AE 482
Spring 2009

Final Report

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Construction Management – B.A.E./M.A.E.
Consultant: Dr. Riley
Bakery Square – Building 1
4/7/2009

Jonathan Revtai

Construction Management

Project Size
378,000 SF

Project Cost
$24 Million

Start Date
03.17.2008

End Date
05.21.2009

Delivery Method
CM at Risk

Building 1 at Bakery Square

Project Team

Owner/ Developer
Bakery Square Holdings, L.P.

Architect
Astorino

CM at Risk
P.J. Dick Inc.

Building 1 is part of the bakery Square Project built around the renovation of the 1918 Nabisco Factory. This facility includes retail spaces, a fitness center, restaraunts, and a parking garage. The parking garage structure is built around all of the other spaces including a cast-in-place swimming pool on level two. Facade finishes will be provided during fit out, and have not been finalized.

www.engr.psu.edu/ae/thesis/portfolios/2009/jar5015

Pittsburgh, PA

MEP

Roof top units are used to condition the retail fitness spaces, while wall units are used in the parking garage section. Plumbing is limited to bathrooms

Electrical

The fitness center is fed by a separate switch board from the rest of the building. The feed to each switchboard is a 3 phase, 480 v connection.

Structural

Precast concrete is used for most of the superstructure. structural steel is used for an outside bridge, and a hanging mezzanine in the fitness center.the foundations are built with Auguer cast piles.

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EXECUTIVE SUMMARY

Building 1 at Bakery Square is the building being investigated for the capstone thesis project. This report documents information gained from technical assignments completed in the fall of 2008 and research of four analysis topics performed in the following spring semester.

Building 1 is a multi-use facility that is comprised of a parking garage, retail space, and a fitness center. Analyses of this building focus on construction management issues of schedule, cost, quality, and constructability of the project. Many of the analyses touch on sustainability because it is a critical issue that the construction industry will have to negotiate.

The first topic analyzes different sustainable technologies that can be used to transform the mechanical energy expended in a gym into electrical energy. The report shows that the technology is still new, and future improvements in efficiency and costs can make these ideas viable. Even still, about 18% of the fitness center's lighting load can be supplied by "green gym" technology. To include M.A.E. research, further sustainability research was performed on a bi-level LED lighting system for the parking garage. This system should reduce the lighting load of the building by 60%.

The second study looked at changing the mezzanine level's structural system to a more constructible system. By using the alternative structure, the project costs and schedule can be reduced by $72,000 and 4 days, respectively.

Another constructability issue was dealt with in the third analysis. A triangularly shaped pile cap configuration, which was slowing the construction manager's progress, was redesigned into a square shape. It was determined that $9,000 could be saved by changing the shape of the pile and the schedule could be shortened by five days. These findings are based on the fact that less material was used and square formwork has a higher productivity rate.

The final analysis focused on the mechanical system for the retail space. The large ductwork for the retail space had to travel through the fitness center, which takes up space and reduces southern exposure. By relocating the system, more light can enter the gym and the members will have a better view of the outside plaza in the Bakery Square Complex. A chiller-based system has been proposed at only a 17% increase in costs.

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank those individuals who helped me throughout this last year with my thesis project. The finish product of my investigation and research for this project would have suffered greatly, had it not been for your input, support, and direction. The following people helped guide my analysis for thesis:

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- Mr. Anthony Dolan
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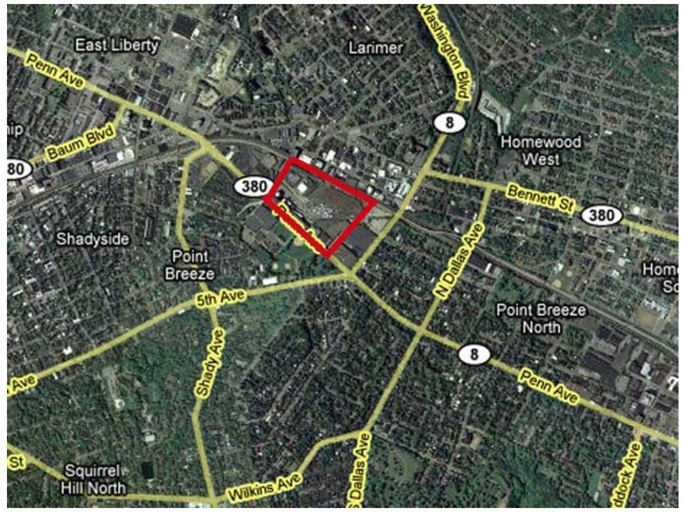
- Mr. Todd Redibord

I would also like to thank my friends and family for their continued support and help throughout my time spent at Penn State.

INTRODUCTION

Project Summary

The Bakery Square development, located about five miles from downtown Pittsburgh, is a multi-phased project that is being constructed over a two-year period in an area known as East Liberty. A 1918 structure that was owned and until recently operated by the Nabisco Corporation is the cornerstone of the project. A development firm from nearby Squirrel Hill gained ownership of the Nabisco Factory and the surrounding buildings early in 2007 with plans to renovate the original portion of the factory and construct an elegant and diverse five building facility that include retail, office, hotel, and entertainment spaces.



- Figure 1 – Pittsburgh Area Map with Bakery Square Highlighted

Building 1, which is positioned directly adjacent to the existing factory, is the focus of this thesis project. It is a six story mixed-use building comprised of a parking garage, retail stores, a restaurant, and a fitness center. The 378,000 square foot building has a current GMP set at $24 million. P.J. Dick has been hired to act as the construction manager at risk for this building along with the other facilities on site. Some unique features of this building include an elevated cast-in-place swimming pool and a hanging mezzanine level inside the fitness center. As of right now, the core and shell of Building 1 is under construction, but the tenant fit outs are scheduled to be completed by the summer of 2009.

Thesis Focus

Since Walnut Capital has been developing more and more areas of Pittsburgh each year, it is important for P.J. Dick, as the onsite construction management team, to continue to make a good impression. Walnut Capital has confidence in the quality of work P.J. Dick has to offer based on past their past performance on other joint projects throughout the area. For this reason, P.J. Dick has been able to secure contracts with Walnut Capital through negotiations rather than hard bidding.

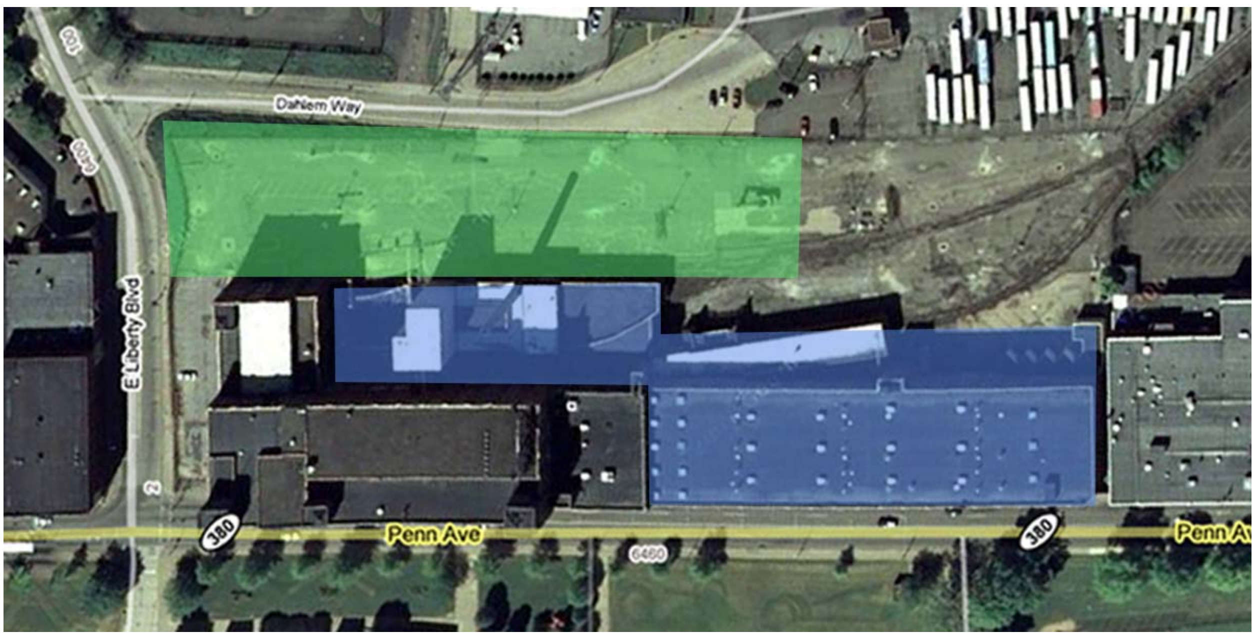
In order to ensure Walnut Capital's continued cooperation with P.J. Dick, they must maintain the high level of management they have provided thus far. For this thesis project, I will attempt to take the knowledge gained during my time as an architectural engineering student at Penn State and apply it to the project at Bakery Square. Analysis topics that are covered will suggest ways to alter the construction and management of Building 1 in ways that will improve the cost, schedule, and quality of the project.

Because of the recent attention being given to green design and construction practices, this project will focus on some alternative ways to incorporate these ideas into Building 1 at Bakery Square. It is also my belief that this surge to green design is an important change that must occur in order to better our industry, but in order to so efficiently and correctly construction management practices need to be altered. This area of interest will comprise the portion of the thesis project required to meet the M.A.E. requirements for the course.

PROJECT INFORMATION

Existing Conditions

The Bakery Square at East Side is located on the corner of Penn Avenue and East Liberty Boulevard in East Liberty. Building 1 is located on the northwest quarter of the property situated alongside the existing building that was once part of the Nabisco Corporation. The area in blue on the aerial photograph shows the portion of the factory that was demolished in the beginning of 2007. Building 1 is being constructed in the green area of the photograph. You can see that a portion of the existing structure and Building 1 are positioned very close to one another. In fact the foundations of the two buildings come within inches of touching. Therefore, the excavation and construction of foundations for Building 1 in this area will need to be executed in a precise and careful manner.



- Figure 2 – Aerial photograph of Bakery Square

Traffic problems are not a concern for the construction at Bakery Square because there is enough onsite space to move equipment that road closures will not be needed. There is also access into the site from all three surrounding roadways, which facilitates the construction managers need for site access and deliveries for at any time throughout project regardless of the current phasing and placement of equipment. The sidewalks along East Liberty Boulevard and Penn Avenue have been closed through city permitting, but pedestrian traffic is simply directed toward sidewalks that are in place directly across each street.

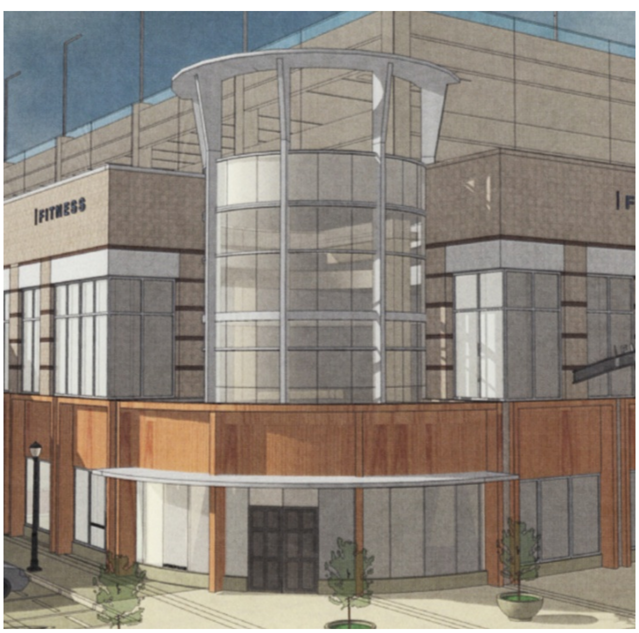
Subsurface conditions have been well documented through a soil investigation report performed in the beginning of 2007. There are no underground gas, water, or electrical lines located inside or nearby the footprint for Building 1. The only major concerns for excavation include an existing storm water system no longer in use and a railroad track that has been covered by the parking lot. Both of these items occur in unknown locations and must be dealt with accordingly if encountered.

Building Systems Summary

As part of the beginning analysis of Building 1 for the thesis project, properties of the building's architecture, design, and building systems were investigated and summarized into multiple reports. Important and unique features of these findings have been identified and included in this paper.

Architectural Features

The architecture of Building 1 is based on the clean lines provided by the precast concrete of the structural system. A majority of the building is a parking garage that is comprised entirely of the exposed precast concrete. An underpass separates the central and west portions of the building from ground level up to the third floor. Included in the design is a glass rotunda, which adds to the aesthetic quality of the building front.



- Figure 3 – Glass Rotunda Rendering

The fitness center located on the second and third floor of the east portion of the building takes advantage of the large open spaces made possible by the use of the 62 foot long double tee spans. Inside the fitness center there will also be a hanging mezzanine level that will add to the light and airy feel of the space.

Tenant spaces designed for retail and restaurant usage can also capitalize on the open floor plan created by the large spanning precast concrete system. The front façade of the building has not yet been determine and will be designed and built during the tenant fit out phase of construction. Each tenant will be responsible for their portion of the façade, but they are expected to follow guidelines provided by Astorino, the architect responsible for the core and shell design. Below is a rendering produced by Astorino that captures the aesthetic design that Walnut Capital is looking to create.

- Figure 4 – Rendering of Building 1's Façade

Structural System

Architectural precast concrete is the primary structural system for Building 1 at Bakery Square. The structural layout of the building follows a common 34' x 62' grid that is mirrored along the length of the building. This formation is based on the use of 62' long double tees that compose the floors throughout the building. Precast concrete columns carry the loads down to an intricate system of piles, which in turn transfer all loads to the bedrock located roughly 32' below the surface.

Structural steel is also included in the design for Building 1 in a few select locations. The pedestrian bridge across to the existing factory is one of these locations. Another area that uses structural steel is the hanging mezzanine level inside the fitness center. The hanging columns are attached to steel supports located beneath the 4th floor's precast tees, and support a 5-½" composite slab. The largest members required for this design include a W33x354. These large members will require hook time on the Manitowoc 999 crane that is being used by the precast erectors.

Lighting and Electrical System

A main switchboard is dedicated to the fitness center, while the retail space and the garge share another separate switchboard. Power to Building 1 is fed through a main electrical bank located underground that is used by all of the buildings located at the Bakery Square facility. Temporary power is produced by using a 100 KW diesel generator positioned directly behind the back of Building 1. This generator provides power to the elevators, emergency lighting and emergency systems when an interruption in grid power occurs.

