

## Structural System Redesign

- Existing Conditions
- Proposal
- Gravity Design
- Lateral Design
- Cost Comparison
- Schedule Impact
- Conclusions



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**Location:** New York, NY

**Owner:** NYC HHC

**Architect:** RMJM Hillier

**Structural Engineer:** Greenman-Pedersen Inc.

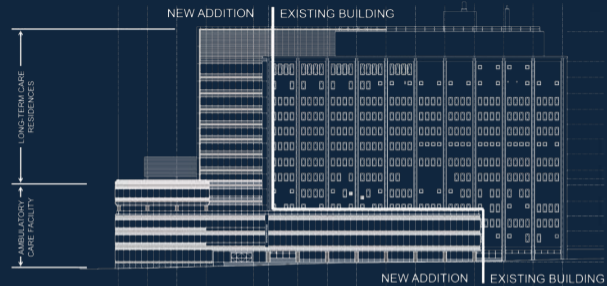
**Construction:** September 2008 – Mid 2012

**Cost:** \$160 million overall project cost

**Delivery:** Design-Bid-Build with multiple prime contracts

**Existing Conditions**

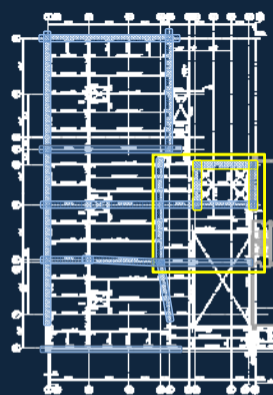
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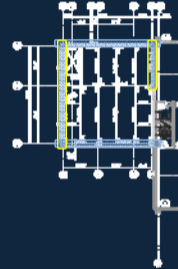
- 75,000 sq. ft. Addition to Existing Hospital
- 13 Stories
- Steel Framed Addition
- Concrete Existing Structure
- 11' Floor-to-Floor

**Existing Conditions**

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3<sup>rd</sup> Floor Framing Plan

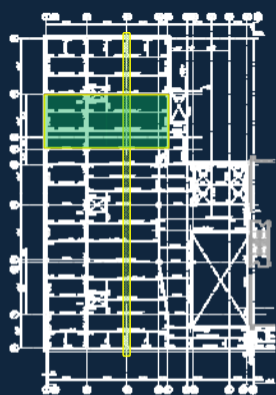


8<sup>th</sup> Floor Framing Plan

- Cellular Beams for all Gravity Members
- Moment Frames
- Braced Frames

**Existing Conditions**

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### Design Choices

- Use of Steel Framing
- Removal of Column Line
- Use of Moment Frames

### Impact

- Need Cellular Beams
- Heavy Lateral Members
- Further Restrictions on MEP systems

**Existing Conditions**

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## Proposal

- Redesign current, steel-framed addition as a concrete structure utilizing two-way flat plate slab and shearwalls

## Design Goals

- Maintain regularity in design
  - Slab
  - Column
  - Shearwalls
- Provide design freedom for other systems
- Design a more cost effective structural system

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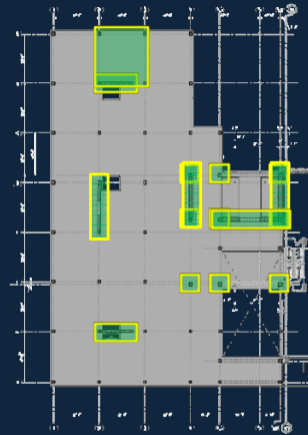
## Codes

- ASCE7-05
  - Wind Loads as per Chapter 6
  - Seismic Loads using Equivalent Later Force
- ACI 318-08

