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Moore Building Addition & Renovation
University Park, PA 16802

Final Report

Penn State AE Senior Thesis

Moore Building Addition
University Park, PA 16802

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PROJECT TEAM

DEPARTMENT	Department of PSYCHOLOGY AT PENN STATE UNIVERSITY
COST	~$26.1 MILLION
SIZE	~57,000 ft^2
TIME	JUNE 2010 TO JANUARY 2012
METHOD	DESIGN BID BUILD

PJ DICK
Project CM Firm

ARCHITECTURE

KLING STUBBINS
Project A/E Firm

ARCHITECTURE The architectural system in the Moore Building Addition and renovation is designed to demonstrate the forward-thinking of Penn State University by incorporating both the classic brick look fused with modern design cues.

FAÇADE The façade is made up of brick and aluminum veneer walls as well as large glass panels in a curtain wall and mullion system that preserves the modern look and feel of the building.

STRUCTURAL

NEW Structural systems used in the Moore building Addition and Renovation include a braced frame system that runs throughout the building's structure. The structure is primarily composed of structural steel and composite decks (4000psi). The floor-to-floor height for all floors is 12'-6".

EXISTING The existing steel structure of the north wing will be used and the new structure will "wrap" around it,

M.E.P.

MECHANICAL

- Structure houses two main AHUs (29 & 48 BHP) in basement level – feed chilled beams and VAVs
- Low pressure steam used
- Two 905 GPM Chilled water pumps, one @130 GPM

LIGHTING/ELECTRICAL

- Main luminaire used: 55Watt T8 lamp (lights 85% of building interior spaces)
- Electrical connection made in manhole #201
- Power is stepped down from 12.47KV via transformer,
- Distributed as 3Phase 480Y/277V.

Construction

CHALLENGES

- Over-crowded football weekends during fall semester requires extra safety and schedule-related pre-cautions
- New and old structure must be connected; requires underpinning and merging steel structures
- Student safety concerns and traffic precautions necessary

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www.engr.psu.edu/ae/thesis/portfolios/2011/mha119

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PAUL BOWERS

PJ DICK

THE PENNSYLVANIA STATE UNIVERSITY

* List ordered alphabetically.
† Unavailable titles not listed

Executive Summary

This report focuses on methods and technologies that would allow the Moore Building Addition to be constructed at a faster pace, which would allow the occupants, including those displaced, to have a more permanent location to conduct their business. The research provided is impartial to the greatest humanly possible degree and does not favor any outcomes over any others.

Analysis I had a research goal of determining the possibility for demolishing the entire North Wing section of the existing Moore Building as opposed to selective demolition for reasons of reducing total project schedule time and determining a possible difference in cost. As a result of the research performed, demolition or deconstruction would cost roughly $425K versus the original $237K for selective demolition. This assumes no asbestos abatement, which would not affect the cost as it is constant for both approaches, as outlined in the research. However, the demolition/deconstruction would reduce the schedule time by at least 10 work-days.

In the **analysis II**, the benefits and implications of replacing the current stick-built façade with a near identical (if possible) pre-cast façade were explored. The research suggested that, based on the system provided by Oldcastle Precast Systems, the precast system would not be exactly identical nor would it be cheaper ($304K-363K precast vs. $300K stick-built), but, it would weigh slightly less and perform better mechanically, requiring no structural redesign and saving $2,300 per year. Most importantly, the reduction in schedule time is 67 days. This includes time for mobilization, lead times, and waiting for the steel structure to be completed.

For **analysis III** there was an initial desire to consider a contract type with the steel prime contractor in order to streamline the process of delivering and erecting steel that would involve OPP holding the contract with steel prime contractor. This was already the case and a shift to study the effect of a design-assist contract on the process in order to develop the case, as OPP does not have the manpower for such a move. Based on research and analysis, the design-assist contract method would be beneficial to the project assuming allocation of funds was not an obstacle. Quantitatively, the benefits would be seen in the form of a schedule reduction of 12 work days and just over $100K in savings. This would also come at a risk of about 14$ percent of the project total, which would be a risk of $3.6M.

Finally, the last analysis **(analysis IV)**, which looks at the viability of integrating an AE program with OPP in order to have a dual-benefit approach of allowing the students in the program produce B.I.M. models for OPP in order to be used for, but not limited to, preventative maintenance, asset management and geographical representations of on-campus buildings. This idea is based on the notion that students in the AE program would be modeling buildings either way, and OPP could benefit from this and pay a lower premium which would, in turn, benefit the AE department. Based on past trials and controversial aspects of the entire project, as well as intensive research on the project, the most appropriate and effective approach would be to hire students to perform the modeling in an internship setting. This solution, although extremely simple, entitles OPP to all their desires for a model and prevents long lead times as well as provides resume-friendly experience.

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The Moore Building Addition

Moore Building is an existing building on campus and it houses the department of psychology. Throughout its existence, the program has grown at a steady pace and so has its faculty and students. Interest in the field is much greater than it was when the Moore Building was initially constructed, a few decades ago. With the department of psychology now being one of the largest departments on the Penn State University campus, an equally monumental expansion was due; The Moore Building Addition & Renovation.

Split into two phases, this structure will be constructed to the highest standards, and satisfy the needs of the entire department, whilst keeping in mind economic decisions and "green" construction and operation practices.

The Moore Building Addition is located on the intersection of Fischer Road and Allen Road on the university campus of The Pennsylvania State University, on the Northeast side of campus. Logistics will be an easier task than previously anticipated due to the student traffic in the area which is much less than that of central campus. This is also in-part due to the fact that the building is close to Park Avenue, which is connected to the highway and where some material may find itself coming through. Although the roadways leading into and out of the areas are tight, the utmost effort will be put forth by all parties to ensure the success of the project.

Building Statistics	
Building Name	Moore Building Addition
Building Location	University Park, PA 16802
Occupancy	Department of Psychology
Classification	B (Business)
Building Size	57,000 SF + 16,000 SF North Wing
Project Start/Finish	06/2010 – 01/2012
Building Cost	$26.1 Million
Project Delivery Method	Design-Bid-Build

Table a-1: *Building Statistics*

The building's design sports the new Penn State trend of modern mixed with historical architecture. This is primarily evident in the extensive use of red brick infuse with aluminum paneling and glass curtain wall systems (Figure a-1). Its design allows the building to stand out and provide more for the image of the university, while maintaining its function very well.

Figure a-1: *Moore Building* Addition

Building Systems Summary

Demolition

In order for construction to begin demolition must occur at the site of the original structure. This is due to the fact that the Moore Building Addition and Renovation must tie into the old building, and the old building's façade must be removed to allow for this to happen. This will be followed by removal and asbestos abatement of the original building before the new structure can be erected. Another large demolition requirement is the removal of the existing building's asphalt parking lot and concrete walkways, which have to be removed so that excavation can take place. This process suffered two sinkholes occurring during first weeks of construction.

Structural Steel Frame

Moore Building Addition and Renovation consists of a typical structural steel system. The structure consists of a predominantly structural steel system that is cross-braced from north to south and from east to west of the building. The typical structure is followed through from the 2^{nd} to 4^{th} floors, as they are very similar. The first floor and basement and the high roof have a few structural differences than the rest of the building. The cross bracing system includes HSS7x7x.25 from the 3^{rd} floor to the high roof, and HSS8x8x.25 from the basement floor to the 3^{rd} floor, with a few exceptions for some of the pieces. The north side of the building's steel is sloped downward for bracing purposes.

The existing building's north wing's structural system was taken down to its structural steel elements and that will be used and built around as a cost-saving method. It also helps tie in with the existing building.

Although a crane and boom size has not yet been specified, the planned and approved location for a crane will be the north side of the building. However, there is a higher possibility that this will be substituted for two cranes on the east and west sides of the building in order to increase productivity and for safety reasons. This also makes transporting the cranes easier as they are smaller in size.

Cast in Place Concrete

Cast-in-place concrete will be used for the strip footings, spread footings, foundation walls, basement slab, SOG, composite decks from the first floor up to the high roof.

The pouring method that will be used to place the concrete will be pump trucks. Typical formwork will be used for the foundations with plywood and steel used. Also, the wood used will be recycled after the limited number of uses in order to comply with the 70% recycling goal for the project.

Mechanical System

In the basement level of the Moore building are chilled/hot water pumps along with the secondary chilled water pumps, all raised 4" on a concrete pad of their own. Two of the Chilled Water Pumps produce a flow of 905GPM, whilst the last produces a flow of 130GPM. The secondary chilled water pumps' flow is rated at 245GPM and the hot water pumps' flow is rated at 500GPM. There also exists a condensate pressure pump as well as several unit heaters. The Hot water supply and return pipes are capped for future phase II. They are located in the basement as well.

There are two main air handling units. The first is supplying a chilled beam system (19,000CFM AHU 29.85BHP @ 1800RPM) whilst the other is supplying the VAVs in the building (31,000CFM AHU 48.80BHP @ 1800RPM). The building consists of both variable and constant air volume systems. The new AHUs are located in the basement level of the new building. There is an existing AHU in the penthouse of the existing structure as well.

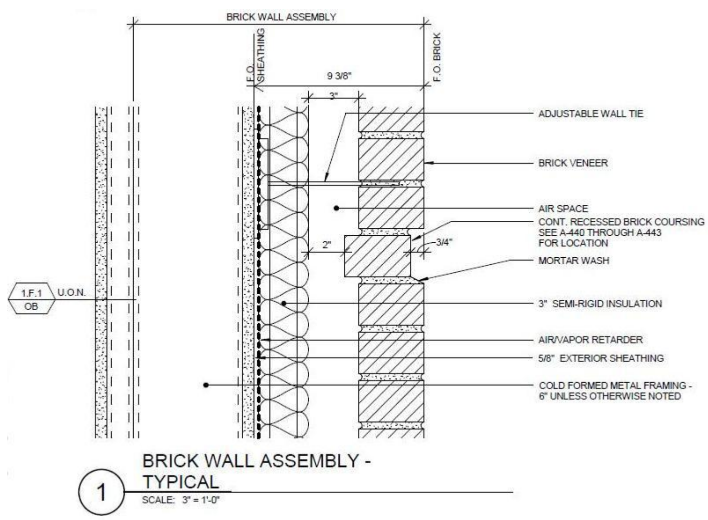


Figure a-2

Electrical System

The electrical system is quite sophisticated in Moore Building Addition. The main equipment panel board has a distribution of 3 Phase 480V. The demand on this panel board is 336KVa. Most if the rest of the panel boards are 480Y/277V 3 Phase wiring with some 240Y/120V three and single phase wiring.

Electrical connection is made in manhole #201. Also at manhole #201 is an emergency connection rated at 4160V. A 1000KVA transformer is used with 12.47KV Primary and 480/277V Secondary coils which provides power to the building and is provided by Office of Physical Plant. Main Switchgear has a rating of 42,000 AIC. Also, there are both a standby service voltage switch and standby distribution panels for the addition.

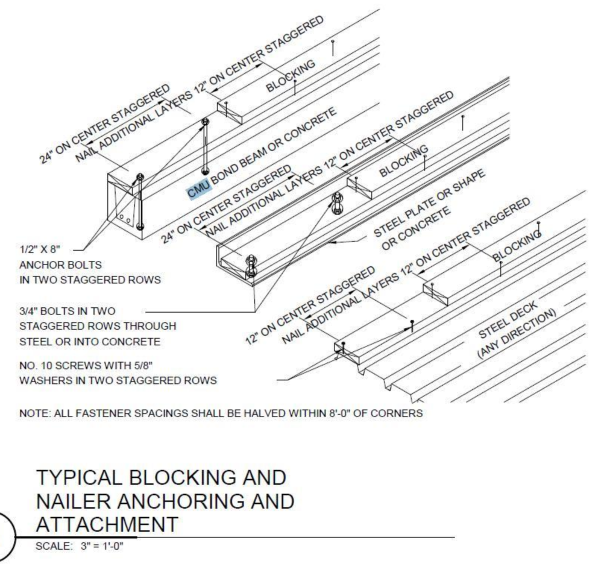


Figure a-3

Masonry

The Moore Building Addition and Renovation consists of a brick façade accompanied by glass and aluminum in order to both retain a traditional look as well as to suggest growth and foresight. This means that the brick is a veneer setup as opposed to load-bearing, which it is not. As shown in figure a-2 the assembly consists of the brick veneer separated from the insulation by an air space and tied to the building using an adjustable wall tie. The brick is surrounded by both glass and metal panels of aluminum, and although it may seem to cover a lot of surface area, the typical installation is the same throughout the entire façade except for a few special brick types for the edges of the building.

The other instance where masonry used is in the roof assembly where the steel deck meets the edge of the wall and a CMU bond beam can be used for the blocking as shown in figure a-3.

Curtain Wall

There is an aluminum curtain wall system that covers most of the first floor. This same curtain wall system is used throughout the façade of the building on the higher levels and is surrounded by glass and brick veneer assemblies, held by mullions. The transition between the lower and higher façades is separated by ornamental metal. The top of the curtain wall system that is held by the mullions is braced for lateral loads, in order to prevent it from being damaged.

Support of Excavation

As support for the excavation shoring will be used to keep the excavated area in place. This process is succeeded by foundation work and, more importantly, the underpinning of the existing structure, which requires care and extra support to keep the existing building from collapsing.

For dewatering systems, there are two standby pumps to remove water should it become a problem. So far, they have not been utilized as there hasn't been a problem with the area in terms of water table. This makes the pumps a safety measure, and they are temporary.

Project Cost Summary

Building Areas	
Addition	57,000 Sq. Ft.
Renovation	16,000 Sq. Ft.
Total Area	73,000 Sq. Ft.

Building Costs	
Construction Cost (CC)	$19,200,000
CC/SF	$263.01/SF
Total Cost (TC)	$26,100,000
TC/SF	$357.53/SF

Building Systems Costs*	
Roofing	$433,170
Curtain Wall	$1,293,556
Asbestos Abatement	$210,365
Excavation, Shoring, Demolition, Concrete, Waterproofing, Landscaping, Site Furnishings, etc.	$1,778,000
Masonry	$314,000
Structural Steel	$1,228,500
Windows, Metal Panels, Curtainwall	$1,283,886
Interior Walls	$3,284,000
Elevator	$361,800
Fire Protection	$288,688
Plumbing	$769,000
HVAC, BAS Controls	3,494,000
Electrical	$1,987,000

*Data obtained from bid results

Table a-2: *Project Cost Summary*

Site Plan of Existing Conditions

The Moore Building Addition lies on the north-east side of the Pennsylvania State University's main campus. Although this area of the campus is less crowded with pedestrian traffic than the core of campus, it still receives some traffic. However, the site is much easier to manage in terms of pedestrians as the buildings here are more sparsely laid out and re-routing is an easier task here. The main construction trailer site will be directly opposite to the project's site. This makes it more convenient for the project managers and personnel. It also provides more space for laydown areas where the "Existing Asphalt Parking Lot and Landscaping" is, as that has been removed and will be used for major laydown for when materials reach the site.

The North Wing of the Moore Building has been intentionally shown as it will be "renovated" as part of the addition phase since it has been stripped to its steel structure and that structure will be incorporated into the addition.

The existing utilities have been shown and most connections will be made in the manholes including electrical connections whose details are contained in the Building Systems Summary portion of this report. There are no gas lines mapped out in this section of campus that are included in the drawings as this building uses steam instead. The boundaries of the site are not defined as the area involved is Penn State owned land. The maximum area of disturbance coincides with the fence lines, and they may be considered "property lines."

Figures a-4 and a-5 show aerial view of the site of the Moore Building Addition. The construction trailer shown in figure a-5 is a temporary site for the duration of the project only.

Figure a-4: Bing Map Aerial View

Figure a-5: Bing Map Aerial View

Parking for the project workers will be a combination of the parking lot on the west side of the construction trailer site as well as off-site parking (the stadium lots on the east side of campus).

*See **APPENDIX A** for more details.*

Local Conditions

The Moore Building Addition is located on the North-East side of the University Park campus and is part of a construction initiative that aims to better the quality of the facilities at Penn State University as well as expand them. The benefits of construction projects on the University Park campus include the relative leniency with the construction site, availability of laydown areas off-site especially if the project is in an area of high density pedestrian traffic. For the Moore Building Addition the project location is at an advantage.

Building methods at the Pennsylvania State University campus are focused on quality structures that can withstand the cold temperatures as well as the hot temperatures, and typically consist of structural steel for the buildings skeleton. This is mainly due to cost and keeping them down than any other factor alone. This is especially true for this project as there are state-funds (DGS Money) involved so low bidders are chosen for some of the building systems.

The subsurface water condition of the site is typical of what is seen on the University Park campus and although there are standby pumps as a safety measure, excavation is not expected to reach the water table.

Seven test borings were used for the Moore Building Addition and were performed by CMT Labs, inc. and ranged from depths of 36 to 55 feet below grade. A groundwater table was not established during these tests but it was possible that the fluctuation in water tables occur due to change in season. This is why there were standby pumps on site. The surface of the site where the parking lot consists of 6 inches of asphalt which lays on top of gravel subbase that is 6 inches deep as well. The areas not covered in asphalt contain a topsoil layer 6 inches thick, and is organic in nature and is highly compressible. There is also fill material around the site which starts at about 2.5 to 5 feet below grade and consists of clay, gravel and shale fragments. Under all different fills there is a consistent layer of natural residual cohesive soils which include silty clay, sand, gravel and weathered dolomite. This layer extends to depths varying between 20 to 36 feet below grade.

The results conclude that the recommended foundations will be conventional shallow foundations consisting of spread footings as well as continuous wall footings.

Client Information

One of the main reasons of this project is to expand the abilities of Penn State's psychology departments and, in turn, its collective abilities. With the departments of Psychology being one of the largest departments on the University Park Campus and the expected tenure-track faculty number to grow from 42 to 50, the addition will be a fitting one for this department.

"A building that effectively serves the varied research activities of the Department is a central goal of the addition to and remodeling of Moore. This will require different lab sizes and configurations, with an eye toward flexibility to accommodate future changes in faculty and research programs."

--Moore Building Program

As the quote above states, Moore Building Addition will aid in research efforts and help the department grow substantially over the coming years. This is in part due to the fact that cramped space for research and makeshift research areas have strangled the efforts of those here at the department of psychology. This addition plans to provide new facilities that keeps in mind all the needs of the department and has a specific goal in mind to provide more and more to the department.

At the Pennsylvania State University there are people who are very particular about the quality, progress and, most importantly, the safety of all construction projects on their campus. These people range from those at OPP to the board of trustees to the students themselves. The bettering of the campus is an interconnected web of relationships between everyone who shares any experience in or at Penn State.

Safety goes a long way at Penn State and could sometimes be considered the number one factor on many projects; Moore Building Addition is no exception and every effort has and is being made to keep that standard. This is reflected on both the university and the contractor so no chances are taken in this department. A strict selection of pre-qualified companies may even bid. The criteria here include EMR ratings among other things.

Cost of the project, as with any project, is a defining factor as well. This is mainly due to the fact that state funding is being used for the Moore Building Addition and so, a low bidder has to be chosen. This means that although Penn State would like to have the utmost in quality, they are also bound to choosing a low bidder for this job for some of the systems. This is especially true because at the Moore Building there are state of the art communications and laboratories equipment included in the specifications and job requirements. So, a low cost will be favored but quality will also be pursued as that is also part of the job's specifications and Penn State's values as a research institute.

The factors above rely on a trust placed by the owner (PSU) in the companies involved in the project as well as their active participants from OPP ensuring that the project proceeds with as few "hiccups" as possible. There is a mutual responsibility. The building will be turned over and occupied while as soon as it is done and the renovation phase will begin on the existing building in a phased occupancy strategy that allows work to be done in one building while the other is being worked on.

