Plaza East
Chantilly, Virginia

Final Thesis Report

Steve Miller

Construction Management

Advisor: Dr. David Riley

Spring 2008

PLAZA EAST

Steven Miller
Construction Management

Chantilly, VA

http://www.engr.psu.edu/ae/thesis/portfolios/2008/smm475/

Project Team:

- Owner - Tishman Speyer Properties
- Architect - Hellmuth, Obata + Kassabaum, P.C.
- Mechanical Contractor - GHT Limited
- Structural Contractor -
- Smislova, Kehnemui & Associates, P.C.
- General Contractor: James G. DAVIS Construction Con-sultants - VIKA, Inc.

Architecture/Design:

- Two office buildings mirroring each other at a 90° angel
- Core and Shell design with the core consisting of 3 elevators, restrooms, mechanical room, and two stairways
- First floor has lobby leading to all aspects of core and 3 exits including loading dock
- Typical floor open for tenant design
- Curtain wall façade consisting of precast concrete, vision and spandrel glass

Basic Project Information:

- 5 stories above grade
- 123,000 sqf per building
- Design-Bid-Build
- Function - General Office Building
- Duration - March 2006 to August 2007
- Cost - $28 to $29.5 million

Structural System:

- Spread and/or continuous footings for foundation
- 5" minimum thickness for Slab-on-Grade
- Cast-in-place columns
- Post-tensioned beam and non-post-tensioned one-way slab for each floor
  -concrete canopies at second floor only
- Typical I.R.M.A. roof

Mechanical System:

- Mechanical penthouse stores one 17,000 cfm packaged, air cooled thru wall unit, a 16,800 cfm natural gas, outdoor air ventilation unit, and a cooling tower
- This system is combined with 5 fan powered terminals, 8 fans, 3 pumps, 3 water cooled A/C units, and 4 electric heaters

Electrical System:

- Main power delivered at 3 phase 480Y/277 Volts with 150 kW
- Emergency power is supplied through a diesel power unit producing 150 kW, 187.5 kVA at 480Y/277 Volts

PLAZA EAST
04.07.2006
TISHMAN SPEYER

Acknowledgements

I would like to thank the following individuals for all their help in aiding me with my senior thesis over the past year.

Tishman Speyer:

Felix Tansil

James G. Davis Construction:

Peter Clark

Computer Integrated Building Processes Group (NIST):

Robert Lipman

Georgia Tech University:

Chuck Eastman

Harmon Inc:

John Myers

Energy 10 Help:

Any Lau

CENTRIA Architectural Systems:

James Flanagan
Benjamin Marnik
Patti Palombo

Gilbane Building Company:

Dale Kopnitsky

Holbert Apple Associates, Inc:

Richard Apple

Pennsylvania State University:

Rovert J. Holland
Dr. John Messner
Dr. M. Kevin Parfait
Dr. David Riley

Table of Contents

Appendices

Executive Summary

The project center for this entire thesis was the Plaza East, an office building located in Chantilly, VA. This was a 5 story cast-in-place office building with no subfloors. Several building components were researched and analyzed to reach the **goals** of better means to save money, time, and building costs. Accompanying the building analyses is research on software implementation for steel buildings, and the benefits that can be used now and in the future.

The first section is research that focused on implementing CIMSteel Integration Standards/Version 2 (CIS/2) protocols for Electronic Data Interchange (EDI). This is to be used to a single 3D model and can be carried through the entire project. This research was basically for steel structures and allows a project to be completely paperless. Even though the type of superstructure does not match that of Plaza East, the software and tools prove that they can be helpful on any project, especially through communication.

The first analysis is focused on the architectural precast building envelope. Researching two separate types of metal panel systems are compared to the existing building envelope. Savings on price and energy costs are shown to prove the different systems could be worth the different look the building would have had.

The next study focuses on green roofs and their advantages to buildings such as Plaza East. The money saved on the building envelope in analysis one is to be used to implement a green roof and prove the aspects of why the industry should be focusing more on sustainability. This analysis contains my mechanical breadth by using Energy 10 software to show energy saving possibilities. Not only will it be used to show savings through the roof, but also through the new wall panels being used.

The last analysis contains my structural breadth. Calculations had to be made to ensure the 5 ½" roof slab could sustain the new load created by the green roof. Post tensioned beams are integrated and poured together with the slab. Most calculations focused on the slab and how much of a reinforcement upgrade should be used for the building's new roof load.

Project Information and Background

Project Information:

Plaza East includes two 5 story cast-in-place, core and shell office buildings located in Chantilly, Virginia, off the Westfeilds Blvd exit of Rt. 28. It is a speculative office building built for the owner, Tishman Speyer, a global developer. Other primary members of the project include the architect HOK, and general contractor DAVIS Construction. The building was designed in 1999, and then put on hold until December 2005 for bidding due to the surrounding area not being heavily populated.

Each building has 123,000 sq ft for a total of 246,000 sq ft, and around 25,000 sq ft per floor. These office buildings are two of the same. Mirroring each other on a ninety degree angle these rectangular shaped buildings have precast concrete slabs and windows covering the exterior wall. Each floor has large windows interrupted by concrete columns and rows running up and along the building. Except for half of the fifth floor, which has a horizontal display of glass, the building is only separated by mullions and then covered by the precast towards the roof. The first floor has a large lobby which extends through the entire building. The lobby leads to the core of the office building which houses the elevators. Two stair cases are located in the center of each side of the building. Other than the lobby, the first floor along with each other floor is open for the tenant to place walls wherever they please.

The entire facade of the building is a curtain wall consisting of precast concrete, mullions, and large panes of vision and spandrel glass. There is a large wall protruding from each side of the building and above, but not connecting across the roof, almost making the appearance that the building is sectioned into two. This wall is covered by precast concrete panels and is completely for show. The roof houses a large mechanical screen wall to block the view of any mechanical and elevator equipment rooms. The roof is built up above a concrete slab with insulation followed by a topping of gravel. The mechanical system runs from the roof down through building by ducts and cutouts in the slabs.

Client Information:

Tishman Speyer is a very large developer with many locations around the world. Their Headquarters is located at Rockefeller Center in New York, New York. Tishman Speyer builds many office buildings to either rent to tenants and manage, or sell them for a profit. Plaza East is a speculative building which HOK designed back in 1999. The building construction was delayed a few years until 2005 and updated to meet the 2003 Business Code. Tishman Speyer wanted to wait for the area around the building to become more economically sustainable.

Tishman Speyer is very devoted to their high quality standard. Safety is their number one concern. They also have a standard for wanting nothing but the best in their material and in the contractors they hire. They only build Class A buildings and will not downgrade for any reason. It does not matter if the building is put in a Class B or Class C area. With that in mind they made sure to have a Fire Safety Consultant and a Building Code Consultant on the Plaza East project in order to follow the Fairfax, fire, jurisdiction, and building codes. They did not have any sequencing issues. They left that up to the general contractor, DAVIS Construction. As long as their standards are followed their projects, such as Plaza East, will be built to their satisfaction.

Project Delivery:

Plaza East was delivered by design-bid-build. Tishman Speyer has used this method to get the best price and scope of work for the project. This project was delayed about six years after its design process in 1999. They choose from multiple architects based on the type of building and project comparisons with the individual architect’s portfolios. For Plaza East they chose HOK with a lump sum contract. After those six years there was a four month period of upgrading the drawings to the 2003 Building Code status in 2005. Bids went out to three major contractors in December of 2005. After a month, Tishman Speyer contracted DAVIS Construction in January of 2006 for Plaza East. The contract was a lump sum contract with DAVIS with a bond of 1- 1 ½% of construction cost. DAVIS has a few insurances on Plaza East also, including, Builders Risk, Workers Comp, Labor, and Material Insurances. DAVIS Construction typically only held bonds on subcontractors whose contract value is over $500,000 or whose scope of work included structural elements that require engineering on the part of the subcontractor (ie: window washing roof davits or similar equipment). There are many subcontractors to list but only a few are in the hierarchy on **Figure 1**.

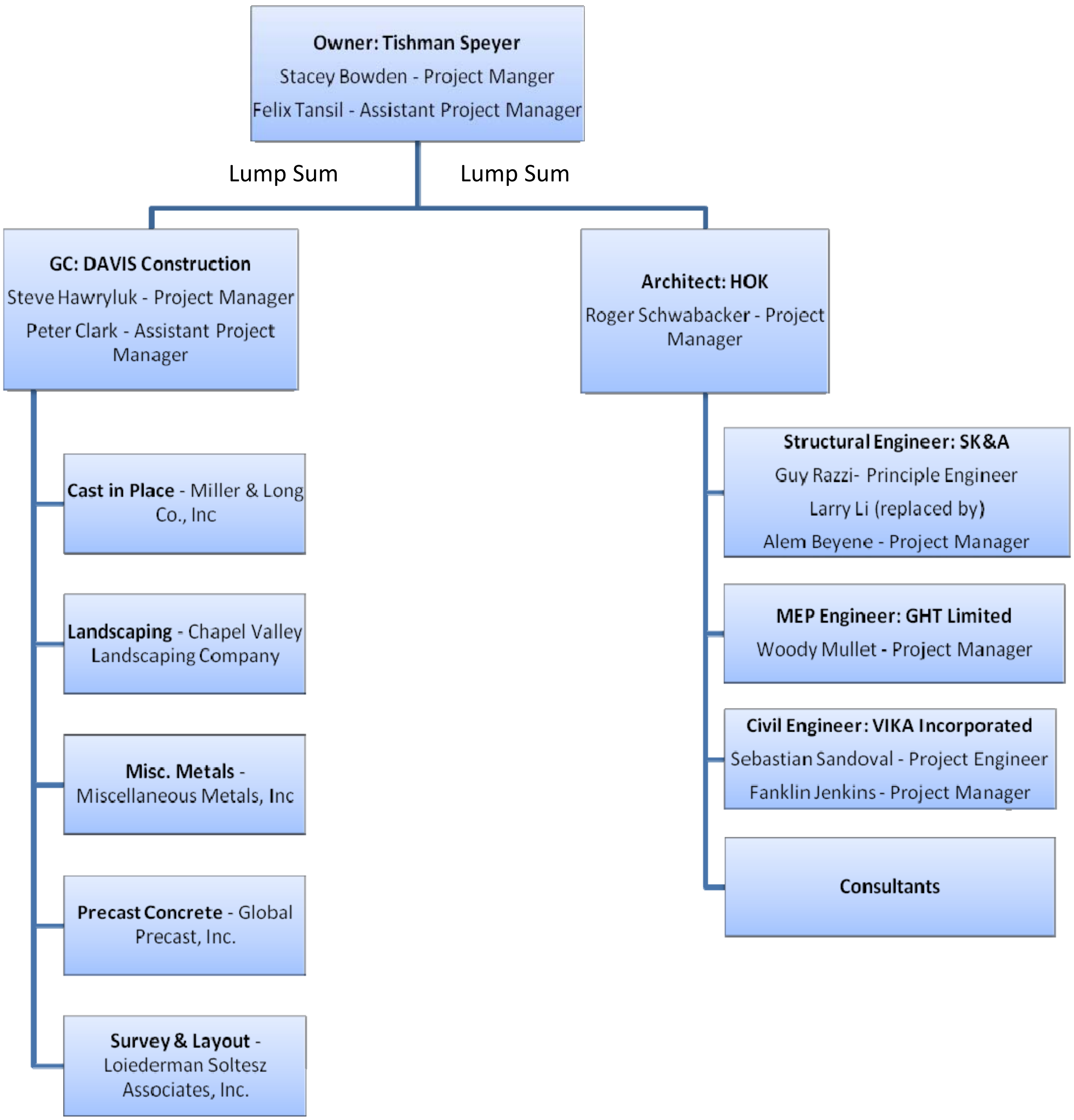


Fig 1

Project Team:

James G. DAVIS Construction Corporation

James G. DAVIS Construction has multiple Vice Presidents. Project Plaza East was being handled under VP Jim Dugan and his group. Mr. Dugan's project manager for Plaza East is Steve Hawryluk, who was then followed by two assistant project managers, Pete Clark and Hammad Khan. They all had help from their intern Steven Miller, who performed many tasks including submittals, updating drawings, and supervising the curtain wall mockup at ATI in York, PA. The two superintendents, who headed up the field progression under Mr. Dugan were, Duke Frederick and Steve Mundy. All five of these men worked with the subcontractors on board for this project. All can be seen in **Figure 2** below.

Plaza East ran very smoothly and it could be because of the appropriate staffing on the job. They had the project work load spread evenly throughout the employees to get the job done well.

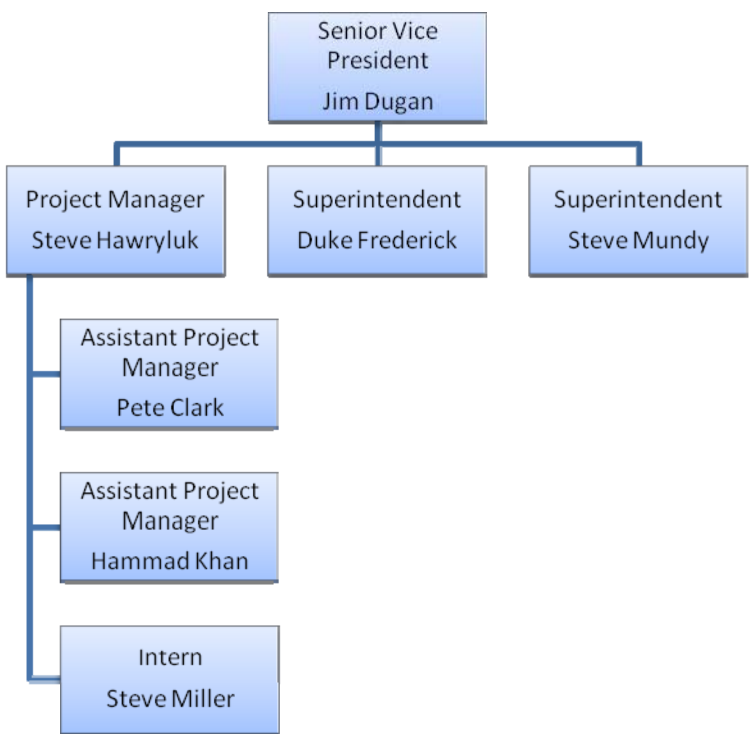


Fig 2

Building Systems Summary:

Structural Cast in Place Concrete:

The entire structure of the building was made of Cast in Place, post tensioned concrete, 80 lb/sq ft live load, 20 lb/sq ft partition load capacity. The foundation used spread footings while the rest of the building included cast in place columns and slabs. The slabs also included post tensioned beams across the main columns. There was a mixture of short and long span areas over each floor slab with bays ranging from 45’ X 20’ at the perimeter and 27’ X 20’ typical interior bay. The roof was a hot - applied rubberized asphalt system with a 15-year system warranty. Crane and bucket was the typical pouring method for the foundation and columns. A pump truck was used for each floor slab. Using both methods helped with time and efficiency. The slab on grade was a 5” thick, 3,500 psi normal weight concrete, reinforced with 6x6-W1.4xW1.4 welded wire fabric on a 6 millimeter polyethylene sheet over 6” wash crushed stone. Each additional floor slab was post-tensioned beam and non-post-tensioned one-way slab construction with 4,000 psi normal weight concrete with 7” thick slabs. Each was reinforced as shown on each structural floor plan. Concrete canopies only occur at second floor level.

Precast Concrete/Curtain Wall:

Precast concrete was used for the curtain wall and the stairs throughout the building. The precast concrete panels were connected through embeds placed in the cast in place concrete slabs and columns. The precast panels were made in Canada and driven down to the jobsite on tractor trailers. The curtain wall façade consisted of precast architectural spandrel panels and column covers with mullions, vision and spandrel glass; 1-inch thin slat Venetian blinds provided for perimeter windows. The curtain wall windows were designed by Arctec Precision Glazing and tested at ATI in York, PA.

Mechanical System:

Each typical floor has a 90-ton A/C unit capable of providing the equivalent capacity ratio of one ton for each 254 sq. ft of usable floor area. There are approximately 17 fan powered VAV boxes with re-heat coils and 8 cooling only VAV boxes to provide sufficient conditioned air to each floor. The self contained A/C unit has a variable frequency drive that allows the fan motor to adjust speed to meet current cooling load demands, with multiple compressors, and economizer coil that allows for free cooling based on outside air and humidity, medium efficiency filters, integrated control panel compatible with the building DDC control system. The supply air ductwork is constructed to medium pressure SMACNA standards as part of the base building.

Electrical/Lighting System:

The building power distribution system will be derived from Dominion Virginia Power transformers located on a concrete pad adjacent to the building. The power throughout the building will be distributed from one (1) 4000 (this should be 3000 per Dominion) amp 277/480V switchboards located in ground floor switchboard room. The power to base building loads will be distributed by conduit and wire risers. The power to tenant floors will be provided from one 3000 amp bus duct and associated bus duct plug in units. The emergency power to Plaza east is supplied through a diesel power unit, producing 150 kW, 187.5 kVA at 480Y/277 Volts. Lighting and telecommunications will be put in on behalf of the tenants and was not under contract of the GC.

Conveying System:

Each building contains one three car group of 350 fpm traction passenger elevators. Each group is provided with two 350 fpm @ 3500 lbs. (passenger) and one 350 fpm @ 4000 lbs. (passenger/freight). The elevators will have an elevator card key access to all floors combined with a perimeter access security to each building. Each floor has emergency exits with stairs located centrally in each half of the building.

Fire Protection System:

Plaza East will be provided with a complete installation for a new Class A system with Style D, Style 6, and Style Z circuit types for multi-plex addressable, fire alarm system with all alarm, audio, elevator recall, mechanical units control, remote station notification, and security system interface. The installation of the project's fire alarm system shall conform to the applicable sections of the NFPA-72 Virginia State Uniform Building Code, requirements of BOCA, NEC, and the Fairfax county Fire Marshal.

Project Cost Summary:

Total Project Cost	**$54,000,000**
Total Project Costs/Square Foot	**$ 219.51/SF**

Major System Cost

Mechanical	$ 3,925,000
Plumbing w/ Mechanical	
Mechanical & Plumbing/Square Foot	$ 15.96/SF
Electrical	$ 2,020,000
Electrical/Square Foot	$ 8.21/SF
Concrete	$ 8,510,000
Structural Concrete/Square Foot	$ 34.59/SF
Masonry	$ 40,000
	$ .16/SF

General Conditions Estimate:

Plaza East had a combination of general conditions, insurance and taxes, bonds, and a general contractor fee estimate equaling $3,265,638 in its proposal. This comes out to be 11.8% of the total construction cost according to their proposal. The breakdown of the General Conditions was done by dividing the total cost given by the weeks of the project. Anything not divided by the duration of the project was considered a Lump Sum. Below, **Table 1**, is a summary of the General Conditions Estimate.

For a detailed breakdown of the General Conditions Estimate see Appendix A

General Conditions Summary	
Labor	$1,107,214.00
Material	$692,152.00
Equipment	$71,670.00
Insurance and Taxes	$165,514.00
Bonds	$175,141.00
General Contractors Fee	$1,053,947.00
Total =	$3,265,638.00

Table 1

Detailed Project Schedule:

Plaza East is a fairly simple project. The duration for this project was planned to span less than 58 weeks. There was no need for multiple complex phases to the project. Each building was being erected at the same time, with building 1 slightly ahead of building 2. On the next page are some key dates from the original schedule put together back in 10/24/2005. The Notice to Proceed came later than expected which pushed some of the dates back. The project still has not been handed over to a tenant for occupancy yet and is still owned by Tishman Speyer.

For the Detailed Project Schedule see Appendix B

<u>Key Project Dates</u>

Notice to Proceed	3/13/06
Complete Excavation	3/27/06
Concrete Complete on Tower #1	6/15/06
Concrete Complete on Tower #2	7/13/06
Complete MEP Risers	11/13/06
Complete All Façade Installation	11/23/06
Complete Main Lobby	12/26/06
Complete All Finishes	12/26/06
Complete All Site Works	2/8/07
Substantial Completion	3/7/07
Building #1 Complete	4/13/07*
Building #2 Complete	5/14/07*

*Project Dates have changed from original schedule

Site Layout Planning

Plaza East was built on a very large lot with no close surrounding buildings. This in turn gave the project plenty of room for whatever was needed during each aspect of the project. There was always plenty of room for parking, material storage, equipment, trailers, etc.

For Excavation Site Plan See Appendix C.1

The first site layout plan for this project is the site work and excavation plan. There wasn't much excavation for these two buildings. The excavation included shallow footings and leveling the ground for the SOG. This in turn made this first phase fairly quick and simple. During excavation, materials were being brought in to begin the structural aspects of the buildings. The majority of materials consisted of cables (for post-tensioning), rebar, and formwork. The traffic was not as strict during this phase and had plenty of room to move around. Cars would enter the site and head left to park. Some cars parked in front of the trailers the entire duration of the project.

