SEISMIC LOADS

- Seismic Zone Factor	Z = 0.15
- Site Class: Hard Rock	A
- Mapped Spectral Acceleration (0.2s)	S_S = 35% g
- Mapped Spectral Acceleration (1.0s)	S_1 = 6.5% g
- Importance Factor	I = 1.0 I_p = 1.0
- Analysis Procedure	Static Force Procedure
- Plan Structural Irregularities	No
- Vertical Structural Irregularities	No
- Building Height	h_n = 110′
- Type of Lateral System (dual system: steel eccentric braced frames with ordinary moment resisting frames)	R = 6 C_T = 0.035

In calculating the weight of the Towers for seismic forces, 100% of the dead load and 25% of the live load are considered. The resultant story force acts at the center of mass of the floor. Figure X below shows the calculated story forces and the story shear applied at each floor under the seismic design criteria.

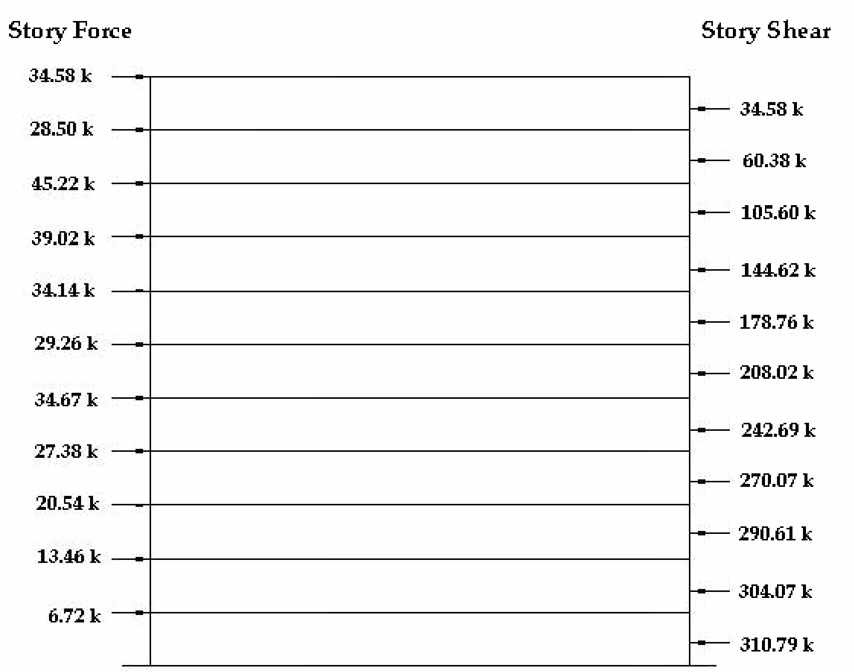

Figure 12: Calculated seismic story forces and story shear acting on the building

6.0 - STRUCTURAL DEPTH

6.1 - COMPOSITE BEAMS

A composite steel gravity system was chosen because of the high strength to weight ratio. Steel was selected for this system because long spans could be achieved. This results in larger column spacing and a regular grid. Composite steel uses shear studs to create a bond and transfer forces from the concrete slab to the steel beam. The beams were modeled and analyzed in RAM Structural System and design checks were performed to check the RAM results. These design checks can be found in Appendix B. The infill beams are W10 or W12 shapes equally spaced between girders. The girders are kept to a maximum W21 to keep the plenum depth at 2′.

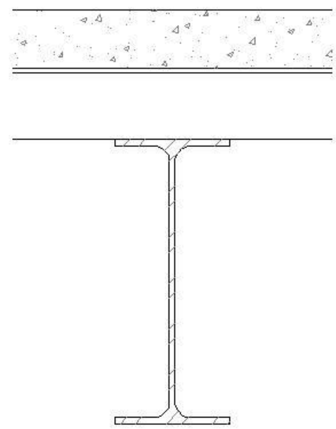

Figure 13: Composite steel section

The steel girders are able to be cantilevered at the building corners where the floor-to-ceiling windows are located. In the RAM analysis, the deflections were kept to a maximum of L/400 to create a stiffer member and reduce deflections and vibrations. The beams and girders were analyzed using LRFD method and were checked using the procedure outlined in the 13th Edition AISC Steel Manual. Hung gypsum board acts as fireproofing for the steel structural members and also provides an acoustical barrier between floors.

