Analysis 1: Structural Analysis

Background and Problem

The Kennedy Krieger Institute Outpatient Medical Center is a cast in place concrete structure with concrete pan and joist flooring system. This system was chosen for this project because at the time of bidding the price of steel was very expensive and the cast in place system would allow the building flexible for future building occupancy. The concrete was scheduled to take 86 days for structural completion. The concrete was completed on time but had scheduling issues during the beginning weeks of construction. Issues that occurred were the following:

- The concrete subcontractors who created the construction schedule were not aware of the actual on site conditions and underestimated the amount of time needed for the construction. This issue was a result of the employees in the office lacking time in the field.

- The first and second floor had complicated sections that needed more attention. There were sections with many cut outs, curves and other sections that varied in floor thickness and elevation.

- Onsite there was one crane which was owned by the concrete subcontractor but was used by all trades during the construction. This would on times interfere with the concrete construction.

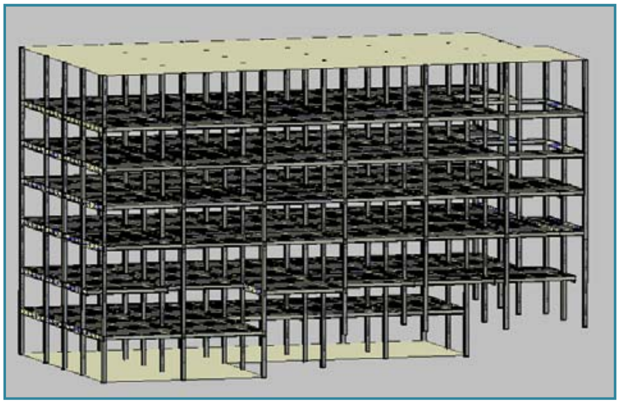
These issues did not result in an extended schedule but did cause the concrete subcontractor, the construction workers and a contractor employee to work every Saturday for 2.5 months until they were back on schedule.

.

Proposal

The proposed solution to this problem is changing the structural system to structural steel instead of cast in place concrete which is the current structural system for the Outpatient Medical Center.

Current Cast in Place Structural Design



Proposed Structural Steel Design

Goal

The goal of changing the structural system is to get the building out the ground quicker and decrease the cost of the overall project.   This would improve the construction schedule, decrease the building cost, and get owners into the building sooner increasing their building profitability.

Analysis: "Structural Breadth"

Please refer to **Appendix D** for the structural steel calculations

The design of the structural steel for the building was done by using a typical bay size of 29' x 29', a metal deck size of 1 ½" with 18 gage intermediate ribs, and 5" in concrete flooring. The books that were used to aid in the design were the Steel Construction Manual, 13th Edition. And the International Building Code 2006.

Step 1: Sizing of the beams and girders

The beam size was found first by calculating the moment on the beam and using that to find the moment of inertia which was 282 in^4. This resulted with a beam size of 16 x 26 with an I=301 in^4 and a ΦMn = 166 kips. Next the Girder was found by the same process. The calculated moment of inertia was 1461 in^4 which gave a girder size of 21 x 68 with I=1480 in^4 and a ΦMn = 600 kips.

Step 2: The total load on the building was found

The next step was calculating the size of the columns. The resulting calculation ended with a total building live load of 246.5 kips and a dead load of 378.1 kips. Using these results the column size was found to be a 14 x 90 wide flange with a ΦPn = 928 kips.

Step 3: Determining Plenum height

Using steel wide flange beams and girders the plenum space was found to be the same depth as the original plans called for. This creates no redesign of the mechanical ductwork, which therefore saves money.

Step 4: Coordination Issues

Now that the plenum height was determined the next issue is coordination of the mechanical, plumbing, and electrical systems in the vertical direction through the building. Areas of concern are, where penetrations through the structural system were located. These areas are the following: 1st – 6th floor between **column lines F-G & 2-4, column line B: 1-2 pipe penetrations**, and **column lines B-C: 3-4.** See Figure below.