For Superstructure Site Plan See Appendix C.2

The second site layout plan demonstrates where everything was placed for the majority of the project. The materials were placed in the same areas as before. After the parking lot was paved, there was plenty of area for everybody's cars. During this phase you can see the traffic direction became stricter, which eventually helped keep the path as a one-way traffic area.

Research: Implementation of Software for Steel Buildings

An important issue facing the construction industry today is the implication of building information modeling (BIM) to projects. It is a growing technology and is not being implemented in the present time as much as it could be. If this software is used more often it can lead to better quality buildings and quicker turnovers.

Problem Statement:

What are the benefits of implementing BIM software into construction projects, particularly with steel lead times? Concrete is often used on a project, when considering lead time, over steel. If BIM can be used to lessen steel delivery lead time, it can be used more frequently than concrete.

Research Goal:

BIM is a growing technology and it is getting past its beginning stages of progression. The goal is to speak to a company who has used BIM for its structural steel erection and to explain how it has helped them speed up the process. Research will be done on other case studies to prove how it has helped speed up the design and lead time process. BIM shall also be incorporated in Plaza East to prove its advantages. Owners and contractors will be the audience and the benefactors of this research.

Research Steps:

Research for this project will begin with reading and reviewing of the subject matter given to me from Bob Lipman and Chuck Eastman. Bob Lipman has vast data on steel from his research and projects he has worked with. After the information is obtained, it will be summarized and put into the outcome. Further use of the model will include steel/concrete take offs for comparison and load testing.

Expectations:

During this process multiple case studies should be found to prove how BIM software has helped with the design process of steel. Also a superstructure of Plaza East will be made in Revit to incorporate the advantages in value engineering and work sequencing. If goals are met and if money for the project is saved, a summary of the research will be presented.

Outcome:

Building Information Modeling (BIM) is sweeping the construction industry and making a big difference. BIM can be used to help with coordinating MEP, visualizing a model, calculating take offs, and the list goes on. Many companies have used such models for so many project activities; one of the more interesting uses is taken from steel design.

When implementing CIMSteel Integration Standards/Version 2 (CIS/2) protocols for Electronic Data Interchange (EDI) a single model can be carried through the entire project. But, what exactly is CIS/2? CIS/2 is not a program or a function or language exactly. It is a translator or a bridge to help software programs to communicate. CIS/2 is endorsed by the American Institute of Steel Construction (AISC) and recognized by International Alliance for Interoperability. This process helps structure steel projects save time, money and get steel on site faster. It can be normal for a design engineer to use a physical model of a building to transpose information to 2D drawings. Through EDI this entire paper process is completely disregarded.

When one looks at this new type of software it raises questions about interoperability in the construction industry, specifically on steel construction. Interoperability relates directly to both the exchange and management of electronic information, as well as comprehend and integrating information across multiple software systems. Back in 2002, The National Institute of Standards and Technology (NIST) did a study of cost inefficient interoperability in commercial, institutional and industrial facilities. The results showed inefficient interoperability increased new construction costs by $6.18 per sq ft as well as operations and maintenance costs by $0.23 per sq ft. In total, inefficient interoperability cost the construction industry more than $15.8 billion in 2002. The three types of interoperability costs included: avoidance, mitigation, and delay. Avoidance costs include redundant computer systems and IT support staffing and inefficient business process management. Mitigation costs include manual reentry of data and RFI management. Delay costs include labor for idled employees. Another NIST study found that losses of $6.73 billion on 1.1 billion sq ft of construction came from lack of interoperability in 2004.

Below (**Table 2**) is the costs of Inadequate Interoperability by the Stakeholder Groups, by Life-Cycle Phase (in $millions)

Stakeholder Group	Planning, Engineering, Design Phase	Construction Phase	O&M Phase	Total
Architects and Engineers	$1,007.2	$147.0	$15.7	$1,169.8
General Contractors	$485.9	$1,265.3	$50.4	$1,801.6
Specialty Contractors/Suppliers	$442.4	$1,762.2	---	$2,204.6
Owners and Operators	$722.8	$898.0	$9,027.2	$10,648.0
All Stakeholders (Total)	$2,658.3	$4,072.4	$9,093.3	$15,824.0

Table 2

CIS/2 is a set of standards that allows a wide variety of design and construction software to seamlessly communicate with each other. It goes far beyond the current CAD formats to transfer information. When using CIS/2, the software incorporates information including loads, end member reactions, and connection types. The development of CIS/2 enables the structural engineer, detailer, and steel fabricator to reduce the time required to convert designs to fabricate components, improve quality control standards, and reduce cost. When importing directly from one computer to the other, engineers can be assured the design will not be changed when put into fabrication and the fabricator knows that the files received from the structural engineer are accurate. This is a great way to reduce design errors, which results in significant costs. This carries on into the erection process, which helps eliminate costly erection problems that come from fabrication errors. These problems can really delay a schedule.

Virtual Reality Modeling Language (VRML), developed by the NIST, is used to make 3D models which can be made to facilitate a paperless project. Bob Lipman, who heads the NIST's CIS/2 to VRML mapping explains, "VRML provides a 3D visual representation of a CIS/2 file. It allows users to visually verify a steel structure down to the bolts and welds to see what works and what doesn't." Lipman further went on to explain how they can link electronic versions (PDF) shop drawings to the appropriate steel members, and because VRML is viewable through the web browsers, multiple parties can view the 3D model and the shop drawings simultaneously, without the need for commercial software licenses. Imagine how much faster that can be without using the snail mail process of paper drawings.

CIS/2 can offer most value when it is used as early as possible in the design process, but it also helps to minimize schedule and cost impacts that can happen later in design. Because the design process happens so quickly, the architect and engineer have much more time to pass the drawings back and forth to refine everything to be 100% accurate. This is because the computers that transfer every bit of information eliminating manual reentry. When a model is updated it will show that update immediately to all trades able to see it. When this is done a timestamp is added to the model to show which version is the latest version.

In order to show how well the software works the original process of design is broken down as follows. Architects will present a conceptual idea to the structural engineer, who would design the structure using a structural analysis program. He would prepare design documents and send them to a fabricator. The fabricator would then do a full take off **by hand** to determine the amount of material needed for the structure. This process would be checked and double checked in order to be sure the shop bill accounts for all the materials. This process took about a week when it was done manually. This is more than a one person process also, so it isn't just 40 hours of work but up to 80 or 120 hours at a minimum. With interoperability this process takes hours. They can send files by noon and receive a bill from the fabricator by 3 o'clock.

Another feature, to save time, offered by CIS/2 is "multiples" method for counting steel more efficiently. Multiples can be calculated by the fabricator's software system. Mill material is normally rolled and stocked between 40 and 60 feet long, so you have to multiply to get the best cost when you purchase mill material. "That means if you need three 18 ft beams, you don't order those exact pieces—order one 55 ft piece and cut it to length in the shop. All those calculations use to be done by hand."

The facts, along with time and money savings, speak for themselves. The Glen Oaks campus in New York is the largest public-school construction project done by the New York School Construction Authority (NYSCA). It is located in Queens adjacent to the Cross Island Parkway. The site includes three separate schools: two grammar/middle schools and a high school. The middle schools are both four-story, 1000-ton steel frames, each about 125,000 sq. ft. The high school is a six-story, 1,500-ton steel frame, about 225,000 sq. ft. The plan was to get the three simultaneously built in 18 months. Using RAM Structural System software, CIS/2, and SDS/2 improved their steel delivery by 2 to 3 weeks. The erection process went at a rate of 700 tons and 100,000 sq. ft. of deck per month.

Chicago's Soldier Field had a $365-million makeover which was paperless. A paperless project of this scale was never before seen in the US, but this is what it took to meet the time restraints. The project needed to be gutted and reconstructed in 4 to 6 months less than a normal National Football League stadium project takes. Steel erection finished after 5 months, two weeks ahead of schedule. They started in January and around September the project was 75% complete and they were on budget.

This last case study is the renovation of Presbyterian Hospital in Albuquerque, NM. The project used 1,200 tons of structural steel to add 150,000 sq. ft to the building. Additional square footage for more rooms for patients and three stories were built on top of an existing four-story building. This entire process was to be done while the hospital was kept fully operational. Design began in September 2001 and in four months construction began. The upgrades were to be completed by July 2003. Using CIS/2 to translate the 3D model of the project to the SDS/2 detailing software saved much time. It would have taken hundreds of hours to recreate the model in SDS/2. Referring to the technology the fabricator was quoted saying, "We saved at least a couple of months as a result."

This goes to show how much time and money can be saved using 3D models, CIS/2, and SDS/s software. More owners every year should be trying to implement this step into their design process. Doing so will not only save them time and money, but give them an extra layer of accountability to the process. "It can force collaborating firms to be more forward in explaining the projects costs." NIST did a study and found that about 85% of owners/operators in the capital facilities industry are largely uninformed on the issues related to project cost. They must rely on the integrity of the people working for them: architect, engineers, and general contractors. They must rely on them to keep projects in specified budget.

You can see that adding on this new technology can add an increase to the structural engineer's fees. However, the money and time saved on the project through schedule reduction, detailing and fabricating costs can more than offset these additional fees.

Conclusion:

There is no apparent reason not to have this technology added to all new and upcoming projects. A problem exists in the fact that not many people know about this technology or use it. I am trying to do my part and help by putting this knowledge out there, using the three case studies listed above. Getting three schools finished in 18 months and increasing steel delivery by 2 to 3 weeks is a significant success for a project of such size. Chicago's Soldier Field needed to be gutted and reconstructed in 4 to 6 months less than a normal National Football League stadium project takes. Along with steel erection finishing 2 weeks ahead of time, shows another success. And last and certainly not least, the Presbyterian Hospital in Albuquerque, NM having a fabricator quoted saying they saved several months on the project points to another success.

In knowing that these projects saved so much time, and that the software helped remove confusion between contractors, subcontractors, superintendents, etc., I can see how this could have helped on Plaza East. Every Thursday the project team had team meetings to go over progress, confusing drawings and/or specifications. This technology could have helped solve over half the questions generated during these meetings just by having the up-to-date electronic copies of the buildings.

When I worked up in York, PA at ATI we had problems with the erectors and precast beams staying in place after the embed welding. The erectors had to come back the following day to fix it, which pushed back the mullion and window installations. This set off an ongoing delay of the mockup which ended up lasting almost 4 to 4 ½ months longer than it was suppose to. With this new technology no one will be out of the loop again and problems such as this can be resolved before they become a greater nuisance. I'm not saying the mockup would have been exactly on time. They had other problems with it that did not involve the erection process; but, those first few delays did not help the situation. It is time to move forward in this industry and by going paperless can be a very helpful first step, not just for certain individuals, for everyone in the industry.

A 3D model was in progress of being made for Plaza East, but the post tensioning of the girders combined with slabs proved to be more over my head than anticipated. In short, the model was then scrapped and the 3rd Analysis, which was to be my structural, had to be changed. I planned on using my new 3D model that was created in Revit Structural to be placed into RAM. Using RAM I was going to then test new roof loads of my building, and to also possibly test to see if steel would have been more cost efficient.

Analysis 1: Alternative Building Envelope

Issue 1:

Plaza's East building envelope uses architectural precast concrete which had difficulty matching colors and problems with glazing leaks. If a different building envelope was used, there would be less load put on the superstructure and energy could be saved through different building envelope panels.

Analysis:

Research will be done on cost, schedule impacts, energy savings, and quality. Contacts will be made with a different subcontractor(s) to compare separate panel systems. Transportation cost could differ depending on where each envelope came from. If the architectural precast is no longer used, there will be no more problems with the color matching of the precast. The precast also came from Canada which contributed to long drives to transport the panels. With no precast panels the erection time can be higher and the crane picks could be smaller. Each of these aspects can change the amount of labor needed on the job. If time permits, a change in the curtain wall glass will also be looked into. This can also save on heating and cooling of the building, adding to energy savings.

Expectations:

After detailed research and analysis of at least two alternate building envelope methods one will be recommended to save on cost, labor, and energy efficiency. With this suggestion incorporated, the money saved can go to other aspects of the building. The money saved is expected to come from the less expensive material, quicker erection time, and energy saving costs.

Outcome:

After creating a few questions about the current precast system, I came in contact with John Myers, Director of Technical Services of Harmon Inc. I wanted to see if there was a more economical or environmentally safer direction the envelope could lean towards. He answered the questions I had given to him pertaining to my building envelop analysis.

John began with the cost benefits of the current building envelope. The benefits are pretty vague because the final installed cost of precast panels are affected by multiple things including means of panelization, access to the structure, finishes, repetition, and availability. Advantages of precast can come from its durability from impact and blast mitigation, good acoustic performance due to density, and the repetitive details such as rustications, accent features, and articulation generated in a single mold can be replicated.

When using precast you must also have to accept the bad with the good. The calcium carbonate matrix of precast is subject to degradation from acid rain and the alkali runoff etches glass and deteriorates metal. This is something Plaza East contractors must worry about considering the glass panels and aluminum mullions. Surface finishes are limited with precast and are inconsistent. Plaza East had this exact problem and had to scrub the building exterior to shade the colors better together. Precast can be very heavy and the weight can be a problem when it comes to the erection. Some of the larger pieces used on the Plaza East project were up to 20 tons, this alone calls for a larger crane, raising equipment costs. The sealant joints rely on field applied materials and the suspect quality of the bond line surface. The laborers must be careful when putting on every sealant to be sure of clean areas and proper bonding, Laborer safety should also be a concern. Mr. Myer concluded that safety is always on people's minds, but a precast erection accident is often fatal.

After having a general look at the precast curtain wall, I wanted some ideas of what to replace it with. Mr. Myers gave a few suggestions:

- GFRC, Glass Fiber reinforced concrete

  - At 5/8" thickness and mounted on a steel framework, GFRC provides the durability but is lighter and allows the insulation to occur further toward the exterior envelope.

- EIFS, Dryvit
  - Although sadly lacking durability, with light weight construction a wide variety of aesthetics can be achieved.

- Centria Duracast Dimension Series Panels
  - A light weight foam core steel skinned panel system that provides an encapsulated temperature gradient and was designed to replace limestone and precast. Its non directional embossed panels, with a beige finish, also approximate a precast finish.

Myers finished saying other metal panel, ceramic and GRFP systems have been used to replace precast although they may have a different surface texture.

Along with new materials to replace the precast panels, some ideas were given for new glass and glazing products. A few suggestions included adding coatings to provide better shading coefficients and low emissivity such as:

- Viracon VE1-2M or Viracon's VRE and VNE coatings
- PPG's Solarban 60 or 70
- Glass Sage Electrochromics
- BIPV (building integrated photovoltaic) this would typically change the façade to maximize the benefits and optimize solar exposure to the panels.

After further investigation I thought of comparing an EIFS system to the precast concrete. After consulting Pete Clark, an assistant project manager on the job, Felix Tansil, Tishman Speyer representative, and John Myers, this choice proved to be not as good as the precast concrete envelope. Mr. Tansil and Mr. Myers told me Tishman Speyer, the owner, nor HOK, the architect would accept EIFS as a cladding material. Both firms understand the limited life expectancy and the common poor quality of EIFS installation. Tishman usually keeps their properties and are not interested in the initial cost savings at the risk of low performance. Mr. Myers also said EIFS does not allow water infiltration and is typically flashed poorly. Degradation of the supporting stud work would be catastrophic and even window washing rigs will severely damage the surface. Mr. Tansil of Tishman Speyer also assured me when accenting the facade; they like to reduce maintenance and operational cost. The precast concrete's durability does that. So after that short conversation EIFS seems to be out of the picture.

The next choice I wanted to look into was the CENTRIA Duracast. The Duracast finish is a shop-applied 100% acrylic coating including silica aggregate that provides the look and feel of precast with an insulated metal panel (**Fig 3**). Compared to precast, Duracast reduces structural requirements and installation costs, eliminates most sealants that degrade and stain from dry seal joinery, shortens material lead times, and has faster installation. It comes in 8 colors, or custom colors can be made. Duracast is fully tested to ensure long service life.

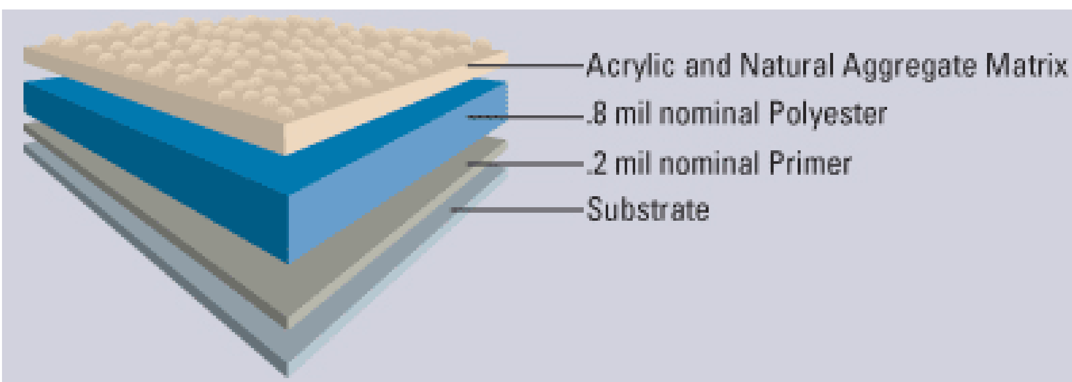


Fig 3

The first type of panel I looked into was the Versawall panels. Looking into appearance and the size of these panels, I don't feel this material could give Plaza East the same look it has with the thick pieces of precast. The thickest Versawall panel had a 4" depth, a 36" width, and a 40' length. Unless you consult CENTRIA for longer lengths, just by sheer dimensions these panels could not resemble the original design. Although this is the case, I wanted to see if it would be cheaper and more energy efficient if used. The R value for a 4" piece was R30.2. Another aspect to be aware of is that these foam filled metal panels can look like concrete, because of the Duracast coat, but are better for the environment than concrete. These panels can receive LEED points up to 10 for optimizing energy performance, 2 for recycling content, and 2 for low-emitting materials (Adhesives and Sealants, Paints and Coatings).

The second type of panel looked into was the Formawall Dimension Series panels, which was an original suggestion from Mr. Myers. Researching appearance and the size of these panels prove the same findings as the Versawall panels. They have the same dimensions, but similar to the Versawall, they look extremely different than the architectural precast façade. The R Value for these panels is a little less than the Versawall at R20. Similar to the Versawall these panels also look like concrete (Duracast) but are still better for the environment. These panels also can receive LEED points up to 2 for recycled content, 1 for regional materials, 2 for low-emitting materials (Adhesives and Sealants, Paints and Coatings), and 10 for optimizing energy performance.

I contacted Benjamin W. Marnik, a P.E. at CENTRIA. He began by informing me my application is not typical for Versawalls. To achieve the level of detail Plaza East shows, a more appropriate material would be CENTRIA Formwall Dimension Series, as stated before by Mr. John Myers from Harmon Inc. The information on the Versawall is as follows: 2.6 psf for 26 Ga. Skins and 3.7 psf for 22 Ga. Skins. He did not have an answer for how much quicker the wall would go up, but he assured it would be less time consuming. For pricing Mr. Marnik told me to use $\$20/ft^2$ to find a total cost and with that I should get a ballpark number. Keeping in mind this would have simple vertical panels, all the same module, with press broken flashing details. If using the Formwall Dimension Series the price per square foot would be doubled to $\$40/ft^2$**.**

After speaking with Peter Clark from DAVIS Construction I was informed that CENTRIA has about only one or two contractors who are certified to apply their panels, which ends up increasing the prices. I was suggested to mark up the price about 50% and came to $\$30/ft^2$ for the Versawall and $\$60/ft^2$ for the Formwall (**Table 3 & 4**).

