Weill Cornell Medical Research Building

413 E. 69th Street

New York, NY

Jonathan Coan

Structural Option

Advisor: Dr. Boothby

Technical Report 3

Submitted: 12/17/11

Table of Contents

Executive Summary

The Weill Cornell Medical Research Building is a 19 story, 455,000 square foot, 294'-6" tall building located on East 69th Street in New York City. The building features three stories below grade and eighteen, plus a penthouse and an interstitial floor, above grade.

The purpose of this *Lateral System Analysis and Confirmation Design* report is to analyze the existing lateral system design. The first step was modeling the building in Etabs. Results from this model would provide information for determining story drift and controlling load cases, as well as stiffness, relative stiffness, and load distribution among the elements of the lateral system. The model was unable to be analyzed due to unknown errors, therefore the only analysis that could be done was a manual investigation of the stiffness and distribution of story shears into direct and torsional shears for each member of the lateral system.

Introduction

The Weill Cornell Medical Research Building is the newest addition to the campus of the Weill Cornell Medical College on the upper east side of Manhattan. Located at 413 East 69th Street in New York City, the Medical Research Building is adjacent to other Weill Cornell buildings. The Weill Greenberg Center on its northeast side is an educational facility designed by the same architects as the Medical Research Building. Olin Hall to the east, and the Lasdon House to the north are residential buildings that house students of the medical college. 69th Street slopes down to the east across the site of the Medical Research Building and the utilities run under it. The Con. Edison power vaults are also located under 69th Street and the sidewalk in front of the building.

The $650 million Medical Research Building is approximately 455,000 square feet with three stories below grade and eighteen, plus a penthouse and an interstitial floor, above grade. The total height of the building above grade is 294'-6." Floors 4-16 are dedicated to laboratory space. The first basement level, as well as the interstitial floor between floors 16 and 17, and the 17th and 18th floors are designated as mechanical floors. The bottom two levels of the basement contain the MRB's animal facility. Service and freight elevators and vertical circulation are located on the west side of the building next to the loading docks on the 69th Street side. Passenger elevators and vertical circulation are nearer the center of the building where the two story lobby atrium welcomes people into this hub of scientific exploration.

In the rear of the building, adjoining the second floor, there is a terrace that bridges the gap between the rear façade of the MRB and the Lasdon House. A grand staircase leads from the lobby on the ground floor up to the enclosed lounge on the second floor that opens onto the terrace. There are two entryways from the Lasdon House to the terrace so anyone living in that building and working in the Medical Research Building would have easy access. The terrace also wraps around the side of the Lasdon House and connects to a stairway leading down to the sidewalk on 70th street.

The building is defined visually by the undulating glass sunshade curtain wall across the front of the building. This curtain wall is attached to the floor slabs that are cantilevered out approximately 9'-8" from the exterior row of columns to meet it. The curtain wall itself has two layers. The outer layer features the glass sunshade wall with aluminum mullions. This wall is tied to the inner layer of insulated glass (also with aluminum mullions) by aluminum struts. The inner layer is anchored to the slab either directly through the mullion or with a steel outrigger.

Structural Systems

Foundation System

The foundation system consists of spread footings bearing on undisturbed bedrock. Strap beams are provided as necessary around the perimeter. This undisturbed bedrock is expected to support 40 tons per square foot. According to the geotechnical report, there are two types of bedrock encountered on the site. One type supports 40 tsf and the other 60 tsf, but it is recommended by Langan Engineering and Environmental Services that the footings be designed to rest on 40 tsf bedrock. The slab on grade is a 6" concrete slab resting on a 3" mud slab on 24" of crushed stone. The perimeter concrete walls of the basement are 20" thick with strip footings. Below, Figure 1 is an image of the foundation plan.

The geotechnical report also states that the water table is approximately 50 feet above the foundation level. This poses the problem of seepage through the rock and also uplift on the foundation. A few different design solutions are presented in the geotechnical report. The resolution of this problem comes in the form of 4-50 ton rock anchors located at the bottom of Stairwell B on the East side of the building to resist the uplift.

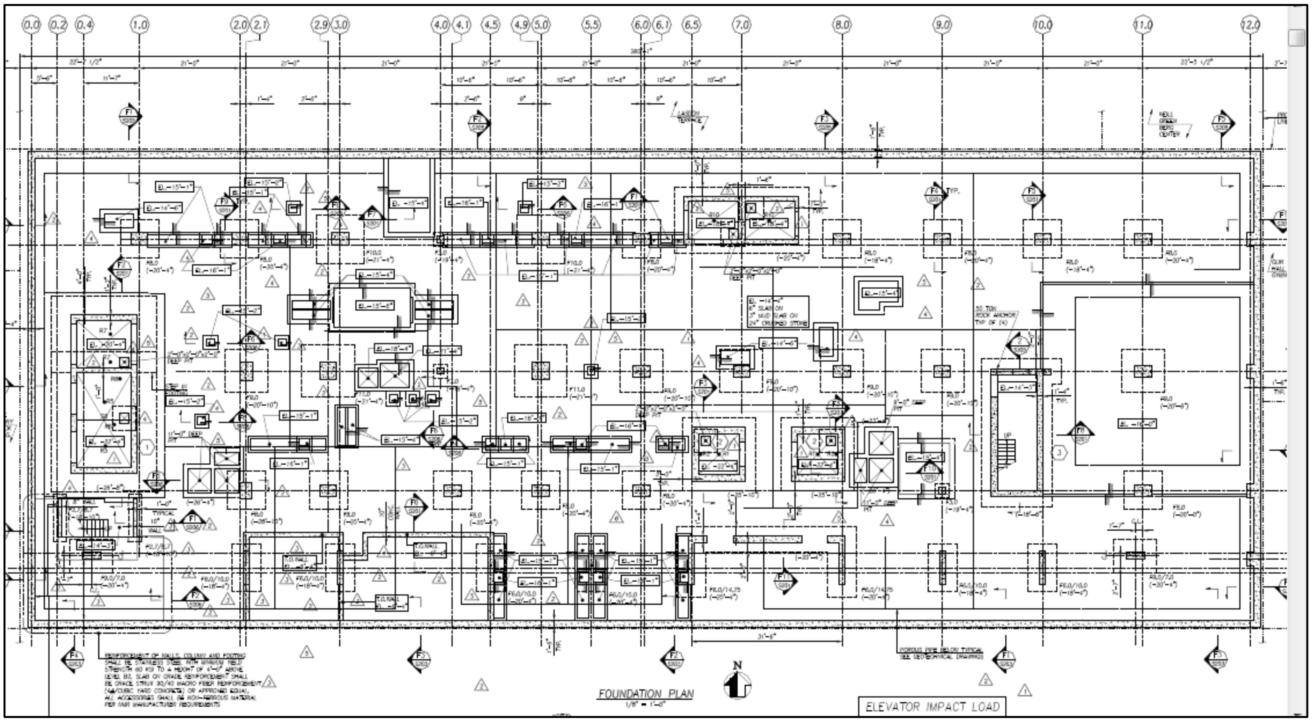

Figure 1: Basement Level 3 – Foundation Plan

Floor System

The floor system in the Medical Research Building is 2 way flat plate concrete slabs. These slabs vary in depth from floor to floor (see Figure 2 below). The bottom reinforcement is typically #5 bars at 12." Top reinforcement and additional bottom reinforcement varies as needed throughout the building. The slabs are especially thick in this building because much of the design was constrained by strict vibration requirements of the medical and research equipment in the building. Laboratory floors were designed to limit vibration velocities to 2000 micro-inches per second. Walking paces were assumed to be moderate (75 footfalls per minute) in the labs and corridors and fast (100 footfalls per minute) only in public areas such as the lobby. There are also vertical HSS members at alternate floors through the middle of the building where the laboratories are located. These members serve no structural load bearing purpose, they are simply meant to tie each floor to another floor to further limit vibrations by forcing any impact to excite vibrations in two floors instead of just one.