Project Delivery System

The Project delivery system being used on this project is a Design-Bid-Build. This is due to the fact that a design has to be agreed on by the board of trustees as well as the university architect, David Zenghut, before a design can be cleared for building. This process ensures that the university's vision of the

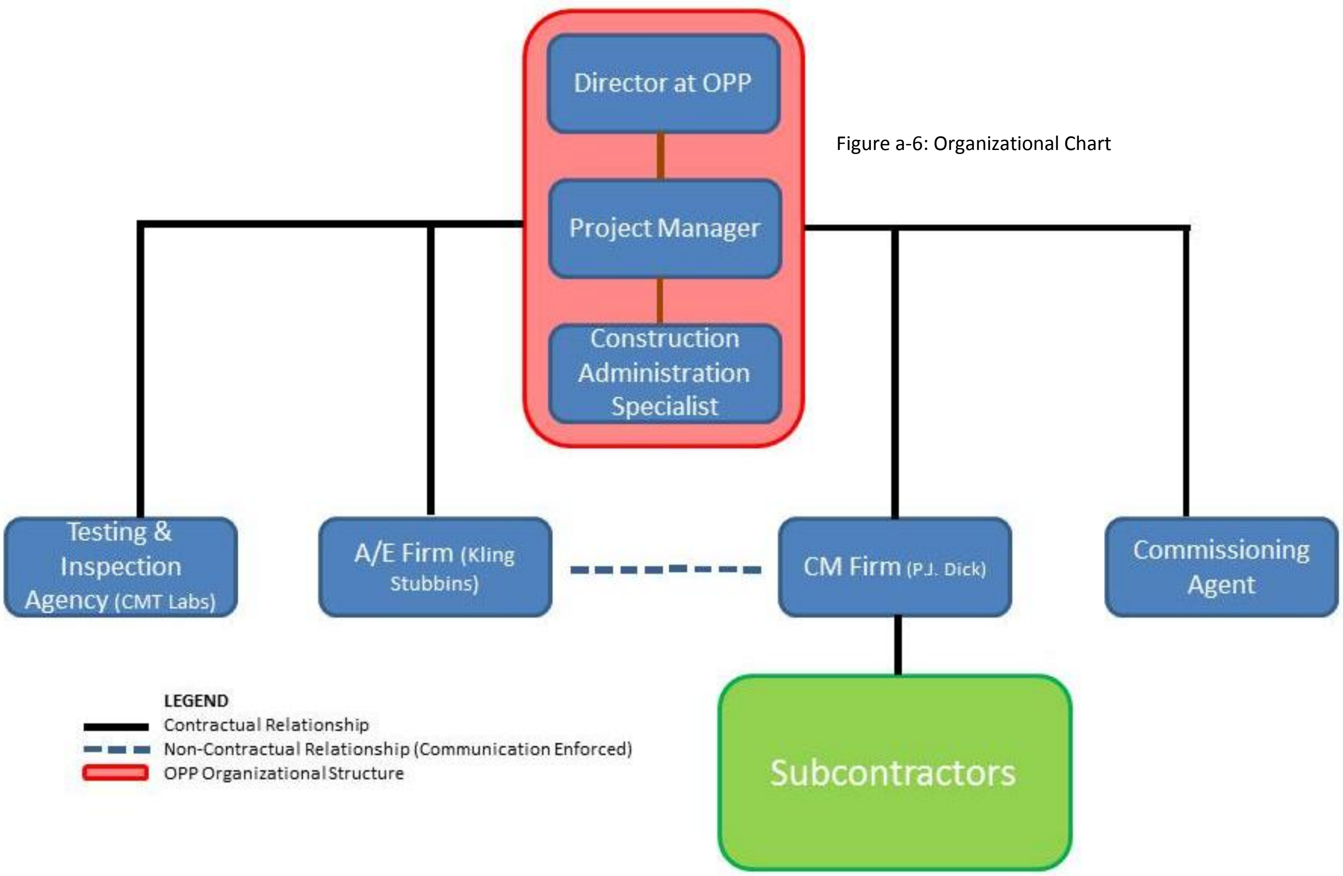


Figure a-6: Organizational Chart

campus design and theme can be maintained. Also, a defined program can be achieved with more confidence before building even begins.

This method was also chosen because of the way that construction works on Penn State's campuses; it is overseen by the Office of Physical Plant (OPP), and they have a big hand in keeping costs down as they are an owners representative that is capable of a lot of in-house maintenance and minor construction and act as a much more competent owner side. This cuts costs of tuition, which is another goal for construction on budget.

Organization structure includes a project manager from OPP, who oversees the Architect/Engineer Firm (Kling Stubbins) as well as the contractor (P.J. Dick) as well as the Geotechnical Firm (CMT) on the project. All these entities are contractually bound to the university and the project manager ensures and facilitates communication between the three. This is done with the project manager's team of in-house engineers at OPP. The main assistant to the OPP project manager is the construction administration specialist, who oversees the project site and handles RFIs and such, in order to keep a better "flow" on the project.

The contract held by the OPP and the CM firm is a GMP (Guaranteed Maximum Price). The subcontractors hold a lump sum contract with the CM firm, PJ Dick.

The Testing and Inspection agency (CMT Labs) is responsible for a certain degree of quality control assurance including, but not limited to, compaction tests, concrete testing, rebar testing, bolts and welds testing and testing mortar samples in the brick. P.J. Dick, the CM firm holds official contracts between themselves and the subcontractors, and, the bidders for all subcontracting work are pre-qualified to the CM firm's standards.

Staffing Plan

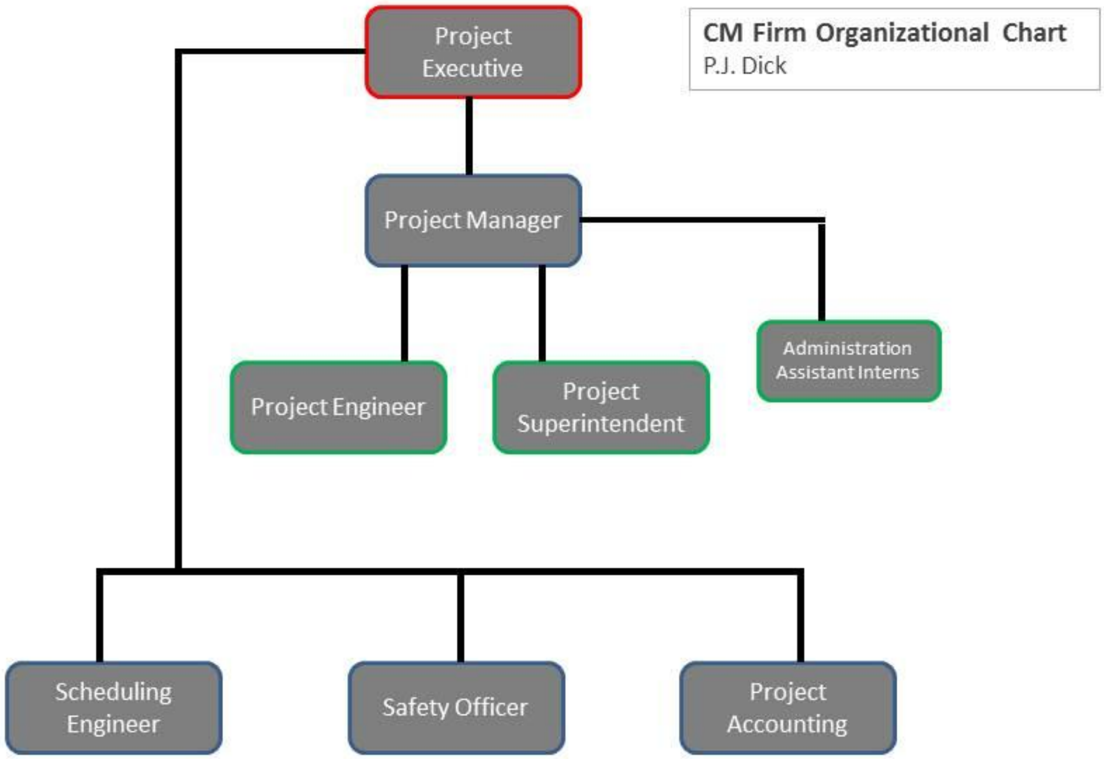


Figure a-7: CM Firm Organizational Chart

The staffing plan for P.J. Dick is structured for efficiency. The project manager on this job is the main person communicating with the OPP, and the communication is mainly between the OPP Project Manager, the construction administration specialist at OPP and P.J. Dick's Project Manager. This is not to say that no other communication lines exist. The project Executive handles all major aspects of the project and can report to OPP when necessary, and coordinates communication between his team. This is because he is in charge of more than one project.

There is a meeting held at the OPP on a bi-weekly basis, and this includes the project manager of the CM firm as well as the project manager at OPP and his construction admin specialist. Other attendees to this meeting are the project architect as well as some OPP engineers. Another meeting is held by the OPP construction administration specialist and the CM firm and all its employees on the job. These sets of meetings facilitate all problem solving issues and get things resolved in a more timely manner and induce communication between all parties involved.

Detailed Project Schedule

The construction of the Moore building addition consists of removing the original brick façade of the existing building and asbestos abatement of the original structure. This will be done for all floors in the beginning and will allow for the removal of the existing concrete and asphalt on the ground level. The structure and foundation will be done in two sections; West, followed by North and East as one section. This will occur for the basement and first floors since the basement is only on the west side and the first floor consists of slab-on-grade. After the first floor is done, the building will be done together.

Although the schedule comprises of many grouped items, the general direction of work will start from the west section followed by the North and East sections of the building. This is due to the way that the new structure will tie into the existing structure. One benefit of this is that time will be freed up by the sections that are completed early, so that work can proceed in segments.

The schedule is broken down into the actual structure as a whole portion, whilst the interior fit-outs (including MEP and Electrical) being sectioned by floor.

Steel

The most important lead time in this process is the structural steel's which will take 40 days to arrive from the time in which it is ordered, making it arrive in October. So, many activities need to either be held off up until that time, or, some need to occur before the arrival of the steel.

Site-Work

One major area in the schedule, as this project is a renovation is the site-work involved, which will take about 100 days. The details of this activity are shown in the schedule.

Demolition and Asbestos Abatement

The demolition and abatement phase takes up about 45 days for the first portion to occur and the last part cannot occur until the last ten days of December.

Interiors

Interior fit-outs begin almost immediately after the final slab is poured on the fourth floor, with the first floor layout of the track being done about two weeks after pouring the slabs.

The sequencing of work from floor to floor occurs in a highly orchestrated manner; the crew working on an activity on the first floor would finish and immediately start the same work on the next floor allowing the next tradespeople to start work on the previous crew's finished activity.

*See **APPENDIX B** for more details.*

Detailed Structural Estimate

The detailed structural estimate was done using RSMeans Costworks to organize and tabulate the costs and line items of the takeoffs, which was done by hand.

Structural Systems Estimate Summary			
System Type	**Estimated Cost**	**Estimated Cost (incl. OH&P)**	**Added Waste Factors (10%)**
Concrete System	**$687,248.47**	**$786,814.72**	**$855,539.57**
Structural Steel System	**$567,265.28**	**$661,384.49**	**$718,111.01**

Table a-3*: Summary of Estimated Costs for Structural Systems*

There was no information provided as to the exact actual cost of the concrete system. This is due to the fact that the concrete for the Moore Building Addition is part of a larger package that includes excavation, shoring, demolition, waterproofing, landscaping, site furnishing, fences, paving and stripping. However, the rough total was around $1 Million estimated by the CM firm, and this number was stated to be inflated due to several factors including this price being part of the GMP (guaranteed maximum price). The subcontractor's prices did come in less than this, but the actual amount, as stated before, cannot be deduced. So, this estimate has come up about ~$145K short of the actual amount which could be attributable to differences in required tolerances of concrete placement, differences in waste factor calculation, and the exclusion of items such as dewatering, concrete curbs, concrete stairs and waterproofing from my estimate.

For the structural steel system, the estimate came about ~$500K short of the estimated value by the lowest bidder (~$1.2 Million). This, according to the CM Firm PJ Dick is very close to the actual cost of the structural system. This is due to the fact that no ornamental steel has been taken into account (this includes stairs, rails, steel panels and other such items and was estimated to be ~$500K) as the structural steel package for the Moore Building Addition takes into account ALL steel for the project. Metal decks have been included as part of this package as well.

Although the comparison is based on the low bidder's estimate, the rest of the bids are a bit higher and that may be because of the added cost of aligning the new structure and making sure that the floors and framing line up with the existing structure. Also, performing work in State College, PA may be a little more costly due to some "invisible" costs that may include laydown, storage and transportation to and from the site. However, although the floors may need to line up, the new structure is independent of the previous structure.

Finally, although the estimate is very close to the actual cost, it may have been slightly lower if the wide-flange members were all priced exactly based on member type. This was not possible through RS Means Costworks as not every member type is included or available with its own costs.

Assumptions & Facts

- Foundation wall heights have been averaged because the difference is minimal.
- NW Concrete on 2" 18 Gage G60 metal decks (actual).
- WWF Reinforcing W2.9xW2.9 (actual) in all slabs.
- No rebar was calculated as part of reinforcing due to time constraints and minimal amount.
- Wide flange and HSS members were grouped as not all member sizes were available for cost .purposes in RS Means Costworks (e.g. if columns were W12X20 and the nearest PLF was W12x22, all members will be estimated based on the assumption that they are W12X22 members).
- Lateral Bracing members were assumed to be 63 members at 14' each; no option for total length was given.
- New Structure and existing structure will be independent structurally speaking.

*See **APPENDIX C** for more details.*

General Conditions Estimate

For the General Conditions Estimate, the layout was broken down into two main sections; Staff/Personnel and Office expenses/OH (including Temporary Utilities), as shown in table a-4.

General Conditions Estimate Summary	
Category	***Cost***
Staff/Personnel	$1,193,900.00
Office Expenses/OH	$214,685.00
TOTAL	**$1,408,585.00**

Table a-4: *Summary of Estimated Costs for General Conditions*

The total cost of $1.2 Million is 5.39% of the entire project cost. The costs do not necessarily reflect the costs of the CM firm PJ Dick, but some items used are accurate in comparison to the project's general conditions estimate, and were derived from the actual General Conditions Estimate, whereas a few other items were added to accommodate for this assignment's requirements. The costs of these added items were estimated.

It was assumed that there is temporary power coming in to the trailers, although this may not be completely true depending on whether the trailers are connected through an existing building or not, as the trailers are directly next to a building on the opposite side of the road to the construction side.

*See **APPENDIX D** for more details.*

Analysis I: Demolition

The Moore Building Addition is set to tie into an existing structure of structural steel members. This existing structure is 16,000SF and will be stripped to its structural steel and concrete decks before any work can or will be done. This portion is called the North Wing and is an independent structure, so, there will not be a need for any structural ties to the new structure that will be built around it.

This North Wing will undergo Asbestos removal and abatement during the “Demolition and Abatement” phase of construction. Most of this demolition and abatement phase will be from June 2010 to up until the beginning of September 2010. So, the process will take about 90 days to complete, and whilst that is part of the schedule, there may be room to accelerate the schedule by eliminating this process entirely.

Analysis’ Importance

Although the Moore Building Addition is scheduled to be both on schedule and under budget, it’s a building long over-due, and its early completion can begin to bring both research and revenue to the department of psychology at Penn State. The idea is not simply for profits, but the Moore Building’s operation is symbolic of the department’s growth as well a new beginning for the program at the university. So, a building handed over early means that the next phases of construction can begin early as well, since there is an entire renovation of the existing building that follows the construction of the new building.

Proposed Solution

The proposed solution to the issue at hand – finishing the building earlier – is to, instead of stripping down the North Wing of the existing building to its structural steel and concrete decks, demolish it and build it back up as part of the new structure. The idea focuses on seeing the entire new portion of the building as one new piece, and treating it as that instead of reducing the North Wing and then rebuilding around it and renovating it.

Possible Drawbacks to Solution

Since this solution proposes to demolish the existing structure, there may be more foundation work involved with the new building, and a possible redesign may be imminent. Also, the demolition may cost more than would be beneficial to the project and cause a large amount of waste on site, which would contribute to the cost of the demolition, making it less cost-effective. Finally, the process requires very specialized companies to carry out the process, since the North Wing is attached to the current Moore Building and a Demolition may require extra attention as not to compromise the structural integrity of the building through a miscalculated demolition, or careless preparations. In other words, there are quite a few risks involved with the operation that may render it useless.

Methodology

- Research and determine cost and schedule time required for Asbestos abatement and removal per square foot.
- Research and determine cost and schedule time required for constructing a superstructure of 16,000SF made up of four levels.
- Research the costs involved with tying in two structures, if any.
- Data of the Asbestos abatement and removal of the current structure will be obtained in order to compare to the researched data, from available documents or from project team on the site.
- Analysis of labor costs of both methods will be evaluated and a comparison made.
- Additional costs due to quality control of tying in will be assessed from current job data and compared to the final costs of both systems.

Resources/Tools

- Project Manager at PJ Dick
- Project Leader at OPP
- Available estimates of Moore Building Addition
- Available schedule of Moore Building Addition
- Applicable publications

Expected Outcome

An expected outcome would be that tearing the entire north wing down and building it back up as part of the entire structure would be a more cost effective option than preserving its structure. Another expected outcome would be that the schedule time would be ultimately reduced as well due to this. This is due to less time spent on the intricate details involved with preserving the structure as well as removing the asbestos in it, and instead, being able to build right up from the site. Also, space on site will be less congested due to this.

Performed Research and Results

The Moore Building Analysis is, as mentioned previously, a 73,000 SF structure which will consist of a 57,000 SF new structure which will be built surrounding the existing North Wing (16,000 SF). This North Wing will initially be stripped down to its bare structure and following this, the two structures will be seamlessly merged. This will occur along with the removal of the brick façade of the original structure, which will be covered by the new structure. So, there will be a demolition crew on site to begin with, as this will be removed as well as the existing pavement and parking lots that are a part of the original building.

The existing North Wing of the Moore Building will then be, by definition, “deconstructed.” This means that as opposed to demolition where it will be torn down, the building will be stripped but with care taken in order to keep certain parts intact. These parts will be load-bearing and their preservation will be essential as the North Wing is not structurally connected to the new structure that will be erected around it.

Demolition Research

Demolitions are not necessarily explosions. They are a controlled method of bringing a building down on top of itself, and require lots of preparation and a very skilled professionals in order to allow for a building to “go down” nicely and cause as little disruption and debris as possible. The use of explosives is not always necessary, but when it is, the preparation becomes extremely time-consuming. The idea is that there will be a lot of debris and flying pieces of concrete and other materials, so, in essence, there will need to be a lot of work before a building can even be fitted with the explosives. Also, the focus of this analysis will be deconstruction; a type of demolition, although the term “demolition” may be used to refer to “deconstruction.”

This work comes in many shapes and forms, with one of these being the removal of certain objects like copper, non-load-bearing items like drywall, and partitions. And, interestingly enough, one more unforeseen thing that must be done before a demolition can occur is asbestos abatement (Loizeaux). However, there are techniques which allow for asbestos to be contained, rather than removed and costing the project; controlled demolition in which the floor columns are removed and replaced by computer-controlled hydraulic jacks, and lowered on these jacks so that deconstruction is more efficient and tidy. This eliminates most debris and risks involved and streamline the process. This has been proven on buildings up to 20 stories high and would not be a problem to use on the Moore Building Addition since it is only 4 stories high ("Popular Science").

