# Granby Tower
515 Granby Street
Norfolk Virginia

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Construction Management
Final Report
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April 9, 2008

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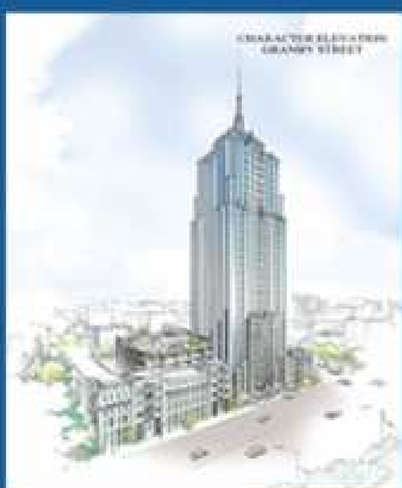
# Granby Tower
## Norfolk, Virginia

Project Information:
Cost including property, design, and construction: $180 million
Total Square Footage: 717,233 sq.ft. (gross)
Building Height: 31 story high rise
Total Site Area: 2.32 acres
Delivery Method: GMP
Construction Dates: July 2, 2007 (NTP) - Nov. 2009

Project Team:
Owner: 515 Granby Tower LLC
General Contractor: Turner Construction
Architect: Humphreys and Associates
Structural Engineer: Abiousness, Cross and Bradshaw
MEP Engineer: Jordan & Scala Engineering



Structural System:
Cast in place concrete with most of the slabs being post-tentioned concrete
1233 piles
Deep mat foundations

Architectural Systems:
Post modern style architecture
Hand set panelized curtain wall for most of building skin
Contains operable aluminum framed windows
Membrane roofing over tapered insulation

MEP:
4 pipe mechanical system
3300 GPM Forced Draft Cooling Tower
87 GPM Natural Gas Boiler
1100 GPM Tower Water Pump (CWP)
1650 GPM Tempered Water Pump (TWP)
87 GPM Boil Heating Pump (HWP)
Riser system has sub panels every three floors
120A/208V wire for the units
277A/480V wire for the equipment
500KW deisel generator for emergency power

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http://www.engr.psu.edu/ae/thesis/portfolios/2008/jap410/

# Executive Summary

The following report is the conclusion to a year's worth of work towards my senior thesis on the Granby Tower in Norfolk, Virginia. There are four analyses' that were performed; they include a structural system analysis, a mechanical system analysis, a site analysis, and a research topic.

The first analysis was a structural system analysis. This analysis compared the existing cast in place structure to an alternate steel structure. Ram Structural System was used to design the steel structure and then comparisons were made with respect to cost, constructability, and schedule. The concrete structure cost less by approximately $1,000,000 and could be constructed in approximately 20 less days.

The next analysis was a site analysis. The current site plans for the concrete system were observed and then site plans for the structural steel system were developed and critiqued until the best possible site layout was determined.

Next came the mechanical system analysis. This analysis compared the existing four pipe system to an alternate two pipe system. The two pipe system cost less and could be constructed quicker than the four pipe system. These were about the only advantages other than space needed for construction.

The last analysis was my research topic. Research was done to determine how the construction industry could bring people into the industry and keep them there. It was determined that safety is a major factor in people's perception of the construction industry. Another main factor is how we treat each.

# Project Overview

The Granby Tower is a thirty-one story mixed use high rise condominium located in Norfolk, Virginia. It consists of retail space, condominiums, and townhouses. It consists of 311 condominiums. It is located on the corner of Granby Street and Brambleton Avenue. The site is in downtown coastal Norfolk near the Elizabeth River.

The owner of this project is 515 Granby, LLC and Marathon Development Group is the developer. The Marathon Development Group has been involved in restoring historic landmarks in the Norfolk area. Not only do they want to restore historic landmarks, but they also want to provide homeowners with a unique living experience. This building is being built to give people a chance to live in a historic neighborhood in what will be the largest building in Norfolk and the second largest in the state of Virginia.

Schedule and cost are the most important factors to the owner for this project. Some of the condominiums have already been sold, so the project being completed on time is very crucial. These people are expecting to be able to move in on a certain date and it is crucial they be able to do so. The total building cost is approximately $180 million, notice to proceed was given on July 2, 2007 and the project is expected to be completed in November of 2009.

# Building Systems Summary

Cast in Place Concrete:

The primary structural elements are cast in place concrete. For the first seven floors the concrete will be placed using a pump. For the remaining floors the concrete will be placed using the crane and bucket technique. Two tower cranes as well as two buckets will be used during this process.

Mechanical System:

The main mechanical system is a four pipe system with individual exchangers in the units. The boilers and chillers are located on the top floors. There are six 87 GPM boilers and one forced draft cooling tower. There are also four cold water pumps, three tempered water pumps, and six hot water pumps. The cold water pumps are 1100 GPM, while the tempered water pumps are 1650 GPM, and the hot water pumps are 87 GPM. There are two different types of heat pumps, split system and water source. The split system pumps are used in the residential and retail areas, while the water source pumps are used in the common areas and the town homes.

# Building Systems Summary (cont)

Electrical/Lighting System:

The riser system has sub panels every three floors. The main systems are 120/208V for the units and 277/480V for the equipment. The emergency power backup is a 500KW diesel generator. There are recessed down lights and wall sconces used for hallway lighting. The wall sconces are metal halide down lights. Metal halide fixtures are used for the parking garage lighting. Recessed shower lights are used in the showers while the exit signs are edge lit. The remaining lights used in the building consist of four foot strip fluorescent lighting and 2x4 fluorescent fixtures. The recessed down lights have a horizontal lamp.

Curtain Wall System:

The façade is comprised of a curtain wall system with metal panels. The façade is glazed with blue glass and has several operable aluminum framed windows. The curtain wall will be hand set for most of the skin and the part that is to be constructed as the store front will be constructed in place.