## Methodology

- ETABS
- RAM Concept
- PCA Column
- Microsoft Excel

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### Gravity System

- 12" slab
- $f'_c = 6\text{ksi}$
- 22' x 24' bay
- 16" columns
- 20" columns

### Lateral System

- 6 shearwalls
- 16" shearwalls
- 20" shearwalls

**Structure Overview**

**3<sup>rd</sup> Floor Plan**



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## Design Loads

- 26 psf Superimposed Dead Load
- 80 psf Live Load

## Deflection Limits

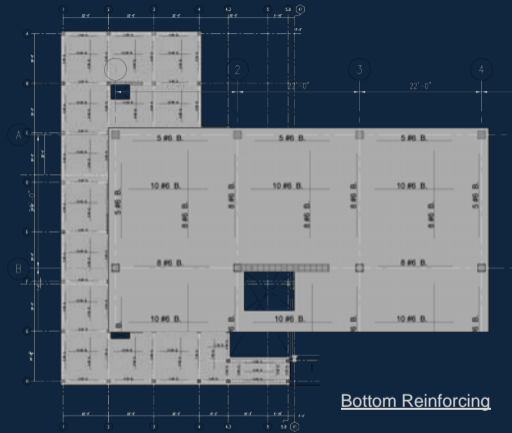
- L/360 Immediate Live Load Defl.
- L/480 Long-term Deflection
- L/240 Long-term Deflection

Creep Factor = 2

20% of Live Load

**Gravity Design**

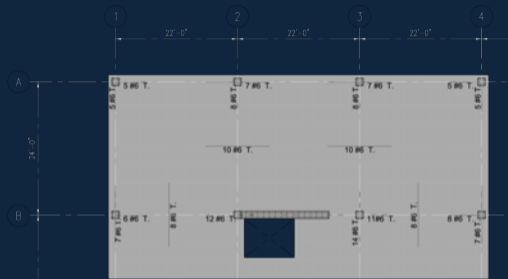
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**Slab Design**

## 3<sup>rd</sup> Floor Reinforcing Plan

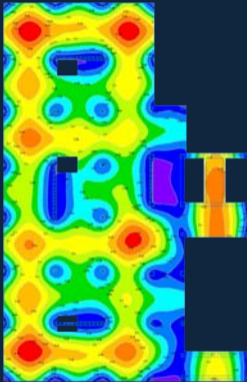
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Top Reinforcing

**Slab Design**

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Model	3rdflr	
slab	12	in
edge bm	no	
edge col	16	16
$\Delta d+l$	0.1775	
$\Delta l_i$	0.0555	ok
$\Delta d_t$	0.2441	
$\Delta 20\%l_t$	0.0222	
$\Delta$	0.4438	ok

Initial. LL Deflection:

**0.0555 in**

Allowable:

**L/360 = 0.80 in**

Max. long-term Deflection:

**0.4438 in**

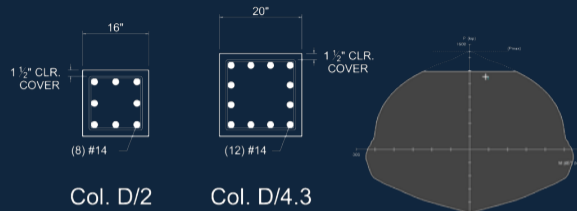
Allowable:

**L/480 = 0.60 in**

Slab Design

## 3<sup>rd</sup> Floor Deflection Plan

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Columns supporting 6 stories: <b>16" x 16"    <math>f_c' = 6 \text{ ksi}</math></b>
Columns supporting 13 stories: <b>20" x 20"    <math>f_c' = 6 \text{ ksi}</math></b>

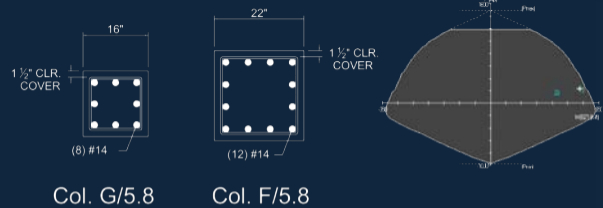
**Column Design**

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**Column Design**

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Column G/5.8 (6 stories): <b>16" x 16"    <math>f_c' = 6</math> ksi</b>
Column F/5.8 (13 stories): <b>22" x 22"    <math>f_c' = 6</math> ksi</b>

**Column Design**

## Slender Column Design

- Existing Conditions
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**Column Shift**  
- Control Deflections  
- Match Floorplan Layout