One aspect of a demolition that may, however, be beneficial in an environmentally friendly way is the recycling of the rubble from the demolition as use in aggregate in the concrete to minimize waste on site and reduce the cost of removal of the waste. Also, if the aggregate is of no use to the concrete used in the Moore Building Addition, it can be stored and used for future roadways and other construction in or around campus. This can even be taken further and the rubble used as aggregate for mortar, and as a recycled product (Corinaldesi, Giuggiolini, and Moriconi 893-99).

The real problem here is, though, the demolition process considering two attached structures. With the Moore Building currently consisting of a North Wing that is attached to the existing structure, it may be a much more difficult job than simply demolishing a free-standing building. This poses question that really challenges the viability of this proposed solution.

Demolition Preparation

Before demolition may begin, preparations must begin in order to ensure both the success of the endeavor and the safety of the general public. Assuming that both are taken care of in the same preparation period, the time for this period must be examined, as well as some of the necessary physical preparations that must take place.

In preparing for demolitions (explosive or non-explosive) the process may take anywhere from two weeks to 3 months. For the Moore Building Addition's North Wing, the period will most likely be *within* one month, or 30 days, since it is small in size, however, no definite answer can be given unless the structure is examined by a professional.

Based on information obtained from an unnamed vendor, there will be no ability to determine the exact amount of time taken to actually demolish or deconstruct the building. This may take up to 1-2weeks depending on many factors, especially since the North Wing must first be isolated from the existing structure.

Project Management Costs & Demolition Time

Through conversations with an experienced project manager, there has been determined to be a different approach to this entire analysis. By comparing two buildings with studies based on selective demolition and full demolition, one can apply the same knowledge to the Moore Building Addition. However, the figures presented are all relative, and may or may not skew the reality of the costs to the actual building. Important factors to note are that both projects require asbestos abatement.

Expert Analysis			
124,000 SF	6	Weeks	Demolition 100% building
	8	Weeks	Selective Demolition 1/3 of building
Factor = 1/3 for time to *demolish* Vs. *selective demo*.			
Hence…			
16,375 SF			
Selective Demo. Schedule Time : 29 Days (~5wks)			
Complete Demo. Schedule Time : 29*2/3 = 19 Days (~3wks)			
GC Costs: $1.4M/570days = $17,200/Wk.			
Saving 2wks **GC savings = $34.4K**			

Table 1-1: *Expert Analysis*

Based on the figures provided, one can deduce that the amount of time required for demolition of the North Wing would be 3 weeks, including the removal of all waste materials. With this time, the required amount of asbestos that would need to be removed before rendering the process non-cost-effective would be 15,000 SF of asbestos removal.

Schedule Time

Also based on expert opinion, there would be a very significant change to the results presented, in that the schedule time required to build the North Wing would be technically negligible. Since the schedule time considered is extremely conservative at 29 days, the amount of time taken can be further reduced by simple good practice. Another large factor considers the simple structure of the North Wing, and the ability for its construction as part of the rest of the structure to be able to reduce its schedule impact by 2/3 of the time. This means that it would only really add about 10 days to the total schedule time, making the proposition much more viable.

Asbestos Research

> *"'Asbestos' is a generic term used for the fibrous forms of 6 naturally occurring minerals. They are all flame retardant, heat insulating, acid resisting, nonconductive and exceptionally stronger than steel. There are only 3 main types of asbestos fibres that are commercially used:*
>
> *1. Crocidolite (also known as 'blue asbestos')*
>
> *2. Amosite (also known as 'brown asbestos')*
>
> *3. Chrysotile (also known as 'white asbestos')*
>
> *There is no simple test to identify the different fibres; laboratory examination is required (you cannot always distinguish by colour alone). All fibres can be dangerous in their raw form (as are nearly all industrial raw materials), but blue and brown asbestos fibres are known to be much more dangerous than white asbestos fibres."* (An Introduction to Asbestos)

With the current state of affairs, the removal of asbestos is a requirement for all new construction and renovation work, and so is the case in the Moore Building Addition. And, to make matters more complicated, the asbestos in the Moore Building is friable, meaning that it can easily vaporize in certain areas and be inhaled. This means that excessive vibrations that may be cause by explosives can result in fibers of asbestos being released and posing a threat to all those around the building as they are extremely fine and can easily be inhaled. These fibers, when inhaled in higher than normal concentrations have detrimental effects to one's health. So, without removing the asbestos, no demolition can occur unless the new technique – described in the last section – is utilized where hydraulic jacks slowly bring down the building.

Another, more appealing technique is to "enclose" the asbestos. This means that the asbestos-sprayed areas or asbestos insulation is sealed so that no fibers or particles can contaminate the atmosphere around them. This may still not work for demolition that involves explosives, but may be utilized in demolition where the computer-controlled hydraulic jacks are employed, as vibrations are minimized.

Asbestos Analysis

A preliminary cost analysis was done to determine the cost-effectiveness of the demolition of the North Wing and rebuilding it. The data was obtained from the available cost breakdown of the Moore Building Addition and Renovation of the North Wing.

The data was taken from two main sections. First, the asbestos abatement and removal costs were determined, and the time taken was considered. The line items included asbestos abatement and removal as well as the selective demolition that was performed on the structure in order to remove necessary pieces. Included was also the allowance for the temporary equipment used to aid in the removal of the asbestos in a safe and efficient manner.

Costs involved with asbestos abatement and removal were followed by the schedule time taken, based on the available schedule of the project. The total time to remove the asbestos was recorded and will be used as a comparison tool. This all pertains to the 16,000 SF North Wing and is shown in *Table 1-2*.

Asbestos Abatement Cost Analysis - North Wing				
Item		**Unit**	**Cost / Unit**	
1	**Asbestos Abatement & Removal**	16,375 SF	$20/SF	$327,500
2	**Selective Demolition for Asbestos Preparation**	3,986 SF	$10/SF	$39,860
3	**Temporary Equipment for Abatement**	1 EA	$25,000	$25,000
4	**Selective Demolition for North Wing**	16,375 SF	$12.10/SF	$198,080
5	**Demolition of Concrete, Casework etc.**	16,375 SF	$2.4/SF	$39,303
			Total	**$629,750**

Table 1-2: *Asbestos Cost Analysis*

As shown, the total cost for asbestos abatement and removal in the North Wing of the existing structure is just under $630K. Since the project is being built almost $6Million under budget, the monetary savings will be mitigated by the possibility of schedule acceleration. The reduction in schedule time would not only need to be significant to the entire project, but all risks involved with the demolition would need to be low. The reason for this is that if the demolition of the entire North Wing poses more of a risk to the timely completion than its possible benefits, then it would be no longer feasible as an alternative.

Asbestos Abatement Schedule Impact Analysis – North Wing + Selective Demolition			
	W/O Basement Abatement	**W/ Basement Abatement**	**Total Area (SF)**
Total Days	93 days	207 days	16,375 SF
Only Workdays	80 days	177 days	
Schedule Day/CSF	0.4885 days/CSF	1.0809 days/CSF	
Schedule Hrs./CSF	11.7252 hrs./CSF	25.9420 hrs./CSF	

Table 1-3: *Asbestos Schedule Analysis*

As shown in *Table 1-3*, which was taken from the final schedule of the project, the process for asbestos abatement is a time-consuming one.

In order for work to begin on the project, asbestos must be removed from the existing building. This is a lengthy process and will occur before most processes. However, once the above-grade floors' asbestos is removed, work will begin and foundations will start. But, the basement's asbestos will not be removed for another ~3months after the first portion occurs. This will not exactly delay or hold-up any construction activities, but will cost time in a very indirect way, and although this is the case, it can be eliminated altogether with the demolition of the structure.

So, the total time required to carry out the abatement as well as selective demolition is 93 days plus the 10 days it will take to remove the asbestos from the basement, which adds up to 103 days. This is time that could be potentially used to begin constructing the building, and, in turn, completing early.

Asbestos Abatement

Through research, it has been determined that a crucial part of preparing for demolition is the removal of asbestos, if it is posing a health hazard (friable). This unforeseen condition may mean that the time necessary to remove asbestos will not be mitigated by demolishing the North Wing, but it will be an addition to the entire process of demolishing and rebuilding the structure.

The only way to determine the amount of time that will be required to contain or remove the asbestos in the North Wing, in a manner that prevents the substance from becoming airborne and dangerous, is to determine the amount of asbestos that is, in fact, friable. And, whilst this task is not exactly possible to determine objectively, some characteristics of asbestos must be looked at once more.

In order to understand how much time would be required to contain/remove the asbestos and then demolish the structure, the structure itself must be examined completely in order to visually identify the way in which the asbestos has aged and been placed. This aging process plays some role in determining whether or not the asbestos is harmful, and whilst asbestos poses no threat if it is sealed away from human interaction and cannot spread its particles into spaces where humans are active in, it can still be dangerous if not contained properly.

Asbestos may also appear in places not documented before, as has been found on the Moore Building Addition. This is due to the discrepancies between the construction documents and the as-built documents. It would not be surprising to find asbestos in more unexpected places, which makes the prospect of completely removing the North Wing much more appealing. The method in which it was applied plays the most important role. Flocking, the act of spraying small fibers onto a surface, is one common method of asbestos' application during its prime. Since it had great fire suppression characteristics, it was sprayed liberally on surfaces, especially since it is a very light material. However, these fibers can be dislodged so easily especially after a little amount of time. Another way in which asbestos was used was in sheets, that were almost "rubbery" yet had a carpet-like texture, and these sheets were used in applications like floor tiles and as insulation. The floor tiles, in their non-friable state may never be problematic, but the insulation may weather over time and its fibers would easily dislodge, returning us to square one.

So, how does one tell what has happened over a long period of time without searching the building of asbestos; it is generally a tough situation. Once maintenance operations occur, the fibers may easily be dislodged from minor vibrations and handling of the asbestos or the material it coats. Hence, safety preparations are crucial if any type of asbestos related work is to take place, and this means that there is a cost for asbestos containment.

Illustrated in *graphs 1-1 & 1-2* is the amount of asbestos that can be removed before the process becomes more costly than the current proposal. Since the total time to remove the asbestos from the

North wing and perform selective demolition is 103 days, and it would take 29 days to reconstruct, in theory, the North Wing, then there are 74 days left in which asbestos abatement can take place along with demolition (3 weeks as discussed in section "Expert Opinion") itself before the demolition proposal loses its cost-effectiveness. So, to determine the amount of asbestos that can be removed and, at the same time, preserve the demolition proposal's effectiveness the graphs have been created to present a clearer picture.

From *graph 1-1* we can deduce that in 74 days, ~17,000 SF of asbestos can be removed, after which the demolition of the North Wing can occur whilst posing no threat to the schedule. However, if there is more than 17,000 SF of asbestos to be removed (which is impossible!), then the operation would become a cost to the project.

Furthermore, *graph 1-2* illustrates the cost of removing asbestos based on square footage, deduced from the original calculation as follows:

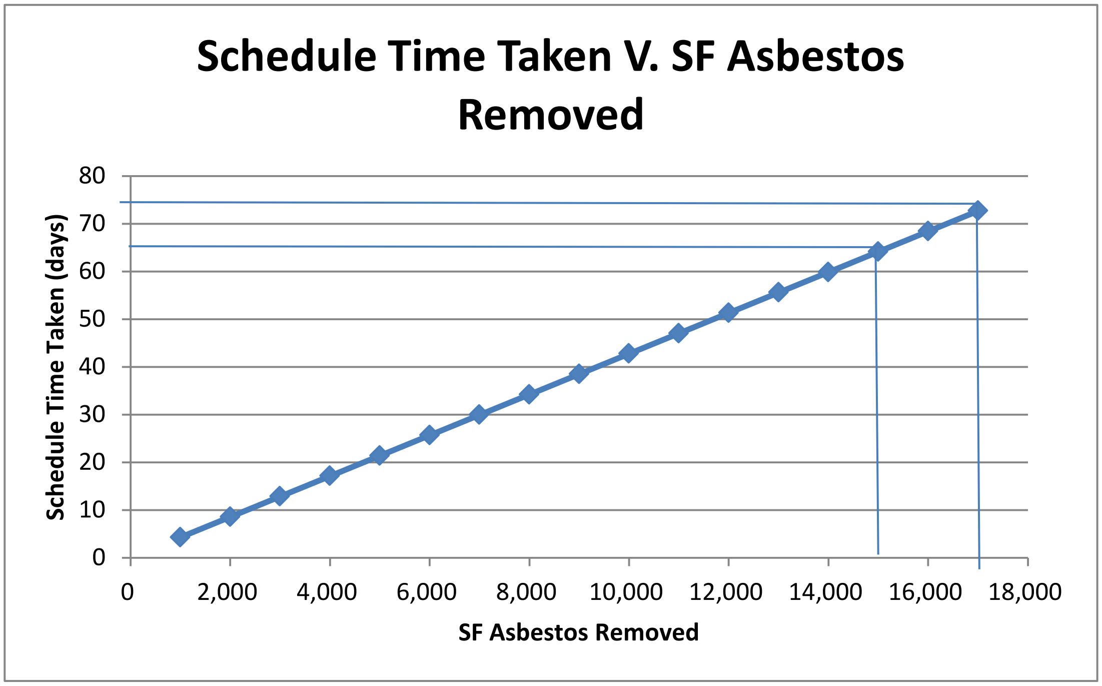
($327,500 + $25,000) / 16,000 SF = **$21.52 / SF**

Cost to abate 16,000 SF asbestos (no preparation costs)

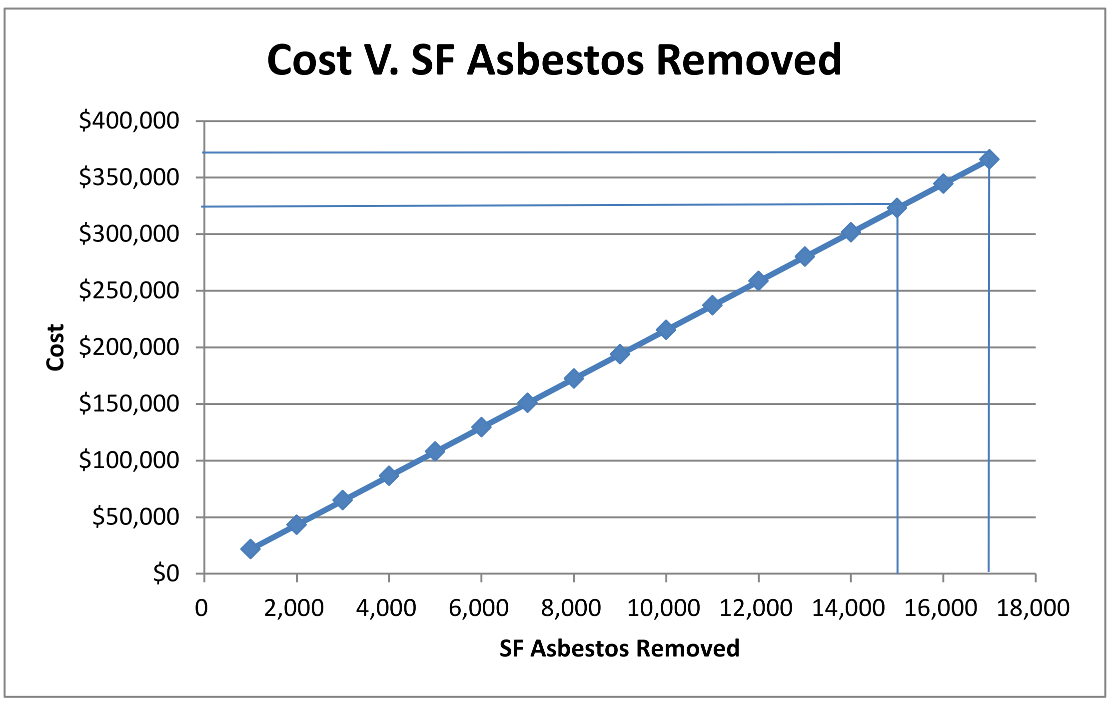
Allowance for asbestos removal preparations

SF of asbestos to removed

Hence, it can be also deduced that in order to remove 17,000 SF of asbestos, it would cost ~$366K. This means that although the cost may be quite high for the entire operation, it would all come down to the savings in schedule time, if at all possible.



Graph 1-1: *Schedule Time Taken V. SF Asbestos Removed*



Graph 1-2: Cost *V. SF Asbestos Removed*

Reconstruction Analysis

In the reconstruction analysis, the cost and schedule time impact for rebuilding a four-story, concrete deck and structural steel structure that's 16,000 SF was studied. The cost data was used from the "Technical Assignment Two" cost estimates that were done for the entire structure's superstructure *(table 1-4)*. The reason for this is that the estimates performed for the technical assignment were extremely close to the original, and would not skew the results enough to be dismissed.

Since the object being considered is simply the structure, which consists of structural steel and concrete, the cost of those items is what was going to be used in order to keep the analysis streamlined. If the cost does not seem reasonable, a re-analysis would be performed.

The costs taken from the existing data have been broken down into "Dollar Value/SF" and used to determine the cost of the 16,000 SF North Wing, should it be rebuilt as part of the rest of the structure *(table 1-5)*.

Structural Systems Estimate Summary (58,000SF)				
System Type	**Estimated Cost**	**Estimated Cost (incl. OH&P)**	**Added Waste Factors (10%)**	**TOTAL $/SF**
Concrete System	$687,248	$786,814	$855,539	$14.75
Structural Steel System	$567,265	$661,384	$718,111	$12.38
Structural Steel (NO HSS BRACING)	$512,265	$589,104	$648,015	$11.17

Table 1-4: *Superstructure Estimate*

Cost of North Wing Superstructure Construction	
Total Area	**16,375 SF**
Concrete Cost	$241,542
Steel Cost	$182,908
Deconstruction Costs	$81,875.00 (=16,375 SF X $5/SF)
Asbestos Abatement	$391,860
Total Cost	**$898,000**

Table 1-5: *North Wing Superstructure Estimate*

Since the cost of concrete and structural steel (no miscellaneous steels added, but decking included) are \$14.75 and \$12.38 per square foot, respectively, it is simple to determine the cost of the North Wing's steel and concrete (Note: The cost includes labor). The final cost would be ~\$900K. *Note: This calculation performed assuming the new structure would NOT be laterally braced with HSS beams, as per a conversation with a project manager and through analyzing the steel drawings.*

In order to determine the deconstruction costs, \$5/SF was used as a conservative figure obtained by a study to determine the cost of deconstruction before salvaged materials were sold (Frisman) in conjunction with an expert's opinion being that as a general rule of thumb, Selective Demolition would cost roughly twice the amount of demolition or deconstruction (Faust). Deconstruction is the method of choice due to the size of the building and its location.

The final portion will demonstrate the schedule time taken in order to erect the four-story, concrete-on-metal-decks and structural steel structure. This estimate of the time taken has been produced by reducing the original schedule time allotted for erecting the Moore Building Addition (the portion which surrounds the North Wing) to "Days/SF" by determining the amount of days per the original 58,000 SF. This is shown in *Table 1-6* and has been multiplied by the North Wing's 16,000 SF in order to estimate the amount of days it would take to construct it.

Schedule Time to Erect North Wing			
	Total SF	**Schedule Time Taken**	**Days/SF**
Calendar Days	58,000	105	0.0018
Workdays	58,000	90	0.0016
Calendar Days	16,375	**29**	0.0018
Workdays	16,375	**26**	0.0016

Table 1-6: *North Wing Superstructure Schedule Impact*

As can be observed, the schedule time to erect the North Wing as part of the rest of the structure would be 29 Days, which would be added to the schedule. This numerical value represents total days, including days-off. If Sundays and holidays are removed, the total work days become 26. The latter number is used purely as a comparative value. *Note: The 29 days include all time for excavation, shoring, backfills, and steel structures and pouring concrete on metal deck; it is the total time required to independently construct the North Wing and is a* ***highly conservative*** *value.*

The values were derived by determining the "Days/SF" for the 58,000 SF since they are allotted 56 days for superstructure construction including the pouring of the concrete on decks. This value was then multiplied by the 16,000 SF in order to determine the amount of days required to erect the North Wing.