# Site Plan

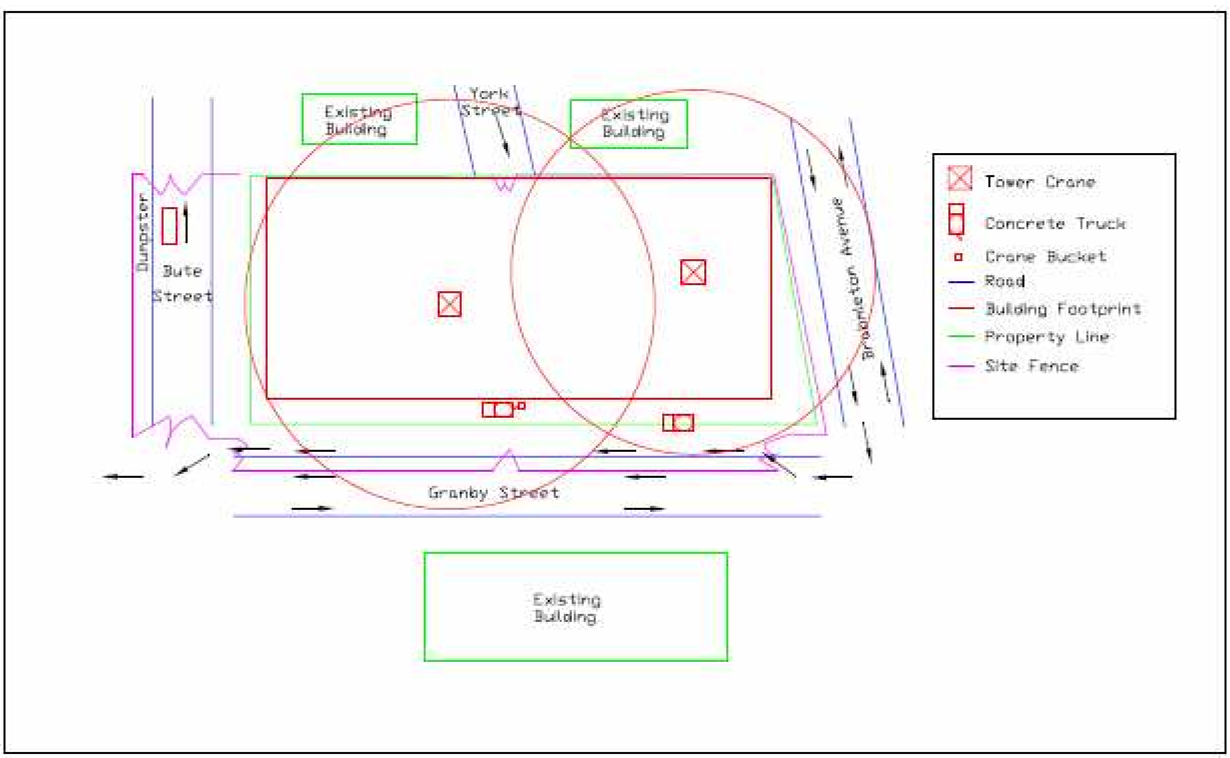



Fig. 1

# Site Plan

The site plan above illustrates the use of the site during the erection of the superstructure from the seventh floor and above. Some key things to note are that Bute Street is closed during construction. The parking lane of Granby Street is closed as well. Day time closures of Brambleton Avenue are not allowed under any circumstances. The deliveries come from Brambleton Avenue.

# Project Cost

Actual Building Construction Cost
- $110,030,520

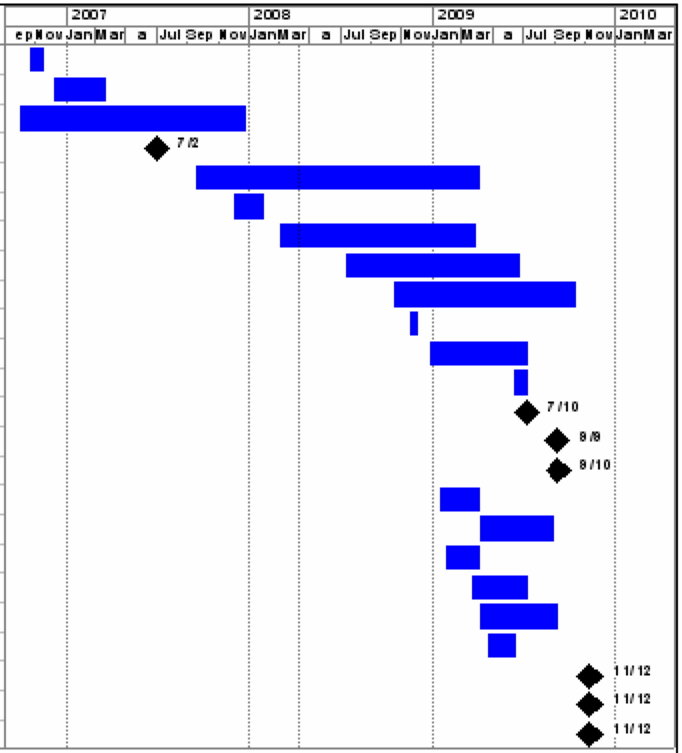
Total Project Cost
- $180,000,000

Major Building Systems Costs
- Mechanical/Plumbing Systems
  - $17,631,324
- Electrical System
  - $7,969,594
- CIP Concrete
  - $24,687,321

# Project Summary Schedule

See next page for schedule.

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | Obtain foundation permit | 21 days | Mon 10/23/06 | Mon 11/20/06 |
| 2 | Obtain building permit | 75 days | Mon 12/11/06 | Fri 3/23/07 |
| 3 | Site preparation | 324 days | Mon 10/2/06 | Thu 12/27/07 |
| 4 | Notice to proceed | 0 days | Mon 7/2/07 | Mon 7/2/07 |
| 5 | Construct concrete foundations | 407 days | Mon 9/17/07 | Tue 4/7/09 |
| 6 | Foundation for parking garage and retail structure | 43 days | Mon 12/3/07 | Wed 1/30/08 |
| 7 | Construct tower levels 1-11 | 280 days | Wed 3/5/08 | Tue 3/31/09 |
| 8 | Construct levels 12-21 | 250 days | Mon 7/14/08 | Fri 6/26/09 |
| 9 | Construct levels 22-31 | 260 days | Fri 10/17/08 | Thu 10/15/09 |
| 10 | Ceramic tile-kitchen and baths | 15 days | Mon 11/17/08 | Fri 12/5/08 |
| 11 | Complete main lobby finishes | 140 days | Mon 12/29/08 | Fri 7/10/09 |
| 12 | Systems test/startup first occupancy | 20 days | Mon 6/15/09 | Fri 7/10/09 |
| 13 | Occupancy floors 1-11 | 0 days | Fri 7/10/09 | Fri 7/10/09 |
| 14 | Occupancy floors 12-21 | 0 days | Wed 9/9/09 | Wed 9/9/09 |
| 15 | Systems test/startup second occupancy | 0 days | Thu 9/10/09 | Thu 9/10/09 |
| 16 | Erect level 32 | 57 days | Mon 1/19/09 | Tue 4/7/09 |
| 17 | MEP level 32 | 105 days | Wed 4/8/09 | Tue 9/1/09 |
| 18 | Erect level 33 | 50 days | Wed 1/28/09 | Tue 4/7/09 |
| 19 | Sitework/landscaping | 80 days | Mon 3/23/09 | Fri 7/10/09 |
| 20 | MEP level 33 | 110 days | Wed 4/8/09 | Tue 9/8/09 |
| 21 | Erect spire | 40 days? | Wed 4/22/09 | Tue 6/16/09 |
| 22 | Occupancy floors 22-31 | 0 days | Thu 11/12/09 | Thu 11/12/09 |
| 23 | Systems test/startup final occupancy | 0 days | Thu 11/12/09 | Thu 11/12/09 |
| 24 | Substantial completeion | 0 days | Thu 11/12/09 | Thu 11/12/09 |




Project: Project Schedule Summary-1
Date: Wed 4/9/08

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

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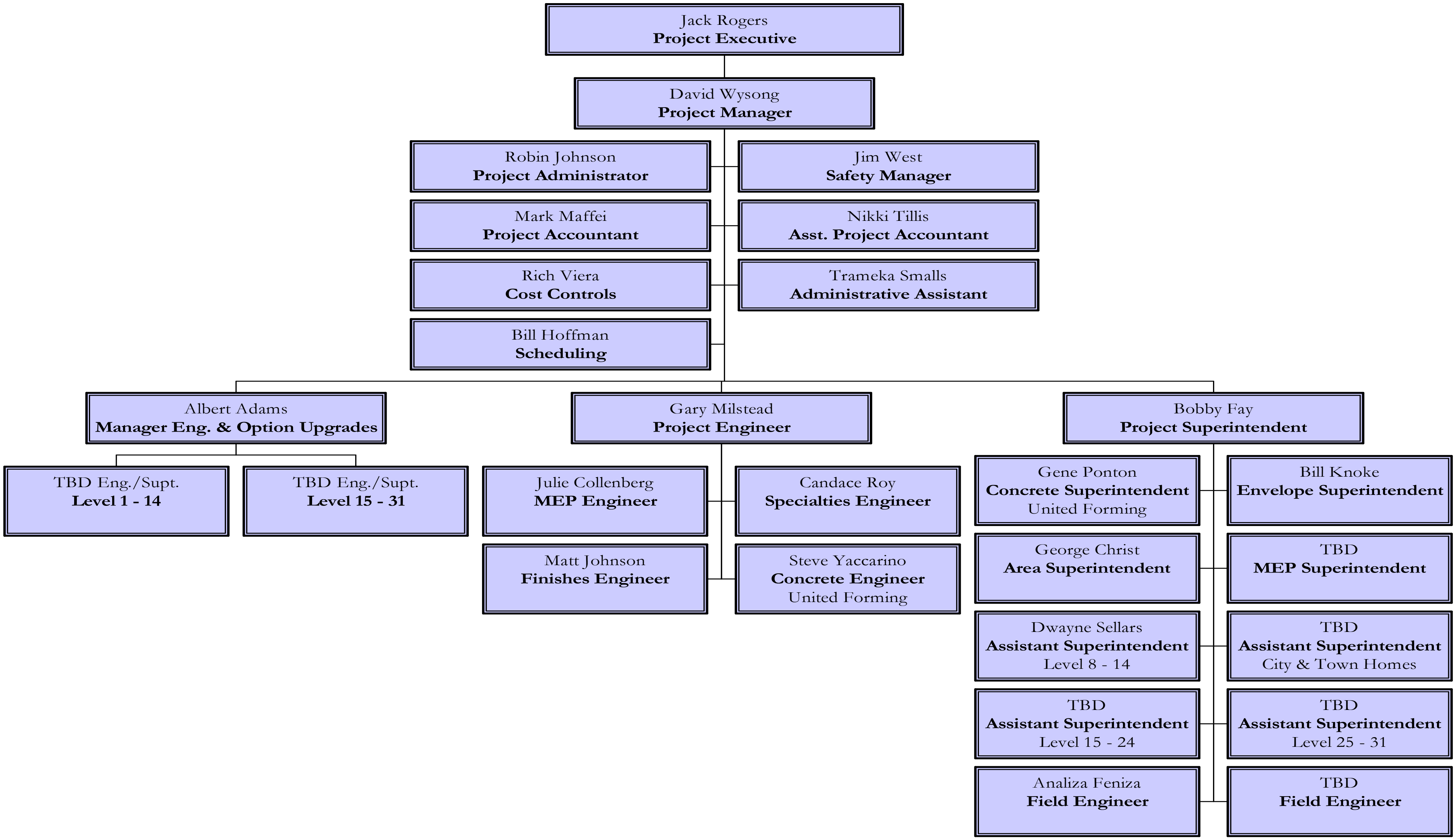
# Staffing Plan