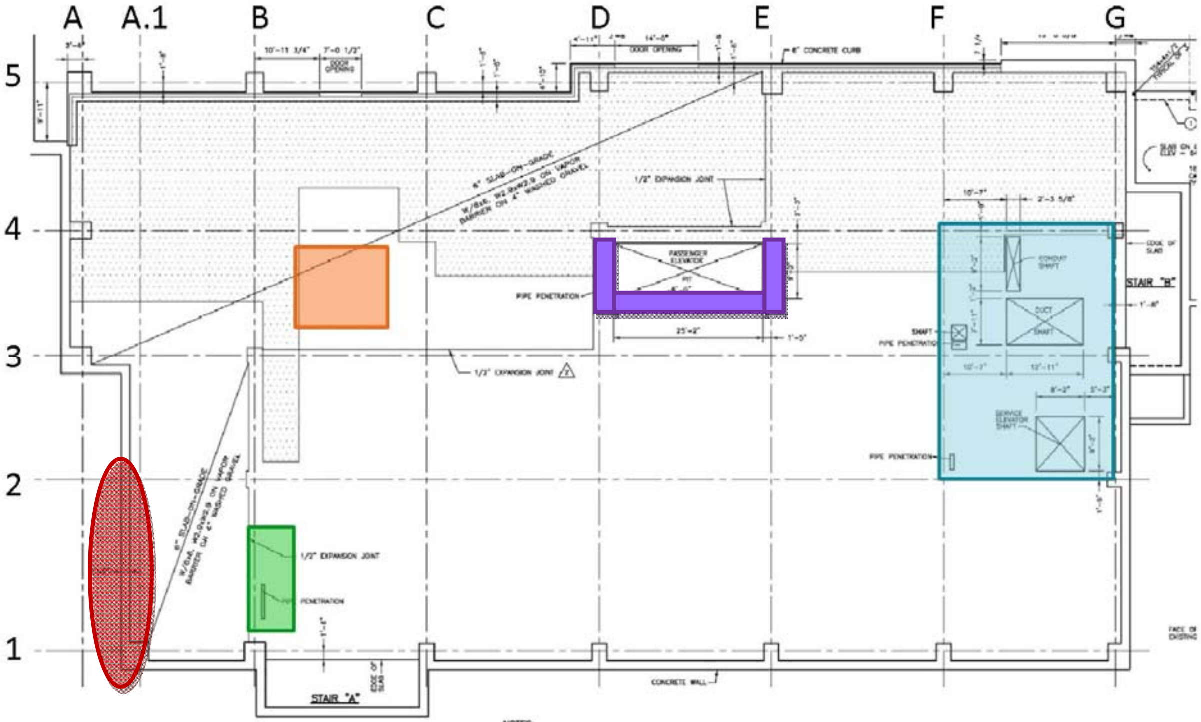


Figure 1.1 Coordination Issues Areas

For these areas the steel beams will need to be removed and steel cross bracing of equal or greater size will be used. This will allow for an equal load bearing capacity without having to change the structural design too much. The girders and columns are not interfered and therefore will not require any changes.

Step 5: Connections

The connections for this structural redesign will be concrete shear walls. Concrete shear walls are more cost effective then moment connections and will be easier to generate. The concrete shear walls will also act as fire protection for the elevator shaft. The shear walls are cast in place concrete and are located at two different locations in the building. The first location is the three sides of the elevator shaft (which can be seen in the above drawing in purple). The shear walls will be 14 inches thick and will rise up through the entire height of the elevator shaft. The second location is at Column A between 1 & 2 (which can be seen in the above drawing in red). This shear wall will be 29 feet long, 14 inches thick and consist of a 30 foot section of wall.

Schedule Comparison

The Outpatient Medical Center's schedule for their original cast in place concrete design was started on June 25, 2007 and was scheduled to take 86 days to complete. This did not include the 15 Saturdays the concrete subcontractor needed to make up for getting behind schedule. Final total for the construction of the super structure was 101 days.