6.2 - COLUMNS

Loads are transferred to the gravity columns by girders. W10 shapes were chosen for the columns to keep the member within the partition and exterior walls. This creates less of an impact on the architectural floor plan. The columns were analyzed in RAM and checked using the method outlined in the 13th Edition of the LRFD. The column's capacity is checked for combined axial and flexural strength, and local buckling. Gypsum board will be used as fireproofing. The steel system creates less of an architectural impact on the floor plan as opposed to the existing concrete system. All columns are located within walls and out of the way, creating unobstructed rooms and corridors.

6.3 - COMPOSITE DECK

Using the maximum spacing of 11′-0″ between beams and the 2 hour fire rating requirement according to the New York City building code, a 2VLI18 composite deck with gypsum board fireproofing will be selected for the floor system. This deck does not need to be shored after the concrete is placed. The depth of the deck is 2″ with 2 ½″ normal weight concrete equals a total slab thickness of 4 ½″. The deck spans perpendicular to the steel infill beams.

6.4 - LATERAL FORCE RESISTING SYSTEM

Lateral forces are to be resisted by a dual system of eccentric braced frames with ordinary moment resisting frames. Eccentric braced frames are located around stair and elevator cores where the frame would be within a wall as shown in Figure 15. Moment frames braced with double angle kickers are located elsewhere throughout the building where eccentric braced frames could not be applied. See Figure 14 for typical moment frame. The frames are laid out to keep the eccentricity between center of mass and center of rigidity at a minimum to reduce the amount of torsion caused by lateral loads.

W12 shapes were applied as the lateral columns to provide additional stiffness for the frames. All braces used were 2L6x6x½ double angles.

See Appendix D for complete frame elevations with sizes.