Floor	Slab Depth (in)
B3	6
B2	12.5
B1	12.5
1	11
2	12
3	12.5
4	12.5
5	12.5
6	12.5
7	12.5
8	12.5
9	12.5
10	12.5
11	12.5
12	12.5
13	12.5
14	12.5
15	12.5
16	12.5
Interstitial	10.5
17	10.5
18	12.5
19	10.5

Figure 2: Slab Depth per Floor

The front of the building features a cantilever slab extending approximately 9'-8" from the center of column line D. The glass sunshade curtain wall is connected to the edge of the slab. The slab is the same thickness as the rest of the floor, but is cambered up to reduce deflections caused by the curtain wall load. On the second floor, the slab is cambered 1" upward. For the third through the interstitial floors, the slab is cambered 5/8" upward.

Lateral System

Lateral loads, such as seismic and wind loads, are primarily resisted by 14"-16" reinforced concrete shear walls located around the stairwells and elevator cores. A couple of these shear walls step in at the second floor. Extra precautions were taken to make sure that the lateral moment still has a viable path to travel through that step in. Severud, the structural engineers for the project, desired to transfer lateral loads toward the perimeter of the building. In the front of the building there are massive 14 x 72 inch columns from which the slabs cantilever out and the glass sunshade curtain wall is hung. These columns also take some of the lateral loads. See the sketch in Appendix E for the location of lateral system elements on a typical floor.

Beams and Columns

There is a very wide variety of beam and column sizes in this building. There are almost forty different sizes of columns with dimensions ranging from 12” to 84,” with the most common column being 24 x 36. There are also approximately fifty five different sizes of beams ranging from 8 x24 to 84 x 48. Except on the laboratory floors, which are quite uniform, the column sizes tend to change from floor to floor. Reinforcement was provided to ensure the continuity of the load path through these column transfers.

Columns are located on the specified grid of 4 major rows in the East-West direction for the majority of the floors—except the first floor and below grade, which have a fifth row in the back of the building. Bay sizes are 27’-7,” 25’-0,” and 16’-3” in the North-South direction and the typical bay in the East-West direction is 21’-0” with end spans approximately 22’-6.” Beams, however, are only placed where they are needed. They are rarely in the same place from floor to floor and each floor has a different number of beams. The fourth floor has the fewest with 6, and the second floor has the most with 33. Below in Figure 3 is a typical framing plan for the 5th-15th floors.

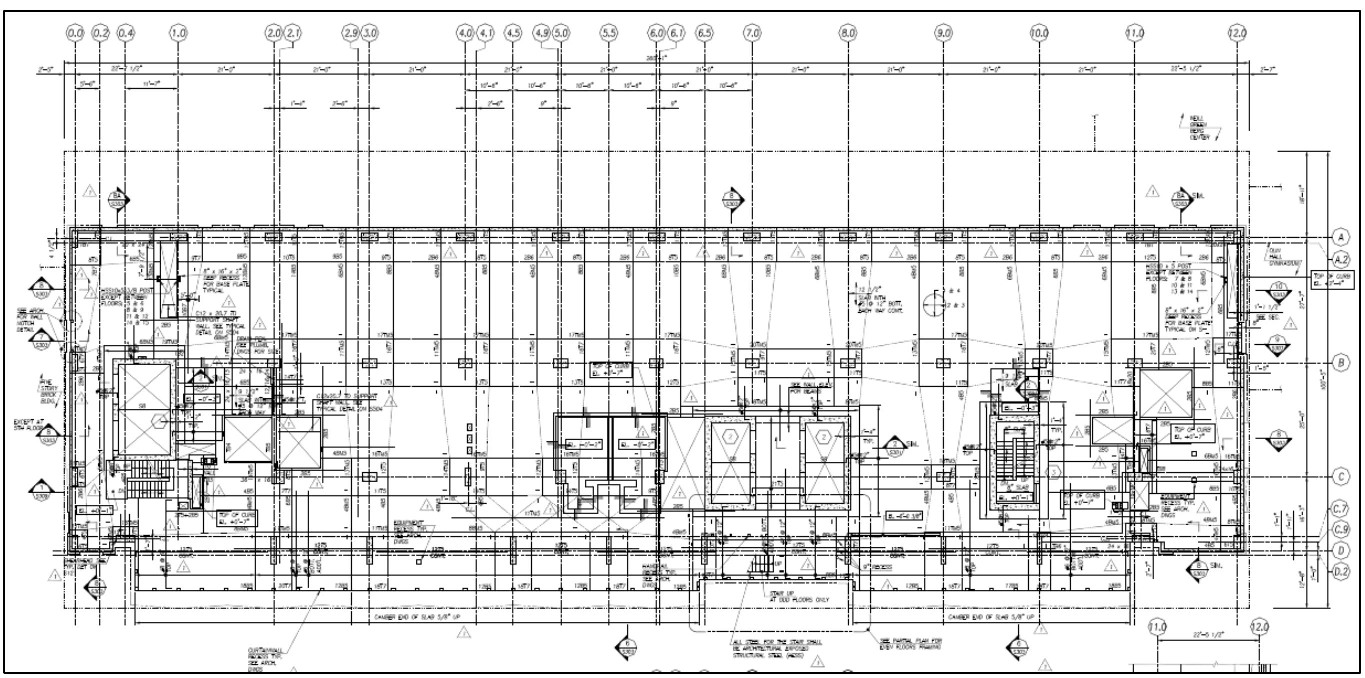

Figure 3: Typical Framing Plan – 5th-15th Floors

Design Codes and Standards

The Weill Cornell Medical Research Building was designed according to the 1968 New York City Building Code based on the UBC. In 2008 New York City updated their building code, which is now based on the IBC. For this report, the new 2008 code for analysis and design is being used; which references ASCE 7-02, ACI 318-02, etc. For relevance, ASCE 7-05, ACI 318-08, and the AISC Steel Construction Manual 14th ed. will be referenced in this report. The design for the Medical Research Building was submitted in 2008 and the project team decided to file under the old code. The MRB is located in New York City's zoning district R8, the use group is 3 (college), the construction class is I-C, and the occupancy group is D-2.

Structural Materials

The Medical Research Building is a predominantly concrete structure. The f'_c of the concrete varies throughout. See the table below in Figure 4 for the strength of concrete per floor.

On the roof and penthouse levels, there are structural steel members that frame platforms for mechanical equipment (cooling towers on the roof level), and also the window washing platform on the penthouse level. This penthouse level platform provides the means from which the window washing apparatus are hung and operated.

