Senior Thesis Final Report

Bryan Darrin – Structural Option
Thesis Advisor – Dr. Linda Hanagan
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Millennium Hall

At Drexel University

Architectural

Architect: Erdy McHenry Arch.

The Millennium Hall building sits on a confined site requiring a very small footprint. This constraint forced the building seventeen stories into the air so it could accommodate 241 dorm rooms. Containing all of its utilities and structural elements in a central core, the design of the building allows the rooms to radiate outward and be free of any obstructions to the beautiful surrounding views. The building's spiraling effect comes from offsetting each floor.

General

Location: Philadelphia, PA

Owner: Drexel University

Size: 153,000 SF/17 Stories

Cost: $42 Million

Occupancy: Residency Hall

Date of Construction:

Aug. 2006 - Aug. 2009

Construction Manager:

InTech Construction

Civil Engineer:

Pennoni Associates

Structural

Structural Engineer: The Harman Group

Two main systems make up the building's structure. The majority of the ground floor is a steel moment frame supporting a slab on metal deck. The design of the tower utilizes a reinforced concrete one way slab system. Two radial lines of columns circle the central core and provide all of the strength for the tower's gravity load. These 22" x 58" columns spaced approximately 10' apart extend the entire seventeen story height. Beams connect each column and provide strength for the supported slabs, which cantilever outward 15' to the exterior of the building. Lateral forces are resisted using ordinary concrete shear walls and moment frames.

MEP

MEP Engineer: AKF Engineers

The MEP system for the building uses a highly efficient design. Geothermal heat pumps provide cooling in the summer and heating in the winter. 89 cooling units are located ranging in size from 15. to 5 tons. Supply fans are variable frequency drive. The main power supply comes through a 3000-amp substation located on the first floor. The majority of the building uses compact fluorescent light fixtures. Metal halide light fixtures provide light on the exterior of the building.

Bryan Darrin

Structural Option

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Table of Contents

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I would also like to thank my great friends who worked along side me, and especially my family for all of their encouragement and support.

EXECUTIVE SUMMARY

The Millennium Hall building is a seventeen story residence hall on the Drexel campus in Philadelphia, PA. Construction completed in 2009. The building's stunning look comes from its fish eye shaped floor plan and its dramatic aluminum and glass curtain wall.

The building used cast in place concrete to create a flat plate structural system. With columns only on the interior of the building, the concrete floor slabs cantilever out fifteen feet to the exterior of the building. All of the buildings vertical circulation and utilities are located in the central core of the building.

The building is very heavy and with such long cantilevered slabs, the floor system has become very thick to accommodate for the high forces it creates. To explore the feasibility of an alternate system, one which could remove the high forces and reduce the overall weight of the building, a steel frame system was examined.

The gravity system was maximized for weight by analyzing the floor system for superimposed dead and live load, and using a composite steel and concrete deck. The height of the floor system was able to remain as thin as possible, while reducing significant weight.

The building was then analyzed for lateral forces of wind and seismic. Braced frames were introduced to replace the heavier shear walls, further lightening the building. The braced frames were analyzed to ensure that the deflections the building would have under these loads would fall within the allowable limits, providing a safe design.

The foundation was checked for adequate strength and it was found that the existing foundation caissons could be reduced in most areas of the building, since the force to each one had been reduced due to the buildings new weight.

The architectural layout and appearance were considered as a way to examine how the structural redesign would impact other systems in the building. It was found that minimal changes to the floor plan would have to be made.

Finally impacts of construction cost and timeline were examined to see if the structural redesign could really be feasible. It was found that although cost of the structural system was increased, the construction timeline was reduced significantly, which in the long run could have added benefits and saving throughout the remainder of construction.

BUILDING OVERVIEW

Millennium Hall is the newest residence hall on the Drexel University Campus located in Philadelphia, Pennsylvania. Built among existing residence halls made from brick and stone, its dramatic glass façade makes the building stand out from the surroundings. The building's contrast also comes from its unique shape, a slender tower appearing to spiral upwards. This was accomplished by offsetting each floor about the building's central core by 10 inches, creating a bold statement for the university. Millennium Hall symbolizes Drexel's commitment towards the future and embraces their great history of engineering and architecture.

Required to house 482 students, the building's main design came from its main constraint, the 20,000 square foot site. Originally a lot containing 3 tennis courts, Millennium Hall had to rise upward, reaching 17 stories. The ground floor takes up most of the lot and contains the main lobby, elevator bank, reception area, a small lounge, offices and storage space. Attached to this base is the tower, where all of the student living facilities are located. Each floor includes 16 two person dorm rooms, individual shower and restrooms, shared kitchen and a study space. The 17th floor is a study lounge providing unobstructed views of the campus and the city skyline of Philadelphia. All of this is achieved in the tower's compact 5,000 square foot layout.

The majority of the building is clad with a combination of a glass and aluminum. These reflective surfaces catch the light and reflections off the neighboring buildings, quickly catching and drawing your eye towards it. The curtain wall allows maximum natural light to enter the dorm rooms and providing pleasing views for the students. Aluminum rain screen panels give the building a unique look and provide enough cover to the curtain wall to achieve an acceptable level of privacy to the rooms. These panels also work as solar shades, further reducing the building's cooling load.

The structural system for Millennium Hall uses two main types. A steel frame holding a slab on metal deck forms the ground floor and supports a green roof over the office and storage area. The tower is comprised of a cast in place concrete flat plate system. Two radial lines of concrete columns circle the central core and provide all of the strength for the tower. These columns extend the entirety of the building. Beams were then added between the columns to provide torsional strength for the slab. Each floor slab is then cantilevered outward 15 feet to the exterior of the building. Lateral forces are resisted by ordinary concrete shear walls in one direction and ordinary concrete moment frames in the other.

EXISTING STRUCTURAL SYSTEM

Foundation Design

A geotechnical Report was prepared by Pennoni Associates, Inc. on March 12th, 2008. It concluded with the following:

- Spread footings and continuous wall footings shall be designed for a net allowable bearing pressure of 6 KSF.
- Drilled piers (caissons) shall be designed for a net allowable bearing pressure of 60 KSF.

With the absence of any sub grade levels, the Millennium Halls foundation consist of only spread footings for the ground floor load and fourteen caissons to support the tower's gravity load. (See Figure 1.1)

Below is a layout of the basic foundation elements for the tower. The drilled caissons are represented as red circles and the outline of the grade beams are shown in blue.

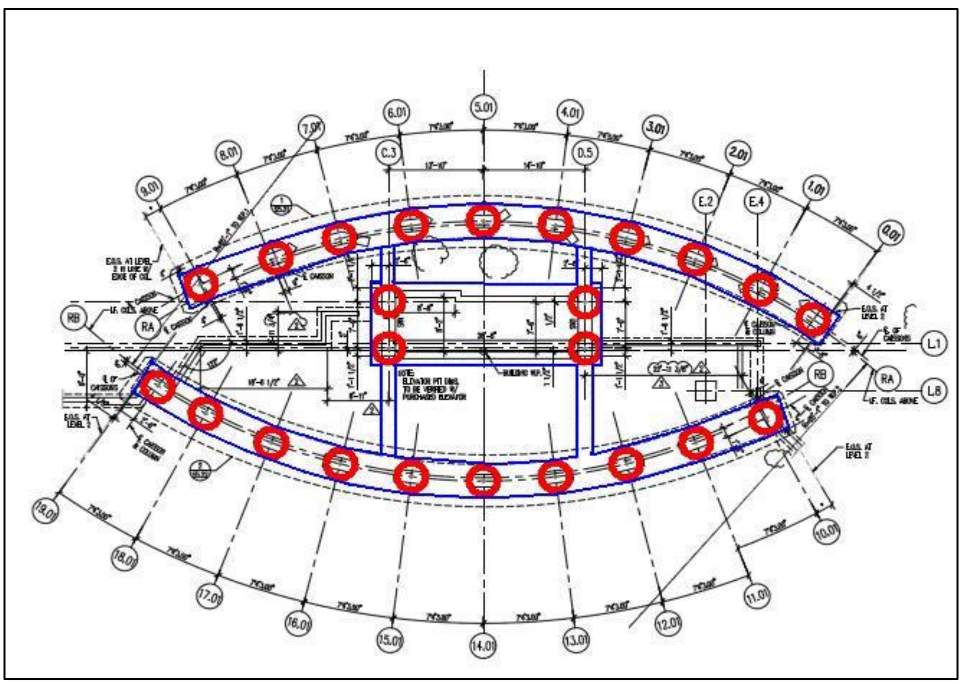


Figure 1.1

These caissons, spaced approximately 10 feet apart, are 5 feet in diameter, giving each one a bearing strength of 1200 Kips. (See Figure 1.2) Running along the line of these caissons is a 30 inch by 60 inch grade beam, reinforced with 4 - #8 on the top and bottom and #5 stirrups spaced at 12 inches. (See Figure 1.3)

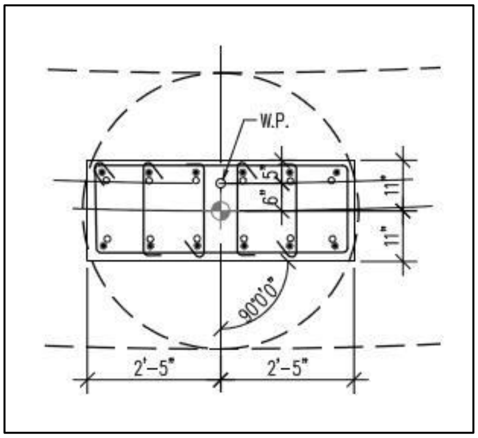


Figure 1.2

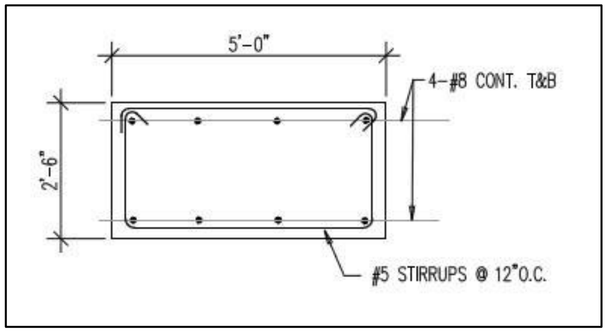


Figure 1.3

The towers twenty reinforced concrete columns sit directly on top of the perimeter caissons and are tied together with grade beams using#5 stirrups at 12 inches on center. This grade beam continues through the building as spread footings to provide strength for the first floors steel structure. The remaining four caissons located towards the center of the building at the elevator core are used to secure the reinforced concrete shear walls. These shear walls are connected to the grade beam and caisson in a way similar to the column connections. (See Figure 1.4)

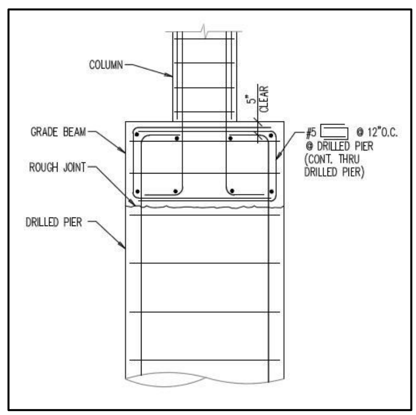


Figure 1.4

Column Design

The millennium Hall's tower is supported by ten concrete columns which circle around the core. This typical beam is 22 inches by 60 inches and extends the entire height of the tower. Each column is directly supported by one of the foundations caissons.

Floor Framing System

Each floor slab is cantilevered outward from the column line 15 feet. This 12 inch slab is reinforced in the east west direction with #4 bar spaced at 18 inches top and bottom. #6 bars spaced at 20 inches on the bottom and #7 bars at the top spaced 7.5 inches reinforce the north/south direction. A typical slab connection to both the column and beams between columns can be seen below. (See Figure 2.1/2.2) The slab located between the column lines is 14 inches thick and is reinforced with #4 bar spaced at 15 inches top and bottom in the east/west direction and #4 bar at 18 inches on the bottom in the north/south direction.

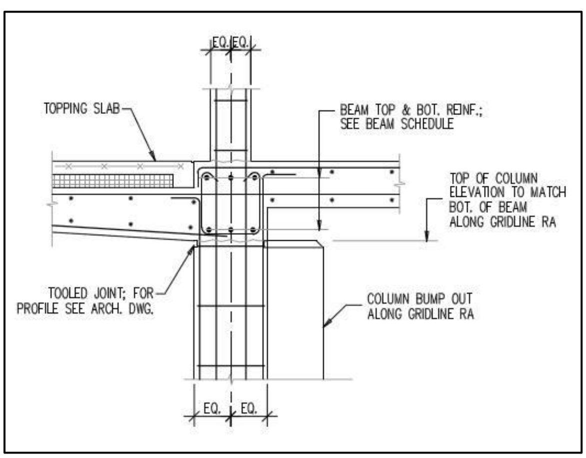


Figure 2.1

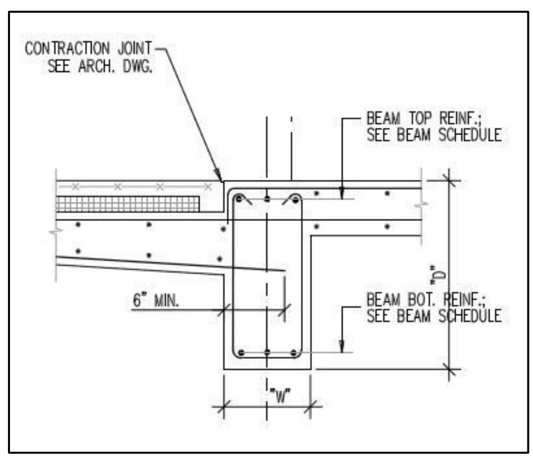


Figure 2.2

Lateral System

Lateral forces in the tower are resisted using an interactive system with ordinary reinforced concrete shear walls and ordinary reinforced concrete moment frame. The shear walls are located at the center of the building in the elevator core, reinforced by splicing a series of #11 steel rebar. (See Figure 3.2) All shear walls from the ground floor to the fourth floor support a compressive strength of 7000 psi. From the fourth floor upward 5000 psi concrete is used. On the ground floor's steel frame, a steel moment connection is used. (See Figure 3.1)

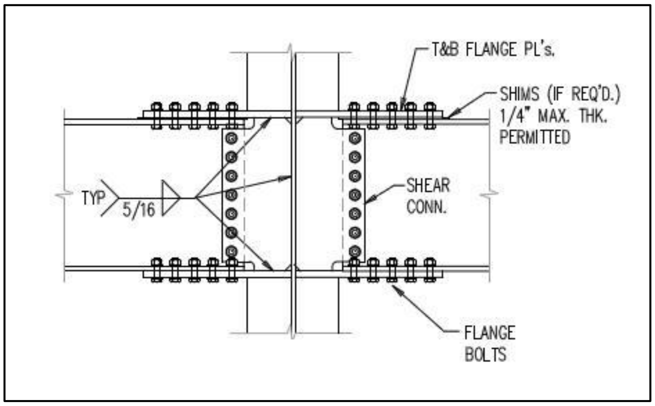


Figure 3.1

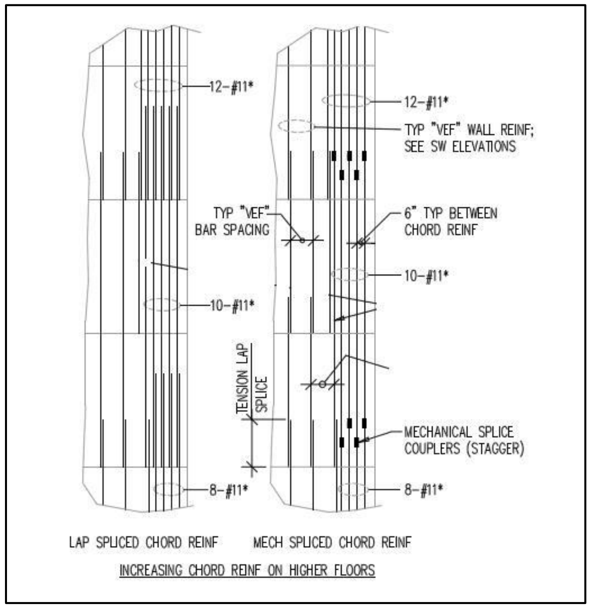


Figure 3.2

Envelope Support

The building's curtain wall and aluminum rain screen panels are connected in two main ways to the building structure. On the first level the wall hangs from the slab on metal deck assembly that is supported by the ground levels steel frame. This is accomplished with 10 gauge metal plate that has been bent.

The plate, which runs continuously along the wall, is secured to the slab on metal deck using shear bolts and is reinforced with 4 foot #4 spaced at 12 inches and fastened to the curtain wall with screws placed at 12 inches. (See Figure 4.1) This bent plate runs continuously along the face of the slab.

The second type of connection is found on the tower where shear bolts embedded into the concrete slab support the curtain wall as well as the aluminum rain screen panels. These bolts connect directly to tabs specified by the curtain wall manufacturer. The slab edge is reinforced with #3 hoops spaced at a minimum of 3 inches that extend 2 feet into the slab. (See Figure 4.2)

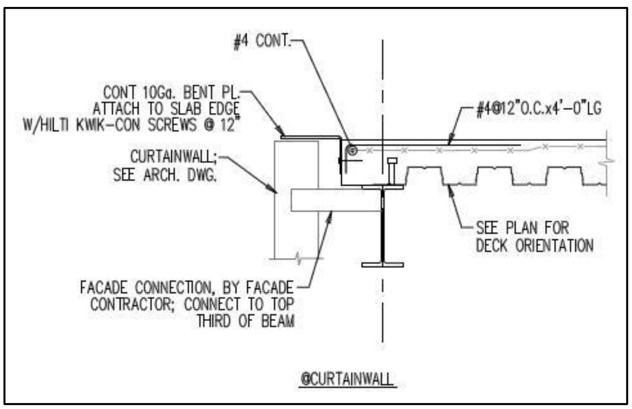


Figure 4.1

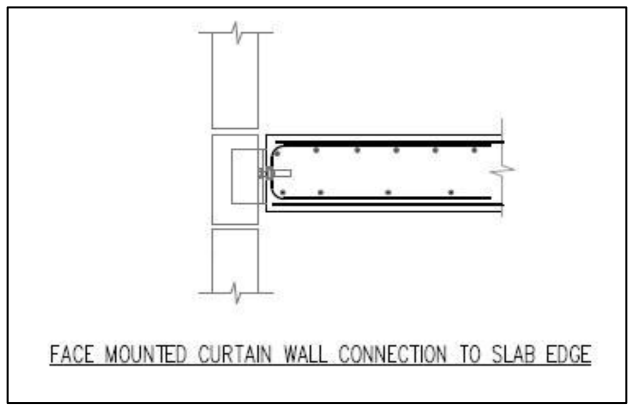


Figure 4.2

PROBLEM STATEMENT

Three structural system studies have been completed for the Millennium Hall building. Separate analyses on the lateral forces, lateral resisting systems, and alternate gravity systems have shown the Millennium Hall design is very efficient. The flat plate floor slab works well with the unique floor plan and curved column line. It also provides adequate strength for the cantilevered section of floor while still maintaining a shallow floor system depth, keeping the overall building height to a minimum.

In Tech Report I, the design of the framing members, floor system, and lateral system all exceeded the design requirements for ASCE 07. In Tech Report II, the flat plate system proved to be the most efficient and effective of the four floor systems analyzed. Tech Report III proved that the lateral force resisting system of the reinforced concrete moment frames and reinforced concrete shear walls were sufficient to carry the controlling lateral loads. Because of this successful and efficient design, the final alternate system proposed may not be the best. The will be to find a design that is about equally as efficient to prove that there are always options to consider when designing a structure such as Millennium Hall residence building.

The greatest area to be improved on the existing structure is the heavy weight of the building. With large cantilevered slabs, the floor system has become very thick, and with solid concrete has become very heavy. Thick shear walls also add to the immense weight of the building.

