107         0.160         0.000         0<	22	211	0.118	0.143	0.060			
20         192         0.117         0.400         0.000         -         -         -         -           18         102         0.116         0.127         0.100         - <t< td=""><td>21</td><td>201</td><td>0.118</td><td>0.142</td><td>0.070</td><td></td><td></td><td></td></t<>	21	201	0.118	0.142	0.070			
19         100         0.116         0.137         0.100         1 <th1< th=""> <th1< th=""> <th1< th="">         &lt;</th1<></th1<></th1<>	20	192	0.117	0.140	0.090			
10         172         0.116         0.126         0.116         -	19	102	0.116	0.137	0.100			
17         102         0.114         0.129         0.120         1         1         0           16         161         0.112         0.120         0.120         0.120         -	18	172	0.115	0.136	0.110			
H6         H3         0.112         0.29         0.120         0.12         0	17	162	0.114	0.131	0.120			
16         10         0.133         0.100         - <t< td=""><td>16</td><td>153</td><td>0.112</td><td>0.128</td><td>0.120</td><td></td><td></td><td>#7</td></t<>	16	153	0.112	0.128	0.120			#7
14         102         0.198         0.119         0.120         -	16	143	0.118	0.133	0.140			
10         102         0.103         0.114         0.120         -         -         6         -	14	132	0.105	0.119	0.120			
12         10         0.000         0.000         0.120	13	123	0 103	0.114	0.120		45	
11         100         0.000         0.100         0.100	12	113	0.100	0.109	0.120			
10         10         0000         0.000         0.100         0000         0.000         0.100         0 <td>11</td> <td>103</td> <td>0.092</td> <td>0.104</td> <td>0.130</td> <td></td> <td></td> <td></td>	11	103	0.092	0.104	0.130			
9         00         0000         0000         0100         - <th< td=""><td>10</td><td>93</td><td>0.093</td><td>0.098</td><td>0.130</td><td>0</td><td></td><td>#9</td></th<>	10	93	0.093	0.098	0.130	0		#9
0         7         0.004         0.004         0.150         -		83	0.089	0.091	0.120		40	
7         64         0.007         0.007         0.100         -		24	0.004	0.004	0.130			
6         54         0.073         0.099         0.130         -         -         -         -         -         -         -         -         -         100         -         -         100         -         -         100         -         -         100         -         -         -         100         -         -         -         100         -         <	2	64	0.079	0.077	0.130			
S         46         0.002         0.000         0.102         40         •		64	0.073	0.000	0.120			
4 29 0000 0.049 0.150 3 14 0.054 0.041 0.150 14 0.054 0.041 0.150 16 0.054 0.041 0.150 16 0.11 0.011 0.000 16 0.11 0.011 0.000 16 0.11 0.011 0.000 16 0.11 0.011 0.000 16 0.11 0.000 16 0.1000 16 0.000 16 0.0000 16 0.00000 16 0.00000 16 0.00000 16 0.00000 16 0.00000 16 0.00000		10	OCET	0.000	0.120	40		#10
3 25 0.099 0.044 0.110 0.110 0.1000 0.100 0.100 0.100 0.100 0.100 0.100 0.100 0.100 0.100 0.1		14	0.060	0.049	0.120		4110	
2         14         0.054         0.041         0.010         0.01         0.011         0.001<		77	0.060	0.045	0.120			
LOBPY         0         0011         0010         0000         1 <th1< th="">         1         <th1< th=""> <!--</td--><td></td><td>14</td><td>0.059</td><td>0.041</td><td>0.130</td><td># 10</td><td></td><td>#11</td></th1<></th1<>		14	0.059	0.041	0.130	# 10		#11
Spatisterior         -0.0         -0.01         -0.000         - <td>LODON</td> <td>0</td> <td>0.054</td> <td>0.041</td> <td>0.000</td> <td>- 10</td> <td></td> <td></td>	LODON	0	0.054	0.041	0.000	- 10		