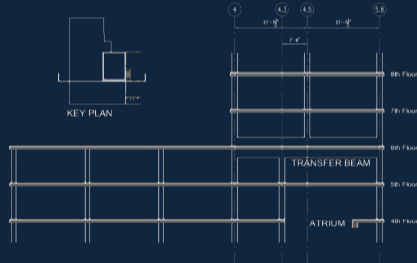
**Transfer Beam Design**



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- 60" deep beam
- 20" width

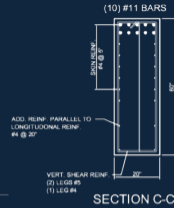
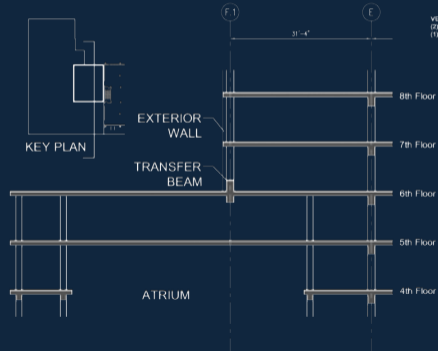
**Column Shift**  
- Control Deflections  
- Mason Floorplan  
Layout



**Transfer Beam Design**

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- 60" deep beam
- 20" width



**Transfer Beam Design**

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## Design Assumptions

### ETABS

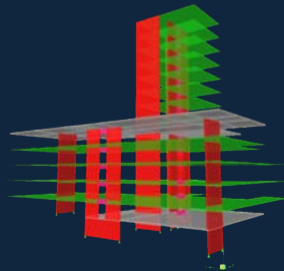
- Diaphragms modeled as Rigid and Semi-Rigid
- Shearwalls modeled as Membranes
- $0.7 f_{22}$  modifier for shearwalls
- $0.35 I_3$  modifier for coupling beam
- Deflection:

**H/400** for wind

**0.015h<sub>x</sub>** for seismic

**3.00"** overall floor deflection

**3.50"** overall deflection at roof



**12.12.3 Building Separation.** All portions of the structure shall be designed and constructed to act as an integral unit in resisting seismic forces unless separated structurally by a distance sufficient to avoid damaging contact under total deflection ( $\delta_x$ ) as determined in Section 12.8.6

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## Seismic Forces

### Equivalent Lateral Force Procedure

- Seismic Design Category      **SDC = B**
- Importance Factor                **I = 1.15**
- Response Modification Coeff.    **R = 4**
- Deflection Amplification Factor   **Cd = 4**
- **Base Shear      V = 303 k**

Story	Floor Height	Floor Weight	$wh_i^4$	$C_w$	Story Force	Story Shear
Main Roof	156.00	595.7	92922	0.096	29.046	29.046
13	140.3	571.2	80135	0.083	25.049	54.095
12	128.30	571.2	73292	0.076	22.910	77.005
11	116.3	571.2	66449	0.069	20.771	97.776
10	105.13	571.2	60052	0.062	18.771	116.548
9	94.9	571.2	53655	0.055	16.772	133.320
8	82.73	571.2	47258	0.049	14.772	148.092
7	70.8	571.2	40415	0.042	12.633	160.726
6	59.55	2478.0	147568	0.152	46.128	206.853
5	47.6	2489.8	118446	0.122	37.025	243.878
4	36.38	2486.9	90461	0.093	28.277	272.155
3	25.2	2486.9	62613	0.065	19.572	291.727
2	13.98	2489.8	34805	0.036	10.880	302.607

(ft)      (kip)      302.61  
Base Shear

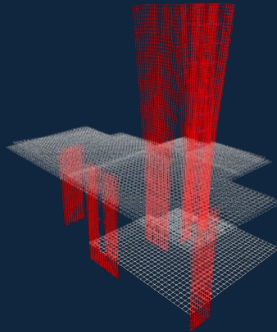
**Lateral Design - Seismic**

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## Seismic Deflection

ETABS Elastic Analysis

- EX Overall Deflection = 1.6257"
- EY Overall Deflection = 1.1233"



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## Final Seismic Deflection

### Accidental Torsion

- Force applied at 5% eccentricity
- Amplification of torsion:

$$A = (d_{\max} / (1.2 \cdot d_{\text{avg}}))^2 \quad (\text{Figure 12.8-1})$$

$$\begin{array}{l} d_{\max} = 1.693" \\ d_{\text{avg}} = 1.573" \end{array} \quad \left| \quad A_x = 0.804 \quad \text{therefore} \quad A_x = 1.00 \right.$$