The lighting system for Building 1 is pretty basic for the purpose of the core and shell portion of the project. Common fluorescent and cold weather parking garage type fixtures are called for throughout the entire garage portion of the building. The retail and fitness center spaces of the building also use a system of fluorescent lighting all along the first and second floor.

Unique Design Features

As a construction manager certain features of the design require some additional attention due to cost, scheduling, or complexity issues. Those features in Building 1 at Bakery Square include the elevated cast-in-place swimming pool that is to be constructed inside the precast concrete shell, the hanging structural steel mezzanine level located inside the shell of the fitness center, and the glass rotunda that is situated at the southeast corner of the building.

The cast-in-place swimming pool is located on the second floor of the building toward the back of the building above the retail space. Since the precast structure completely envelops the pool, P.J. Dick decided that the best course of action was to erect the pool during the early phase of the project while concrete was being placed for the foundation walls. By doing so, they allowed the precast subcontractor to work continuously along the building without any interruptions.

The hanging mezzanine level added additional concerns to the fabrication and scheduled erection of the precast pieces in that area. Steel supports needed to be embedded into the precast columns through early coordination. The erection of the large supporting members, which ranged from 99 to 354 pounds per linear foot could possibly slow the erection of surrounding precast because the same crane was to be used by both crews. Early lead times were required for these massive beams and were required to be delivered onsite at the appropriate time.

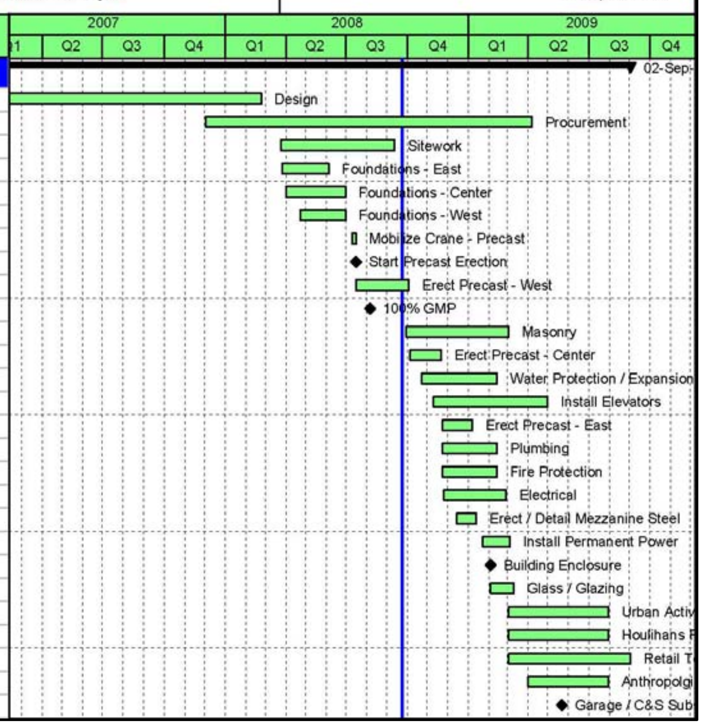
P.J. Dick had already value engineered the glass rotunda due to constructability issues. The complex glass structure was detailed in a way that limited the number of quotes the construction manager could get for the façade. But by working with the architect and owner P.J. Dick was able to share valuable input that increased the productivity for the construction of the rotunda and decrease the cost of the materials needed without sacrificing the quality or aesthetic appeal of the original design.

Project Schedule

Important phasing for Building 1 at Bakery Square include the foundation and underground work, bridge construction, finishes, and the precast erection sequencing. A summary schedule, which illustrates the major activity groups anticipated schedule, can be viewed directly below. However, a project schedule that shows detail activities and project milestones is attached in Appendix A.

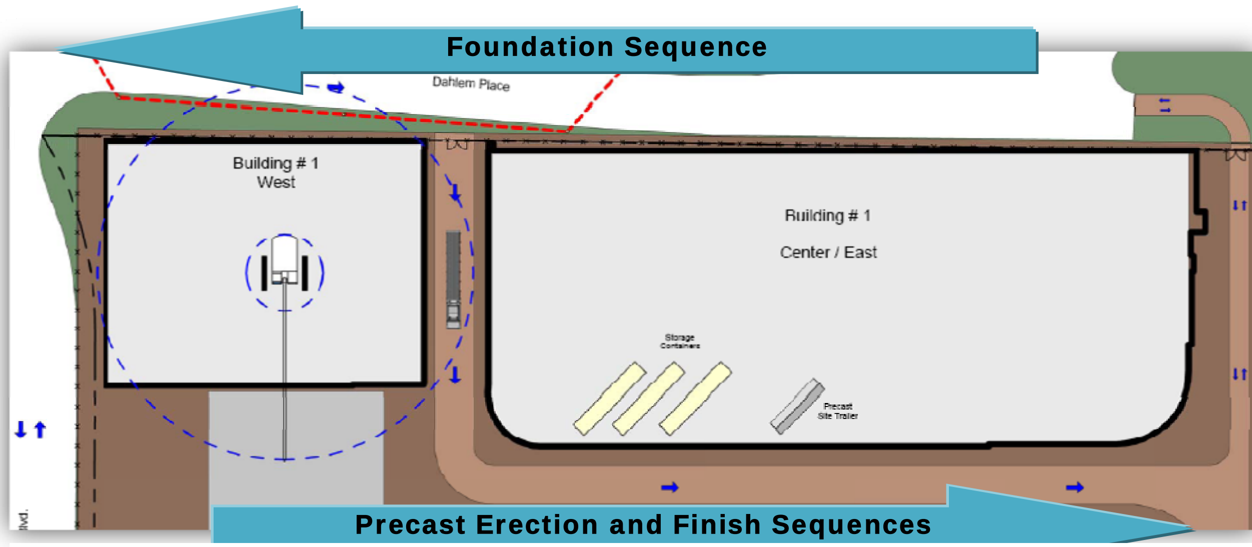
Project Schedule Summary | Classic WBS Layout | 29-Sep-08 14:14

Activity ID	Activity Name	Original Duration	Start	Finish
Building 1 @ Bakery Sq...		697	02-Jan-07	02-Sep-09
01	Design	300	02-Jan-07	25-Feb-08
02	Procurement	351	03-Dec-07	06-Apr-09
03	Sitework	124	25-Mar-08	12-Sep-08
04	Foundations - East	51	27-Mar-08	05-Jun-08
05	Foundations - Center	65	01-Apr-08	30-Jun-08
06	Foundations - West	49	23-Apr-08	30-Jun-08
07	Mobilize Crane - Precast	5	09-Jul-08	15-Jul-08
08	Start Precast Erection	0	16-Jul-08	
09	Erect Precast - West	58	16-Jul-08	03-Oct-08
10	100% GMP	0		06-Aug-08
11	Masonry	112	29-Sep-08	03-Mar-09
12	Erect Precast - Center	35	06-Oct-08	21-Nov-08
13	Water Protection / Expa...	82	23-Oct-08	13-Feb-09
14	Install Elevators	123	10-Nov-08	29-Apr-09
15	Erect Precast - East	32	24-Nov-08	06-Jan-09
17	Plumbing	59	24-Nov-08	12-Feb-09
16	Fire Protection	59	24-Nov-08	12-Feb-09
18	Electrical	69	24-Nov-08	27-Feb-09
19	Erect / Detail Mezzanine...	22	15-Dec-08	13-Jan-09
20	Install Permanent Power	30	22-Jan-09	04-Mar-09
21	Building Enclosure	0		03-Feb-09
22	Glass / Glazing	25	04-Feb-09	10-Mar-09
25	Urban Active Fit-out	110	02-Mar-09	31-Jul-09
24	Houlihans Fit-out	110	02-Mar-09	31-Jul-09
23	Retail Tenant Fit-out	132	03-Mar-09	02-Sep-09
26	Anthropolgie Fit-out	88	01-Apr-09	31-Jul-09
27	Garage / C&S Substanti...	0		21-May-09



- Figure 5 – Summary Schedule for Building 1 at Bakery square

The project schedule follows a path down and back the length of the building. The foundations were placed starting at the east end of the project and finishing on the west. From there the precast subcontractor moved from West to East with their erection sequence. Below is a portion of the site plan during the first phase of precast installation. Finishes and system installations followed the path of the precast erectors moving from West to East.



- Figure 6 – Site Plan with Sequencing Illustrations

Project Cost

The overall cost for the six-story, 378,000 square foot building was established through a GMP with Walnut capital listed at $24 million. This is roughly equivalent to $64 per square foot for a mixed-use garage, retail, and fitness center. During cost evaluation for thesis analysis, a combination of parking garage and retail store estimate information was used to determine the accuracy of construction costs. The multiuse nature of the building made it very difficult to compare it to other projects using standard parametric and square foot estimating methods, but costs were found to be within a 5% tolerance range.

P.J. Dick was hired by Walnut Capital using a Cost Plus Fee with a GMP type contract. A fixed fee of 4%, with a contingency for unfinished portions of the design, was established prior to the start of construction. The contingency will be divided 75% - 25% to the owner and the construction manager respectively if the project is brought in below the $24 million budge. All other cost information was withheld from the report by the request of Walnut Capital.

Local Conditions

Since labor unions are an important part of construction around the Pittsburgh region, this project is quite standard in the fact that it requires 100% union participation. It is standard in the region to use cast-in-place concrete as the structural system for many of the buildings. However, precast concrete systems have made an immergence in recent years due to schedule and cost constraints. This trend is especially true for parking garage structures.

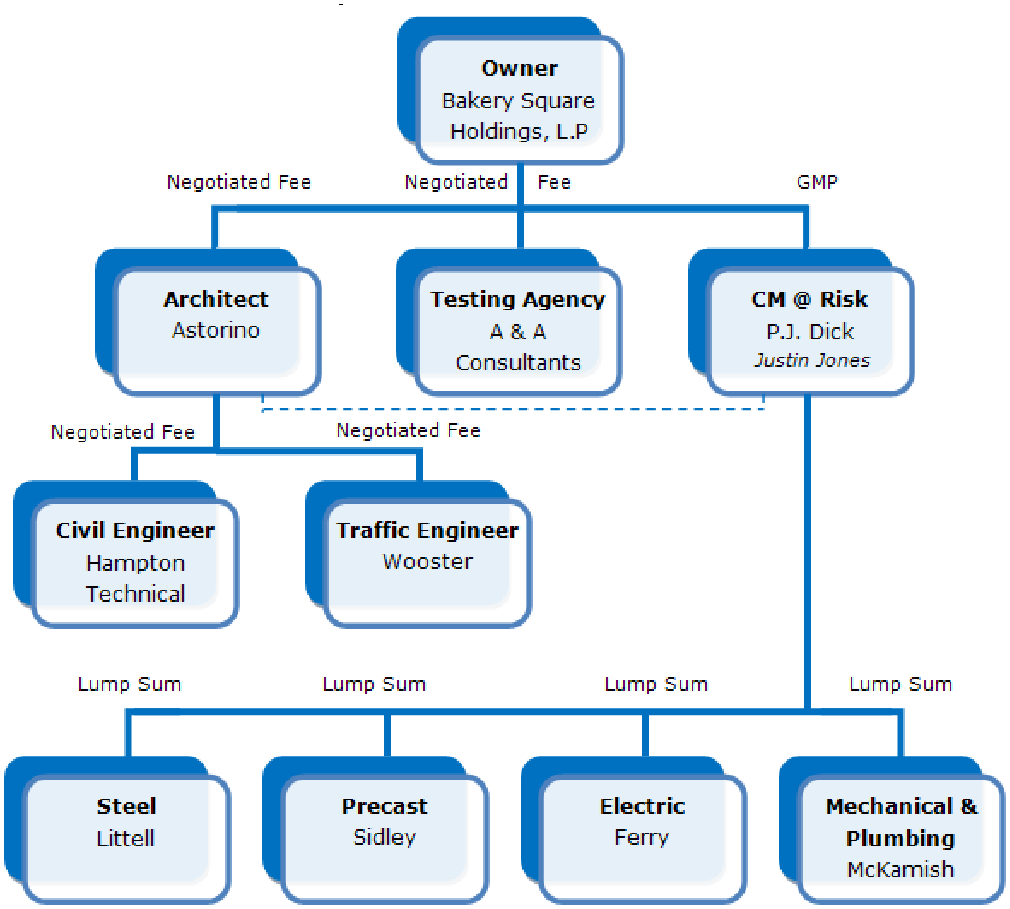
A diminishing labor pool was a concern for the construction managers at P.J. Dick. Construction had recently begun on a number of large scale projects in the Pittsburgh area, which drastically reduced the number of available workers. This affected the mechanical, electrical, and plumbing subcontractors in particular. They had to plan their work carefully in order to ensure that the unions were able to supply them with the necessary number of workers required to complete the work on schedule.

With the concurrent construction and renovation of four other Bakery Square Development buildings, the site logistics were an important factor to consider. The constant phasing requirements of the project made the site very congested. Parking privileges were given to the construction management team, subcontractor superintendants, and one foreman per company. This allowed them to take advantage of the limited onsite parking. Additional vehicles were required to find alternative parking offsite. Workers took advantage of free side street parking located a block from the site to avoid parking costs. After the first phase of precast concrete was finished on the West portion of the garage, additional parking spaces were made available. Recycling and tipping fees in the area were priced around $400 for a two week rental on a 30 CY dumpster.

A subsurface investigation was performed in early 2007 with a total of twelve bores drilled within the footprint of Building 1. It was revealed that the soil was of silty/sandy composition and heavily saturated with ground water. Due to the nature of the soil and the moderate to high load of Building 1, the subsurface investigation report recommended the use of deep foundations.

Delivery System

A construction management at risk type delivery system is being used by P.J. Dick for Building 1 at Bakery Square. Since Walnut Capital was familiar with the construction management team through previous working relationships, this type of delivery system was comfortable for both parties involved. Because time, cost, and quality are important to any project, the owner must choose the appropriate delivery system to ensure project success. The factors taken into consideration for this project include the criticality of time, the well experienced owner and project team, the high quality demanded, and the strict adherence to budget. A construction management at risk structure is a well delivery system for all of these qualities. The project organization chart, which is detailed down to the major subcontractors, can be seen below.



- Figure 7 – Project Delivery System Chart

Subcontractors were chosen based on lump sum evaluations. Scope reviews were performed prior to awarding the contract to the low bidder in order to adjust prices and compare comparable bids. Since the project was insured through an Owner Controlled Insurance Policy (OCIP), subcontractor pricing did not include any insurance costs. However, bonds were required if the value of any subcontract exceeded $500,000.