To determine if an alternate proposed design is successful, it will be compared to the existing structure through many aspects, including strength, serviceability, cost, scheduling and architectural success.

PROJECT SOLUTION

The proposed solution for the Millennium Hall building is to move the existing column lines to the exterior of the building. This will allow the building to be redesigned using a steel frame with composite steel deck. This will affect the buildings architectural design and the cost and schedule for the structural system.

Structural Depth

The existing floor system experiences high moment forces due to the 15 foot cantilever that extends around the perimeter of the building. To try and reduce these loads while maintaining the same building floor plan, the column line will be moved to the exterior eliminating the cantilevered floor slab. This will increase the overall span by 15 feet but with the small footprint the building has, this increased span will still be 35 feet, which can be still be safely designed with steel.

To help with this span, a concrete composite steel deck will be used, which after being analyzed in Tech II, will provide the strength required while keeping the floor system thickness to a minimum, which will be necessary with the 18 story building. The interior end of this floor system will be supported with a second added column line which will frame out the elevator core. Short girders between these will allow the long span girders to be attached while at the required 7 degree angle.

These short girders and exterior beams will be connected to the column using steel moment connections. This will create the steel moment frame. The elevator core will still need to be used as an area to add steel braced frames, since the steel moment frame will not be adequate to resist lateral loads alone. These steel braced frames with be designed to optimize their weight in contrast to the stiffness they provide the tall and slender building.

PROJECT GOALS

Through this study, the following goals are to be addressed and completed:

1. Reduce the weight of the overall building by optimizing the gravity system

2. Optimize the lateral force resisting system in coordination with the gravity system

3. Verify the impact on the foundation system

4. Determine the impact on the architectural design including floor plan layout

5. Determine the impact that the redesign has on the construction schedule and cost of the building

This redesign may result in a structural system that is less optimized than the existing system, but this alternate system was selected as an exercise to explore other options than the concrete system used.

The twisting floor offset of the original building has been removed to allow a more simple design solution and to reduce complicated calculations, since this unique element is not the main focus. The redesign should not be compared to the actual building, since this element was not taken into consideration throughout the existing system technical reports completed last semester.

STRUCTURAL STUDY (DEPTH)

The following is the complete structural redesign of the Millennium Hall residence building, including a preliminary gravity system, a lateral system revised for lateral design loads, and a verified foundation design.

GRAVITY SYSTEM REDESIGN

The gravity system has been completed in three steps. First gravity loading and load combinations have been determined. Then, using these loads, initial member sizes can be calculated by hand, and finally checked using RAM to verify member sizes, resulting in an initial gravity system design.

DESIGN LOADS

The gravity system has been designed using load values determined in the Technical Reports and load combinations are in accordance with ASCE7-05. A chart of design loads can be seen below.

Gravity Loads		
Load Type	**Description**	**Design Load**
Superimposed D.L.	Partitions	20 psf
	Suspended MEP	15 psf
	Topping Slab	50 psf
	Façade	150 plf
Live Load	Lobbies	100 psf
	Public Area	100 psf
	Residence Room	40 psf

For the design of the composite steel deck, the following loads were used from the previous chart.

Loads: SDL = 20 psf + 15 psf = 35 psf

LL = 100 psf (majority of floor is public area, so 100psf was used as a conservative value)

Load Combo: 1.2 DL + 1.6 LL

DESIGN PROCESS

The design begins with the new layout of the structural system, which moves the existing column line to the exterior and introduces a new line of columns at the buildings center. (See Figure 5.1)

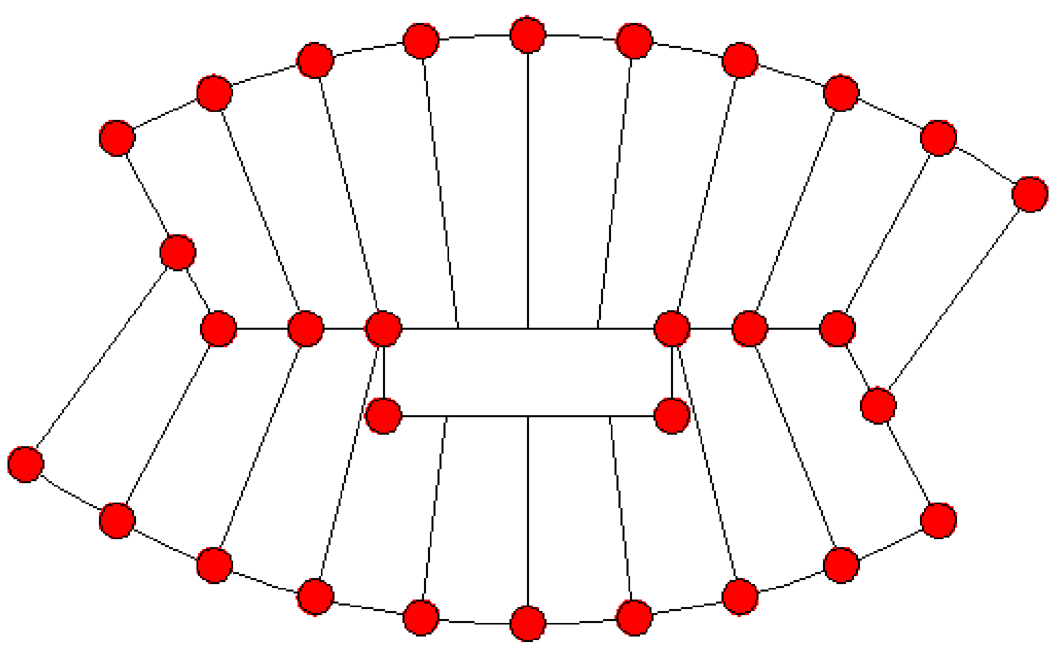


Figure 5.1

Preliminary member sizes have been determined using hand calculations. To model this, a typical bay has been converted so members would be adequate for the largest distances. (See Figure 5.2)

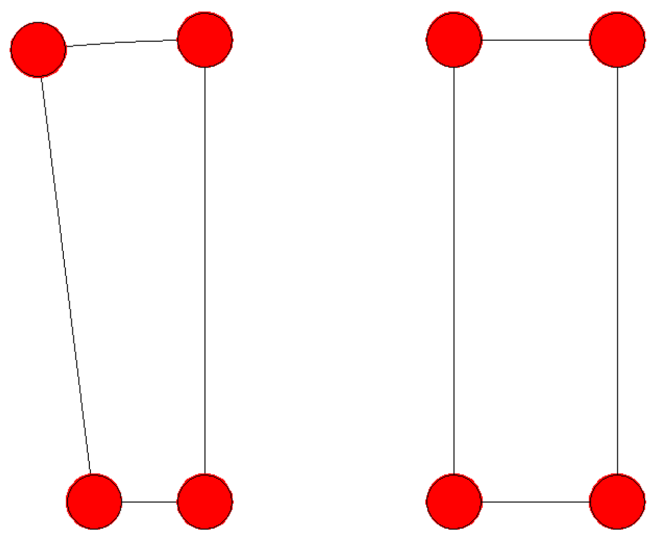


Figure 5.2

The Vulcraft catalog for composite deck design was used to determine deck gauge and floor system self weight. A 3VLI16 gauge deck has been selected. The self weight of this deck was found to be 44 psf. See Appendix A.

Using the load combination listed previously, and an assumed beam self weight of 5 psf, a distributed load has been determined for a typical beam. See Appendix B. A load of 3.13 kips per linear foot was determined, resulting on a beam moment of 452 foot-kips.

From AISC 3-19, a composite section with a W16x45 was found to be adequate for strength, with a total of 32 studs placed at 12 in. This section was then checked for live load deflection as well as wet concrete construction, and both were found within the acceptable limits. See appendix B.

The system uses two main girders around the elevator core to distribute beam loads around the elevator openings to the columns. In this process the girders will be referred to as shown below. (See Figure 5.3)

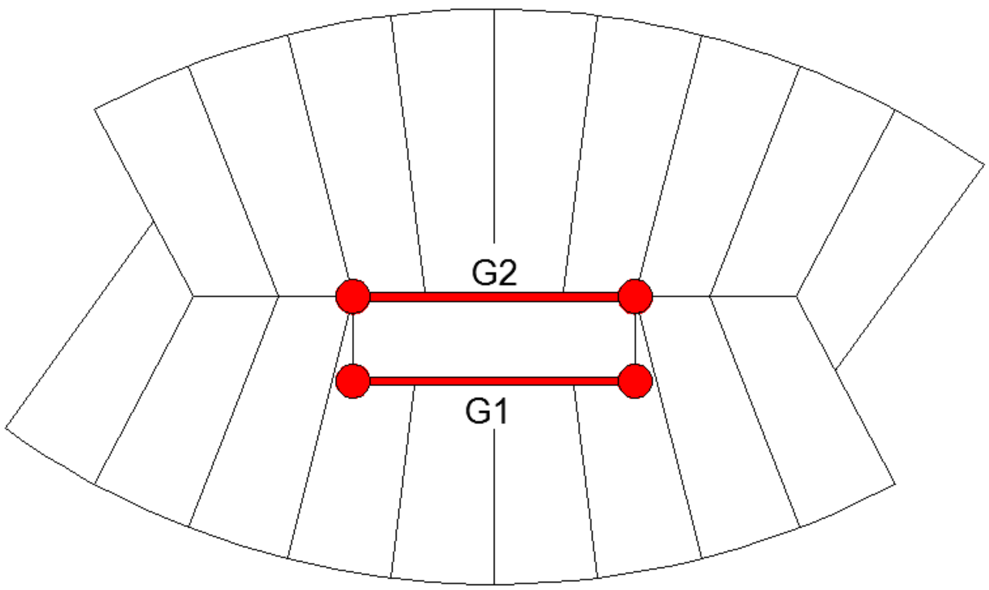


Figure 5.3

Girders G1 and G2 were designed in a similar manner, with each having three point loads from beams framing into them. Each girder is modeled as seen below. (See Figure 5.4) Point loads calculated for G1 and G2 are 37.6 kips and 53.2 kips respectively. This loading pattern resulted in maximum moments of 492 foot-kips and 762 foot-kips.

Using AISC 3-10, it was determined that a W21x68 would be adequate for G1 strength and a W24x84 for G2. These calculations can be found in Appendix B.

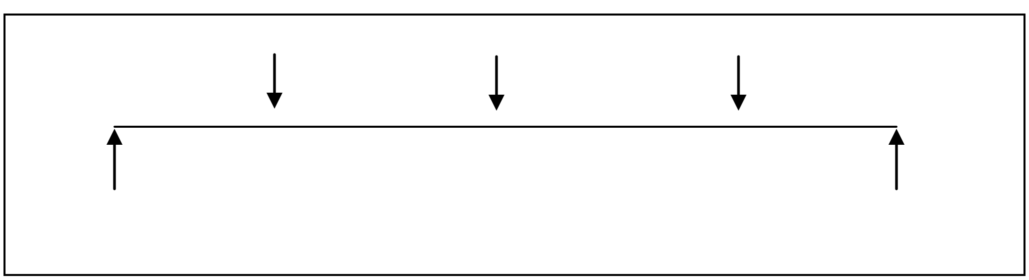


Figure 5.4

From these member sizes, a preliminary framing plan can be seen below. (See Figure 5.5)

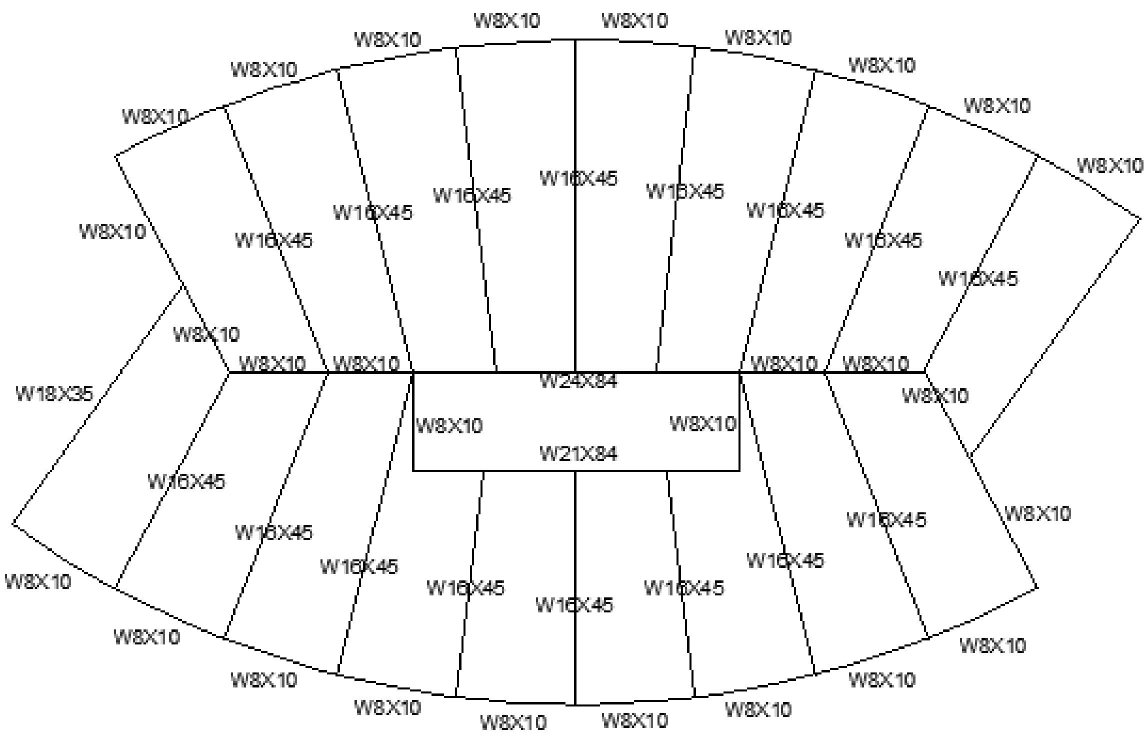


Figure 5.5

RAM MODEL

To verify the member sizes determined by hand calculations, a RAM model was prepared. The same loading was applied as an area load and the floor system was analyzed. The resulting member sizes were found to be slightly smaller than those calculated. Since the hand calculations were on the conservative side, due to estimations in tributary width of the bays, these smaller member sections seem consistent and have been accepted as correct for the remainder of this design. (See Figure 6.1)

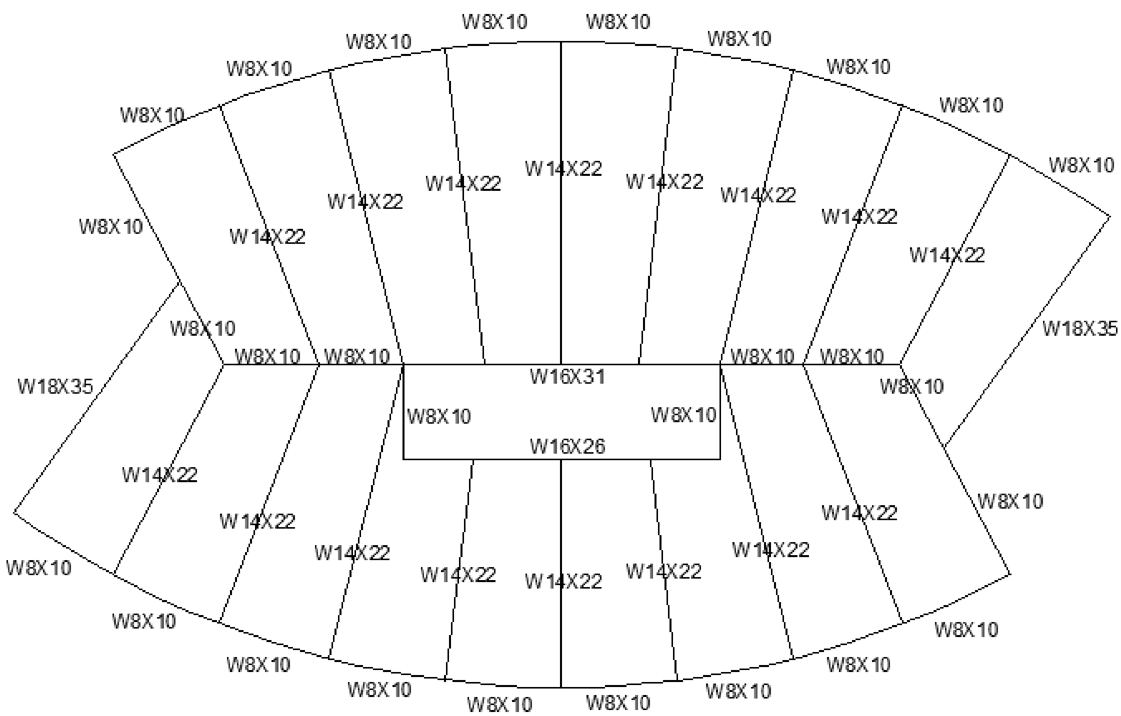


Figure 6.1

Next Ram was used to approximate column size when each floor system was modeled. The column sizes are tabulated and can be found in Appendix C. A sample of these tables can be found below, (See Figure 6.2), for a single column line for all 17 stories. These sections were later used in the ETABS model used to analyze lateral resistance.

Column Line B-5

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	6.6	3.4	0.2	1	0.05 Eq (H1-1b)	90.0	50	W10X33
level 16	13.1	1.7	0.1	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 15	19.7	1.7	0.1	1	0.09 Eq (H1-1b)	90.0	50	W10X33
level 14	26.2	1.7	0.1	1	0.12 Eq (H1-1b)	90.0	50	W10X33
level 13	32.8	1.7	0.1	1	0.15 Eq (H1-1b)	90.0	50	W10X33
level 12	39.4	1.7	0.1	1	0.18 Eq (H1-1b)	90.0	50	W10X33
level 11	45.9	1.7	0.1	1	0.23 Eq (H1-1a)	90.0	50	W10X33
level 10	52.5	1.7	0.1	1	0.26 Eq (H1-1a)	90.0	50	W10X33
level 9	59.0	1.7	0.1	1	0.29 Eq (H1-1a)	90.0	50	W10X33
level 8	65.6	1.7	0.1	1	0.32 Eq (H1-1a)	90.0	50	W10X33
level 7	72.2	1.7	0.1	1	0.35 Eq (H1-1a)	90.0	50	W10X33
level 6	78.7	1.7	0.1	1	0.38 Eq (H1-1a)	90.0	50	W10X33
level 5	85.3	1.7	0.1	1	0.41 Eq (H1-1a)	90.0	50	W10X33
level 4	91.8	1.7	0.1	1	0.44 Eq (H1-1a)	90.0	50	W10X33
level 3	98.4	1.7	0.1	1	0.46 Eq (H1-1a)	90.0	50	W10X33
level 2	104.9	2.2	0.1	1	0.50 Eq (H1-1a)	90.0	50	W10X33
level 1	112.0	1.1	0.2	1	0.97 Eq (H1-1a)	90.0	50	W10X39

Figure 6.2

DESIGN SUMMARY AND CONCLUSION

The new structural system's design for gravity began with the defined loads. These superimposed dead and live loads, as determined in previous tech reports, were applied to the metal deck. The deck, which was picked so no bracing would be required during construction, was sized to resist these loads. Once this was done, sizing of the supporting members could be calculated by hand.

Ram was then used to verify these member sizes. The sizes were found to be similar enough to verify them as accurate. Column sizes were then determined using the weight of each floor system. The two methods resulted in an initial framing floor plan for gravity.

Meeting all the requirements for strength and deflection, the gravity plan shows a lightweight and simple design option, compared to the existing concrete plan. Moving the columns has removed the large cantilevered slab, as well as reduced the amount of concrete thickness required, thanks to the composite design.

