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STRUCTURAL OPTION

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AE 481 W

SENIOR THESIS PROPOSAL

EXECUTIVE SUMMARY

Memorial Sloan-Kettering Cancer Center is an 85,000 square foot, four-story healthcare facility located in Somerset County, New Jersey. Currently under construction, when MSK opens its doors in the summer of 2006, it will serve as one of the premiere cancer treatment centers in the nation. A combination of steel, concrete, and masonry, MSK is designed to hold a plethora of examination rooms, offices, laboratories, and various types of cancer treatment bays. Furthermore, an 88,000 square foot addition is currently in its design phase which will double the building's size.

Memorial Sloan Kettering's infrastructure is made up of braced steel framing supported by a concrete foundation. The floor systems consist of one-way slab on the first floor and slab on composite metal deck for the remaining four stories. MSK is laterally supported by four identical systems composed of diagonal bracing and shear walls. The building envelope is made up of brick and glass, and is attached directly to the steel framing by seat angles.

The focus of this thesis project will be to investigate the structural design of both the current four-story building and the Outpatient Addition. Right now, the site plan calls for the addition to be erected on the north side of MSK, extending its signature curved façade an additional 120 feet. This thesis will instead construct that addition vertically onto MSK and redesign the structural system to support the gravity and lateral loads experienced from this new building plan. To help analyze the loading on MSK, a model of will be created in the ETABS computer program. This program will also assist in calculating the building's total drift, displacement, base shear, and overturning moments. The lateral loads will be developed using ASCE 7-02, as shown in Technical Report 3.

Two breadth studies will also be performed in the areas of construction management and MEP design. The first will be a detailed cost analysis and time schedule of the Outpatient Addition compared to that of the original four floors of MSK. The second will focus on a redesign of the building's mechanical system. Currently, MEP equipment is located in both the basement and on the roof of Memorial Sloan Kettering. This equipment will be moved and resized in order to accommodate MSK both during and after the addition's construction. This project will be completed in incremental steps and presented at the end of the semester.

BUILDING INTRODUCTION

Memorial Sloan-Kettering is a four-story cancer research and health-care facility located in the scenic region of Somerset County, New Jersey. When MSK opens its doors in the summer of 2006, it will serve as one of the premiere cancer treatment centers in nation. This structure is designed to hold 27 offices, 38 exam rooms, 23 chemotherapy bays, radiotherapy treatment, a laboratory, and pharmacy. A three-story parking garage is located on the north side of MSK, providing over 280 parking spaces to accommodate both patients and staff. In addition, an 88,000 square foot Outpatient Addition is currently under design which will add a second four-story building to MSK and expand the parking garage to five levels.

Following the tradition of the highly regarded Memorial Sloan Institute, this "patient-oriented" cancer care facility was designed to create a serene environment for all of its patients. The building's footprint is strategically located on the north end of the 25-acre wood lot to maximize patient interaction with the surrounding nature. The exterior of MSK articulates soft undulating curves with large windows. The façade's natural face, composed of brick and stone, accents the calming views of the mountain surrounding it. The exterior curves of the building transform the interior by creating dynamic hallways filled with natural light and breathtaking views of the wilderness. Soft tones and textures, natural materials such as wood and stone, a large fish aquarium, and many other interior elements are fine-tuned to focus on the patient. From an architectural standpoint, Memorial Sloan-Kettering Cancer Center creates a soothing and relaxing atmosphere.

Memorial Sloan Institute brought a number of high profile firms on board to create this facility. Ewing Cole was put in charge of both the structural and architectural design of Memorial Sloan-Kettering Cancer Center. Barr & Barr Builders is responsible for the construction management services of the project. All environmental and geotechnical engineering fell into the hands of Langan Engineering & Environmental Services. AKF Engineers is the MEP designer for this project.

BUILDING STRUCTURE

The infrastructure of Memorial Sloan-Kettering is made up of steel braced-framing supported by a concrete foundation. The structure below grade consists of 16" thick foundation walls and 2'x2' piers made exclusively of reinforced concrete. The structural steel skeleton in MSK begins at the first floor level and continues for the remainder of the building. Because each steel column sits directly on top of a concrete pier, the typical bay size remains at 30'x 30' throughout the first floor. However, beginning on the second floor, a number of columns near the south end of the building are removed in order to create more of an open floor plan. This causes some bays to span 30' x 45' in the upper level floors. A number of bays are also reduced in size near the exterior walls of the building due to Memorial Sloan Kettering's curved exterior façade. Each story spans 14 feet from floor to floor, and with a two foot parapet located on the roof, the building's total height is approximately 58 feet.