Owner Information

Walnut Capital is the developer in charge of the Bakery Square project at East Side whom prides themselves as a leading developer and property manager of real estate in the Pittsburgh region. Community improvement has been a major priority of theirs, which can be recognized by the number of their developments placed in and around the East Side. Their office is located less a mile from the Bakery Square site.

There are a number of concerns for this property that Walnut Capital is focused on in order to make this project a success. Just as is expected of the entire Bakery Square facility, Building 1 must meet the high standard of quality required by the development team. Since the funding for this project is coming from limited sources, the budget must be adhered to in order for a successful completion. This building is also part of the first LEED rated facilities that Walnut Capital has endeavored on, but they do not expect a decrease in efficiency for the project. Scheduling is another concern of the owners due to the multi-phased nature of the project. Tenants must be able to occupy their finished spaces on time even while other construction is still occurring on site and inside Building 1. Last but not least, Walnut Capital demands a strict control on safety during construction.

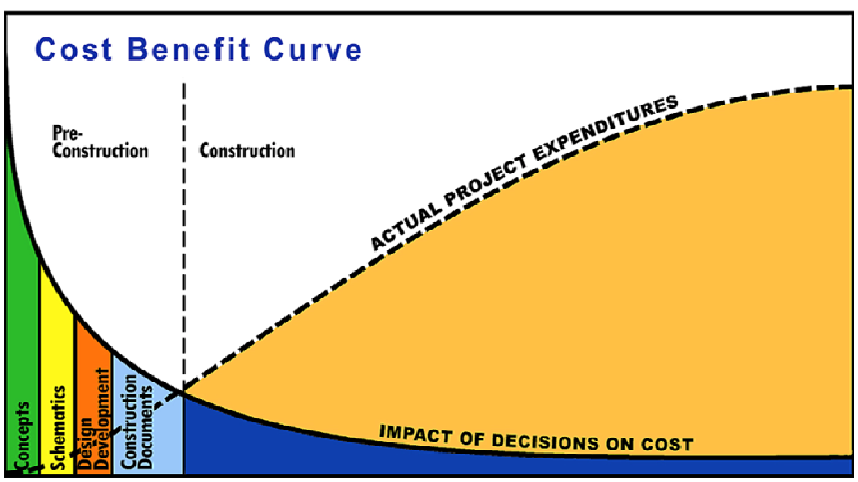
SUSTAINABLE GYM FEATURES INVESTIGATION

Background

Ever decreasing natural resources, potable water supplies, and ecosystem stability, coupled with increasing energy costs, and global population create a monumental problem that this and future generations must overcome. This global emergency is the basis of the second analysis for the thesis report and the reason why sustainable design should be considered a critical industry issue. Sustainable or green design principles include the use of renewable and recycled materials, lower energy consumption, less site and natural disturbances, decreasing water consumption, and improving the air quality inside buildings.

Architectural engineers have a unique opportunity to be able to affect the design of a building in many ways through an integrated approach. Sustainable design in particular requires a unified design. The diverse background of an architectural engineer allows him / her to cross the normal boundaries in construction and create a better building through interdisciplinary design. By changing one system in the design of a building, multiple changes will occur throughout the rest of the design. It is critical that these cause and effect scenarios be better understood in order to provide a more sustainable building.

Since the basic design of Bakery Square has already been completed, changes made at this point will have minor effects to the overall building performance. As with any decision that is made for a project, when sustainable design alternatives are adopted earlier in the project, they will have larger impacts on the building with lower expenditures. Without going back and redesigning the entire building, there are still some green technology ideas that can be cost-effectively added to the project. The study for this analysis will focus on choosing better materials and reducing the amount of energy used by the facilities.



- Figure 8 – Cost Benefit Curve

It is estimated that buildings consume over a third of the energy used in the United States. By decreasing energy usage in new facilities, the design and construction industries can play a major role in reducing negative impacts to the global environment. Building 1 has a couple of features where energy reducing technology could be applied. The fitness facility inside Building 1 offers a unique situation. Is it possible to use the energy expended by the gym members to power the building by transforming physical energy to electrical energy?

After analyzing the different green technologies that could be implemented in Building 1, this report will determine which ideas would be most viable. Any incorporation of these systems should improve the quality of Building 1, but it is unknown what the cost implications will be at this time.

Pedal Power

The first idea of how to transfer mechanical energy to electrical energy is through the use of exercise bikes located in the fitness center. It can be easily noticed that by rotating the pedals of a bicycle the rider can produce electricity in a way similar to how a hand powered flashlight is operated. The flywheel of the bicycle can be attached to the fan belt of an electric generator. Energy can then either be used directly from this generation, stored in battery banks, or fed onto the grid and sold to the power company. There are a few models that are available for sale, and they will be used during the analysis of this green technology.

- Figure 9 – Electric Generating Bicycle

In order to properly determine if this technology will be viable, a couple of factors must be put into consideration. How much power can an average gym member produce while riding on a stationary bicycle? This is the most important question that must be answered to test the feasibility of this idea. The cost of the equipment, cost of electricity from the power company, and the electrical load must also be found to complete the analysis.

A research project performed in 1977 by Oxford Professor James McCullagh studied how muscle power could be turned into electrical power through the use of a stationary bike. In his book *Pedal Power*, it is pointed out that an ordinary bicyclist could produce an average of 75 watts of power or 200 watts for shorter periods. More recent studies have found that Lance Armstrong is able to generate 500 watts for 30 minutes at peak performance.

- Figure 10 – Windstream Generator

Windstream Power offers a different type of electrical generator that is used along with an actual riding bicycle. This type of technology allows a user to mount their bicycle to a holding frame where the rear tire rests on a friction drum. When the bicyclist pedals, the tire rotates the friction drum, which then turns the generator and produces electricity. They claim that by using the Bike Power Generator an average user can expect to produce about 150 watts of power sustainably. A peak of 275 watts can also be produced during short bursts.

For the purpose of this analysis, the calculations will be based on an average output of 150 watts. This is a reasonable assumption because even if the claims are a little inflated it is most likely that the gym members will not be on the bicycles for an overextended period of time. It is common for most gyms to restrict equipment use to 20 minutes when other people are waiting to use a machine.

Equipment schedules for the fitness facility indicate that Building 1 will contain 25 stationary bicycles. If all of these bicycles were being used at one time the average output for the group would be about 3,750 watts of power. However, the fitness center will not be at full capacity at all times of the day. An average of 50% bicycles used and 90% efficiency of the inverter or battery bank can be applied to this calculation to determine that the average output for the bicycles is about 1,690 watts of power. In order to understand this number the lighting loads must be calculated for Building 1's fitness center.

There are two areas inside the fitness facility that can be considered for the purpose of this analysis. The spinning room by itself should be analyzed to determine if the bicycles could power this area alone. The entire area of the fitness center should also be considered in order to see what percentage of electricity can be generated. ASHRAE Standard 90.1 and the actual electrical plans will be used in order to calculate the loads inside the fitness facility.

By reviewing the electrical drawings, it was determined that 478 watts of power is required to light the spinning room. This loading consists of fourteen 25 watt incandescent and four 32 watt fluorescent fixtures. The entire lighting load for the fitness center can be approximated using ASHRAE Standard 90.1, which defines the maximum power density allowed for lighting. The power density for a fitness facility must be equal to or lesser than 1 watt per square foot. This means that for the 42,000 square foot fitness center the lights may use 42,000 watts.

The last part of the bicycle analysis is the cost of the equipment. Products listed online were listed from anywhere between $380 and $600 per machine. With the assumption of an average cost of $500 per bike and $500 for a 5,000 watt inverter, the cost before installation would be around $13,000. A similar project completed at Oregon State University cost $15,000 for 22 elliptical machines. Therefore with installation included the green bicycles should cost about $16,000.

Description	Cost per Unit	Units	Cost
Equipment	$500	25	$12,500
Inverter	$500	1	$500
Installation	$3,000	1	$3,000
Total			$16,000

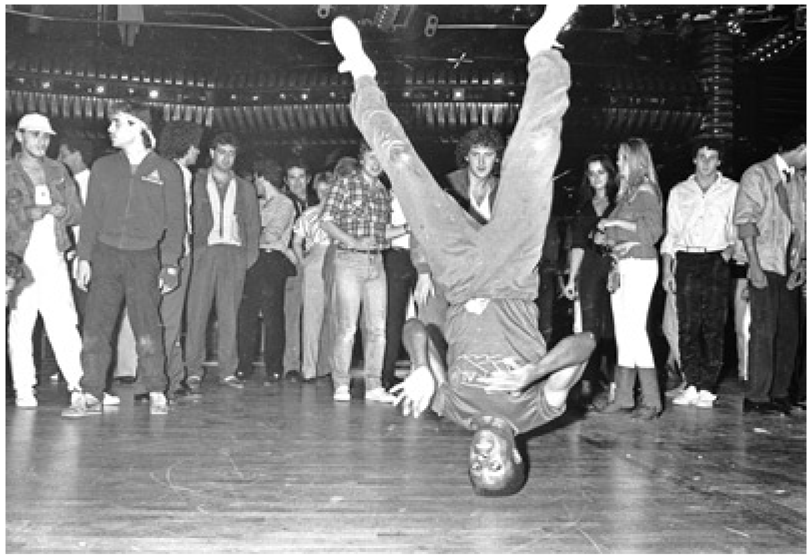
- Table 1 – Bicycle Generator Costs

At an electrical rate of 10 cents per kilowatt hour, it will cost $4.20 per hour to light the fitness facility. If the same assumption that the bikes are used only 50% of the time, then for every hour the facility is being lit, the bicycles will produce 1,690 watts worth of power. This translates to saving 16.9 cents per hour. Only three riders would be required in order to power the lights in the spinning room. If the gym is open for twelve hours a day and the bicycles were used only 50% of the time, the payback period for the equipment is about 21 years.

Piezoelectric Floor Tiles

The second form of green technology that could be introduced and used inside the fitness facility is piezoelectric floor tiles. Specially made floor tiles can be used to harness the mechanical energy of walking and turn it into electrical energy. These systems have been installed in a train station in Tokyo and numerous dance clubs around the world. The technology is based on piezoelectricity, which is the ability for quartz crystals or ceramics to create an electric charge when they are stressed. This same principle is used in gas grill igniters, microphones, and quartz watches.

The main problem with piezoelectric generation is that the quantity of energy produced by each interaction is quite small. Therefore the best places to use this technology are in locations where there is a lot of foot traffic. For example, the train station in Tokyo is able to harness the energy from walking because over 400,000 people walk through the station each day. Dance clubs are also able to use piezoelectric floor tiles because of the intense bouncing and movements created by the club goers. The London club Surya claims that they are able to produce 60% of their energy needs through harnessing power through piezoelectric floor tiles.



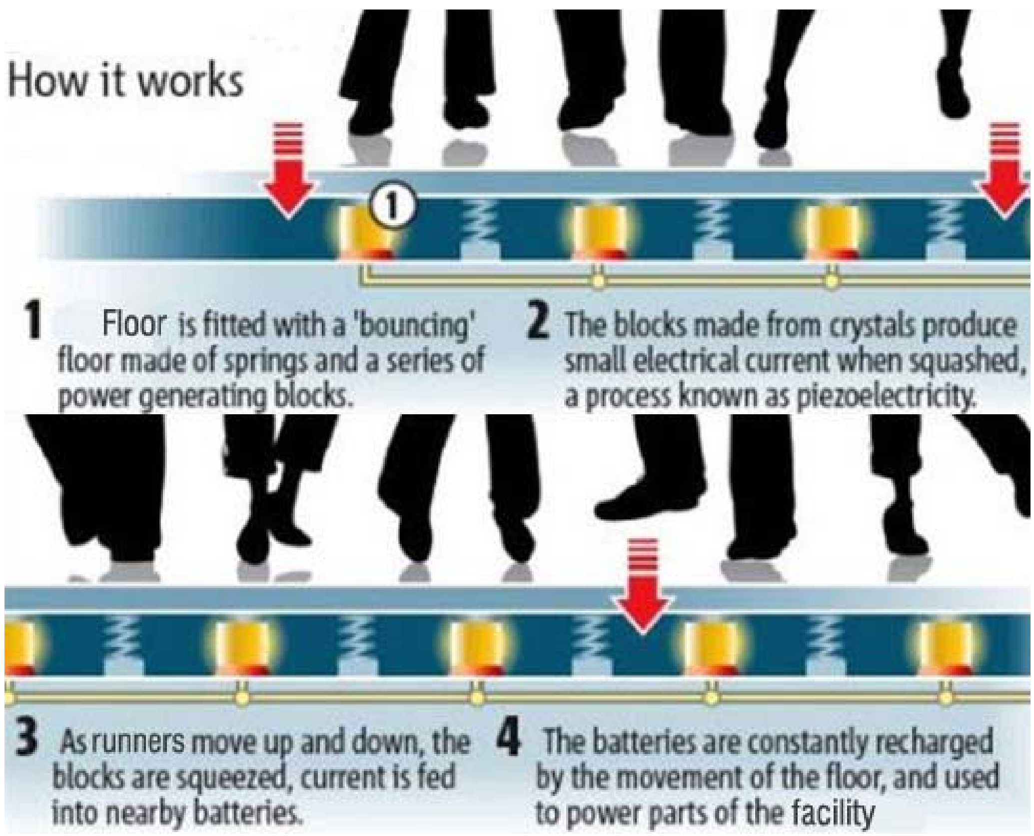
- Figure 11 – Piezoelectric Floor Tiles Harness Energy from Dancers

Just how much energy is created from people walking? A person weighing 132 pounds would be able to generate .033 watt per each step he / she takes. This means that one footstep would be able to power a 60 watt bulb for two seconds. Some assumptions need to be made in order to determine how much energy can be created by the floor tiles.

The calculations for this analysis use the following assumptions. An average of 140 steps per minute (SPM) will be used as the rate at which walkers and runners will move around the track. It is recommended that walkers aim to keep stride at 100 SPM, and it is documented that runners in full stride tend to run at over 180 SPM. Therefore a rate of 140 SPM can be considered a reasonable assumption. By polling several similar sized facilities in the Pittsburgh region, the fitness facility at Bakery Square is projected to service about

1,000 members per day. This analysis will also assume that only 50% of the gym goers will actually use the track. It is also assumed that for these 500 members they will only walk or run for a limited 30 minute timeframe. This should accurately account for entire walking / running workouts and those using the track for warming and cooling down.

By following the assumptions and completing the calculations, the average daily energy output for the piezoelectric floor tiles can be found. A total of 69,300 watt hours would be produced daily. This would account for almost 14% of energy used to light the facility. These figures could differ depending on the number of footsteps taken on the tile based on the number of users and their steps per minute. A walker/ runner with a different weight would also cause the energy output to differ. The average weight of gym goers is probably higher than 132 pounds, but energy generating data was only found for that given weight.