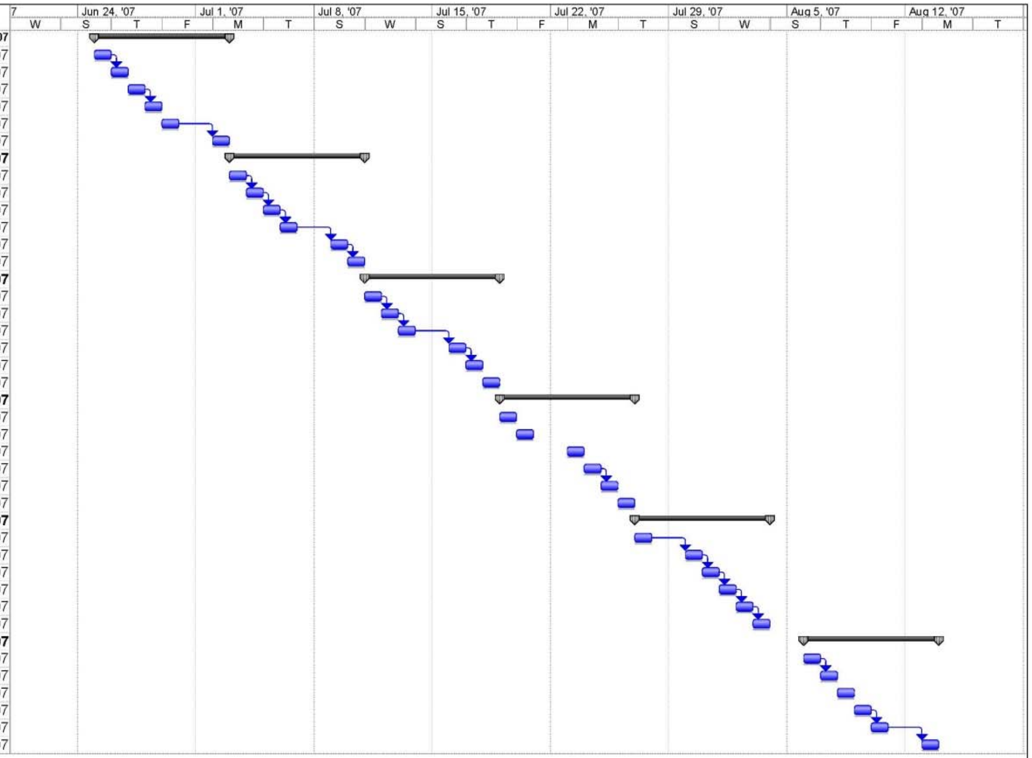
The proposed structural system, which consists of structural steel is also scheduled to start on June 25, 2007 but it will take only 43 days to complete structural construction/erection. This is a total of 58 days less of scheduled work which would get the project finished 3 months earlier.

The schedule that can be found on the next page is broken up into floors and each floor will take about 6 days to complete the steel erection. The floors are then broken up into 6 sections and each section then consists of 4 bays. The sections are made up of 20 to 30 pieces of steel. This allows for each section to be completed in an 8 hour work day. Once the first section is complete, installation of the metal decking and placing of the concrete will take place. (A schedule of this process can be seen below but only shows up to the first section on floor 2.) The concrete will be placed the day after the metal decking and rebar are placed because the concrete will cure better if it is placed in the morning as opposed to mid to late afternoon. This order of work will be consistent throughout each floor. The steel will be scheduled to be delivered the day of its erections to eliminate double picking the steel and to save space on site since it is such a small area with already limited free space.