LATERAL FORCE RESISTING SYSTEM REDESIGN

The lateral system has been completed in three steps. First wind and seismic loading have been determined, as well as which will control in each major direction. Then allowable limits for each load have been determined, as well as placement of the lateral resisting elements. ETABS was then used to apply these load combinations to the structure and checked for drift. Finally, sizes were adjusted to meet these allowable limits, and member sizes were checked by hand to verify acceptable member forces.

DESIGN LOADS

Wind loading has been determined using ASCE7-05 Method II for wind analysis. For this analysis, I will use the projected width and length of the building to estimate the loads. (See Figure 7.1) This assumption will keep wind loads conservative.

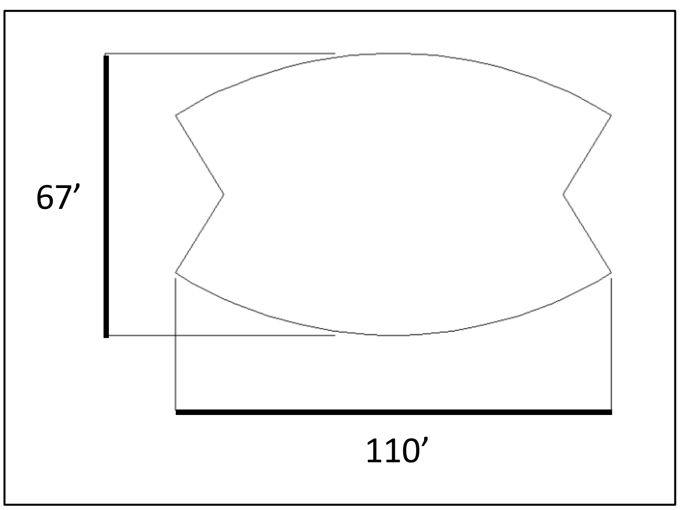


Figure 7.1

The following basic parameters were used for the wind calculations. ASCE references to find each value have been provided.

Wind Speed	V = 90mph	(ASCE7-05 Figure 6-1)
Occupancy Category	II	(ASCE7-05 Table 1-1)
Importance Factor	I = 1.00	(ASCE7-05 Table 6-1)
Exposure	B	(ASCE7-05 § 6.5.6.3)
Velocity Pressure Exposure	K_z = Varies	(ASCE7-05 Table 6-3)
Topographic Factor	$K_{zt} = 1.0$	(ASCE7-05 Table 6-4)
Wind Directionality Factor	$K_d = 0.85$	(ASCE7-05 Table 6-6)
Gust Effect Factor	G =0.85	(ASCE7-05 Table 6-6)
Internal Pressure Coefficient	$GC_{pi} = \pm 0.18$	(ASCE7-05 Table 6-5)
External Pressure Coefficient	C_p (wind) = 0.8	(ASCE7-05 Table 6-6)
External Pressure Coefficient, N/S	C_p (lee,) = -0.5	(ASCE7-05 Table 6-6)
External Pressure Coefficient, E/W	C_p (lee,) = -0.372	(ASCE7-05 Table 6-6)

North/South Direction L = 67 ft B = 110 ft

Level	Story Ht. (ft)	Ht - z (ft)	Kz	qz	Wind Pressure (psf)		Total Pressure (psf)	Total Force (k)	Total Story Shear (K)
					Windward	Leeward			
17	10	180	1.17	20.622	14.023	-8.764	22.787	25.066	25.066
16	10	170	1.150	20.269	13.783	-8.764	22.548	24.802	49.868
15	10	160	1.130	19.917	13.544	-8.764	22.308	24.539	74.407
14	10	150	1.110	19.564	13.304	-8.764	22.068	24.275	98.682
13	10	140	1.090	19.212	13.064	-8.764	21.828	24.011	122.693
12	10	130	1.065	18.771	12.764	-8.764	21.529	23.682	146.375
11	10	120	1.040	18.331	12.465	-8.764	21.229	23.352	169.727
10	10	110	1.015	17.890	12.165	-8.764	20.930	23.022	192.749
9	10	100	0.990	17.449	11.866	-8.764	20.630	22.693	215.442
8	10	90	0.960	16.921	11.506	-8.764	20.270	22.297	237.740
7	10	80	0.930	16.392	11.146	-8.764	19.911	21.902	259.641
6	10	70	0.890	15.687	10.667	-8.764	19.431	21.374	281.016
5	10	60	0.850	14.982	10.188	-8.764	18.952	20.847	301.863
4	10	50	0.810	14.277	9.708	-8.764	18.473	20.320	322.183
3	10	40	0.760	13.395	9.109	-8.764	17.873	19.661	341.843
2	10	30	0.700	12.338	8.390	-8.764	17.154	18.870	360.713
1	10	20	0.700	12.338	8.390	-8.764	17.154	37.739	398.452
								Total	398.452

East/West Direction L = 110 ft B = 67 ft

Level	Story Ht. (ft)	Ht - z (ft)	Kz	qz	Wind Pressure (psf)		Total Pressure (psf)	Total Force (k)	Total Story Shear (K)
					Windward	Leeward			
17	10	180	1.17	20.622	14.023	-6.521	20.544	13.764	13.764
16	10	170	1.150	20.269	13.783	-6.521	20.304	13.604	27.368
15	10	160	1.130	19.917	13.544	-6.521	20.064	13.443	40.811
14	10	150	1.110	19.564	13.304	-6.521	19.824	13.282	54.093
13	10	140	1.090	19.212	13.064	-6.521	19.585	13.122	67.215
12	10	130	1.065	18.771	12.764	-6.521	19.285	12.921	80.136
11	10	120	1.040	18.331	12.465	-6.521	18.985	12.720	92.856
10	10	110	1.015	17.890	12.165	-6.521	18.686	12.520	105.376
9	10	100	0.990	17.449	11.866	-6.521	18.386	12.319	117.695
8	10	90	0.960	16.921	11.506	-6.521	18.027	12.078	129.772
7	10	80	0.930	16.392	11.146	-6.521	17.667	11.837	141.609
6	10	70	0.890	15.687	10.667	-6.521	17.188	11.516	153.125
5	10	60	0.850	14.982	10.188	-6.521	16.708	11.195	164.320
4	10	50	0.810	14.277	9.708	-6.521	16.229	10.873	175.193
3	10	40	0.760	13.395	9.109	-6.521	15.630	10.472	185.665
2	10	30	0.700	12.338	8.390	-6.521	14.910	9.990	195.655
1	10	20	0.700	12.338	8.390	-6.521	14.910	19.980	215.635
								Total	215.635

From this data, Millennium Halls wind load base shear is 398 kips in the North/South direction and 216 kips in the East/West. To see sample calculations that were used to generate this data, please see Appendix D.

Seismic Loading for the Millennium Hall building has been determined using ASCE5-07. All required variables have been listed below. See Appendix E for sample calculations of these values.

Seismic Design (North/South Direction)			
Sym.	Description	Value	ASCE Ref.
Ordinary Concrete Shear Wall			
-	Site Class	C	Table 20.3
-	Occupancy Category	II	Table 1-1
-	Importance Factor	1.00	Table 11-5
S_s	Spectral Response Acceleration, short	0.28	USGS
S_1	Spectral Response Acceleration, 1 sec.	0.06	USGS
F_a	Site Coefficient	1.20	Table 11.4-1
F_v	Site Coefficient	1.70	Table 11.4-2
S_{ms}	MCE Spectral Response Accel., short	0.336	Eq. 11.4-1
S_{m1}	MCE Spectral Response Accel., 1 sec.	0.102	Eq. 11.4-2
S_{ds}	Design Spectral Aceeleration, short	0.224	Eq. 11.4-3
S_{d1}	Design Spectral Aceeleration, 1 sec.	0.068	Eq. 11.4-4
S_{dc}	Seismic Design Category	B	Table 11.6-2
R	Response Modification Coefficent	4.50	Table 12.2-1
C_t	Approximate Period Perameter	0.02	Table 12.8-2
h_n	Building Height	180	-
x	Approximate Period Perameter	0.75	Table 12.8-2
C_u	Calculated Period Upper Limit	1.70	Table 12.8-1
T_a	Approximate Fundamental Period	0.95	Eq. 12.8-7
T	Fundamental Period	4.00	§12.8.2
T_L	Long Period Transistion Period	6.00	Figure 22-15
Cs	Seismic Response Coefficient	0.013	Eq. 12.8-6
k	Structural Period Exponent	2	§12.8.3

Seismic Design (East/West Direction)			
Sym.	Description	Value	ASCE Ref.
Ordinary Concrete Moment Frame			
-	Site Class	C	Table 20.3
-	Occupancy Category	II	Table 1-1
-	Importance Factor	1.00	Table 11-5
S_s	Spectral Response Acceleration, short	0.28	USGS
S_1	Spectral Response Acceleration, 1 sec.	0.06	USGS
F_a	Site Coefficient	1.20	Table 11.4-1
F_v	Site Coefficient	1.70	Table 11.4-2
S_{ms}	MCE Spectral Response Accel., short	0.336	Eq. 11.4-1
S_{m1}	MCE Spectral Response Accel., 1 sec.	0.102	Eq. 11.4-2
S_{ds}	Design Spectral Aceeleration, short	0.224	Eq. 11.4-3
S_{d1}	Design Spectral Aceeleration, 1 sec.	0.068	Eq. 11.4-4
S_{dc}	Seismic Design Category	B	Table 11.6-2
R	Response Modification Coefficent	3.00	Table 12.2-1
C_t	Approximate Period Perameter	0.016	Table 12.8-2
h_n	Building Height	180	-
x	Approximate Period Perameter	0.90	Table 12.8-2
C_u	Calculated Period Upper Limit	1.70	Table 12.8-1
T_a	Approximate Fundamental Period	1.65	Eq. 12.8-7
T	Fundamental Period	2.60	§12.8.2
T_L	Long Period Transistion Period	6.00	Figure 22-15
Cs	Seismic Response Coefficient	0.011	Eq. 12.8-6
k	Structural Period Exponent	2	§12.8.3

Base Shear & Overturning Moment (North/South Direction)						
Story	hx (ft)	Story Wt. (k)	$w_x h_x^k$	C_{vx}	Lateral Force (k)	Story Shear (k)
17	180	1610	8.4E+10	0.124	47.7	47.7
16	170	1828	9.7E+10	0.142	54.9	102.6
15	160	1828	8.6E+10	0.126	48.6	151.3
14	150	1828	7.5E+10	0.111	42.7	194.0
13	140	1828	6.5E+10	0.096	37.2	231.3
12	130	1828	5.6E+10	0.083	32.1	263.4
11	120	1828	4.8E+10	0.071	27.4	290.7
10	110	1828	4.0E+10	0.060	23.0	313.7
9	100	1828	3.3E+10	0.049	19.0	332.7
8	90	1828	2.7E+10	0.040	15.4	348.1
7	80	1828	2.1E+10	0.031	12.2	360.3
6	70	1828	1.6E+10	0.024	9.3	369.6
5	60	1828	1.2E+10	0.018	6.8	376.4
4	50	1828	8.4E+09	0.012	4.7	381.2
3	40	1828	5.3E+09	0.008	3.0	384.2
2	30	1828	3.0E+09	0.004	1.7	385.9
1	20	658	1.7E+08	0.000	0.1	386.0
	Total	29688	6.8E+11			386

Base Shear & Overturning Moment (East/West Direction)						
Story	hx (ft)	Story Wt. (k)	$w_x h_x^k$	C_{vx}	Lateral Force (k)	Story Shear (k)
17	180	1610	8.4E+10	0.124	40.45	40.45
16	170	1828	9.7E+10	0.142	46.51	86.96
15	160	1828	8.6E+10	0.126	41.20	128.16
14	150	1828	7.5E+10	0.111	36.21	164.37
13	140	1828	6.5E+10	0.096	31.54	195.91
12	130	1828	5.6E+10	0.083	27.20	223.11
11	120	1828	4.8E+10	0.071	23.17	246.29
10	110	1828	4.0E+10	0.060	19.47	265.76
9	100	1828	3.3E+10	0.049	16.09	281.85
8	90	1828	2.7E+10	0.040	13.04	294.89
7	80	1828	2.1E+10	0.031	10.30	305.19
6	70	1828	1.6E+10	0.024	7.89	313.08
5	60	1828	1.2E+10	0.018	5.79	318.87
4	50	1828	8.4E+09	0.012	4.02	322.89
3	40	1828	5.3E+09	0.008	2.57	325.47
2	30	1828	3.0E+09	0.004	1.45	326.92
1	20	658	1.7E+08	0.000	0.08	327.00
	Total	29688	6.8E+11			327

From this analysis we can see the design seismic base shears for the North/South and East/West directions are 386 kips and 327 kips respectively. Sample calculations for these values can be found in Appendix E.

DESIGN PROCESS

The following allowable drift criteria that will be used to check deflection for the redesign of the buildings lateral system will be in accordance with the International Building Code, 2006 edition.

(Allowable Building Drift) Δwind = H/400 = 180*12/400 = 5.4 inches

(Allowable Story Drift) Δseismic = 0.015Hsx = 0.015*10*12 = 1.8 inches

Comparing the wind and seismic values determined previously, the North/South direction will be governed by wind, and the allowable building drift limit of 5.4 inches. The East/West direction will be governed by seismic and the allowable story drift limit of 1.8 inches.

The design of the braced frame lateral system originally had two braced frames in the more critical North/West direction, and one in the East/West. These braced frames were placed around the elevator core where they would not interrupt the floor plan. (See Figure 8.1) As calculations showed in a previous tech report, braced frames would not provide enough lateral resistance, and the entire structure would need to be designed as a moment frame, in combination with the braced frames.

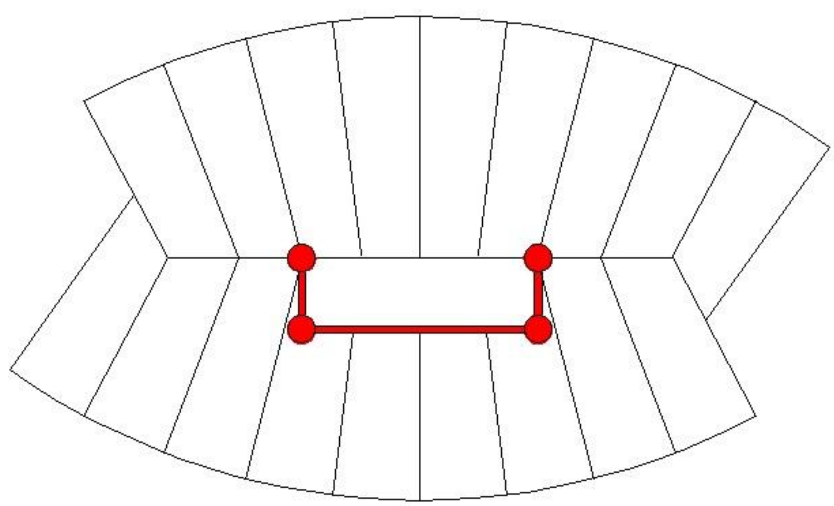


Figure 8.1

ETABS MODEL

The gravity system originally determined was modeled using ETABS. Braced frames were added between the columns around the core, and lateral forces were added to load cases for both North/South wind and East/West seismic.

The model was run and building drift was in the magnitude of 30 inches. It was determined more braces would be needed in the North/South direction. Two brace frames were added on either side of the building. (See Figure 8.2 & 8.3)

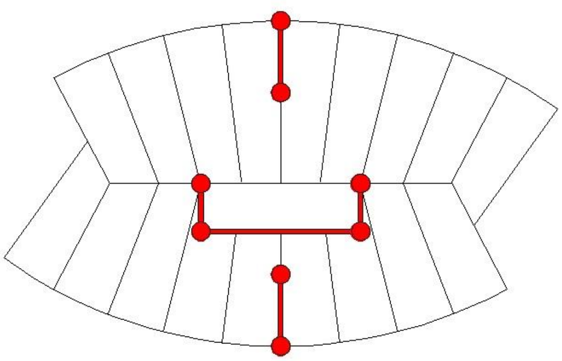


Figure 8.2

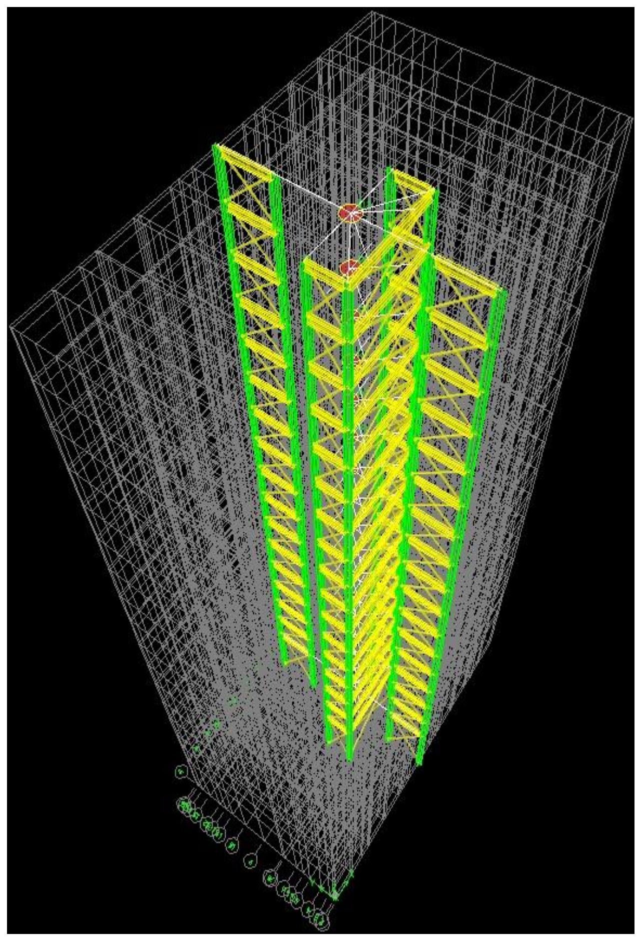


Figure 8.3

Members in the braced frame were resized to add more stiffness and the resulting system was run. Building drift for the North/South direction was below the allowable limit, with the maximum deflection of 5.33 inches. (See Figure 8.4)

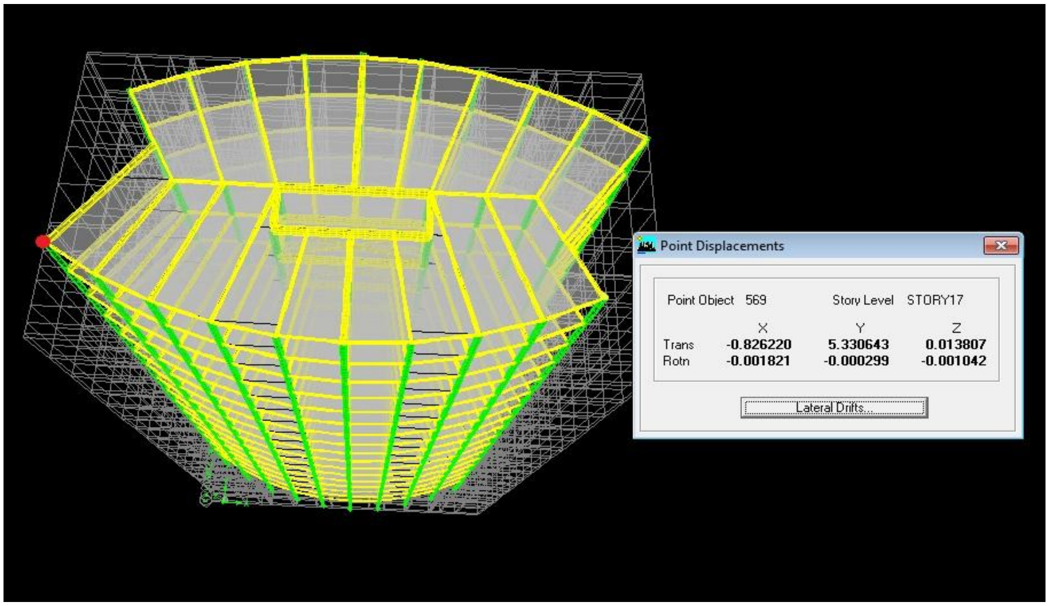


Figure 8.4

Story drift for the East/West seismic loading also fell with the allowable limit, with the maximum story drift of 1.22 inches. (See Figure 8.5)

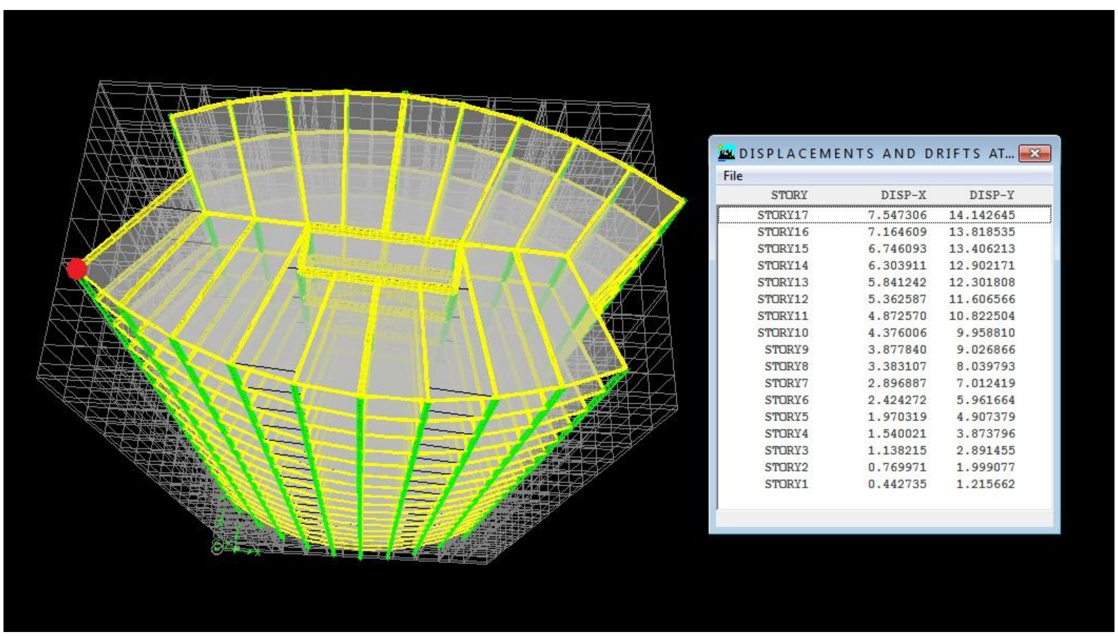


Figure 8.5

Verify the member forces the lateral system resists, tension forces were evaluated at their maximum force on the building. (See Figure 8.6) It was found that the greatest forces experienced on the structure fall well within the allowable stress for individual members. Sample calculations can be found in Appendix F.