- Figure 12 – Piezoelectric Floor Tile Description

The cost for the piezoelectric floor tiles is going to be very expensive due to the fact that it is an extremely new technology. Actual prices have not been published for the floor tiles, but estimates have been made to place the costs around $100 per square foot. The piezoelectric floor tiles would be able to generate electricity throughout the entire fitness center, but due to the high cost of the system, it would be best if the floor tiles were placed in only high trafficked and high impact areas. For that reason, the piezoelectric floor tiles should be placed only on the track area located on the mezzanine. This area is approximately 3,000 square feet and would cost around $300,000. With an annual cost savings of $2,529 this technology would have a payback period of over 100 years making it practically unfeasible for Building 1 at Bakery Square.

While the technology for a piezoelectric floor is extremely expensive at this point in time, the owners could possibly justify the additional expense by realizing the amount of attention that the floor system would bring. The system is a great example of innovations in green technology and would be a great item to showcase at Bakery Square. With future improvements to the technology by increasing efficiency and decreasing cost of the floor tiles, the piezoelectric floor system could soon become more feasible.

Green Materials

Another important part of sustainable design is the use of green materials, which are made from either recycled content or rapidly renewable resources. In fact a total section of the LEED program is dedicated to materials and resources. Floors located in the gymnasium and cardio spaces are specified to be constructed using maple hardwood flooring. Alternative flooring materials will be investigated with the hope of providing a more sustainable fitness center.

While maple hardwood is considered certified wood by the Forest Stewardship Council (FSC), this product cannot be considered to be a rapidly renewable resource. The definition of a rapidly renewable resource is a product that is made from plants typically harvested within a ten-year cycle. The average harvesting period for maple hardwood is about fifteen years long. Bamboo flooring, which has a harvesting period of three to five years, will be investigated as a possible alternative.

Questions about the durability, strength, hardness, and ball rebounding properties of bamboo flooring must first be answered. Through the production process the bamboo plant is boiled and hardened. The durability and hardness of bamboo flooring is comparable to traditional wood floors. A product by the name of Plyboo Sport has the following physical characteristics, and it can be seen that the system has met all the requirements of DIN, a worldwide sports standard for many decades.

Evaluated Characteristics of DIN 18032 Part II (1991)	Test Results (Avg. Values)	DIN 18032 Part II (1991) Requirements
Ball Rebound	93%	90% Minimum
Force Reduction	54.2%	53% Minimum
Vertical Deflection	2.80mm	2.30mm Minimum
Area Indentation	15%	15% Maximum

- Table 2 – Plyboo Sport Flooring Test Results

Since it has been determine that bamboo meets the quality requirements and is more sustainable than a traditional maple floor, the other factor that must be considered is cost. The Concord II flooring system is specified to be used for all of the wood floors inside the fitness center. A finished installation cost for the maple gym floor would equal $10.50 per square foot. The Plyboo Sport flooring system has been determined to have a total cost of $10.00 per square foot. For the 6,000 square feet of gymnasium space, the total costs for each system have been documented below.

System	Cost / SF	Area	Total Cost
Maple Concord II	$10.50	6,000	$63,000
Bamboo Plyboo Sport	$7.75	6,000	$46,500

- Table 3 – Floor Cost Comparison

A more sustainable choice of material was considered for the gymnasium spaces in the fitness center. A rapidly renewable bamboo floor could be used instead of maple, without sacrificing costs or quality. This should be considered to be a successful value engineering suggestion.

Green Gym Design Summary

The analysis of sustainable technology for a gym application has yielded has some interesting results. Both energy reducing technology and sustainable material choices were evaluated. While both power producing systems are expensive in upfront costs, the bicycle generator appears to have a reasonable payback period. All of the discussion topics are a good example of value engineering for the fitness center portion of Building 1 at Bakery Square.

The idea that human energy from a gym can be harnessed and used to generate electricity is an exciting topic. Since the technology for this application is relatively new, large gains in efficiencies and decreases in costs should be seen in the following years making it even more worthwhile. The electrical generation ability of the bicycles and floor tiles are summarized below and compared to the total lighting loads of the fitness center.

Description	Daily Power (WH)	Daily Cost	Yearly Cost	% of Load
Spinning Room	5,736	$0.57	$209	-
Fitness Facility	504,000	$50.40	$18,396	-
Bicycles -50%	20,280	$2.03	$740	4.0%
Bicycles -75%	30,360	$3.04	$1,108	6.0%
Bicycles -100%	40,500	$4.05	$1,478	8.0%
Piezoelectric	69,300	$6.93	$2,529	13.8%

- Table 4 – Resulting Energy Reductions with Green Gym Technology

The green material investigation has proven to be a success. The fitness center should be able to provide a more sustainable workout area without sacrificing in terms of cost or quality. However, it might be hard to persuade a chain like Urban Active to deviate from tried and true materials. At the end of the day the owner will have to decide if the Plyboo Sport floor is acceptable.

ADDITIONAL SUSTAINABILITY STUDY

Background

The parking garage is one area where electricity could be saved by reducing the amount of time the lights are on inside the garage, especially during night when there the space is minimally used. The integrated M.A.E. research portion of thesis is completed in this portion of the report. An innovative green lighting system used for parking garages is researched and documented.

Alternative Garage Lighting

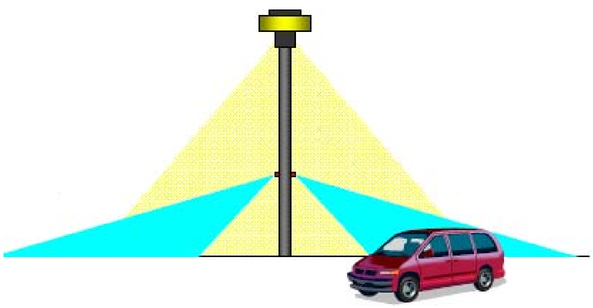
A learning objective of AE 597D is to gain a detailed understanding of a "green" building technology. As an extension of the green gym analysis this research will focus creating a more sustainable parking garage by reducing the energy required to illuminate the parking structure. The lights in a parking garage are normally operated 24 hours a day even when the lights may be unnecessary or when the structure is minimally being used. This analysis will evaluate an alternative system that combines the use of bi-level lighting and motion sensing equipment to reduce the lighting load of the parking garage.

Even while parking garages are not being heavily used, such as the late hours of the night, all of the lights in the building are still on. Through the use of motion sensing technology, the building would be able to operate at a more efficient manner. In essence it would be similar to turning off the lights when you leave the room.

- Figure 13 – Empty Parking Garage Fully Lit

A study is being done in California by the Smart Energy Initiative on the ability of bi-level lighting systems to save energy in parking garages and similar locations. Dr. Siminovitch at UC Davis heading the research project and expects to find a viable way to improve the energy performance, safety, and maintenance requirement for exterior lighting systems.

The system itself is a combination of bi-level LED lights coupled with microwave motion sensors. To begin with, the LED lights should prove to be more energy efficient. When the parking garage is not being used, the lighting system operates the lights in a standby mode by dimming the lamps. When motion sensors detect movement in the parking garage the lights will begin to illuminate the garage at the luminaries' full capacity.



- Figure 14 – How Bi-level Controls Work

A question of safety arises when reviewing this approach to energy savings because dimmed lights will create a dark space inside the parking garage. However, due to the motion sensing system an area will can be lit prior to someone's entrance into the garage. By spacing the motion sensors appropriately and connecting them to several surrounding lights, the parking garage can light up the path of the car or pedestrian traveling through the garage.

An experimental system was installed in a parking garage located on Sacramento State University's campus. The bi-level LED lighting system's effect on light quality, energy consumption, and maintenance requirements were all studied and have be summarized into the following table.

Design	Outcome
Light Quality	Improved light quality from CRI 22 to CRI 80
LED Energy Savings	40% less energy
Bi-level Controls Energy Savings	30% less energy
Maintenance Savings	6 times long lifespan

- Table 5 – Properties of Bi-level LED Lighting System

A similar system could be installed into the parking garage portion of Building 1 as a way to improve the sustainability of the building. However, the energy consumption of the two buildings differs and must be adjusted for correct analysis. While the parking garage at Sacramento State initially used 150W high pressure sodium lights, Building 1 is designed for four 32W fluorescent lights totaling 128W per fixture. Therefore the energy savings from switching to LED lights is only about 30%, and the total energy consumption reduction would equal 60% of the original design.

A sample area inside the Bakery Square parking garage of almost 10,000 square feet uses 2,944 watts of electricity. When extrapolated to the entire parking garage, the lighting load totals over 81,000 watts. By implementing the bi-level LED system, 60% or almost 49,000 watts of electricity could be saved. This translates roughly to $59 a day or $21,535 per year in cost savings if the lights are operated for 12 hours a day.

Description	Daily Power (WH)	Daily Cost	Yearly Cost	% of Load
Parking Garage	977,000	$97.70	$35,672	-
Bi-level LED	586,400	$58.64	$21,403	60%

- Table 6 – Bi-Level Energy Reductions

Summary

The bi-level system appears to be a very worthwhile system to install in the parking garage at Bakery Square. Parking garages are not considered to be sustainable, but this system could change that perception. The system would save over $21,000 or 200,000 Megawatt-hours worth of electricity per year. This accounts for a 60% decrease in energy and even if the energy saving is half of the projected value it still has a significant impact. A bi-level LED garage is a promising alternative for Bakery Square and should be considered for all new parking facilities.

LIGHTWEIGHT MEZZANINE SYSTEM ANALYSIS

Background

The mezzanine level located inside the fitness center is being analyzed for this portion of the thesis report. Large structural members, which span across the gym between precast columns, support the hanging level below. These large pieces of steel slow the progression of the precast subcontractor because crane time must be used to erect these large members. Lightweight structural systems will be reviewed as possible alternatives to this bulky system.

The purpose of using a lightweight system instead of structural steel is to improve the project through a successful value engineering exercise. A lightweight system should prove to be an improvement in the mezzanine level's constructability, which in turn should also improve the schedule by reducing the time required to erect the hanging floor system.

A lighter weight system will eliminate a need for hook time from the precast crane. It should also decrease the schedule because the members will be smaller than a structural steel system. Production for the erection of structural systems increase when smaller members are used because the pieces become more manageable for the workers and require less people or machinery to erect.

Lightweight System Review

Alternative structural systems were investigated for use on the mezzanine level inside Building 1. Alternative systems were included in the review by meeting some initial design criteria. The new systems should be lightweight, should not impede the progress of the precast erection, and be able to connect to the precast superstructure. The systems that meet these criteria include a wire rope assembly, precast concrete, and open web joist supports.

- Figure 15 – Wire Rope

A Wire rope assembly would support the mezzanine level by attaching the system to the parking garage structure above. This system differs from the current structural steel design because the large beams do not have to be erected in order to support the hanging columns. Instead of using the bulkier structural steel, the wire ropes can be arranged into a web system of tensioned supports. Steel imbeds must then be incorporated into the precast design as anchoring points for the cables. This system would give the fitness center a unique aesthetic look that would make the structure appear to be very lightweight and airy.

Constraints determined by the fitness center's use of the mezzanine would limit the usefulness of a wire rope system. In order to support the track, additional supports would need to be added to eliminate the floor from bouncing. The large size of the level also requires an extremely large number of cables for proper support. While this system might be the best aesthetically, it is not the best system for this particular application.

The second system reviewed was a precast concrete structure. A logical alternative is to continue to use the same structural system throughout the entire facility. A mezzanine level composed of precast concrete easily ties into the existing structure. The long spans of the precast will create an open floor plan on the mezzanine level. The erection of these additional double tees can easily be incorporated into the precast contractor's schedule.

This system will be cheap and easy to implement, but required crane time remains unchanged and the aesthetics of the space changes drastically. Crane time required to erect the mezzanine is not affected when precast concrete is used. The precast contractor will still have to devote hook time to the mezzanine level. The light and open-air aesthetics of the fitness facility will also suffer from this type of system because the mezzanine will take up a lot more area, which will close in the lower level. The down sides of a precast concrete mezzanine eliminate the design as an applicable alternative.

- Figure 16 – Open Web Joist Example

An open web joist support system is the final alternative design reviewed for this analysis. This system is lightweight, open, and easily integrated with the precast concrete structure. Crane time will no longer be required to erect the mezzanine floor, which will decrease the project schedule. The lightweight open system can retain the airy feel inside the fitness center. Imbeds in the precast columns will be used to support the system. An open web joist system meets all of the criteria defined for an alternative mezzanine structure. To continue the analysis, the loads must be determined, the joist system will be sized, and the costs of the two designs need to be found for comparison.

Web Joist Design

The construction documents specify that the design load for the mezzanine level is 100 psf. An open web joist system was designed according to the column spacing and floor layout from the original design. Some areas toward the rear of the building were specified to be open to the lower level, but these locations are directly above storage space and locker room facilities. Therefore, it is acceptable for the web joists to span over top of these spaces.

Open web joist construction is based on evenly spaced joists supported by a girder beam, which can be attached to the precast concrete. The typical bay size for the fitness center is 34′ x 62′. Therefore, the girder beams will span 34 feet and the open web joists will span 62 feet between the girders. The maximum loading occurs in areas where the floor of the mezzanine level covers the entire bay. The loads for the mezzanine level include a dead load of 57 psf for the composite deck and a live load of 100 psf. The following calculations were made to determine what joists and girders should be used:

Joist Calculations

1.2(DL) + 1.6(LL) = FL	1.2(57) + 1.6(100) = 228.4 psf
FL(spacing) = Distributed Load	228.4(5.67′) = 1,295 plf
Distributed Load + self weight = Joist Load	1,295 + 47 = 1,342 plf
Joist Load(Joist Span) = Total Load	1,342(34′) = 83,204 lbs
Check that Total Load < Safe Load	83,204 < 87,300 OK

Girder Calculations

Joist Load(Joist Span) = Total Load	1,342(34′) = 83,204 lbs

Based on the above calculations and using Vulcraft catalogs the size of each open web member could be determined. The following table describes the properties of both the joist and girder beam required for the mezzanine level.

Member	Name	Unit Weight (lb/ft)	Depth (in)	Span (ft)	Load
Joist	44LH17	47	44	62	83.2 kips
Girder	36G6N83.2F	177	36	34	505 kips

- Table 7 – Steel Joist Properties

Cost Comparison

The costs of each system must be compared in order to complete the analysis. Costs for a typical bay of the steel joist system are calculated and then extrapolated into a total cost for the whole mezzanine level. The costs for the structural steel system were calculated for technical assignment 2 and can be used for this study.