Section Schedule	25-Jun	26-Jun	27-Jun	28-Jun	29-Jun	2-Jul	3-Jul	4-Jul	5-Jul
Section 1-1	Steel erection	Metal Deck	Concrete						
Section 1-2		Steel erection	Metal Deck	Concrete					
Section 1-3			Steel erection	Metal Deck	Concrete				
Section 1-4				Steel erection	Metal Deck	Concrete			
Section 1-5					Steel erection	Metal Deck	Concrete		
Section 1-6						Steel erection	Metal Deck	Concrete	
Section 2-1							Steel erection	Metal Deck	Concrete

Table 1.1 Detail Construction Schedule

ID	Task Name	Duration	Start	Finish
1	**First Floor**	**6 days**	**Mon 6/25/07**	**Mon 7/2/07**
2	1st Floor Bay Section #1	1 day	Mon 6/25/07	Mon 6/25/07
3	1st Floor Bay Section #2	1 day	Tue 6/26/07	Tue 6/26/07
4	1st Floor Bay Section #3	1 day	Wed 6/27/07	Wed 6/27/07
5	1st Floor Bay Section #4	1 day	Thu 6/28/07	Thu 6/28/07
6	1st Floor Bay Section #5	1 day	Fri 6/29/07	Fri 6/29/07
7	1st Floor Bay Section #6	1 day	Mon 7/2/07	Mon 7/2/07
8	**Second Floor**	**6 days**	**Tue 7/3/07**	**Tue 7/10/07**
9	2nd Floor Bay Section #1	1 day	Tue 7/3/07	Tue 7/3/07
10	2nd Floor Bay Section #2	1 day	Wed 7/4/07	Wed 7/4/07
11	2nd Floor Bay Section #3	1 day	Thu 7/5/07	Thu 7/5/07
12	2nd Floor Bay Section #4	1 day	Fri 7/6/07	Fri 7/6/07
13	3rd Floor Bay Section #5	1 day	Mon 7/9/07	Mon 7/9/07
14	2nd Floor Bay Section #6	1 day	Tue 7/10/07	Tue 7/10/07
15	**Third Floor**	**6 days**	**Wed 7/11/07**	**Wed 7/18/07**
16	3rd Floor Bay Section #1	1 day	Wed 7/11/07	Wed 7/11/07
17	3rd Floor Bay Section #2	1 day	Thu 7/12/07	Thu 7/12/07
18	3rd Floor Bay Section #3	1 day	Fri 7/13/07	Fri 7/13/07
19	3rd Floor Bay Section #4	1 day	Mon 7/16/07	Mon 7/16/07
20	3rd Floor Bay Section #5	1 day	Tue 7/17/07	Tue 7/17/07
21	3rd Floor Bay Section #6	1 day	Wed 7/18/07	Wed 7/18/07
22	**Fourth Floor**	**6 days**	**Thu 7/19/07**	**Thu 7/26/07**
23	4th Floor Bay Section #1	1 day	Thu 7/19/07	Thu 7/19/07
24	4th Floor Bay Section #2	1 day	Fri 7/20/07	Fri 7/20/07
25	4th Floor Bay Section #3	1 day	Mon 7/23/07	Mon 7/23/07
26	4th Floor Bay Section #4	1 day	Tue 7/24/07	Tue 7/24/07
27	4th Floor Bay Section #5	1 day	Wed 7/25/07	Wed 7/25/07
28	4th Floor Bay Section #6	1 day	Thu 7/26/07	Thu 7/26/07
29	**Fifth Floor**	**6 days**	**Fri 7/27/07**	**Fri 8/3/07**
30	5th Floor Bay Section #1	1 day	Fri 7/27/07	Fri 7/27/07
31	5th Floor Bay Section #2	1 day	Mon 7/30/07	Mon 7/30/07
32	5th Floor Bay Section #3	1 day	Tue 7/31/07	Tue 7/31/07
33	5th Floor Bay Section #4	1 day	Wed 8/1/07	Wed 8/1/07
34	5th Floor Bay Section #5	1 day	Thu 8/2/07	Thu 8/2/07
35	5th Floor Bay Section #6	1 day	Fri 8/3/07	Fri 8/3/07
36	**Sixth Floor**	**6 days**	**Mon 8/6/07**	**Mon 8/13/07**
37	6th Floor Bay Section #1	1 day	Mon 8/6/07	Mon 8/6/07
38	6th Floor Bay Section #2	1 day	Tue 8/7/07	Tue 8/7/07
39	6th Floor Bay Section #3	1 day	Wed 8/8/07	Wed 8/8/07
40	6th Floor Bay Section #4	1 day	Thu 8/9/07	Thu 8/9/07
41	6th Floor Bay Section #5	1 day	Fri 8/10/07	Fri 8/10/07
42	6th Floor Bay Section #6	1 day	Mon 8/13/07	Mon 8/13/07