Steel members include W14s as horizontal framing members and HSS 10x8x5/8 for the perimeter. Columns, some of which extend down to the 19th floor (on the west side of the building) and some which continue to the 18th floor (on the east side) are HSS 8x8x3/8. The cooling tower platform consists of horizontal members ranging from W8s – W18s and HSS 8x8s as the columns. Figures 5 and 6 show the window washing platform and 19th floor framing plans.

Floor	f'_c Beams and Slabs(psi)	f'c Columns (psi)
B3	4000	8000
B2	5950	8000
B1	5950	8000
1	5950	8000
2	5950	8000
3	5950	8000
4	5950	8000
5	5950	8000
6	5000	5950
7	5000	5950
8	4000	5000
9	4000	5000
10	4000	4000
11	4000	4000
12	4000	4000
13	4000	4000
14	4000	4000
15	4000	4000
16	4000	4000
Interstitial	4000	4000
17	4000	4000
18	4000	4000
19	4000	4000

Figure 4: Concrete Strength per floor

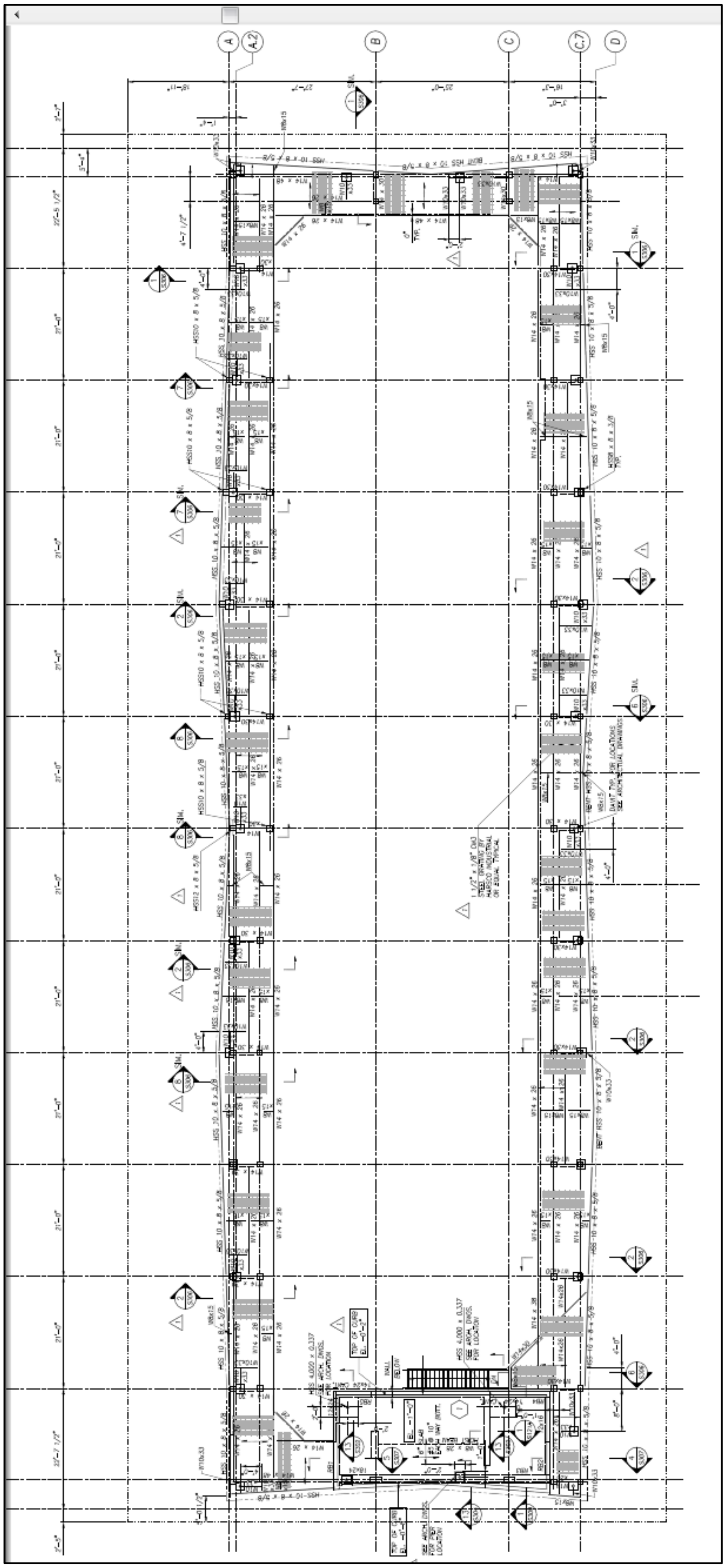

Figure 5: Window Washing Platform Framing Plan

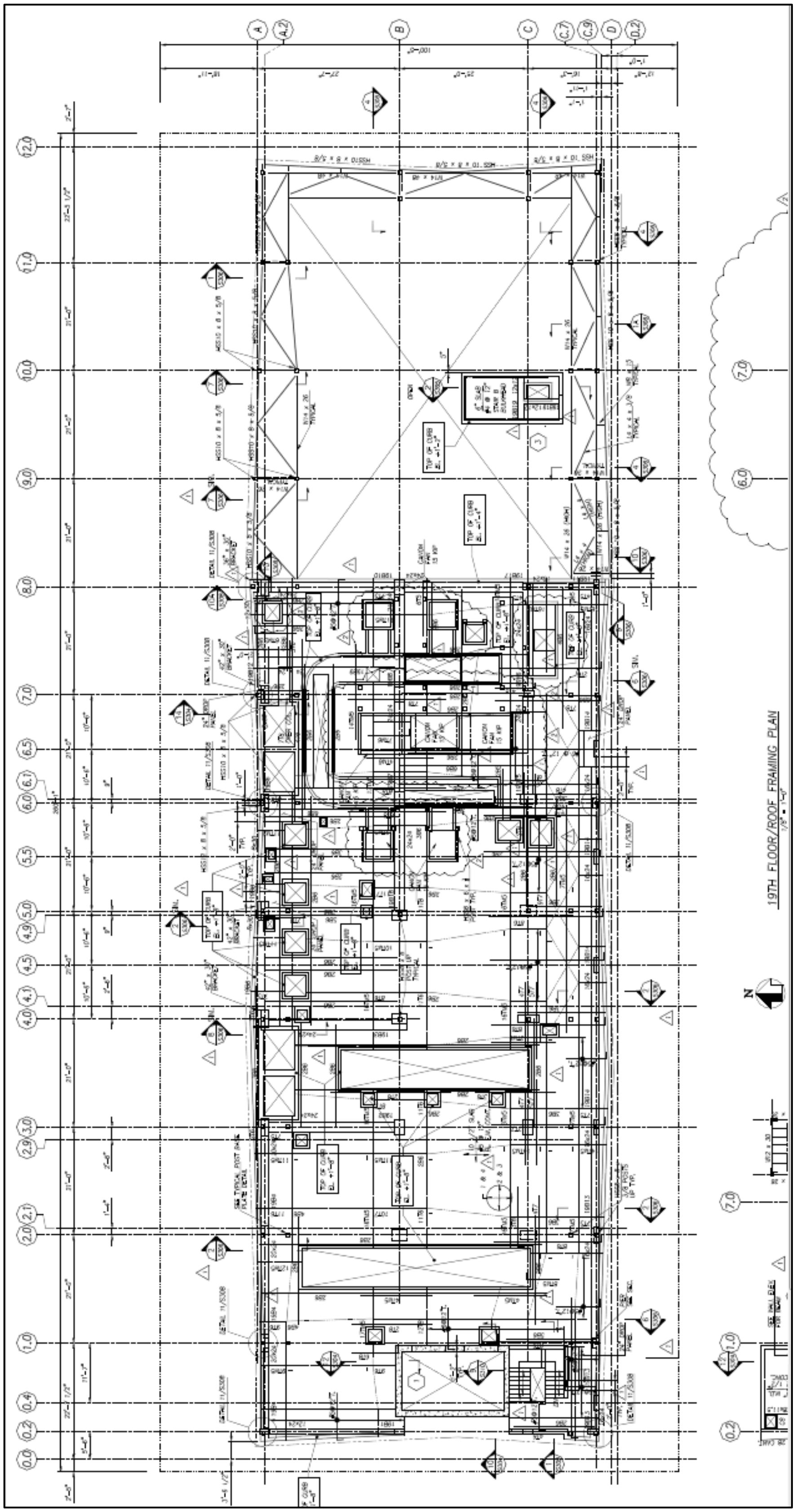

Figure 6: 19th Floor/Roof Framing Plan

Building Loads

Dead and Live Loads

There are a number of different occupancies within this building. The lower floors feature more business and office-like occupancies while the labs and mechanical rooms present circumstances more unique to the function of this building. The table below in Figure 7 shows some typical loads seen throughout the building. Unique loads for this building include the vivarium, which is located on the third basement level in the animal facility. It is an enclosed facility that acts as a recreation of an ecosystem for the study of plants and animals.

LOADING SCHEDULE (PSF)

LEVEL	SLAB	CEILING AND MECH.	PART'N.	MISC. DL.	LIVE LOAD	TOTAL LOAD	REMARKS
VIVARIUM	160	20	60	5	60	305	–
VIVARIUM MEZZ.	VARIES	10	–	15	50	VARIES	OR EQUIP.
B1	VARIES	30	10	15	150	VARIES	OR EQUIP.
LOADING DOCK	150	10	60	5	400	625	+4" TOPPING SLAB
SIDEWALK	150	10	–	50	600	810	–
LOBBY	140	10	–	25	100	275	–
AUDITORIUM	140	10	12	15	100	277	–
LABORATORY	160	10	12	5	60	247	–
OFFICES	160	10	12	5	50	237	–
MECHANICAL	160	30	12	5	150	357	OR EQUIP.
CORRIDOR	VARIES	10	12	5	100	VARIES	–
INTERSTITIAL	130	30	–	5	50	195	–
DATA CENTER	150	10	12	15	300	487	–
ROOF	130	30	–	15	30	205	OR EQUIP.
STORAGE	VARIES	10	12	5	150	VARIES	–

FACADE LOADS:
BLOCK AND BRICK 95 PSF
DOUBLE GLASS CURTAIN WALL 46 PSF
3

Figure 7: Loading Schedule

Wind Load

ASCE 7-05 was used to calculate wind pressures and story forces transferred to the Main Wind Force Resisting System (MWFRS) for both the East-West and North-South direction.