The cost of the steel mezzanine structure was broken down into material, labor, and equipment costs. Complete calculations are included in Appendix B. The total cost of the structural steel system came out to be $341,558. The cost break down is shown in the following table.

Description	Material ($)	Labor ($)	Equipment ($)	Total Cost ($)
Steel System	$264,134	$22,793	$11,053	$341,558

- Table 8 – Structural Steel Costs

Each bay has two girders and six joists supporting the mezzanine floor. By simply counting bays and taking into consideration to not count girders twice, there is a total of 12 girders and 60 joists. R.S. Means was used to determine the final costs of the steel joists.

Member	Count	Weight (Ton)	Unit Cost ($/Ton)	Total Cost ($)
Joists	60	73.2	$2,898	$212,100
Girders	12	25.5	$2,249	$57,300
Total	72	98.7	-	$269,400

- Table 9 – Steel Joist Costs

Mezzanine Analysis Summary

The lightweight mezzanine analysis was completed successfully with promising results. A steel joist design is used instead of a structural steel system in order to decrease cost and schedule on the project. The new design should also maintain the desired aesthetic qualities from the original design.

The cost of the steel joist structure totals almost $270,000, but the original steel design was estimated to cost just over $340,000. The total cost savings on this portion of the project equal $72,000 when the steel joist structure is used. This is a significant savings and accounts for 21% of the original design costs.

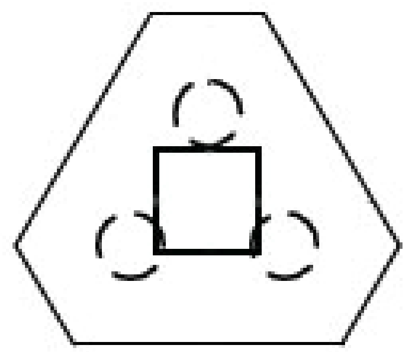
The schedule of the project can also be reduced by using the steel joist system. Since the largest member sizes are drastically smaller than the huge W-beams used in the original design, the schedule is able to be reduced by four days. The large precast crane on site will not have to stop precast erection in order to lift the structural steel into place. Therefore, all of the steel joist placement can be sequenced independently and does not have to wait for the precast crane. This will also decrease the complexity of the erection sequence for Building 1.

ALTERNATIVE PILE CAP DESIGN ANALYSIS

Background

The foundation system for Building 1 at Bakery Square is comprised of almost 500 auger cast piles that transfer the loads from the building down to the bedrock, which is located about 32 feet below grade on average. The auger cast piles are all 18 inches in diameter and are placed in groups to be topped with pile caps. The pile caps will cover between 2 and 10 pile caps in order to transfer loads from a column or grade beam to a group of piles.

A type PC3 pile cap is has a triangular shape and spans between 3 piles. There are 31 locations throughout Building 1 where this pile cap type exists. During the investigation phase of the thesis class, P.J. Dick explained that they had difficulty building the forms for this triangularly shaped pile cap. A reusable type of formwork system called Doka was being used to form all of the cast-in-place concrete. P.J. Dick has experienced that triangularly shaped Doka forms have a lower productivity rate than square ones.



- Figure 17 – Original Pile Cap Design

Since P.J. Dick expected the triangular pile caps to be more expensive and take longer to form, they asked the architect to redesign the pile caps as a suggested value engineering idea. The in-house structural engineer did not feel that the redesign of the pile caps would be beneficial to the project and left the structural plans unaltered. P.J. Dick believes that had an alternative square pile cap been used for the entire foundation, the schedule and cost of construction could have been improved. However, since they were required to construct the foundations as they were originally designed, they did not investigate this matter further.

For this technical analysis, the triangular pile cap will be evaluated and then redesigned to a more efficient shape. This analysis will seek to improve the constructability of the pile caps which in turn will improve the schedule and reduce the costs associated with Building 1. Since information taught in the concrete design class will be required to complete this analysis, this is also used to fulfill the requirement of a structural breadth study.

The steps taken to complete this study include:

- Performing a takeoff to determine the quantity of pile caps to be redesigned
- Analyze the loading requirements for a type PC3 pile cap
- Design a new pile cap based on concrete design knowledge
- Perform a material take of both pile caps for comparison
- Investigate productivity rates for both pile caps for comparison
- Compare cost and schedule changes due to the redesign of the PC3 pile cap

Results were expected to show that the square pile caps had higher productivity rates than the triangular pile caps. Therefore the schedule and construction costs should also decrease. The extra material costs used for a square shaped design is not expected to outweigh the cost savings realized by faster production rates.

Determining the Load Requirements

In order to successfully design an alternative pile cap, the correct loads needed to be found. The contract documents listed the assumed design loads, but the area these loads were applied across needed to be determined to be able to use these values. The loads that occurred on the areas supported by a type PC3 pile cap include the following.

Description	Load (PSF)
Floor Live Load	100
Garage Live Load	40
Stairs & Lobby Live Load	100
Roof Live Load	30
Snow Load	25

- Table 10 – Design Loading Requirements

With the use of a spreadsheet, the loads on each column supported by a PC3 pile cap were calculated. The areas of each type of load were determined from the drawing and entered into the spreadsheet. The areas were then multiplied by the correct square foot load and each floor was added together. There were also some given dead loads that were given on the construction documents to assume for the weight of the hanging steel mezzanine. This was also factored into the total for each column as was the dead load of the precast concrete structure.

The dead weight of the precast structure were not given, but by using an assumed concrete weight of 150 pcf for normal weight concrete, which was used by Sidley Precast Group, the correct figures could be found. There were three types of precast components and a composite floor that needed to be accounted for in this case. They included the L-Beams, which were located on the outside walls of the structure, the double tees used as the floor, and the precast columns. The table to the right shows the dead loads of each member.

Description	Load	Units
Precast Double Tee	60	PSF
Precast L-Beam	866	PLF
Composite Deck	57	PSF
Precast Column	1,313	PLF

- Table 11 – Unit Weights of Structural Members

All of this information was added to the spreadsheet, and the total unfactored load was determined. However, the double tee members created large spans and made it possible to include a live load reduction into the analysis. The live load reduction formula was used and enabled the live load on the upper levels to be reduced by up to almost 20 psf, and the lower levels to be reduced by almost 30 psf. After calculating this in the spreadsheet, the total load on each triangular pile cap was determined and the largest load was used to base the pile cap design on.

The PC3 pile cap located at column line M-7 is the worst case and has a live load of 106,000 pounds and a dead load of 415,000 pounds for a total load of 521,000 pounds. This is suitable since each pile cap is required to hold a minimum of 125 tons. This means that a three pile configuration should be able to hold 750,000 pounds, which is well above the determined load at M-7.

Pile Cap Design

The design of the alternative pile cap is based on concrete foundation design taught in both AE 404 and CE 397A. Since the square footing will be essentially supporting a point load from the column, it is most likely that the column will fail due to punching shear. The assumptions that were used for the calculations include the following:

- Live Load = 106 kips
- Dead Load = 412 kips
- Pile Diameter = 18”
- Strength of Concrete (f’c) = 3,000 psi
- B_1 = 0.85
- Column dimension = 30” x 42”
- Φ = 0.75

The design of the pile cap begins by applying the appropriate load factors of 1.2 and 1.6 for the live load and dead load respectively. This factor increases the total load on the pile cap to 667,000 pounds, which is still below the pile strength minimum of 750,000 pounds. Since the pile cap in question is a reinforced square foundation, the concrete design should start with shear then continue to flexure. The strength of the pile cap was determined to have to meet a shear strength requirement of 164 psi.

The process then continues by determining the required depth of the rebar in order to support the concrete as needed. This depth is determined to be 37.625" which results in a pile cap height of 3'–5". The flexural strength of the pile cap was calculated to meet 252 foot-kip of torque. Based on these design criteria, the rebar required to support this load are #11 bars spaced at 12" on center each way.

The design was also checked to ensure that maximum rebar requirements were met and strain due to shrinkage and temperature was good. This resulted in a final design of a square pile cap 6'-6" x 6'6" x 42" deep. Complete calculations are attached in Appendix C.

Takeoff Comparison

In order to compare the two types of pile caps, a takeoff of each type was performed and documented. The analysis required that a quantity of formwork, concrete, and rebar was known to determine the costs for each design. Below is a table that compares the quantity of material for each pile cap.

Description	Triangular Design	Square Design
Formwork	96 SF	91 SF
Concrete	187 CF	148 CF
Rebar	292 lb	446 lb

- Table 12 – Material Quantity Comparison for Triangular and Square Designs

Cost Comparison

Based on this information and material and labor rates for these items found in R.S. Means, the cost of construction each pile cap design could be determined. The price for formwork framing and stripping was given by P.J. Dick because a reusable Doka system was being used on the site, and R.S. Means does not have a similar product listed in it cost data tables. A cost breakdown is shown in the following table for each type of pile cap.

Description	Triangular Design	Square Design
Formwork	$744	$564
Concrete Material	$769	$608
Concrete Placing	$80	$63
Rebar	$318	$486
Total	**$1,911**	**$1,721**

- Table 13 – Cost Comparison for Triangular and Square Pile Cap Designs

This means that for each pile cap placed there is an estimated cost savings of almost $200. When this figure is applied to all 31 of the triangular pile caps construction costs can be reduced by $5,890. With the new square design there is a decrease in the amount of formwork and concrete necessary for the foundations. Unfortunately, according the concrete design there is more than a 50% increase in the amount of reinforcing steel. Even with the increase in cost of the rebar, the new design is cheaper to construct.

After looking at the square PC4 pile cap that is 8′ x 8′ x 3′-6″ in dimension, the amount of reinforcement calculated in the design of the alternative PC3 pile cap seems pretty high. The PC4 pile cap has #10 rebar spaced at about 13″ on center. A similar reinforcing layout might work with the new design for the PC3 pile cap. It is probable that through a more advanced calculation, which can be performed with a structural analysis program, this same bar size and spacing could be proven to work for the PC3 pile cap design. Therefore a reduction in reinforcement to be #10 bars spaced 13″ on center is a reasonable assumption. By applying this change to the pile cap design a new cost per pile cap is found. The total amount of reinforcement would change to 361 pounds, which is only a 25% increase in rebar. With this change the final quantities and costs can be seen below.

Description	Quantity	Cost
Formwork	91 SF	$564
Concrete Material	148 CF	$608
Concrete Placing	148 CF	$63
Rebar	361 lb	$393
Total		**$1,628**

- Table 14 – Final Material and Cost Breakdown for Square Pile Cap Design

Final cost savings would come out $283 per pile cap and a total construction cost saving of $8,773 when applied to all of the type PC3 pile caps. This cost savings alone does not have a big affect on the overall $24 million dollar budget. However, for a tight budgeted job multiple smaller savings can have meaningful impact in the long run.

Schedule Comparison

Inefficient productivity rates are the reason why P.J. Dick wanted to construct the pile caps in an alternative way. The triangular shape of the pile caps were the reason for the slower construction of the formwork. P.J. Dick's past experience with the Doka formwork system made it possible to accurately estimate the productivity rates and cost of installing the differently shaped pile caps.

According to P.J. Dick's information, carpenters would be able to form roughly 25% more square foot of surface area in a day for a square pile cap in comparison to a triangular shape. The estimated amount of formwork that could be placed/ stripped in a day was 176 square feet for a square pile cap and 140 square feet for a triangular pile cap. When this number is multiplied by the 31 type PC3 pile caps, a noticeable reduction in schedule can be seen.

Type	Formwork per Pile (SF)	Total Formwork (SF)	Productivity (SF / Day)	Length (Days)
Triangular	96	2,976	140	21.3
Square	91	2,821	176	16
Difference	(5)	(155)	(36)	(5.3)

- Table 15 – Formwork Productivity Comparison

By changing the formwork to a rectangular shape with square angles, the time required to form the pile caps can be reduced by over 5 days. For such a small number of pile caps being formed, this is quite a significant time saver. Therefore the construction schedule can effectively reduced by 5 days, or P.J. Dick can place some additional float time into their schedule if need be.

Pile Cap Analysis Summary

After completing the design of the new pile cap and completing the cost and schedule comparisons, it can be seen that the redesign might have been a worthwhile endeavor. The cost and time required to construct the type PC3 pile cap were both decreased.

Comparison	Results
Cost Savings Per Pile Cap	$283
Total Cost Savings	$8,773
Schedule Reduction	5 Days

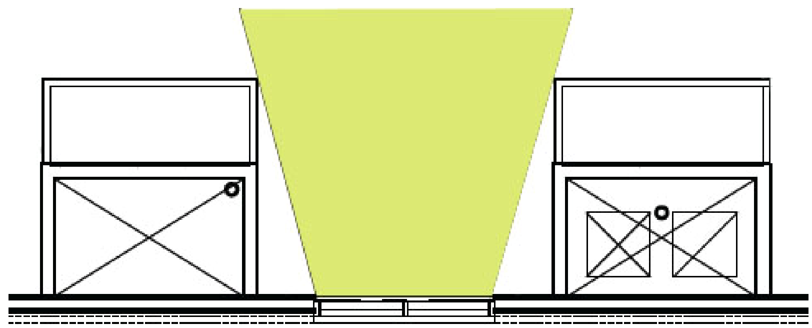
- Table 16 – Square Pile Cap Results

While the reduction in cost might not be enough to warrant the redesign of the pile cap, the ability to decrease the schedule by 5 days does make the idea more favorable. Another possible alternative would be to use a different forming system that is more easily used with irregularly shaped foundations. This did not seem to be an option for P.J. Dick because this is the standard forming system they stock at their construction yard and supply to the jobsites. In the end, the square pile cap appears to be the better choice.

MECHANICAL EQUIPMENT LOCATION ANALYSIS

Background

The last analysis for this report is performed on the retail mechanical equipment located on the roof of the fitness center. The reason for moving and possibly redesigning the system is to improve the quality of the fitness center by removing large ductwork shafts that line the outside wall and limit the amount of light that enters the space. This analysis will seek to provide an alternative location for the mechanical equipment, which in turn may require a different system to be used.



- Figure 18 – Mechanical Ducts Limit Light into Fitness Center

On the left is a picture of the conditions that will exist if the original design for the mechanical system is used. Eight of these large ductwork plenums are designed to be installed along the south facing exterior wall of Building 1. The plenums, which are 10 feet wide by 10 feet deep, pass through both the second and third floor of the gym and extremely limit the amount of exterior light that can enter into the space. They also create a large amount of unusable space along the south wall.