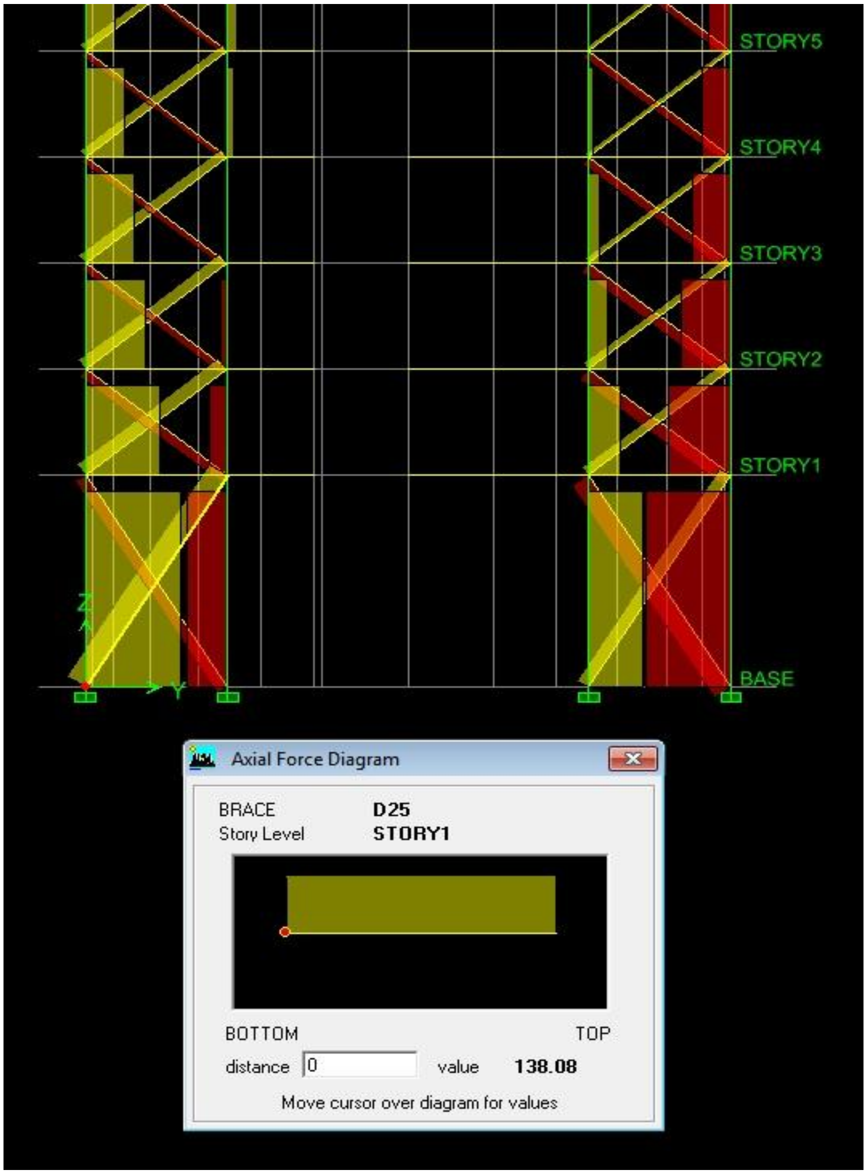


Figure 8.6

DESIGN SUMMARY AND CONCLUSION

The lateral system's design for lateral began with determining the wind and seismic loading for Millennium Hall. Once these forces were calculated, controlling loads were applied to the building.

ETABS was used to model the braced frames and to determine overall building and story drift. Two braced frames needed to be added, and all the frames needed to be strengthened. These frames, in combination with the entire floor system moment frame, provided enough strength to meet allowable drift limits.

The final design results in the initial gravity system design, with the columns of the four braced frames being constructed of W21x132, with the remaining non lateral system columns being W10x100. The diagonal members are made up of HSS 7" x 5" x 1/2".

Diagonal braced frame members were then evaluated for tension force and were found to have member forces that are within the strength of the member.

Meeting all the requirements for strength and deflection, the lateral system demonstrates the ability of the light weight braced frames to provide adequate lateral resistance, even with a very tall and slender building.

IMPACT ON FOUNDATION

To complete the structural redesign of the Millennium Hall building, the foundation must be checked for adequate strength. The foundation is made up of drilled caissons, one for each column of the building. To analyze if the caissons are strong enough for the new design, the existing design is evaluated for the force on each caisson. If the new design keeps the force equal to or below this value, the existing caissons can be used.

The existing plan has 20 caissons supporting the concrete structure's 20 columns. (See Figure 9.1) Assuming each column has an equal amount of the building load, each caisson supports 920 kips of the structure weight. See Appendix G for detailed calculations.

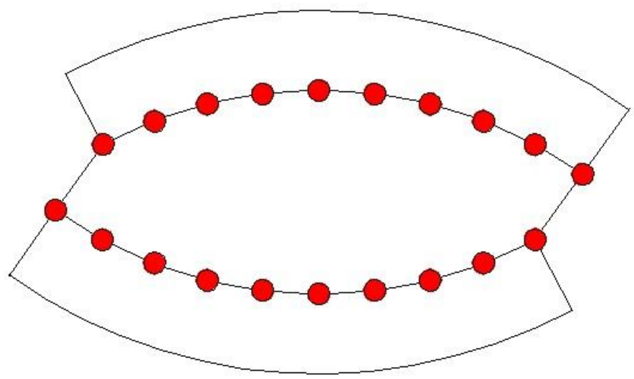


Figure 9.1

The new structural plan calls for 30 columns, increasing the number of caissons by 10. Since the floor loads are transferred to the 20 columns on the exterior and 10 columns on the interior, it is assumed that the interior 10 columns will take half of the load, which will make them the critical columns. (See Figure 9.2)

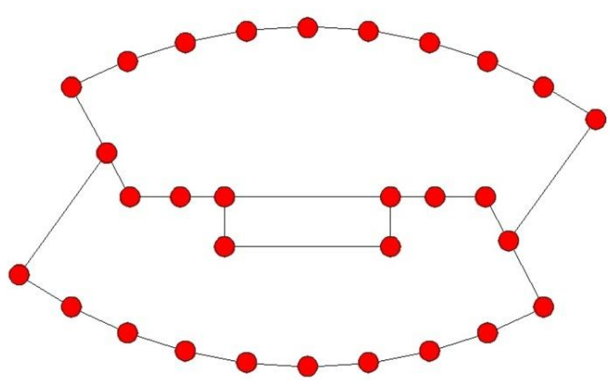


Figure 9.2

Although these columns are taking more of the load, the decreased overall weight of the structural system still results in a caisson load of 678 kips at the critical columns, well below that of the existing system. See Appendix G for detailed calculations.

The final design for the foundation will include an increase of 10 caissons for a total of 30 caissons, but the decreased weight mean most if not all of the caissons can be reduced in size because of the lower forces on each.

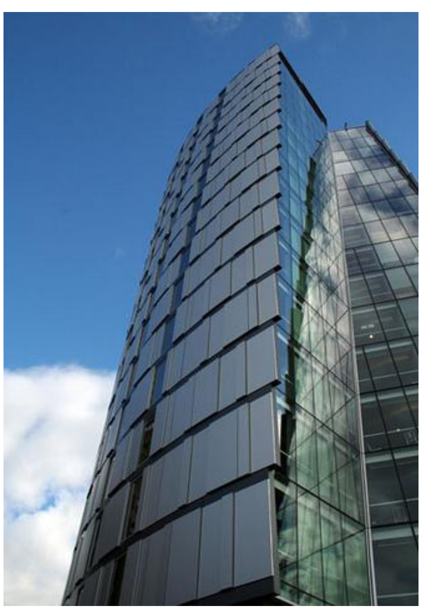
BREADTH STUDY I: ARCHITECTURAL IMPACT

To demonstrate knowledge outside of the structural depth, two breadth topics have been considered in the redesign of the Millennium Hall building. The first to be discussed is the architectural impacts the structural redesign has on the building. These impacts include the appearance from the outside of the building and the adjustment to the layout of a typical floor.

FAÇADE APPEARANCE

In the structural redesigns, the columns were moved to the exterior of the building, removing the cantilevered slab that extended out 15 feet to the curtain wall. The existing design has the curtain wall connecting directly to the slab edge. Moving the columns has allowed the curtain wall to be connected directly to the column, removing any moment do to this point load at the exterior building. This also eliminates the curtain wall from the floor system loads, and becomes a direct load on the column line.

Since the curtain wall can remain the same material and design, there is no change in the exterior of the building. The buildings exterior and a detail of the curtain wall material can be seen below.



TYPICAL FLOOR LAYOUT

While redesigning the structure, attention was taken to preserve the serviceability of the space, and minimize changes to the original floor plan. Below is a typical floor layout with the position of columns and shear walls superimposed on the existing floor plan. (See Figure 10.1)

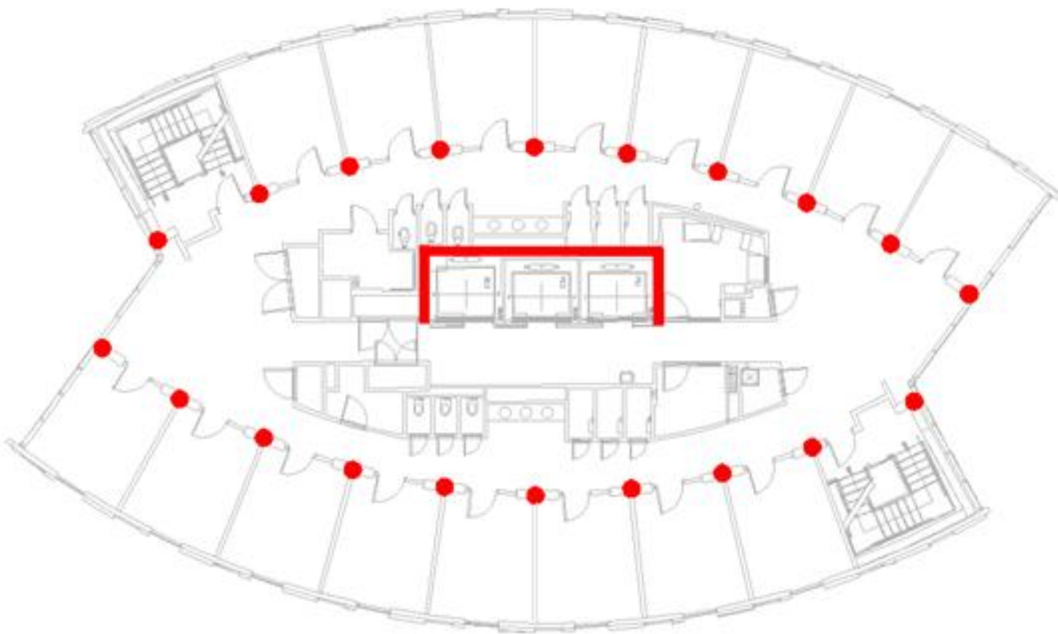


Figure 10.1

The columns shown here as red dots, fit into the walls that separate the residence rooms and the public hallway. The shear walls encase the elevator core.

The next figure below, shows the same floor plan, but includes the new column layout and the addition of braced frames. (See Figure 10.2)

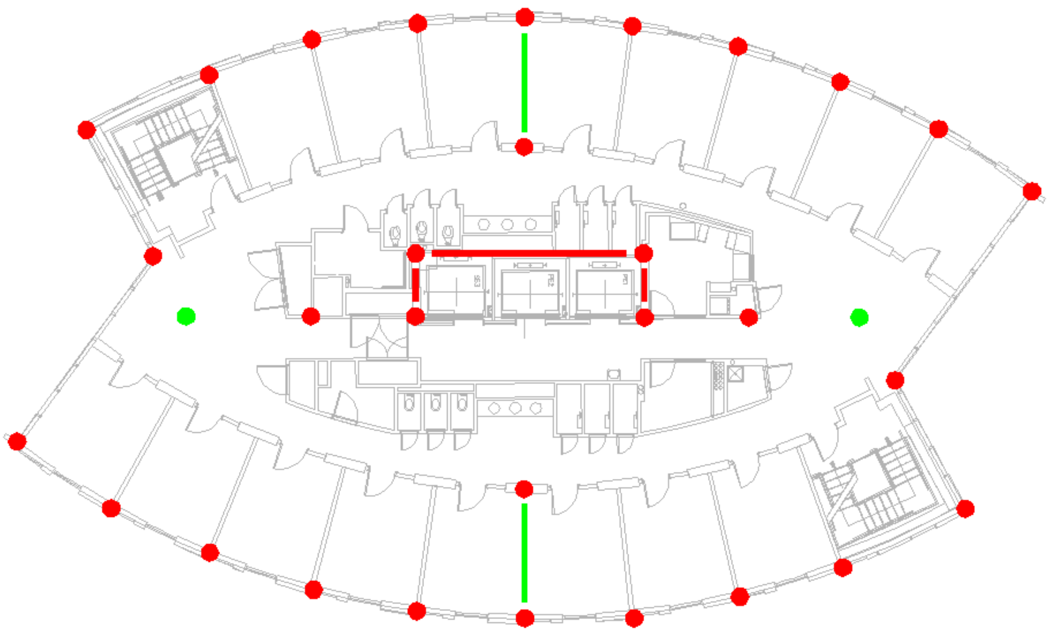


Figure 10.2

Once again the red dots represent the columns that have not affected to current layout. The green shows elements that need to be addressed. The two columns, shown in green, are not within a wall line. This open area is used as public space where students can gather to study and converse. The addition of these columns may affect the layout of furniture within the space, but should not affect the serviceability of the space. These columns can easily be encased to improve the look of the space and hide the bare structural element.

The green lines represent braced frames that will affect the existing layout. The walls between rooms are 5 inches thick, but the new design requires a 7 inch wide brace to pass inside the wall. To fit this, the center wall on both sides of the building will need to be enlarged. To alleviate this adjustment, the remaining non bearing load walls between rooms will have to be moved slightly outward so the area of all the room can remain equal.

BREADH STUDY II: CONSTRUCTION MANAGEMENT

The second breadth to be discussed outside of the structural depth will be the cost and timeline of construction, and how both are affected by the redesign. Specifically, the cost and timeline for construction of the structural system will be compared, since this is the only change be evaluated. To compare the existing and new systems equally, all elements that are required for the complete structural system will be included. RSMeans cost data was used to approximate the unit cost and production for each system.

Special notice should be taken that the systems provided below are not complete structural systems, small items or items appearing in both system were excluded to reduce the calculations needed to make a comparison. Because of this, costs and timelines may not reflect actual values, but can successfully be used to compare systems equally.

EXISTING SYSTEM

The cast in place concrete system was first broken down into the amount of materials. This included structural concrete, reinforcement, and framing. Once these values were determined, total cost and daily crew output were determined. With these values, total cost and length of construction could be calculated. This estimate shows a cost of $1.7 million with a timeline of 330 days. Item used for these calculations, as well as the values extracted from RSMeans, can be found in Appendix H.

NEW SYSTEM

The steel system with composite deck was then evaluated. This system includes the steel framing, steel decking, metal studs to develop composite strength, concrete, reinforcement, and fire proofing. These elements will provide an equal result of a complete system. As before, the quantities were calculated and with the cost and output known, the total cost and schedule could be determined. This estimate shows a cost of $2.3 million with a timeline of 130 days. Item used for these calculations, as well as the values extracted from RSMeans, can be found in Appendix H.

COMPARISON AND CONCLUSIONS

The results of these two systems are very different. The original concrete system is cheaper, by $600,000. The best way to evaluate the difference may be to say the new system is 35% more expensive.

The timeline for construction, is 200 days faster, a reduction of 40%. This seems to be expected as the labor involved in framing out the concrete columns and slabs takes a significant amount of time. Contrast this with the speed at which steel can be erected and the lack of framing due to the steel deck, which has been designed to require no framing during construction.

To make the comparison between the two, the cost and schedule must be weighted against each other. The new structural system is more expensive, but a faster construction time, along with the rest of the building's systems, could mean savings significant enough to make the steel system more economical to the owner.

REFLECTIONS AND CONCLUSIONS

The redesign of the structural system of the Millennium Hall building had five main goals, which were:

1. Reduce the weight of the overall building by optimizing the gravity system
2. Optimize the lateral force resisting system in coordination with the gravity system
3. Verify the impact on the foundation system
4. Determine the impact on the architectural design including floor plan layout
5. Determine the impact that the redesign has on the construction schedule and cost of the building

For the structural redesign, starting with the gravity system, a preliminary framing plan was developed which removed the concrete cantilevered slab and replaced it with a lighter steel composite deck. The members were then analyzed for lateral forces and column members and diagonal braces were added and sizes were adjusted to keep drift under allowable limits. The foundation was then checked to ensure the current caisson foundation design was acceptable, which it was found to be.

To provide knowledge outside of the structural depth, the architectural design, including appearance and floor plan layout were analyzed, as well as the cost and schedule affects the redesign would have on both. The curtain wall design was proved to be adequate for the new system, and with small adjustments to the typical floor layout, the floor plan went mainly untouched. Finally the cost was determined to have gone up 35%, but the length of building schedule improved by almost 40%.