CENTRIA 4" Versawall with Duracast Finishing						
	Quantity	Unit	Mat. Cost	Inst. Cost	Total Unit Cost	Total Cost
North Elevation	6,240	sf	-	-	30.00	$187,200.00
East Elevation	5,236	sf	-	-	30.00	$157,080.00
South Elevation	7,413	sf	-	-	30.00	$222,390.00
West Elevation	4,774	sf	-	-	30.00	$143,220.00
Total	23,663	sf				$709,890.00

Table 3

CENTRIA Formwall Dimension Series with Duracast Finishing						
	Quantity	Unit	Mat. Cost	Inst. Cost	Total Unit Cost	Total Cost
North Elevation	6,240	sf	-	-	60.00	$374,400.00
East Elevation	5,236	sf	-	-	60.00	$314,160.00
South Elevation	7,413	sf	-	-	60.00	$444,780.00
West Elevation	4,774	sf	-	-	60.00	$286440.00
Total	23,663	sf				$1,419,780.00

Table 4

Savings: <u>4" Versawall with Duracast Finishing</u>
Actual precast cost (not including change orders):
$2,600,000.00 - $709,890.00 = **$1,890,110.00**

<u>Formawall Dimension Series with Duracast Finishing</u>
Actual precast cost (not including change orders):
$2,600,000.00 - $1,419,780.00 = $**1,180,220.00**

Looking into wall sections and areas, a few calculations were performed using Energy 10 to perform an energy saving cost analysis for the new envelope system. The Versawall panels seem to be by themselves with some sheathing, so I will choose a wall in the Energy 10 library near the R30 value given from the website. The Formwall Dimension Series has an R value of 20, so a wall system in Energy 10 resembling an R20 value was used. Keeping the windows the same I isolated the walls to see how much annual savings you could have.

When starting with Energy 10, I first put information into the ***New Project Information*** **(Fig 4)** box, which would closely match my building, into the system. Most of my original suggestions when importing information came from Andy Lau, who was well informed on how

Energy is to be used. I was suggested to break up my top floor into two zones, zone 1 the perimeter of the building 20' from the outside and zone 2, the remaining interior. This included:

- Location: Sterling, Virginia
- Utility Rates: (given by Tishman Speyer)

  Elec. Rate: 0.35 $/kWh

  Elec. Demand: 0.30 S/kW

  Fuel Cost: 0.00 $/Therm
- Zone 1 (perimeter):

  Building Use: Office

  HVAC System: VAV DX Cooling w/ Gas HW reheat

  Floor Area: 11,840 ft^2

  # of Stories: 1
- Zone 2 (interior):

  Building Use: Office

  HVAC System: VAV DX Cooling w/ Gas HW reheat

  Floor Area: 14221.8 ft^2

  # of Stories: 1
- Aspect Ratio: Long/Short side –> 214.5/121.5 = 1.765

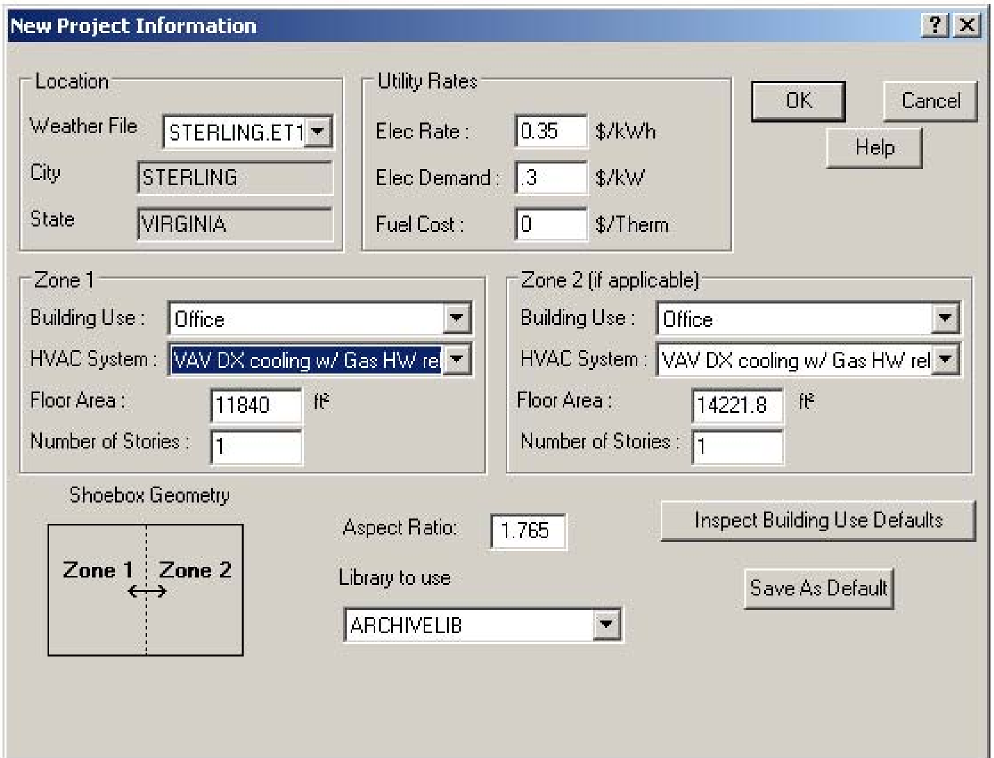


Fig 4

The next box was the ***Provisional Data for Bldg-1 – Zone 1 (perimeter)*** **(Fig 5)**. Information added in this box included:

- Gross Dimensions:

  North, South Facades:

  Length and Height 214.5' x 12.5'

  East, West Facades:

  Length and Height 121.5' x 12.5'

  Ceiling Area: 11,840 ft^2

- Construction:

  Roof Construction: flat, r-19 (was closest to drawings, r-18)

  Wall Construction: Concrete (due to precast panels)

  Floor Construction: Slab

- Windows (Number and Type):

    When trying to create my own windows later in the process, the simulations did not seem to run a without an error. So I took the square foot area of the 1" thick thermalite insulated low e and the ¼" reflective spandrel glass and added them up to get a total area of glass. Then I set it equal to a 6' x 6' double, low e window in the program, for each façade coming up with:

    North: 43 windows

    East: 20 windows

    South: 37 windows

    West: 22 windows

- Occupancy:

    Number of People: 114 (when added to Zone 2 will equal 250 total, from drawings)

    Open: 5 days

    Lighting: 2 W/ft^2 (given by Tishman Speyer)

- Thermostat:

    Set Point Heating: 72^o and Cooling 75^o

    Schedule: 8 to 5

- Recommended to put Ducts Inside

- Rotated Building 30 degrees to match site placement of building 1

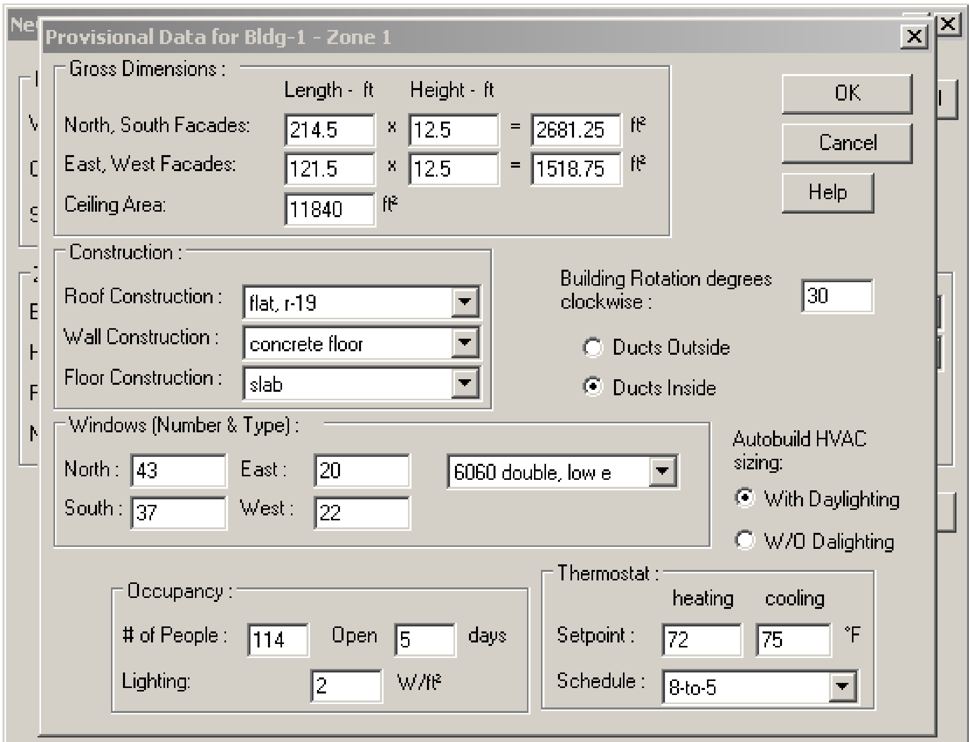


Fig 5

The next box was the ***Provisional Data for Bldg-1 – Zone 2 (Interior)*** **(Fig 6)**. Information added in this box included:

- Gross Dimensions:

  North, South Facades:

  Length and Height 174.5' x 12.5'

  East, West Facades:

  Length and Height 81.5' x 12.5'

  Ceiling Area: 14,221.8 ft^2

- Construction:

  Roof Construction: flat, r-19 (was closest to drawings, r-18)

  Wall Construction: r1000 (no walls in interior zone)

Floor Construction: Slab

- Windows (Number and Type):

  Zero windows for each face

- Occupancy:

  Number of People: 136 (when added to Zone 1 will equal 250 total, from drawings)

  Open: 5 days

  Lighting: 2 W/ft^2 (given by Tishman Speyer)

- Thermostat:

  Set Point Heating: 72^o and Cooling 75^o

  Schedule: 8 to 5

- Recommended to put Ducts Inside

- Rotated Building 30 degrees to match site placement of building 1

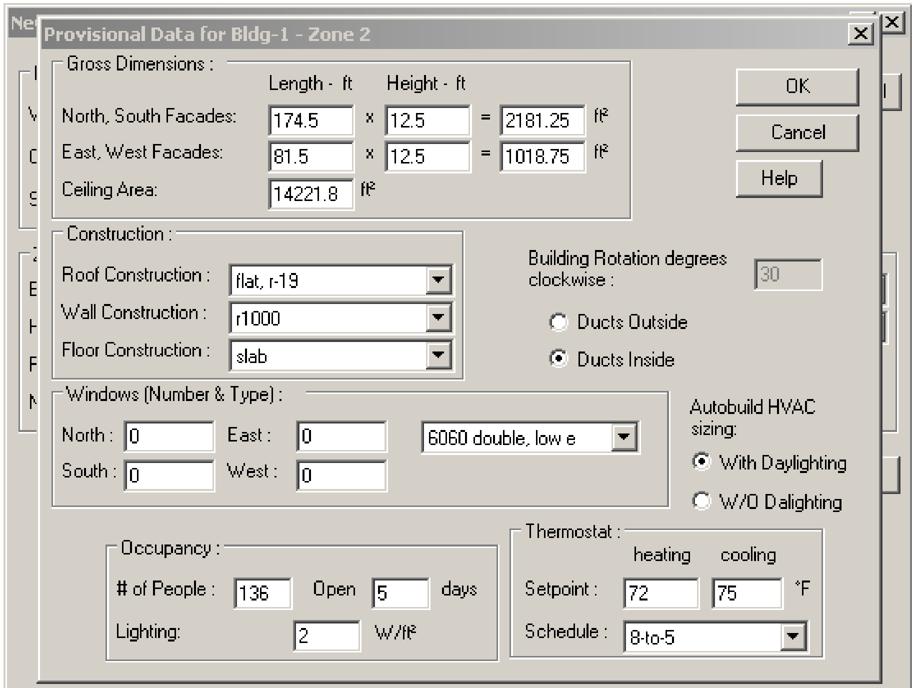


Fig 6

After this initial data is placed into Energy 10 you can begin to further detail your building by going into the buildings menu and choosing building 1(**Fig 7**). This menu allows you to change walls, roofs, floors, partitions infiltration, HVAC systems, HVAC Controls, Internal Gains, and Lighting Zones. Leaving everything to default you can go into the Walls and roof button and change your windows and roofs, and window area.

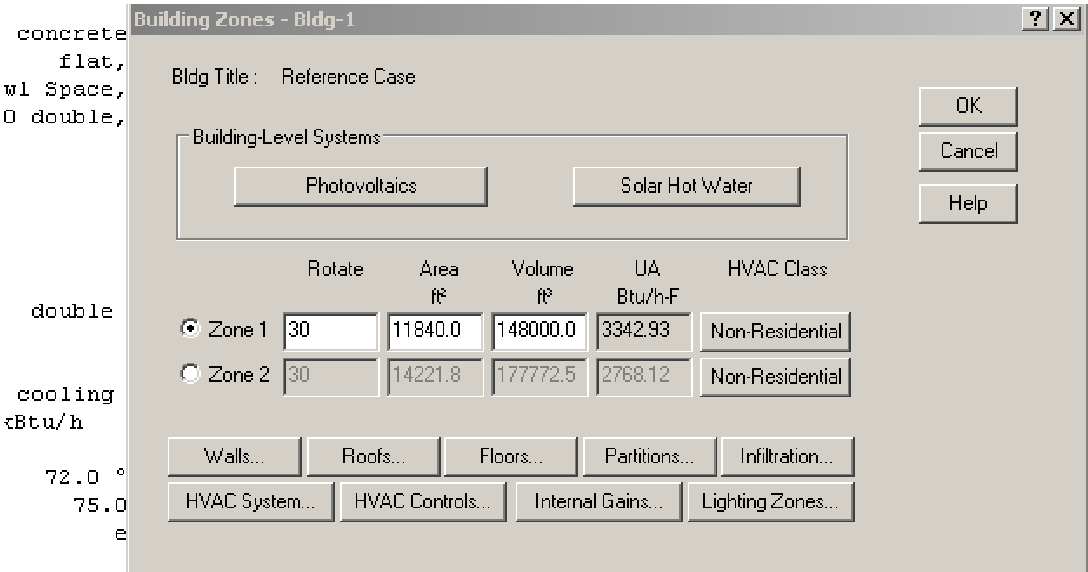


Fig 7

Clicking on the Walls button of **Fig 7** you are brought to another menu, where changing your wall types becomes more detailed. You click on the little folder next to the name of one of your facades and it brings you to **Fig 8**. I created my own wall type for each façade called *arch conc panel*. This "wall" gave me an R Value of 10, which is exactly what the wall was said to have in the drawings. I only used one type of wall cross section at 100% because the precast panels are all we are looking at. After changing the name and information you can click on the "*New"* button and this will now be an option for all the other walls as seen on **Fig 9**.

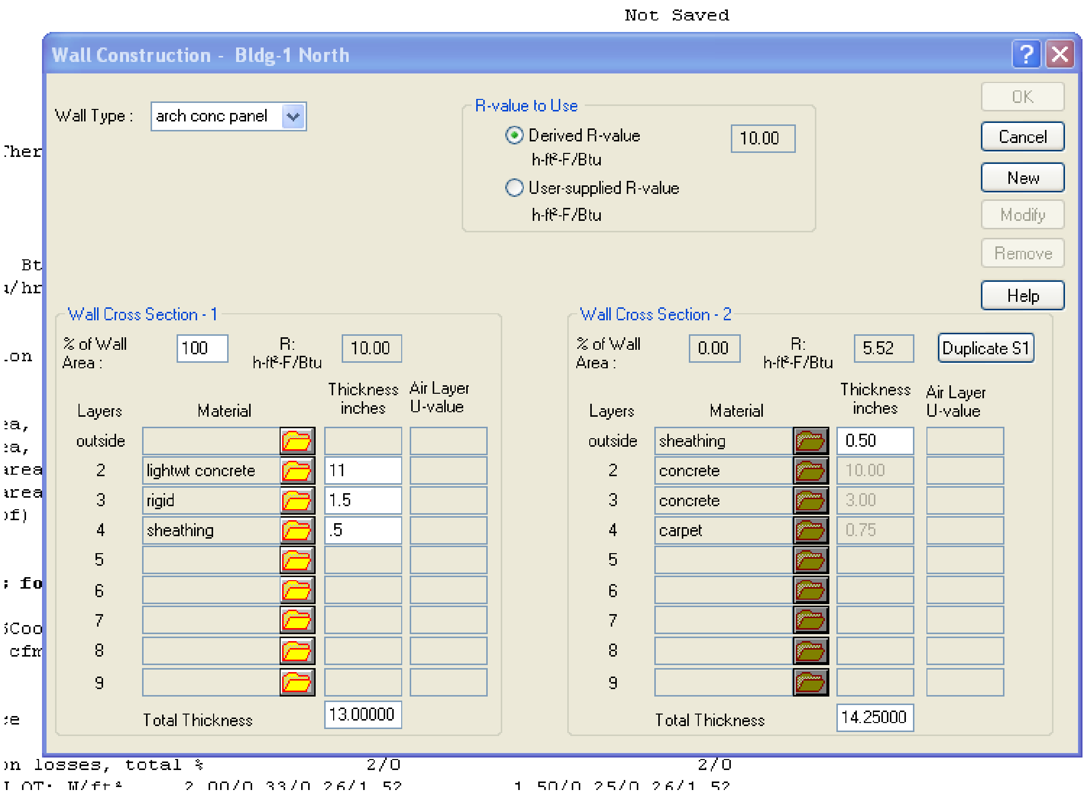

Not Saved
Wall Construction - Bldg-1 North
Wall Type : arch conc panel
R-value to Use
Derived R-value 10.00 h-ft²-F/Btu
User-supplied R-value h-ft²-F/Btu
OK
Cancel
New
Modify
Remove
Help
Wall Cross Section - 1
% of Wall Area : 100
R: h-ft²-F/Btu 10.00
Layers Material Thickness inches Air Layer U-value
outside
2 lightwt concrete 11
3 rigid 1.5
4 sheathing .5
5
6
7
8
9
Total Thickness 13.00000
Wall Cross Section - 2
% of Wall Area : 0.00
R: h-ft²-F/Btu 5.52
Duplicate S1
Layers Material Thickness inches Air Layer U-value
outside sheathing 0.50
2 concrete 10.00
3 concrete 3.00
4 carpet 0.75
5
6
7
8
9
Total Thickness 14.25000

Fig 8

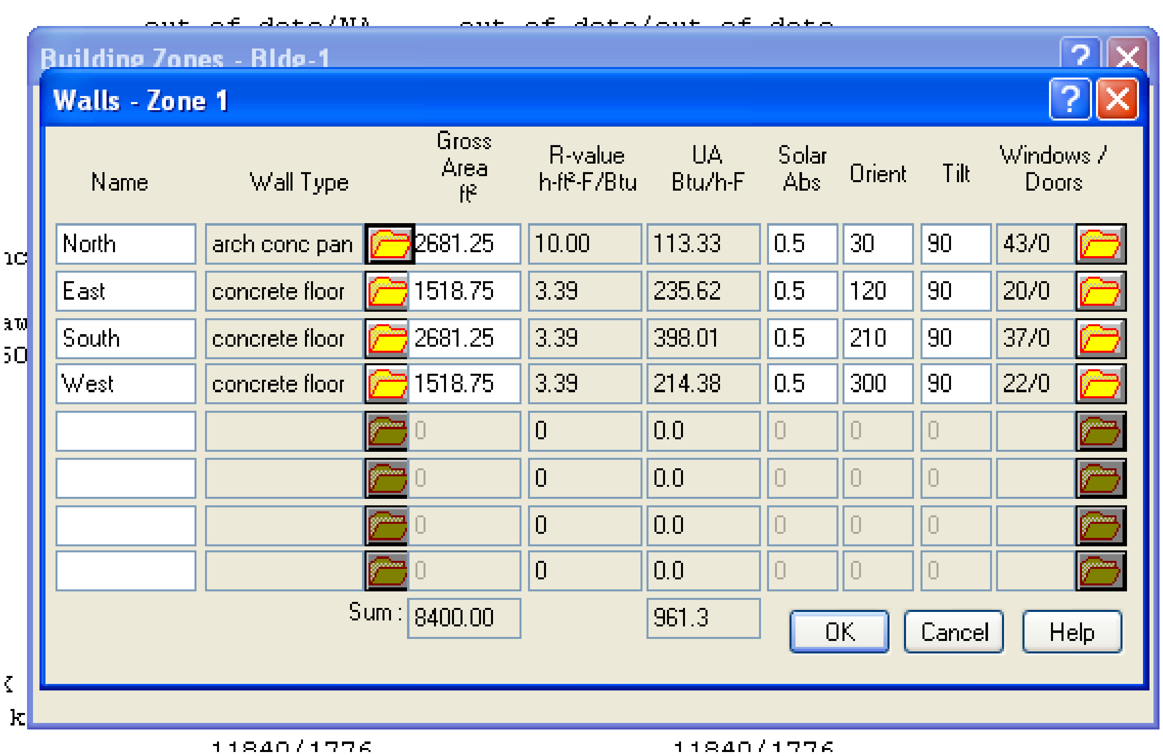

Building Zones - Bldg-1
Walls - Zone 1
Name Wall Type Gross Area ft² R-value h-ft²-F/Btu UA Btu/h-F Solar Abs Orient Tilt Windows / Doors
North arch conc pan 2681.25 10.00 113.33 0.5 30 90 43/0
East concrete floor 1518.75 3.39 235.62 0.5 120 90 20/0
South concrete floor 2681.25 3.39 398.01 0.5 210 90 37/0
West concrete floor 1518.75 3.39 214.38 0.5 300 90 22/0
Sum : 8400.00 961.3
OK
Cancel
Help

Fig 9

After putting in all your information for building 1 you click on the Buildings button from the menu and copy building 1 to building 2. This will make sure you have exactly two of the same buildings. Then going back into building 2 you can change your façade panels to a different R Value and run a simulation to find your energy savings. So going into building 2 and clicking on the walls button again, I changed the R Value to match that of the Versawall and the Dimension Series panels, R-30 and R-20. To simulate an annual energy usage and annual utility cost you simply select *"Misc"* from the menu and select *"Simulate…"*(**Fig 10**). After this another box will appear and you click "ok". The first window you see is the Annual Energy Use graph, building 1 in red and building 2 in green (**Fig 11 & 12**).