# (Structural Breadth) Structural System Redesign – Change Structural System from Cast in Place Concrete to Structural Steel

**Problem:**

The existing structural system is a primarily cast in place concrete system, however there are some CMU and pre-cast concrete elements as well. This causes a problem with coordination when all three are being erected on the same floor at the same time. Another issue with the concrete system is the differing size columns that are being used on the same levels. The varying size columns require multiple formwork sizes and some of the column sizes are only used once per floor, this seems inefficient because the formwork has to be built for that one specific column when if they were the same size the formwork could be used again (at least for a couple times). This issue raises concerns with time and scheduling.

Another reason I chose to analyze these two systems was because typically high rise buildings are constructed using steel and residential building are constructed using concrete, so I wanted to see what differences there might be between the two systems. Another reason the steel alternative should be addressed is construction will take place during the winter months. If concrete placement is being performed during these months there could be added prices involved because additional heating may be needed to ensure that the concrete cures correctly and achieves its maximum strength. There could also be an increase in schedule if it gets too cold and concrete placement can not occur on a certain day.

**Goal:**

The expectation of this analysis is to analyze an alternative structural system (steel) and compare it to the existing concrete structure. The varying number of member sizes will hopefully decrease, a decrease in the number of structural elements is also part of the expectations. An advantage of steel with respect to concrete is its span to weight ratio, steel has a better ratio and can therefore span a longer distance with a smaller beam. I will try to utilize this advantage in my design. The last goal would be to be able to reduce the schedule duration of the project and cut some costs as well.

**Steps:**

The first step is to determine the loading for the structure. Once the loads have been determined, the preliminary design process can start. Once the design is complete constructability issues with this design should be looked into. Is it really feasible to do what was just designed? After the constructability issues have been addressed a new/better design option can be looked into. The constructability issues are still looked into until a satisfactory design is completed. Once a finished design is at hand cost and schedule analysis can be looked into.

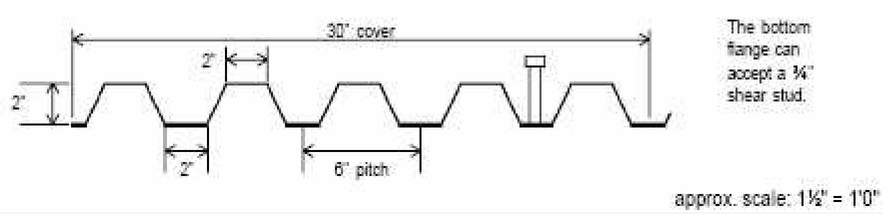
**Outcome:**

Structural Design

My first goal was to determine the structural loading for the building. Let it be noted that wind load will control for the structural design of this building, in order for the lateral system to be adequate the existing concrete shear walls will be used for lateral support. I first determined the live load for the building; I began with a live load in the residential spaces of 40 psf and a live load in the corridors of 100 psf. I was then informed that a live load of 100 psf seemed high and that a load of 80 psf seemed more reasonable. Once the live load was determined it was time to calculate the dead load for the building. I started by using a 6 inch slab for my concrete floor system, however I was informed that this was too thick. It was brought to my attention during my breadth consultation with Dr. Hanagan that if I were using light weight concrete a proper slab thickness would be 3.25 inches and if I were using normal weight concrete a proper slab thickness would be 4.5 inches. From this I decided to use a normal weight concrete and a slab thickness of 4.5 inches. Using 150 pcf for normal weight concrete and a slab thickness of 4.5 inches I came up with a dead load of 56.25 psf. To this I added allowances of 5 psf for MEP and 5 psf for miscellaneous loading that may occur. This gave me a dead load of 66.25 psf, now I needed to determine the total load so I could determine my deck size and from that determine what beam spacing I may use. So by adding the 80 psf for the live load (using ASD standards) I came up with a total load of 146.25 psf. I then took this load and looked in the United Steel Deck Design Manual and Catalog to determine the metal deck for my system; I chose a 20 gauge UF2X deck using a double span condition with a beam to beam span of 7'-0" that could withstand a load of 165 psf which exceeds my load of 146.25 psf.

| SECTION PROPERTIES | | | | | | ASD | | | LRFD | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal Thickness | | Wt. | $I_p$ | $S_p$ | $S_n$ | V | $R_1$ | $R_2$ | ϕV | $\phi R_1$ | $\phi R_2$ |
| Gage | Inches | (psf) | (in.⁴) | (in.³) | (in.3) | (lbs) | (lbs) | (lbs) | (lbs) | (lbs) | (lbs) |
| 24 | 0.0239 | 1.50 | 0.232 | 0.192 | 0.200 | 2360 | 360 | 836 | 3223 | 532 | 1156 |
| 22 | 0.0295 | 2.00 | 0.300 | 0.252 | 0.263 | 4205 | 528 | 1484 | 5477 | 736 | 1992 |
| 20 | 0.0358 | 2.00 | 0.379 | 0.325 | 0.339 | 6062 | 728 | 2224 | 8067 | 1004 | 3084 |
| 18 | 0.0474 | 3.00 | 0.523 | 0.488 | 0.485 | 8798 | 1204 | 3948 | 11182 | 1648 | 5398 |