The steel columns vary in size throughout the building according to their location and purpose. These columns remain constant in size between the first floor and fourth floor. A typical interior column ranges between W12 x 87 and W12 x 96.These steel columns connect into the concrete piers below through ASTM A572, Grade 50 steel base plates. A typical base plate used for these connections is 18"x 18" and 1-½" thick. These plates are kept in place by four ¾" A449 anchor bolts embedded 2' into the concrete column.

The first floor of Memorial Sloan-Kettering is constructed as a one-way concrete slab system that is structurally supported by the foundation walls and concrete columns below. The 6" slab lies on top of concrete beams spanning in the E – W direction and concrete girders spanning in the N – S direction. The second, third, and fourth floors of MSK make use of steel beams and girders to support their floor systems. The second floor is the last floor to maintain the typical bays sizes and because of this, has the most consistent steel sizes throughout the floor. A typical interior beam is a W16 x 26 while a typical interior girder is a W24 x 96. For smaller bays near the exterior walls, beam sizes fall to a W12 x 16. The exterior girder sizes do not show much consistency, ranging anywhere from a W18 x 35 to a W30 x 108. The third floor and fourth floor both have the same layout. Where the interior spans continue from the second floor, the structural design is maintained with W16 x 26 beams connecting into W24 x 96 girders. For those spans which become 30' x 45', beam sizes are W24 x 62 and girders use W30 x 90. The roof of the building follows the same framing as the fourth floor, only with slighting smaller beams and girders that support the 30' x 45' bays.

The lateral force resisting system of Memorial Sloan Kettering is made up of a combination of shear walls and steel cross-bracing. The four shear walls are located below grade and are all positioned near the exterior walls, typically around stairwells or elevator shafts. This positioning allows for 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 through the base plates described earlier. These columns span the remaining four floors to the roof and frame the lateral bracing steel members. Two lateral systems span in the N – S direction and two span in the E – W direction.

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 25' 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.

PROBLEM STATEMENT

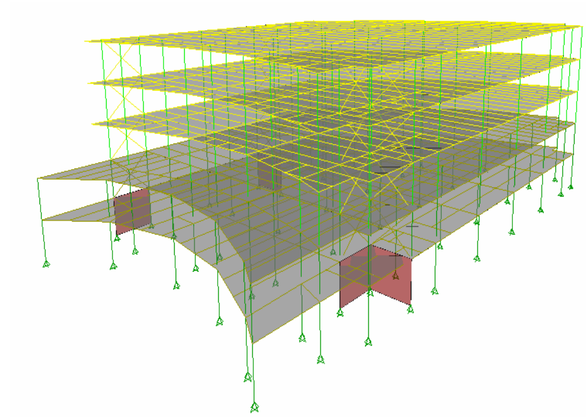
After analyzing Memorial Sloan-Kettering's steel framing, floor system, and lateral system, it is implicit that the original design of the building was expertly performed. All calculations carried out along with all software used to analyze the structural integrity of MSK concluded that the system is structurally sound. Even after the completion of all three technical assignments, areas of possible altercation to the initial building design were not obvious. In Technical Report Two, the original composite floor system proved to be the most efficient out of all five systems analyzed. Similarly in Technical Report Three, the lateral system designed for MSK proved to be extremely efficient in resisting both wind and seismic loads acting on the building. Because of this, ideas for a redesign of the structure were initially difficult to find.

After some thought, it was determined that instead of changing the existing structural system of MSK, it would be better to redesign the Outpatient Addition which will be built in the future. The current plan calls for the 88,000 square foot, four story addition to be erected on the north side of the MSK, extending the signature curved façade that it possesses an additional 120 feet. It is assumed that this lateral addition to the building is due to the amount of open space provided on the site. But what if the design called for the addition to be built vertically? How would that change the current structural design?

The proposed thesis is to investigate the structural design of both the current building and Outpatient Addition if the design called for those four stories to be placed on top of the MSK instead of to its north side. Because the current floor areas are approximately 19,500 square feet and the addition intends to add 88,000 square feet, it will be necessary to add five additional stories, making Memorial Sloan Kettering a total of nine stories tall. In addition, the entire infrastructure of MSK will be converted to structural steel. This will only affect the first floor and structural system below grade. The reason for doing this is explained in the breadth section of the report.

PROBLEM SOLUTION

By building this addition vertically above the existing floors of Memorial Sloan-Kettering, there are a number of factors which will need to be re-evaluated in the current structural system. The steel columns, intended to only support four floors, will be dramatically under-designed to withstand all gravity loads acting on MSK. Similarly, the member components of each lateral system will need to be resized in order to ensure they resist the lateral loads without excessive story drift. The entire building will need to be reanalyzed to determine the seismic and wind loads acting on each floor. Although seismic currently controls for lateral loads, wind loads may prove to now become larger due to the significant increase in building height. Finally, the footings supporting each column must be checked for shear and overturning moments. From these calculations, appropriate member sizes and footing dimensions will be allocated for each structural component.