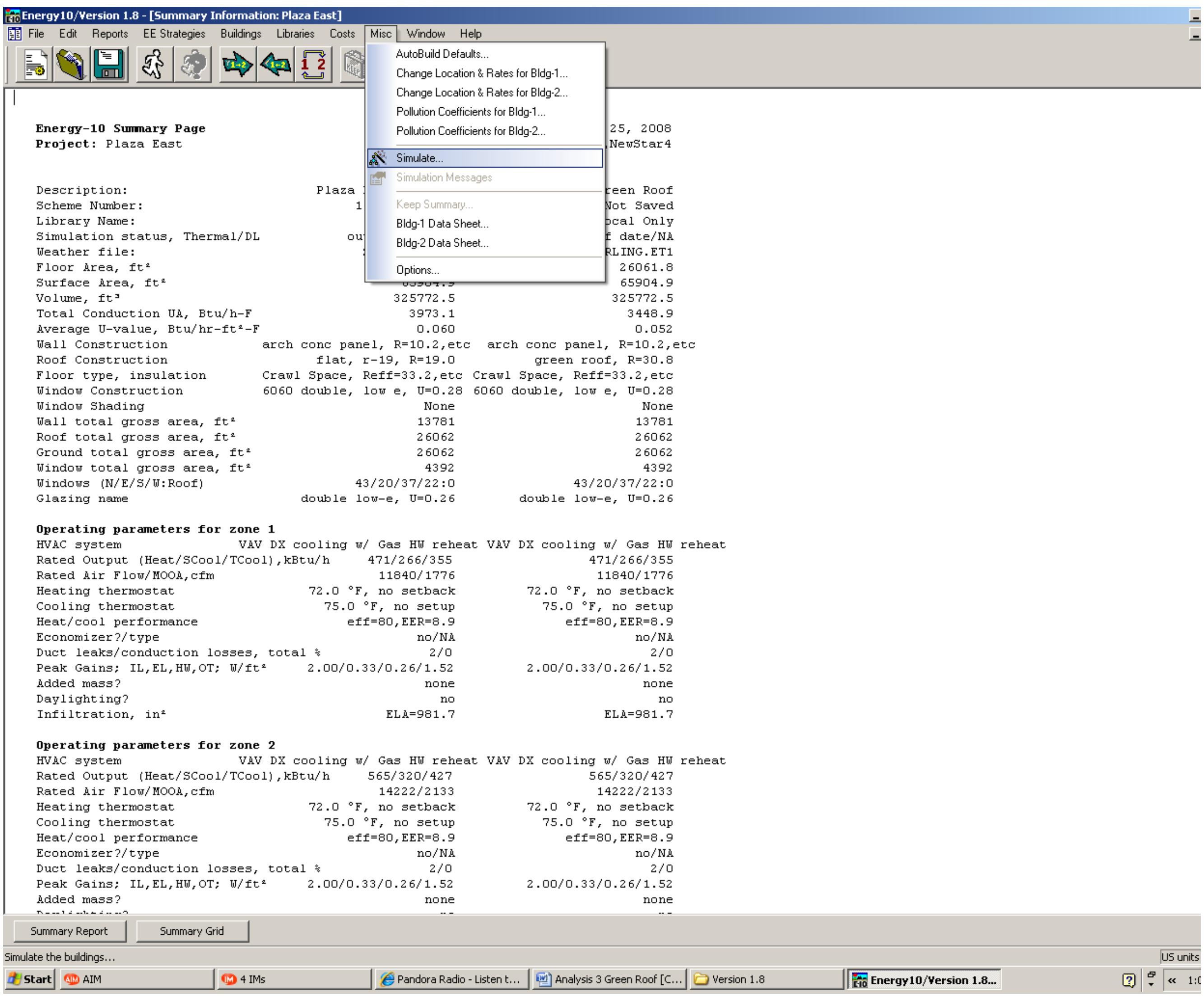


Fig 10

Be reminded the calculations will only be for the top floor because Energy 10 tends to not simulate correctly when given too large of an area to calculate. The answer given was still recommended to be a close comparison to a percentage for the whole building considering each floor is fairly similar. After finding the answers you would also have to multiply by two, considering Plaza East is two separate buildings.

Conclusion:

The results of energy saved per year from Versawall were (**Fig 11**): 1.6 kBtu/ft^2 Heating, -0.3 kBtu/ft2 Cooling, -0.1 kBtu/ft^2 Other, and a total of 1.1 kBtu/ft^2. The Annual Energy Costs savings were very minor at $0.012/ft^2. The results of energy saved per year from Dimension Series were (**Fig 12**): 1.90 kBtu/ft^2 Heating, -0.1 kBtu/ft^2 Cooling, and a total of 1.8 kBtu/ft^2. The Annual Energy Costs were also very minor at $0.041/ft^2. Multiplying by two wouldn't give that much more energy savings, considering the low numbers found. Even though a strict rate could not be given on how much quicker the erection time could be, it was still said to be higher than precast. This in turn saves time and money for the project. The LEED points also given to the new materials are also a positive addition to the new façade.

With these results the new façade does not affect much energy use or cost savings, but the money saved on material and assembly could be a good reason to look into the material for this project or the next project. In addition, one should also take note the material does have some durability, but possibly not as much as precast would have, which Tishman Speyer usually looks for. Further investigation will be put into combining each new façade's energy savings results with the new green roof energy savings results in Analysis 2.

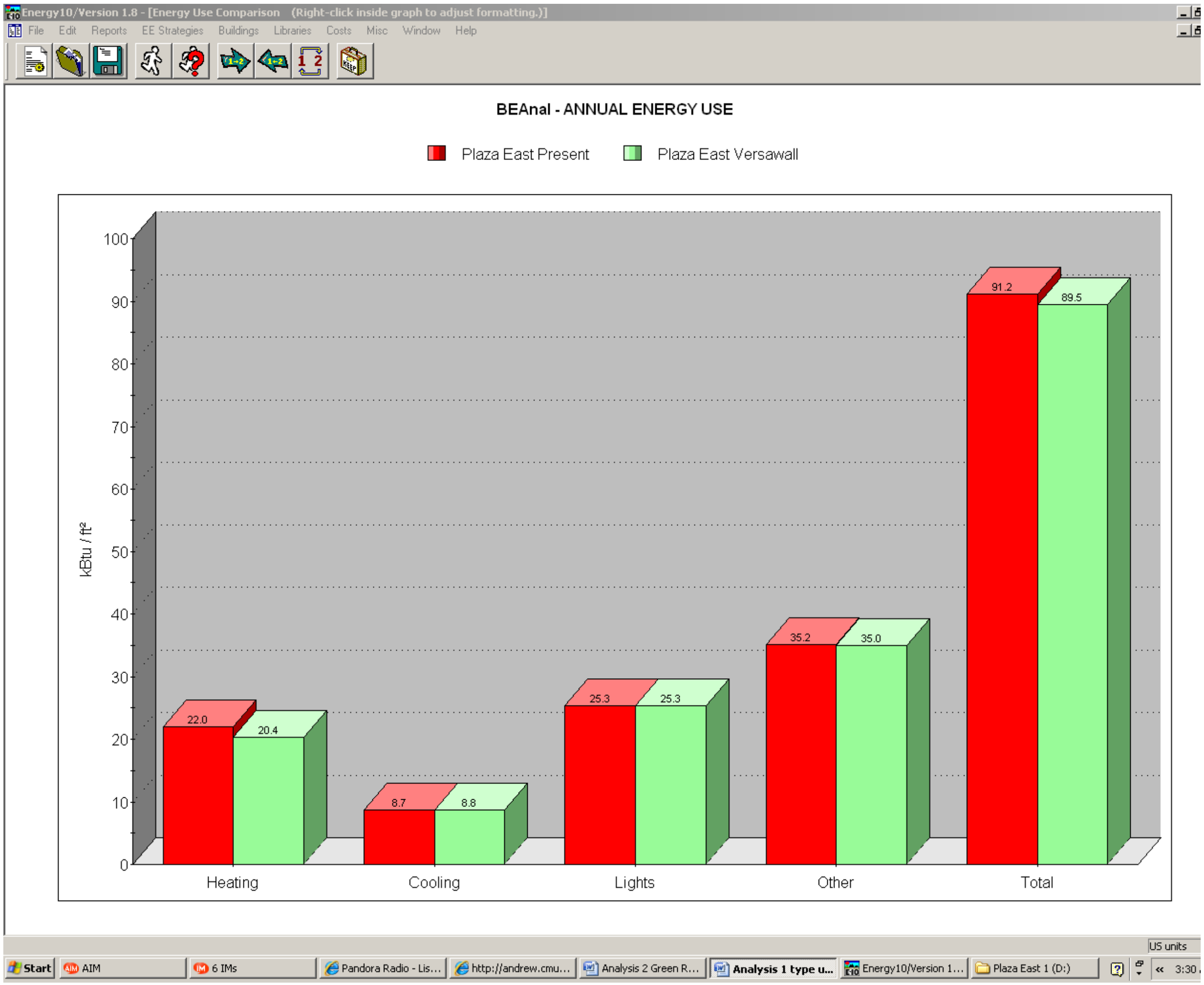

Energy10/Version 1.8 - [Energy Use Comparison (Right-click inside graph to adjust formatting.)]
File Edit Reports EE Strategies Buildings Libraries Costs Misc Window Help
BEAnal - ANNUAL ENERGY USE
Plaza East Present
Plaza East Versawall
kBtu / ft²
100
90
80
70
60
50
40
30
20
10
0
22.0
20.4
8.7
8.8
25.3
25.3
35.2
35.0
91.2
89.5
Heating
Cooling
Lights
Other
Total
US units
Start
AIM
6 IMs
Pandora Radio - Lis...
http://andrew.cmu...
Analysis 2 Green R...
Analysis 1 type u...
Energy10/Version 1...
Plaza East 1 (D:)
3:30

Fig 11

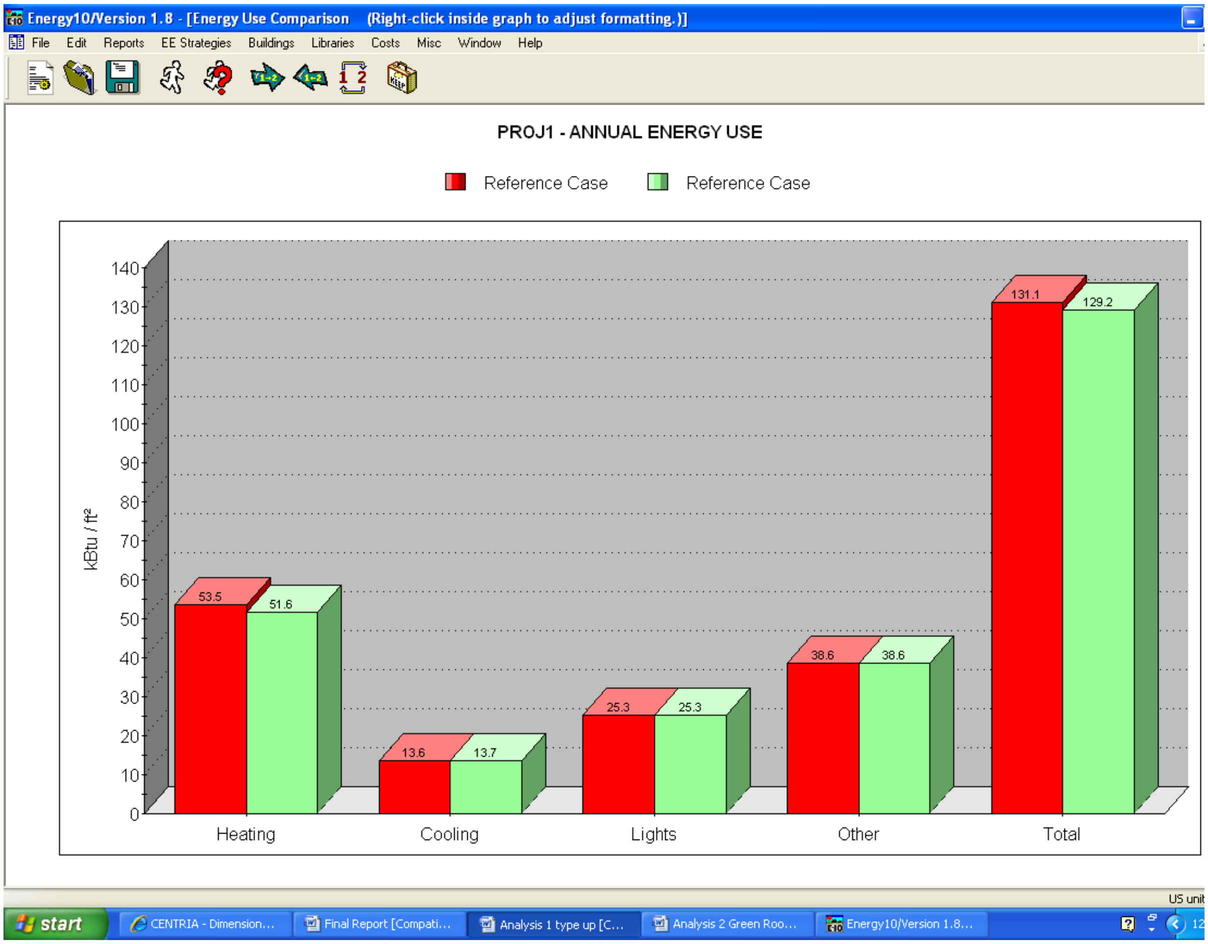


Fig 12

Analysis 2: Green Roof Implementation

Issue 2:

The roof is a regular built up roof with no general real problem, but with a green roof replacement, Plaza East could benefit in many ways.

Analysis:

Green roofs will be researched to be in place of the current built up roof. Adding a green roof to a project can have multiple advantages. It is expected to cost more than the original roof designed for Plaza East, but the cost savings, in the long run, could be much better. With a green roof you can have a higher LEED accreditation, reduced energy costs, and extended roof life. A new structural system was planning on being designed for the building, making it easier to add the additional loads a green roof entails.

Expectations:

After the analysis of the first cost and time saving issues, the money and time saved will be put forth to pay for the green roof addition to the building. With the green roof the initial cost will be higher, but money is expected to be saved in the future from the green roof's long life capabilities.

Outcome:

A green roof consists of living vegetation installed atop of a building. With the application of green roofs, many advantages can be gained including: storm water runoff reduction, improvement of air quality, sound absorbing and insulating properties, increase life expectancy of rooftop waterproofing, reduce urban heat island effect, increase habitat for birds and butterflies, provide attractive views for other people, and insulating a building reducing heating and cooling costs.

With a green roof addition to Plaza East, they can help manage the storm water by mimicking a variety of hydrologic processes normally associated with open space. Plants absorb the water into their roots and promote evapotranspiration allowing them to prevent much storm water from leaving the roof and entering the runoff stream. With this effect, green roofs greatly reduce the risk of flooding, sewer overflows, and subsequent discharges. Water does not run off these roofs until the entire roof is saturated, which happens hours after peak flow for a storm. For short duration storms, green roofs have been shown to reduce cumulative annual runoff by 50%. GreenGrid's Intensive (8-inch) system retained 93% of a 1-inch rainfall that occurred in 15 minute intervals and its Extensive (4-inch) system retained 72%. With Plaza East having such a large parking lot, this aspect can help manage a costly retention and detention system for Plaza East. It can also give some habitat back to the birds and other animals that were taken from the area.

Green roofs can help with noise reduction and tests have been shown to reduce indoor noise pollution from outdoor contributors by 10 decibels. Plaza East is not in a very noise impacted area, well at least not for the time being. As time goes on the area should begin to grow and when it does the noise levels are sure to increase. Having a green roof could be a good way to prepare for that.

The roof of Plaza East is very simple built-up roof and changing to a green roof can increase its life expectancy. This is based on the fact that the roof membrane is protected from ultraviolet radiation, extreme temperature fluctuations, ozone, punctures and other physical damage. Built up roofs can average around 20 to 25 years for life expectancy. Green roofs can have the life expectancy up to or more than 40 years, however green roofs in Berlin have shown to protect roofs up to 100years.

The urban heat island effect comes from roads and building rooftops absorbing heat during daylight hours and then radiating it back into the atmosphere causing further warming. This effect has been shown to actually change weather patterns in some large cities. For some of these large cities the factors can result in a 6 to 10 degree temperature difference. Green roofs help lower this effect and because urban area in DC and Virginia is only growing, it is a good idea to get as many green roofs built as possible. Covering dark conventional roofs with green roofs can significantly reduce the temperature above the roof. Green roofs have been shown to out-perform white or reflective roof surfaces in reducing the ambient air temperature. If sufficient urban surfaces are covered, this cooling (and attendant improvement of air quality) can have significant positive effects on human health, especially for the young and elderly in congested urban areas.

Green roofs do not only look nice but are very energy efficient. They can increase the value of condominiums, apartment complexes, office buildings, as well as help save money through heating and cooling costs. A traditional black rooftop can reach up to 180^{o}F when the outside air temperature reaches 80^{o}F. This has a drastic effect on the energy used to cool the building. The additional layers of the green roof help mediate the extreme temperature differences; annually from 212^{o}F to 95^{o}F and daily from 140^{o}F to 59^{o}F. Green roofs have been shown to reduce the heating and cooling costs from 25% to 50% for the floor directly below the roof and can also slow down a buildings heat gain or loss.

Energy demands have been threatening the power supply of our country and the world. With the oil prices doing nothing but rising, the industry must look into better ways for sustainability and green roofs are an easy fix to help with that. Governments are giving cities different incentives to increase sustainability for their building. Some include financial, technical, educational incentives along with tax credits and avoidance of fees assessed for impervious surface cover.

For my analysis I will use Energy 10 software, the same software used for the building envelope energy analysis, to show a few benefits that can be seen by using a green roof. It was recommended I just try and simulate the top floor space because Energy 10 was used for smaller scale projects and a green roof is said to predominately affect the top floor. How the building information was put into the program can be seen in **Analysis 1: Building Envelope Investigation**.

After **Fig 4** from the Building Envelope Investigation some of the steps change. Looking at the drawings I saw R values for the roof and the façade. Stated before, I calculated the average window area for each side of the building faces and used an amount of an existing window in the Energy 10 library that closely resembled that number. I used the same method for the architectural concrete panels to come up with an R value of 10 for the walls and R value of 18 to 19 for the roof, as seen on the drawings. After detailing building 1, be sure to enter into the building pull down menu again and copy building 1 to building 2. After this is done I shall change the roof R-values and solar absorption values to resemble a green roofs values; changing solar absorption from .6 to .2 as recommended. Changing the R-value was much more difficult. I used the cross section below (**Fig 13**) to construct a layered roof in Energy 10. The resulting R-Value being 30.75.

