STRUCTURAL SYSTEM

STRUCTURAL SYSTEM DESCRIPTION

INTRODUCTION

Memorial Sloan-Kettering utilizes a combination of steel and concrete to create its efficient structural system. Below grade, MSK consists of shear walls and piers made exclusively of reinforced concrete. The infrastructure switches over to steel at the first floor level and continues for the remainder of the building. W12 columns support the gravity loads while braced frames, spanning diagonally between floors, resist the lateral forces that act on MSK.

Because each steel column sits directly on top of a concrete pier, the typical bay size remains at 30'x 30' through much of the building. The only alteration begins on the second floor, where a number of columns on the south end of the building are removed, creating a more open floor plan. This architectural layout creates bays sizes of 30'x 45'on the building's south side for floors two through four. Furthermore, a number of bays are also reduced in size near the exterior walls of the building due to the Memorial Sloan Kettering's curved exterior façade.

Photos courtesy of Ewing Cole

EXISTING FLOOR SYSTEM

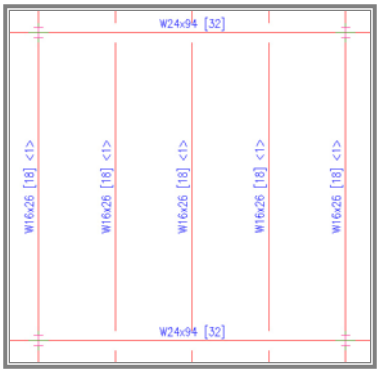
1st floor

MSK's first floor is constructed as a one-way concrete slab system. The 6" floor slab is supported by concrete beams spanning in the east-west direction and concrete girders spanning in the north-south direction. The concrete beams have a typical tributary width of 10' and span 30' between girders. The girders, in turn, span 30' from pier to pier. All beams are identical with an 18" x 24" dimension, and are reinforced by four #8 top bars and four #7 bottom bars. A typical girder's dimensions are 24" wide and 30" deep with top reinforcement of eight #9 bars and bottom reinforcement of six #8 bars.

First Floor Slab

2nd Floor through Roof

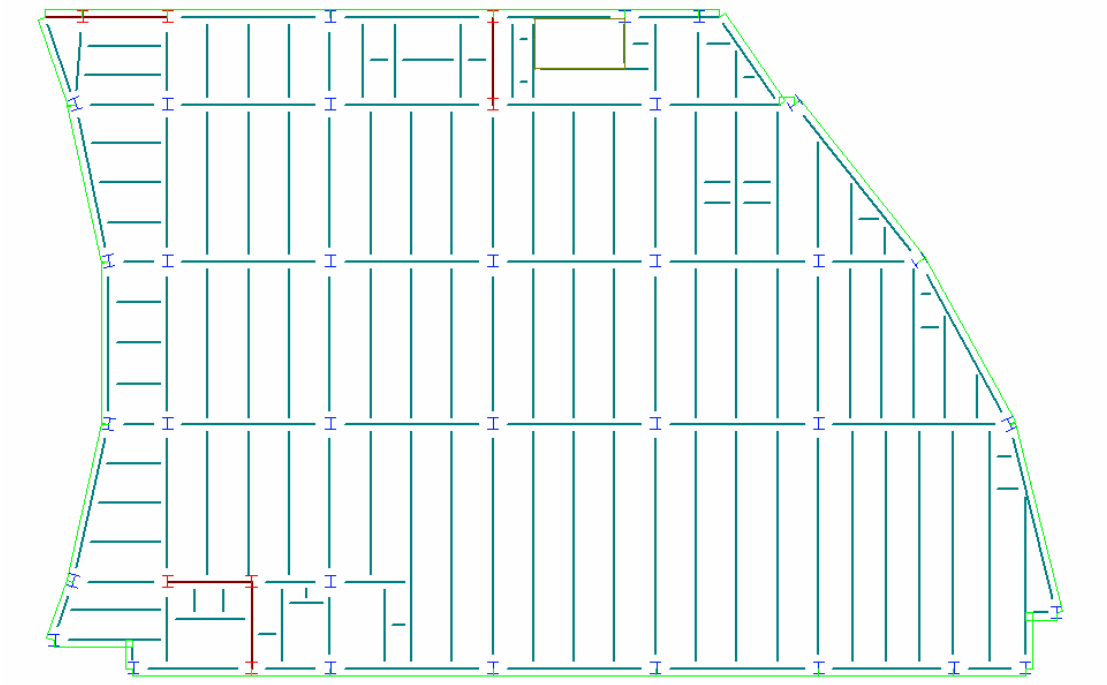
The existing floor system for Floors 2 through 4 in Memorial Sloan-Kettering is a composite concrete slab on metal decking. This system consists of a 4 ½" normal-weight concrete slab poured onto 2" 20-gauge galvanized metal decking. The slab is reinforced with 6x6-W2.9 x W2.9 welded wire fabric. The metal floor deck spans in the east – west direction and is continuous over a minimum of two or more spans. This decking ties into the wide flange steel beams through equally spaced ¾" diameter by 4" long headed shear studs welded into the center of the flange.