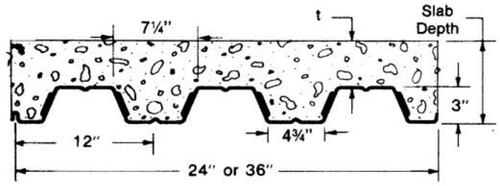
Throughout this feasibility study of the structural redesign, it has been proven that a steel system with a composite deck is a very viable option, one that could have been seriously considered.

APPENDIX A: VULCRAFT CATALOG

VULCRAFT

3 VLI

Maximum Sheet Length 42'-0
Extra Charge for Lengths Under 6'-0
ICBO Approved (No. 3415)



STEEL SECTION PROPERTIES — Fy= 40 KSI

Deck Type	Design Thick.	Weight PSF	Ip in^4/Ft	In in^4/Ft	Sp in^3/Ft	Sn in^3/Ft
3VLI22	0.0295	1.77	0.746	0.745	0.429	0.442
3VLI21	0.0329	1.97	0.850	0.848	0.495	0.511
3VLI20	0.0358	2.14	0.938	0.937	0.553	0.572
3VLI19	0.0418	2.50	1.105	1.103	0.677	0.700
3VLI18	0.0474	2.84	1.251	1.251	0.795	0.803
3VLI17	0.0538	3.22	1.421	1.421	0.913	0.913
3VLI16	0.0598	3.58	1.580	1.580	1.013	1.013

(N=9) NORMAL WEIGHT CONCRETE (145 PCF)

Total Slab Depth	Deck Type	SDI Max. Unshored Clear Span			Superimposed Live Load, PSF — Clear Span (ft.-in.)														
		1 Span	2 Span	3 Span	7'-0	7'-6	8'-0	8'-6	9'-0	9'-6	10'-0	10'-6	11'-0	11'-6	12'-0	12'-6	13'-0	13'-6	14'-0
5"	3VLI22	7'-8	9'-7	9'-7	216	195	149	133	120	109	99	90	83	76	70	64	59	54	50
	3VLI21	8'-11	11'-3	11'-4	230	206	187	170	128	116	106	96	88	81	74	68	63	58	54
(t=2")	3VLI20	9'-6	11'-11	12'-4	241	216	196	178	163	150	111	101	93	85	78	72	66	61	57
	3VLI19	10'-8	13'-2	13'-7	265	237	214	194	178	163	151	140	102	94	86	79	73	67	62
	3VLI18	11'-8	14'-1	14'-6	289	261	238	218	201	186	173	161	151	142	106	98	92	86	80
44 PSF	3VLI17	12'-7	14'-11	15'-5	309	278	253	231	212	196	182	170	159	150	141	133	97	91	85
	3VLI16	13'-4	15'-8	15'-11	327	294	267	243	223	206	191	178	167	156	147	139	132	96	89
5 1/2"	3VLI22	7'-0	8'-9	8'-9	247	190	170	152	137	124	113	103	94	87	80	73	67	62	57
	3VLI21	8'-4	10'-4	10'-4	262	235	213	162	146	133	120	110	101	92	85	78	72	66	61
(t=2 1/2")	3VLI20	9'-0	11'-5	11'-9	275	247	223	203	186	140	127	116	106	97	89	82	76	70	65
	3VLI19	10'-1	12'-7	13'-0	302	270	244	222	203	186	172	128	117	107	98	90	83	77	71
	3VLI18	11'-1	13'-5	13'-11	330	298	271	248	229	212	197	184	173	130	121	112	105	98	92
50 PSF	3VLI17	11'-11	14'-3	14'-9	352	317	288	263	242	224	208	194	182	171	128	119	111	104	97
	3VLI16	12'-8	15'-0	15'-5	373	335	304	277	255	235	218	203	190	178	168	159	117	109	102
6"	3VLI22	6'-5	8'-1	8'-1	242	214	191	171	154	140	127	116	106	97	89	82	76	70	65
	3VLI21	7'-8	9'-7	9'-7	294	264	204	183	165	149	135	124	113	104	95	88	81	75	69
(t=3")	3VLI20	8'-7	10'-11	10'-11	309	277	250	228	173	157	143	130	119	109	100	92	85	79	73
	3VLI19	9'-8	12'-1	12'-6	339	304	274	249	227	209	157	143	131	120	110	102	94	87	80
	3VLI18	10'-7	12'-11	13'-4	370	334	304	279	257	238	221	207	158	146	136	126	118	110	103
57 PSF	3VLI17	11'-5	13'-9	14'-2	395	356	323	296	272	251	233	218	204	155	144	134	125	117	109
	3VLI16	12'-0	14'-5	14'-11	400	376	341	311	286	264	245	228	213	200	189	141	132	123	115
6 1/2"	3VLI22	6'-0	7'-5	7'-5	268	237	212	190	171	155	141	129	118	108	99	91	84	78	72
	3VLI21	7'-1	8'-10	8'-10	326	254	226	203	183	165	150	137	126	115	106	97	90	83	77
(t=3 1/2")	3VLI20	8'-1	10'-1	10'-1	343	307	278	214	192	174	158	144	132	121	111	103	95	87	81
	3VLI19	9'-3	11'-7	12'-0	377	337	304	276	252	192	175	159	146	134	123	113	104	96	89
	3VLI18	10'-1	12'-5	12'-10	400	371	338	309	285	264	246	189	175	162	151	140	131	122	115
63 PSF	3VLI17	10'-11	13'-3	13'-8	400	395	359	328	302	279	259	242	186	172	160	149	139	130	121
	3VLI16	11'-6	13'-11	14'-4	400	400	378	345	317	293	272	253	237	222	169	157	146	136	128
7"	3VLI22	5'-7	6'-11	6'-11	295	261	233	209	188	171	155	142	130	119	109	101	93	86	79
	3VLI21	6'-7	8'-3	8'-3	316	279	249	223	201	182	165	151	138	127	116	107	99	91	84
(t=4")	3VLI20	7'-6	9'-5	9'-5	377	338	262	235	212	192	174	159	145	133	122	113	104	96	89
	3VLI19	8'-11	11'-3	11'-7	400	370	334	303	234	211	192	175	160	147	135	124	115	106	98
	3VLI18	9'-9	12'-0	12'-5	400	400	371	340	313	290	226	208	192	178	166	154	144	135	126
69 PSF	3VLI17	10'-6	12'-9	13'-2	400	400	394	360	331	306	285	265	204	189	176	164	153	143	134
	3VLI16	11'-1	13'-5	13'-10	400	400	400	379	348	322	298	278	260	200	185	172	161	150	140
7 1/2"	3VLI22	5'-2	6'-6	6'-6	321	285	254	228	205	186	169	154	141	130	119	110	101	93	86
	3VLI21	6'-2	7'-9	7'-9	344	304	271	243	219	198	180	164	150	138	127	117	108	100	92
(t=4 1/2")	3VLI20	7'-1	8'-10	8'-10	400	321	286	256	231	209	190	173	158	145	134	123	114	105	97
	3VLI19	8'-7	10'-10	11'-2	400	400	364	331	255	231	209	191	175	160	147	136	125	116	107
	3VLI18	9'-4	11'-7	12'-0	400	400	400	370	341	269	246	227	210	195	181	168	157	147	138
75 PSF	3VLI17	10'-1	12'-4	12'-9	400	400	400	393	361	334	310	241	223	206	192	179	167	156	146
	3VLI16	10'-8	13'-0	13'-5	400	400	400	400	380	351	325	303	235	218	202	188	175	164	153

Notes:
1. Minimum exterior bearing length required is 2.5 inches. Minimum interior bearing length required is 5.0 inches. If these minimum lengths are not provided, web crippling must be checked.
2. Always contact Vulcraft when using loads in excess of 200 psf. Such loads often result from concentrated, dynamic, or long term load cases for which reductions due to bond breakage, concrete creep, etc. should be evaluated.
3. All fire rated assemblies are subject to an upper live load limit of 250 psf.
4. Inquire about material availability of 17, 19 & 21 gage.

COMPOSITE

48

APPENDIX B: COMPOSITE DECK CALCULATIONS

COMPOSITE DECK

LOADS: SDL = 35 psf (SEE TECH #1 LOADING)
LL = 100 psf

VULCRAFT ⇒ TRY 3VLI16

UNSHORED LENGTH, ONE SPAN CONDITION (SEE GEOMETRY)
= 13'-4" > 12'-3" REQUIRED ∴ OK

L = 35 + 100 = 135 psf

3VLI16 @ 12'-6" SPAN = 139 psf > 135 psf

SELF WT. = 44 psf ∴ OK FOR STRENGTH
5" (2" TOPPING)

BEAM (LONGEST)

SELF WT. = ASSUME 5 psf

LONGEST WIDTH

$$W_u = [1.2(44+5+35) + 1.6(100)](12)/1000 = 3.13 \text{ klf}$$

$$M_u = \frac{3.13(34)^2}{8} = 452'^k$$

FROM AISC 3-19

ASSUME $Y2 = 5 - 0.5 = 4.5''$

TRY W16x45 $\Sigma Q_N = 266^k$

$\phi M_n = 482'^k > 452'^k$ $\therefore$ OK

$\frac{266}{17.2} = 15.5(2) = 31 \Rightarrow$ 32 STUDS SPACED 12"

UNSHORED STRENGTH : W16x45 $\phi_b M_p = 309'^k$

$W_u = 1.4(44 \times 12 + 45) = 0.8022$ klf

$M_u = \frac{(0.8022)(34)^2}{8} = 116'^k < 309'^k$ $\therefore$ OK

CHECK Δ_{LL} :

$W_{LL} = 100(12) = 1200 = 1.2$ klf

$I_{LB} = 1190 \text{ in}^4$ (3-20)

$L/360 = \frac{34 \cdot 12}{360} = 1.13''$ (ALLOWABLE)

$\Delta_{LL} = \frac{(5)(1.2)(34)^4(1728)}{(385)(29,000)(1190)} = 1.04'' < 1.13''$

$\therefore$ OK

WET CONCRETE Δ:

$$MAX = L/240 = \frac{34 \cdot 12}{240} = 1.7'' \text{ ALLOWABLE}$$

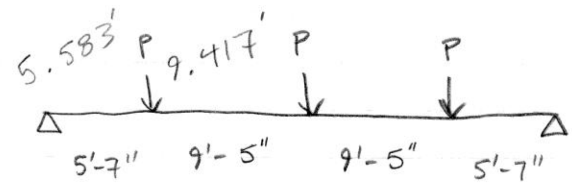
44.12 + 45

$$\Delta_{WC} = \frac{5(0.573)(34)^4(1728)}{385(29{,}000)(586)} = 1.01'' < 1.7$$

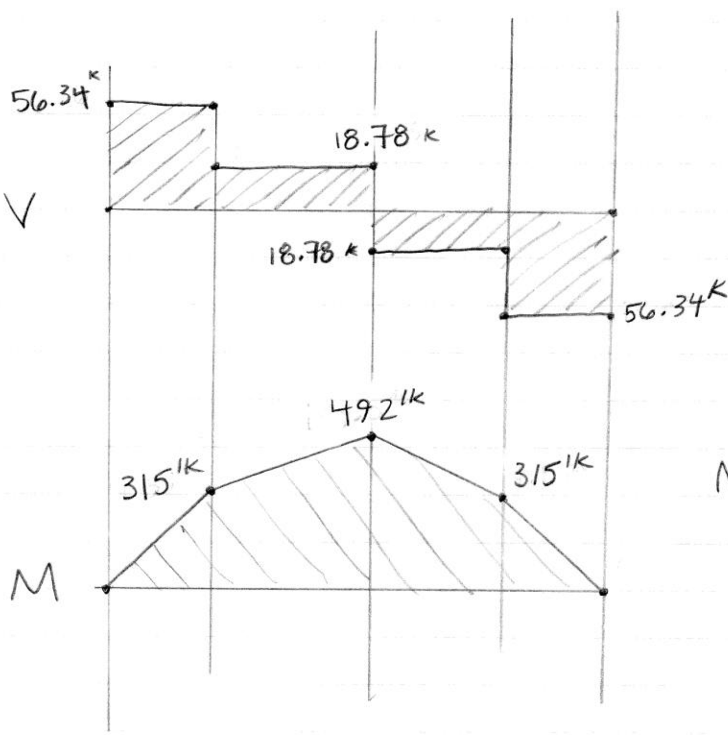
$\therefore$ OK

USE W16 x 45 w/ 62 3/4" ϕ STUDS

G1 DESIGN



$W_u = 3.13$ klf (SEE BM DESIGN) $P = 3.13(24)/2 = 37.56^k$



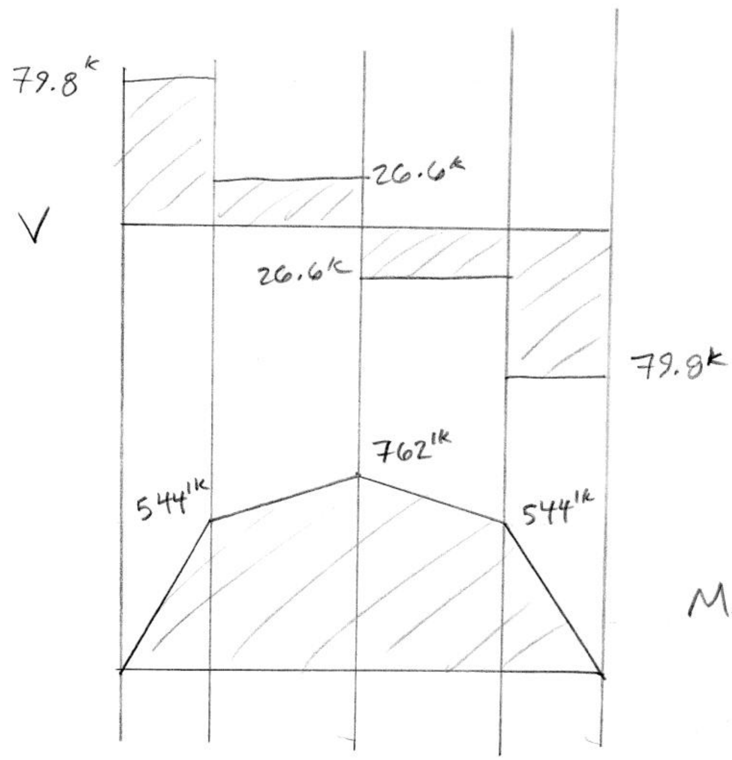
$M_{MAX} = 492'^k$

FROM AISC 3-10

UNBRACED LENGTH = 10'
$M_u = 492'^k$ ⟹ W21 x 68 ($\phi M_n = 531'^k$ MOST ECONOMICAL) OR W16 x 77

G2 DESIGN

$P = 3.13(34') = 106.4/2 = 53.2^k$



$M_{MAX} = 762'^k$

FROM AISC 3-10

UNBRACED = 8.5'
$M_u = 762'^k$

⇒

MOST ECONOMICAL ↓

W24x84 $\phi M_n = 801'^k$
W21x93 $\phi M_n = 786'^k$

APPENDIX C: RAM COLUMN TABLES

Gravity Column Design Summary

RAM Steel v14.03.01.00
DataBase: ram model 02/22/11 13:23:17
Building Code: IBC Steel Code: AISC360-05 ASD

Column Line A-6

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	4.4	1.1	1.0	1	0.05 Eq (H1-1b)	90.0	50	W10X33
level 16	8.9	0.6	0.5	1	0.04 Eq (H1-1b)	90.0	50	W10X33
level 15	13.3	0.6	0.5	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 14	17.8	0.6	0.5	1	0.08 Eq (H1-1b)	90.0	50	W10X33
level 13	22.2	0.6	0.5	1	0.10 Eq (H1-1b)	90.0	50	W10X33
level 12	26.7	0.6	0.5	1	0.12 Eq (H1-1b)	90.0	50	W10X33
level 11	31.1	0.6	0.5	1	0.14 Eq (H1-1b)	90.0	50	W10X33
level 10	35.6	0.6	0.5	1	0.16 Eq (H1-1b)	90.0	50	W10X33
level 9	40.0	0.6	0.5	1	0.18 Eq (H1-1b)	90.0	50	W10X33
level 8	44.5	0.6	0.5	1	0.22 Eq (H1-1a)	90.0	50	W10X33
level 7	48.9	0.6	0.5	1	0.24 Eq (H1-1a)	90.0	50	W10X33
level 6	53.4	0.6	0.5	1	0.26 Eq (H1-1a)	90.0	50	W10X33
level 5	57.8	0.6	0.5	1	0.28 Eq (H1-1a)	90.0	50	W10X33
level 4	62.3	0.6	0.5	1	0.30 Eq (H1-1a)	90.0	50	W10X33
level 3	66.7	0.6	0.5	1	0.32 Eq (H1-1a)	90.0	50	W10X33
level 2	71.2	0.8	0.6	1	0.35 Eq (H1-1a)	90.0	50	W10X33
level 1	76.0	0.4	0.6	1	0.81 Eq (H1-1a)	90.0	50	W10X33

Column Line B-5

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	6.6	3.4	0.2	1	0.05 Eq (H1-1b)	90.0	50	W10X33
level 16	13.1	1.7	0.1	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 15	19.7	1.7	0.1	1	0.09 Eq (H1-1b)	90.0	50	W10X33
level 14	26.2	1.7	0.1	1	0.12 Eq (H1-1b)	90.0	50	W10X33
level 13	32.8	1.7	0.1	1	0.15 Eq (H1-1b)	90.0	50	W10X33
level 12	39.4	1.7	0.1	1	0.18 Eq (H1-1b)	90.0	50	W10X33
level 11	45.9	1.7	0.1	1	0.23 Eq (H1-1a)	90.0	50	W10X33
level 10	52.5	1.7	0.1	1	0.26 Eq (H1-1a)	90.0	50	W10X33
level 9	59.0	1.7	0.1	1	0.29 Eq (H1-1a)	90.0	50	W10X33
level 8	65.6	1.7	0.1	1	0.32 Eq (H1-1a)	90.0	50	W10X33
level 7	72.2	1.7	0.1	1	0.35 Eq (H1-1a)	90.0	50	W10X33
level 6	78.7	1.7	0.1	1	0.38 Eq (H1-1a)	90.0	50	W10X33
level 5	85.3	1.7	0.1	1	0.41 Eq (H1-1a)	90.0	50	W10X33
level 4	91.8	1.7	0.1	1	0.44 Eq (H1-1a)	90.0	50	W10X33
level 3	98.4	1.7	0.1	1	0.46 Eq (H1-1a)	90.0	50	W10X33
level 2	104.9	2.2	0.1	1	0.50 Eq (H1-1a)	90.0	50	W10X33
level 1	112.0	1.1	0.2	1	0.97 Eq (H1-1a)	90.0	50	W10X39

Column Line B-12

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	2.6	1.1	0.3	1	0.03 Eq (H1-1b)	90.0	50	W10X33
level 16	5.3	0.6	0.1	1	0.02 Eq (H1-1b)	90.0	50	W10X33
level 15	7.9	0.6	0.1	1	0.04 Eq (H1-1b)	90.0	50	W10X33