The basic wind speed was determined to be 110 mph in New York City from Figure 6-1C. The plans list the exposure category as B, and the occupancy category was determined to be III because it is an educational research lab and part of Weill Cornell Medical College.

The structure was assumed to be rigid, which meant the gust effect factor, G=.85. An excel spreadsheet was created to carry out the calculations of wind pressure and force for each story on the windward and leeward sides (Figures 8 and 9). Another excel spreadsheet was created to calculate the total base shear and overturning moment (Figure 11). Wind pressure diagrams were drawn to show how pressure is distributed in each direction (Figure 10).

Floor	Elev	z	K_z	q_z	Windward (psf)	Windward (plf)	Windward (k)	Leeward (psf)	Leeward (plf)	Leeward (k)
1	5.08	0.00	0.57	17.26	18.712	1309.871	9.824	-14.158	-991.06	-7.433
2	20.08	15.00	0.57	17.26	18.712	1309.871	18.884	-14.158	-991.06	-14.288
3	33.92	28.83	0.66	19.98	20.566	1439.587	19.914	-14.158	-991.06	-13.710
4	47.75	42.67	0.76	23.01	22.624	1583.715	21.908	-14.158	-991.06	-13.710
5	61.58	56.50	0.81	24.53	23.654	1655.779	22.905	-14.158	-991.06	-13.710
6	75.42	70.33	0.89	26.95	25.301	1771.082	24.500	-14.158	-991.06	-13.710
7	89.25	84.17	0.93	28.16	26.125	1828.733	25.297	-14.158	-991.06	-13.710
8	103.08	98.00	0.96	29.07	26.742	1871.971	25.896	-14.158	-991.06	-13.710
9	116.92	111.83	0.99	29.98	27.360	1915.210	26.494	-14.158	-991.06	-13.710
10	130.75	125.67	1.04	31.49	28.390	1987.274	27.491	-14.158	-991.06	-13.710
11	144.58	139.50	1.09	33.00	29.419	2059.338	28.488	-14.158	-991.06	-13.710
12	158.42	153.33	1.09	33.00	29.419	2059.338	28.488	-14.158	-991.06	-13.710
13	172.25	167.17	1.13	34.22	30.243	2116.989	29.285	-14.158	-991.06	-13.710
14	186.08	181.00	1.17	35.43	31.066	2174.641	30.083	-14.158	-991.06	-13.710
15	199.92	194.83	1.17	35.43	31.066	2174.641	30.083	-14.158	-991.06	-13.710
16	213.75	208.67	1.20	36.33	31.684	2217.879	32.252	-14.158	-991.06	-14.412
Interstitial	229.00	223.92	1.20	36.33	31.684	2217.879	28.001	-14.158	-991.06	-12.512
17	239.00	233.92	1.20	36.33	31.684	2217.879	34.377	-14.158	-991.06	-15.361
18	260.00	254.92	1.28	38.76	33.331	2333.182	44.914	-14.158	-991.06	-19.078
19	277.50	272.42	1.28	38.76	33.331	2333.182	40.247	-14.158	-991.06	-17.096
Penthouse	294.50	289.42	1.28	38.76	33.331	2333.182	19.832	-14.158	-991.06	-8.424