### Amplified Seismic Deflections

- Amplification of Elastic Output

$$\delta_x = C_d \delta_{xe} / I * (T_a / T) \quad (\text{eq 12.8-15})$$

- Maximum Overall Floor Deflection

$$2.9393" \text{ (EXMZ)} \quad < \quad 3.00" \text{ upper limit}$$

- Maximum Overall Roof Deflection

$$3.2132" \text{ (EXMZ)} \quad < \quad 3.50" \text{ upper limit}$$

- Maximum Story Drift

$$0.0022 \text{ (EXMZ)} \quad < \quad 0.015 \text{ max allowable}$$

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## Wind Forces

- Basic Wind Speed **V = 100mph**
- Importance Factor **I = 1.15**
- **Base Shear X-dir V = 382 k**
- **Base Shear Y-dir V = 314 k**

Wind X		Floor Elev. (ft)	Elev. above datum (ft)	Story Height (ft)	Story Force (kip)	Story Shear (kip)
Zone 2	main roof	154.00	171.01	11.98	23.6	23.6
	13	138.28	159.03	11.98	23.6	47.1
	12	126.30	147.05	11.98	23.4	70.6
	11	114.32	135.07	11.20	22.1	92.6
	10	103.13	123.88	11.20	21.2	113.8
	9	91.93	112.68	11.20	20.4	134.2
	8	80.73	101.48	11.98	20.8	155.0
	7	68.75	89.50	11.20	20.4	175.4
Zone 1	6	57.55	78.30	11.98	34.8	210.2
	5	45.57	66.32	11.20	47.6	257.8
	4	34.38	55.13	11.20	43.9	301.8
	3	23.18	43.93	11.20	41.0	342.7
	2	11.98	32.73	11.98	39.5	382.2
	Ground	0.00	20.75	0.00	0.0	382.2
		Datum	20.75		382.2	Total

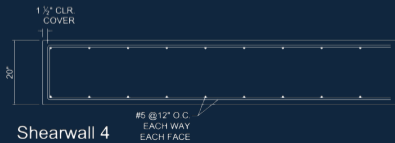
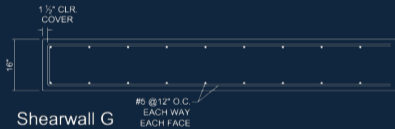
**Lateral Design - Wind**

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## Controlling Case

- Seismic Deflection governed design
- Wind Combinations produced highest forces
- **Provide Minimum Reinforcing:**

**(2) #5 bars @ 12" O.C. Each Way**



**Lateral Design**



## Existing vs. Proposed

- Compared elements of structure that change
- Assumed 3% O&P
- Materials, Labor, and Equipment
- Moment Connections *not* considered

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	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total	Ext. Mat. O&P	Ext. Labor O&P	Ext. Equip. O&P	Ext. Total O&P	Total
STEEL	\$ 2,499,334	\$ 517,484	\$ 153,911	\$ 3,170,730	\$ 2,748,275	\$ 910,631	\$ 169,192	\$ 3,828,099	\$ 6,998,829
SLAB ON DECK	\$ 525,088	\$ 151,849	\$ 16,997	\$ 693,933	\$ 578,300	\$ 254,510	\$ 18,166	\$ 850,975	\$ 1,544,909
FOUNDATION	\$ 221,129	\$ 103,059	\$ 82,177	\$ 406,364	\$ 243,239	\$ 161,164	\$ 90,283	\$ 494,687	\$ 901,050
EQUIPMENT	\$ -	\$ 67,637	\$ 340,282	\$ 407,919	\$ -	\$ 102,395	\$ 374,566	\$ 476,960	\$ 884,879
	\$ 3,245,551	\$ 840,028	\$ 593,367	\$ 4,678,946	\$ 3,569,815	\$ 1,428,699	\$ 652,207	\$ 5,650,721	
<b>Total</b>									<b>\$ 10,329,667</b>