Project: steel schedule
Date: Sat 3/29/08

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Page 1

Figure 1.2 Erection Schedule

Sequencing

The structural steel will be erected differently than the original system. The original system started construction on the east side and worked toward the west, all the way up the building. For the steel erection, the process is going to be reversed. Reason for this is so that the crane will not be passing over the already erected steel sections, permitting concrete subcontractor to work on the flooring system while the steel erection continues on.

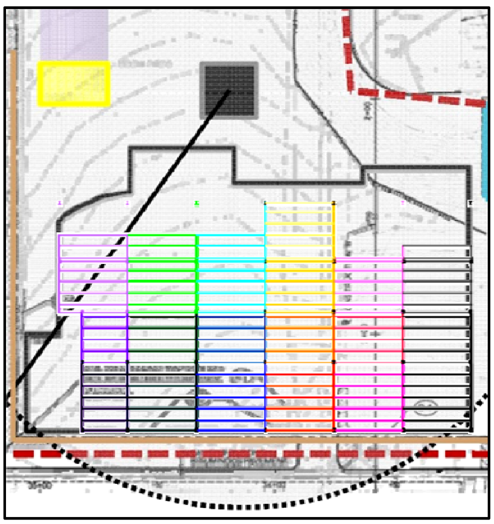


Figure 1.3 Erection Sequencing

The picture on the left (figure 1.2) is the building foot print with the second floor structural design. This image illustrates the erection sequence by color variations. Each section is shown in a different color and each bay is in a different shape of that sections color theme. The erection sequence goes from the darkest shape to the lightest shape of color starting with purple and going east to the black section.

This construction sequence is the best choice to keep construction continuing and keeping a safe working environment for the other trades that will be performing work close by. This sequence does not impact the site set up, although it will determine the path of the crane. The crane path will start out as counterclockwise until the first sections of that particular floor are complete. Then the crane will continue steel erection by a clockwise rotation. This is way the crane will not be passing large pieces of steel over the entire site. This alone will reduce the erection time by several minutes with every piece that is moved into place, creating a smooth safe erection process.

Site Impact

The site is currently a small area where a lot of different activities and trades are all going on at the same time. Because of the tight space, the steel will be delivered the day it is to be erected. This will eliminate the need for a shakeout area. There will be however a small section set aside for steel that may be delivered out of order or early. This area is located near the east side of the site next to the construction fence and next to the area where the trucks will unload the steel. The site plan below shows theses areas.