Figure 8: Wind Load Excel Sheet – East-West Direction

Floor	Elev	z	K_z	q_z	Windward (psf)	Windward (plf)	Windward (k)	Leeward (psf)	Leeward (plf)	Leeward (k)
1	5.08	0.00	0.57	17.26	18.712	4771.674	35.788	-23.448	-1641.37	-12.310
2	20.08	15.00	0.57	17.26	18.712	4771.674	68.792	-23.448	-1641.37	-23.663
3	33.92	28.83	0.66	19.98	20.566	5244.209	72.545	-23.448	-1641.37	-22.706
4	47.75	42.67	0.76	23.01	22.624	5769.247	79.808	-23.448	-1641.37	-22.706
5	61.58	56.50	0.81	24.53	23.654	6031.766	83.439	-23.448	-1641.37	-22.706
6	75.42	70.33	0.89	26.95	25.301	6451.797	89.250	-23.448	-1641.37	-22.706
7	89.25	84.17	0.93	28.16	26.125	6661.813	92.155	-23.448	-1641.37	-22.706
8	103.08	98.00	0.96	29.07	26.742	6819.324	94.334	-23.448	-1641.37	-22.706
9	116.92	111.83	0.99	29.98	27.360	6976.836	96.513	-23.448	-1641.37	-22.706
10	130.75	125.67	1.04	31.49	28.390	7239.355	100.144	-23.448	-1641.37	-22.706
11	144.58	139.50	1.09	33.00	29.419	7501.874	103.776	-23.448	-1641.37	-22.706
12	158.42	153.33	1.09	33.00	29.419	7501.874	103.776	-23.448	-1641.37	-22.706
13	172.25	167.17	1.13	34.22	30.243	7711.890	106.681	-23.448	-1641.37	-22.706
14	186.08	181.00	1.17	35.43	31.066	7921.905	109.586	-23.448	-1641.37	-22.706
15	199.92	194.83	1.17	35.43	31.066	7921.905	109.586	-23.448	-1641.37	-22.706
16	213.75	208.67	1.20	36.33	31.684	8079.417	117.488	-23.448	-1641.37	-23.868
Interstitial	229.00	223.92	1.20	36.33	31.684	8079.417	102.003	-23.448	-1641.37	-20.722
17	239.00	233.92	1.20	36.33	31.684	8079.417	125.231	-23.448	-1641.37	-25.441
18	260.00	254.92	1.28	38.76	33.331	8499.448	163.614	-23.448	-1641.37	-31.596
19	277.50	272.42	1.28	38.76	33.331	8499.448	146.615	-23.448	-1641.37	-28.314
Penthouse	294.50	289.42	1.28	38.76	33.331	8499.448	72.245	-23.448	-1641.37	-13.952

Figure 9: Wind Load Excel Sheet – North-South Direction

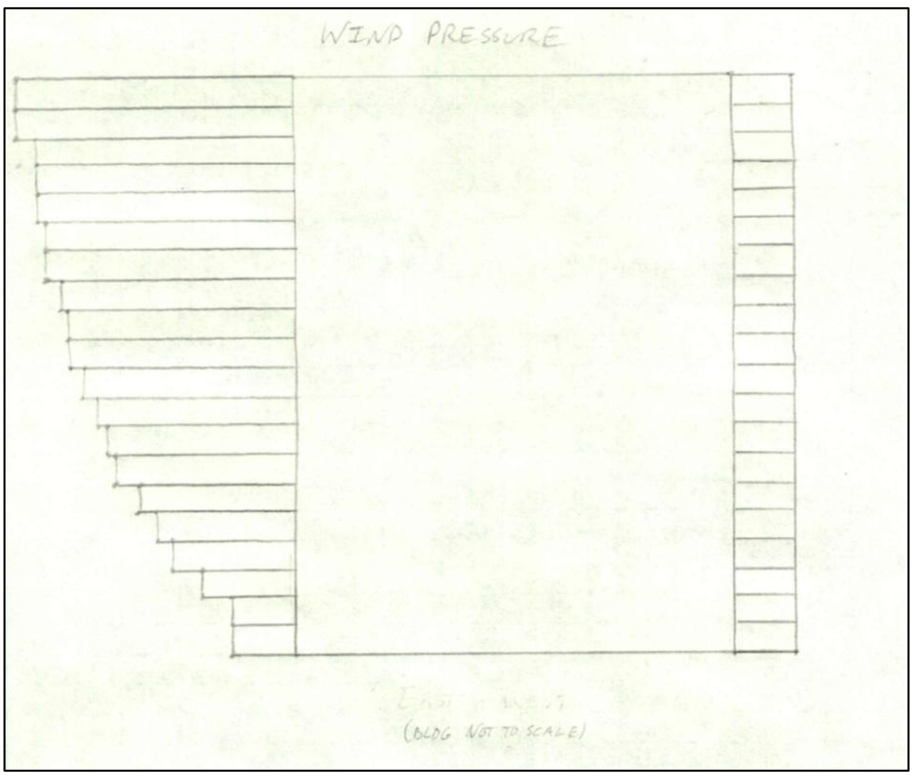

Figure 10: Wind Pressure Diagram

Floor	Force (k)	Height (ft)	Moment (k-ft)
1	17.257	0.00	0.00
2	33.172	15.91	527.92
3	33.624	16.37	550.32
4	35.618	18.36	653.97
5	36.615	19.36	708.77
6	38.210	20.95	800.59
7	39.007	21.75	848.41
8	39.605	22.35	885.11
9	40.203	22.95	922.52
10	41.200	23.94	986.47
11	42.197	24.94	1052.41
12	42.197	24.94	1052.41
13	42.995	25.74	1106.58
14	43.792	26.54	1162.03
15	43.792	26.54	1162.03
16	46.663	29.41	1372.20
Interstitial	40.513	23.26	942.16
17	49.739	32.48	1615.59
18	63.992	46.73	2990.63
19	57.343	40.09	2298.67
Penthouse	28.256	11.00	310.79
Total	855.990		21949.58

Floor	Force (k)	Height (ft)	Moment (k-ft)
1	48.098	0.00	0.00
2	92.455	44.36	4101.00
3	95.250	47.15	4491.31
4	102.513	54.42	5578.34
5	106.145	58.05	6161.42
6	111.955	63.86	7149.21
7	114.861	66.76	7668.42
8	117.040	68.94	8068.91
9	119.218	71.12	8478.90
10	122.850	74.75	9183.30
11	126.481	78.38	9914.09
12	126.481	78.38	9914.09
13	129.387	81.29	10517.70
14	132.292	84.19	11138.20
15	132.292	84.19	11138.20
16	141.356	93.26	13182.70
Interstitial	122.725	74.63	9158.60
17	150.672	102.57	15455.09
18	195.211	147.11	28718.00
19	174.929	126.83	22186.47
Penthouse	86.197	38.10	3284.03
Total	2548.409		205487.98

Figure 11: Wind Load Base Shear and Overturning Moment – East-West Direction (to the left), and North-South (to the right)

Seismic Load

For the seismic load evaluation of the Medical Research Building, the Equivalent Lateral Force Method as outlined in ASCE 7-05 was employed. The Site Class was determined to be A from Table 20.3-1 because the building sits on hard rock. An occupancy category of III resulted in an importance factor of 1.25 from Table 11.5-1. The Seismic Design Category based on short period response yielded Category B (Table 11.6-1), while the SDC based on 1 second period response yielded Category A (Table 11.6-2). To be conservative, Category B (the more severe category) was chosen. The Seismic Response Modification Factor, R, was labeled 4 on the drawings, which corresponds to the lateral resisting system of Ordinary Reinforced Concrete Shear Walls in Table 12.2-1.

The remainder of the procedure was followed resulting in a seismic base shear of approximately 980 kips. A spreadsheet developed in AE 597A was used to calculate the forces and moment at each floor as well as the overall overturning moment, calculated as 191,420 kip-ft.