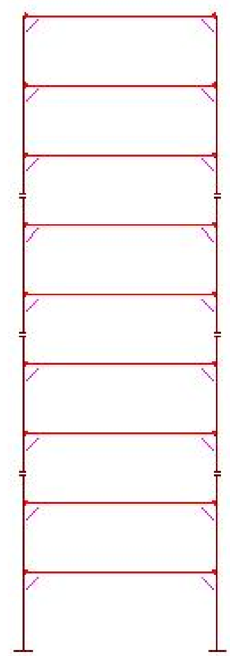

Figure 14: Typical moment frame braced with kicker angles

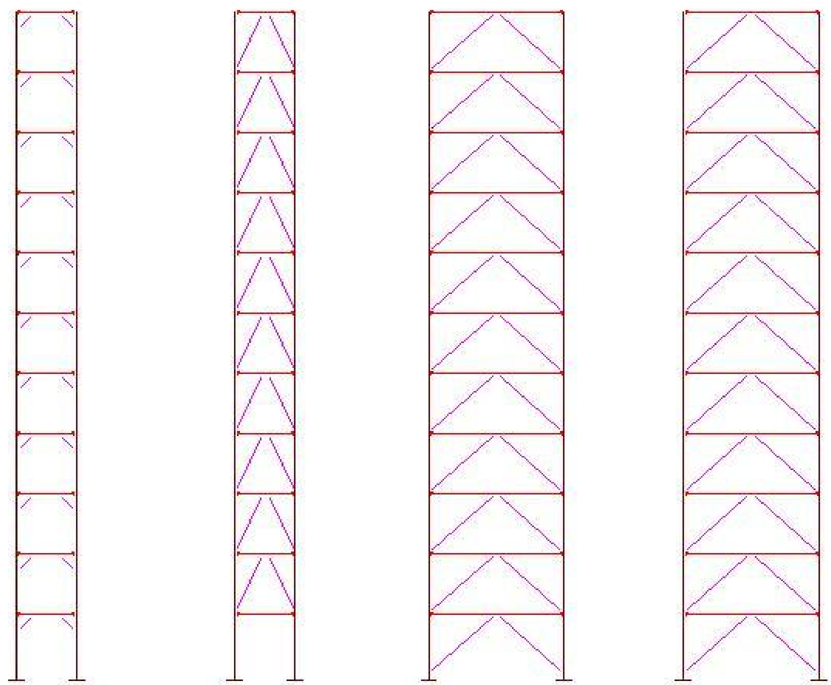

Figure 15: Typical braced frame layout around stair core

With the new steel structure, the earthquake loads in the x-direction and the wind loads in the y-direction will control. The following are diagrams depicting the deflected shape of the frame under the controlling earthquake loads in the x-direction and wind loads in the y-direction. The load combinations used were generated from RAM Frame and comply with ASCE 7-05. These load combinations are:

- 1.4 D
- 1.2 D + 1.6 L
- 1.2 D + 0.5 L + 1.6 W
- **1.2 D + 1.6 W** Controls y-direction deflection
- 0.9 D + 1.6 W
- **1.2 D + 0.5 L + 1.0 E** Controls x-direction deflection
- 1.2 D + 1.0 E
- 0.9 D + 1.0 E