Over 2,000 square feet of wall space is covered by the plenums, and an additional 1,800 square feet between the ductwork is also not used as window area. Day light is an important part of sustainability and should be incorporated as much as possible in design. The south facing exposure of this wall provides excellent light throughout the entire year and would be a location for a curtain wall system. Gym members would benefit from the additional day light and the view of the Bakery Square plaza located adjacent to the fitness facility.

The roof top units have fans and compressors that also produce a lot of noise. Since the Bakery Square plaza is located below these units and outside terraces on Building 3 and 2 are also nearby, the noise pollution from the units might negatively impact these spaces.

- Figure 19 – Rendering of Nearby Terraces and Square

Due to the lighting and noise effects from the mechanical system, this analysis will look to move the rooftop units to a better place. An alternative mechanical system design may be required because of the relocation and will therefore be considered in this analysis.

Mechanical Equipment Relocation

The initial plan for relocating the equipment was to use the same roof top units but place them on the backside of Building 1 and reroute the ductwork. There is not a lot of room behind the back of the building, so the equipment would have to be hung off the bottom of the second floor level of the parking garage.

However, after an initial discussion with a mechanical engineer, he pointed out that this would not be possible without a costly redesign of the structural system because the equipment is too heavy. This also led to the discovery that even if the equipment could be supported it would decrease the vertical clearance space of the driveway behind Building 1. This driveway is used by the retail space for inventory delivery, and a decrease in clearance would prohibit box trucks from traveling through this space.

This means that if the equipment is to be moved, then an alternative system must be used. Possible systems for the thesis building were suggested by the mechanical engineer and include an all air system, an all water system, and a newer technology in the United States known as a chilled beam system. Based on these suggestions, a review of the different systems was performed to determine what the best choice will be for the retail space in Building 1.

Mechanical System Investigation

In order to decide which type of mechanical system is best suited for this application, several factors must be considered. Controllability, efficiency, space requirements, complexity, ease of changeover, maintenance requirements, and cost must all be considered. The following table lists the advantages and disadvantages of each system.

System	Advantages	Disadvantages
All Air	• Central equipment location • No piping in occupied area • Free cooling • Easy seasonal change • Heat recovery possible	• Duct clearance • Large ducts • Air balancing difficulties
All Water	• Less space • Locally shutoff • Quick pull down • Good for existing buildings	• More maintenance in occupied area • Coil cleaning difficulties • Filter • Open window for IAQ
Chilled Beam	• Noise Reduction • Energy Savings • Reduced maintenance	• Condensation is a common problem • Humidity is a problem • Very expensive

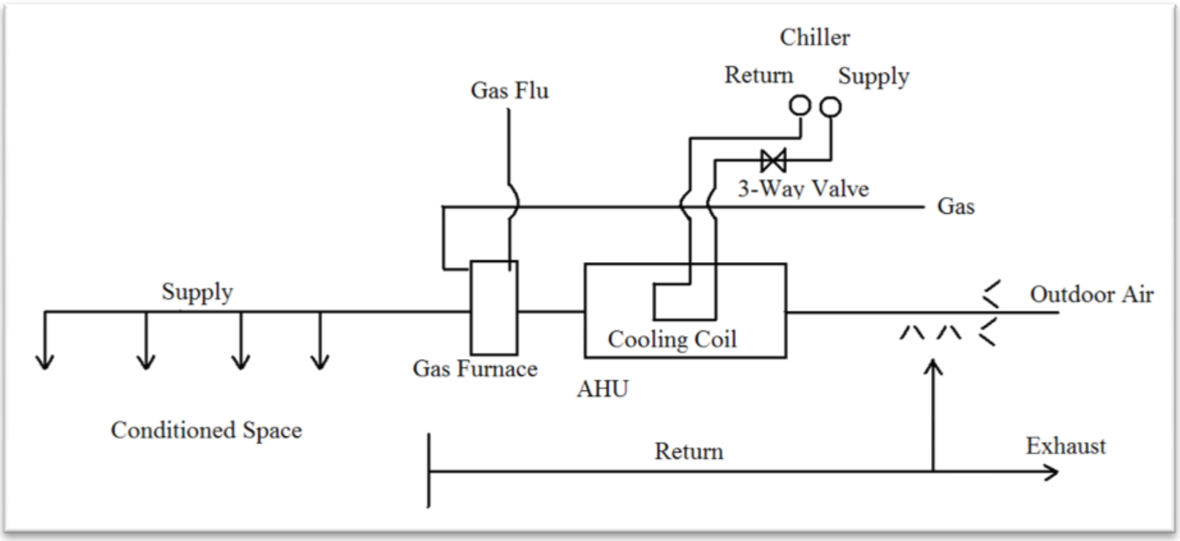
- Table 17 – Mechanical System Comparison

A mechanical system design was chosen based on the above factors and with input from the mechanical engineer about feasibility. While an all water system would be a good choice because of the limited amount of space it would take to install, the poor indoor air quality and insufficient space for a cooling tower eliminates this choice. The chilled beam system is also very good for its noise, energy, and maintenance capability. However, the condensation and humidity problems pose a problem and the system is extremely expensive to install. The mechanical engineer stated that this system is usually used in laboratory type facilities where air movement is undesirable.

It was determined that an all air system would be most well suited for Building 1. The consultant agreed that the packaged units should be replaced with a forced air system that had dedicated air handling units for each retail space and a shared chiller located behind the building. He pointed out that the sizes of the air handling units could be drastically reduced by using a chiller. This would also decrease the weight of the equipment and allow them to be hung from the parking garage structure. The ductwork inside the retail space would be identical, but the mechanical shafts through the fitness center could be eliminated. The chiller, piping from the chiller to the air handling units, and controls will have to be included in the cost analysis.

Mechanical System Design

The design loads of the mechanical system must first be determined by using the area of each retail space. The tonnage for each retail space will be used to price the air handling equipment used to supply the facility. By summing the loads for all of the retail area, the appropriate chiller can be chosen.



- Figure 20 – Schematic of Chiller Based Mechanical System

Above is a schematic diagram of the alternate mechanical system that is being suggested for use in Building 1. When air conditioning is required, the chiller supplies coolant at 45°F to the air handling unit, which will cool the incoming air. Coolant will leave the air handling unit and return to the chiller at 55°F. When heat is required, the air will be conditioned in the gas furnace. From hear the air will be supplied into the conditioned space and a portion will be returned to start the cycle again. Each air handling unit will supply a designated retail space.

The loading calculations were made based on the assumptions that the volume of air requirement is 1 ½ CFM/ SF and 400 CFM/ Ton of refrigeration. Individual heating and cooling loads are required for the retail spaces in order to size each air handling unit, but the total refrigeration tonnage will be used to size the chiller. By performing a square foot takeoff of the retail space the following loads were found and listed in the table located on the following page.

Space Description	Area (SF)	Volume (CFM)	RT (Ton)
Retail 1	11,500	17,250	44
Retail 2	4,700	7,050	18
Retail 3	4,800	7,200	18
Retail 4	4,000	6,000	15
Retail 5	7,700	11,550	29
Total	29,100	49,050	124

- Table 18 – Calculated Load Requirements for Retail Space

Mechanical Equipment Costs

In order to complete the analysis of the alternative mechanical system, a cost comparison needs to occur. Since the owner did not wish any of the actual costs of the project broken out from the overall project value, an estimate of the original design is used. The cost analysis compares the costs associated with each system including controls, duct work, and piping.

R.S. Means was used to price the rooftop units based on the refrigeration tonnage of each unit. Load requirements for the retail spaces were listed on the HVAC schedule and used to determine the costs of each unit. Based on the assumption listed above of 400 CFM/Ton, the costs are broken down in the following table.

Space	Volume (CFM)	RT (Ton)	Equipment (Ton/MBH)	Cost
Retail 1	16,116	41	40 / 675	$37,175
Retail 2	7,914	20	20 / 360	$22,350
Retail 3	6,478	17	18 / 330	$17,525
Retail 4	5,774	15	15 / 270	$14,425
Retail 5	12,453	32	30 / 540	$29,025
Total	48,735	125	-	$120,500

- Table 19 – Rooftop Unit Costs

Cost estimates for the alternate system were provided by the mechanical consultant are based on the following unit prices:

- Chiller – $750/ Ton
- Gas Furnace – $4,000/ unit
- Air Handling Unit – $300/ Ton

Description	RT (Ton)	Chiller Cost	AHU Cost	Furnace Cost	Total Cost
Retail 1	44	$33,000	$13,200	$4,000	$50,200
Retail 2	18	$13,500	$5,400	$4,000	$22,900
Retail 3	18	$13,500	$5,400	$4,000	$22,900
Retail 4	15	$11,250	$4,500	$4,000	$19,750
Retail 5	29	$21,750	$8,700	$4,000	$34,450
Total	124	$93,000	$37,200	$20,000	$150,200

- Table 20 – Chiller Equipment Costs

Controls for the new system were estimated by the mechanical consultant to be about $15,000 more than the original design. The duct work that is eliminated from the fitness center can be removed from the project scope, but the costs for additional piping lines for the chiller must be included. The quantity takeoff and costs for the duct work and chiller piping can be seen in the table below.

Space	Duct Size (in)	Lb / ft	Length (ft)	Weight (lb)
Retail 1	38x38	19	52	988
Retail 2	30x30	12.9	52	671
Retail 3	28x28	12	52	624
Retail 4	26x26	11.2	52	582
Retail 5	34x34	17	52	884
Total	-	-	-	3,750

- Table 21- Ductwork Takeoff

Conveyance system	Amount	Unit Cost	Cost
Ductwork	3,750 lb	$7.15/ lb	$26,800
Chiller Piping	182 ft	$40.25/ Lf	$7,325

- Table 22 – Mechanical Conveyance System Cost Estimate

Final costs for the two systems account for controls, conveyance system, and the mechanical equipment for each design. The chiller based mechanical design is about 17% more expensive than the original design

System	Total Cost
Original Design	$147,300
Alternate Design	$172,500

- Table 23 – Mechanical Systems Overall Cost Comparison

Mechanical Analysis Summary

Initial cost for the alternate mechanical system is significantly higher and is probably the reason why Walnut Capital chose to install the rooftop units. However, the owners might want to choose the new design based on the effects it has for the rest of the building. The newer system will be more energy efficient, which in turn will reduce the operating expense of the building.

By eliminating the large ductwork through the fitness facility, a curtain wall façade could be installed on the south side of the building. This would provide a better view to the gym members, allow more light into the building, and reduce the energy needs of the fitness facility by decreasing energy and lighting loads because of improved solar gain. The owner would have to choose if the advantages of the newly designed system are worth the upfront costs. An energy model showing an in depth analysis of the performance for each system could help them in their decision making process.

CONCLUSION

The research conducted for the thesis report has yielded some interesting results. Analyses of sustainable gym designs, mezzanine constructability, pile cap constructability, and mechanical system affects were completed successfully. The following is a recap of the findings documented throughout the report.

Green technologies for the gym include electric generating bicycles, piezoelectric floor tiles, and bamboo wood gym floors. The electric generating ideas are able to reduce the lighting load inside the fitness center by about 18%. Further improvements in efficiencies and costs within the near future along with ever increasing energy costs will make the more feasible. The bi-level LED lighting system for parking garages is expected to reduce lighting loads by 60%. This is based on the reduced wattage of LED lights and the ability for motion sensing equipment to lower and raise lighting levels.

Steel Joists are the lightweight alternative structure chosen for use on the mezzanine level. The floor will no longer hang from the parking structure; instead, it is attached to the precast columns from below. By using the steel joist system the construction costs for the mezzanine structure decreased from $72,000 for a total cost of $270,000. The schedule was reduced by four days, and the erection sequence became less complex. Overall, this analysis was a successful implementation of value engineering the mezzanine structure.

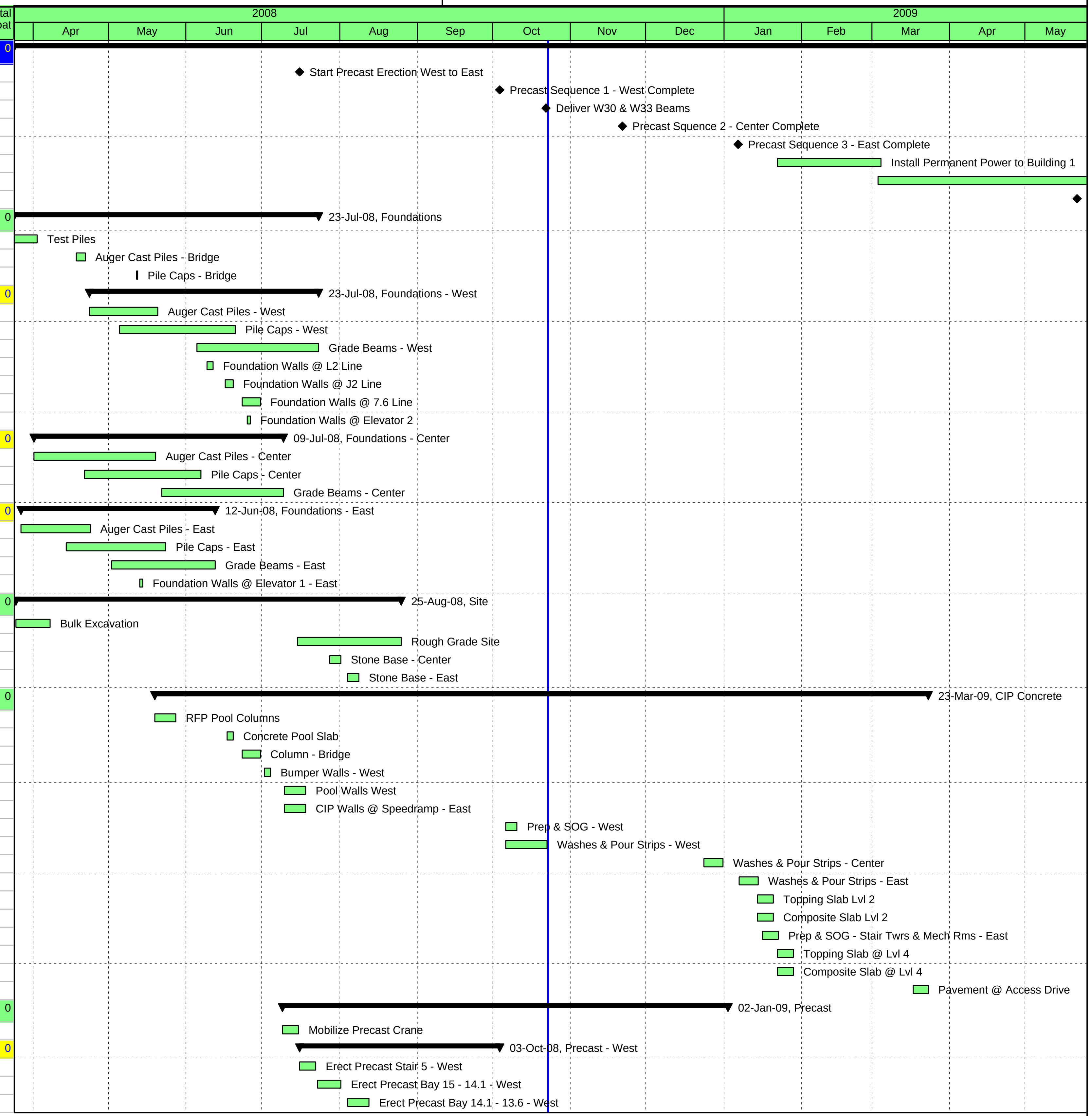
Pile cap redesign resulted in a predicted savings of $283 per pile cap. This would result in a total cost reduction of almost $9,000 and a five day schedule reduction. While the monetary value of the redesign is not significant on a $24 million job, the week gained from the schedule can have a large impact on the project.