SOLUTION METHOD

In Technical Report Three, a 3-D model of Memorial Sloan-Kettering was created in ETABS to assist in the analysis of the lateral loads and how they affect each lateral member in the building. The ETABS program has the ability to both analyze and design buildings based on the parameters set in the program. Because this software package is relatively straightforward and has the ability to take both gravity and lateral loads into consideration, it will be used to assist in finding the loads acting on MSK for the remainder of this thesis. As always, hand calculations will be performed as well to double check all numbers and ensure that accurate values are being outputted from this program.

BREADTH STUDIES

Two breadth studies will be performed as part of this thesis project. The first study will focus on the construction management aspect of this Outpatient Addition. Both a detailed cost estimate and schedule estimate will be completed. Because the addition is still currently in its design stage, there are no existing time tables or price estimates to compare these values to. However because this addition will be tremendously similar to the first four floors of MSK, it may be possible to compare the schedule and cost created from this breadth study to that of the first four floors.

The second breadth study for this thesis will involve the redesign of Memorial Sloan-Kettering's MEP system in order to support the five-story addition. Currently, MSK's mechanical equipment is located both in the basement and on the roof. Due to five stories being added vertically to the infrastructure, it is necessary to move the existing roof mechanical system elsewhere in the building. Furthermore, an MEP system must be designed for the top five-stories. Because the addition is roughly the same square footage as the existing building, it could be assumed that the amount of MEP equipment will need to be doubled in order to adequately support Memorial Sloan Kettering. It will be a challenge to determine how much of this additional equipment can be added in the basement, and how much must be added after the addition is finally constructed.

TASKS AND TOOLS

The first step in analyzing and redesigning the structural system of Memorial Sloan-Kettering with all addition floors would be to design the floor plans of floors 5 through 9. Because the 2^{nd} through 4^{th} floors all have similar structural layouts, it makes sense to continue with the same structural framing. The only difference between floors would be architectural layouts in order to accommodate particular purposes of each floor.

The next step would be to calculate all gravity loads acting on each floor as well as the cumulative loads acting on the columns of each floor. From these values, each column in Memorial Sloan-Kettering will be able to be roughly redesigned to support the vertical loads acting on them. After gravity loads have been developed, it will be necessary to analyze and redesign the lateral system to verify and refine the new seismic and wind loads acting on the building. As in both Technical Reports One and Three, the wind loads will follow the Analytical Approach (Method 2) developed in Chapter 6 of ASCE7-02. Similarly, the seismic loads will follow the Equivalent Lateral Force Method found in Chapter 9 of the code. The two lateral loads will be compared to establish which lateral load controls.

After all loads have been calculated, the next step would be to update the 3-D model previously created in E-TABS. A 3-D model will be used due to the irregular geometry of the building. The 5^{th} through 9^{th} floors must be added and the column sizes must all be changed. Proper gravity loads must be assigned to each floor along with mechanical loads on the roof. Wind and seismic loads will then be analyzed and compared to the hand calculations. From these results, member sizes will be re-evaluated and changed if necessary.

The next step of this thesis would be to determine the time schedule and cost estimate of this addition if it were built vertically. This will be accomplished by researching similar cases of steel additions as well as looking up values and time frames in RS Means. Finally, the MEP issues will be looked at for the building's addition. Both mechanical and electrical equipment will be moved and resized in order to accommodate MSK's addition both during and after its construction. See below for the project timetable.

THESIS TIMETABLE

	JANUARY			FEBUARY				MARCH	
	8th - 14th	15th - 21st	22nd - 28th	29th - 4th	5th - 11th	12th - 18th	19th - 25th	26th - 4th	5th - 11th
Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Update Proposal									
Floor Structural Framing									
Verify Gravity/Lateral Loads									
Redesign Members/Columns									
E-TABS model									**B**
Check/Resolve Service Issues									**R**
Verify Member Sizes									**E**
Redesign Column Footings									**A**
Addition Schedule/Cost									**K**
MEP Redesign									
Written Report									
Presentation Preparation									
Presentation									
Review									

	MARCH				APRIL			
	5th - 11th	12th - 18th	19th - 25th	26th - 1st	2nd - 8th	9th - 15th	16th - 22nd	23nd - 29th
Week	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Update Proposal								
Floor Structural Framing								
Verify Gravity/Lateral Loads								
Redesign Members/Columns								
E-TABS model	**B**							
Check/Resolve Service Issues	**R**							
Verify Member Sizes	**E**							
Redesign Column Footings	**A**							
Addition Schedule/Cost	**K**							
MEP Redesign								
Written Report								
Presentation Preparation								
Presentation								
Review								