Gravity Column Design Summary

RAM Steel v14.03.01.00
DataBase: ram model
Building Code: IBC

Page 2/14
02/22/11 13:23:17
Steel Code: AISC360-05 ASD

level 14	10.5	0.6	0.1	1	0.05 Eq (H1-1b)	90.0	50	W10X33
level 13	13.2	0.6	0.1	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 12	15.8	0.6	0.1	1	0.07 Eq (H1-1b)	90.0	50	W10X33
level 11	18.4	0.6	0.1	1	0.08 Eq (H1-1b)	90.0	50	W10X33
level 10	21.1	0.6	0.1	1	0.10 Eq (H1-1b)	90.0	50	W10X33
level 9	23.7	0.6	0.1	1	0.11 Eq (H1-1b)	90.0	50	W10X33
level 8	26.3	0.6	0.1	1	0.12 Eq (H1-1b)	90.0	50	W10X33
level 7	29.0	0.6	0.1	1	0.13 Eq (H1-1b)	90.0	50	W10X33
level 6	31.6	0.6	0.1	1	0.14 Eq (H1-1b)	90.0	50	W10X33
level 5	34.2	0.6	0.1	1	0.16 Eq (H1-1b)	90.0	50	W10X33
level 4	36.9	0.6	0.1	1	0.17 Eq (H1-1b)	90.0	50	W10X33
level 3	39.5	0.6	0.1	1	0.18 Eq (H1-1b)	90.0	50	W10X33
level 2	42.1	0.7	0.2	1	0.19 Eq (H1-1b)	90.0	50	W10X33
level 1	45.1	0.4	0.1	1	0.48 Eq (H1-1a)	90.0	50	W10X33

Column Line C-10

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	5.6	0.5	0.6	1	0.04 Eq (H1-1b)	0.0	50	W10X33
level 16	11.3	0.3	0.3	1	0.05 Eq (H1-1b)	0.0	50	W10X33
level 15	16.9	0.3	0.3	1	0.08 Eq (H1-1b)	0.0	50	W10X33
level 14	22.6	0.3	0.3	1	0.10 Eq (H1-1b)	0.0	50	W10X33
level 13	28.2	0.3	0.3	1	0.13 Eq (H1-1b)	0.0	50	W10X33
level 12	33.9	0.3	0.3	1	0.15 Eq (H1-1b)	0.0	50	W10X33
level 11	39.5	0.3	0.3	1	0.18 Eq (H1-1b)	0.0	50	W10X33
level 10	45.2	0.3	0.3	1	0.22 Eq (H1-1a)	0.0	50	W10X33
level 9	50.8	0.3	0.3	1	0.24 Eq (H1-1a)	0.0	50	W10X33
level 8	56.5	0.3	0.3	1	0.27 Eq (H1-1a)	0.0	50	W10X33
level 7	62.1	0.3	0.3	1	0.29 Eq (H1-1a)	0.0	50	W10X33
level 6	67.8	0.3	0.3	1	0.32 Eq (H1-1a)	0.0	50	W10X33
level 5	73.4	0.3	0.3	1	0.34 Eq (H1-1a)	0.0	50	W10X33
level 4	79.1	0.3	0.3	1	0.37 Eq (H1-1a)	0.0	50	W10X33
level 3	84.7	0.3	0.3	1	0.40 Eq (H1-1a)	0.0	50	W10X33
level 2	90.4	0.4	0.4	1	0.42 Eq (H1-1a)	0.0	50	W10X33
level 1	96.5	0.2	0.4	1	0.83 Eq (H1-1a)	0.0	50	W10X39

Column Line D-4

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	7.9	4.3	0.1	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 16	15.8	2.1	0.0	1	0.07 Eq (H1-1b)	90.0	50	W10X33
level 15	23.7	2.1	0.0	1	0.11 Eq (H1-1b)	90.0	50	W10X33
level 14	31.6	2.1	0.0	1	0.14 Eq (H1-1b)	90.0	50	W10X33
level 13	39.5	2.1	0.0	1	0.18 Eq (H1-1b)	90.0	50	W10X33
level 12	47.4	2.1	0.0	1	0.24 Eq (H1-1a)	90.0	50	W10X33
level 11	55.3	2.1	0.0	1	0.27 Eq (H1-1a)	90.0	50	W10X33
level 10	63.2	2.1	0.0	1	0.31 Eq (H1-1a)	90.0	50	W10X33

Gravity Column Design Summary

RAM Steel v14.03.01.00
DataBase: ram model
Building Code: IBC

Page 3/14
02/22/11 13:23:17
Steel Code: AISC360-05 ASD

level 9	71.1	2.1	0.0	1	0.34 Eq (H1-1a)	90.0	50	W10X33
level 8	79.0	2.1	0.0	1	0.38 Eq (H1-1a)	90.0	50	W10X33
level 7	86.9	2.1	0.0	1	0.42 Eq (H1-1a)	90.0	50	W10X33
level 6	94.8	2.1	0.0	1	0.45 Eq (H1-1a)	90.0	50	W10X33
level 5	102.8	2.1	0.0	1	0.49 Eq (H1-1a)	90.0	50	W10X33
level 4	110.7	2.1	0.0	1	0.52 Eq (H1-1a)	90.0	50	W10X33
level 3	118.6	2.1	0.0	1	0.56 Eq (H1-1a)	90.0	50	W10X33
level 2	126.5	2.8	0.0	1	0.60 Eq (H1-1a)	90.0	50	W10X33
level 1	134.9	1.5	0.1	1	0.98 Eq (H1-1a)	90.0	50	W10X45

Column Line D-13

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	7.9	4.3	0.1	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 16	15.8	2.1	0.0	1	0.07 Eq (H1-1b)	90.0	50	W10X33
level 15	23.7	2.1	0.0	1	0.11 Eq (H1-1b)	90.0	50	W10X33
level 14	31.6	2.1	0.0	1	0.14 Eq (H1-1b)	90.0	50	W10X33
level 13	39.5	2.1	0.0	1	0.18 Eq (H1-1b)	90.0	50	W10X33
level 12	47.4	2.1	0.0	1	0.24 Eq (H1-1a)	90.0	50	W10X33
level 11	55.3	2.1	0.0	1	0.27 Eq (H1-1a)	90.0	50	W10X33
level 10	63.2	2.1	0.0	1	0.31 Eq (H1-1a)	90.0	50	W10X33
level 9	71.1	2.1	0.0	1	0.34 Eq (H1-1a)	90.0	50	W10X33
level 8	79.0	2.1	0.0	1	0.38 Eq (H1-1a)	90.0	50	W10X33
level 7	86.9	2.1	0.0	1	0.42 Eq (H1-1a)	90.0	50	W10X33
level 6	94.8	2.1	0.0	1	0.45 Eq (H1-1a)	90.0	50	W10X33
level 5	102.8	2.1	0.0	1	0.49 Eq (H1-1a)	90.0	50	W10X33
level 4	110.7	2.1	0.0	1	0.52 Eq (H1-1a)	90.0	50	W10X33
level 3	118.6	2.1	0.0	1	0.56 Eq (H1-1a)	90.0	50	W10X33
level 2	126.5	2.8	0.0	1	0.60 Eq (H1-1a)	90.0	50	W10X33
level 1	134.9	1.5	0.1	1	0.98 Eq (H1-1a)	90.0	50	W10X45

Column Line E-9

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	7.6	0.0	2.1	1	0.08 Eq (H1-1b)	0.0	50	W10X33
level 16	15.2	0.0	1.0	1	0.07 Eq (H1-1b)	0.0	50	W10X33
level 15	22.9	0.0	1.0	1	0.10 Eq (H1-1b)	0.0	50	W10X33
level 14	30.5	0.0	1.0	1	0.14 Eq (H1-1b)	0.0	50	W10X33
level 13	38.1	0.0	1.0	1	0.17 Eq (H1-1b)	0.0	50	W10X33
level 12	45.7	0.0	1.0	1	0.23 Eq (H1-1a)	0.0	50	W10X33
level 11	53.4	0.0	1.0	1	0.27 Eq (H1-1a)	0.0	50	W10X33
level 10	61.0	0.0	1.0	1	0.30 Eq (H1-1a)	0.0	50	W10X33
level 9	68.6	0.0	1.0	1	0.34 Eq (H1-1a)	0.0	50	W10X33
level 8	76.2	0.0	1.0	1	0.37 Eq (H1-1a)	0.0	50	W10X33
level 7	83.9	0.0	1.0	1	0.41 Eq (H1-1a)	0.0	50	W10X33
level 6	91.5	0.0	1.0	1	0.44 Eq (H1-1a)	0.0	50	W10X33
level 5	99.1	0.0	1.0	1	0.48 Eq (H1-1a)	0.0	50	W10X33

Gravity Column Design Summary

RAM Steel v14.03.01.00
DataBase: ram model
Building Code: IBC

Page 4/14
02/22/11 13:23:17
Steel Code: AISC360-05 ASD

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 4	106.7	0.0	1.0	1	0.51 Eq (H1-1a)	0.0	50	W10X33
level 3	114.4	0.0	1.0	1	0.55 Eq (H1-1a)	0.0	50	W10X33
level 2	122.0	0.0	1.4	1	0.59 Eq (H1-1a)	0.0	50	W10X33
level 1	130.2	0.0	1.9	1	0.97 Eq (H1-1a)	0.0	50	W10X45

Column Line F-9

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	14.4	0.0	0.0	1	0.07 Eq (H1-1b)	0.0	50	W10X33
level 16	28.7	0.0	0.0	1	0.13 Eq (H1-1b)	0.0	50	W10X33
level 15	43.1	0.0	0.0	1	0.20 Eq (H1-1b)	0.0	50	W10X33
level 14	57.4	0.0	0.0	1	0.26 Eq (H1-1a)	0.0	50	W10X33
level 13	71.8	0.0	0.0	1	0.33 Eq (H1-1a)	0.0	50	W10X33
level 12	86.1	0.0	0.0	1	0.39 Eq (H1-1a)	0.0	50	W10X33
level 11	100.5	0.0	0.0	1	0.46 Eq (H1-1a)	0.0	50	W10X33
level 10	114.8	0.0	0.0	1	0.52 Eq (H1-1a)	0.0	50	W10X33
level 9	129.2	0.0	0.0	1	0.59 Eq (H1-1a)	0.0	50	W10X33
level 8	143.5	0.0	0.0	1	0.65 Eq (H1-1a)	0.0	50	W10X33
level 7	157.9	0.0	0.0	1	0.72 Eq (H1-1a)	0.0	50	W10X33
level 6	172.2	0.0	0.0	1	0.78 Eq (H1-1a)	0.0	50	W10X33
level 5	186.6	0.0	0.0	1	0.85 Eq (H1-1a)	0.0	50	W10X33
level 4	200.9	0.0	0.0	1	0.91 Eq (H1-1a)	0.0	50	W10X33
level 3	215.3	0.0	0.0	1	0.98 Eq (H1-1a)	0.0	50	W10X33
level 2	229.7	0.0	0.0	1	0.87 Eq (H1-1a)	0.0	50	W10X39
level 1	244.8	0.0	0.0	1	0.99 Eq (H1-1a)	0.0	50	W10X54

Column Line G-3

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	8.4	4.7	0.0	1	0.07 Eq (H1-1b)	90.0	50	W10X33
level 16	16.8	2.4	0.0	1	0.08 Eq (H1-1b)	90.0	50	W10X33
level 15	25.2	2.4	0.0	1	0.11 Eq (H1-1b)	90.0	50	W10X33
level 14	33.6	2.4	0.0	1	0.15 Eq (H1-1b)	90.0	50	W10X33
level 13	42.1	2.4	0.0	1	0.19 Eq (H1-1b)	90.0	50	W10X33
level 12	50.5	2.4	0.0	1	0.25 Eq (H1-1a)	90.0	50	W10X33
level 11	58.9	2.4	0.0	1	0.29 Eq (H1-1a)	90.0	50	W10X33
level 10	67.3	2.4	0.0	1	0.33 Eq (H1-1a)	90.0	50	W10X33
level 9	75.7	2.4	0.0	1	0.37 Eq (H1-1a)	90.0	50	W10X33
level 8	84.1	2.4	0.0	1	0.40 Eq (H1-1a)	90.0	50	W10X33
level 7	92.5	2.4	0.0	1	0.44 Eq (H1-1a)	90.0	50	W10X33
level 6	100.9	2.4	0.0	1	0.48 Eq (H1-1a)	90.0	50	W10X33
level 5	109.3	2.4	0.0	1	0.52 Eq (H1-1a)	90.0	50	W10X33
level 4	117.8	2.4	0.0	1	0.56 Eq (H1-1a)	90.0	50	W10X33
level 3	126.2	2.4	0.0	1	0.60 Eq (H1-1a)	90.0	50	W10X33
level 2	134.6	3.1	0.0	1	0.64 Eq (H1-1a)	90.0	50	W10X33
level 1	143.6	1.6	0.0	1	0.65 Eq (H1-1a)	90.0	50	W10X49

Gravity Column Design Summary

RAM Steel v14.03.01.00
DataBase: ram model
Building Code: IBC

Page 5/14
02/22/11 13:23:17
Steel Code: AISC360-05 ASD

Column Line G-14

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	8.4	4.7	0.0	1	0.07 Eq (H1-1b)	90.0	50	W10X33
level 16	16.9	2.4	0.0	1	0.08 Eq (H1-1b)	90.0	50	W10X33
level 15	25.3	2.4	0.0	1	0.12 Eq (H1-1b)	90.0	50	W10X33
level 14	33.8	2.4	0.0	1	0.15 Eq (H1-1b)	90.0	50	W10X33
level 13	42.2	2.4	0.0	1	0.19 Eq (H1-1b)	90.0	50	W10X33
level 12	50.7	2.4	0.0	1	0.25 Eq (H1-1a)	90.0	50	W10X33
level 11	59.1	2.4	0.0	1	0.29 Eq (H1-1a)	90.0	50	W10X33
level 10	67.6	2.4	0.0	1	0.33 Eq (H1-1a)	90.0	50	W10X33
level 9	76.0	2.4	0.0	1	0.37 Eq (H1-1a)	90.0	50	W10X33
level 8	84.4	2.4	0.0	1	0.41 Eq (H1-1a)	90.0	50	W10X33
level 7	92.9	2.4	0.0	1	0.44 Eq (H1-1a)	90.0	50	W10X33
level 6	101.3	2.4	0.0	1	0.48 Eq (H1-1a)	90.0	50	W10X33
level 5	109.8	2.4	0.0	1	0.52 Eq (H1-1a)	90.0	50	W10X33
level 4	118.2	2.4	0.0	1	0.56 Eq (H1-1a)	90.0	50	W10X33
level 3	126.7	2.4	0.0	1	0.60 Eq (H1-1a)	90.0	50	W10X33
level 2	135.1	3.2	0.0	1	0.64 Eq (H1-1a)	90.0	50	W10X33
level 1	144.2	1.6	0.0	1	0.65 Eq (H1-1a)	90.0	50	W10X49

Column Line H-7

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	8.6	5.0	0.1	1	0.07 Eq (H1-1b)	0.0	50	W10X33
level 16	17.3	2.5	0.1	1	0.08 Eq (H1-1b)	0.0	50	W10X33
level 15	25.9	2.5	0.1	1	0.12 Eq (H1-1b)	0.0	50	W10X33
level 14	34.5	2.5	0.1	1	0.16 Eq (H1-1b)	0.0	50	W10X33
level 13	43.1	2.5	0.1	1	0.20 Eq (H1-1b)	0.0	50	W10X33
level 12	51.8	2.5	0.1	1	0.26 Eq (H1-1a)	0.0	50	W10X33
level 11	60.4	2.5	0.1	1	0.30 Eq (H1-1a)	0.0	50	W10X33
level 10	69.0	2.5	0.1	1	0.34 Eq (H1-1a)	0.0	50	W10X33
level 9	77.7	2.5	0.1	1	0.38 Eq (H1-1a)	0.0	50	W10X33
level 8	86.3	2.5	0.1	1	0.42 Eq (H1-1a)	0.0	50	W10X33
level 7	94.9	2.5	0.1	1	0.46 Eq (H1-1a)	0.0	50	W10X33
level 6	103.6	2.5	0.1	1	0.50 Eq (H1-1a)	0.0	50	W10X33
level 5	112.2	2.5	0.1	1	0.53 Eq (H1-1a)	0.0	50	W10X33
level 4	120.8	2.5	0.1	1	0.57 Eq (H1-1a)	0.0	50	W10X33
level 3	129.4	2.5	0.1	1	0.61 Eq (H1-1a)	0.0	50	W10X33
level 2	138.1	3.3	0.1	1	0.66 Eq (H1-1a)	0.0	50	W10X33
level 1	147.4	1.7	0.1	1	0.66 Eq (H1-1a)	0.0	50	W10X49

Column Line H-9

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	25.0	6.6	0.5	1	0.14 Eq (H1-1b)	0.0	50	W10X33
level 16	50.1	3.3	0.3	1	0.26 Eq (H1-1a)	0.0	50	W10X33
level 15	75.1	3.3	0.3	1	0.38 Eq (H1-1a)	0.0	50	W10X33

Gravity Column Design Summary

RAM Steel v14.03.01.00 Page 6/14
DataBase: ram model 02/22/11 13:23:17
Building Code: IBC Steel Code: AISC360-05 ASD

level 14	100.2	3.3	0.3	1	0.49 Eq (H1-1a)	0.0	50	W10X33
level 13	125.2	3.3	0.3	1	0.61 Eq (H1-1a)	0.0	50	W10X33
level 12	150.3	3.3	0.3	1	0.72 Eq (H1-1a)	0.0	50	W10X33
level 11	175.3	3.3	0.3	1	0.83 Eq (H1-1a)	0.0	50	W10X33
level 10	200.4	3.3	0.3	1	0.95 Eq (H1-1a)	0.0	50	W10X33
level 9	225.5	3.3	0.3	1	0.89 Eq (H1-1a)	0.0	50	W10X39
level 8	250.6	3.3	0.3	1	0.98 Eq (H1-1a)	0.0	50	W10X39
level 7	275.7	3.4	0.3	1	0.93 Eq (H1-1a)	0.0	50	W10X45
level 6	301.0	3.4	0.3	1	0.84 Eq (H1-1a)	0.0	50	W10X49
level 5	326.2	3.4	0.3	1	0.91 Eq (H1-1a)	0.0	50	W10X49
level 4	351.4	3.4	0.3	1	0.98 Eq (H1-1a)	0.0	50	W10X49
level 3	376.6	3.4	0.3	1	0.96 Eq (H1-1a)	0.0	50	W10X54
level 2	401.9	4.5	0.4	1	0.92 Eq (H1-1a)	0.0	50	W10X60
level 1	428.6	2.4	0.4	1	0.89 Eq (H1-1a)	0.0	50	W10X100

Column Line I-2

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	6.3	3.5	0.0	1	0.05 Eq (H1-1b)	90.0	50	W10X33
level 16	12.5	1.8	0.0	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 15	18.8	1.8	0.0	1	0.09 Eq (H1-1b)	90.0	50	W10X33
level 14	25.0	1.8	0.0	1	0.11 Eq (H1-1b)	90.0	50	W10X33
level 13	31.3	1.8	0.0	1	0.14 Eq (H1-1b)	90.0	50	W10X33
level 12	37.5	1.8	0.0	1	0.17 Eq (H1-1b)	90.0	50	W10X33
level 11	43.8	1.8	0.0	1	0.20 Eq (H1-1b)	90.0	50	W10X33
level 10	50.0	1.8	0.0	1	0.24 Eq (H1-1a)	90.0	50	W10X33
level 9	56.3	1.8	0.0	1	0.27 Eq (H1-1a)	90.0	50	W10X33
level 8	62.5	1.8	0.0	1	0.30 Eq (H1-1a)	90.0	50	W10X33
level 7	68.8	1.8	0.0	1	0.33 Eq (H1-1a)	90.0	50	W10X33
level 6	75.0	1.8	0.0	1	0.36 Eq (H1-1a)	90.0	50	W10X33
level 5	81.3	1.8	0.0	1	0.39 Eq (H1-1a)	90.0	50	W10X33
level 4	87.5	1.8	0.0	1	0.41 Eq (H1-1a)	90.0	50	W10X33
level 3	93.8	1.8	0.0	1	0.44 Eq (H1-1a)	90.0	50	W10X33
level 2	100.0	2.3	0.0	1	0.48 Eq (H1-1a)	90.0	50	W10X33
level 1	106.7	1.2	0.0	1	0.92 Eq (H1-1a)	90.0	50	W10X39