The last analysis looked to free space inside the fitness center by moving mechanical equipment for the retail stores. Large ductwork inside the gym blocked great views to the outside plaza of Bakery Square and limited the square feet of windows on the southern facing façade. By removing the ducts, more light can enter into the fitness center, which should also reduce the lighting and conditioning loads for that space. The new location for the mechanical equipment required a redesign in order to decrease the size of the air handling unit. This was accomplished by using a chiller to provide cooling capabilities. Overall costs for the redesign would only cause costs to increase by 17%.

APPENDIX A

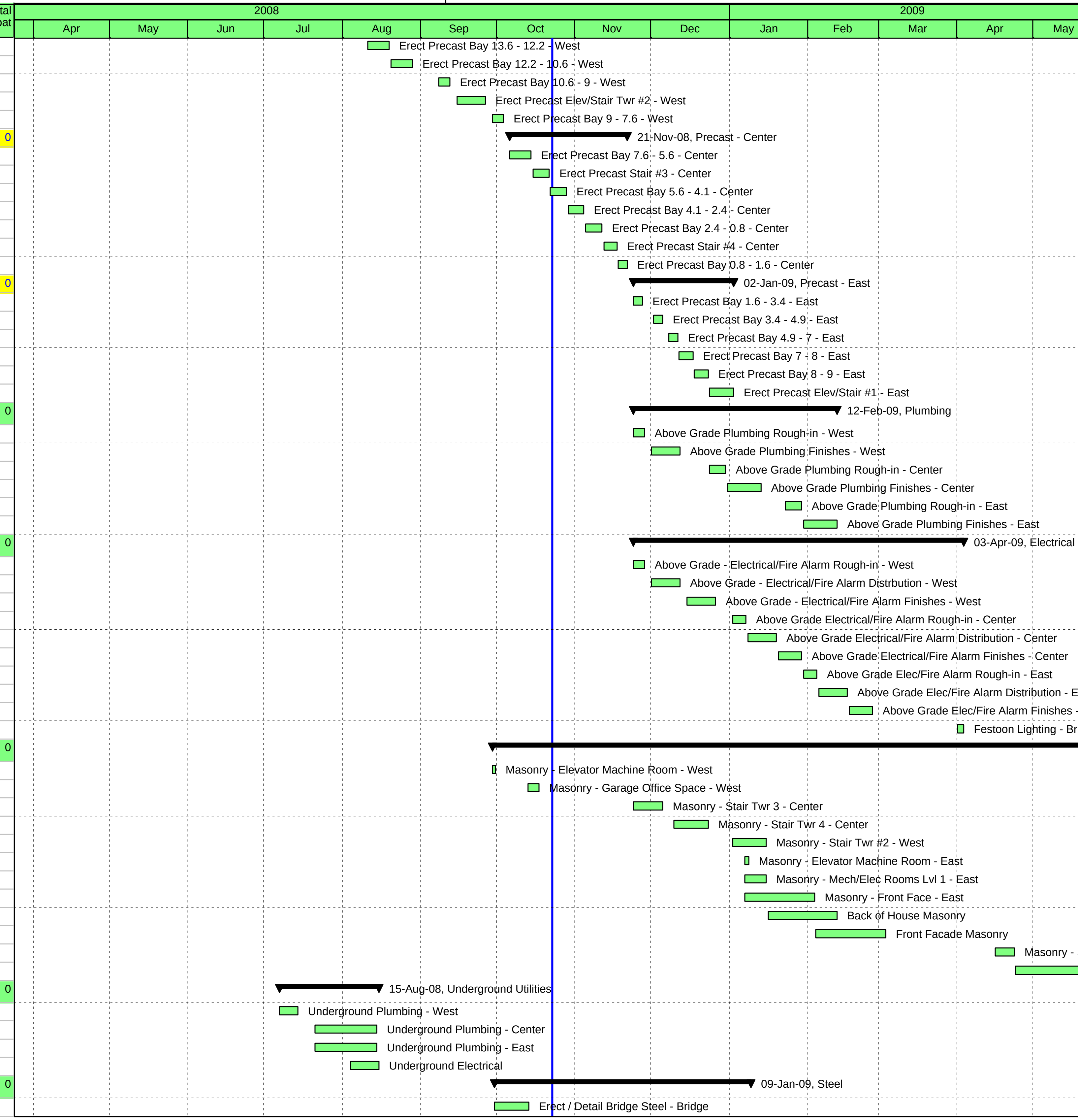
Detail Project Schedule

Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
Bakery Square - Building #1		376	376	0%	24-Mar-08	31-Aug-09	0
001	Start Precast Erection West to East	0	0	100%	16-Jul-08		
002	Precast Sequence 1 - West Complete	0	0	100%		03-Oct-08	
003	Deliver W30 & W33 Beams	0	0	100%	22-Oct-08		
004	Precast Squence 2 - Center Complete	0	0	0%		21-Nov-08	
005	Precast Sequence 3 - East Complete	0	0	0%		06-Jan-09	
006	Install Permanent Power to Building 1	30	30	0%	22-Jan-09	04-Mar-09	
007	Urban Active Fit-out	130	130	0%	03-Mar-09	31-Aug-09	
008	Parking Garage Complete	0	0	0%		21-May-09	
Foundations		88	88	0%	24-Mar-08	23-Jul-08	0
013	Test Piles	8	8	100%	24-Mar-08	02-Apr-08	
014	Auger Cast Piles - Bridge	2	2	100%	18-Apr-08	21-Apr-08	
015	Pile Caps - Bridge	1	1	100%	12-May-08	12-May-08	
Foundations - West		66	66	0%	23-Apr-08	23-Jul-08	0
023	Auger Cast Piles - West	20	20	100%	23-Apr-08	20-May-08	
024	Pile Caps - West	35	35	100%	05-May-08	20-Jun-08	
025	Grade Beams - West	35	35	100%	05-Jun-08	23-Jul-08	
026	Foundation Walls @ L2 Line	3	3	100%	09-Jun-08	11-Jun-08	
027	Foundation Walls @ J2 Line	4	4	100%	16-Jun-08	19-Jun-08	
028	Foundation Walls @ 7.6 Line	6	6	100%	23-Jun-08	30-Jun-08	
029	Foundation Walls @ Elevator 2	2	2	100%	25-Jun-08	26-Jun-08	
Foundations - Center		72	72	0%	01-Apr-08	09-Jul-08	0
020	Auger Cast Piles - Center	35	35	100%	01-Apr-08	19-May-08	
021	Pile Caps - Center	35	35	100%	21-Apr-08	06-Jun-08	
022	Grade Beams - Center	35	35	100%	22-May-08	09-Jul-08	
Foundations - East		56	56	0%	27-Mar-08	12-Jun-08	0
016	Auger Cast Piles - East	20	20	100%	27-Mar-08	23-Apr-08	
017	Pile Caps - East	30	30	100%	14-Apr-08	23-May-08	
018	Grade Beams - East	30	30	100%	02-May-08	12-Jun-08	
019	Foundation Walls @ Elevator 1 - East	2	2	100%	13-May-08	14-May-08	
Site		110	110	0%	25-Mar-08	25-Aug-08	0
009	Bulk Excavation	10	10	100%	25-Mar-08	07-Apr-08	
010	Rough Grade Site	30	30	100%	15-Jul-08	25-Aug-08	
011	Stone Base - Center	5	5	100%	28-Jul-08	01-Aug-08	
012	Stone Base - East	5	5	100%	04-Aug-08	08-Aug-08	
CIP Concrete		221	221	0%	19-May-08	23-Mar-09	0
0030	RFP Pool Columns	7	7	100%	19-May-08	27-May-08	
031	Concrete Pool Slab	3	3	100%	17-Jun-08	19-Jun-08	
032	Column - Bridge	6	6	100%	23-Jun-08	30-Jun-08	
033	Bumper Walls - West	3	3	100%	02-Jul-08	04-Jul-08	
034	Pool Walls West	7	7	100%	10-Jul-08	18-Jul-08	
035	CIP Walls @ Speedramp - East	7	7	100%	10-Jul-08	18-Jul-08	
036	Prep & SOG - West	5	5	100%	06-Oct-08	10-Oct-08	
037	Washes & Pour Strips - West	13	13	100%	06-Oct-08	22-Oct-08	
038	Washes & Pour Strips - Center	6	6	0%	24-Dec-08	31-Dec-08	
039	Washes & Pour Strips - East	6	6	0%	07-Jan-09	14-Jan-09	
040	Topping Slab Lvl 2	5	5	0%	14-Jan-09	20-Jan-09	
041	Composite Slab Lvl 2	5	5	0%	14-Jan-09	20-Jan-09	
042	Prep & SOG - Stair Twrs & Mech Rms - East	5	5	0%	16-Jan-09	22-Jan-09	
043	Topping Slab @ Lvl 4	5	5	0%	22-Jan-09	28-Jan-09	
044	Composite Slab @ Lvl 4	5	5	0%	22-Jan-09	28-Jan-09	
045	Pavement @ Access Drive	5	5	0%	17-Mar-09	23-Mar-09	
Precast		128	128	0%	09-Jul-08	02-Jan-09	0
050	Mobilize Precast Crane	5	5	100%	09-Jul-08	15-Jul-08	
Precast - West		58	58	0%	16-Jul-08	03-Oct-08	0
051	Erect Precast Stair 5 - West	5	5	100%	16-Jul-08	22-Jul-08	
052	Erect Precast Bay 15 - 14.1 - West	8	8	100%	23-Jul-08	01-Aug-08	
053	Erect Precast Bay 14.1 - 13.6 - West	7	7	100%	04-Aug-08	12-Aug-08	



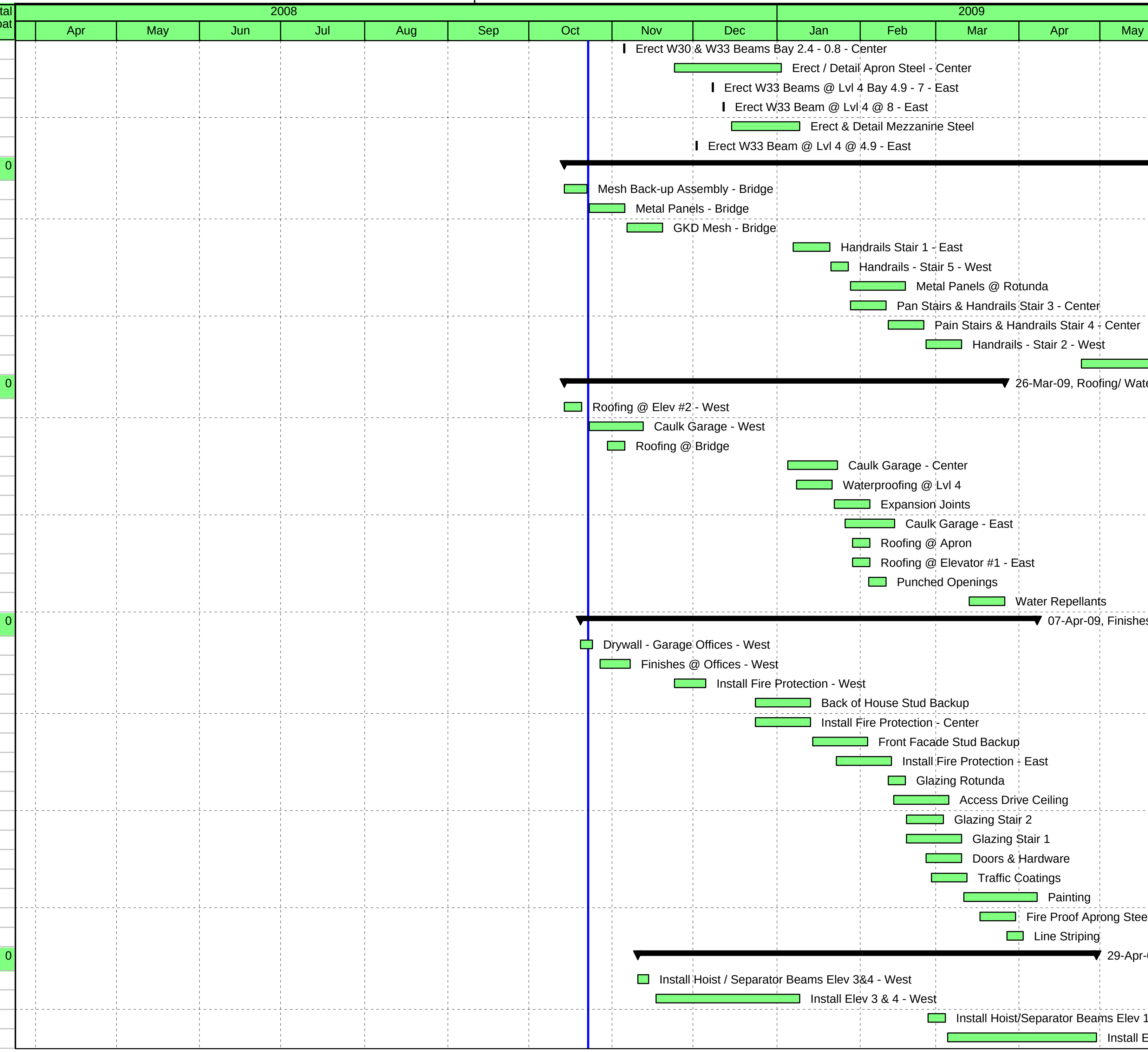
Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone

Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
054	Erect Precast Bay 13.6 - 12.2 - West	7	7	100%	11-Aug-08	19-Aug-08	
055	Erect Precast Bay 12.2 - 10.6 - West	7	7	100%	20-Aug-08	28-Aug-08	
056	Erect Precast Bay 10.6 - 9 - West	5	5	100%	08-Sep-08	12-Sep-08	
057	Erect Precast Elev/Stair Twr #2 - West	10	10	100%	15-Sep-08	26-Sep-08	
058	Erect Precast Bay 9 - 7.6 - West	5	5	100%	29-Sep-08	03-Oct-08	
Precast - Center		35	35	0%	06-Oct-08	21-Nov-08	0
059	Erect Precast Bay 7.6 - 5.6 - Center	7	7	100%	06-Oct-08	14-Oct-08	
060	Erect Precast Stair #3 - Center	5	5	100%	15-Oct-08	21-Oct-08	
061	Erect Precast Bay 5.6 - 4.1 - Center	5	5	20%	22-Oct-08	28-Oct-08	
062	Erect Precast Bay 4.1 - 2.4 - Center	5	5	0%	29-Oct-08	04-Nov-08	
063	Erect Precast Bay 2.4 - 0.8 - Center	5	5	0%	05-Nov-08	11-Nov-08	
064	Erect Precast Stair #4 - Center	4	4	0%	12-Nov-08	17-Nov-08	
065	Erect Precast Bay 0.8 - 1.6 - Center	4	4	0%	18-Nov-08	21-Nov-08	
Precast - East		30	30	0%	24-Nov-08	02-Jan-09	0
066	Erect Precast Bay 1.6 - 3.4 - East	4	4	0%	24-Nov-08	27-Nov-08	
067	Erect Precast Bay 3.4 - 4.9 - East	4	4	0%	02-Dec-08	05-Dec-08	
068	Erect Precast Bay 4.9 - 7 - East	4	4	0%	08-Dec-08	11-Dec-08	
069	Erect Precast Bay 7 - 8 - East	4	4	0%	12-Dec-08	17-Dec-08	
070	Erect Precast Bay 8 - 9 - East	4	4	0%	18-Dec-08	23-Dec-08	
071	Erect Precast Elev/Stair #1 - East	8	8	0%	24-Dec-08	02-Jan-09	
Plumbing		59	59	0%	24-Nov-08	12-Feb-09	0
132	Above Grade Plumbing Rough-in - West	5	5	0%	24-Nov-08	28-Nov-08	
133	Above Grade Plumbing Finishes - West	10	10	0%	01-Dec-08	12-Dec-08	
134	Above Grade Plumbing Rough-in - Center	5	5	0%	24-Dec-08	30-Dec-08	
135	Above Grade Plumbing Finishes - Center	10	10	0%	31-Dec-08	13-Jan-09	
136	Above Grade Plumbing Rough-in - East	5	5	0%	23-Jan-09	29-Jan-09	
137	Above Grade Plumbing Finishes - East	10	10	0%	30-Jan-09	12-Feb-09	
Electrical		95	95	0%	24-Nov-08	03-Apr-09	0
138	Above Grade - Electrical/Fire Alarm Rough-in - West	5	5	0%	24-Nov-08	28-Nov-08	
139	Above Grade - Electrical/Fire Alarm Distrbution - West	10	10	0%	01-Dec-08	12-Dec-08	
140	Above Grade - Electrical/Fire Alarm Finishes - West	10	10	0%	15-Dec-08	26-Dec-08	
141	Above Grade Electrical/Fire Alarm Rough-in - Center	4	4	0%	02-Jan-09	07-Jan-09	
142	Above Grade Electrical/Fire Alarm Distribution - Center	8	8	0%	08-Jan-09	19-Jan-09	
143	Above Grade Electrical/Fire Alarm Finishes - Center	8	8	0%	20-Jan-09	29-Jan-09	
144	Above Grade Elec/Fire Alarm Rough-in - East	4	4	0%	30-Jan-09	04-Feb-09	
145	Above Grade Elec/Fire Alarm Distribution - East	8	8	0%	05-Feb-09	16-Feb-09	
146	Above Grade Elec/Fire Alarm Finishes - East	8	8	0%	17-Feb-09	26-Feb-09	
147	Festoon Lighting - Bridge	3	3	0%	01-Apr-09	03-Apr-09	
Masonry		169	169	0%	29-Sep-08	21-May-09	0
079	Masonry - Elevator Machine Room - West	2	2	100%	29-Sep-08	30-Sep-08	
080	Masonry - Garage Office Space - West	5	5	100%	13-Oct-08	17-Oct-08	
081	Masonry - Stair Twr 3 - Center	10	10	0%	24-Nov-08	05-Dec-08	
082	Masonry - Stair Twr 4 - Center	10	10	0%	10-Dec-08	23-Dec-08	
083	Masonry - Stair Twr #2 - West	10	10	0%	02-Jan-09	15-Jan-09	
084	Masonry - Elevator Machine Room - East	2	2	0%	07-Jan-09	08-Jan-09	
085	Masonry - Mech/Elec Rooms Lvl 1 - East	7	7	0%	07-Jan-09	15-Jan-09	
086	Masonry - Front Face - East	20	20	0%	07-Jan-09	03-Feb-09	
087	Back of House Masonry	20	20	0%	16-Jan-09	12-Feb-09	
088	Front Facade Masonry	20	20	0%	04-Feb-09	03-Mar-09	
089	Masonry - Stair Twr 1 - East	6	6	0%	16-Apr-09	23-Apr-09	
090	Brick Veneer @ Stair Twr 1 - East	20	20	0%	24-Apr-09	21-May-09	
Underground Utilities		30	30	0%	07-Jul-08	15-Aug-08	0
046	Underground Plumbing - West	6	6	100%	07-Jul-08	14-Jul-08	
047	Underground Plumbing - Center	19	19	100%	21-Jul-08	14-Aug-08	
048	Underground Plumbing - East	19	19	100%	21-Jul-08	14-Aug-08	
049	Underground Electrical	10	10	100%	04-Aug-08	15-Aug-08	
Steel		74	74	0%	30-Sep-08	09-Jan-09	0
072	Erect / Detail Bridge Steel - Bridge	10	10	100%	30-Sep-08	13-Oct-08	



Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone

Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
073	Erect W30 & W33 Beams Bay 2.4 - 0.8 - Center	1	1	0%	05-Nov-08	05-Nov-08	
0740	Erect / Detail Apron Steel - Center	30	30	0%	24-Nov-08	02-Jan-09	
076	Erect W33 Beams @ Lvl 4 Bay 4.9 - 7 - East	1	1	0%	08-Dec-08	08-Dec-08	
077	Erect W33 Beam @ Lvl 4 @ 8 - East	1	1	0%	12-Dec-08	12-Dec-08	
078	Erect & Detail Mezzanine Steel	20	20	0%	15-Dec-08	09-Jan-09	
75	Erect W33 Beam @ Lvl 4 @ 4.9 - East	1	1	0%	02-Dec-08	02-Dec-08	
Miscellaneous Metals		158	158	0%	14-Oct-08	21-May-09	0
102	Mesh Back-up Assembly - Bridge	7	7	100%	14-Oct-08	22-Oct-08	
103	Metal Panels - Bridge	10	10	0%	23-Oct-08	05-Nov-08	
104	GKD Mesh - Bridge	10	10	0%	06-Nov-08	19-Nov-08	
105	Handrails Stair 1 - East	10	10	0%	07-Jan-09	20-Jan-09	
106	Handrails - Stair 5 - West	5	5	0%	21-Jan-09	27-Jan-09	
107	Metal Panels @ Rotunda	15	15	0%	28-Jan-09	17-Feb-09	
108	Pan Stairs & Handrails Stair 3 - Center	10	10	0%	28-Jan-09	10-Feb-09	
109	Pain Stairs & Handrails Stair 4 - Center	10	10	0%	11-Feb-09	24-Feb-09	
110	Handrails - Stair 2 - West	10	10	0%	25-Feb-09	10-Mar-09	
111	Garage Fencing	20	20	0%	24-Apr-09	21-May-09	
Roofing/ Waterproofing		118	118	0%	14-Oct-08	26-Mar-09	0
091	Roofing @ Elev #2 - West	5	5	100%	14-Oct-08	20-Oct-08	
092	Caulk Garage - West	15	15	0%	23-Oct-08	12-Nov-08	
093	Roofing @ Bridge	5	5	0%	30-Oct-08	05-Nov-08	
094	Caulk Garage - Center	15	15	0%	05-Jan-09	23-Jan-09	
095	Waterproofing @ Lvl 4	10	10	0%	08-Jan-09	21-Jan-09	
096	Expansion Joints	10	10	0%	22-Jan-09	04-Feb-09	
097	Caulk Garage - East	15	15	0%	26-Jan-09	13-Feb-09	
098	Roofing @ Apron	5	5	0%	29-Jan-09	04-Feb-09	
099	Roofing @ Elevator #1 - East	5	5	0%	29-Jan-09	04-Feb-09	
100	Punched Openings	5	5	0%	04-Feb-09	10-Feb-09	
101	Water Repellants	10	10	0%	13-Mar-09	26-Mar-09	
Finishes		122	122	0%	20-Oct-08	07-Apr-09	0
112	Drywall - Garage Offices - West	5	5	60%	20-Oct-08	24-Oct-08	
113	Finishes @ Offices - West	10	10	0%	27-Oct-08	07-Nov-08	
114	Install Fire Protection - West	10	10	0%	24-Nov-08	05-Dec-08	
115	Back of House Stud Backup	15	15	0%	24-Dec-08	13-Jan-09	
116	Install Fire Protection - Center	15	15	0%	24-Dec-08	13-Jan-09	
117	Front Facade Stud Backup	15	15	0%	14-Jan-09	03-Feb-09	
118	Install Fire Protection - East	15	15	0%	23-Jan-09	12-Feb-09	
119	Glazing Rotunda	5	5	0%	11-Feb-09	17-Feb-09	
120	Access Drive Ceiling	15	15	0%	13-Feb-09	05-Mar-09	
121	Glazing Stair 2	10	10	0%	18-Feb-09	03-Mar-09	
122	Glazing Stair 1	15	15	0%	18-Feb-09	10-Mar-09	
123	Doors & Hardware	10	10	0%	25-Feb-09	10-Mar-09	
124	Traffic Coatings	10	10	0%	27-Feb-09	12-Mar-09	
125	Painting	20	20	0%	11-Mar-09	07-Apr-09	
126	Fire Proof Aprong Steel Center	10	10	0%	17-Mar-09	30-Mar-09	
127	Line Striping	5	5	0%	27-Mar-09	02-Apr-09	
Elevators		123	123	0%	10-Nov-08	29-Apr-09	0
128	Install Hoist / Separator Beams Elev 3&4 - West	5	5	0%	10-Nov-08	14-Nov-08	
129	Install Elev 3 & 4 - West	40	40	0%	17-Nov-08	09-Jan-09	
130	Install Hoist/Separator Beams Elev 1&2 - East	5	5	0%	26-Feb-09	04-Mar-09	
131	Install Elevator 1 & 2 - East	40	40	0%	05-Mar-09	29-Apr-09	



Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone

APPENDIX B

Structural Steel Costs

Typical Steel Bay

Unit Cost Estimate

6425 Penn Ave.
Pittsburgh PA, 15206

Data Release : Year 2008 Quarter 1

Quantity	Unit	LineNumber	Description	Ext. Mat. O&P	Ext. Labor O&P	Ext. Equip. O&P	Ext. Total O&P
46.33	L.F.	051202607050	Column, structural, 2-tier, W10x68, A992 steel, incl shop primer, splice plates, bolts	$ 3,983.45	$ 233.04	$ 92.66	$ 4,309.15
27.12	L.F.	051206401100	Structural steel member, 100-ton project, 1 to 2 story building, W12x14, A992 steel, shop fabricated, incl shop primer, bolted connections	$ 480.57	$ 152.96	$ 60.75	$ 694.27
307.36	L.F.	051206403300	Structural steel member, 100-ton project, 1 to 2 story building, W18x35, A992 steel, shop fabricated, incl shop primer, bolted connections	$ 13,579.16	$ 2,335.94	$ 685.41	$16,600.51
76.84	L.F.	051206403900	Structural steel member, 100-ton project, 1 to 2 story building, W18x55, A992 steel, shop fabricated, incl shop primer, bolted connections	$ 5,328.85	$ 611.65	$ 180.57	$ 6,121.07
4.66	S.F.	051205600450	Steel plate, structural, for connections & stiffenners, 3/4" T, shop fabricated, incl shop primer	$ 163.80	$ -	$ -	$ 163.80
28.25	L.F.	051206404900	Structural steel member, 100-ton project, 1 to 2 story building, W24x55, A992 steel, shop fabricated, incl shop primer, bolted connections	$ 1,959.14	$ 185.04	$ 54.24	$ 2,198.42
Total				**$ 25,494.97**	**$ 3,518.63**	**$ 1,073.63**	**$30,087.22**

APPENDIX C

Pile Cap Calculations

LL = 106 kips

DL = 415 kips

f'c = 3,000 psi

$\phi = 0.75$

pile diameter = 18"

column dimension = 30" x 42"

$B_1 = 0.85$

$P_u = 1.2(415 \text{ kips}) + 1.6(106 \text{ kips}) = 667.6 \text{ kips}$

$A = 3\pi(9")^2 = 5.3$ SF

q = 667.6 kip / 5.2 SF = 126 ksf = 875 psi

$V_c = 4\,\phi\sqrt{(f'c)} = 4(0.75)\sqrt{(3000)} = 164$ psi

$d^2(4(164 + 875) + d(2(164) + 875)(30+42) = 875(84^2 - (30*42))$

$1531d^2 + 86616d - 5071500 = 0$ ➔ d = 35.84"

35.84 + 1.375 + 3 = 40.215 ➔ h = 42"

D = 42 – 3 – 1.375 = 37.625

l = 2'

$M_u = (126 \text{ ksf } (2')^2(1)) / 2 = 252$ ft-k

$A = A_s(60) / ((0.85)(3)(12")) = 1.96\,A_s$

$(252 \text{ ft-k})(12") = 0.9A_s\,(60)(37.625 - (1.96A_s / 2))$

$.98A_s^2 - 37.625A_s + 56 = 0$ ➔ $A_s \geq 1.55$

Therefore # 11's @ 12" o.c.

$\rho = 1.56 / (12*42) = 0.0031 \geq 0.0018$ O.K.

$E_s = (0.003(37.625 - 3.597)) / 3.597 = 0.028 \geq 0.005$ O.K. $\phi = 0.9$