	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total	Ext. Mat. O&P	Ext. Labor O&P	Ext. Equip. O&P	Ext. Total O&P	Total
CONCRETE	\$ 807,762	\$ -	\$ -	\$ 807,762	\$ 892,491	\$ -	\$ -	\$ 892,491	\$ 1,700,253
FOUNDATION	\$ 283,334	\$ 146,147	\$ 169,123	\$ 578,604	\$ 290,172	\$ 226,057	\$ 186,662	\$ 702,891	\$ 1,281,495
SLAB	\$ 357,860	\$ 907,391	\$ 21,109	\$ 1,286,361	\$ 396,051	\$ 1,423,441	\$ 23,178	\$ 1,842,670	\$ 3,129,031
COLUMNS	\$ 101,617	\$ 317,591	\$ 3,090	\$ 422,297	\$ 111,433	\$ 500,739	\$ 3,394	\$ 615,565	\$ 1,037,863
WALLS	\$ 55,800	\$ 317,502	\$ 6,158	\$ 379,460	\$ 61,093	\$ 494,496	\$ 6,770	\$ 562,359	\$ 941,820
EQUIPMENT	\$ -	\$ 135,274	\$ 633,027	\$ 768,301	\$ -	\$ 204,789	\$ 696,841	\$ 901,630	\$ 1,669,930
	\$ 1,586,373	\$ 1,823,905	\$ 832,507	\$ 4,242,785	\$ 1,751,240	\$ 2,849,522	\$ 916,845	\$ 5,517,607	
<b>Total</b>									<b>\$ 9,760,392</b>

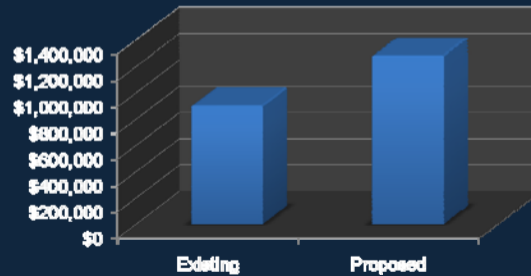
**Cost Comparison**

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## Existing vs. Proposed

- Existing Foundation	\$ 901,050
- Proposed Foundation	\$ 1,281,495
- Percent Increase	~ 40%

**Foundation Comparison**

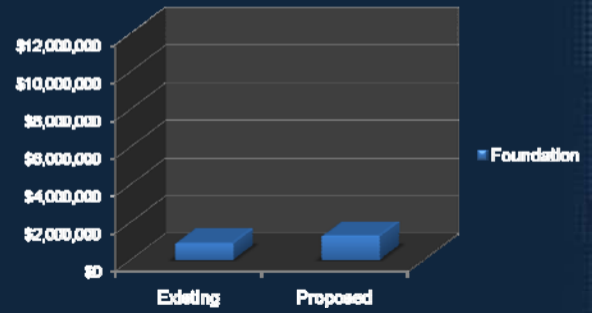


**Cost Comparison**

# Existing vs. Proposed

- Existing Conditions
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**SCOTT M. RABOLD**  
structural

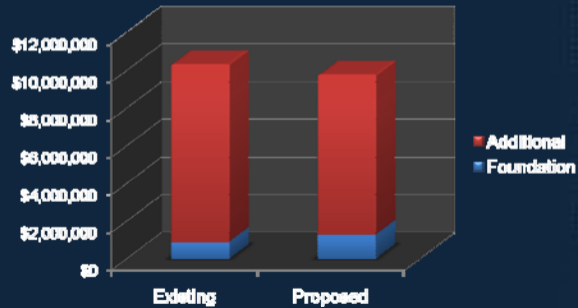


**Cost Comparison**

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## Existing vs. Proposed

- Existing Structure	\$ 10,329,667
- Proposed Structure	\$ 9,760,392
- Percent Saving	~ 5%
<b>-Overall Project Cost</b>	<b>\$ 130,000,000</b>



**Cost Comparison**

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## Existing vs. Proposed

- Existing Structure sequenced in two portions
- Existing Duration **6.5 Months**
- Proposed Structure sequenced in three portions  
~ 3 weeks per floor
- Proposed Duration **12 Months**



**Schedule Impact**

- Existing Conditions
- Proposal
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- **Conclusions**

## Design Goal Achievement

- Maintain Structural Regularity ✓
- Promote design freedom for other systems ✓
- Design a more cost-effective structure ✓

## Recommendations

**Conclusions**

- Existing Conditions
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## Thank You

- Entire AE Faculty
- Dr. Memari
- Professor Holland
- Professor Parfitt
- AE Structural Professors
  - Dr. Boothby
  - Dr. Geschwindner
  - Dr. Hanagan
  - Dr. Lepage
- Greenman- Pedersen Inc.
- Friends and Family

Questions?

Questions?