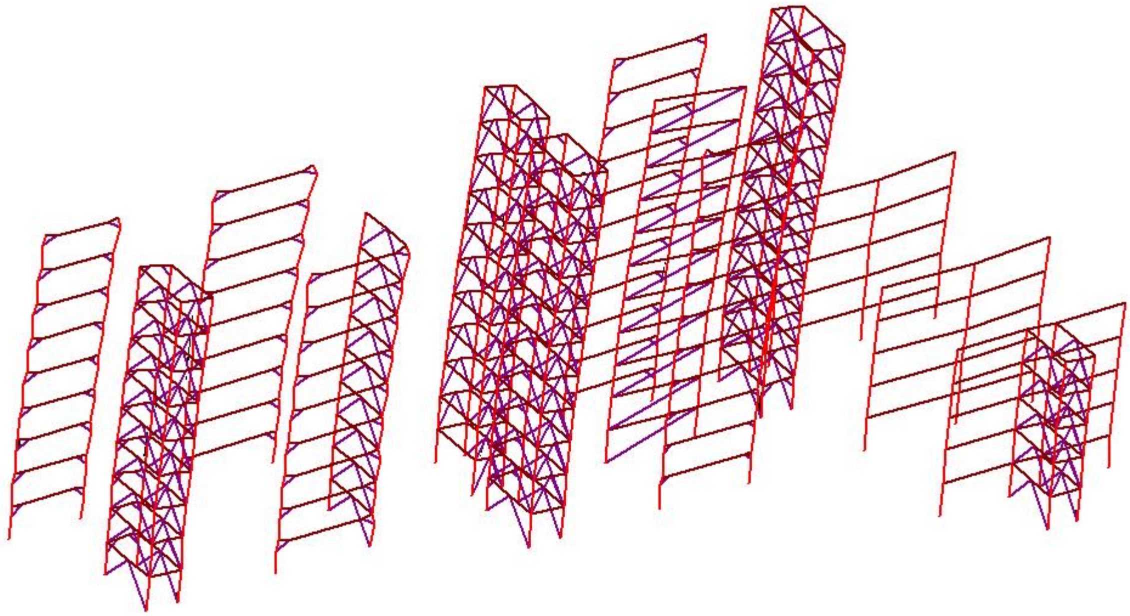

Figure 16: Frame deflections under controlling load factors in the x-direction

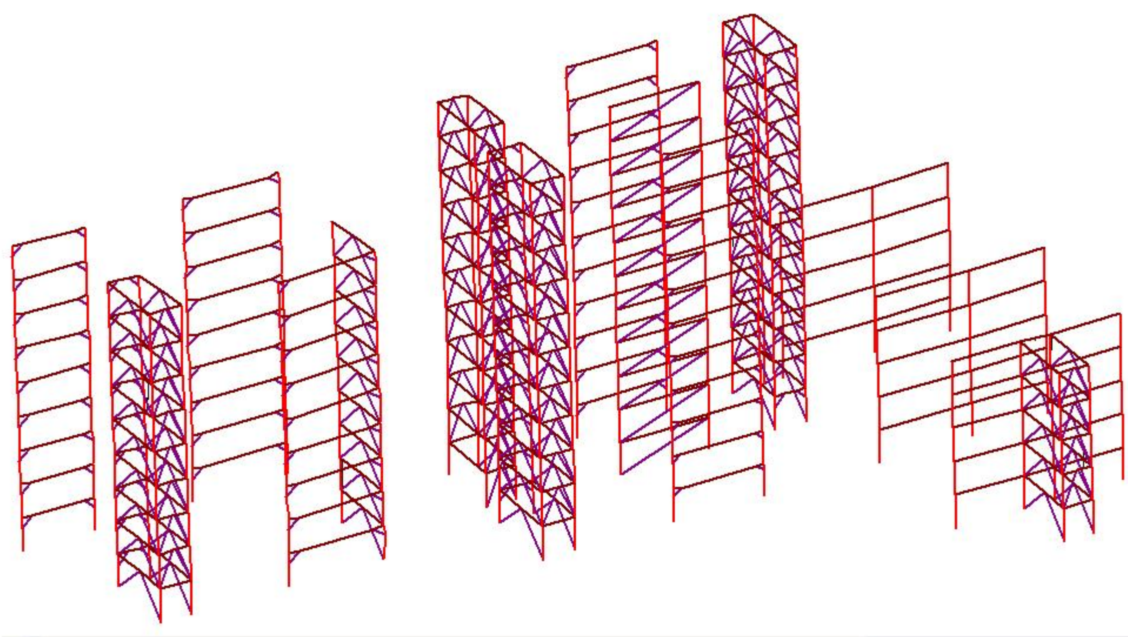

Figure 17: Frame deflections under controlling load factors in the y-direction

STORY	STORY DISPLACEMENT		STORY DRIFT	
	X	Y	X	Y
Roof	3.53″	1.87″	0.36″	0.17″
10	3.17″	1.70″	0.32″	0.08″
9	2.85″	1.62″	0.38″	0.21″
8	2.47″	1.41″	0.40″	0.21″
7	2.07″	1.20″	0.40″	0.21″
6	1.67″	0.99″	0.39″	0.27″
5	1.28″	0.72″	0.33″	0.18″
4	0.95″	0.54″	0.30″	0.17″
3	0.65″	0.37″	0.26″	0.16″
2	0.39″	0.21″	0.19″	0.12″
1	0.20″	0.09″	0.20″	0.09″

The displacement at the roof level in the x direction is slightly higher than the H/400 industry standard, which equals 3.50″.

6.5 - TYPICAL CONNECTIONS

For most of the connections, in the building, typical shear and moment connections can be applied. The connections are designed using the controlling ultimate factored loads obtained from the analysis. The procedure for connection design is outlined in the 13th edition of the LRFD Manual of Steel Construction.

For the beam to girder connections, single angles can be applied as the shear connection. The angles are shop welded to the girder and bolted in the field to the beam. Appendix B shows the complete design calculation for this type of connection

For typical gravity beam to gravity column connections, shear tabs can be used. The steel plates are shop welded to the columns and bolted to the girder in the field. In some instances, web stiffener plates are welded in the column web to protect the column web from crippling under panel zone shear. Shown below are schematics for the typical shear connections.