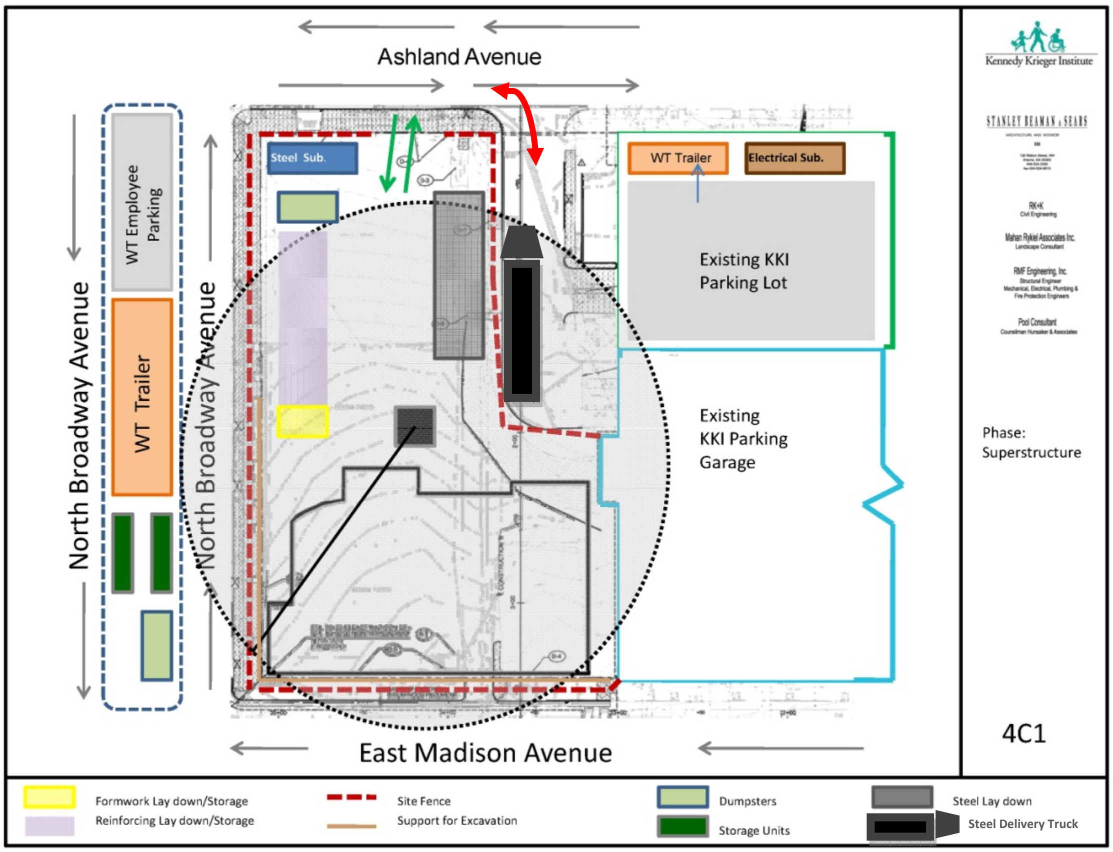


Figure 1.4 Site Layout

The only entrance to the site is located at the north end of the site. This area is small so this is why the steel deliveries will be dropped off next to the site as shown. The reinforcing, metal deck and formwork for the concrete floor will be stored on the west side of the site. These areas are shown on the site in yellow and purple sections. These are the only major changes to the original site plan.

Cost Comparison

The original cost for the cast in place concrete structural system cost a total of $4,181,700. This includes the price of the foundation system which was $580,800. The costs of the re-design to structural steel are as followed:

The cost estimate of the structural steel construction totals $3,517,972. This total also includes the $580,800 needed for the foundation system. This amount for the steel is $663,738 less than the cost of the cast in place concrete.

Description	Cost
Foundation system	580,800
Structural Steel	1,899,951
Concrete Shear Walls	388,292
Concrete Flooring	406,350
Fire Proofing	173,179
Tower Crane	69,400
Total	**$3,517,972**

Table 1.2 Cost Comparisons

Total cost savings = $663,738

For a more detailed cost breakdown of the different systems listed above please refer to **Appendix E**.

Conclusion

The proposed solution to the structural system has many benefits. The first benefit is the amount of time needed to construct the super structure is reduced by three months, completing the project by Oct. 20th 2008 instead of Jan. 20th, 2009. This schedule change will save money by getting the building out of the ground quicker. The second benefit is the amount of money saved by using steel. Over half a million dollars would be saved which could be used for more specialized equipment and research for the developmental disabilities in adolescents and children. This proposal seems like a good idea to reduce cost and the schedule, resulting in happier owners.