UF2X




| UNIFORM TOTAL LOAD / Load that Produces l/180 Deflection, psf | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gage | Span Condition | Span 6'0" | 6'6" | 7'0" | 7'6" | 8'0" | 8'6" | 9'0" | 9'6" | 10'0" |
| ASD | 24 | Single | 128 / 94 | 109 / 74 | 94 / 59 | 82 / 48 | 72 / 40 | 64 / 33 | 57 / 28 | 51 / 24 | 46 / 20 |
| ASD | 24 | Double | 130 / 226 | 111 / 178 | 96 / 143 | 84 / 116 | 74 / 96 | 66 / 80 | 59 / 67 | 53 / 57 | 48 / 49 |
| ASD | 24 | Triple | 162 / 177 | 138 / 139 | 120 / 112 | 105 / 91 | 92 / 75 | 82 / 62 | 73 / 52 | 66 / 45 | 59 / 38 |
| ASD | 22 | Single | 168 / 122 | 143 / 96 | 123 / 77 | 108 / 62 | 94 / 51 | 84 / 43 | 75 / 36 | 67 / 31 | 60 / 26 |
| ASD | 22 | Double | 173 / 293 | 148 / 230 | 128 / 184 | 111 / 150 | 98 / 123 | 87 / 103 | 78 / 87 | 70 / 74 | 63 / 63 |
| ASD | 22 | Triple | 215 / 229 | 184 / 180 | 159 / 144 | 139 / 117 | 122 / 97 | 108 / 81 | 97 / 68 | 87 / 58 | 78 / 49 |
| ASD | 20 | Single | 217 / 154 | 185 / 121 | 159 / 97 | 139 / 79 | 122 / 65 | 108 / 54 | 96 / 46 | 86 / 39 | 78 / 33 |
| ASD | 20 | Double | 224 / 370 | 191 / 291 | 165 / 233 | 144 / 189 | 126 / 156 | 112 / 130 | 100 / 110 | 90 / 93 | 81 / 80 |
| ASD | 20 | Triple | 279 / 289 | 238 / 228 | 205 / 182 | 179 / 148 | 158 / 122 | 140 / 102 | 125 / 86 | 112 / 73 | 101 / 63 |

fig. 2

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Construction Management

Once I knew the spacing I could start working on the design. The central tower of the building is the area that was designed. For simplicity reasons when doing the design this region was treated as a box, when there are actually step backs at some locations. The first time I started with the design, some of my numbers were off and I had a span of 4'-0" which did not seem to make sense and would have been very difficult to construct. I then went back and revised my numbers and came up with the spacing mentioned above. I wanted to choose a metal deck that would allow me to span a longer distance, but with the loading I had it wasn't going to happen.

From here I used Ram Structural System to lay out the columns for my design. I used almost exactly the same column grid that is currently being used with the current system. I then placed the beams and input the data for the concrete floor slab. The number of stories was entered, when doing this I was asked whether or not I wanted to splice the columns, I chose to splice them every third floor. The layout for the design can be seen in figure 3 below.

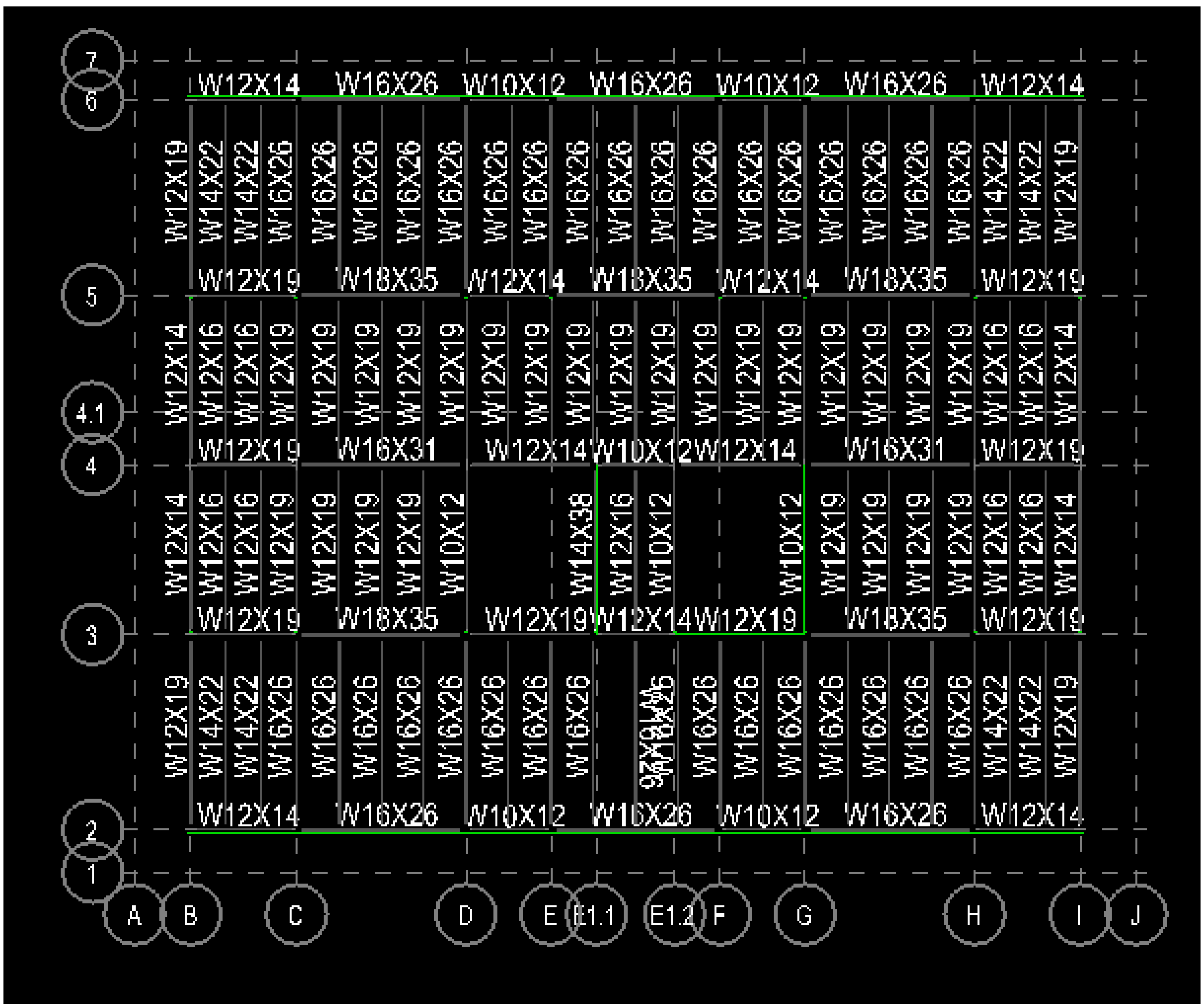



figure 3

I tried other layouts but this was the best layout constructability wise.

Constructability Comparisons

One advantage of steel in comparison to concrete is you can have longer spans. I designed a layout with longer spans, but the beams where columns were removed to allow for the longer spans were W27x84's. With a depth of 26.7 inches for that beam and a floor to floor height of 10'-3" it did not seem reasonable. With the current concrete system the floor to ceiling height is 9'-7", with the layout mentioned above the floor to ceiling height would have been approximately 8'-0". A disadvantage of cast in place concrete is that it is place outside in the elements, whereas steel can be prefabricated and when it arrives on site can be put into place. One advantage of cast in place concrete over steel is there is no need for a lay down area, whereas for steel this is always something that needs to be taken into considerations especially on a site like this project site. This will be discussed later in this report.

Cost Comparisons

The next thing to do was compare the costs of the current system with that of the newly designed system. This cost data reflects the cost of the central tower of the building and not the entire building. RS Means 2008 Building Construction Cost Data was used to determine the cost of the new system. This system includes costs for structural steel beams and columns, cast in place concrete, welded wire fabric, sprayed on fireproofing, and metal decking. The steel takeoff from the Ram Structural System data was used to determine the amount of steel pieces needed. This information along with a more detailed takeoff can be found in Appendix A. The cost for the new structural system was approximately $6,241,850 this cost is the total cost including O and P from RS Means. Some of the structural steel members used in the design were not in the Means data and were substituted with similar members. The approximate cost of the central tower with the current structural system is $5,100,744 (from technical assignment #2)

Schedule Comparisons

Using the crews and daily outputs from RS Means a schedule was developed for the construction of the central tower, the total duration was 132.75 days. The details of this schedule can be found in Appendix A. The duration for the cast in place concrete system based off of the current schedule and information obtained by Turner Construction is approximately 112 days.

Conclusions/Recommendations

The steel structure cost more than the concrete structure by approximately $1,000,000. It also expands the duration by approximately 20 days. The one advantage would be the unforeseen conditions that may cause the concrete to fall behind schedule; cool temperatures that cause the concrete to not be able to cure. Based off of the information above I would have to recommend continuing using the cast in place concrete system.