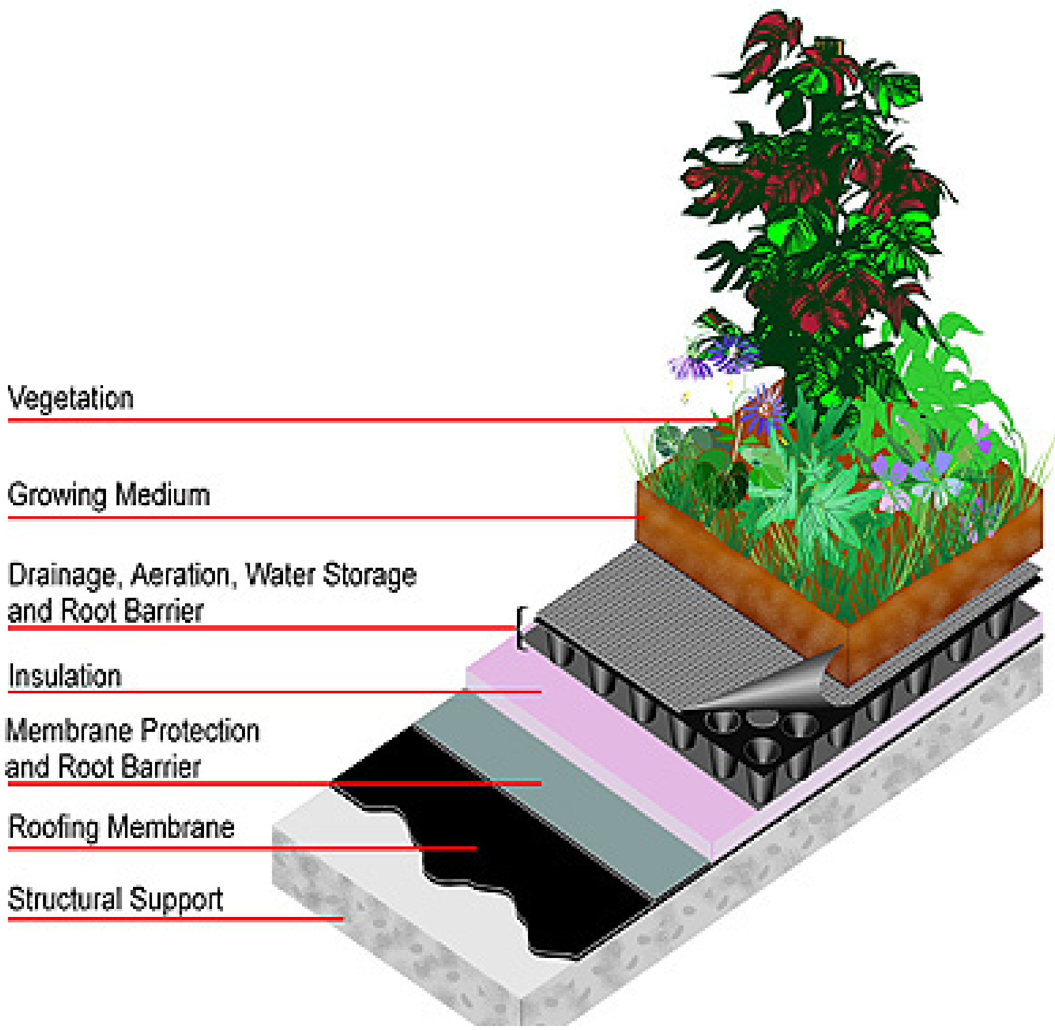


Fig 13

Then leaving everything else at default for both simulated buildings you can run the simulation. To run the energy simulation you simply click on the Misc window and then simulate (**Fig 14**). After this another box will appear and you click "ok". The first window you see is the Annual Energy Use graph, building 1 in red and building 2 in green (**Fig 15**). As seen 4.5 kBtu/ft^2 in heating, 0.1 kBtu/ft^2 in cooling, and 0.2 kBtu/ft^2 in the category "Other" is saved over a year.

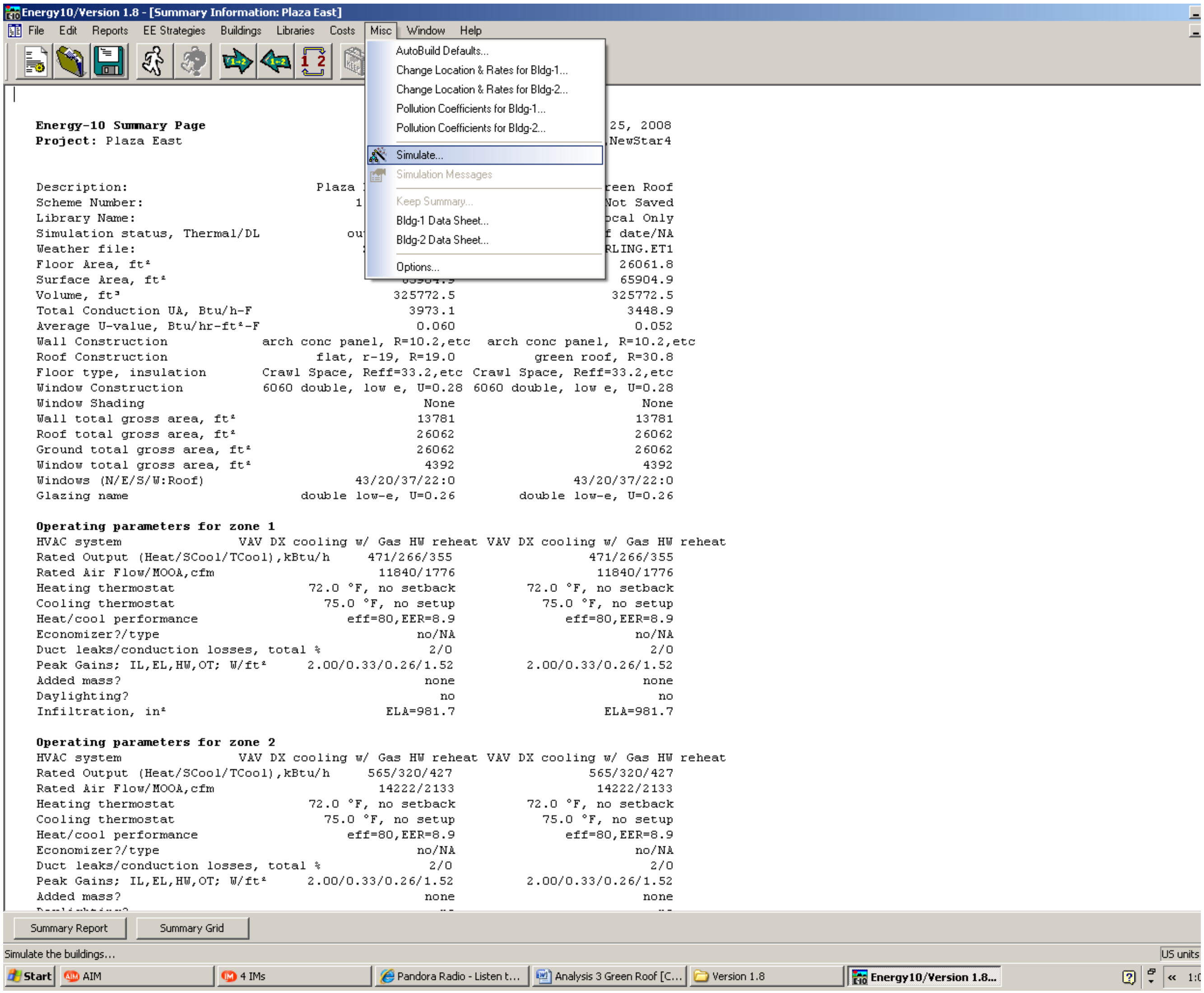

Energy10/Version 1.8 - [Summary Information: Plaza East]
File Edit Reports EE Strategies Buildings Libraries Costs Misc Window Help
AutoBuild Defaults...
Change Location & Rates for Bldg-1...
Change Location & Rates for Bldg-2...
Pollution Coefficients for Bldg-1...
Pollution Coefficients for Bldg-2...
Simulate...
Simulation Messages
Keep Summary...
Bldg-1 Data Sheet...
Bldg-2 Data Sheet...
Options...
Energy-10 Summary Page
Project: Plaza East
25, 2008
NewStar4
Description: Plaza
een Roof
Scheme Number: 1
Not Saved
Library Name:
ocal Only
Simulation status, Thermal/DL
f date/NA
Weather file:
RLING.ET1
Floor Area, ft² 26061.8
Surface Area, ft² 65904.9
Volume, ft³ 325772.5 325772.5
Total Conduction UA, Btu/h-F 3973.1 3448.9
Average U-value, Btu/hr-ft²-F 0.060 0.052
Wall Construction arch conc panel, R=10.2,etc arch conc panel, R=10.2,etc
Roof Construction flat, r-19, R=19.0 green roof, R=30.8
Floor type, insulation Crawl Space, Reff=33.2,etc Crawl Space, Reff=33.2,etc
Window Construction 6060 double, low e, U=0.28 6060 double, low e, U=0.28
Window Shading None None
Wall total gross area, ft² 13781 13781
Roof total gross area, ft² 26062 26062
Ground total gross area, ft² 26062 26062
Window total gross area, ft² 4392 4392
Windows (N/E/S/W:Roof) 43/20/37/22:0 43/20/37/22:0
Glazing name double low-e, U=0.26 double low-e, U=0.26
Operating parameters for zone 1
HVAC system VAV DX cooling w/ Gas HW reheat VAV DX cooling w/ Gas HW reheat
Rated Output (Heat/SCool/TCool),kBtu/h 471/266/355 471/266/355
Rated Air Flow/MOOA,cfm 11840/1776 11840/1776
Heating thermostat 72.0 °F, no setback 72.0 °F, no setback
Cooling thermostat 75.0 °F, no setup 75.0 °F, no setup
Heat/cool performance eff=80,EER=8.9 eff=80,EER=8.9
Economizer?/type no/NA no/NA
Duct leaks/conduction losses, total % 2/0 2/0
Peak Gains; IL,EL,HW,OT; W/ft² 2.00/0.33/0.26/1.52 2.00/0.33/0.26/1.52
Added mass? none none
Daylighting? no no
Infiltration, in² ELA=981.7 ELA=981.7
Operating parameters for zone 2
HVAC system VAV DX cooling w/ Gas HW reheat VAV DX cooling w/ Gas HW reheat
Rated Output (Heat/SCool/TCool),kBtu/h 565/320/427 565/320/427
Rated Air Flow/MOOA,cfm 14222/2133 14222/2133
Heating thermostat 72.0 °F, no setback 72.0 °F, no setback
Cooling thermostat 75.0 °F, no setup 75.0 °F, no setup
Heat/cool performance eff=80,EER=8.9 eff=80,EER=8.9
Economizer?/type no/NA no/NA
Duct leaks/conduction losses, total % 2/0 2/0
Peak Gains; IL,EL,HW,OT; W/ft² 2.00/0.33/0.26/1.52 2.00/0.33/0.26/1.52
Added mass? none none
Summary Report
Summary Grid
Simulate the buildings...
US units
Start
AIM
4 IMs
Pandora Radio - Listen t...
Analysis 3 Green Roof [C...
Version 1.8
Energy10/Version 1.8...

Fig 14

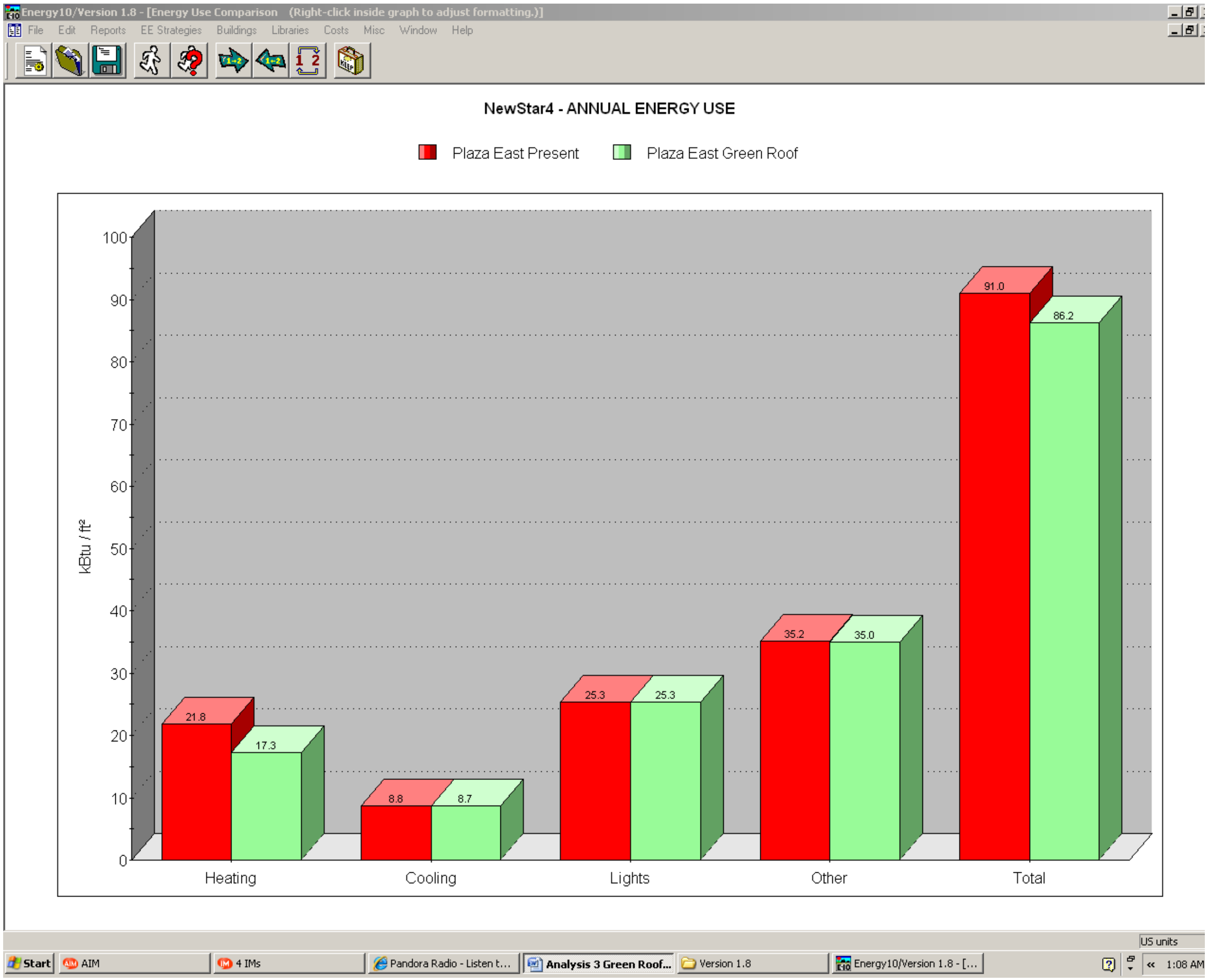


Fig 15

Multiple other graphs can be seen from the Reports and Comparative Graphs menus. As seen from the results the green roof did not save as much on energy usage or energy cost as I anticipated. Tishman Speyer representative told me the original roof was $9 per square foot, when adding a green roof each value per square foot would increase up $8 to $12 per square foot (taken from Jay Britton, Project Manager of Prospect Waterproofing Company). Saving a total energy use of 4.8 kBtu/ft^2 and energy cost of 0.003 \$/ft^2 accompanied with price shows the benefits do not outweigh the work involved with adding a green roof.

Original Roof: $\$9/ft^2 \times 26000\ ft^2 = \$234000$

Green Roof Best Case Scenario: $\$17/ft^2 \times 26000\ ft^2 - \$0.003/ft^2 \times 26000 = \$441220$

No Good!

Years needed to make money back: $441220 - $234000 = $207220 / $780 per year = 265 years and 8 months No Good!

Conclusion:

With the green roof alone or when included with a different building envelope, the energy usage savings and cost are not very significant. If the owner would like to go strictly with cost savings there seems to be no real reason to switch to a green roof for this project. But as listed before in the analysis, the green roof has many other attributes that go outside of energy usage savings and costs.

After noticing that neither the new envelope panels nor the green roof saved much energy individually, I've decided to go back into Energy 10 and apply both at the same time. If a green roof and a new façade were combined it may show a significant difference in energy savings and energy utility costs. The results of energy saved per year from using a Versawall and a Green Roof are seen in (**Fig 16 & Table 5**). The results of energy saved per year from using the Dimension Series panels and a Green Roof equaled (**Fig 17 & Table 5**).

Energy Savings from Façade and Green Roof vs Existing (kBtu/sqf)					
	Heating	Cooling	Other1	Total Energy Savings	Total Cost Savings ($/sqf)
Versawall and Green Roof	5.9	-0.2	0.3	6.0	$0.015
Dimension Series and Green Roof	6.2	-0.1	0.3	6.4	$0.028

Table 5

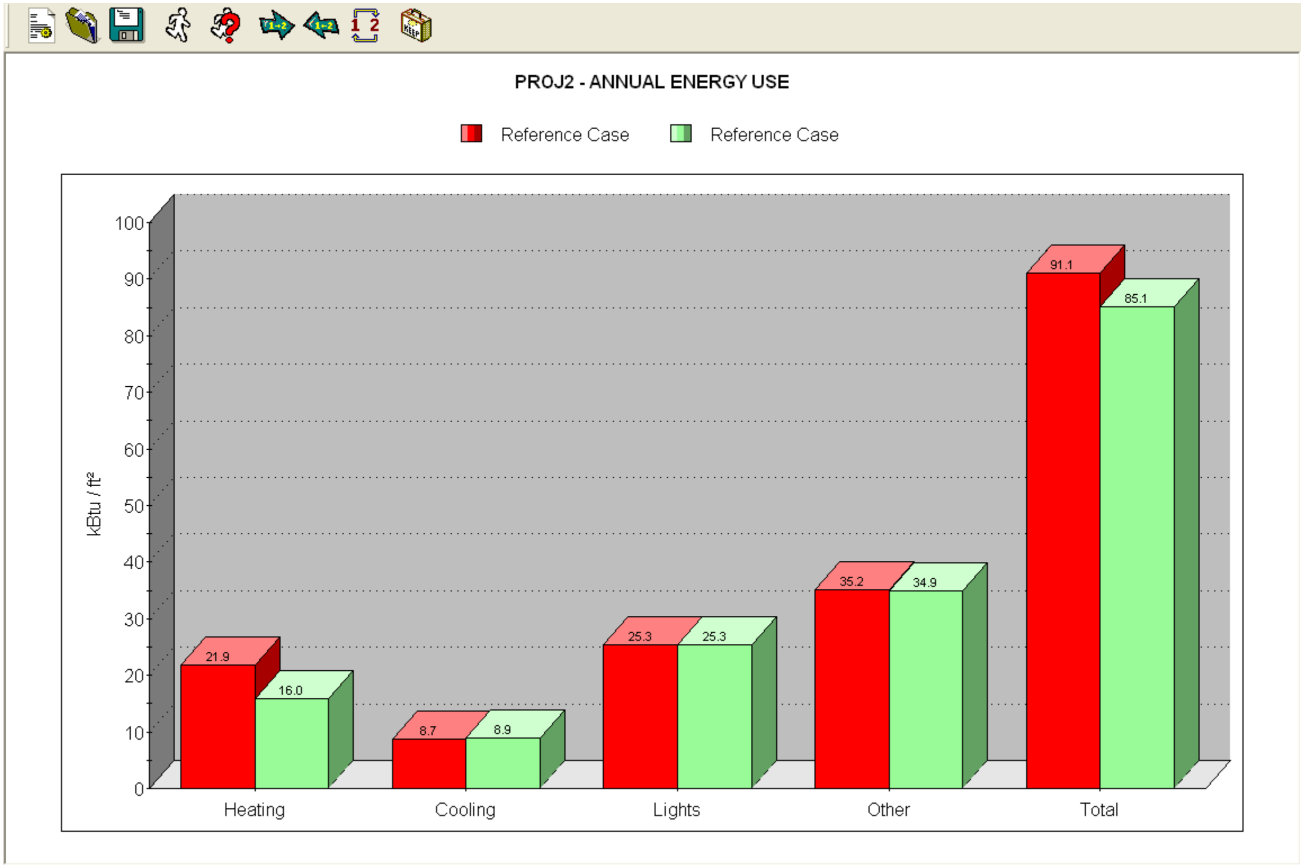

PROJ2 - ANNUAL ENERGY USE
Reference Case
Reference Case
kBtu / ft²
100
90
80
70
60
50
40
30
20
10
0
21.9
16.0
8.7
8.9
25.3
25.3
35.2
34.9
91.1
85.1
Heating
Cooling
Lights
Other
Total