Analysis Review

The most important factors come to play in the understanding of how "do-able" or realistic the proposal of demolishing the North Wing and rebuilding it as part of the entire structure is. It is important to note that no finishes, mechanical, electrical, plumbing or any other construction has been considered in this analysis so far and this is with good reason; the comparison is between stripping the North Wing down to its basic structure, which consists purely of concrete on metal decks and structural steel.

With the North Wing, there will be removal of a few parts (e.g. the stairwell will be removed midway through the project, but will be used as vertical transportation for personnel working on site) of the concrete that exists. This has been included in the asbestos and abatement costs as "selective demolition" and covers all removal of concrete from the North Wing during construction.

Had the North Wing been demolished, the necessary costs to consider would be the asbestos abatement of friable asbestos – as it is harmful – as well as the cost of the concrete and structural steel. This has been broken down into a "cost/SF" type of measure due to the fact that the North Wing would not be erected separately in the case that it was demolished. Instead, it would be built as part of the entire superstructure. In reality, this would reduce the overall "cost/SF" of the superstructure, but for simplicity's sake, and in order to be as logical as possible, it will be assumed that the cost/sf will not change by rebuilding the North Wing as a part of the whole structure.

Based on the current information, a preliminary analysis can be made by comparing the two methods in terms of cost and schedule time. This is tabulated in *Table 1-7*.

Preliminary Comparison			
Method	Selective Demolition	Demolition/Deconstruction + Reconstruction	Ratio (Original Demolition)
Cost	$629,700	$898,200	1 : 1.426
Schedule Time	103-74 = 29	29	1 : 1

Table 1-7: *Preliminary Comparison of Proposed Ideas*

So far, the time necessary for demolition has not been included purposefully in order to understand if the rebuild time and cost are cost-effective or not to begin with, which they seem to be.

Supplemental Research

Environmental impacts

In demolition comes great waste in the form of rubble, and most importantly, particulate matter, with the latter being more harmful than the former. But, how harmful are the particles emitted from a building like the North Wing of the Moore Building, considering it was built over 40 years ago, is the real question to be asked. And, considering that there is asbestos in the North Wing, demolition options must be studied closely as not to disturb the fibers of asbestos and pose an even greater risk.

The first issue, with particulate matter, is to determine how realistic it is to consider. Or, in other words, the degree to which dust from demolition, be it by explosive charges or an excavator removing chunks at a time, actually affect the air quality of the surrounding environment must be determined. In fact, the size of particulate matter at distances up to ~50m away from the demolition site may increase in size up to 9-fold, thus becoming a threat to those exposed (Dorevitch, Demirtas, Persky, Erdal, Conroy, Schoonover, and Scheff 1022-32).

Underpinning

Based on expert opinion, it was determined that should the North Wing be demolished, it would allow for a larger basement to be built as there would no longer be a need for underpinning *(figure 1)* the structure, since not all of the structure is below grade, as it is a means to keep structural stability. This would reduce the cost of construction by $81,000.

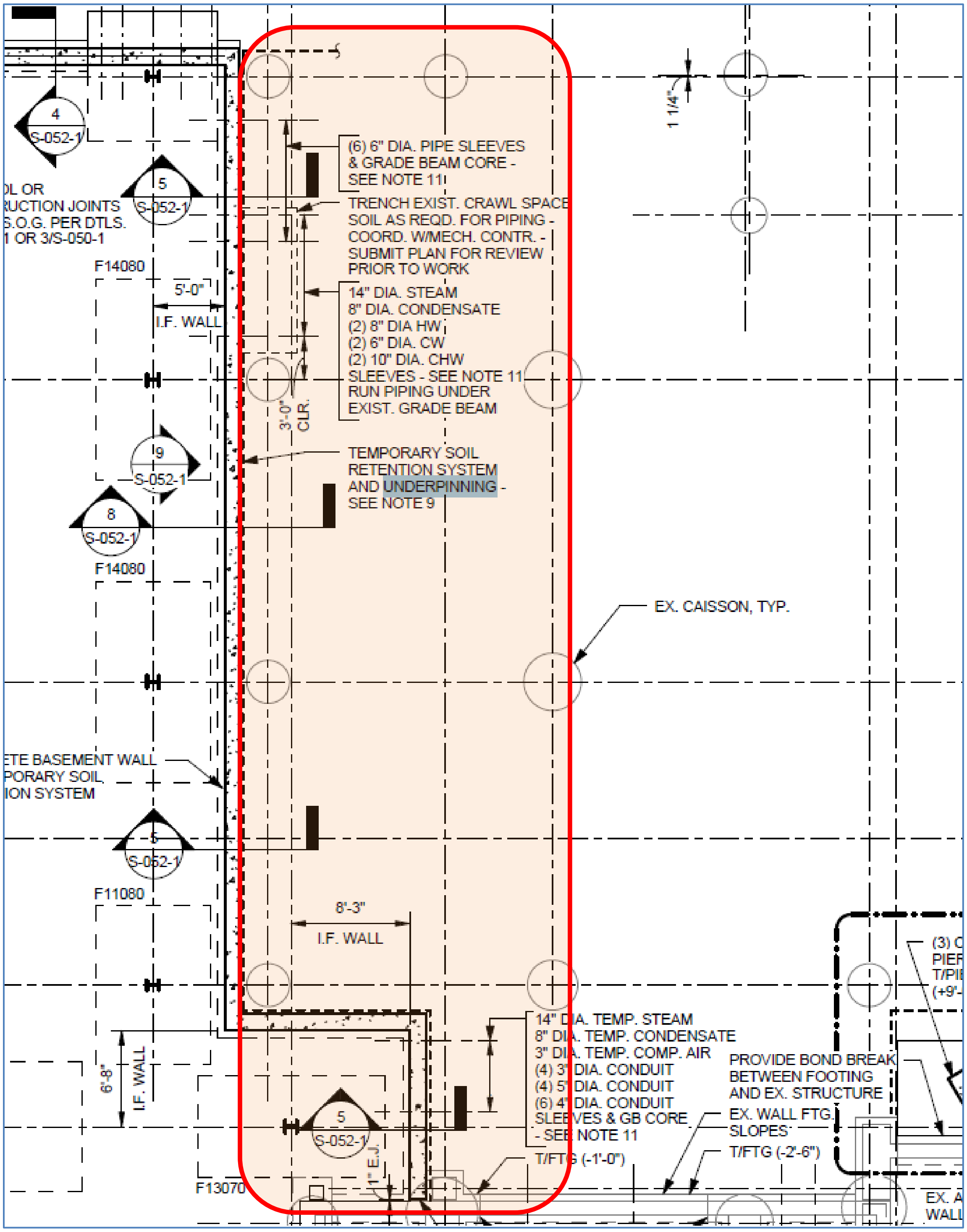


Figure 1-1: *Underpinning at North Wing*

Underpinning Elimination and Basement Expansion Analysis					
Condition	Item	Quantity		Unitcost	Totalcost
Existing	SOG Basement	5,788	SF	9.26	$53,596.88
Deduct	Underpin North Wing	1,620	SF	50	$81,000.00
Add	SOG New Basement	5,461	SF	9.26	$50,568.86
Add	Concrete Deck Fill New	5,461	SF	6.41	$35,005.01
Deduct	Strip Footings 18X12	136	LF	130	$17,680.00
Add	Strip Footings 24X12	500	LF	140	$70,000.00
Total Cost					**$57,000**

Table 1-8: *Underpinning Elimination Analysis*

Based on the calculations in *table 1-8* the total cost to increase the basement's square footage by 5400 SF will be about $57,000 due to the elimination of underpinning at the North Wing. The extra space will be able to house more mechanical equipment, and this would only be a viable option with the demolition of the North Wing.

Actual Events

Based on a conversation with a project manager on the site of the Moore Building Addition, the asbestos abatement and selective demolition that occurred on the site went "very smoothly and caused no delays," nor were there any issues with the operation. The second part, which took place from December through to January *did* take longer than expected but did not affect any other activities. This was due to the tightness of the crawlspace in the basement which required more attention due to the need to reroute a few plumbing lines and remove asbestos around them.

Also, through the same conversation, it was determined that there is at least 10,000 SF of asbestos in the North Wing alone.

Conclusions

To conclude, the factors discussed all come into play. The main goal for the proposed demolition idea was for it to simply save time. No more was expected of this idea and incurring a cost was not abnormal of the proposal. In fact, with general rule of thumb, to save time you need to pay money.

There are many factors that both deter from the idea of demolishing the North Wing and make the idea appealing. The stripping-down of the North Wing would require several activities to occur before it is ready to become part of a new structure. First and foremost, the North Wing must have all finishes, furnishings, mechanical, electrical and plumbing equipment removed. This activity could, in theory be mitigated by a demolition. Finally, asbestos must be removed from the building in order to render it safe.

Secondly, one must consider the required activities should a demolition occur. The first look shows us that preparation time is not a constant but can fluctuate, and whilst its fluctuation may even cause it to occur earlier than normal, its lateness could affect the entire flow of activities on the project as asbestos abatement is a critical path item. Although risk is normal on all construction projects, in this case, the demolition directly affects the short schedule for construction of the Moore Building Addition. Another very large factor is the fact that all friable asbestos must be removed, which means that asbestos abatement will occur regardless of whether there is a demolition or a strip-down. This poses the greatest question of whether or not the entire demolition is even necessary given that the North Wing will need to be stripped down regardless. The next argument is that technically, demolition cannot occur before the project begins, as it would typically be part of the contract with the Construction Management firm.

Based on the data collected, the proposition of demolishing the North Wing would be cost effective in quite a few scenarios. This is due to the possible demolition in a significantly shorter time frame of only 10 days, and a cost only slightly higher than the original proposed cost. Assuming that 10,000 SF of asbestos was to be removed, the savings would be in the range of 25 days including demolition of the structure, time to prepare (which would be done before the project even begins according to an expert) and all tasks related to demolition. Not only would this reduce schedule time, but the general conditions costs that would be saved are substantial as well at roughly $43,000.00. Again, this is considering only 10,000 SF of asbestos that needs to be removed, but that is the risk involved.

Recommendations

Asbestos Present

In the case of the Moore Building Addition, given all the factors discussed, the risk of demolishing the North Wing is not a great one at all. It is in fact a better proposal than the original one to perform selective demolition. This is due to several factors including the fact that it would take 15,000 SF of asbestos removal in order for the demolition to suffer a loss. In reality, most of the asbestos that will be brought down in a demolition will be removed, but non-friable asbestos would only need to be contained in order to make sure that the fibers do not spread. The recommendation considers an extra week to examine and prepare for the building’s demolition and as shown above, frees up a decent amount of money.

Asbestos Absent

Assuming that there is no asbestos in the building, there would still be good reason to demolish the structure and bring it back up. There would be time savings, but it would still cost more than the deconstruction.

Final Comparison (no asbestos)				
	Selective Demolition		**Demolition/Deconstruction**	
Costs	$198,080	Selective Demo. North Wing	$506,326	Total cost for Demo.
	$39,303	Demo. of Concrete, Casework etc.	($81,000)	Underpinning
			($34,400)	GC Savings
	$237,000	**TOTAL**	**$390,200**	**TOTAL**
Duration (work days)	29	Days	10	Days to erect
			9	Days to Demo.

Table 1-9: *Final Comparison (no asbestos)*

As can be deduced from table 1-9 the cost to deconstruct even in the event that no asbestos is present in the structure may benefit the project. With the schedule a little tighter as no asbestos abatement will take place, there will still be time saved.

Analysis II: Façade

For the façade of the Moore Building Addition all masonry and panel work will be installed on site by masons. This is a time-consuming process that will produce large amounts of waste as well as congestion and possibly quality control issues. However, the most important part of this is that the process is time-consuming. The ability to mitigate this can prove to be very beneficial to all those involved in the project.

Analysis' Importance

Although the Moore Building Addition is scheduled to be both on schedule and under budget, it's a building long over-due, and its early completion can begin to bring both research and revenue to the department of psychology at Penn State. The idea is not simply for profits, but the Moore Building's operation is symbolic of the department's growth as well a new beginning for the program at the university. So, a building handed over early means that the next phases of construction can begin early as well, since there is an entire renovation of the existing building that follows the construction of the new building.

Proposed Solution

A prefabricated façade system may be extremely beneficial to the Moore Building Addition; it may potentially reduce the time taken for erecting the façade whilst eliminating a lot of the waste involved with erecting the façade on site. This, along with the reduction in congestion is a very appealing combination and could potentially accelerate the schedule as well as improve the overall safety of the site.

Although not the most important benefit, the decongestion of the site that will occur is typically very noticeable on the project. It will allow for much better coordination between the trades and reduce coordination time between them, and that alone may be worth the benefits.

Possible Drawbacks to Solution

Some concerns of the proposed solution is that the transportation may cost a significant amount, and the size of the trucks may be a concern in that the roads leading to the Moore Building Addition are very tight and can pose a safety hazard as well as logistical issues. Also, the picks must be coordinated thoroughly as well as the possible laydown areas for the façade pieces that are fabricated off site and brought to the campus.

Methodology

- Research and determine the cost and schedule time required to erect the façade system currently approved for the Moore Building Addition.

- Research and determine cost and time required to pre-fabricate a near-identical façade system through interaction with the industry.
- Determine transportation and erection costs involved with a pre-fabricated façade system as well as schedule time required to erect the system.
- Research and determine any change in structure to the Moore Building Addition that may be required in order for this system to be viable.

Resources/Tools

- Available estimates of façade system
- Available schedule time to erect façade system
- Prefabrication company – façade
- Construction transportation company
- Structural Faculty and/or peers @ PSU AE

Expected Outcome

The most likely outcome of this research analysis topic would be that the pre-fabricated system's total cost would not exceed the total cost of the currently approved system, and the schedule time would be greatly reduced; enough to create a desirable impact on the project's overall schedule.

Performed Research and Analysis

Precast Facades

A precast façade is one where the veneer brick or masonry units are fabricated off-site, and then brought to the site and erected by lifting the pieces off the truck that they are brought in through, or by laying the pieces down near or on the site and erecting them once they are needed.

In the case of the Moore Building Addition, the most suitable method to prefabricate the façade is to have precast concrete with half-brick as part of the façade system, in order to be applicable under code. Although less aesthetically pleasing, the cost difference and schedule impact may play an important role in changing the consensus on the idea.

Precast Design Selection

In order to make the proposal the most effective it can be, a very specific type of precast system was chosen. Oldcastle Precast Systems provided some information on a system that could be used to fulfill the requirements of the Moore Building Addition's brick façade. There would be no need to change the metal panels' design as they are lifted onto place in the same manner as the new precast façade system would be. The glazing will also be left the same for this portion.

As shown in *table 2-1* the costs associated with the current system of masonry on the Moore Building Addition are as follows:

Masonry Construction Costs				
Item	**Quantity**		**Unitcost**	**Totalcost**
Metal Panels	2,020	SF	40	$80,800
Window Sills	585	LF	35	$20,475
				$101,275
Masonry Veneer	13,360	SF	20	$267,200
Stone Base - Granite	168	SF	100	$16,800
Caulking & Sealants	13,360	SF	0.75	$10,020
Rigid Insulation 3"	13,260	SF	2.5	$33,150
				$327,170
			TOTAL	**$428,500**

Table 2-1: *Masonry Construction Costs*

The costs consider the entire assembly, but more importantly, the cost of the brick masonry assembly including insulation and caulking is around $330K. The Granite stone base will not be part of the precast system as it is on ground level and there would be very visible quality differences between the two systems.

In the current system there are recessed bricks every 11-12 bricks up. There bricks will not be seen, but will house the mullion caps, which are an aesthetic feature when installed on the brick. With the precast system, these recessed areas can be concrete and will eliminate the need to purchase the extra brick in order to install them. This will save money.

As shown in *table 2-2* all the details of the two systems can be compared. The rigid insulation will be calculated with the brick due to the precast system including insulation in its configuration as the insulation will be “sandwiched” in between the concrete. The system comes in an 8” configuration due to the insulation that is included in between the concrete layers. The original system has 4” brick followed by a 2” air cavity and 2” of rigid insulation. This will allow the new system to be tied into the beams using the same shelf-angles that are currently to be used by the existing system.

NOTE: Original calculations were based on 3-4” rigid insulation for the original system, but due to a discrepancy in drawings and actual values, the final value came out to be 2”. This has been considered a negligible decrease and will not affect structural breadth or further calculations.

Systems Comparison			
Precast Panel			
Cost	$25(-3)/SF	Cost to install at jobsite	
Details	Insulated		
Picks	10-12 Panels / Day	200 LF / Day	45 Min / Panel
Size	12' X 8" X 30'	Largest Piece	
Weight	20,000 lbs	Largest Piece	
		95 pcf (TOTAL includes insulation)	
	43 psf (6" concrete + thinbrick)	1.5 psf insulation required	
Brick Veneer			
Cost	$22.5/SF	Cost to Install at jobsite	
Details	W/ Insulation		
Schedule Time	North	28 Days	
	East & West	70 Days	
	TOTAL	**98 Days**	
Size	2 X 8	4" Depth	
Weight		138 pcf (TOTAL includes insulation)	
	40 psf (4" thick Brick)	6 psf insulation required	

Table 2-2: *Systems Comparison*

Panel Sizes (8" thick)

North			*Count*	**South**			*Count*	**East**			*Count*	**West**			*Count*
12	x	30	*2*	12	x	15	*4*	3	x	24	*4*	4	x	24	*2*
12	x	20	*4*	12	x	17	*4*	12	x	19	*8*	12	x	24	*8*
3	x	24	*8*	8	x	24	*2*	9	x	24	*2*	3	x	24	*2*
12	x	17	*4*	12	x	19	*4*	4	x	24	*2*	6	x	24	*2*
6	x	24	*2*					12	x	16	*1*	7	x	16	*1*

Total Panels = 66

Total SF = 12,160

Total CF = 8,106.67 (w/ insulation) 6,080 (w/o ins.)