# (CM Depth) Site Layout/Analysis

**Problem:**

There is limited room on site as the building footprint takes up the majority of the site. Steel lay down areas could be hard to determine and maintain. Site congestion could become an issue as construction continues and more and more trades are on site at the same time. Not only is the site congested but the site is in downtown Norfolk, Virginia and the areas surrounding the site could be congested; this could make getting deliveries on time an issue and could ultimately cause the project to fall behind schedule. There are also ordinances and other requirements that need to be followed that could make maintaining a construction site difficult.

**Goal:**

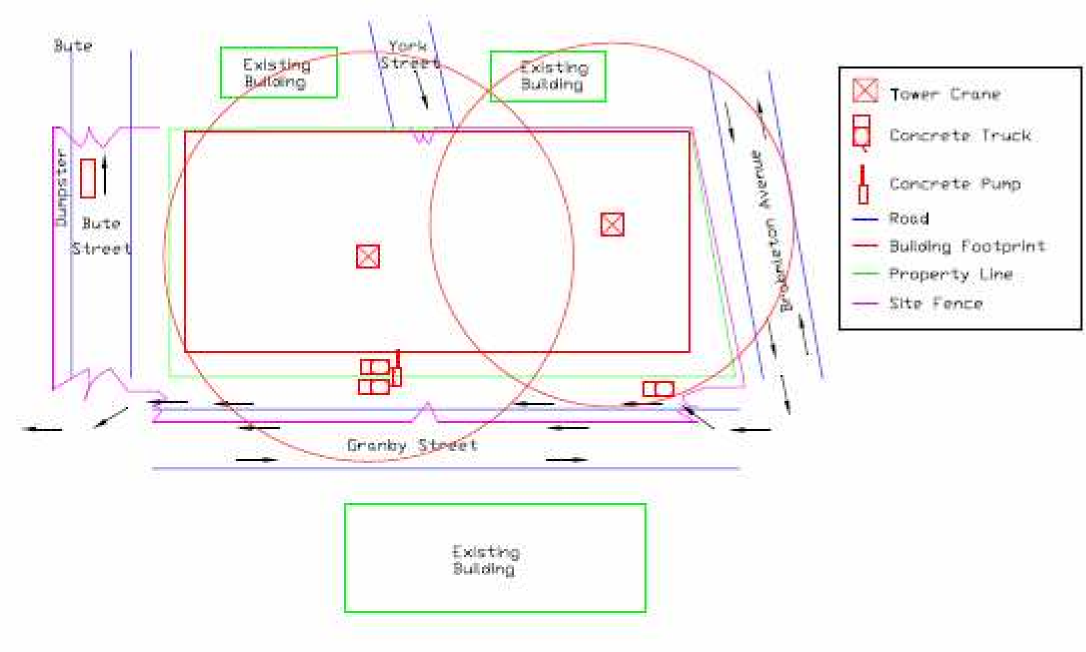
The main goal of this analysis is to look into the site plan for the current cast in place concrete system and the alternate structural steel system mentioned earlier. Constructability issues with the site will be looked into, safety issues will be addressed, and what impact the site has on schedule will be addressed.

**Steps:**

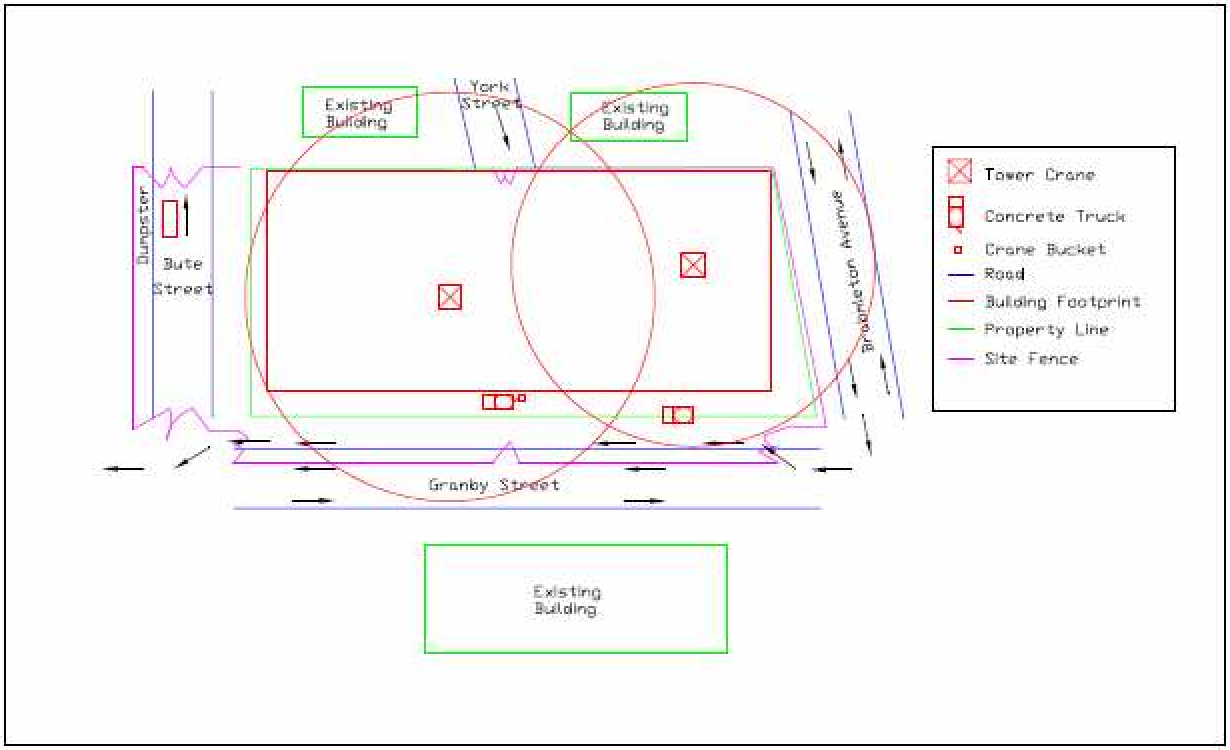
The first step is to look into areas where a possible steel lay down area may occur. Once this is done the site plan for the steel erection can occur. Now the site plans can be addressed, what could be better about them, where can the steel be placed, where do deliveries come from? These are the things we need to think about when developing a site plan.

**Outcome:**

Since the building footprint and the property line are very close to one another see figure 3, one has to think about what options there are to optimize the size of the site. In the case of this project Bute Street was closed as well as the closure of the parking lane of Granby Street. Once the extents of the site have been determined a site plan can be made. It is now time to analyze the site plans.