Typical Bay

This floor system is supported by steel beams and girders that span from column to column. Because the second floor maintains the typical 30' x 30' bay size, its framing members remain consistent. A typical interior beam size is W16x26 while a typical interior girder size is W24x96. For the smaller bays adjacent to the exterior walls, beam sizes decrease to W12x16.

As previously mentioned, the third and fourth floor layouts eliminate columns on the south side in order to create a more open space. Where the interior spans remain constant from the second floor, structural member sizes are maintained with W16x26 beams connecting into W24x96 girders. For the spans which become 30' x 45', beam and girder sizes increase to W24x62 and W30x90, respectively.



3rd Floor Structural Framing

GRAVITY COLUMNS

With the exception of those columns framing the building's lateral braces, all columns in Memorial Sloan-Kettering are designed as gravity columns. These steel columns vary in size throughout MSK depending on their location and purpose. A typical interior column has a tributary area of 900 square feet ranges between W12x87 and W12x96. Columns near the exterior walls are typically smaller, ranging between W12x 45 and W12x72.

These steel columns connect into the concrete piers below through ASTM A572, Grade 50 steel base plates. The base plates used for these connections are dimensioned at 18"x 18" and are typically 1 ½" thick. The plates are secured in place by four ¾" A449 anchor bolts embedded 2' into the concrete below.

LATERAL SYSTEM

The lateral force resisting system of Memorial Sloan Kettering is made up of a vertical combination of shear walls and steel cross-bracing. The four shear walls are located below grade and are all positioned near the exterior, typically around stairwells or elevator shafts. This positioning creates a lateral system that does not protrude into the interior office space of the building. At grade level, these shear walls connect into steel columns though the base plates described earlier. These columns span the remaining four floors to the roof and frame the lateral bracing. Two lateral systems span in the north-south direction and two span in the east-west direction.

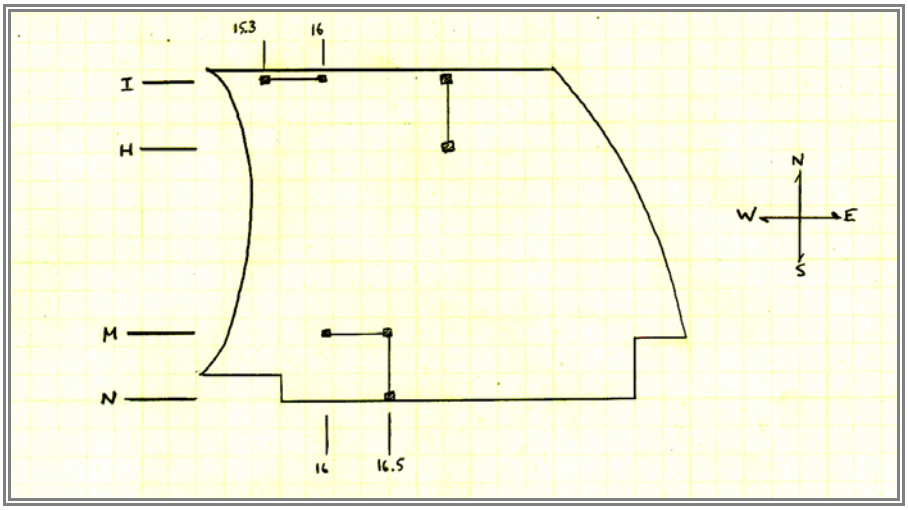
Lateral Cross-Bracing

The first lateral system oriented in the north-south direction is located on the north side of MSK, between column lines H and I. This system is comprised of a 12" thick shear wall spanning between the first floor and foundation. Once above grade, this wall connects into two W12x79 columns through a 1 ½" thick base plate. These two columns sizes remain the same throughout the four floors above grade; however, the diagonal bracing between them does not. Between the 1st and 2nd floor, two HSS 8x8x½ members span diagonally through the steel frames and are braced at midspan by a ¾" gusset plate. The bracing between the 2nd and 3rd floors also consists of two diagonal HSS 8x8x ½ members. These braces gradually become smaller, with two HSS 7x7x½ steel members between the third and fourth floors. The system culminates with two HSS 6x6x ½ members between the fourth floor and the roof.