Table 2-3: *Panel Sizes*

*See **APPENDIX E** for visual representation of panels.*

	Quantitative Comparison of two Façade Systems			
	Precast Panel		**Brick Veneer**	
Cost	*$25(-30)/SF * 12,160 SF*	**$304,000.00** (-$363,000)	*$22.5/SF * 13,360 SF*	**$300,600.00**
Schedule time	*66 panels/10 panels per day*	**7-20 days**	*Based on schedule*	**98 days**
Weight	*(86 pcf * 6,080 cf)+ (9 pcf * 2,026.67 cf)*	**541,120.03 lbs**	*(138 pcf * 4,453.33 cf)*	**614,559.54 lbs**
Lead times	30 days per batch		Materials available almost immediately	

Table 2-4: *Quantitative Comparison*

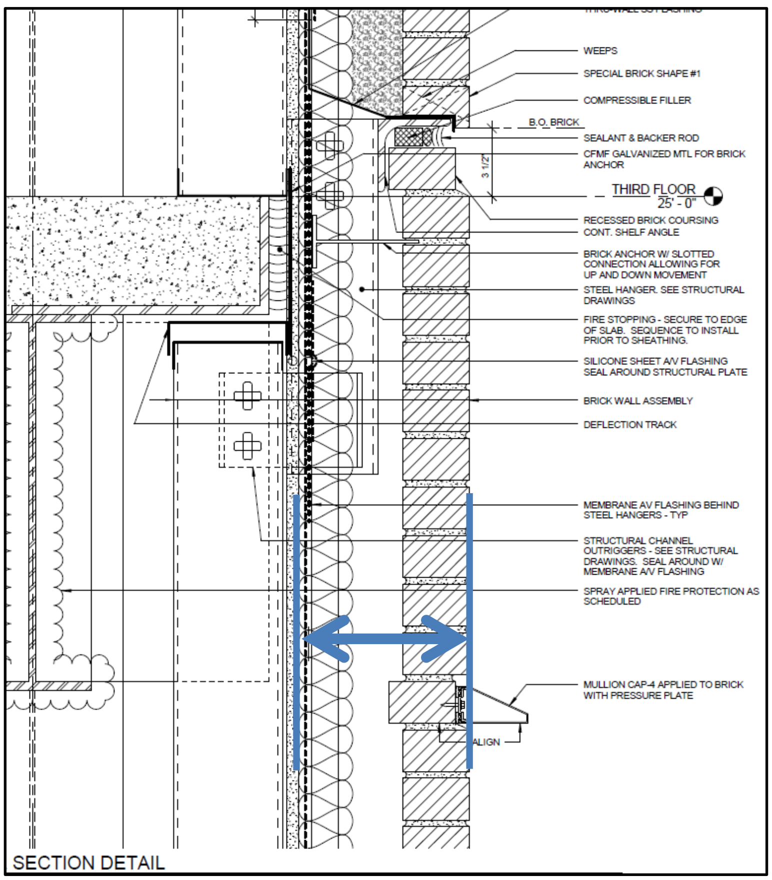


Diagram 2-1: *Original Façade Section*

Diagram 2-1 shows the wall section of the existing wall. The blue arrow shows the section that will be replaced with the precast system, only. The backing is cold formed metal framing and it will NOT be changed.

Based on the information from *tables 2-3 & 2-4* one can deduce which of the two systems will save more money and which will save more time. Although the precast panel system will cost slightly more than the brick veneer system, it is not a significant, at less 1.5% of the total cost. This considers the lower cost, which could rise up to $360K. Although a higher cost, it is still not a cumbersome cost to the project. Either way, there is an inescapable increase in cost for producing a pre-cast system that doesn't compromise efficiency, as will be discussed in the mechanical breadth section. The cost that will be discussed is the lower cost, for ease of comparison.

The information for cost (installed in state college and based on the Moore Building Addition's shape and size), weights and lead times were obtained from Oldcastle precast systems' office in Maryland. The schedule time, although misleadingly short, is based on the information also obtained from Oldcastle precast systems. The number used was 10 panels per day in order to account for possible delays on the construction site. This number may go up to 20 days based on site access, laydown areas and other factors. Nevertheless, 20 days is a much shorter duration than the original 98.

For the weight of the precast panels, 6,080 cf was used for the 6" of thin brick and concrete, whereas the 2,026 cf was used to determine the weight of the insulation. *Note: Assumed insulation sandwiched between concrete in precast panel is 2".* With this information, the total weights of both systems were determined and the change to a precast structure would not necessitate a redesign of the structural system due to its lower weight. The full brick system's weight was calculated along with 4" insulation at 6 psf.

In terms of the square footage used for the cost only 12,160 SF was used for the total of the precast panels as there would be no need for a waste factor as it is almost identical to the actual square footage of the current system. For the brick veneer system a 10% waste factor was added bringing up the total square footage to 13,360, which is what the construction management firm had done as well.

Schedule Effect

The precast façade system will require at least 30 days before materials arrive. This means that there must be that much time before the masonry is scheduled. Otherwise, there might be inefficiency. Based on the schedule, masonry is not set to begin until the 11th of January 2011. This means that there is plenty of time to have the precast panels ordered, fabricated and delivered to the site. With the precast panels being able to be installed only when the superstructure is complete, there might be a delay as to when the precast erection may begin. With the structure being complete on the 7th of February, almost 30 days are lost, but despite this delay, the total reduction in schedule time is 67 days.

Although hard to quantify, there may be a delay due to mobilization of cranes/equipment needed to carry out the erection of the precast façade. However, this is mentioned in order for one to understand that there may be additional time-consuming factors involved with the precast approach.

Structural Breadth

In order to demonstrate the difference of having each of the systems as a façade in terms of the structural implications, a portion of the steel structure which carries brick the whole way through has been used to model the different loads, reactions and deflections caused by the weight of the façade systems.

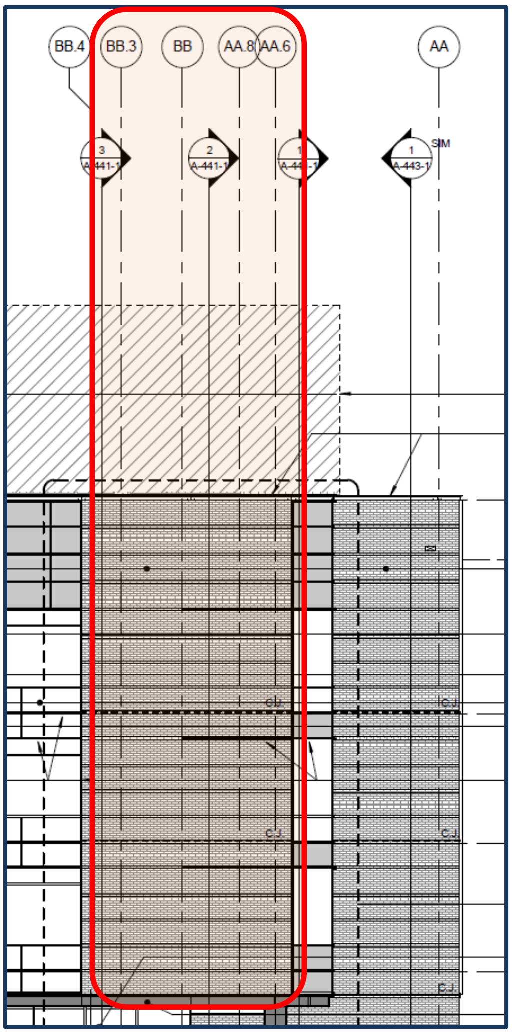


Figure 2-1a: *Elevation View of Selected Columns*

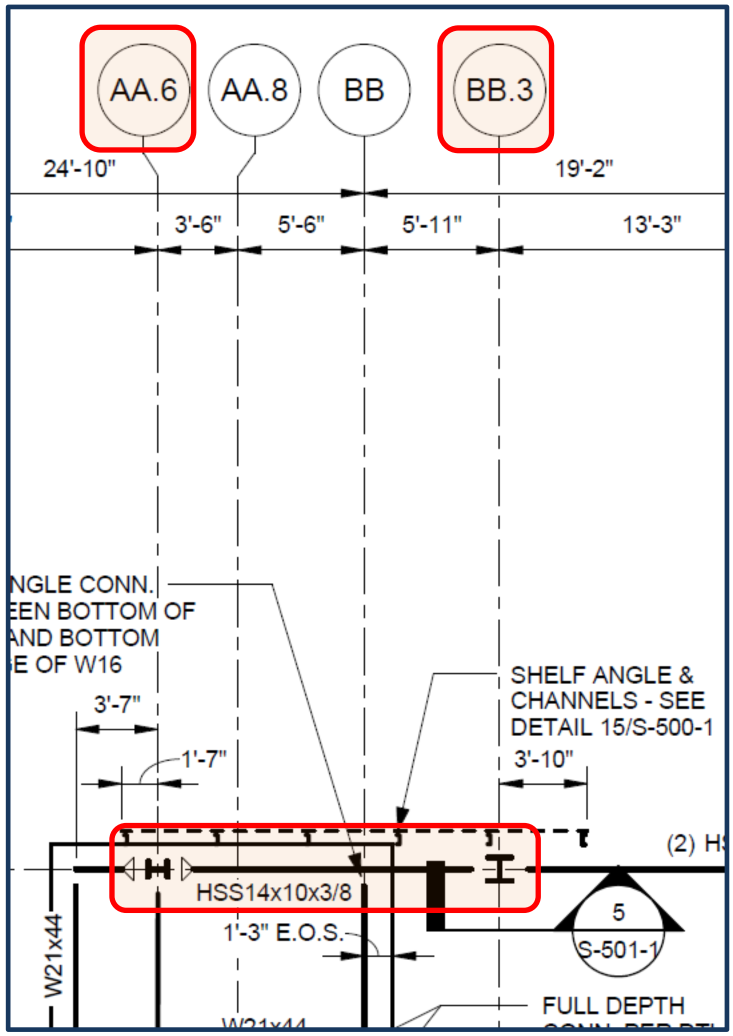


Figure 2-1b: *Plan View of Selected Beams*

Shown in *figure 2a* is the elevation from the 2nd floor to the high roof where the beams and columns have been modeled in order to determine loads and deflections produced by the two façade systems. The reason these two columns were chosen is because the entire façade between the two columns is made up of brick. In *figure 2b* it can be seen that the columns modeled have one moment connection and one pin connection, which have also been taken into account when modeling the bays.

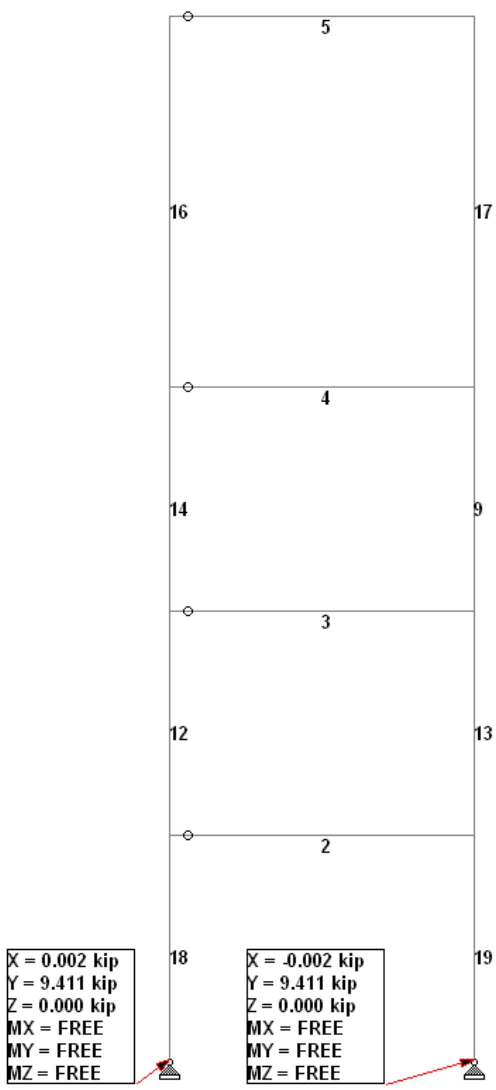


Figure 2-2a: *Elevation View of Modeled Columns and Beams Reactions with Precast Façade*

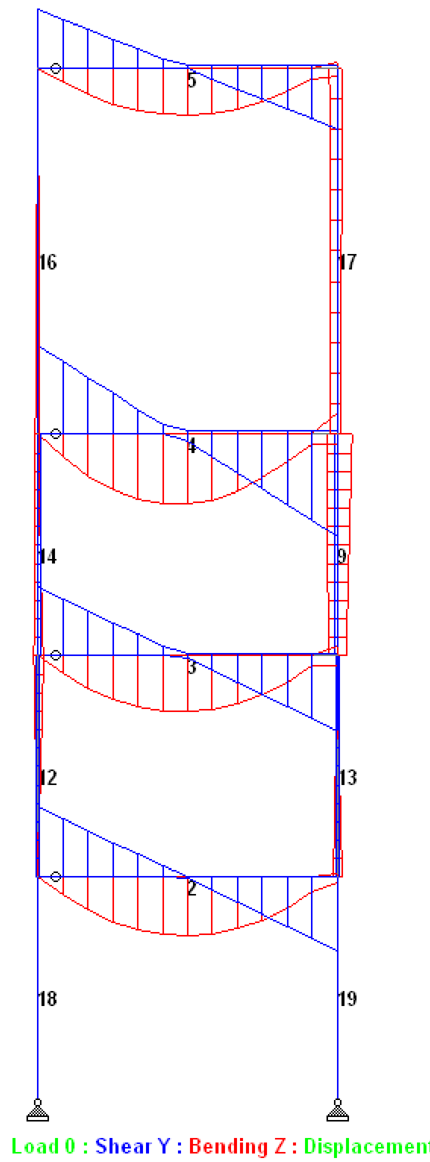


Figure 2-2b: *Elevation View of Modeled Columns and Beams Shear & Moment with Precast Facade*

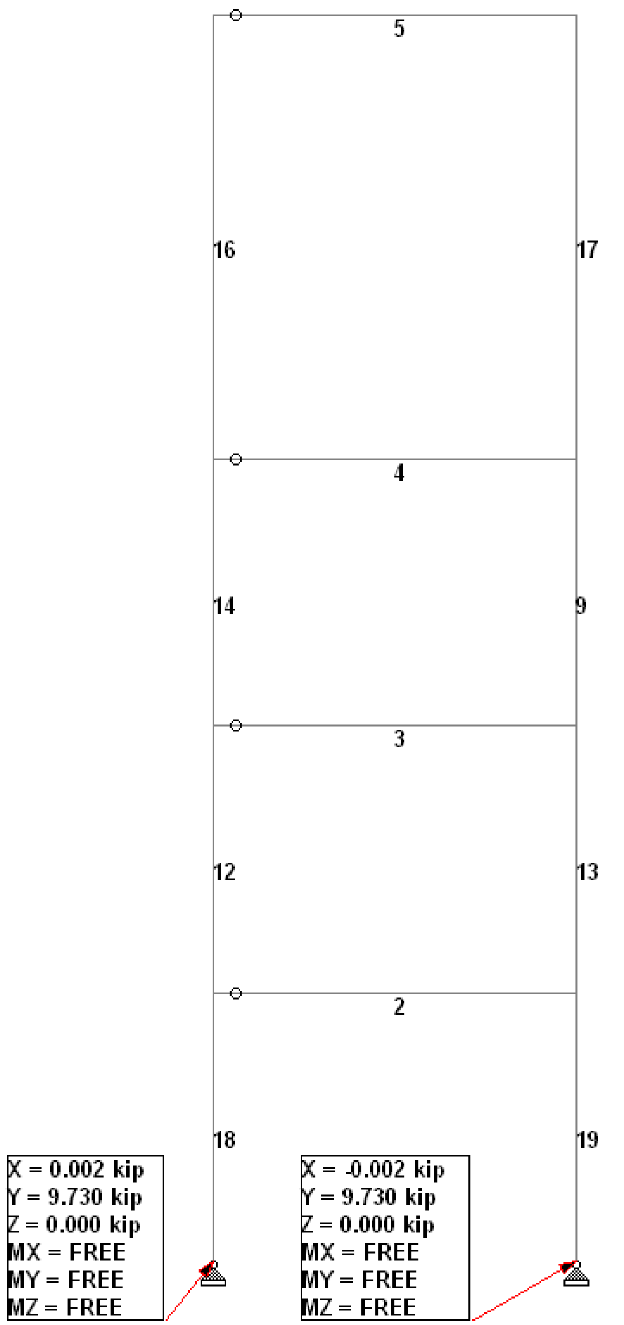


Figure 2-3a: *Elevation View of Modeled Columns and Beams Reactions with Brick Facade*

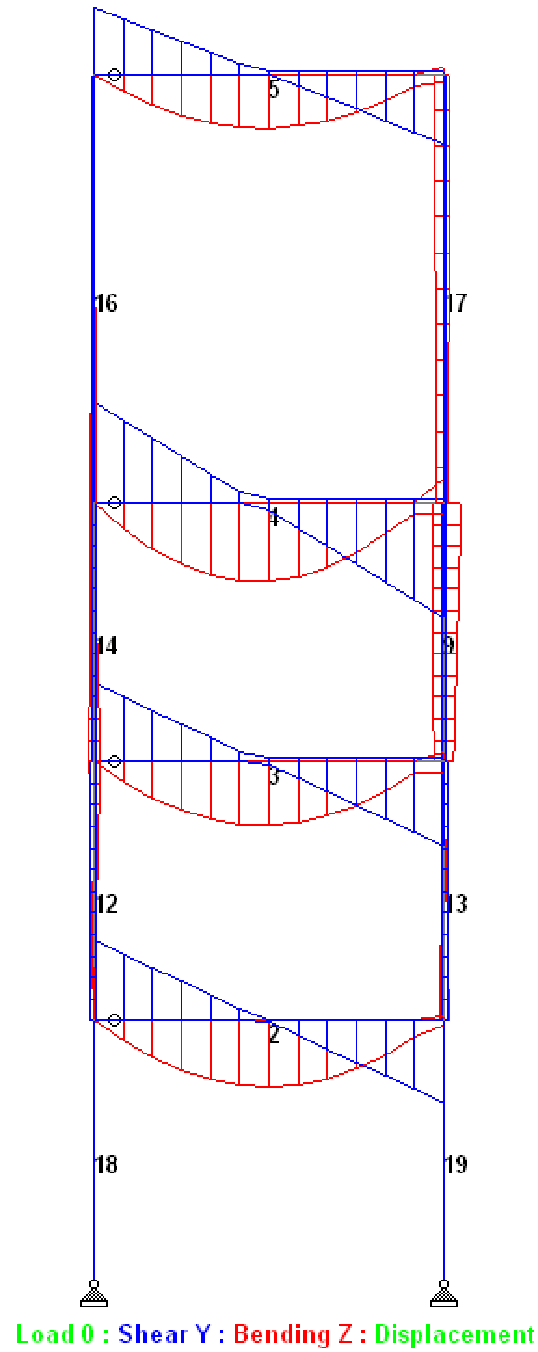


Figure 2-3b: *Elevation View of Modeled Columns and Beams Shear & Moment with Brick Facade*

Figures 3 & 4 show the reactions, shear and moment diagrams of both systems. Whilst the reactions are visibly different, in both *figures 3a & 4a*, the other two figures are diagrammatic representations of the values provided below.

Beam	Max .Deflection – x (in)	Max. Deflection – y (in)	Resultant Deflection (in)
2 Precast HSS	0	-0.059	0.059
3 Precast HSS	0	-0.055	0.055
4 Precast HSS	0	-0.068	0.068
5 Precast W	0	-0.032	0.032
2 Brick HSS	0	-0.061	0.061
3 Brick HSS	0	-0.057	0.057
4 Brick HSS	0	-0.07	0.07
5 Brick W	0	-0.034	0.034

Table 2-5: *Deflections due Precast v Brick Facades*

Table 2-5 shows the different maximum deflections of both systems, at different points in the system. This comparison can be used to determine whether or not the new system would be suitable for the current system of shelf angles that hold up the brick system.

Note: The STAAD Pro model was modeled using a line load, and not separate loads due to the limited information available about the locations of the shelf angles. Also, there have been minimal factors added to the model due to its comparative nature.

With the above information, one can deduce that there needn't be any structural redesigns due to heavier loads and larger deflections, as the new system is lighter than the old system, despite having a larger mass of solid.

*See **APPENDIX F** for line load calculations and more details.*

Mechanical Breadth

The intent of this study is to determine which of the two facades would be a more efficient one considering the change in materials used and the difference in thickness of both facades.

The first step was to determine the typical R values of the materials being used in the two facades, whilst using the same value for the same materials in order to be consistent, and prevent unfair advantages to the results of one of the systems over the other.