Lateral System Analysis

Computer Model

A computer model of the Weill Cornell Medical Research Building was made in Etabs, a Computer and Structures Inc. modeling and analysis program. The purpose of this model was to determine the building's lateral drift and to determine the controlling wind load case. Only the elements of the lateral system and the diaphragms that hold them together were modeled. Figures 12 & 13 below feature a typical floor plan and a 3-D image of the computer model.

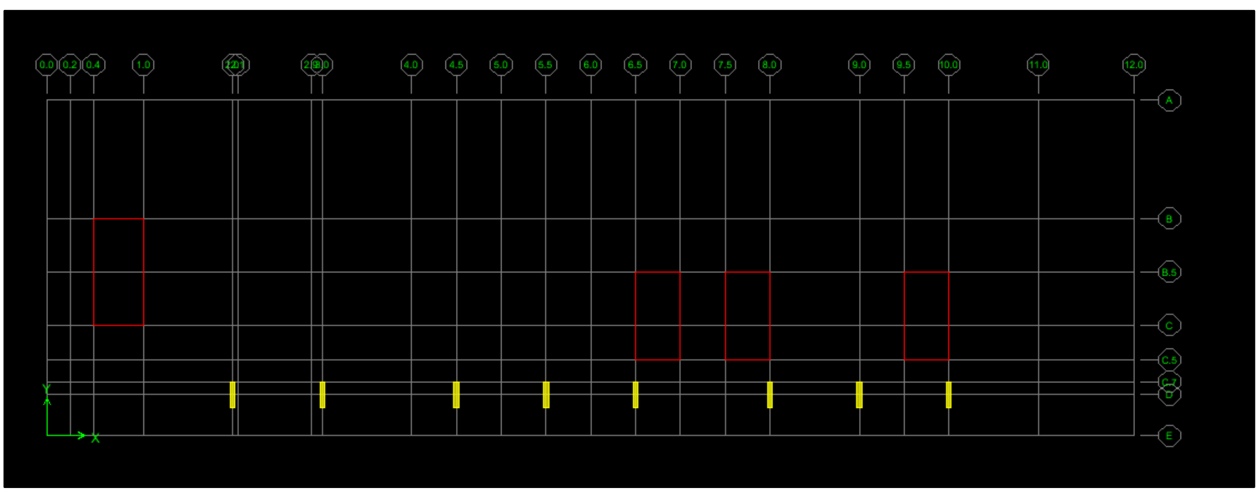

Figure 12: Typical Floor Plan in Etabs model

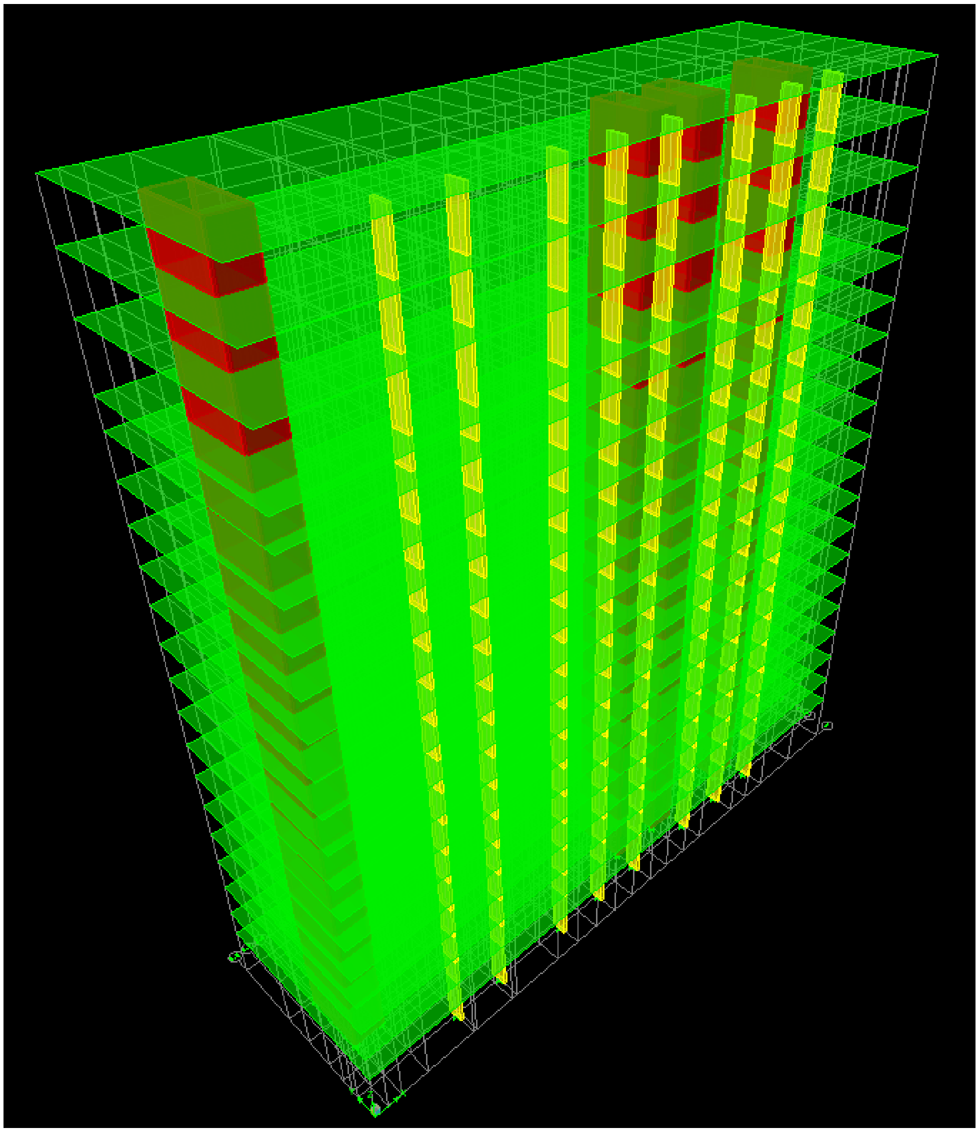

Figure 13: 3-D view from the South-West of the Etabs model

When analysis was attempted on the computer model, unknown errors occurred and no results could be obtained.

Relative Stiffness

Relative stiffness values for the shear walls and columns were calculated using an excel spreadsheet. Because the diaphragms are rigid, the distribution of lateral load is based on the relative stiffness of the elements. Due to the unavailability of the computer output of deflections due to a 1 kip load, the relative stiffness of the lateral elements was determined manually. First, stiffness and rigidity were found using a formula learned in AE 430 and AE 538 for fixed-end concrete shear walls (see table in Appendix). Next, relative stiffness was determined by applying a 1 kip lateral load to each element and using the relationship P=KU to determine the deflection. The ratio of the minimum deflection to the individual element's deflection provides the relative stiffness. See the table below (Figure 14) for relative stiffness values. The Shear Wall 1 core around the freight elevators is the stiffest, which makes sense because that shear wall core is the only one on the western half of the building, whereas the two Shear Wall 2 cores around the passenger elevators and the Shear Wall 3 core around the stairs are spaced closer together.