Data Song Denhaming         19571         19544           Star Detroction         19712         202 millional         #	LUCOT	0	0.011	0.011	0.000			
Fred B of union         TOT         TOT         2.02 millional           Intel Definition         H11-00         H11-00         Bhara Rebair         #5         #7         #6           Testa Robins         H11-00         H11-00         Testa Robins         #5         #7         #6           Testa Robins         100         Testa Robins         100         777         206         100           Testa Robins         100         7202         242,110         100 <t< td=""><td>DAGEWENI</td><td>-10</td><td>110770</td><td></td><td></td><td>-</td><td></td><td></td></t<>	DAGEWENI	-10	110770			-		
stal Defection 3.32 307 2027min ed tad Defection 101109 101004 506 175 07 05 Tetal Robard 073) 77 206 100 Tetal Concrete 073 9,700 22,825 24,110 Tetal Concrete 073 9,700 22,825 24,110	Max Story De	mechen	19571	19.644				
Interfection         H01140         H01004         Shear Rehar         #5         #7         #6           Total Rehar (#*3)         77         206         150         150         150         27.025         24.11           Total Rehar (#*3)         77         206         150         27.102         24.11         150         24.11         150         24.11         150         24.11         150         24.11         150         24.11         150         24.11         150         24.11         150         24.11         150         24.11         150         24.11         150         24.11         150         150         24.11         150         24.11         150         24.11         150         24.11         150         24.11         150         24.11         150         24.11         150         150         24.11         150         1	I stal Deflect	iom .	3.32"	3.80*	2.82 mill+rad			
Shear Rebar         #5         #7         #6           Total Rebar (#*3)         77         206         150           Total Concrete (#*3)         3/250         22/825         24/110           Total Concrete (#*3)         3/200         12/000         12/000	Total Deflect	ion	H/1149	H/1004		-		
Tetal Rebar (#*3) 77 206 150 Tetal Cencrete (#*3) 9,750 27,825 24,110					Shear Rebar	#5	#7	#6
Tetal Cencrete (#73) 9750 27.825 24,110 Tetal Cencrete (#73) 9750 27.825 24,110					Total Dahas dat Ti	79	100	160
Tetel Economic (01-3) 5750 27,025 24,010					Yotal Concests (Bt 3)	0.700	37.035	24.110
					Total Constants (ht 3)	13,000	37 100	12,055



_	New	Wind	Deflect	New Rebar Plans				
Heer	Floor Height	Shory X Deflection (in)	Story Y Deflection tint	Story Torsional Deflection millicadi	Sheet Wall	Short Wall	Long Walls	Camples
Building Tap	310	0.116	0.151	0.000	-			
EMR FLOOR	304	0.212	0.272	0.020			#5	#6
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	8.129	0.155	0.030				
25	240	0.119	0.145	0.043	#5			
24	231	0.119	0.146	0.040	· · · · · ·			
20	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				
10	182	0.115	0.137	0.000				
18	172	0.114	0.135	0.100				•
17	162	0.111	0.132	0.100				1.1.1
16	153	0.108	0.128	0.110				87
15	143	0.112	0.133	0.120				
1.4	132	0.099	0.119	0.110	#7			
13	123	0.094	0.114	0.110				
12	113	0.000	0.111	0.110				
11	103	0.077	0.105	0.110		#5		
10	- 90	8.072	0.097	0.110				90
9	83	0.069	0.091	0.110		#0		
8	74	0.066	0.004	0.110				
7	64	0.062	0.076	0.110		#11		
6	54	0.057	0.068	0.120				+
6	45	0.052	0.059	0.100	80			#10
4	36	0.040	0.049	0 110				+
3	3	0.045	0.042	0.120		#14		
2	14	0.049	0.041	0.150	#11		#7	#11
LOBBY	0	0.012	0.011	0.060				
			10.00		1.0			. *
Max Story D Total Deflec Total Deflec	offection Son Son	L/566 3.13* L/1218	L/441 3.01* L/1002	2.49 milli-rad				
				Shear Rebar	#5	#5	#7	#6
				Total Rebar (M*3) Total Concrete (M*3)	43 4,333	49 3,390	179 27 825	150 24,290