Column Line I-15

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	8.5	4.9	0.0	1	0.07 Eq (H1-1b)	90.0	50	W10X33
level 16	16.9	2.4	0.0	1	0.08 Eq (H1-1b)	90.0	50	W10X33
level 15	25.4	2.4	0.0	1	0.12 Eq (H1-1b)	90.0	50	W10X33
level 14	33.9	2.4	0.0	1	0.15 Eq (H1-1b)	90.0	50	W10X33
level 13	42.4	2.4	0.0	1	0.19 Eq (H1-1b)	90.0	50	W10X33
level 12	50.8	2.4	0.0	1	0.25 Eq (H1-1a)	90.0	50	W10X33
level 11	59.3	2.4	0.0	1	0.29 Eq (H1-1a)	90.0	50	W10X33
level 10	67.8	2.4	0.0	1	0.33 Eq (H1-1a)	90.0	50	W10X33

Gravity Column Design Summary

RAM Steel v14.03.01.00 Page 7/14
DataBase: ram model 02/22/11 13:23:17
Building Code: IBC Steel Code: AISC360-05 ASD

level 9	76.2	2.4	0.0	1	0.37 Eq (H1-1a)	90.0	50	W10X33
level 8	84.7	2.4	0.0	1	0.41 Eq (H1-1a)	90.0	50	W10X33
level 7	93.2	2.4	0.0	1	0.45 Eq (H1-1a)	90.0	50	W10X33
level 6	101.6	2.4	0.0	1	0.48 Eq (H1-1a)	90.0	50	W10X33
level 5	110.1	2.4	0.0	1	0.52 Eq (H1-1a)	90.0	50	W10X33
level 4	118.6	2.4	0.0	1	0.56 Eq (H1-1a)	90.0	50	W10X33
level 3	127.1	2.4	0.0	1	0.60 Eq (H1-1a)	90.0	50	W10X33
level 2	135.5	3.3	0.0	1	0.65 Eq (H1-1a)	90.0	50	W10X33
level 1	144.6	1.7	0.0	1	0.65 Eq (H1-1a)	90.0	50	W10X49

Column Line K-1

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	6.3	3.6	0.0	1	0.05 Eq (H1-1b)	90.0	50	W10X33
level 16	12.5	1.8	0.0	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 15	18.8	1.8	0.0	1	0.09 Eq (H1-1b)	90.0	50	W10X33
level 14	25.0	1.8	0.0	1	0.11 Eq (H1-1b)	90.0	50	W10X33
level 13	31.3	1.8	0.0	1	0.14 Eq (H1-1b)	90.0	50	W10X33
level 12	37.5	1.8	0.0	1	0.17 Eq (H1-1b)	90.0	50	W10X33
level 11	43.8	1.8	0.0	1	0.20 Eq (H1-1b)	90.0	50	W10X33
level 10	50.0	1.8	0.0	1	0.24 Eq (H1-1a)	90.0	50	W10X33
level 9	56.3	1.8	0.0	1	0.27 Eq (H1-1a)	90.0	50	W10X33
level 8	62.5	1.8	0.0	1	0.30 Eq (H1-1a)	90.0	50	W10X33
level 7	68.8	1.8	0.0	1	0.33 Eq (H1-1a)	90.0	50	W10X33
level 6	75.0	1.8	0.0	1	0.36 Eq (H1-1a)	90.0	50	W10X33
level 5	81.3	1.8	0.0	1	0.39 Eq (H1-1a)	90.0	50	W10X33
level 4	87.6	1.8	0.0	1	0.41 Eq (H1-1a)	90.0	50	W10X33
level 3	93.8	1.8	0.0	1	0.44 Eq (H1-1a)	90.0	50	W10X33
level 2	100.1	2.4	0.0	1	0.48 Eq (H1-1a)	90.0	50	W10X33
level 1	106.8	1.2	0.0	1	0.92 Eq (H1-1a)	90.0	50	W10X39

Column Line K-16

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	8.8	5.1	0.0	1	0.07 Eq (H1-1b)	90.0	50	W10X33
level 16	17.5	2.6	0.0	1	0.08 Eq (H1-1b)	90.0	50	W10X33
level 15	26.3	2.6	0.0	1	0.12 Eq (H1-1b)	90.0	50	W10X33
level 14	35.0	2.6	0.0	1	0.16 Eq (H1-1b)	90.0	50	W10X33
level 13	43.8	2.6	0.0	1	0.20 Eq (H1-1b)	90.0	50	W10X33
level 12	52.6	2.6	0.0	1	0.26 Eq (H1-1a)	90.0	50	W10X33
level 11	61.3	2.6	0.0	1	0.30 Eq (H1-1a)	90.0	50	W10X33
level 10	70.1	2.6	0.0	1	0.34 Eq (H1-1a)	90.0	50	W10X33
level 9	78.8	2.6	0.0	1	0.38 Eq (H1-1a)	90.0	50	W10X33
level 8	87.6	2.6	0.0	1	0.42 Eq (H1-1a)	90.0	50	W10X33
level 7	96.4	2.6	0.0	1	0.46 Eq (H1-1a)	90.0	50	W10X33
level 6	105.1	2.6	0.0	1	0.50 Eq (H1-1a)	90.0	50	W10X33
level 5	113.9	2.6	0.0	1	0.54 Eq (H1-1a)	90.0	50	W10X33

Gravity Column Design Summary

RAM Steel v14.03.01.00
DataBase: ram model
Building Code: IBC

Page 8/14
02/22/11 13:23:17
Steel Code: AISC360-05 ASD

level 4	122.7	2.6	0.0	1	0.58 Eq (H1-1a)	90.0	50	W10X33
level 3	131.4	2.6	0.0	1	0.62 Eq (H1-1a)	90.0	50	W10X33
level 2	140.2	3.4	0.0	1	0.67 Eq (H1-1a)	90.0	50	W10X33
level 1	149.6	1.7	0.0	1	0.67 Eq (H1-1a)	90.0	50	W10X49

Column Line M-2

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	6.3	3.5	0.0	1	0.05 Eq (H1-1b)	90.0	50	W10X33
level 16	12.5	1.8	0.0	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 15	18.8	1.8	0.0	1	0.09 Eq (H1-1b)	90.0	50	W10X33
level 14	25.0	1.8	0.0	1	0.11 Eq (H1-1b)	90.0	50	W10X33
level 13	31.3	1.8	0.0	1	0.14 Eq (H1-1b)	90.0	50	W10X33
level 12	37.5	1.8	0.0	1	0.17 Eq (H1-1b)	90.0	50	W10X33
level 11	43.8	1.8	0.0	1	0.20 Eq (H1-1b)	90.0	50	W10X33
level 10	50.0	1.8	0.0	1	0.24 Eq (H1-1a)	90.0	50	W10X33
level 9	56.3	1.8	0.0	1	0.27 Eq (H1-1a)	90.0	50	W10X33
level 8	62.5	1.8	0.0	1	0.30 Eq (H1-1a)	90.0	50	W10X33
level 7	68.8	1.8	0.0	1	0.33 Eq (H1-1a)	90.0	50	W10X33
level 6	75.0	1.8	0.0	1	0.36 Eq (H1-1a)	90.0	50	W10X33
level 5	81.3	1.8	0.0	1	0.39 Eq (H1-1a)	90.0	50	W10X33
level 4	87.5	1.8	0.0	1	0.41 Eq (H1-1a)	90.0	50	W10X33
level 3	93.8	1.8	0.0	1	0.44 Eq (H1-1a)	90.0	50	W10X33
level 2	100.0	2.3	0.0	1	0.48 Eq (H1-1a)	90.0	50	W10X33
level 1	106.7	1.2	0.0	1	0.92 Eq (H1-1a)	90.0	50	W10X39

Column Line M-15

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	8.5	4.9	0.0	1	0.07 Eq (H1-1b)	90.0	50	W10X33
level 16	16.9	2.4	0.0	1	0.08 Eq (H1-1b)	90.0	50	W10X33
level 15	25.4	2.4	0.0	1	0.12 Eq (H1-1b)	90.0	50	W10X33
level 14	33.9	2.4	0.0	1	0.15 Eq (H1-1b)	90.0	50	W10X33
level 13	42.4	2.4	0.0	1	0.19 Eq (H1-1b)	90.0	50	W10X33
level 12	50.8	2.4	0.0	1	0.25 Eq (H1-1a)	90.0	50	W10X33
level 11	59.3	2.4	0.0	1	0.29 Eq (H1-1a)	90.0	50	W10X33
level 10	67.8	2.4	0.0	1	0.33 Eq (H1-1a)	90.0	50	W10X33
level 9	76.2	2.4	0.0	1	0.37 Eq (H1-1a)	90.0	50	W10X33
level 8	84.7	2.4	0.0	1	0.41 Eq (H1-1a)	90.0	50	W10X33
level 7	93.2	2.4	0.0	1	0.45 Eq (H1-1a)	90.0	50	W10X33
level 6	101.6	2.4	0.0	1	0.48 Eq (H1-1a)	90.0	50	W10X33
level 5	110.1	2.4	0.0	1	0.52 Eq (H1-1a)	90.0	50	W10X33
level 4	118.6	2.4	0.0	1	0.56 Eq (H1-1a)	90.0	50	W10X33
level 3	127.1	2.4	0.0	1	0.60 Eq (H1-1a)	90.0	50	W10X33
level 2	135.5	3.3	0.0	1	0.65 Eq (H1-1a)	90.0	50	W10X33
level 1	144.6	1.7	0.0	1	0.65 Eq (H1-1a)	90.0	50	W10X49

Gravity Column Design Summary

RAM Steel v14.03.01.00 Page 9/14
DataBase: ram model 02/22/11 13:23:17
Building Code: IBC Steel Code: AISC360-05 ASD

Column Line N-7

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	8.6	5.0	0.1	1	0.07 Eq (H1-1b)	0.0	50	W10X33
level 16	17.3	2.5	0.1	1	0.08 Eq (H1-1b)	0.0	50	W10X33
level 15	25.9	2.5	0.1	1	0.12 Eq (H1-1b)	0.0	50	W10X33
level 14	34.5	2.5	0.1	1	0.16 Eq (H1-1b)	0.0	50	W10X33
level 13	43.1	2.5	0.1	1	0.20 Eq (H1-1b)	0.0	50	W10X33
level 12	51.8	2.5	0.1	1	0.26 Eq (H1-1a)	0.0	50	W10X33
level 11	60.4	2.5	0.1	1	0.30 Eq (H1-1a)	0.0	50	W10X33
level 10	69.0	2.5	0.1	1	0.34 Eq (H1-1a)	0.0	50	W10X33
level 9	77.7	2.5	0.1	1	0.38 Eq (H1-1a)	0.0	50	W10X33
level 8	86.3	2.5	0.1	1	0.42 Eq (H1-1a)	0.0	50	W10X33
level 7	94.9	2.5	0.1	1	0.46 Eq (H1-1a)	0.0	50	W10X33
level 6	103.6	2.5	0.1	1	0.50 Eq (H1-1a)	0.0	50	W10X33
level 5	112.2	2.5	0.1	1	0.53 Eq (H1-1a)	0.0	50	W10X33
level 4	120.8	2.5	0.1	1	0.57 Eq (H1-1a)	0.0	50	W10X33
level 3	129.4	2.5	0.1	1	0.61 Eq (H1-1a)	0.0	50	W10X33
level 2	138.1	3.3	0.1	1	0.66 Eq (H1-1a)	0.0	50	W10X33
level 1	147.4	1.7	0.1	1	0.66 Eq (H1-1a)	0.0	50	W10X49

Column Line N-9

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	24.4	6.6	0.5	1	0.14 Eq (H1-1b)	0.0	50	W10X33
level 16	48.8	3.3	0.3	1	0.26 Eq (H1-1a)	0.0	50	W10X33
level 15	73.2	3.3	0.3	1	0.37 Eq (H1-1a)	0.0	50	W10X33
level 14	97.5	3.3	0.3	1	0.48 Eq (H1-1a)	0.0	50	W10X33
level 13	121.9	3.3	0.3	1	0.59 Eq (H1-1a)	0.0	50	W10X33
level 12	146.3	3.3	0.3	1	0.70 Eq (H1-1a)	0.0	50	W10X33
level 11	170.7	3.3	0.3	1	0.81 Eq (H1-1a)	0.0	50	W10X33
level 10	195.1	3.3	0.3	1	0.92 Eq (H1-1a)	0.0	50	W10X33
level 9	219.5	3.3	0.3	1	0.87 Eq (H1-1a)	0.0	50	W10X39
level 8	244.0	3.3	0.3	1	0.96 Eq (H1-1a)	0.0	50	W10X39
level 7	268.5	3.4	0.3	1	0.90 Eq (H1-1a)	0.0	50	W10X45
level 6	293.0	3.4	0.3	1	0.98 Eq (H1-1a)	0.0	50	W10X45
level 5	317.5	3.4	0.3	1	0.89 Eq (H1-1a)	0.0	50	W10X49
level 4	342.1	3.4	0.3	1	0.96 Eq (H1-1a)	0.0	50	W10X49
level 3	366.6	3.4	0.3	1	0.93 Eq (H1-1a)	0.0	50	W10X54
level 2	391.3	4.5	0.4	1	0.90 Eq (H1-1a)	0.0	50	W10X60
level 1	417.4	2.4	0.3	1	0.87 Eq (H1-1a)	0.0	50	W10X100

Column Line O-3

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	8.3	4.6	0.0	1	0.07 Eq (H1-1b)	90.0	50	W10X33
level 16	16.5	2.3	0.0	1	0.08 Eq (H1-1b)	90.0	50	W10X33
level 15	24.8	2.3	0.0	1	0.11 Eq (H1-1b)	90.0	50	W10X33

Gravity Column Design Summary

RAM Steel v14.03.01.00 | Page 10/14
DataBase: ram model | 02/22/11 13:23:17
Building Code: IBC | Steel Code: AISC360-05 ASD

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 14	33.1	2.3	0.0	1	0.15 Eq (H1-1b)	90.0	50	W10X33
level 13	41.4	2.3	0.0	1	0.19 Eq (H1-1b)	90.0	50	W10X33
level 12	49.6	2.3	0.0	1	0.25 Eq (H1-1a)	90.0	50	W10X33
level 11	57.9	2.3	0.0	1	0.28 Eq (H1-1a)	90.0	50	W10X33
level 10	66.2	2.3	0.0	1	0.32 Eq (H1-1a)	90.0	50	W10X33
level 9	74.5	2.3	0.0	1	0.36 Eq (H1-1a)	90.0	50	W10X33
level 8	82.7	2.3	0.0	1	0.40 Eq (H1-1a)	90.0	50	W10X33
level 7	91.0	2.3	0.0	1	0.44 Eq (H1-1a)	90.0	50	W10X33
level 6	99.3	2.3	0.0	1	0.47 Eq (H1-1a)	90.0	50	W10X33
level 5	107.6	2.3	0.0	1	0.51 Eq (H1-1a)	90.0	50	W10X33
level 4	115.8	2.3	0.0	1	0.55 Eq (H1-1a)	90.0	50	W10X33
level 3	124.1	2.3	0.0	1	0.59 Eq (H1-1a)	90.0	50	W10X33
level 2	132.4	3.1	0.0	1	0.63 Eq (H1-1a)	90.0	50	W10X33
level 1	141.3	1.6	0.0	1	0.64 Eq (H1-1a)	90.0	50	W10X49

Column Line O-14

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	8.3	4.7	0.0	1	0.07 Eq (H1-1b)	90.0	50	W10X33
level 16	16.6	2.3	0.0	1	0.08 Eq (H1-1b)	90.0	50	W10X33
level 15	24.9	2.3	0.0	1	0.11 Eq (H1-1b)	90.0	50	W10X33
level 14	33.2	2.3	0.0	1	0.15 Eq (H1-1b)	90.0	50	W10X33
level 13	41.5	2.3	0.0	1	0.19 Eq (H1-1b)	90.0	50	W10X33
level 12	49.8	2.3	0.0	1	0.25 Eq (H1-1a)	90.0	50	W10X33
level 11	58.2	2.3	0.0	1	0.29 Eq (H1-1a)	90.0	50	W10X33
level 10	66.5	2.3	0.0	1	0.32 Eq (H1-1a)	90.0	50	W10X33
level 9	74.8	2.3	0.0	1	0.36 Eq (H1-1a)	90.0	50	W10X33
level 8	83.1	2.3	0.0	1	0.40 Eq (H1-1a)	90.0	50	W10X33
level 7	91.4	2.3	0.0	1	0.44 Eq (H1-1a)	90.0	50	W10X33
level 6	99.7	2.3	0.0	1	0.47 Eq (H1-1a)	90.0	50	W10X33
level 5	108.0	2.3	0.0	1	0.51 Eq (H1-1a)	90.0	50	W10X33
level 4	116.3	2.3	0.0	1	0.55 Eq (H1-1a)	90.0	50	W10X33
level 3	124.6	2.3	0.0	1	0.59 Eq (H1-1a)	90.0	50	W10X33
level 2	132.9	3.1	0.0	1	0.63 Eq (H1-1a)	90.0	50	W10X33
level 1	141.9	1.6	0.0	1	0.64 Eq (H1-1a)	90.0	50	W10X49

Column Line P-9

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	14.4	0.0	0.0	1	0.07 Eq (H1-1b)	0.0	50	W10X33
level 16	28.7	0.0	0.0	1	0.13 Eq (H1-1b)	0.0	50	W10X33
level 15	43.1	0.0	0.0	1	0.20 Eq (H1-1b)	0.0	50	W10X33
level 14	57.4	0.0	0.0	1	0.26 Eq (H1-1a)	0.0	50	W10X33
level 13	71.8	0.0	0.0	1	0.33 Eq (H1-1a)	0.0	50	W10X33
level 12	86.1	0.0	0.0	1	0.39 Eq (H1-1a)	0.0	50	W10X33
level 11	100.5	0.0	0.0	1	0.46 Eq (H1-1a)	0.0	50	W10X33
level 10	114.8	0.0	0.0	1	0.52 Eq (H1-1a)	0.0	50	W10X33

Gravity Column Design Summary

RAM Steel v14.03.01.00
DataBase: ram model
Building Code: IBC

Page 11/14
02/22/11 13:23:17
Steel Code: AISC360-05 ASD

level 9	129.2	0.0	0.0	1	0.59 Eq (H1-1a)	0.0	50	W10X33
level 8	143.5	0.0	0.0	1	0.65 Eq (H1-1a)	0.0	50	W10X33
level 7	157.9	0.0	0.0	1	0.72 Eq (H1-1a)	0.0	50	W10X33
level 6	172.2	0.0	0.0	1	0.78 Eq (H1-1a)	0.0	50	W10X33
level 5	186.6	0.0	0.0	1	0.85 Eq (H1-1a)	0.0	50	W10X33
level 4	200.9	0.0	0.0	1	0.91 Eq (H1-1a)	0.0	50	W10X33
level 3	215.3	0.0	0.0	1	0.98 Eq (H1-1a)	0.0	50	W10X33
level 2	229.7	0.0	0.0	1	0.87 Eq (H1-1a)	0.0	50	W10X39
level 1	244.8	0.0	0.0	1	0.99 Eq (H1-1a)	0.0	50	W10X54