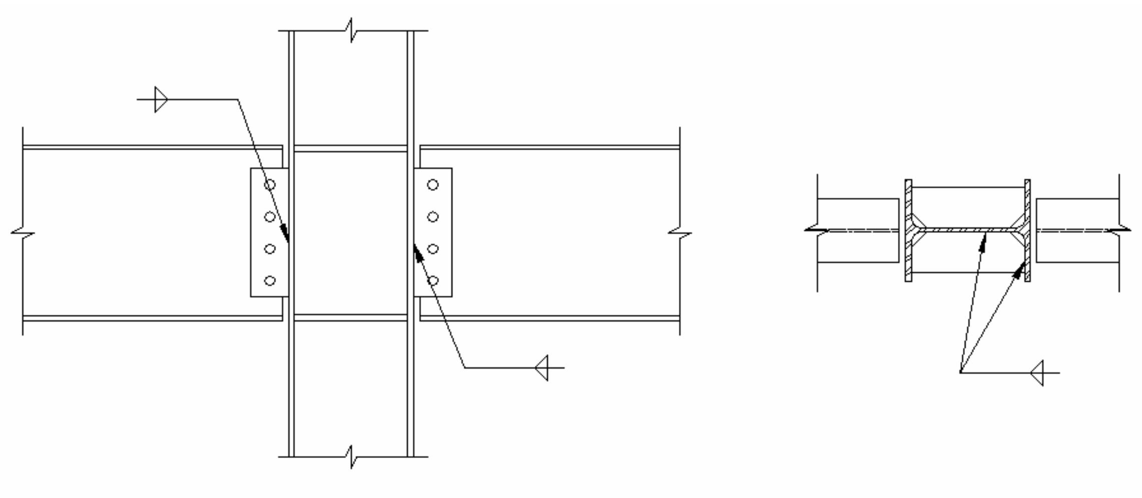

Figure 18: Typical girder to column shear tab connection shown with stiffener plates

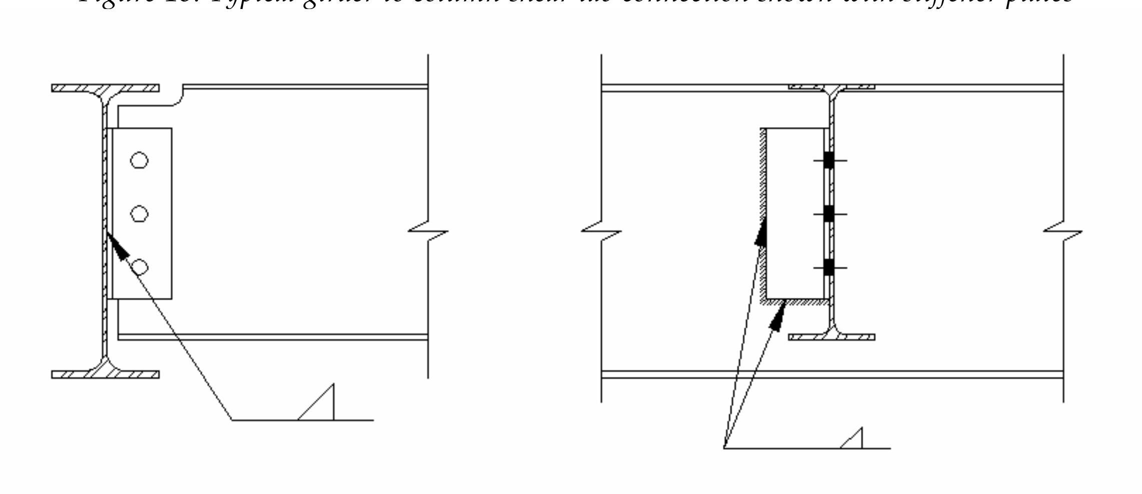

Figure 19: Typical beam to girder single angle connection

For the moment frames, end plate fully restrained moment connections can be used for the frame beam to frame column connections. These are designed using the procedure outlined in the AISC Design Guide 16 (Flush and Extended Multiple-Row Moment End-Plate Connections) Stiffener plates will have to be welded in the column web to reduce the effects of panel zone shear. For the braced frames, light bracing connections can be used.