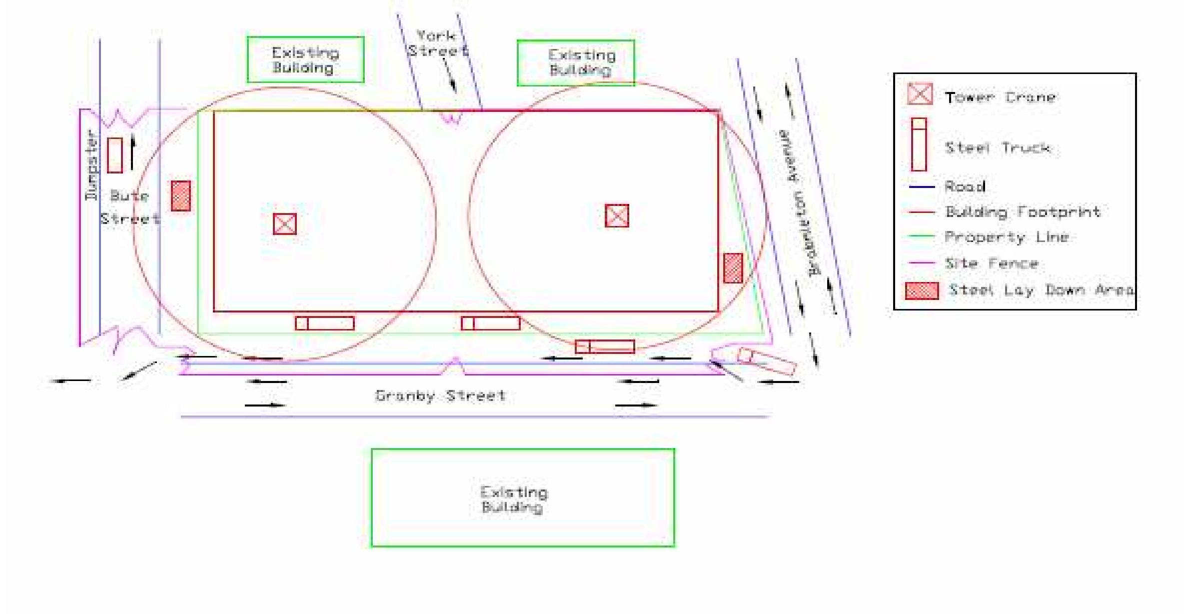



This is the site plan for the existing concrete structure; it will be used while the first seven floors are being erected. As one can see there is not much extra room on site. The deliveries are made from Brambleton Avenue and will exit back to Granby Street when they are through with their deliveries. For this particular part in the construction sequence the concrete is being placed by a pump. In this instance three to four concrete trucks may be on the site at a time. Typically there will be two at the pump, one cleaning up, and one getting ready. The radius from the two cranes can swing over roads that are being traveled on; this is something that really needs to be taken into consideration. Now let's look at the site layout for the erection of the remaining floors.

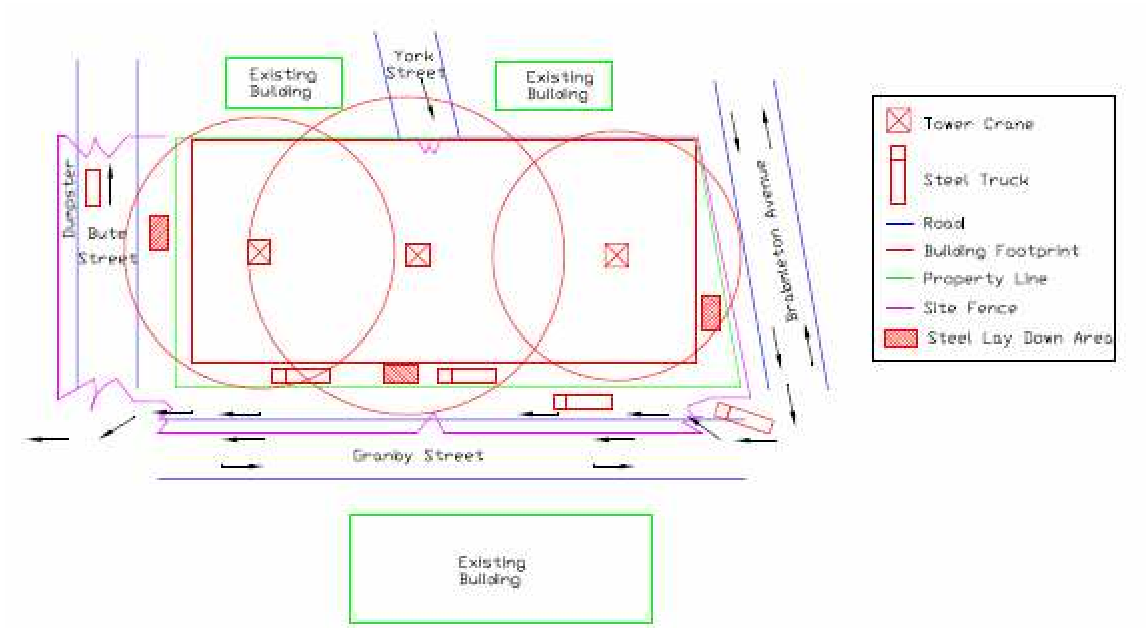



This site plan is for the erection of the remaining floors of the building, it is plain to see that the two site plans are almost identical. The only real difference between the two is the way the concrete is being placed. In this instance it is being placed by crane and bucket, each crane has a three yard bucket to place concrete. As just mentioned in this process two buckets will be used, when one of the buckets is being filled the other bucket will be going up the deck placing the concrete and coming back down. At the most there will be three concrete trucks on site at a time, one leaving, one filling the buckets, and one waiting to fill the buckets. The most economical way would to only have two trucks on the site at a time.

Now let's look into possible lay down areas for the structural steel system that was mentioned earlier in this report.




This is the first attempt at find a steel lay down area. The main goal of this site plan was to keep the crane boom swing away from existing building and heavily traveled roads. For the most part this was accomplished. A lay down area was established for each crane; however there is a section in the middle of the building that neither crane can reach. Now another problem arises if I get a crane with a bigger swing radius I risk being over traffic or an existing building. If I move them closer together, they can't reach the edges of the buildings. Maybe a third crane should be added for this purpose.




A third crane was added and the area of the building that can't be reached is smaller yet. Once again effort was taken to shy away from the existing buildings and the roads. It appears that the only way to be able to reach every location of the building is to have some overlap with a road or existing building.  A fourth crane could be added but that wouldn’t be beneficial, cost would increase and a lot of coordination would need to happen between the crane operators so they don’t get in each other’s way.

Another alternative would be to pick the steel right off the truck and lift it into place that way you don’t have to handle the steel more than once.  This would be the case with two or even three cranes.

Conclusions/Recommendations:

Based off the site plans mentioned previously for the steel structure I would have to recommend the cranes be placed where they are for the current concrete system.  I would also recommend that the concrete be picked directly off the truck and then placed.  This would eliminate the need to tough a piece of steel more than once.

# (Mechanical Breadth) Mechanical System Analysis – Compare the Existing Four Pipe Mechanical System with a Proposed Two Pipe System

**Problem:**

At the time the system was being designed a two pipe system and the four pipe system were being considered with the four pipe system ultimately being chosen.  This system was chosen because it allows cold water and hot water to be available for heating and cooling throughout the year which can be beneficial because it maintains one's comfort level.  However if when the system is in heating and a warm day doesn't occur energy is wasted through the use of the extra cooling pipes that were never used.

**Goal:**

The goal of this analysis is to show that a two pipe system can maintain the same comfort levels as a four pipe system.

**Steps:**

First information about how the two systems work will be gathered; once this information is obtained the two systems will be compared from a comfort standpoint.  Constructability issues of each system will be looked into.  Finally cost and schedule impacts will be addressed.  Then a recommendation will be made.

**Outcome:**

A two pipe system is a fan coil system with two pipes, one is a supply pipe the other is a return pipe.  A four pipe system has four pipes two chilled water pipes and two hot-water pipes; once again these pipes are return and supply pipes.  The main disadvantage with the two pipe system is that it is either in heating mode or it is in cooling mode.  This is the big reason why a four pipe system was chosen for the Granby Tower Condominiums, the four pipe system has hot and cold water flowing all year long.  A disadvantage of the four pipe system is it is more complicated because it has twice as many pipes, coils, and valves.  This is good and all if the temperature is constantly changing to the point where the system would need to either change from heating to cooling or vice versa, but what if the temperature remains steady throughout that particular season isn't having both hot and cold water going a little overboard if only one of them is actually needed.  The downfall for the two pipe system is if indeed the temperature does change, how is a level of comfort maintained for the resident of that space, with a typical two pipe system it could take a day or longer to change from hot to cold or vice versa.  Most people will tell you to live with it, but what if you can't.  There are alternative means out there.

Combating Change-Over Temperatures

One way to overcome this chang-eover is with an external heating or cooling source. One such system is a DOAS (Dedicated Outdoor Air System); this system can provide enough heating or cooling in the months leading up to the changeover that simultaneous heating and cooling can occur with a two pipe system. This system also has the potential to generate up to 21 LEED Green Building Rating Points. There is also a significant reduction in the amount of water used with this system; a 20 to 30% reduction can be expected. This system allows for a decrease in the size of the chillers, air handling units, and because of the chiller reduction a reduction in the pump size is also noticed.