Fig 16

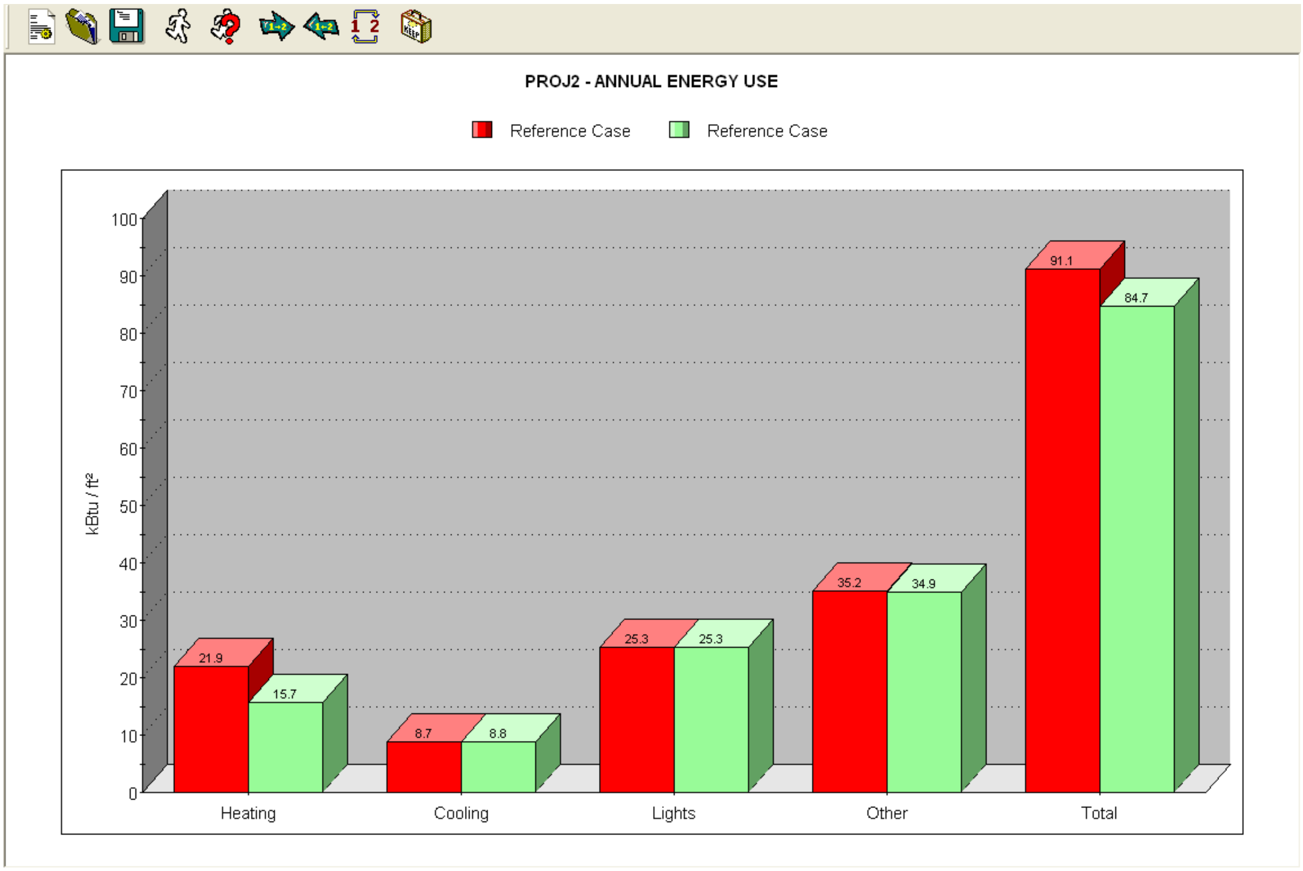

PROJ2 - ANNUAL ENERGY USE
Reference Case
Reference Case
kBtu / ft²
100
90
80
70
60
50
40
30
20
10
0
21.9
15.7
8.7
8.8
25.3
25.3
35.2
34.9
91.1
84.7
Heating
Cooling
Lights
Other
Total

Fig 17

Analysis 3: Structural Analysis (Breadth)

Issue 3:

The new green roof that is to be implemented will add an additional dead load to the roof. A structural analysis must be made to be sure the roof can handle the new load, or if more reinforcement or concrete is needed. The original analysis was to see if steel would have been a better choice for the superstructure than cast-in-place concrete. After speaking to some advisors and having the 3D model unusable, a new analysis was put together. Also further investigation is to be put into the perimeter beams and post tension girders, because of the new structural loads to the building.

Analysis:

The original proposal was to be: By using steel instead of cast-in-place concrete more of the steel pieces will be able to be fabricated before brought to the site; this will ensure a faster erection time. After changing the building envelope, the building will have a lesser load on the entire structure. With that information, smaller columns and beams can be used to support the entire building. This can affect the size of the crane, which in turn can save money. Research will be put into the cost of steel erection compared to the cast-in-place concrete used. BIM was going to be incorporated in the structural design of the steel frame in order to show BIM's value engineering and work sequencing abilities.

Expectations:

Original expectations were: After constructing a BIM superstructure of Plaza East, the software will be used for take offs and work sequencing to show increases in savings. The money and time saved on the steel erection will be put to other aspects of the building. New expectations are to find out how much more rebar is to be placed in the roof slab to hold the new dead load of the green roof.

Outcome:

When trying to create a 3D model, my analysis has changed. I no longer had a chance to use my 3D model to test steel erection over concrete, because the analysis was too big for a breadth. I also spoke with Dale Kopnitsky from Gilbane about the idea of using steel in the Chantilly, VA area. Mr. Kopnitsky basically told me concrete was the material for the job. He explained this to me with the following information. Some believe steel could possibly be better than concrete because of the erection time, but I was told different. With steel, the skeleton would be up quicker but you would still have to fire proof and poor the slab before MEP, which ends up having the MEP for concrete and steel starting around the same time. The fire proofing spray also ends up being about $2.25/ft^2, concrete does not use any. With steel, the deeper members end up having bigger floor heights, further more increasing costs. You would need to add at least a foot per floor, which would add about 5 feet to the exterior of the building, increasing the price of the building envelope, interior partitions, and piping. Also using concrete you tend to get an extra floor, than when using steel. This is nice for the DC area where no buildings can be taller than the capital. Mr. Kopnitsky went on saying the deflection is greater in the slab, even if the slab is cambered. This would then have the need for a self leveling agent. Mr. Kopnitsky said another advantage is that all engineers are trained to use concrete frames.

The new structural breadth will be to ensure the green roof, that is to be applied to the building, will be able to be held up by the original roof or if additional reinforcement or concrete is needed. I've come to two separate types of green roofs and plan on doing a calculation on an extensive sedum and herbs (3" think) or sedum, herbs, and perennials (5" thick). Each will be using drainage plates instead of granular drainage or drainage mats. A slab calculation will be done to see if the current 5 ½" slab will hold or if there is a need to have more reinforcement and if the slab needed to be increased up to the 7" slab equal to the rest of the floors or if .

Plans to contact the structural engineer of Plaza East have been made to further investigate what should or could be done on the perimeter concrete beams and the post tension girders to see what actions are usually taken when the building envelope load is reduced and the roof load is increased. No help was given from the structural engineer from Plaza East, but a few general suggestions were given to me from Richard Apple, P. E. and Vice President of Holbert Apple Associates, Inc.

After seeing the post tension girders schedule I developed a few questions for Mr. Apple. He is not completely clear with the building design so his answers were general for all post tensioning buildings. Looking at the schedule I saw Force (Kips) and a tendon profile section with A, B, and C positions on it (**Fig 18**). Mr. Apple explained the force is usually given as the total effective post tension force that you want in the tendons after all losses. This can be equated to a total number of tendons by dividing by approximately 26.5k per tendon. For the two beams my slab calculations go across, this seems reasonable. My exterior post tension girder has 110 kips. Divided by 26.5 kips, this gives me 4.15 tendons, and the next interior girder has 530 kips divided by 26.5 kips which gives me exactly 20 tendons. The exterior also has rebar stated in the drawings to hold the extra 0.15 tendons needed. The tendon profiles A, B, and C was explained as positions measured from either the top or bottom of the post tension girder. Profile A can be the end of the member, which usually has the tendons anchored at the center of gravity of the member cross section. Profile B could be the low point of the tendons at the mid-span and profile C could be the tendon high point at the supports.

BUILDING 2							
MARK	WIDTH	DEPTH	FORCE (KIPS)	TENDON PROFILE			
				A	B	C	L.E.
PTTB1	24	12	110	7 1/8	3 1/2	9 7/8	36
PTTB2	24	12	110	9 7/8	4	7 1/8	---
PTTB3	24	12	110	7 1/8	4 1/2	9 7/8	36
PTTB4	24	12	110	9 7/8	5	9 7/8	---
PTTB5	24	12	110	9 7/8	3 1/2	7 1/8	---
PTTB6	24	12	110	9 7/8	5 1/2	9 7/8	---
PTTB7	48	19	500	11 7/8	2 1/8	16 7/8	87
PTTB8	48	19	500	16 7/8	12 1/2	16 7/8	97
PTTB9	48	19	500	16 7/8	2 1/8	11 7/8	---
PTTB10	48	19	530	11 7/8	2 1/8	16 7/8	97
PTTB11	48	19	530	16 7/8	12 1/2	16 7/8	107
PTTB12	48	19	530	16 7/8	2 1/8	11 7/8	---

Fig 18

Inquiring about how to increase the capacity for the green roof load, I was told to analyze the beams for their capacity as they are scheduled, so that I can determine the tension and compression stresses at the critical locations (midspan, at supports, etc.). The beam size may or may not be able to accommodate more post tensioning force to get additional capacity. The beam could end up having too high of compression forces for the cross section available, so an increase in either the depth of the beams, or an additional width may help if the net increase in loads are not very significant overall. Not much information was given about the perimeter beams and the new building envelope loads.

Typed out hand calculations for the roof slab is presented below:

Roof Loads

Live Load: 35 psf

Dead Loads: (150 pcf)(5 ½”/12”per ft) = 68.75 psf

Green Roof 37 psf

Snow Load: 27 psf

Total Load: 1.2(68.75+37) + 1.6(35) + 27 = 209.9 => 210psf

210 psf/1ft = 210 plf

Moments

At Exterior Support: $-M = 1/12\ (210)\ (20')^2 = 7{,}000$ ft-lb

At Mid-Span 1: $+M = 1/14\ (210)\ (20)^2 = 6{,}000$ ft-lb

At Interior Support: $-M = 1/12\ (210)\ (20')^2 = 7{,}000$ ft-lb

At Mid-Span 2: $+M = 1/16\ (210)\ (20)^2 = 6{,}250$ ft-lb

Area of Steel (A_s)

d = 5.5" – 0.75" = 4.75"

a = [(As)(f_y)] / [0.85(f'c)(b)]

Using a=1"

A_s = M_U / [ϕ(f_y)(d – a/2)] = [(7 kips)(12)] / [.9(60)(4.75 – 1/2)] = 0.366 in^2

Check a

a = [0.366(60)] / [0.85(3.5)(12)] = 0.615"

A_s at Exterior Support:

A_s = [(7 kips)(12)] / [.9(60)(4.75 – 0.615/2)] = 0.35 in^2

A_s at Mid Span 1:

A_s = [(6 kips)(12)] / [.9(60)(4.75 – 0.615/2)] = 0.30 in^2

A_s at Mid Span 2:

A_s = [(5.25 kips)(12)] / [.9(60)(4.75 – 0.615/2)] = 0.26 in^2

Minimal Reinforcement for Shrinkage & Temperature Cracking

A_s = (0.0018)(12")(5.5") = 0.12 in^2 < 0.35, 0.30, 0.26 in^2 GOOD

Minimal Reinforcement for Shrinkage & Temperature Cracking in Perpendicular Direction

Use #3 @ 10" = 0.13 in^2, 10" < Five times slab thickness & less than 18" GOOD

Existing Reinforcement: #4 @ 15"

A_s = #4 @ 15" = 0.20in^2(12"/15") = 0.16 in^2 < 0.35 in^2 NOT GOOD

New Reinforcement

For Ext. Support use: #4 @ 6" = 0.40 in^2 or #5 @ 10" = 0.37 in^2

For Mid Span 1 use: #4 @ 7 ½" = 0.31 in^2 or #5 @ 12" = 0.31 in^2

For Int. Support use same as Ext Support

For Mid Span 2 use: #3 @ 5" = 0.26 in^2 or #4 @ 9" = 0.26 in^2

Factor Shear @ d

$V_U = (1.15)(210)(20)/2 - (210)(4.75/2) = 2{,}332$ lb

$V_n = V_c = 2(f'c)^{0.5}(b)(d) = 2(3{,}500)^{0.5}(12)(4.75) = 6{,}744.33$ lb

$\phi V_c = 0.75(6{,}744.33) = 4{,}721$ lb $> V_U = 2{,}332$ lb GOOD

For hand calculations of the roof slab see Appendix D

Conclusion:

Using the new upgraded area of steel will let the roof slab hold the load. The cost will increase but only slightly. This extra cost is found in the next section with the conclusion to all three analyses.

Conclusions

Each analysis has had its own individual conclusions stated in each section, but when combining the conclusions you can see that the project can save money with the new façade in order to add a green roof. The energy and cost savings can be minor, but every little bit helps. With these new materials the building is much more environmentally safe and the savings shown in **Table 5**, proves a green roof is feasible and the project still saves money.

I've also decided to add a **very rough estimate** of how much more it would cost to add the rebar. I used the existing building value of #4 @ 15", 0.668 lb/ft and compared it to the biggest difference in steel area from the hand calculations #5 @ 10", 1.043 lb/ft. Using these numbers over the area of the entire roof, with a length of 214.5' and width of 121.5' is not completely accurate and will end up giving me a larger number difference than needed considering not every area needs #5 @ 10 in. Money is still saved by using the equations below to find the difference in steel weight to equal:

#4 @ 15", 0.668 lb/ft

(121.5')(12"/15") = 97.2 bars, (97 bars)(214 ft)(0.668 lb/ft) = 13,866.344 lb

#5 @ 10", 1.043 lb/ft

(121.5')(12"/10") = 145.8 bars, (146 bars)(214)(1.043 lb/ft) = 32,587.492 lb

Change in lb –> 32, 587.492 lb - 1 3,866.344 lb = 18,721.148 lb

Using RS Means 2006 and a 1.03% year inflation to find price/lb of an elevated slab, #4 to #7 reinforcement = $0.93/lb

(18,721.148 lb)($0.93/lb) = $17,410.67 more than the original reinforcement

Façade Costs					
	Quantity	Unit	Total Unit Cost	Total Cost	Money Saved
Precast (Existing)	23,663	sf	109.88	$2,600,000.00	0
Versawall	23,663	sf	30	$709,890.00	$1,890,110.00
Dimension Series	23,663	sf	60	$1,419,780.00	$1,180,220.00

Table 5

By using either Dimension Series or Versawall, buying a green roof, and using extra reinforcement you can save:

Dimension Series:

$2,600,000 - $1,419,780 - $441220 - $17,410.67 = <u>**$721,589.33**</u>

Versawall:

$2,600,000 - $709,890 - $441220 - $17,410.67 = <u>**$1,431,479.33**</u>

This fact accompanied by the list of metal panel and green roof advantages below proves to be a good decision to be applied to this project.

- Tested Insulation Value – series panels have insulation U-Values, based on independent testing, which exceed baseline values prescribed in ASHRAE 90
- High Recycled Content – an average postconsumer recycled content of 16% to 19% and an average postindustrial recycled content of 6% to 7% for a total of 22% to 26%
- Low-Emitting Materials – sealant used in side joints have less than the limit of grams/liter established by the LEED Green Building Rating System
- Reduced Jobsite Scrap – panels are fabricated-to-length in the factor, meaning little or no jobsite scrap is generated
- Miscellaneous – the panels are available with a natural metallic surface and reflective coatings for high solar reflectance to potentially result in lower building cooling costs.
- Life Span – Panels require little maintenance and are extremely durable with a realistic service life of 20 years or more
- Faster Installation for metal panels
- Storm water runoff reduction
- Improvement of air quality
- Sound absorbing and insulating properties
- Increase life expectancy of rooftop waterproofing
- Reduce urban heat island effect
- Increase habitat for birds and butterflies
- Provide attractive views for other people
- Insulating a building reducing heating and cooling costs.

With the new designs of this building the façade looks may change, but saving up to about a quarter million to a million and a half dollars per change could be worth it. Using these new materials is not only cost effective, but they do reach the goals I set out to do, which is save money, time, and energy costs no matter how minor they are. So my recommendations are to use the CENTRIA Formawall Dimension Series and the green roof because of the money, time, and energy saved. Also this type of building envelope material was recommended by other building envelop contractors such as Mr. Myers, from Harmon Inc., and Ben Marnyk, from CENTRIA, to closely resemble the precast look. Also returning some green to the surface area taken up by the building and the vast parking lot seems to be more environmentally sustainable. Using this new envelope material the building will not have to be scrubbed down repeatedly to match the color of each other, which took 4 days for Plaza East to do for the precast panels. The architectural precast used also had a fairly expensive aggregate to enhance its darker shade, this in turn made the value of these panels so costly. The perimeter girders will most likely be smaller saving on concrete and rebar. The crane picks can be lighter and less dangerous.

In the end the building will look different from the original design, but the project can still keep the architectural wall that looks to split the building in half. This wall was covered with flat precast panels which can easily be switched to the Dimension Series panels, leaving Plaza East's looks changed, but not completely.

References

Coleman, Gabrial S., and Joseph W. Jun. "Interoperability and the Construction Process." American Institute of Steel Construction Inc. AISC. 8 Apr. 2008 <http://www.aisc.org/Content/NavigationMenu/Steel_Solutions_Center/My_Project/Utilizing_CIS2_Interoperability/Interoperability_white_paper11_29.pdf>.

"Duracast." Centria.Com. 2006. CENTRIA. 8 Apr. 2008 <http://www.centria.com/C1/Duracast/default.aspx>.

"FAQ About Green Roofs." Life on Roofs. 8 Apr. 2008 <http://www.zinco-usa.com/faq/faq4.html>.

Faulkner, Luke. "Interoperability for the Steel Industry." Structuremag.Org. Feb. 2006. Structural Magazine. 8 Apr. 2008 <http://www.structuremag.org/archives/2006/February-2006/C-Technology-Feb-06.pdf>.

Fowler, Joele. "Building Better." Modern Steel Construction. June 2003. 8 Apr. 2008 <http://www.modernsteel.com/Uploads/Issues/June_2003/30718_hospital.pdf>.

"Green Roof Benefits." Greengridroofs.Com. 2008. GreenGrid. 8 Apr. 2008 <http://www.greengridroofs.com/advantages/greenroofben/redenergycosts.htm>.

"Heat Island Effect." www.epa.gov. 12 Oct. 2007. U.S. Environmental Protection Agency. 8 Apr. 2008 <http://www.epa.gov/hiri/strategies/greenroofs.html>.

"Metal Wall Panels." Arcat.Com. 2006. CENTRIA. 8 Apr. 2008 <http://www.arcat.com/sdspecs/htm/07412cas.htm>.

"Structural Steel: the Material of Choice." American Institute of Steel Construction Inc. 2002. AISC. 8 Apr. 2008 <http://www.aisc.org/Content/NavigationMenu/Steel_Solutions_Center/Time,_Money_and_Management/Electronic_Data_Interchange/CIS_2_Case_Studies/CIS_2_Case_Studies.htm>.