R & U Values for Different Systems				
Material	**R Value/Inch**	**Brick Façade**	**Precast Façade**	
Concrete	0.08	0.00 (0”)	0.40 (5”)	
Brick	0.11	0.44 (4”)	0.11 (1”)	
Air Film	1.00 (0.5” – 4”)	1.00 (2”)	0.00 (0”)	
Rigid Insulation	4.00	8.00 (2”)	0.00 (0”)	
Polyurethane Insulation	6.25	0.00 (0”)	12.50 (2”)	
	Sum of R Values	9.44	13.01	
	U Value (1/R)	**0.1059**	**0.0769**	**BTU/(ft^2 * ˚F * h)**

Table 2-6: *R & U Values of Façade Materials*

Variables Used			
ΔT	100˚F - 75˚F =	25	˚F
Area of Brick		12,100	ft^2
Time	1 year =	8,736	hours

Table 2-7: *Variables Used*

Energy Through Façade Systems					
q = U * A * Δ T					
Brick Façade	q = 0.1059 * 12100SF * 25 F	32,044	BTU/h	279,900,000	BTU/year
Precast Façade	q = 0.0769 * 12100SF * 25 F	23,251	BTU/h	203,100,000	BTU/year
			Difference	76,800,000	BTU/year
				22,500	kWh/year
$0.1026/kWh Commercial 2010 Data		**Cost Saving = 22,500*0.1026 = 2,310 $/year**			

Table 2-8: *Energy through Façade Systems*

Table 2-6 shows the R values per inch for four different materials, all of which are used in either one or both façade systems ("ColoradoENERGY"). Again, this does not include the cold-formed metal framing backing as that is considered a constant for both systems. This allows for the next step in the procedure, which is to determine the actual energy loss per year of heat through only the brick portions of the façade (*table 2-7)*. Whilst this may not be the entire structure, the difference is quite significant as observed in *table 2-8*. There is a savings of just fewer than 8 Million BTUs per year, which translates into $2,310 a year of savings on the façade's efficiency based on $0.1026 per kWh ("Electric Power Monthly").

While this may not seem like much, it is the cost associated only with the savings of the brick portion of the façade, and it goes to show that the precast system is even more efficient, thermally, than the brick system. Finally, the precast system is assumed to use polyurethane insulation, which allows it to become more efficient than the original system. With this knowledge, the lowest savings for the Moore Building Addition by changing the façade system would be $2,310 and in practice would save even more money due to its actual higher thermal efficiency.

Insulation Types Used

In order to prevent any confusion as to the differences in cost of the rigid insulation and the polyurethane insulation, there cost for polyurethane comes in at $1.25-2.50/SF for a typical type with a lower R value (RoofHelp.com). In contrast, higher end rigid foam insulation; with R values similar to those used in the calculations come in at a cost of $0.54-1.12/SF whilst these numbers are different, the increase in cost of using polyurethane would be as follows:

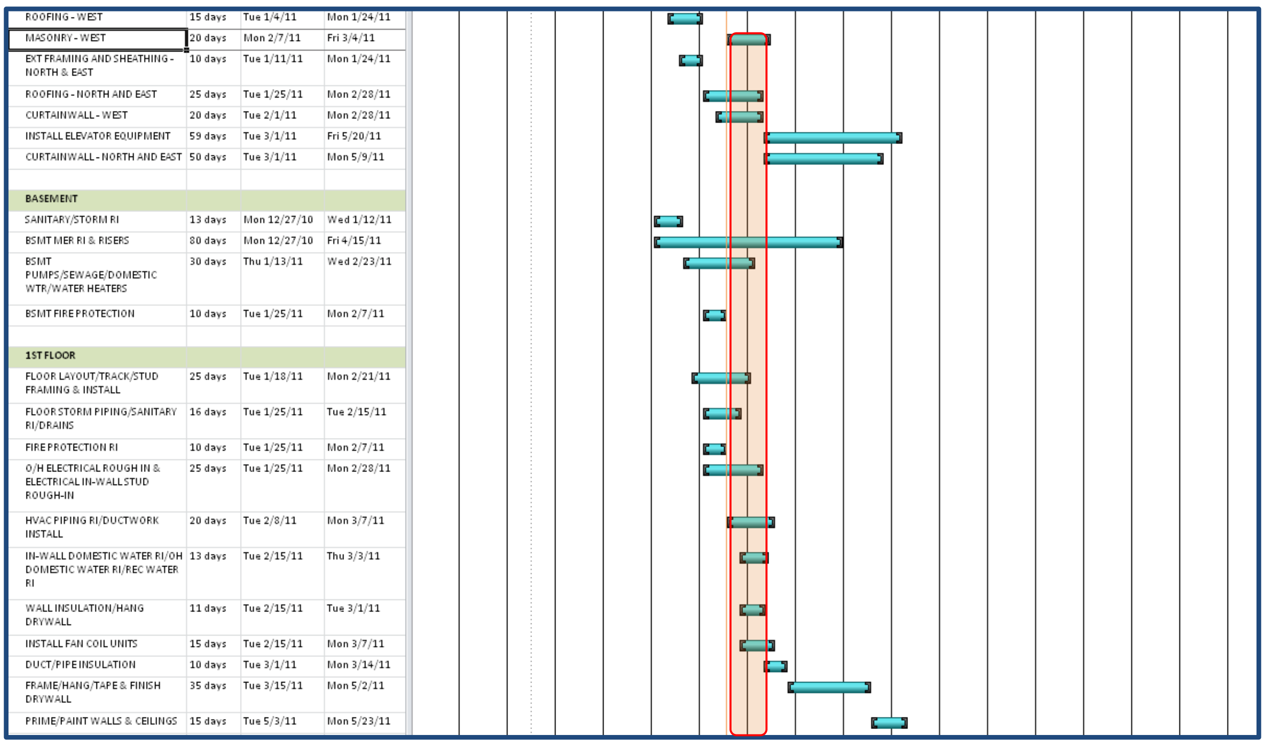
	Rigid Insulation	Polyurethane
Cost Average	$0.83	$1.88
Cost * 12,100 SF	$10,043.00	$22,687.50
Savings/Year	$2,310.00	
Investment	$12,644.50	
Payback	5.47	Years

Table 2-9: *Investment and Payback of Insulation*

Shown in *table 2-9*, one can deduce that increase in investment in the polyurethane insulation would be paid back within 6 years of operating the building, and this is a cost included in the original cost of the entire system, not an added cost.

Constructability

With the elimination of the majority of the time required for masonry installation, the benefits are immediately realized. During the time in which the superstructure is being built, there will be less clutter on site due to masonry activities, which also reduce a large amount of waste especially due to corner brick. Some HVAC rough-ins as well as pump installations, electrical rough-ins and other rough-ins will be able to occur a little more smoothly as there will be much more laydown areas for all of the equipment, and much less congestion on site. All these activities can be seen in *figure 6,* where many rough-ins are occurring all at once.



ROOFING - WEST	15 days	Tue 1/4/11	Mon 1/24/11
MASONRY - WEST	20 days	Mon 2/7/11	Fri 3/4/11
EXT FRAMING AND SHEATHING - NORTH & EAST	10 days	Tue 1/11/11	Mon 1/24/11
ROOFING - NORTH AND EAST	25 days	Tue 1/25/11	Mon 2/28/11
CURTAINWALL - WEST	20 days	Tue 2/1/11	Mon 2/28/11
INSTALL ELEVATOR EQUIPMENT	59 days	Tue 3/1/11	Fri 5/20/11
CURTAINWALL - NORTH AND EAST	50 days	Tue 3/1/11	Mon 5/9/11
BASEMENT			
SANITARY/STORM RI	13 days	Mon 12/27/10	Wed 1/12/11
BSMT MER RI & RISERS	80 days	Mon 12/27/10	Fri 4/15/11
BSMT PUMPS/SEWAGE/DOMESTIC WTR/WATER HEATERS	30 days	Thu 1/13/11	Wed 2/23/11
BSMT FIRE PROTECTION	10 days	Tue 1/25/11	Mon 2/7/11
1ST FLOOR			
FLOOR LAYOUT/TRACK/STUD FRAMING & INSTALL	25 days	Tue 1/18/11	Mon 2/21/11
FLOOR STORM PIPING/SANITARY RI/DRAINS	16 days	Tue 1/25/11	Tue 2/15/11
FIRE PROTECTION RI	10 days	Tue 1/25/11	Mon 2/7/11
O/H ELECTRICAL ROUGH IN & ELECTRICAL IN-WALL STUD ROUGH-IN	25 days	Tue 1/25/11	Mon 2/28/11
HVAC PIPING RI/DUCTWORK INSTALL	20 days	Tue 2/8/11	Mon 3/7/11
IN-WALL DOMESTIC WATER RI/OH DOMESTIC WATER RI/REC WATER RI	13 days	Tue 2/15/11	Thu 3/3/11
WALL INSULATION/HANG DRYWALL	11 days	Tue 2/15/11	Tue 3/1/11
INSTALL FAN COIL UNITS	15 days	Tue 2/15/11	Mon 3/7/11
DUCT/PIPE INSULATION	10 days	Tue 3/1/11	Mon 3/14/11
FRAME/HANG/TAPE & FINISH DRYWALL	35 days	Tue 3/15/11	Mon 5/2/11
PRIME/PAINT WALLS & CEILINGS	15 days	Tue 5/3/11	Mon 5/23/11

Figure 2-4: *Schedule Activities that Overlap during Masonry (New Schedule)*

ROOFING - WEST	15 days	Tue 1/4/11	Mon 1/24/11
MASONRY - WEST	20 days	Tue 1/11/11	Mon 2/7/11
EXT FRAMING AND SHEATHING - NORTH & EAST	10 days	Tue 1/11/11	Mon 1/24/11
ROOFING - NORTH AND EAST	25 days	Tue 1/25/11	Mon 2/28/11
CURTAINWALL - WEST	20 days	Tue 2/1/11	Mon 2/28/11
MASONRY - NORTH AND EAST	50 days	Tue 2/8/11	Mon 4/18/11
INSTALL ELEVATOR EQUIPMENT	59 days	Tue 3/1/11	Fri 5/20/11
CURTAINWALL - NORTH AND EAST	50 days	Tue 3/1/11	Mon 5/9/11
BASEMENT			
SANITARY/STORM RI	13 days	Mon 12/27/10	Wed 1/12/11
BSMT MER RI & RISERS	80 days	Mon 12/27/10	Fri 4/15/11
BSMT PUMPS/SEWAGE/DOMESTIC WTR/WATER HEATERS	30 days	Thu 1/13/11	Wed 2/23/11
BSMT FIRE PROTECTION	10 days	Tue 1/25/11	Mon 2/7/11
1ST FLOOR			
FLOOR LAYOUT/TRACK/STUD FRAMING & INSTALL	25 days	Tue 1/18/11	Mon 2/21/11
FLOOR STORM PIPING/SANITARY RI/DRAINS	16 days	Tue 1/25/11	Tue 2/15/11
FIRE PROTECTION RI	10 days	Tue 1/25/11	Mon 2/7/11
O/H ELECTRICAL ROUGH IN & ELECTRICAL IN-WALL STUD ROUGH-IN	25 days	Tue 1/25/11	Mon 2/28/11
HVAC PIPING RI/DUCTWORK INSTALL	20 days	Tue 2/8/11	Mon 3/7/11
IN-WALL DOMESTIC WATER RI/OH DOMESTIC WATER RI/REC WATER RI	13 days	Tue 2/15/11	Thu 3/3/11
WALL INSULATION/HANG DRYWALL	11 days	Tue 2/15/11	Tue 3/1/11
INSTALL FAN COIL UNITS	15 days	Tue 2/15/11	Mon 3/7/11
DUCT/PIPE INSULATION	10 days	Tue 3/1/11	Mon 3/14/11
FRAME/HANG/TAPE & FINISH DRYWALL	35 days	Tue 3/15/11	Mon 5/2/11
2ND FLOOR			
FLOOR LAYOUT/TRACK/STUD FRAMING & INSTALL	35 days	Tue 1/25/11	Mon 3/14/11
FLOOR STORM PIPING/SANITARY RI/DRAINS	29 days	Wed 2/2/11	Mon 3/14/11
FIRE PROTECTION RI	10 days	Tue 2/1/11	Mon 2/14/11
O/H ELECTRICAL ROUGH IN & ELECTRICAL IN-WALL STUD ROUGH-IN	35 days	Tue 2/1/11	Mon 3/21/11
HVAC PIPING RI/DUCTWORK INSTALL	20 days	Tue 3/8/11	Mon 4/4/11
IN-WALL DOMESTIC WATER RI/OH DOMESTIC WATER RI/REC WATER RI	10 days	Fri 3/11/11	Thu 3/24/11
WALL INSULATION/HANG DRYWALL	25 days	Tue 3/8/11	Mon 4/11/11
INSTALL FAN COIL UNITS	15 days	Tue 3/15/11	Mon 4/4/11
DUCT/PIPE INSULATION	10 days	Tue 3/29/11	Mon 4/11/11
FRAME/HANG/TAPE & FINISH DRYWALL	41 days	Tue 4/5/11	Tue 5/31/11
PRIME/PAINT WALLS & CEILINGS	15 days	Wed 6/1/11	Tue 6/21/11
INSTALL ACOUSTIC GRID & TILE	31 days	Wed 6/8/11	Wed 7/20/11
CERAMIC TILE	15 days	Wed 6/8/11	Tue 6/28/11
LIGHT FIXTURES	15 days	Wed 6/22/11	Tue 7/12/11
FIRE PROTECTION TRIM	6 days	Wed 6/29/11	Wed 7/6/11
INSTALL PLUMBING FIXTURES	5 days	Thu 7/7/11	Wed 7/13/11
INSTALL TOILET PARTITIONS/TOILET & BATH ACCESSORIES	10 days	Thu 7/14/11	Wed 7/27/11
FINISH PAINT & WALL COVERING	10 days	Thu 7/14/11	Wed 7/27/11
INSTALL CARPET/BASE	10 days	Thu 7/28/11	Wed 8/10/11
ELECTRICAL DEVICES & TRIM	10 days	Thu 7/28/11	Wed 8/10/11
INSTALL WOOD DOORS / HARDWOOD	5 days	Fri 8/12/11	Thu 8/18/11
PAIN TOUCHUPS	5 days	Fri 8/19/11	Thu 8/25/11
FINAL CLEANING	5 days	Tue 8/23/11	Mon 8/29/11
PUNCHLISTS (IN-HOUSE/ARCH/WORKOFF)	22 days	Tue 8/30/11	Wed 9/28/11
INSTALL FURNITURE	5 days	Fri 10/28/11	Thu 11/3/11

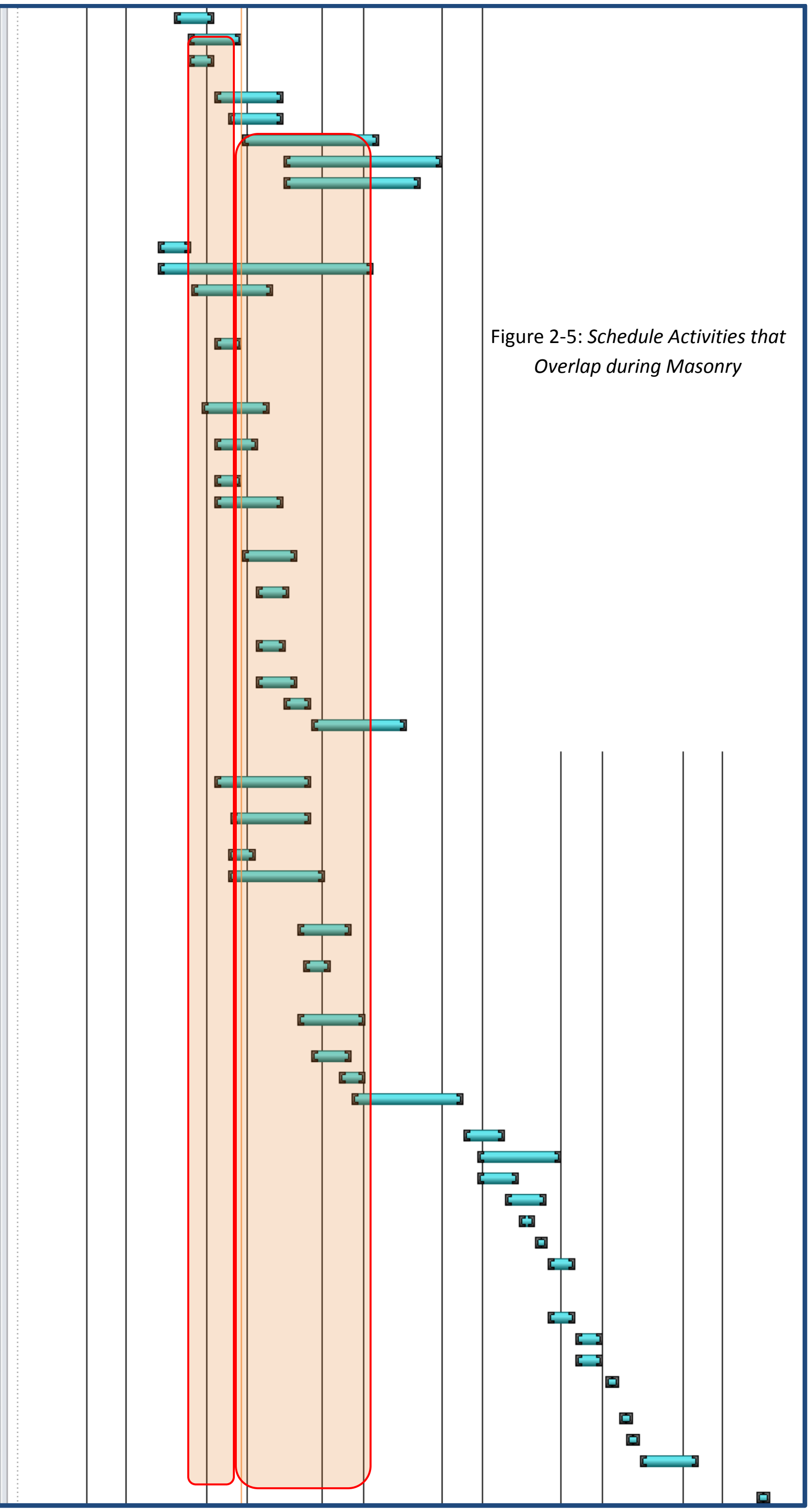


Figure 2-5: *Schedule Activities that Overlap during Masonry*

Figure 5 shows the new schedule and what it would look like if masonry occurred starting February 7 2011 and showed a worst-case-scenario duration of 20 days. The activities that would occur during the same time are many similar activities, although the precast erection crew would be off site in a matter of less than three weeks. Both *figures 5 & 6* highlight the activities that occur simultaneously with the masonry erection.

Logistics

The panels shown in *table 2-3* are not estimates, but are actual sizes that would be used in order to fulfill an identical façade appearance in precast masonry instead of the current masonry option. Each panel has been sized appropriately for each side of the building. The panel sizes will be used to determine the number of truckloads that need to occur as well as maximum weights and sizes that can be loaded per semi-trailer. *Note: all panel sizes are within limits of the manufacturer in Maryland.*

A typical semi-trailer size, for steel platform flatbeds is (45', 48' and) 53' X 102" (8'-6") wide and these dimensions will be used to determine the maximum number of panels, laid side-by-side that can be delivered in one trip with a maximum load capacity of 55,000lbs. *Note: This is not to determine the cost of transportation as this has already been accounted for in the cost section.*

	Trailer	Trailer	Trailer	Trailer	Trailer
Slot	**1 (x2)**	**2 (x2)**	**3 (x3)**	**4 (x1)**	**5 (x2)**
1	12x30	6x24	12x19	9x24	12x24
	12x20	12x17	3x24	9x24	12x24
2	12x30	6x24	12x19	4x24	12x24
	12x20	12x17	3x24	4x24	12x24
3	3x24	12x17	3x24	4x24	12x24
	12x20	12x17	3x24	4x24	12x24
		12x15			
4	3x24	12x17	12x19	3x24	12x24
	12x20	12x17	12x19	3x24	12x24
		12x15			
5	3x24	12x15	12x19	6x24	
	3x24	12x17	12x19	6x24	
		12x19			
6	3x24	12x15	12x19	12x16	
	3x24	12x17	12x19	7x16	
		12x19			
7	3x24	8x24	12x19		
	3x24	8x24	12x19		

Table 2-10: *Panels & Trucks*

Assuming that each panel is delivered with a wood base with 3" on either side to prevent panels from colliding, the total amount of space per panel would be 14". This would mean that 7 panels can be laid side-by-side safely, without a high risk of damage. Lengthwise, the total length that can be used per panel is 51' for offset purposes and to keep the panels on the truck within a reasonable amount.