Constructability Issues:

When it comes to construction issues the two pipe system a better choice, to start with it has half as much pipe. This allows for more room in the plenum space, because of the availability of more space less trade coordination is needed. Don't get me wrong coordination between the mechanical contractor, electrical contractor, and plumbing contractor are still very important. Coordination with the concrete contractor is important with this building since the structure is primarily cast in place concrete.

Cost and Schedule Impacts:

Through discussion on the senior thesis message board I have found that initial cost of a two pipe system is lower than that of a four pipe system. This is fairly obvious because there is half as much pipe for the two pipe system, there is also twice as many coils valves for a four pipe system which will also increase the price. According to the 2004 ASHRAE Handbook-HVAC Systems and Equipment the four pipe system has a better efficiency and lower operating costs. The schedule will also decrease with the two pipe system because once again there is half as much pipe and equipment that needs to be installed.

Summary/Conclusions

I would recommend using the two pipe system; it has a lower initial cost and can be installed in less time. The climate control issues during the changeover periods are minor, the temperature change isn't usually too dramatic and hopefully you would be able to withstand the change for a day or two.

# Research – Workforce Development

**Problem:**

Over the years the workforce in the construction industry has been dwindling. People are either leaving the workforce or they are just not entering it. The perception that people have about the construction industry has something to do with this, whether it be the perception of the job or the perception of the people in the industry. Some of this has to do with the shortage of skilled laborers as well. Whatever the reason is for the diminishing size in the workforce, we as and industry need to do what we can to promote ourselves and the industry well.

**Goal:**

The goal of this research is to pinpoint the reasons why people are not entering the workforce and use this to improve the industry so that people will be interested in construction and will in turn join the industry.

**Steps:**

The first step was to determine some of the issues as to why people are not entering the workforce. Once these issues were determined I could look into what we could do to change people's minds about the industry. Once I determined the issues and some possible solutions to these issues I wanted to get some feedback on these issues.

**Outcome:**

I had a meeting with Dr. Riley to discuss my research and he mentioned to me about a book by Brent Darnell called The People-Profit Connection How Emotional Intelligence Can Maximize People Skills and Maximize Your Profits, so I decided to look into it. It had lots of information on how to improve yourself which in turn improves the people around you. After reading through this book I decided to talk to Craig Dubler a Penn State AE Grad student about some of the experiences he has had and how they related to what had come to my attention after reading through Brent's book.

Issues:

Let's look at the reasons why people are not entering the workforce before going into how much detail about what we need to change about the industry and about ourselves. One of the main reasons people are not entering the workforce is a negative perception they have about the industry; other factors are involved in this as well. The long hours worked in the industry have a negative effect on people. The work we do is sometimes very hard and this can shy people away. The physical labor that goes hand in hand with the long hours and hard work that we put in can take its toll on people. If someone sees someone doing a hard job for a prolonged period of time its going to make them think twice about entering that workforce when they can do an easier job and make just as much money if not more. This brings me to another point, some people feel they don't get enough pay for the long hours and hard work they do. Safety is also a key issue in bringing people into the industry as well as keeping people in the industry. People are not going to want to perform a job/task if they don't feel safe. The stress that comes with the job also takes its toll on people.

Ways to Improve:

Let's start with safety, how do we improve safety? One way to improve safety is by implementing safety programs. You can't just saw that everything is safe because you have a safety program; the program needs to be enforced. Another way to improve safety and people's perception is to have a good healthcare plan for your employees/fellow workers. This makes people feel better about coming to work; they know if something happens to them their families are taken care of.

Now let's work on improving stress, one way to relieve stress is to exercise whether it be yoga, meditating, or any other form of exercise it will help make you feel better. You can improve your emotional intelligence, this helps you understand people better. It might only make you feel better about yourself but it could make those around you feel better about themselves as well. Another way to help with stress is to do teambuilding exercises and emphasize good communication and teamwork skills. If you work well and communicate well with those around you it will be a better environment to be in and to be around.

Now how do we combat the long hard hours that we work that take a toll on our bodies? One way to combat this is to let people go home early on a Friday if they have been working hard all week. Another option would be to have a company softball or basketball league, anything to help the people that work together get to know each other. These also help to relieve stress as well.

If we improve on these things we can make the construction industry a better place for ourselves and for anybody who is thinking about becoming part of it. A lot of the things mentioned above with more than just the things mentioned. The company sports league could help relieve stress, it helps establish a better atmosphere at work. All the suggestions mentioned help to change people's perception of what the construction industry is all about.

When I spoke with Craig Dubler about his experiences I wanted to see if he had experienced any of the issues mentioned above. He had mentioned some things like the suggestions mentioned above. One thing he mentioned that really stuck in my mind was that some people would quit a job because it wasn't what they thought it would be, as if the company didn't really sell themselves. He also mentioned how some of the companies in the industry have more of a family atmosphere where other companies are more of a you came here to work so get working type of atmosphere.

The one big thing I will take from speaking with Craig is that safety is very important, you can have best atmosphere but if the job isn't safe people aren't going to want to do it, whereas if a job is extremely hard but you feel really safe you are more likely to do that job. There are four important things to remember when it comes to safety:

- training
- attitude
- having the right tool
- enforcement

These four things are required in order for a safety program to work efficiently. Training, you need the right training to do the job or you won't do it right and you may hurt yourself or someone. This wouldn't make the industry look good. Next is attitude, you need to have the right attitude when performing a task. After that come having the right tool, you may have the right training a good attitude but if you don't have the right tool you aren't going to feel safe and neither will the people around you. Lastly is enforcement, a safety program must be enforced, if it is not enforced it won't work.

The last thing that I want to take away from my talk with Craig is that you have to take people for who they are. Don't treat people like you are better than they are, it won't get you anywhere. You need to understand people's personal needs, not only will this make them feel better but it will help you feel better about yourself and make people respect you.

## Conclusion:

In conclusion there are several things we can do to keep people in the industry and to get more people into the industry. Some companies already implement these ideas and others are well on their way. Work on improving yourself if you want other people to respect you.

# Summary and Conclusions

The structural system analysis did not turn out the way I thought it would. I thought the steel would be cheaper because of using smaller members than the concrete, but since I couldn't have a beam span larger than 7'-0" there was a lot of steel members that may not have been there otherwise. The schedule surprised me a little bit, but since I used the labor units recommended by RS Means which might not be how you would staff the project if you had worked on a similar project before.

The site plan analysis came out the way I thought it would. I knew with the congestion on site and around site that it would be most beneficial to pick the steel beams off the delivery truck directly. I did not expect however that I would need 4 cranes to be able to reach the entire building without having a crane span over a traveled road or an existing building.

The mechanical analysis was similar to what I expected. I expected the two pipe system to be cheaper initially and that it would reduce the schedule. I did not however expect the four pipe system to have cheaper operating costs. I thought since the four pipe system had twice as many coils and fans that it would cost more to maintain and operate.

The industry research was a fun experience, I enjoyed getting to talk with Craig about his experiences and I think that the information I received will be beneficial in improving the construction industry,

# Acknowledgements

I would like to thank the following people for their help and feedback throughout the duration of my senior thesis project.

Dave Wysong – Turner Construction
Dr. Riley – PSU AE
Professor Parfitt – PSU AE
Professor Holland – PSU AE
Professor Hanagan – PSU AE
Craig Dubler – PSU Grad Student

# Appendix A

# Gravity Column Design TakeOff

RAM Steel v11.0
DataBase: Granby
Building Code: IBC

04/09/08 15:31:15
Steel Code: ASD 9th Ed.