Appendix A

General Conditions Estimate

General Conditions				
Labor	**Quantity**	**Units**	**Unit Price**	**Amount**
Superintendent	58	Wks	$6,596.98	$382,625.00
Layout Engineer	58	Wks	$1,289.12	$74,769.00
DAVIS Safety Personnel	58	Wks	$344.83	$20,000.00
DAVIS Carpentry	58	Wks	$1,379.31	$80,000.00
Project Manager	58	Wks	$2,718.10	$157,650.00
Assistant Project Manager	58	Wks	$3,739.21	$216,874.00
Project Administrator	58	Wks	$524.93	$30,446.00
DAVIS Courier	58	Wks	$43.21	$2,506.00
DAVIS Yard Delivery	58	Wks	$149.57	$8,675.00
DAVIS Carpentry - Mock	58	Wks	$344.83	$20,000.00
DAVIS Labor - Clean Up	58	Wks	$1,196.55	$69,400.00
Punchlist	1	LS	$9,060.00	$9,060.00
DAVIS Carpentry	58	Wks	$607.05	$35,209.00
Labor Total =				$1,107,214.00

Material	Quantity	Units	Unit Price	Amount
Permits and Expediting	1	LS	$500.00	$500.00
Document Reproduction	58	Wks	$301.72	$17,500.00
Progress Photos	58	Wks	$56.03	$3,250.00
Travel and Road	58	Wks	$86.21	$5,000.00
Overnight & Hand	58	Wks	$117.79	$6,832.00
Davis Courier Vehicle	58	Wks	$22.12	$1,283.00
Field Office Equipment	58	Wks	$183.84	$10,663.00
Main Office Equipment	58	Wks	$51.02	$2,959.00
Temporary Site Office	58	Wks	$86.21	$5,000.00
Field Office Trailers	58	Wks	$347.84	$20,175.00
Field Telephone	58	Wks	$135.12	$7,837.00
Mobile Phones	58	Wks	$216.97	$12,584.00
Construction Signage	58	Wks	$129.31	$7,500.00
Construction Fence	58	Wks	$488.28	$28,320.00
Material Hoist	58	Wks	$258.62	$15,000.00
Temporary Power	58	Wks	$1,262.48	$73,224.00
Security Services	58	Wks	$86.21	$5,000.00
Vehicle Allowance	58	Wks	$202.95	$11,771.00
Final Cleaning	1	LS	$37,950.00	$37,950.00
Dumpsters	58	Wks	$1,560.29	$90,497.00
Trash Chute	58	Wks	$199.57	$11,575.00
Temporary Protection	58	Wks	$88.14	$5,112.00
Safety Incentives	58	Wks	$86.21	$5,000.00

First Aid Kit and Refill	1	LS	$2,000.00	$2,000.00
Temporary Fire	58	Wks	$43.10	$2,500.00
Temporary Toilets	58	Wks	$280.17	$16,250.00
Water Cooler for Trailer	58	Wks	$56.03	$3,250.00
Personal Protective	1	LS	$10,250.00	$10,250.00
Gross Receipts Tax	58	Wks	$525.71	$30,491.00
Punchlist	1	LS	$5,000.00	$5,000.00
General Liability	1	LS	$110,699.00	$110,699.00
Site Furnishings	58	Wks	$155.17	$9,000.00
Site Development	58	Wks	$2,037.59	$118,180.00
Material Total =				$692,152.00

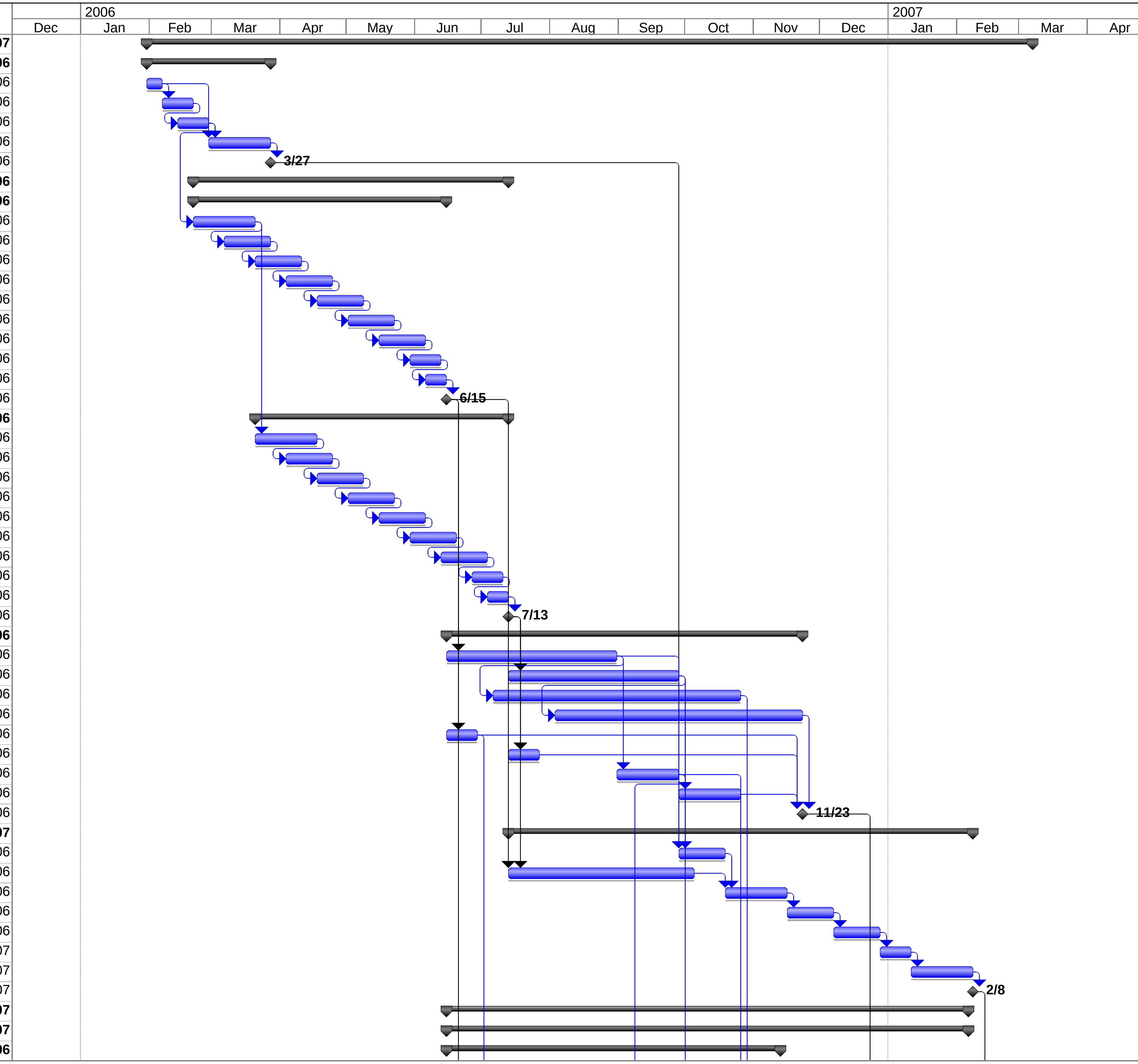
Equipment	Quantity	Units	Unit Price	Amount
DAVIS Tools and	58	Wks	$144.36	$8,373.00
Computer/LAN/Misc.	58	Wks	$389.17	$22,572.00
Field Staff Vehicle	58	Wks	$292.91	$16,989.00
Office Staff Vehicle	58	Wks	$366.14	$21,236.00
Survey/Layout	1	LS	$2,500.00	$2,500.00
Equipment Total =				$71,670.00

Insurance and Taxes =	$165,514.00
Bonds =	$175,141.00
General Contractor Fee =	$1,053,947.00
Total =	**$3,265,638.00**

Appendix B

Detailed Project Schedule

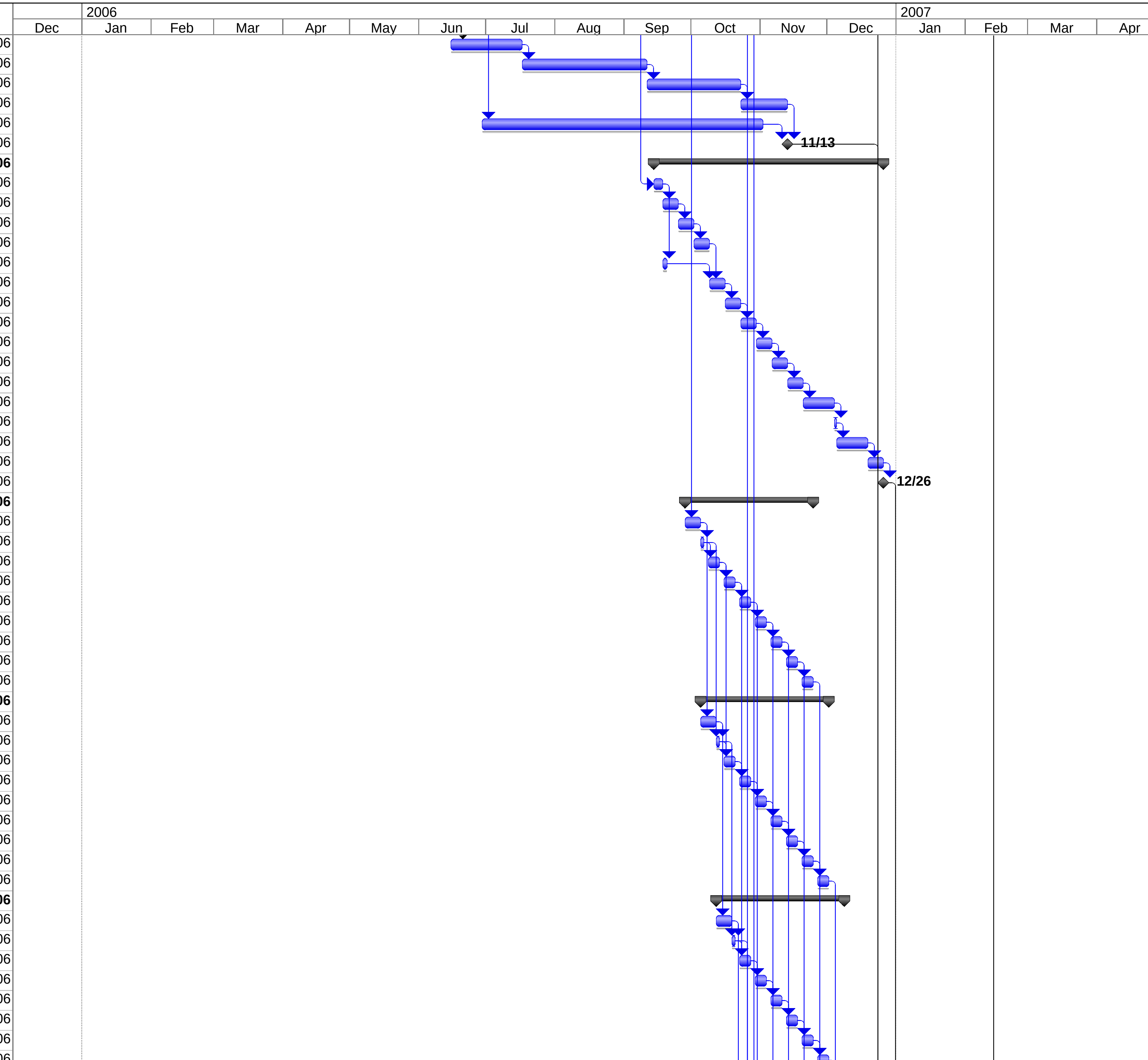
ID	Task Name	Duration	Start	Finish
1	**CONSTRUCTION**	**286.5 days**	**Tue 1/31/06**	**Wed 3/7/07**
2	**Site Work Construction**	**40 days**	**Tue 1/31/06**	**Mon 3/27/06**
3	Site Preparation, Silt Fencing, SEC Inspection	5 days	Tue 1/31/06	Mon 2/6/06
4	Clearing	10 days	Tue 2/7/06	Mon 2/20/06
5	Grade for Building Pad	10 days	Tue 2/14/06	Mon 2/27/06
6	Complete Site Grading	20 days	Tue 2/28/06	Mon 3/27/06
7	Complete excavation	0 days	Mon 3/27/06	Mon 3/27/06
8	**Structure**	**102.5 days**	**Tue 2/21/06**	**Thu 7/13/06**
9	**Concrete Building (25,200 per floor)**	**82.5 days**	**Tue 2/21/06**	**Thu 6/15/06**
10	Foundation Concrete, Columns to first floor	4 wks	Tue 2/21/06	Mon 3/20/06
11	Underslab plumbing	3 wks	Tue 3/7/06	Mon 3/27/06
12	Pour Slab on Grade	3 wks	Tue 3/21/06	Mon 4/10/06
13	Form and Pour Columns and 2nd Floor	3 wks	Tue 4/4/06	Mon 4/24/06
14	Form and Pour Columns and 3rd Floor	3 wks	Tue 4/18/06	Mon 5/8/06
15	Form and Pour Columns and 4th Floor	3 wks	Tue 5/2/06	Mon 5/22/06
16	Form and Pour Columns and 5th Floor	3 wks	Tue 5/16/06	Mon 6/5/06
17	Form and Pour Columns and Roof	2 wks	Tue 5/30/06	Mon 6/12/06
18	Form and Pour Columns and Penthouse Roof	1.5 wks	Tue 6/6/06	Thu 6/15/06
19	Concrete Complete on Tower #1	0 days	Thu 6/15/06	Thu 6/15/06
20	**Concrete Building (25,200 per floor)**	**82.5 days**	**Tue 3/21/06**	**Thu 7/13/06**
21	Foundation Concrete	4 wks	Tue 3/21/06	Mon 4/17/06
22	Underslab plumbing	3 wks	Tue 4/4/06	Mon 4/24/06
23	Pour First Floor Columns, Slab on Grade	3 wks	Tue 4/18/06	Mon 5/8/06
24	Form and Pour Columns and 2nd Floor	3 wks	Tue 5/2/06	Mon 5/22/06
25	Form and Pour Columns and 3rd Floor	3 wks	Tue 5/16/06	Mon 6/5/06
26	Form and Pour Columns and 4th Floor	3 wks	Tue 5/30/06	Mon 6/19/06
27	Form and Pour Columns and 5th Floor	3 wks	Tue 6/13/06	Mon 7/3/06
28	Form and Pour Columns and Roof	2 wks	Tue 6/27/06	Mon 7/10/06
29	Form and Pour Columns and Penthouse Roof	1.5 wks	Tue 7/4/06	Thu 7/13/06
30	Concrete Complete on Tower #2	0 wks	Thu 7/13/06	Thu 7/13/06
31	**Façade**	**115 days**	**Thu 6/15/06**	**Thu 11/23/06**
32	Precast Building No. 1	11 wks	Thu 6/15/06	Thu 8/31/06
33	Precast Building No. 2	11 wks	Thu 7/13/06	Thu 9/28/06
34	Install windows and Storefronts Building No. 1	16 wks	Thu 7/6/06	Thu 10/26/06
35	Install Windows and Storefronts Building No. 2	16 wks	Thu 8/3/06	Thu 11/23/06
36	Install Penthouse Roofing Building No. 1	2 wks	Thu 6/15/06	Thu 6/29/06
37	Install Penthouse Roofing Building No. 2	2 wks	Thu 7/13/06	Thu 7/27/06
38	Install Main Roof Building No. 1	4 wks	Thu 8/31/06	Thu 9/28/06
39	Install Main Roof Building No. 2	4 wks	Thu 9/28/06	Thu 10/26/06
40	Complete all Façade Installation	0 days	Thu 11/23/06	Thu 11/23/06
41	**Sitework**	**150 days**	**Thu 7/13/06**	**Thu 2/8/07**
42	Final Grade site	3 wks	Thu 9/28/06	Thu 10/19/06
43	Install site utilities	12 wks	Thu 7/13/06	Thu 10/5/06
44	Install Curb and gutter	4 wks	Thu 10/19/06	Thu 11/16/06
45	Install sidewalks	3 wks	Thu 11/16/06	Thu 12/7/06
46	Fine grade and Install stone subbase	3 wks	Thu 12/7/06	Thu 12/28/06
47	Install asphalt paving	2 wks	Thu 12/28/06	Thu 1/11/07
48	Complete misc. sitework	4 wks	Thu 1/11/07	Thu 2/8/07
49	Complete all siteworks	0 wks	Thu 2/8/07	Thu 2/8/07
50	**Finishes - North Building Only**	**168 days**	**Thu 6/15/06**	**Tue 2/6/07**
51	**Core and Shell**	**168 days**	**Thu 6/15/06**	**Tue 2/6/07**
52	**MEP Risers Floors 1-5, Penthouse**	**107 days**	**Thu 6/15/06**	**Mon 11/13/06**



Date: Fri 11/2/07

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

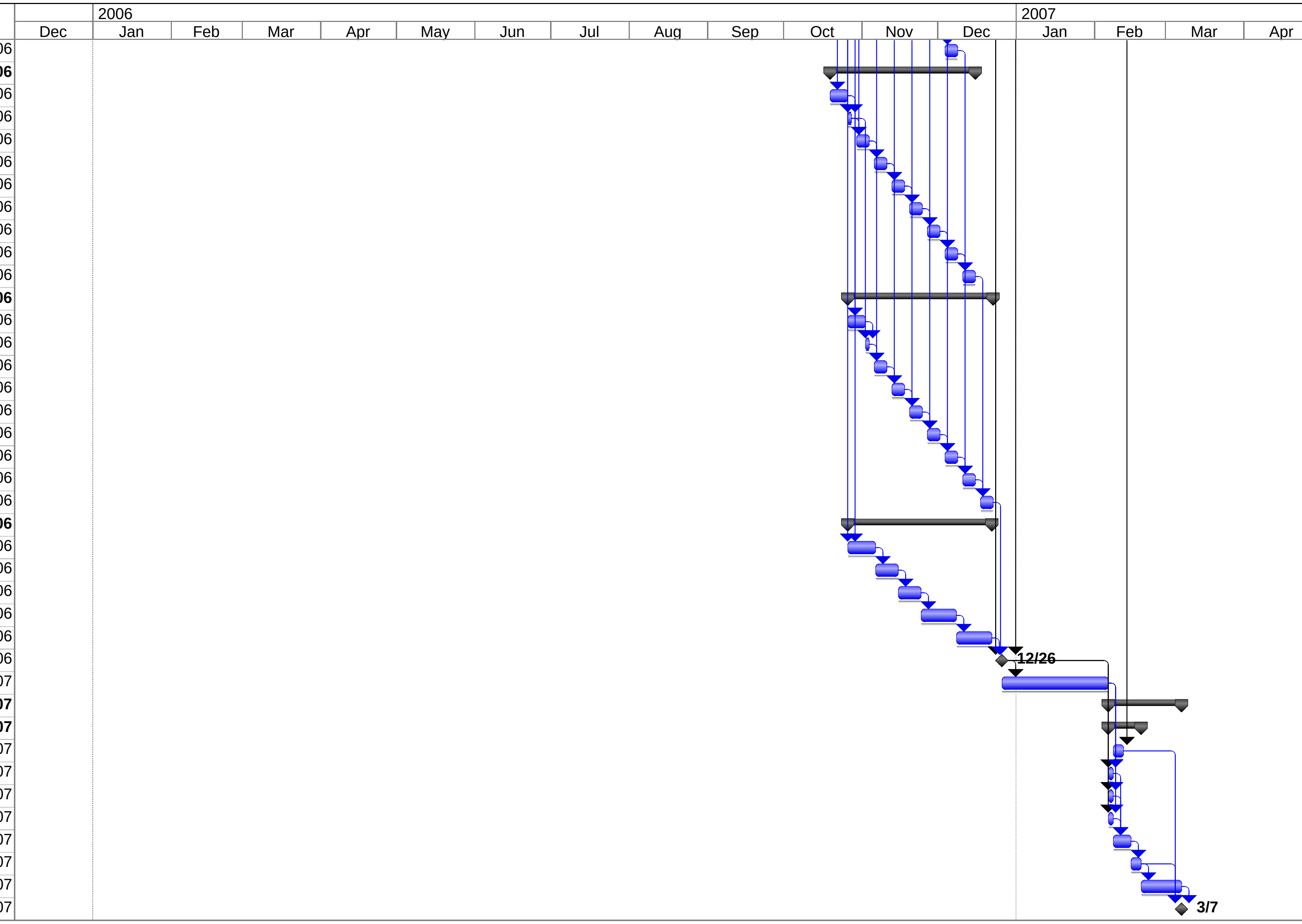
ID	Task Name	Duration	Start	Finish
53	Mechanical - Ductwork Risers, Condenser Water	22 days	Thu 6/15/06	Mon 7/17/06
54	Electrical - Buss Duct, Conduit, Panels	40 days	Mon 7/17/06	Mon 9/11/06
55	Plumbing - Storm, Sewer, Water	30 days	Mon 9/11/06	Mon 10/23/06
56	Sprinkler - Standpipe	15 days	Mon 10/23/06	Mon 11/13/06
57	Elevators	18 wks	Thu 6/29/06	Thu 11/2/06
58	Complete MEP Risers	0 days	Mon 11/13/06	Mon 11/13/06
59	**Main Lobby**	**73 days**	**Thu 9/14/06**	**Tue 12/26/06**
60	Layout Lobby Walls	2 days	Thu 9/14/06	Mon 9/18/06
61	Install Ductwork above ceiling	5 days	Mon 9/18/06	Mon 9/25/06
62	Install Sprinkler above ceiling	5 days	Mon 9/25/06	Mon 10/2/06
63	Install Lighting above ceiling	5 days	Mon 10/2/06	Mon 10/9/06
64	Install Elevator Entrances	2 days	Mon 9/18/06	Wed 9/20/06
65	Frame Lobby Walls	5 days	Mon 10/9/06	Mon 10/16/06
66	Frame Ceilings and Bulkheads	5 days	Mon 10/16/06	Mon 10/23/06
67	Roughin MEP to Ceilings and Bulkheads	5 days	Mon 10/23/06	Mon 10/30/06
68	Close in Inspections	5 days	Mon 10/30/06	Mon 11/6/06
69	Hang Drywall Ceilings, Walls, Bulkheads	5 days	Mon 11/6/06	Mon 11/13/06
70	Finish Drywall	5 days	Mon 11/13/06	Mon 11/20/06
71	Install stone flooring and base	2 wks	Mon 11/20/06	Mon 12/4/06
72	Finish Paint	1 day	Mon 12/4/06	Tue 12/5/06
73	Install Millwork Panels	2 wks	Tue 12/5/06	Tue 12/19/06
74	Final Touch up of all finishes	1 wk	Tue 12/19/06	Tue 12/26/06
75	Complete Main Lobby	0 days	Tue 12/26/06	Tue 12/26/06
76	**1st Floor**	**41.5 days**	**Thu 9/28/06**	**Fri 11/24/06**
77	Frame Cores	1 wk	Thu 9/28/06	Thu 10/5/06
78	Rough in / Close in	1.5 days	Thu 10/5/06	Fri 10/6/06
79	Hang and Finish Drywall	1 wk	Mon 10/9/06	Fri 10/13/06
80	Frame Ceilings	1 wk	Mon 10/16/06	Fri 10/20/06
81	Hang and Finish Ceilings	1 wk	Mon 10/23/06	Fri 10/27/06
82	Bathroom Tile	1 wk	Mon 10/30/06	Fri 11/3/06
83	Bathroom Paint	1 wk	Mon 11/6/06	Fri 11/10/06
84	Bathroom Fixtures and Partitions	1 wk	Mon 11/13/06	Fri 11/17/06
85	Accessories and Trim	1 wk	Mon 11/20/06	Fri 11/24/06
86	**2nd Floor**	**41.5 days**	**Thu 10/5/06**	**Fri 12/1/06**
87	Frame Cores	1 wk	Thu 10/5/06	Thu 10/12/06
88	Rough in / Close in	1.5 days	Thu 10/12/06	Fri 10/13/06
89	Hang and Finish Drywall	1 wk	Mon 10/16/06	Fri 10/20/06
90	Frame Cilings	1 wk	Mon 10/23/06	Fri 10/27/06
91	Hang and Ceilings	1 wk	Mon 10/30/06	Fri 11/3/06
92	Bathroom Tile	1 wk	Mon 11/6/06	Fri 11/10/06
93	Bathroom Paint	1 wk	Mon 11/13/06	Fri 11/17/06
94	Bathroom Fixtures and Partitions	1 wk	Mon 11/20/06	Fri 11/24/06
95	Accessories and Trim	1 wk	Mon 11/27/06	Fri 12/1/06
96	**3rd Floor**	**41.5 days**	**Thu 10/12/06**	**Fri 12/8/06**
97	Frame Cores	1 wk	Thu 10/12/06	Thu 10/19/06
98	Rough in / Close in	1.5 days	Thu 10/19/06	Fri 10/20/06
99	Hang and Finish Drywall	1 wk	Mon 10/23/06	Fri 10/27/06
100	Frame Cilings	1 wk	Mon 10/30/06	Fri 11/3/06
101	Hang and Ceilings	1 wk	Mon 11/6/06	Fri 11/10/06
102	Bathroom Tile	1 wk	Mon 11/13/06	Fri 11/17/06
103	Bathroom Paint	1 wk	Mon 11/20/06	Fri 11/24/06
104	Bathroom Fixtures and Partitions	1 wk	Mon 11/27/06	Fri 12/1/06