Table 2-10 shows that 10 deliveries are required to deliver all panels, and in a fashion that allows each façade to begin at a certain time (i.e. does not disrupt coordination). The multiples are shown where the weights of a truckload exceed 55,000 lbs. and, hence, require two trips to fulfill the delivery.

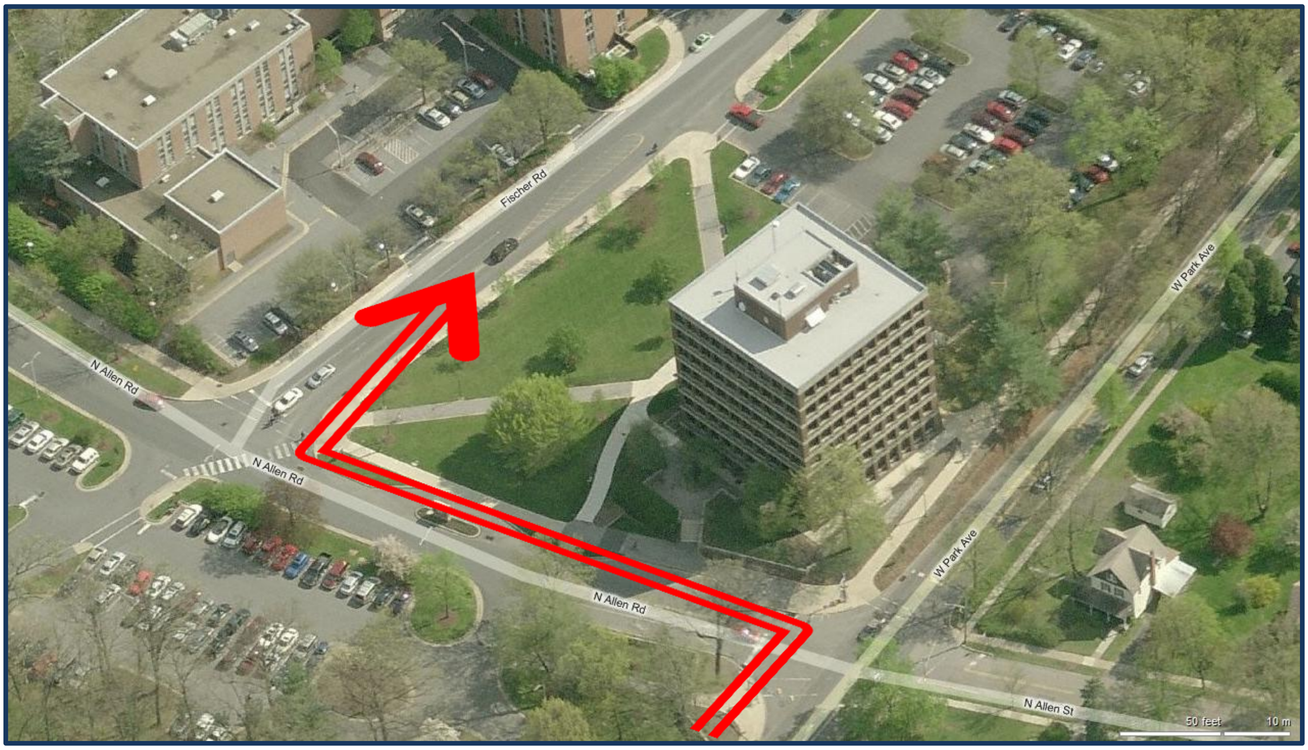


Figure 2-6: *Truck Route to Site*

Figure 7 shows the preferred route from the highway to the site via Park Avenue. This roadway, as can be seen by the scale, is more than adequate for the entry of long semi-trailers.

Conclusions

Architectural Implications

In order to conclude this analysis one must consider the finished look of the building and whether a precast façade finish will suffice on the Moore Building Addition. With new innovations and techniques, the authentic masonry finish can be mimicked very well, and although this will cost a little bit more to achieve, it will still be done as a prefabricated process, which minimizes more than just waste, clutter and noise, but reduces risks with on-site injury. Besides the fact that the mortar in between the bricks may looks a little different since it is concrete in the precast façade's case, the price may be justifiable, or even a small increase may be just as justifiable.

Recommendations

Besides the architectural discrepancy that may or may not be an issue, there is a clear "winner" in this analysis, and that is to produce pre-fabricated panels. This is not only true because of the schedule time that will be freed up, as well as no need for a structural design or even the fact that the new precast system would be more efficient thermally as well as almost identical in terms of cost, to the old system, but because for most categories including the efficiency, the structure and schedule time, the precast façade system was given worst-case-scenario figures in order to compare with an almost best-case-scenario set of figures for the brick façade. This is especially true for the weights, yet the ultimate goal was to be able to compare the two fairly and relatively. In terms of the cost, the cost provided is the cost of fabricating the façade, delivering it and installing it all the way from Maryland. This is also a disadvantage to the precast façade as there are many closer prefabricators in the area which would offset the cost of transportation, again, proving that there is a great advantage to the precast façade.

The most important point to consider is the ability to reduce the schedule time by at least two months, which has been an important part of the project. It would be very wise indeed to consider a precast façade system.

Analysis III: Structural Steel

The structural steel on the Moore Building Addition was and still is the most important critical path item. This is due to the fact that the structural steel opens the doors for every other subcontractor to begin putting work in place. However, with the two failed attempts to have the structural steel delivered early, it is possible that more could have been done to ensure its early delivery.

Proposed Solution

Solving this problem may be in the hands of PSU; if OPP were to award a design-assist contract to the steel prime contractor, then they would be on board about the time that the CM agency is, allowing for a head-start on the design and implementation of the structural steel.

Possible Drawbacks to Solution

The biggest concerns with this approach to reduce schedule time are the risks involved with holding separate contracts and trying to coordinate more than one at the same time. Although it is a very doable concept, the increase in risk may prove to be costly, since the structural steel is the single most important critical path item on the project.

Methodology

- Research risk involved with owner-held contract to a subcontractor.
- Determine importance of early completion and value in achieving early completion to the owner.
- Research risk involved with design changes to contract after awarding steel contract.
- Research time savings and expense of early fabrication as well as overall impact to schedule.
- Determine risk involved with keeping contract with steel subcontractor in long term case.
- Analyze all risks involved against owner's value for early completion and determine if a separate contract would be feasible.

Resources/Tools

- Industry professionals
- Applicable publications and articles – risk management
- Steel fabrication company
- Available schedule time and estimates for structural steel erection

Expected Outcome

The outcome expected of this analysis would be that if OPP was to award a design-assist contract to the steel prime contractor, as they are well equipped to do so, this would save time and money on the construction of the Moore Building Addition. This is due to the steel arriving earlier on site allowing all other work to begin earlier, which, in turns allows the building to operate earlier which increases the business that it produces as part of its department.

Performed Research and Analysis

Organization

The question of whether or not to hold a contract by the Office of Physical Plant or not in order to carry out the management of the structural steel is an important decision if the project's structural steel is to be erected quicker. This is mainly due to the lead times, and the unavailability of the steel. In reality, if the structural steel was to go up faster, this could, in theory, allow the precast façade to go up even quicker than before, making the construction site more "relaxed."

Initially, the idea was to create a contract with OPP and the steel prime contractor, which would have looked as follows:

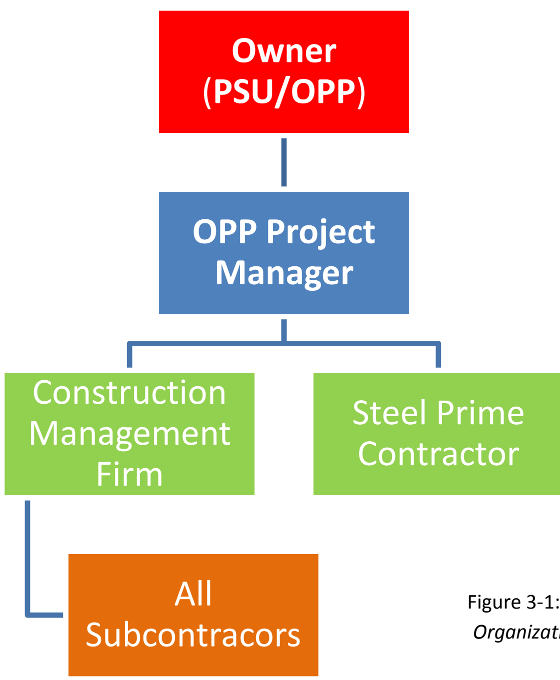


Figure 3-1: Hypothetical *Organizational Chart 1*

The main misconception with the organizational chart shown in *figure 8*, which will be referred to as "organization 1," is that OPP currently holds a contract with the steel prime contractor (as well as all subcontracts) on the Moore Building Addition, but is managed by the Construction Management firm (CM Agency). This is because the Moore Building Addition is funded by the State of Pennsylvania (Bechtel). This requires the OPP to take care of the contracts from their end, and, although that is the case, there is a better potential solution (discussed later).

The second proposition was that OPP hire a separate subcontractor, which is more in line with the way the project is actually set up. The main difference is that there is direct communication between the CM firm as well as the steel prime contractor.

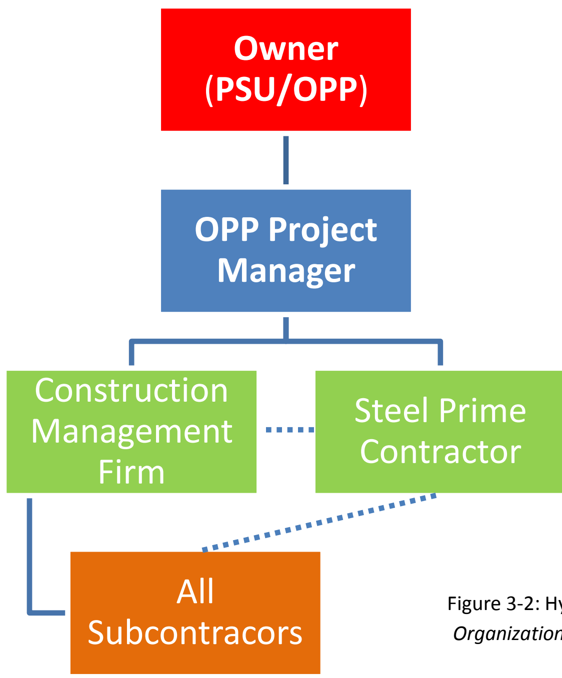


Figure 3-2: Hypothetical *Organizational Chart 2*

Since the case with the project is that the steel contract is held by an OPP PM the next question is to determine whether or not Organization 1 is viable as an option, since there would be cut costs and more direct communication between the steel prime contractor and the Project Manager from OPP. The idea here is that the project manager would coordinate with the CM firm, and essentially become the steel prime contractor, but have more responsibility than simply that; the project manager from OPP's side would take care of finances involving the project, ensure communication between CM firm and OPP to ensure that the project is proceeding as expected. This, along with the role of ensuring that the steel prime contractor is performing all duties accordingly may be an overload of work for one person. There simply aren't enough resources for such an organizational structure to be put into place from OPP's side (Bechtel).

Design Assist (DA)

The next option, as advised by industry experts, is a relatively more uncommon approach to the project organizational structure, which is called Design Assist. An organization chart is portrayed in *figure 3-3.*

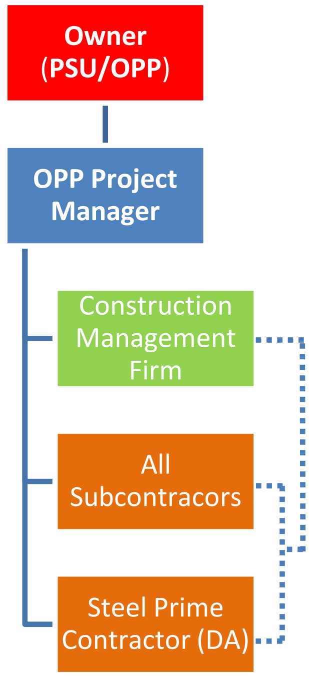


Figure 3-3: *Hypothetical Design-Assist Organizational Chart*

In essence, design assist is the awarding of a contract to the most compatible contractor, prior to design completion, in order for them to assist the architect or engineer of record for a certain project, by using a design professional of their own. This means that the contractor is "on-board" earlier than they would normally be.

Primary goals for design-assist contracting are to improve quality and maintain cost of the project at hand (Hart 1-2). Its best suited construction management methods are design-build, design-bid-build and construction manager at risk where the owner and architect are in constant communication with the tradespeople and subcontractors. This allows the parties involved to create much more efficient designs, have much better trust for one another throughout the project lifecycle, as well as reduce schedule time due to changes, inefficiencies and bad habits.

One of the main issues with today's construction industry is not that it lacks innovation or that it is run by older, more primitive methods. The main issue is that with new technologies and innovations the main interceptors of these are tradespeople who are manufacturing and or installing the products. The inefficiencies are a result of less knowledgeable owners not knowing of these new methods etc. This leaves many owners at the hands of tradespeople who repeat unnecessary and outdated steps in their construction practices, as well as prevent themselves from assimilating with the new technologies. Whether the reason for these actions is pure habit or opportunistic and exploiting behavior, is another debate altogether.

Design-assist construction management practices help to eliminate such efficiencies and streamline most processes in order to save time and money especially with increasingly complex projects.

Design-Assist Process (Hart 1-2)

Phase i. The owner, in this phase, must be very clear of the scope of work that is required of the project, along with a schedule time (rough) and finally a budget set forth. This must be coupled with the goals in mind for the design-assist part of the project (i.e. the entire project may not be design-assist).

Phase ii. Phase two consists of the collaboration between the design-assist professional or design-assist contractor to help the architect research design goals and together write specifications for the building to be constructed. The owner pays a fee in order for the two parties to produce the documentation. The specifications will be ultimately used by the design-assist contractor, and, if they cannot meet the budget determined by the owner in phase one, the owner has the right to hire a different design-assist contractor who can.

Phase iii. Finally, the contract must be adapted for the design-assist introduction, and a design-assist professional is formally selected. If there are no design-assist contractors who can meet the schedule, budget and scope within a reasonable amount, the owner may choose to bid the project and utilize the documentation purchased in phase two.

The selection of an appropriate design-assist contractor is almost identical to that of a normal contract in that there must be an RFP and RFQ issued to those the owner is interested in, except that the interviews or presentations may be a little more intricate and focus on more complex aspects of the projects than a typical contractor's presentation. This is followed by a shortlist and finally a presentation for those shortlisted in order to have them demonstrate their abilities.

The ultimate benefits of this type of contract are:

> *By using the methods described above, the owner, architect, and contractor should be able to deliver a project on schedule, with fewer requests for information and fewer changes (Hart 1-2.)*

In contrast, design-assist is almost identical to design-build except that it is focused on one specific aspect or subcontract of the project. In other words, if only the steel structure needed early fabrication (as in the Moore Building Addition's case), then instead of bidding the project as a design-build, or compromising the public nature of the funds provided to some of the project, a design-assist method can be applied to the project. This way, the rest of the project's management and organization is left untouched, but with the structural steel prime contractor being brought on board as early as the construction management firm (as they had been involved for an extended period of time), which would allow for, in theory, an early design to occur as well as early implementation.

Direct Correlations to Steel (Proffer 1-4)

In this next section, there will be examples of the benefits to a project's structural steel aspects in introducing design-assist methods to that specific trade. The company in the titel is the former Havens Steel, bankrupt after a class-action lawsuit against deceptive financial management of stock ownership. In other words, their work was credible, but not their bosses!

Case 1: Dakota Dome

According to Havens Steel, this project's success relied heavily on the ability to use design-assist. The project was to tear the existing roof that was an air supported fabric, into a conventional steel-supported roof. This was to be done in a window of 4.5 months, which made this project a challenge. The most important part of the project was the schedule and with Havens Steel as structural engineers, a design assist method between all steel-related entities was put into play. This resulted in constant communication and a much more "team-oriented feel" rather than focus on individual opportunity. This sense of teamwork served the project very well, as the steel fabricator and the steel designer had figured out the cost of transportation of steel, fabrication, erection, and all relating durations in a very tight but realistic manner.

The structural steel had originally been a much more time consuming set of 15' deep trusses, but as schedule impact was crucial, this labor intensive design was to be rethought. Instead, the trusses' size was reduced to 11'6" and shipped to site with little additional labor needed to install them, as they were able to fit on semi-trailer for transportation without violating height restrictions. These trusses were heavier in order to withstand the loads, but were pre-fabricated and required no site-modifications. This one change, which required collaboration of all parties concerned with the structural steel, meant the difference between a project completed on time and not; it was a success due to the ability for these parties to collaborate on the design, taking into account the cost of fabrication and delivery as part of the actual design.

Case 2: Convention Center/Arena

This, more design-assist-revolving- approach has an appealing quality to it that can be applied to the Moore Building Addition. This convention center started out as nine pages of conceptual designs and a GMP contract was put into place for its timely and on-budget completion. The most important part of this entire project is that the structural steel was design-assist based, and Havens Steel, a local steel fabricator, knew the "ins and outs" of the industry and could provide the project with real, achievable designs of steel. In other words, whereas a "foreign" or unfamiliar contractor may have been conservative with steel designs and what can or cannot be done, the addition of Havens Steel as part of the design-assist process meant that they could contribute their expertise in the field and provide factual data of what they can or cannot do in terms of fabrication, transportation and erection.

Combined efforts of the contractor and Havens Steel provided an advantage to the project in that small inefficiencies that would cost time and money are eliminated through streamlining the process and having the steel fabricator on board early. This not only helps produce a smarter design, but one where no party is left wondering why the other party had designed or produced certain members in an inconsistent way. For example, suppose that 14' trusses were designed by the structural engineer only to find out later that these must be delivered in pieces whose heights did not exceed 12.5' in order to be transported (height limits); these pieces would need to be put together on site, costing labor and time. However, if the same structural engineer had run his design through a fabricator, the fabricator would have instantly told him that trusses would need to be a little bit shorter in order to be transported to the site and be installed instantly without further modification.

The ideas set forth above are what the intent of design-assist are; a collaborative approach to the construction process focusing heavily on critical path items, in order to reduce inefficiencies and create relationships with contractors who are competent and, through this practice, maximizing efficiencies and minimizing all waste.

However, these cases cannot be quantified, as there is limited information about them especially since the entity involved is now dissolved.

Relation to Moore

For the Moore Building Addition, the proposed design-assist idea is a very appealing one. It allows all structural work to be performed early, allowing the most important critical path item, the structural steel (fabrication, delivery and erection) to be performed in a manner that reduces the overall schedule time.

Assuming that all else was equal, there could not have been a design-assist contract put in place as soon as would be necessary to make a positive impact to the schedule. The benefits may have been to the cost of the steel contract as there would have been fewer changes to the design. Along with long steel lead times, this proposal would have hurt the project overall. But, the main reason design-assist would not have been very viable on the Moore Building Addition is because the funding was not available until mid-May 2010, which meant that a design-assist contract would have started late, essentially rendering it useless (Schrenk).