**Steel Grade: 50**

**I section**

| Size | # | Length (ft) | Weight (lbs) |
|---|---|---|---|
| W10X33 | 247 | 7513.3 | 248245 |
| W10X39 | 49 | 1486.3 | 58160 |
| W12X40 | 4 | 123.0 | 4897 |
| W12X45 | 1 | 30.8 | 1371 |
| W10X45 | 42 | 1168.5 | 52883 |
| W10X49 | 51 | 1363.3 | 66799 |
| W12X50 | 1 | 30.8 | 1528 |
| W12X53 | 1 | 30.8 | 1632 |
| W10X54 | 16 | 410.0 | 22043 |
| W12X58 | 1 | 30.8 | 1779 |
| W10X60 | 14 | 410.0 | 24554 |
| W12X65 | 1 | 30.8 | 1999 |
| W10X68 | 14 | 389.5 | 26508 |
| W12X72 | 1 | 30.8 | 2208 |
| W10X77 | 16 | 451.0 | 34683 |
| W12X79 | 2 | 41.0 | 3237 |
| W10X88 | 19 | 399.8 | 35231 |
| | 480 | | 587756 |

## Gravity Beam Design Takeoff

RAM Steel v11.0
DataBase: Granby
Building Code: IBC

04/09/08 15:31:43
Steel Code: ASD 9th Ed.

**STEEL BEAM DESIGN TAKEOFF:**

**Floor Type: S1**
**Story Levels 1 to 34**
**Steel Grade: 50**

| SIZE | # | LENGTH (ft) | WEIGHT (lbs) |
|---|---|---|---|
| W10X12 | 8 | 142.00 | 1711 |
| W12X14 | 13 | 246.67 | 3492 |
| W12X16 | 9 | 234.00 | 3750 |
| W12X19 | 37 | 907.00 | 17191 |
| W14X22 | 8 | 240.00 | 5300 |
| W16X26 | 40 | 1176.00 | 30733 |
| W16X31 | 2 | 52.00 | 1616 |
| W18X35 | 5 | 130.00 | 4556 |
| W14X38 | 1 | 26.00 | 991 |
| | ----- | | ------------- |
| | **123** | | **69339** |

Total Number of Studs = **0**

**TOTAL STRUCTURE GRAVITY BEAM TAKEOFF**

**Steel Grade: 50**

| SIZE | # | LENGTH (ft) | WEIGHT (lbs) |
|---|---|---|---|
| W10X12 | 272 | 4828.00 | 58157 |
| W12X14 | 442 | 8386.64 | 118718 |
| W12X16 | 306 | 7956.00 | 127511 |
| W12X19 | 1258 | 30837.97 | 584487 |
| W14X22 | 272 | 8160.00 | 180206 |
| W16X26 | 1360 | 39984.00 | 1044915 |
| W16X31 | 68 | 1768.00 | 54927 |
| W18X35 | 170 | 4420.00 | 154915 |
| W14X38 | 34 | 884.00 | 33690 |
| | ----- | | ------------- |
| | **4182** | | **2357526** |

Total Number of Studs = **0**

## STEEL TAKEOFF

### BEAMS

| Member | Cost | SIZE |
|---|---|---|
| W 10x12 | $25.50/LF | 4828 LF |
| W 12x14 (includes W12x16) | $25.00/LF | 16 342.64 LF |
| W 12x22 (includes W 12x19) | $36.00/LF | 30837.97 LF |
| W 14x26 (replaces W 14x22) | $40.50/LF | 8160 LF |
| W 16x26 | $40.50/LF | 39984 LF |
| W 18x35 | $54.50/LF | 4420 LF |
| W 14 x34 (replaces W14x38) | $52.5/LF | 884 LF |

### Columns

| Member | Cost | SIZE |
|---|---|---|
| W 10x45 (includes W 10x33, W 10x39, W 10x49, W 10x54) | $65.50/LF | 11941.4 LF |
| W 10x68 (includes W 10x68, W 10x77, W 16x88) | $96.5/LF | 1650.3 LF |
| W 12x50 (includes W 12x40, W 12x45, W 12x53, W 12x58, W 12x65) | $72.00/LF | 277 LF |
| W 12x87 (replaces W 12x72, W12x79) | $ 122.00/LF | 71.8 LF |

STEEL COSTS: $4,849,098
x location factor (0.874) ⇒ $4,238,111

## Fire proofing Takeoff

sprayed cementitious fireproofing

1" thick on steel beams

| cost | size |
| --- | --- |
| $1.39 /SF | 42,580 SF |

1-1/8" thick on columns

| cost | size |
| --- | --- |
| $1.78 /SF | 10694 SF |

Fireproofing cost => $78,222

$78,222 × 0.874 = $68,366

## Concrete Floor Takeoff

3000 psi normal weight concrete
4 1/2" thick

| cost | size |
| --- | --- |
| $110/cy | 253cy/FL |

Concrete cost => $946,220

$946,220 × 0.874 = $826,090

## Metal Deck

20 GA

| cost | size |
| --- | --- |
| $5.50/SF | 18 250 SF |

Metal Deck Cost => $100,375

$100,375 × 0.874 = $87,728

## Welded Wire Fabric

6x6 xW2.1 xW2.1

| cost | size |
| --- | --- |
| $53.5 CSF | 18,250 SF |

WWF cost => $9,764

$9,764 × 0.874 = $8,534

Concrete Placement

placed via crane and bucket

| Cost | Size |
| --- | --- |
| \$22/CY | 253 CY/FL |

Concrete placement ⇒ \$189,244

\$189,244 × 0.874 = \$165,399

Steel connections

Assume 20% of steel costs ⇒ \$847,622

TOTAL COST \$6,241,850

## SCHEDULE

### Concrete placement

crew Type C-7 can place 95 cy/day

8602cy / 95cy/day = 90.75 days

### Fire proofing

crew type G-2
2 crews used

for beams can place 1500 SF/day
for columns can place 1100 SF/day

beams: 42,580/1500 = 28.5 days
columns: 10694/1100 = 9.75 days

### metal deck

crew E-4

can place 2700 SF/day

18,250/2700 = 7 days

### Welded wire fabric

crew 2 rodmen can place 31 CSF/day

182.5/31 = 6 days

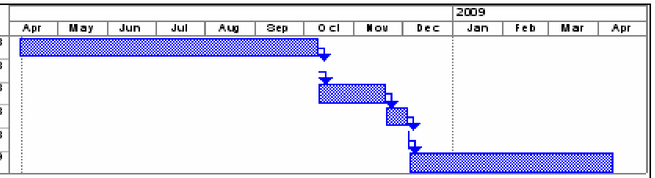
### Steel

crew E-2

| | | |
|---|---|---|
| W 10x45 | 1032 LF/day ≈ | 11.75 days |
| W 10x68 | 984 LF/day ≈ | 1.75 days |
| W 12x50 | 1032 LF/day ≈ | 0.5 days |
| W 12x87 | 984 LF/day ≈ | 0.25 days |
| W 10x12 | 600 LF/day ≈ | 8.25 days |
| W 12x14 | 880 LF/day ≈ | 18.75 days |
| W 12x22 | 880 LF/day ≈ | 35.25 days |
| W 14x26 | 990 LF/day ≈ | 8.25 days |
| W 16x26 | 1000 LF/day ≈ | 40 days |
| W 16x31 | 900 LF/day ≈ | 2 days |
| W 18x35 | 960 LF/day ≈ | 4.75 days |
| W 14x34 | 810 LF/day ≈ | 1.25 days |

Total: 132.75 days

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | Steel Erection | 132.75 days | Tue 4/8/08 | Thu 10/9/08 |
| 2 | Place metal deck | 1 day? | Thu 10/9/08 | Fri 10/10/08 |
| 3 | Steel Beams fireproofing | 28.5 days | Fri 10/10/08 | Thu 11/20/08 |
| 4 | Steel columns fireproofing | 9.75 days | Thu 11/20/08 | Wed 12/3/08 |
| 5 | Place welded wire fabric | 1 day? | Thu 12/4/08 | Thu 12/4/08 |
| 6 | Place concrete floor | 90.75 days | Fri 12/5/08 | Fri 4/10/09 |




Project: steel schedule
Date: Wed 4/9/08

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

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