Date: Fri 11/2/07

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

ID	Task Name	Duration	Start	Finish
105	Accessories and Trim	1 wk	Mon 12/4/06	Fri 12/8/06
106	**4th Floor**	**41.5 days**	**Thu 10/19/06**	**Fri 12/15/06**
107	Frame Cores	1 wk	Thu 10/19/06	Thu 10/26/06
108	Rough in / Close in	1.5 days	Thu 10/26/06	Fri 10/27/06
109	Hang and Finish Drywall	1 wk	Mon 10/30/06	Fri 11/3/06
110	Frame Cilings	1 wk	Mon 11/6/06	Fri 11/10/06
111	Hang and Ceilings	1 wk	Mon 11/13/06	Fri 11/17/06
112	Bathroom Tile	1 wk	Mon 11/20/06	Fri 11/24/06
113	Bathroom Paint	1 wk	Mon 11/27/06	Fri 12/1/06
114	Bathroom Fixtures and Partitions	1 wk	Mon 12/4/06	Fri 12/8/06
115	Accessories and Trim	1 wk	Mon 12/11/06	Fri 12/15/06
116	**5th Floor**	**41.5 days**	**Thu 10/26/06**	**Fri 12/22/06**
117	Frame Cores	1 wk	Thu 10/26/06	Thu 11/2/06
118	Rough in / Close in	1.5 days	Thu 11/2/06	Fri 11/3/06
119	Hang and Finish Drywall	1 wk	Mon 11/6/06	Fri 11/10/06
120	Frame Cilings	1 wk	Mon 11/13/06	Fri 11/17/06
121	Hang and Ceilings	1 wk	Mon 11/20/06	Fri 11/24/06
122	Bathroom Tile	1 wk	Mon 11/27/06	Fri 12/1/06
123	Bathroom Paint	1 wk	Mon 12/4/06	Fri 12/8/06
124	Bathroom Fixtures and Partitions	1 wk	Mon 12/11/06	Fri 12/15/06
125	Accessories and Trim	1 wk	Mon 12/18/06	Fri 12/22/06
126	**Perimeter Wall Fire Caulk, Frame, Hang Drywall & Finish**	**41 days**	**Thu 10/26/06**	**Fri 12/22/06**
127	1st Floor	7 days	Thu 10/26/06	Mon 11/6/06
128	2nd Floor	7 days	Mon 11/6/06	Wed 11/15/06
129	3rd Floor	7 days	Wed 11/15/06	Fri 11/24/06
130	4th Floor	10 days	Fri 11/24/06	Fri 12/8/06
131	5th Floor	10 days	Fri 12/8/06	Fri 12/22/06
132	Complete all Finishes	0 days	Tue 12/26/06	Tue 12/26/06
133	COMPLETE FINISHES IN CORE OF BUILDING NO. 2	6 wks	Tue 12/26/06	Tue 2/6/07
134	**INSPECTIONS**	**21 days**	**Tue 2/6/07**	**Wed 3/7/07**
135	**Trade Inspections**	**9 days**	**Tue 2/6/07**	**Mon 2/19/07**
136	Site work inspections	2 days	Thu 2/8/07	Mon 2/12/07
137	Mechanical	2 days	Tue 2/6/07	Thu 2/8/07
138	Electrical	2 days	Tue 2/6/07	Thu 2/8/07
139	Plumbing	2 days	Tue 2/6/07	Thu 2/8/07
140	Fire Marshall Inspections	5 days	Thu 2/8/07	Thu 2/15/07
141	Final Base Building Inspections	2 days	Thu 2/15/07	Mon 2/19/07
142	Weather	12 days	Mon 2/19/07	Wed 3/7/07
143	SUBSTANTIAL COMPLETION	0 days	Wed 3/7/07	Wed 3/7/07

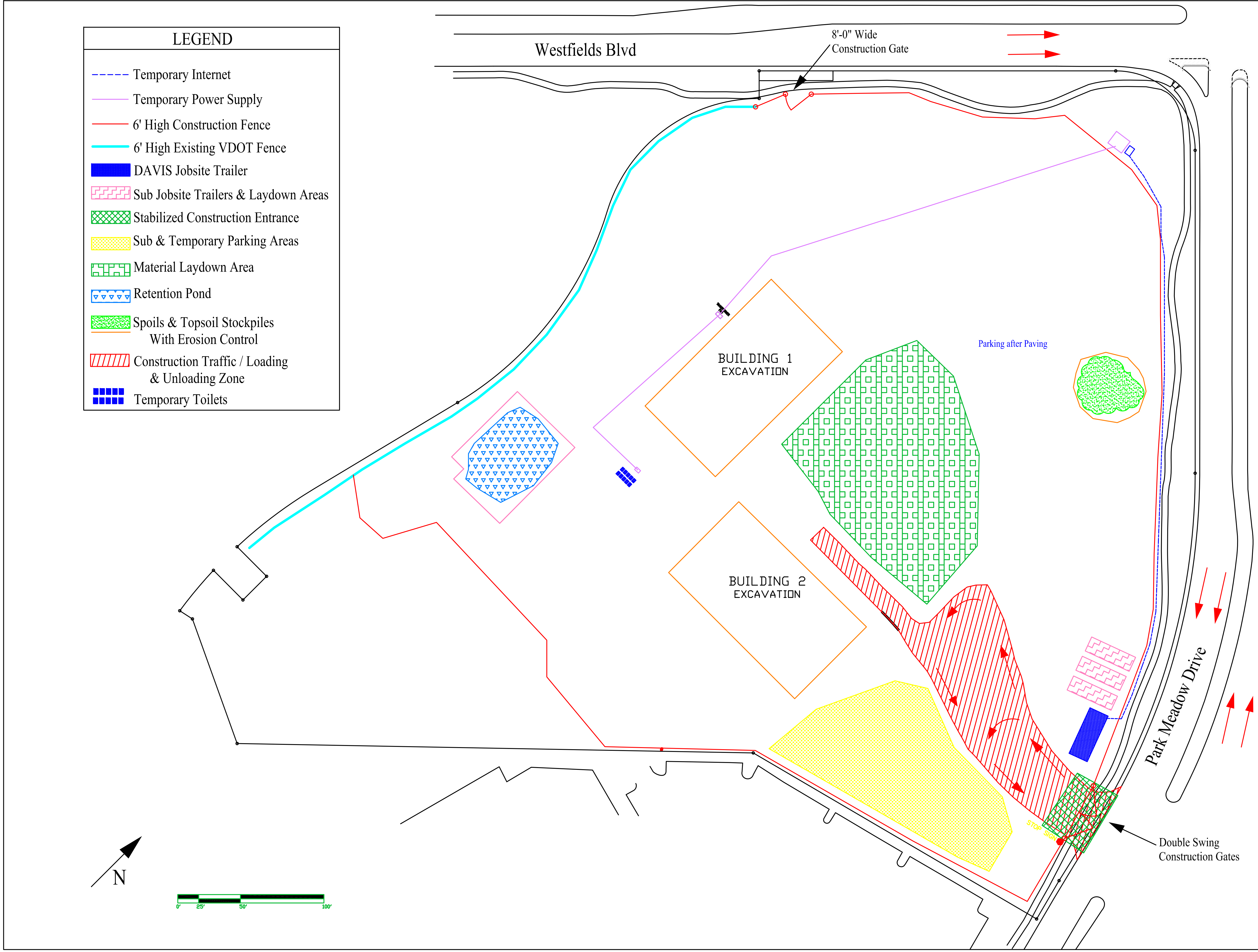


Date: Fri 11/2/07

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

Appendix C.1 & C.2

Site Layout Plan Phase 1 & 2



Technical Assignment 2 - Site Plan

Plaza East Site Work/Excavation

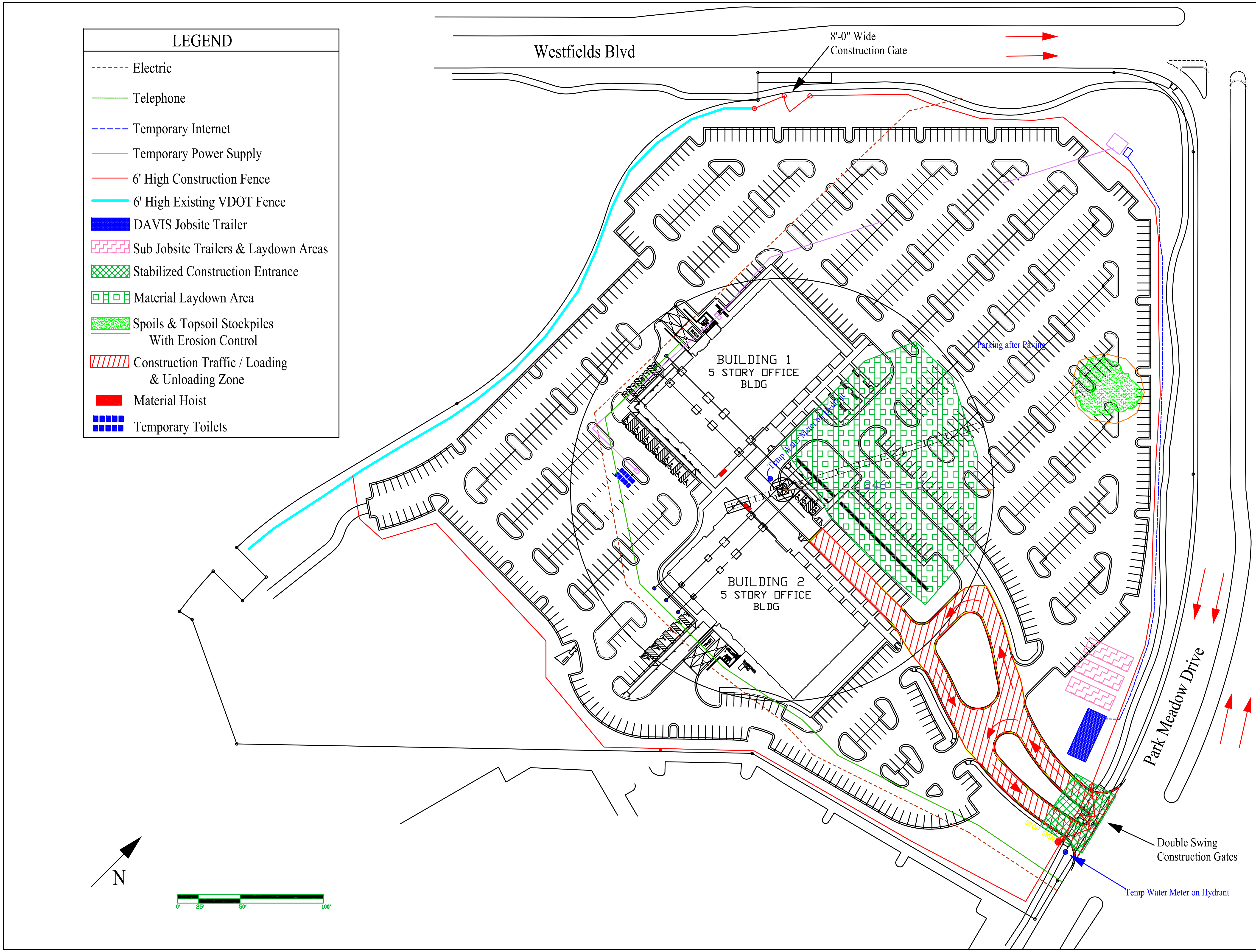
1/31/06 - 3/27/06

Steven M. Miller

Construction Management

Dr. Riley

$\frac{1}{32}$" = 1' - 0"



Technical Assignment 2 - Site Plan

Plaza East Superstructure

2/21/06 - 7/13/06

PENNSTATE

1855

Steven M. Miller
Construction Management
Dr. Riley

$\frac{1}{32}$" = 1' - 0"

Appendix D

Structural Hand Calculations

STEVE MILLER | STRUCTURAL ANALYSIS | CM DR RILEY

ROOF LOADS

LIVE LOAD - 35 PSF

DEAD LOAD - $150\text{ PCF}(5\tfrac{1}{2}''/12'') = 68.75$ PSF

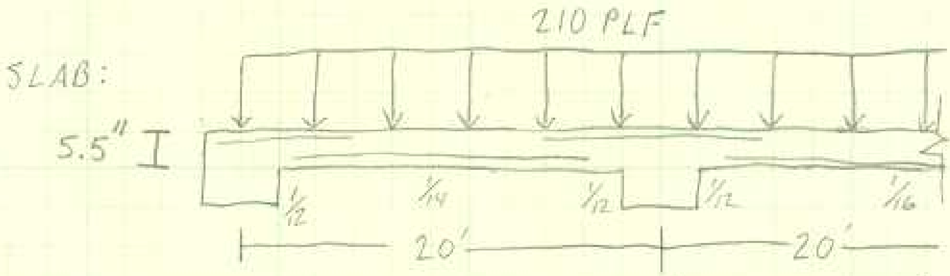
GREEN ROOF = 37 PSF

SNOW LOAD - 27 PSF

TOTAL LOAD $= 1.2(68.75+37) + 1.6(35) + 27 = 209.9 \approx 210$ PSF

$210\text{ PSF}/1\text{ ft} = 210$ PLF

SLAB:

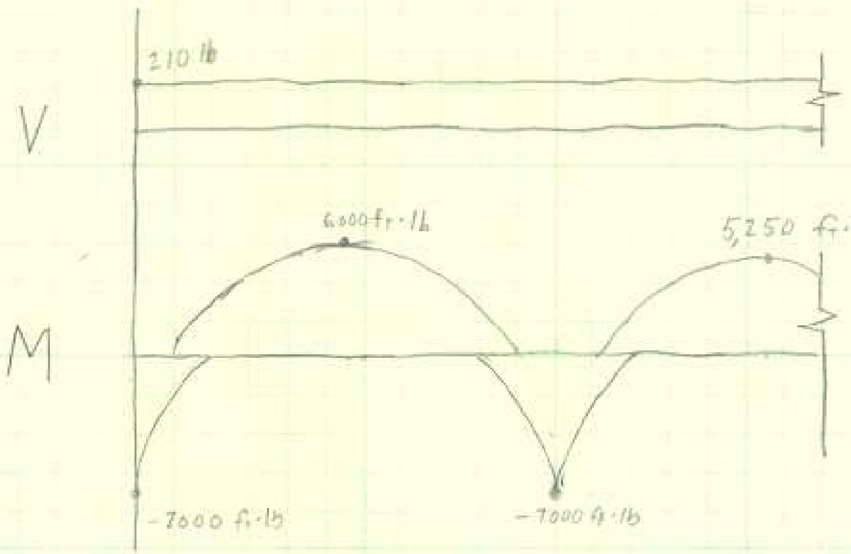


MOMENTS: AT EXTERIOR SUPPORT: $-M$ $\frac{1}{12} \times 210 \times 20^2 = 7{,}000$ ft-lb

AT MID SPAN 1: $+M$ $\frac{1}{14} \times 210 \times 20^2 = 6{,}000$ ft-lb

AT INTERIOR SUPPORT: $-M$ $\frac{1}{12} \times 210 \times 20^2 = 7{,}000$ ft-lb

AT MIDSPAN 2: M $\frac{1}{16} \times 210 \times 20^2 = 5{,}250$ ft-lb



$$d = 5.5'' - 0.75'' = 4.75''$$

$$a = \frac{A_s f_y}{.85 f'_c b}$$

AREA OF STEEL (A_s) w/ $a = 1''$

$$A_s = \frac{M_u}{\phi f_y (d - a/2)} = \frac{7 \text{ ft·k} (12)}{.9(60)(4.75 - .5)} = 0.366 \text{ in}^2$$

CHECK a

$$a = \frac{.366(60)}{(.85)(3.5)(12)} = 0.615''$$

A_s @ EXT.

$$A_s = \frac{7(12)}{.9(60)\left(4.75 - \frac{0.615}{2}\right)} = \boxed{0.35 \text{ in}^2}$$

A_s @ MIDSPAN 1

$$A_s = \frac{6(12)}{.9(60)\left(4.75 - \frac{0.615}{2}\right)} = \boxed{0.30 \text{ in}^2}$$

A_s @ MID SPAN 2

$$A_s = \frac{5.25(12)}{.9(60)\left(4.75 - \frac{0.615}{2}\right)} = \boxed{0.26 \text{ in}^2}$$

MINIMAL REINFORCEMENT FOR SHRINKAGE & TEMP. CRACKING

$$A_s = 0.0018 \times 12'' \times 5.5'' = 0.12 \text{ in}^2 < 0.35, 0.30, 0.26$$ GOOD

PERPENDICULAR SHRINKAGE & TEMP. REINFORCING

USE #3 @ 10" = $\boxed{0.13 \text{ in}^2}$ > 0.12 in² GOOD

10" < 5 TIMES SLAB THICKNESS & 18" GOOD

EXISTING REINFORCEMENT: #4 @ 15"

$$A_s = \#4 @ 15 = 0.20\ in^2 \left(\frac{12''}{15''}\right) = 0.16\ in^2 < 0.35\ in^2 \quad \underline{\text{NOT GOOD}}$$

FOR 0.35 in² USE #4 @ 6" = 0.40 in², #5 @ 10" = 0.37 in²

FOR 0.30 in² USE #4 @ 7½" = 0.31 in², #5 @ 12" = 0.31 in²

FOR 0.26 in² USE #4 @ 9" = 0.26 in², #3 @ 5" = 0.26 in²

FACTORER SHEAR @ d

$$V_u = 1.15 \times \frac{210 \times 20'}{2} - 210 \times \frac{4.75''}{2} = 2,331.88\ lb \approx 2,332\ lb$$

$$V_n = V_c = 2\sqrt{f'_c}\,bd = 2\sqrt{3,5000}(12)(4.75'') = 6,744.33\ lb$$

$$\phi V_c = 0.75(6744.33) = 4,721\ lb > V_u = 2,332\ lb \quad \underline{\text{GOOD}}$$