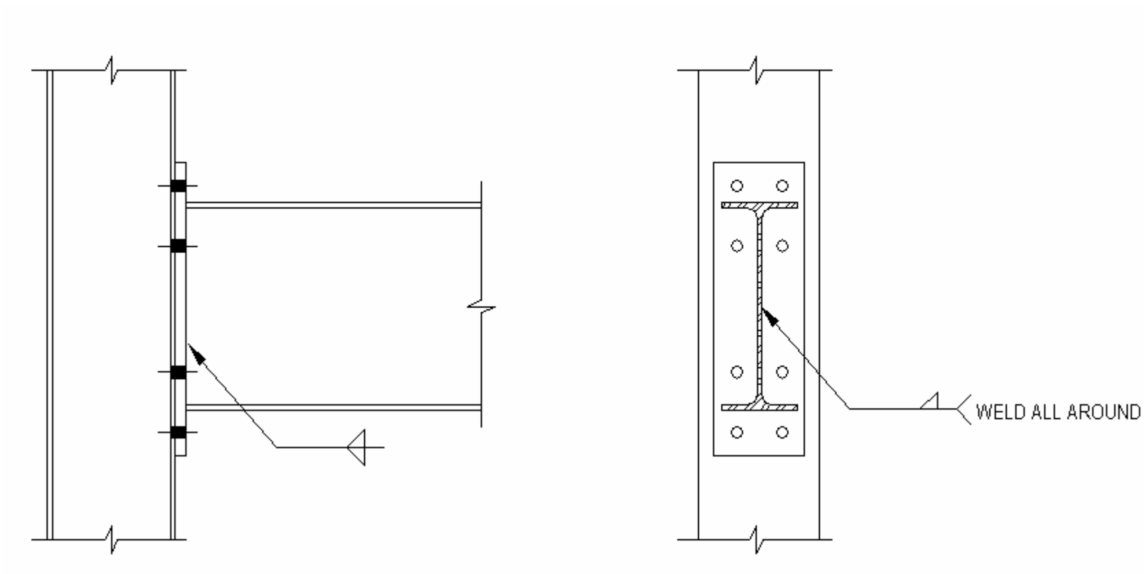

Figure 20: Typical frame beam to frame column fully restrained moment connection

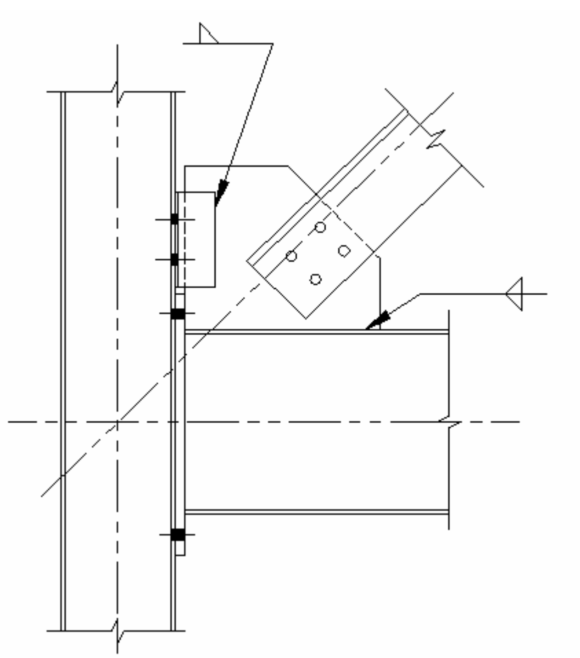

Figure 21: Typical light bracing connection in a moment frame

6.6 - IMPACT ON FOUNDATIONS

The steel structure produces a lighter frame which in turn produces less dead load on the foundations. A typical foundation for the same column was checked for the existing concrete structure and the proposed steel structure. The total unfactored dead and live load for the steel column was reduced by 47%. This resulted in a much smaller foundation size and less reinforcing. A decrease in foundation sizes will result in a cost savings in concrete.