The second lateral system oriented in the north-south direction in located on the southwest end of MSK, between column lines M and L. This lateral system is slightly smaller with two HSS 7x7x ½ diagonal members spanning between the first and second

floor and supported beneath by a 12" thick shear wall. The remaining three floors reduce the diagonal member size to two HSS 6x6x ½'s spanning between floors.

The two lateral systems running in the E – W direction follow the same framing as the two systems previously described. The larger system is located in the S-W corner of MSK, between column lines 16 and 16.5. The slightly smaller system is located against the northern wall of the building, between column lines 15.3 and 16. The sketch below demonstrates where each lateral system is located within the building.



Lateral System Locations

SHEAR WALLS

As previously mentioned, shear walls are located on the north and south sides of Memorial Sloan-Kettering surrounding the basement's concrete stairwells and framing into supporting columns. These 12" thick shear walls span in both the N-S and E-W directions and are approximately 14' long. Two of these walls span in the N-S direction and two span in the E-W direction. Each shear wall is reinforced vertically with #5 bars at 12" on center for both faces of the wall. These two faces are tied together with #4 ties spaced 12" on center. Similarly, the horizontal reinforcement on each wall face is made up of #5 bars at 12" on center. The columns supporting these shear walls have sixteen #9 bars of vertical reinforcement, about twice as much as that found in a typical column.

The lateral system is tied into concrete footings beneath each shear wall that have a minimum depth of 4 feet below the basement floor. The footings around each shear wall also extend at least 4 feet beyond the face of wall to create a plan dimension of 8' wide by 30' long. These massive footings are created to be large enough to counteract the overturning moments produced by the wind and seismic forces acting on the building.

FOUNDATION

The lateral system of Memorial Sloan-Kettering is supported by a shallow foundation that sits directly on top of basalt bedrock. Reinforced concrete piers, spaced in 30' x 30' bays, support the steel structural system above. Spanning between the piers at the basement level are concrete grade beams which provide support for the basement slab. Furthermore, each pier rests on a 6' x 6' footing, typically four feet thick, that disperses the axial loads uniformly.

LATERAL LOAD DEVELOPMENT

The wind and seismic loads acting on the existing structure of Memorial Sloan-Kettering have been calculated from the methods provided by ASCE 7-02. Seismic forces were found using the Equivalent Lateral Force Method, outlined in Chapter 9 of the code. Because MSK is a healthcare facility, a number of design parameters are required to be increased in order to reach an adequate safety factor. For instance, due to being a healthcare facility, Memorial Sloan-Kettering uses Seismic Use Group III and has an Occupancy Importance Factor of 1.5. Because of these factors, seismic loading produces relatively large forces acting on the building.

Due to the irregular shape of MSK, the wind forces acting on the existing structure were found using the Analytical Method, provided in Chapter 6 of the code. Once again, a healthcare facility warrants a higher Importance Factor and Design Category. Because the existing infrastructure of Memorial Sloan-Kettering is four stories tall, its natural frequency value is above 1.0 and is therefore deemed a rigid structure.

CONTROLLING LATERAL FORCE

After analyzing both lateral forces on the existing infrastructure of Memorial Sloan-Kettering, it becomes apparent that the seismic forces control the lateral loads in both directions. When comparing the both shears created by the lateral loads, seismic generates 349 kips whereas 225 kips due to wind. The building's drift is also controlled in both directions by seismic loads. The center of rigidity is displaced approximately 1.37 inches in the north-south direction and 1.70 inches in the east-west direction.

Exponent k_{N-S} : 0.954711

North - South Direction							
Level, x	w_x	h_x	$w_x h_x^k$	C_{vx}	F_x	V_x	M_x
	kips	feet			kips	kips	ft-kips
Roof	1622	56	75,676	0.333	116.3		6510.3
4	2106	42	74,691	0.329	114.7	116.3	4819.2
3	2106	28	50,717	0.223	77.9	231.0	2181.5
2	2106	14	26,167	0.115	40.2	308.9	562.8
1						349.1	
Σ	7941		227251.4	1	349.1		14073.8

Seismic: Equivalent Lateral Force Method (ASCE 7-02)