Relative Stiffness:	P (k)	K (k/in)	U (in)	K_{rel} (k/in)
14x72 Columns	1	188.034	0.005318	0.09542
SW1 E-W Elements	1	681.992	0.001466	0.34609
SW1 N-S Elements	1	1970.572	0.000507	1.00000
SW2 & SW3 E-W Elements	1	577.808	0.001731	0.29322
SW2 & SW3 N-S Elements	1	1558.018	0.000642	0.79064

Figure 14: Relative Stiffness calculation

Load Distribution

It was determined in the 1st Technical Report that wind load controls in the North-South direction and seismic loads control in the East-West direction. The tables below (Figures 15-18) show the results of distributing the direct and torsional shears to all of the lateral elements in both the North-South direction and the East-West direction. The stiffer elements, the North-South components of the shear wall cores, received more load. The maximum direct shear was approximately 12 kips seen in Shear Wall 1.

Direct Shear N-S:	R_i	R_i*V/ΣRi (kips)
SW1A	27588.003	12.151
SW1B	27588.003	12.151
SW1C	9547.881	4.205
SW1D	9547.881	4.205
SW2AA	24928.285	10.979
SW2AB	24928.285	10.979
SW2AC	9244.925	4.072
SW2AD	9244.925	4.072
SW2BA	24928.285	10.979
SW2BB	24928.285	10.979
SW2BC	9244.925	4.072
SW2BD	9244.925	4.072
SW3A	24928.285	10.979
SW3B	24928.285	10.979
SW3C	9244.925	4.072
SW3D	9244.925	4.072
Column D2.0	2632.478	1.159
Column D3.0	2632.478	1.159
Column D4.5	2632.478	1.159
Column D5.5	2632.478	1.159
Column D6.5	2632.478	1.159
Column D8.0	2632.478	1.159
Column D9.0	2632.478	1.159
Column D10.0	2632.478	1.159
Sum Total:	300370.857	132.292

Figure 15: Direct Shear in the North-South Direction

Torsional Shear N-S:	R_i	d_i	$V*e*d_i*R_i/J$ (kips)
SW1A	27588.003	118.811	0.8712
SW1B	27588.003	107.227	0.7863
SW1C	9547.881	10.267	0.0261
SW1D	9547.881	10.267	0.0261
SW2AA	24928.285	8.273	0.0548
SW2AB	24928.285	18.773	0.1244
SW2AC	9244.925	15.934	0.0392
SW2AD	9244.925	11.316	0.0278
SW2BA	24928.285	29.273	0.1940
SW2BB	24928.285	39.773	0.2635
SW2BC	9244.925	15.934	0.0392
SW2BD	9244.925	11.316	0.0278
SW3A	24928.285	71.273	0.4722
SW3B	24928.285	81.773	0.5418
SW3C	9244.925	15.934	0.0392
SW3D	9244.925	11.316	0.0278
Column D2.0	2632.478	124.352	0.0870
Column D3.0	2632.478	65.227	0.0456
Column D4.5	2632.478	33.727	0.0236
Column D5.5	2632.478	12.727	0.0089
Column D6.5	2632.478	8.273	0.0058
Column D8.0	2632.478	39.773	0.0278
Column D9.0	2632.478	60.773	0.0425
Column D10.0	2632.478	81.773	0.0572
Sum Total:	300370.857		3.8597

Figure 16: Torsional Shear in the North-South Direction

Direct Shear E-W:	R_i	$R_i*V/\Sigma R_i$
SW1A	27588.003	6.990
SW1B	27588.003	6.990
SW1C	9547.881	2.419
SW1D	9547.881	2.419
SW2AA	24928.285	6.316
SW2AB	24928.285	6.316
SW2AC	9244.925	2.343
SW2AD	9244.925	2.343
SW2BA	24928.285	6.316
SW2BB	24928.285	6.316
SW2BC	9244.925	2.343
SW2BD	9244.925	2.343
SW3A	24928.285	6.316
SW3B	24928.285	6.316
SW3C	9244.925	2.343
SW3D	9244.925	2.343
Column D2.0	2632.478	0.667
Column D3.0	2632.478	0.667
Column D4.5	2632.478	0.667
Column D5.5	2632.478	0.667
Column D6.5	2632.478	0.667
Column D8.0	2632.478	0.667
Column D9.0	2632.478	0.667
Column D10.0	2632.478	0.667
Sum Total:	300370.857	76.110

Figure 17: Direct Shear in the East-West Direction

Torsional Shear E-W:	R_i	d_i	$V*e*d_i*R_i/J$
SW1A	27588.003	118.811	2.5887
SW1B	27588.003	107.227	2.3364
SW1C	9547.881	10.267	0.0774
SW1D	9547.881	10.267	0.0774
SW2AA	24928.285	8.273	0.1629
SW2AB	24928.285	18.773	0.3696
SW2AC	9244.925	15.934	0.1163
SW2AD	9244.925	11.316	0.0826
SW2BA	24928.285	29.273	0.5763
SW2BB	24928.285	39.773	0.7830
SW2BC	9244.925	15.934	0.1163
SW2BD	9244.925	11.316	0.0826
SW3A	24928.285	71.273	1.4032
SW3B	24928.285	81.773	1.6100
SW3C	9244.925	15.934	0.1163
SW3D	9244.925	11.316	0.0826
Column D2.0	2632.478	124.352	0.2585
Column D3.0	2632.478	65.227	0.1356
Column D4.5	2632.478	33.727	0.0701
Column D5.5	2632.478	12.727	0.0265
Column D6.5	2632.478	8.273	0.0172
Column D8.0	2632.478	39.773	0.0827
Column D9.0	2632.478	60.773	0.1264
Column D10.0	2632.478	81.773	0.1700
Sum Total:	300370.857		11.4689

Figure 18: Torsional Shear in the East-West Direction

Drift

Due to the errors in the Etabs model, drift values for the building could not be obtained. The drift values would be compared to H/400 for wind load and $0.015h_{sx}$ for seismic loads.

Conclusion

The errors in the computer model prevented a full analysis of the lateral systems in this report. The only thing that could be investigated was the stiffness, relative stiffness, and distribution of loads.