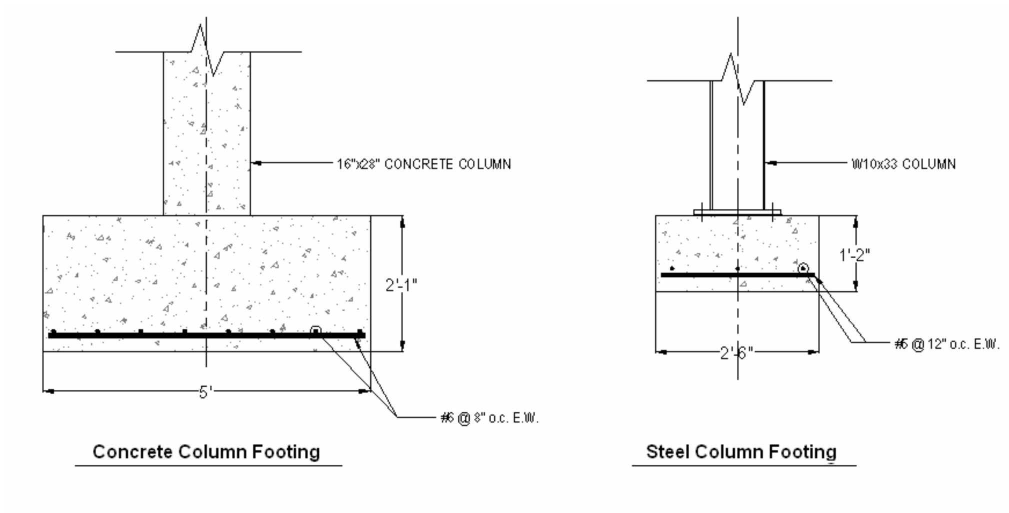

Figure 22: Comparison of gravity column footings for existing concrete structure and proposed steel structure

7.0 - STRUCTURAL DEPTH SUMMARY

GRAVITY SYSTEM

A composite steel frame was proposed for the gravity system of The Towers. The beams were W10 or W12 shapes and the girders were kept to a maximum depth of 21″ to keep a 2′ plenum depth. A 2″ composite metal deck with 2 ½″ of normal weight concrete was used as the floor system. This is capable of spanning the maximum beam spacing of 11′-0″ without needing shoring. The columns for the gravity loads are W10 shapes.

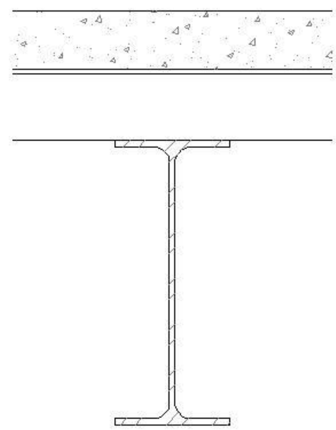

Figure 23: Section of composite floor slab and beam

The use of steel imposes less dead load on the foundations, which results in a decrease in foundation size and less reinforcing required for the gravity system. The beam to girder connections are single angles shop welded to the girder and bolted to the beam. The beam to column connections are shear tabs shop welded to the column flange and bolted to the beam.

LATERAL SYSTEM

The lateral forces imposed on the building are resisted by a dual system of eccentric braced frames with ordinary moment resisting frames. Braced frames are used where they line up within a wall. Moment frames with kickers are used where the wall has window or door openings.

For the lateral system, light bracing connections consisting of L6x6x½″ angles are used to connect the double angle braces to the beams and columns. All lateral columns are W12 shapes for added stiffness. The lateral beams range in size from W10′s to W14′s. Fully restrained moment connections are required at the beam to column connections to resist wind and seismic loads.

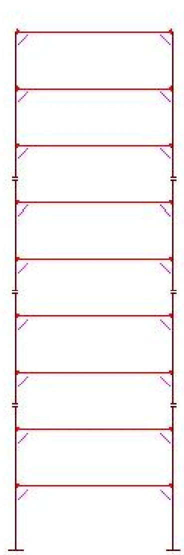

Figure 24: Typical moment frame