Column Line Q-9

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	8.0	0.0	2.2	1	0.08 Eq (H1-1b)	0.0	50	W10X33
level 16	16.1	0.0	1.1	1	0.07 Eq (H1-1b)	0.0	50	W10X33
level 15	24.1	0.0	1.1	1	0.11 Eq (H1-1b)	0.0	50	W10X33
level 14	32.2	0.0	1.1	1	0.15 Eq (H1-1b)	0.0	50	W10X33
level 13	40.2	0.0	1.1	1	0.18 Eq (H1-1b)	0.0	50	W10X33
level 12	48.2	0.0	1.1	1	0.25 Eq (H1-1a)	0.0	50	W10X33
level 11	56.3	0.0	1.1	1	0.28 Eq (H1-1a)	0.0	50	W10X33
level 10	64.3	0.0	1.1	1	0.32 Eq (H1-1a)	0.0	50	W10X33
level 9	72.4	0.0	1.1	1	0.36 Eq (H1-1a)	0.0	50	W10X33
level 8	80.4	0.0	1.1	1	0.39 Eq (H1-1a)	0.0	50	W10X33
level 7	88.4	0.0	1.1	1	0.43 Eq (H1-1a)	0.0	50	W10X33
level 6	96.5	0.0	1.1	1	0.47 Eq (H1-1a)	0.0	50	W10X33
level 5	104.5	0.0	1.1	1	0.50 Eq (H1-1a)	0.0	50	W10X33
level 4	112.6	0.0	1.1	1	0.54 Eq (H1-1a)	0.0	50	W10X33
level 3	120.6	0.0	1.1	1	0.58 Eq (H1-1a)	0.0	50	W10X33
level 2	128.6	0.0	1.4	1	0.62 Eq (H1-1a)	0.0	50	W10X33
level 1	137.3	0.0	0.9	1	0.62 Eq (H1-1a)	0.0	50	W10X49

Column Line R-4

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	7.9	4.3	0.1	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 16	15.8	2.1	0.0	1	0.07 Eq (H1-1b)	90.0	50	W10X33
level 15	23.7	2.1	0.0	1	0.11 Eq (H1-1b)	90.0	50	W10X33
level 14	31.6	2.1	0.0	1	0.14 Eq (H1-1b)	90.0	50	W10X33
level 13	39.5	2.1	0.0	1	0.18 Eq (H1-1b)	90.0	50	W10X33
level 12	47.5	2.1	0.0	1	0.24 Eq (H1-1a)	90.0	50	W10X33
level 11	55.4	2.1	0.0	1	0.27 Eq (H1-1a)	90.0	50	W10X33
level 10	63.3	2.1	0.0	1	0.31 Eq (H1-1a)	90.0	50	W10X33
level 9	71.2	2.1	0.0	1	0.34 Eq (H1-1a)	90.0	50	W10X33
level 8	79.1	2.1	0.0	1	0.38 Eq (H1-1a)	90.0	50	W10X33
level 7	87.0	2.1	0.0	1	0.42 Eq (H1-1a)	90.0	50	W10X33
level 6	94.9	2.1	0.0	1	0.45 Eq (H1-1a)	90.0	50	W10X33
level 5	102.8	2.1	0.0	1	0.49 Eq (H1-1a)	90.0	50	W10X33

Gravity Column Design Summary

level 4	110.7	2.1	0.0	1	0.52 Eq (H1-1a)	90.0	50	W10X33
level 3	118.6	2.1	0.0	1	0.56 Eq (H1-1a)	90.0	50	W10X33
level 2	126.6	2.8	0.0	1	0.60 Eq (H1-1a)	90.0	50	W10X33
level 1	135.0	1.5	0.1	1	0.98 Eq (H1-1a)	90.0	50	W10X45

Column Line R-13

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	7.9	4.3	0.1	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 16	15.8	2.1	0.0	1	0.07 Eq (H1-1b)	90.0	50	W10X33
level 15	23.7	2.1	0.0	1	0.11 Eq (H1-1b)	90.0	50	W10X33
level 14	31.6	2.1	0.0	1	0.14 Eq (H1-1b)	90.0	50	W10X33
level 13	39.5	2.1	0.0	1	0.18 Eq (H1-1b)	90.0	50	W10X33
level 12	47.5	2.1	0.0	1	0.24 Eq (H1-1a)	90.0	50	W10X33
level 11	55.4	2.1	0.0	1	0.27 Eq (H1-1a)	90.0	50	W10X33
level 10	63.3	2.1	0.0	1	0.31 Eq (H1-1a)	90.0	50	W10X33
level 9	71.2	2.1	0.0	1	0.34 Eq (H1-1a)	90.0	50	W10X33
level 8	79.1	2.1	0.0	1	0.38 Eq (H1-1a)	90.0	50	W10X33
level 7	87.0	2.1	0.0	1	0.42 Eq (H1-1a)	90.0	50	W10X33
level 6	94.9	2.1	0.0	1	0.45 Eq (H1-1a)	90.0	50	W10X33
level 5	102.8	2.1	0.0	1	0.49 Eq (H1-1a)	90.0	50	W10X33
level 4	110.7	2.1	0.0	1	0.52 Eq (H1-1a)	90.0	50	W10X33
level 3	118.6	2.1	0.0	1	0.56 Eq (H1-1a)	90.0	50	W10X33
level 2	126.6	2.8	0.0	1	0.60 Eq (H1-1a)	90.0	50	W10X33
level 1	135.0	1.5	0.1	1	0.98 Eq (H1-1a)	90.0	50	W10X45

Column Line S-8

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	5.9	0.5	0.6	1	0.04 Eq (H1-1b)	0.0	50	W10X33
level 16	11.8	0.3	0.3	1	0.05 Eq (H1-1b)	0.0	50	W10X33
level 15	17.6	0.3	0.3	1	0.08 Eq (H1-1b)	0.0	50	W10X33
level 14	23.5	0.3	0.3	1	0.11 Eq (H1-1b)	0.0	50	W10X33
level 13	29.4	0.3	0.3	1	0.13 Eq (H1-1b)	0.0	50	W10X33
level 12	35.3	0.3	0.3	1	0.16 Eq (H1-1b)	0.0	50	W10X33
level 11	41.2	0.3	0.3	1	0.19 Eq (H1-1b)	0.0	50	W10X33
level 10	47.1	0.3	0.3	1	0.22 Eq (H1-1a)	0.0	50	W10X33
level 9	52.9	0.3	0.3	1	0.25 Eq (H1-1a)	0.0	50	W10X33
level 8	58.8	0.3	0.3	1	0.28 Eq (H1-1a)	0.0	50	W10X33
level 7	64.7	0.3	0.3	1	0.30 Eq (H1-1a)	0.0	50	W10X33
level 6	70.6	0.3	0.3	1	0.33 Eq (H1-1a)	0.0	50	W10X33
level 5	76.5	0.3	0.3	1	0.36 Eq (H1-1a)	0.0	50	W10X33
level 4	82.4	0.3	0.3	1	0.38 Eq (H1-1a)	0.0	50	W10X33
level 3	88.2	0.3	0.3	1	0.41 Eq (H1-1a)	0.0	50	W10X33
level 2	94.1	0.4	0.4	1	0.44 Eq (H1-1a)	0.0	50	W10X33
level 1	100.5	0.2	0.4	1	0.87 Eq (H1-1a)	0.0	50	W10X39

Gravity Column Design Summary

RAM Steel v14.03.01.00
DataBase: ram model
Building Code: IBC

Page 13/14
02/22/11 13:23:17
Steel Code: AISC360-05 ASD

Column Line T-5

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	2.7	1.1	0.3	1	0.03 Eq (H1-1b)	90.0	50	W10X33
level 16	5.4	0.6	0.1	1	0.02 Eq (H1-1b)	90.0	50	W10X33
level 15	8.2	0.6	0.1	1	0.04 Eq (H1-1b)	90.0	50	W10X33
level 14	10.9	0.6	0.1	1	0.05 Eq (H1-1b)	90.0	50	W10X33
level 13	13.6	0.6	0.1	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 12	16.3	0.6	0.1	1	0.07 Eq (H1-1b)	90.0	50	W10X33
level 11	19.1	0.6	0.1	1	0.09 Eq (H1-1b)	90.0	50	W10X33
level 10	21.8	0.6	0.1	1	0.10 Eq (H1-1b)	90.0	50	W10X33
level 9	24.5	0.6	0.1	1	0.11 Eq (H1-1b)	90.0	50	W10X33
level 8	27.2	0.6	0.1	1	0.12 Eq (H1-1b)	90.0	50	W10X33
level 7	30.0	0.6	0.1	1	0.14 Eq (H1-1b)	90.0	50	W10X33
level 6	32.7	0.6	0.1	1	0.15 Eq (H1-1b)	90.0	50	W10X33
level 5	35.4	0.6	0.1	1	0.16 Eq (H1-1b)	90.0	50	W10X33
level 4	38.1	0.6	0.1	1	0.17 Eq (H1-1b)	90.0	50	W10X33
level 3	40.9	0.6	0.1	1	0.19 Eq (H1-1b)	90.0	50	W10X33
level 2	43.6	0.8	0.2	1	0.20 Eq (H1-1b)	90.0	50	W10X33
level 1	46.6	0.4	0.1	1	0.49 Eq (H1-1a)	90.0	50	W10X33

Column Line T-12

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	6.7	3.5	0.2	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 16	13.5	1.7	0.1	1	0.06 Eq (H1-1b)	90.0	50	W10X33
level 15	20.2	1.7	0.1	1	0.09 Eq (H1-1b)	90.0	50	W10X33
level 14	27.0	1.7	0.1	1	0.12 Eq (H1-1b)	90.0	50	W10X33
level 13	33.7	1.7	0.1	1	0.15 Eq (H1-1b)	90.0	50	W10X33
level 12	40.5	1.7	0.1	1	0.18 Eq (H1-1b)	90.0	50	W10X33
level 11	47.2	1.7	0.1	1	0.23 Eq (H1-1a)	90.0	50	W10X33
level 10	54.0	1.7	0.1	1	0.26 Eq (H1-1a)	90.0	50	W10X33
level 9	60.7	1.7	0.1	1	0.29 Eq (H1-1a)	90.0	50	W10X33
level 8	67.4	1.7	0.1	1	0.32 Eq (H1-1a)	90.0	50	W10X33
level 7	74.2	1.7	0.1	1	0.36 Eq (H1-1a)	90.0	50	W10X33
level 6	80.9	1.7	0.1	1	0.39 Eq (H1-1a)	90.0	50	W10X33
level 5	87.7	1.7	0.1	1	0.42 Eq (H1-1a)	90.0	50	W10X33
level 4	94.4	1.7	0.1	1	0.45 Eq (H1-1a)	90.0	50	W10X33
level 3	101.2	1.7	0.1	1	0.48 Eq (H1-1a)	90.0	50	W10X33
level 2	107.9	2.3	0.1	1	0.51 Eq (H1-1a)	90.0	50	W10X33
level 1	115.1	1.2	0.2	1	0.99 Eq (H1-1a)	90.0	50	W10X39

Column Line U-11

Level	P	Mx	My	LC	Interaction Eq.	Angle	Fy	Size
level 17	4.4	1.1	1.0	1	0.05 Eq (H1-1b)	90.0	50	W10X33
level 16	8.9	0.6	0.5	1	0.04 Eq (H1-1b)	90.0	50	W10X33
level 15	13.3	0.6	0.5	1	0.06 Eq (H1-1b)	90.0	50	W10X33

Gravity Column Design Summary

RAM Steel v14.03.01.00 Page 14/14
DataBase: ram model 02/22/11 13:23:17
Building Code: IBC Steel Code: AISC360-05 ASD

level 14	17.8	0.6	0.5	1	0.08 Eq (H1-1b)	90.0	50	W10X33
level 13	22.2	0.6	0.5	1	0.10 Eq (H1-1b)	90.0	50	W10X33
level 12	26.7	0.6	0.5	1	0.12 Eq (H1-1b)	90.0	50	W10X33
level 11	31.1	0.6	0.5	1	0.14 Eq (H1-1b)	90.0	50	W10X33
level 10	35.6	0.6	0.5	1	0.16 Eq (H1-1b)	90.0	50	W10X33
level 9	40.0	0.6	0.5	1	0.18 Eq (H1-1b)	90.0	50	W10X33
level 8	44.5	0.6	0.5	1	0.22 Eq (H1-1a)	90.0	50	W10X33
level 7	48.9	0.6	0.5	1	0.24 Eq (H1-1a)	90.0	50	W10X33
level 6	53.4	0.6	0.5	1	0.26 Eq (H1-1a)	90.0	50	W10X33
level 5	57.8	0.6	0.5	1	0.28 Eq (H1-1a)	90.0	50	W10X33
level 4	62.3	0.6	0.5	1	0.30 Eq (H1-1a)	90.0	50	W10X33
level 3	66.7	0.6	0.5	1	0.32 Eq (H1-1a)	90.0	50	W10X33
level 2	71.2	0.8	0.6	1	0.35 Eq (H1-1a)	90.0	50	W10X33
level 1	76.0	0.4	0.6	1	0.81 Eq (H1-1a)	90.0	50	W10X33

APPENDIX D: WIND CALCULATINONS

TECH #1 | WIND CALCULATIONS | 1/2

$K_z \Rightarrow$ FROM TABLE, SOME INTERPOLATED

EX. FLOOR 16 : $y_2 = \dfrac{(170-160)(1.17-1.13)}{(180-160)} + 1.13$

$y_2 = 1.15$

$q_z = 0.00256 K_z K_{zt} K_d V^2 I$

EX. FLOOR 2: $0.00256(0.7)(1.0)(0.85)(90)^2(1.0) = 12.338$

$\bar{z} = 180'$

$q_h = 0.00256(1.17)(1.0)(0.85)(90)^2(1.0) = 20.622$

C_p WINDWARD $= 0.8$

C_p LEEWARD $= -0.5$ N/S

C_p LEWARD $= -0.372$ E/W

$GC_{pi} = \pm 0.18$

$p_z = q_z G C_p - q_h G C_{pi}$ WINDWARD

$p_h = q_h G C_p - q_h G C_{pi}$ LEEWARD

EX. FLOOR 5: $p_z = (14.982)(0.85)(0.8) - (20.622)(-0.18)$

$= 13.900$ psf

TECH #1 WIND CALCULATIONS 2/2

EX. FLOOR 5: $p_h = (20.622)(0.85)(-0.5) - (20.622)(0.18)$

$= -12.476 \text{ psf } (N/S)$

$p_h = (20.622)(0.85)(-0.372) - (20.622)(0.18)$

$= -10.233 \text{ psf } (E/W)$

TOTAL PRESSURE $= |p_z| + |p_h|$

EX. FLOOR 8: $|15.218| + |-12.476| = 27.694 \text{ psf}$ (N/S)

TOTAL FORCE $= T_p \times$ AREA

EX. FLOOR 10: $28.353\,(10' \times 110')/1000 = 31.189 \text{ K}$

TOTAL SHEAR $= T_{F \text{ OF LEVEL}} + T_{F \text{ LEVELS ABOVE}}$

EX. FLOOR 16: $(32.969) + (33.232) = 66.201 \text{ K}$

TOTAL MOMENT FROM LEVEL $= T_F \times$ MEAN FLOOR HT.

EX. FLOOR 12: $(31.848) \times \left(\frac{130+120}{2}\right) = 3980.998 \text{ 'K}$

APPENDIX E: SEISMIC CALCULATIONS

TECH #1 SEISMIC CALCS. 1/2

EX. N/S

$$S_{MS} = F_a S_s = 1.2(0.28) = 0.336$$

$$S_{M1} = F_v S_1 = 1.7(0.06) = 0.102$$

$$S_{DS} = 2/3\, S_{MS} = 2/3\,(0.336) = 0.224$$

$$S_{D1} = 2/3\, S_{M1} = 2/3\,(0.102) = 0.068$$

$$T_a = C_x h_n^x = 0.02(180)^{0.75} = 0.95\text{s}$$

$$T = T_a C_u = (0.95)(1.7) = 4.00$$

TOTAL BLDG WT. $= 658 + 15(1828) + 1610 = 29{,}688\text{ K}$

BASE SHEAR $(V) = C_s W_T$

$$V = 0.016(29{,}688) = 475\text{ K}$$

$W_x h_x^k$

EX. LEVEL 2: $\left[(30)(1828)\right]^2 = 3.0 \times 10^9$

$$C_{vx} = \frac{W_x h_x^k}{\Sigma W_x h_x^k} \qquad \Sigma W_x h_x^k = 6.8 \times 10^{11}$$

EX. LEVEL 2: $\frac{3.0 \times 10^7}{6.8 \times 10^{11}} = 0.004$

TECH #1 | SEISMIC CALCS. | 2/2

$F_x = C_{vx} V$

EX. LEVEL 9: $(0.049)(475) = 23.4\ k$

SHEAR STORY = $F_{x\ \text{OF LEVEL}} + \Sigma F_{x\ \text{LEVELS ABOVE}}$

EX. LEVEL 16: $(67.6) + (58.8) = 126.3\ k$

$M_x = F_x \cdot$ MEAN FLOOR HT

EX. LEVEL 3: $(3.7)\left(\frac{40+30}{2}\right) = 130.92\ 'k$

APPENDIX F: MEMBER CHECK SAMPLE CALCULATION

DIAGONAL MEMBER – A1

TENSILE FORCE = 138^k

HSS 7″ × 5″ × ½″ ⇒ $A_s = 9.75 \text{ in}^2$

(AISC 1-11)

A992 STEEL ⇒ $F_y = 50$ ksi

$$\frac{138^k}{9.75 \text{ in}^2} = 14.2 \text{ ksi} < 50 \text{ ksi}$$

∴ OK FOR TENSION

APPENDIX G: FOUNDATION CALCULATIONS

Existing System		
Reinforced Slab	3206	cy
+ Reinforced Columns	1333	cy
	4539	cy
(4539cy x 150 pcf x 27 cf/cy) =	18,383	kips
18,383 kips/ 20 columns =	920	kips/col.

New System						
W10 x 100	100	x	4320 lf	=	432,000	lbs
W21 x 132	132	x	1440 lf	=	190,080	lbs
W8 x 10	10	x	5032 lf	=	50,320	lbs
W14 x 22	22	x	6426 lf	=	141,372	lbs
W18 x 35	35	x	1020 lf	=	35,600	lbs
W21 x 132	132	x	2448 lf	=	323,136	lbs
16 gauge deck/concrete/reinf.	44	x	281320 sf	=	12,378,080	lbs
				=	13550588	lbs
				=	13551	kips
13551 kips / 2 = 6776 kips	6776	/	10 columns	=	678	kips/col.

APPENDIX H: COST & SCHEDULE CALCULATIONS

Existing System							
concrete		daily output	units	total o&p	amount	days	$ cost
slab-3000 psi			c. y.	107	3206		343042
placing >10		180	c. y.	24	3206	17.81	
column-3000			c.y.	107	1333		142631
placing column		140	c.y.	31	1333	9.52	
framing		daily output	units	total o&p	amount	days	$ cost
slab, flat slab		560	s.f.	6.8	86560	154.57	588608
column		250	sfca	8.4	4760	19.04	39984
reinforcing		daily output	units	total o&p	amount	days	$ cost
		2.3	ton	1925	306.38	133.2087	589781.5
total							
						334.1487	1704046.5

New System

columns		daily output	units	total o&p	amount	days	$ cost
W10x100		960	l. f.	155	4320	4.5	669600
W21x132		1000	l. f.	170	1440	1.44	244800

beams		daily output	units	total o&p	amount	days	$ cost
W8x10		600	l. f.	23.5	5032	8.39	118252
W14X22		990	l. f.	40.5	6426	6.5	260253
W18x35		960	l. f.	55	1020	1.06	56100
W21X132		1000	l. f.	170	2448	2.45	416160

decking		daily output	units	total o&p	amount	days	$ cost
16 Gauge		3200	s. f.	3.25	86560	27.05	281320

concrete		daily output	units	total o&p	amount	days	$ cost
3000 psi			c. y.	107	801		85707
placing <6		140	c. y.	31	801	5.72	
fire proofing		daily output	units	total o&p	amount	days	$ cost
flat decking		2400	s.f.	1.16	86560	36.07	100409.6
welded studs		daily output	units	total o&p	amount	days	$ cost
studs		1025	each	2.23	9600	9.37	21408
W W F		daily output	units	total o&p	amount	days	$ cost
4' x 4'		25	csf	100	685.6	27.424	68560
total							
						129.974	2322570