Appendix A: Seismic Load

Jonathan Coan | AE Senior Thesis | Seismic Loads | 1

ASCE 7-05
Equivalent Lateral Force method

Fig 22-1: $S_S = 35\%g$ for NYC
Fig 22-2: $S_1 = 6\%g$ for NYC

Table 20.3-1: Site Class A (Hard Rock)

Table 11.4-1: $F_a = .8 \Rightarrow S_{MS} = F_a S_S = .8(.35) = .28$
Table 11.4-2: $F_v = .8 \Rightarrow S_{M1} = F_v S_1 = .8(.06) = .048$

$$S_{DS} = \frac{2}{3} S_{MS} = \frac{2}{3}(.28) = .187$$
$$S_{D1} = \frac{2}{3} S_{M1} = \frac{2}{3}(.048) = .032$$

Table 1-1: Occupancy Category III
Table 11.5-1: $I = 1.25$

Table 11.6-1: $SDC = B$ $\Rightarrow$ use $SDC = B$
Table 11.6-2: $SDC = A$

Table 12.2-1: $R = 4$

Table 12.8-2: $C_t = .02$, $x = .75$

$$T = C_t h_n^x = .02(294.5)^{.75} = 1.42 \text{ sec}$$

Fig 22-15: $T_L = 6 \text{ sec} \Rightarrow T < T_L$

$$C_s = \frac{S_{DS}}{R/I} = \frac{.187}{\frac{4}{1.25}} = .058 < \frac{S_{D1}}{(R/I)T} = \frac{.032}{\frac{4}{1.25}(1.42)} = .007$$

$C_s = .01$ calculated separately

$$V = C_s W = .01(97,960) = \boxed{979.6 \text{ kips}}$$

Base Shear

$$F_x = C_{vx} V \qquad C_{vx} = \frac{w_x h_x^k}{\sum_{i=1} w_i h_i^k}$$

(by interpolation) $k = 1.46$

See spreadsheet on p5 for the rest of the calculations

Level	Height (ft)	Weight (k)	$w*h^k$	C_{vx}	F_i (k)	V_i (k)	M (k-ft)
Penthouse	294.50	318.29	1281420	0.0106	10.42	10.42	3069.51
19	277.50	1669.14	6161082	0.0512	50.11	60.54	13906.32
18	260.00	4997.25	16772289	0.1393	136.42	196.96	35469.73
17	239.00	5402.93	16035778	0.1331	130.43	327.39	31173.11
Interstitial	229.00	3547.31	9891438	0.0821	80.45	407.84	18424.14
16	213.75	4091.69	10317278	0.0857	83.92	491.76	17937.56
15	199.92	4091.69	9357110	0.0777	76.11	567.87	15215.39
14	186.08	4091.69	8427041	0.0700	68.54	636.41	12754.83
13	172.25	4091.69	7528261	0.0625	61.23	697.65	10547.42
12	158.42	4091.69	6662105	0.0553	54.19	751.84	8584.29
11	144.58	4091.69	5830084	0.0484	47.42	799.26	6856.23
10	130.75	4091.69	5033929	0.0418	40.94	840.20	5353.54
9	116.92	4091.69	4275646	0.0355	34.78	874.98	4066.03
8	103.08	4091.69	3557602	0.0295	28.94	903.92	2982.90
7	89.25	4091.69	2882639	0.0239	23.45	927.36	2092.62
6	75.42	4091.69	2254263	0.0187	18.34	945.70	1382.81
5	61.58	4091.69	1676944	0.0139	13.64	959.34	839.99
4	47.75	4214.07	1191249	0.0099	9.69	969.03	462.67
3	33.92	4598.03	788815.4	0.0065	6.42	975.44	217.61
2	20.08	6402.62	511090.6	0.0042	4.16	979.60	83.49
				Base Shear:	979.60	Total Mom:	191420.19

Appendix B:
Wind Load

Jonathan Coan | AE Senior Thesis | Wind Load | 1

ASCE 7-05

Basic Wind Speed (Fig 6-1C): 110mph
Exposure Category (From Plans): B
Occupancy Category (Table 1-1): III

K_z = See spreadsheet
$K_{zt} = 1.0$
$K_d = .85$ (Table 6-4)
$V = 110$mph
$I = 1.15$ (Table 6-1)

$q_z = .00256\, K_z K_{zt} K_d V^2 I$
See spreadsheet for calculations

Assume: Rigid Structure $\Rightarrow G = .85$
Figure 6-5: $GC_{pi} = \pm .18$
Figure 6-6: $C_p = .8$ (windward)
$C_p = -.5$ (leeward) N-S, $-.218$ E-W (from interpolation ($L/B = 3.64$))
$p = q\,GC_p - q_h(GC_{pi})$

See spreadsheet for calculations

Appendix C:
Stiffness/Rigidity, Center of Rigidity, and Load Distribution

Stiffness/Rigidity:	E (ksi)	h (in)	b (in)	K = E/((h/b)^3+3h/b) (k/in)	t (in)	R = K*t
14x72 Columns	3605	166	72	188.034	14	2632.478
SW1 E-W Elements	3605	166	139	681.992	14	9547.881
SW1 N-S Elements	3605	166	300	1970.572	14	27588.003
SW2 & SW3 E-W Elements	3605	166	126	577.808	16	9244.925
SW2 & SW3 N-S Elements	3605	166	247.5	1558.018	16	24928.285

	R_i	x_i	R_i*x_i	y_i	R_i*y_i	d_i	$R_i*d_i^2$
SW1A	27588.003	11.042	304617.54	38.417	1059839.126	118.811	389432126.027
SW1B	27588.003	22.625	624178.57	38.417	1059839.126	107.227	317199132.080
SW1C	9547.881	16.833	160722.67	25.917	247449.253	10.267	1006432.766
SW1D	9547.881	16.833	160722.67	50.917	486146.281	10.267	1006432.766
SW2AA	24928.285	138.125	3443219.43	24.792	618013.744	8.273	1705981.249
SW2AB	24928.285	148.625	3704966.43	24.792	618013.744	18.773	8784970.141
SW2AC	9244.925	143.375	1325491.06	11.167	103234.991	15.934	2347084.876
SW2AD	9244.925	143.375	1325491.06	38.417	355159.185	11.316	1183922.642
SW2BA	24928.285	159.125	3966713.43	24.792	618013.744	29.273	21360645.982
SW2BB	24928.285	169.625	4228460.42	24.792	618013.744	39.773	39433008.772
SW2BC	9244.925	164.375	1519634.47	11.167	103234.991	15.934	2347084.876
SW2BD	9244.925	164.375	1519634.47	38.417	355159.185	11.316	1183922.642
SW3A	24928.285	201.125	5013701.42	24.792	618013.744	71.273	126630218.832
SW3B	24928.285	211.625	5275448.42	24.792	618013.744	81.773	166689329.416
SW3C	9244.925	206.375	1907921.30	11.167	103234.991	15.934	2347084.876
SW3D	9244.925	206.375	1907921.30	38.417	355159.185	11.316	1183922.642
Column D2.0	2632.478	5.500	14478.63	9.667	25447.292	124.352	40707395.979
Column D3.0	2632.478	64.625	170123.92	9.667	25447.292	65.227	11200186.311
Column D4.5	2632.478	96.125	253047.00	9.667	25447.292	33.727	2994546.766
Column D5.5	2632.478	117.125	308329.04	9.667	25447.292	12.727	426427.941
Column D6.5	2632.478	138.125	363611.09	9.667	25447.292	8.273	180155.148

Column D8.0	2632.478	169.625	446534.16	9.667	25447.292	39.773	4164207.266
Column D9.0	2632.478	190.625	501816.21	9.667	25447.292	60.773	9722549.550
Column D10.0	2632.478	211.625	557098.26	9.667	25447.292	81.773	17602737.865
Sum Totals:	300370.857		39003882.98		8140117.115		1170839507.413

Center of Rigidity:	(129.9 , 27.1)

Center of Mass:	(127.5 , 39.25)

e_x =	2.3524	ft
e_y =	12.1498	ft
J =	1170839507.4	k-ft/in

$V_{wind, N-S}$ =	132.292	kips
$V_{seismic, E-W}$ =	76.11	kips