However, if the "money-procurement-barrier" was overcome, design-assist would have accelerated the schedule, and although not quantifiable, it is clear that there would not only be a benefit to the schedule, but to the overall cost of the project (Schrenk). This actually makes design- assist for the steel contract a much more realistic option. *Note: Assume monetary issues resolved, and funding would be available 6 months in advance.*

Risks Involved

Assuming that funding will NOT be an issue, there is a benefit to having a design-assist contract with the steel prime contractor, but this is not without risks.

The first, most obvious risk is the risk that the steel design is not complete by the time a mill order must be placed. Although this risk would cost the project a delay in the form of one day extra per day late, this risk is exacerbated by the inability of trades to perform their work at their allotted times.

Design-Assist Minimum Risk			
Contract Value	$26,100,000.00		
Project Time	577	Days	(from ground breaking to project complete)
Project Cost/Day	$/Day = 26.1M/577	**$45,233.97**	

Table 3-1: *Design-Assist Minimum Risk*

As shown in *table 3-1* it is clear that there is a sizeable cost to the project for delays. The value of the entire project was used in order to stay consistent with previous cost comparisons. Also, the duration, as stated, is from the ground breaking ceremony to the week just before handing over the building. During this week the building would be complete by all standards. Finally, the cost is a little bit conservative in order to refrain from always considering the best-case scenario and in order to prevent the owner from running into costs that they have not been familiarized with. In other words, a cost of $45K per day late, would not come as a surprise to the owner, should there be a delay.

At $45K a day, it is easy to rack up expenses, and the reason this cost/delay is conservative is also because there are many other factors that are hard to consider. These factors may include, but in no way are limited to the following:

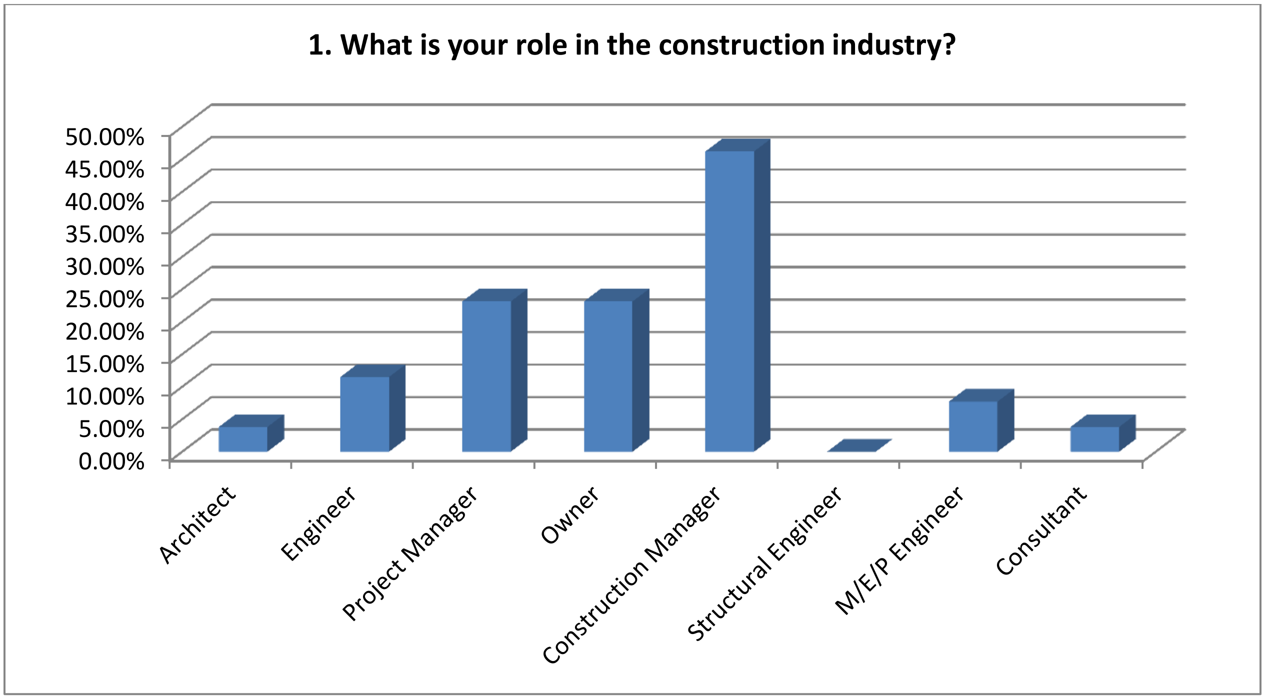
- Laborers on available for short intervals needing to leave for other contractual obligations
- Equipment rental overlaps with other clients' needs and, therefore, loss of rental money and usefulness of equipment
- Material laydown area complications due to lateness of some items that would have already been used and put in place had they not arrived late

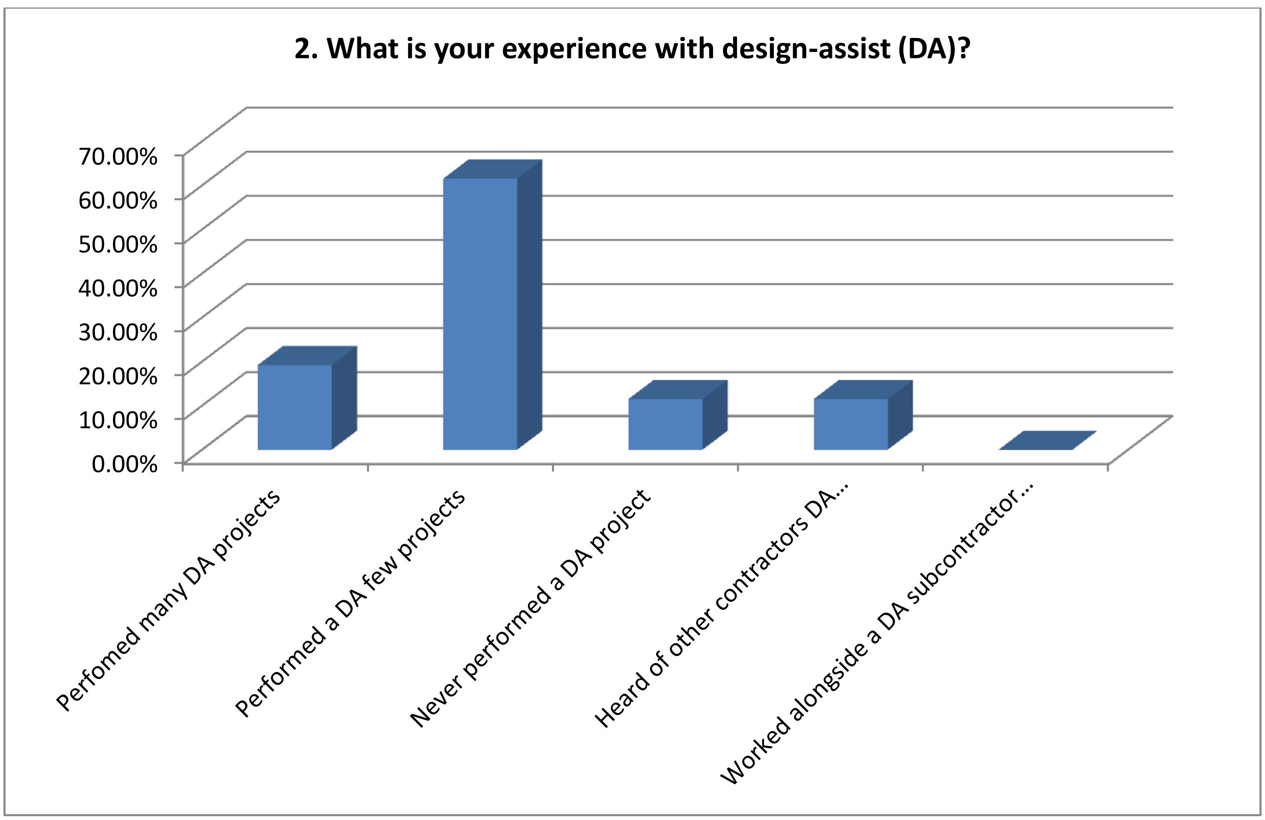
These are a few of the factors that can prove disastrous, but are accounted for qualitatively in order to be prepared for the risk. Additionally, the risks would not be so tragic with small delays of a few days, and the project can recuperate, but essentially, there is a risk with delay on this project, as with any.

Survey Results

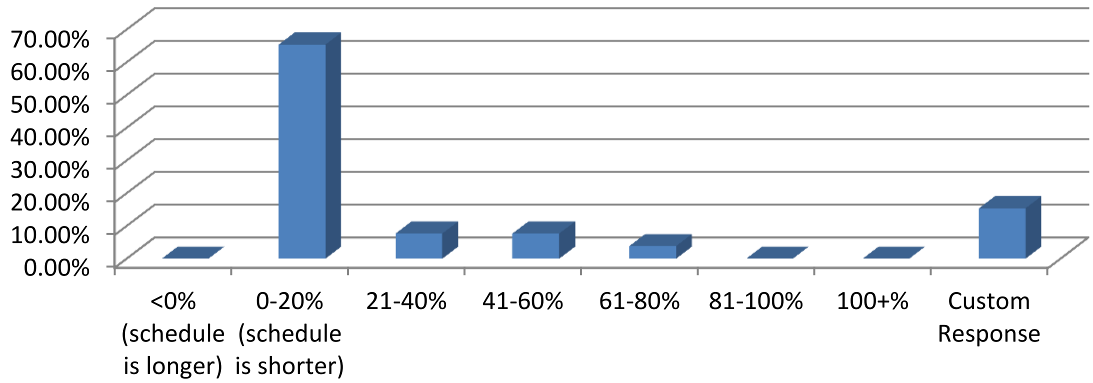
As can be deduced by the qualitative information provided, it is hard to come by figures to help determine the savings in terms of cost and schedule that may be achievable on this project. So, it was necessary to create and send out a survey to some industry professionals in order to achieve a more realistic determination of the savings involved with this approach.

The professionals contacted all had very similar views on the topic, which would allow one to be able to make solid judgments on the benefits of a design-assist contract held with the steel subcontractor.

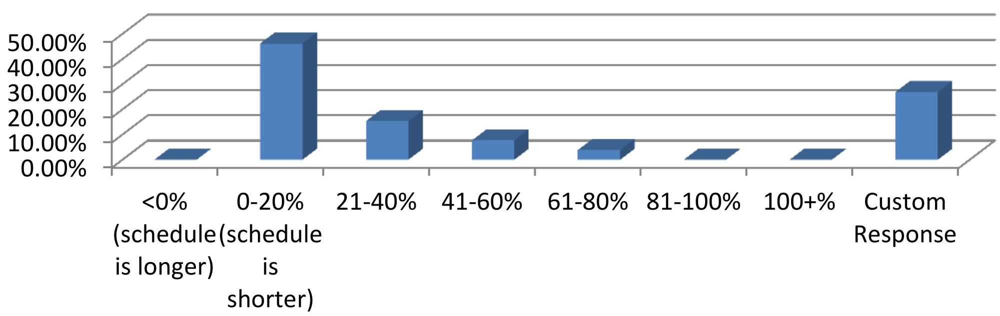

1. What is your role in the construction industry?
50.00%
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Architect
Engineer
Project Manager
Owner
Construction Manager
Structural Engineer
M/E/P Engineer
Consultant


2. What is your experience with design-assist (DA)?
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Perfomed many DA projects
Performed a DA few projects
Never performed a DA project
Heard of other contractors DA...
Worked alongside a DA subcontractor...

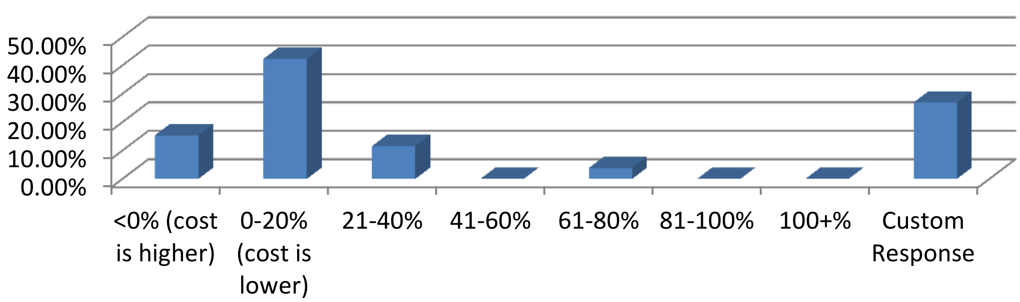
3. How much more (or less) effective is a design-assist contract (generally) in terms of schedule reduction than a typical contract?

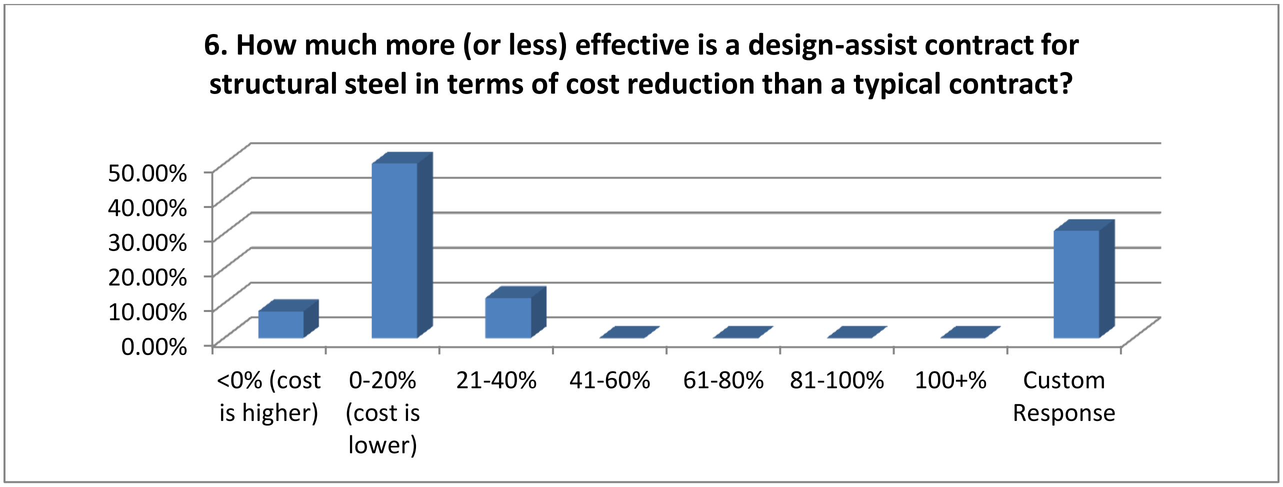


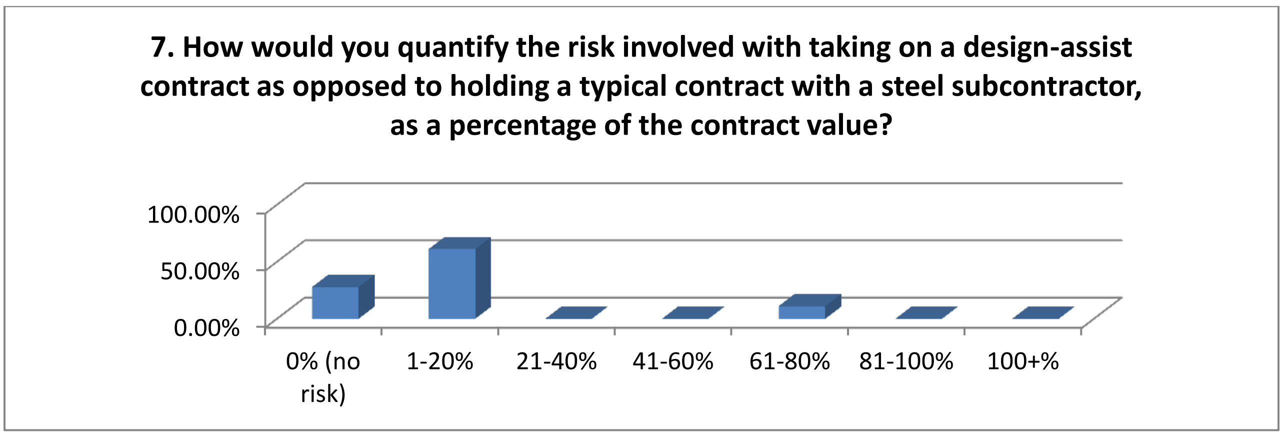
4. How much more (or less) effective is a design-assist contract for structural steel in terms of schedule reduction than a typical contract?

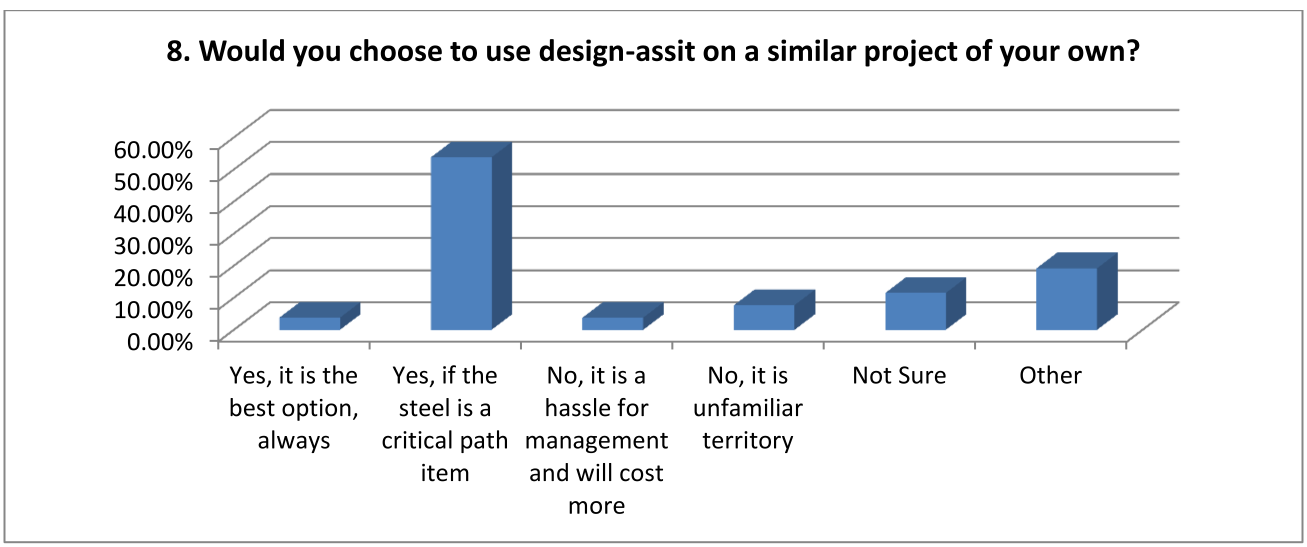


5. How much more (or less) effective is a design-assist contract (generally) in terms of cost reduction than a typical contract?




6. How much more (or less) effective is a design-assist contract for structural steel in terms of cost reduction than a typical contract?
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
<0% (cost is higher)
0-20% (cost is lower)
21-40%
41-60%
61-80%
81-100%
100+%
Custom Response


7. How would you quantify the risk involved with taking on a design-assist contract as opposed to holding a typical contract with a steel subcontractor, as a percentage of the contract value?
100.00%
50.00%
0.00%
0% (no risk)
1-20%
21-40%
41-60%
61-80%
81-100%
100+%


8. Would you choose to use design-assit on a similar project of your own?
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Yes, it is the best option, always
Yes, if the steel is a critical path item
No, it is a hassle for management and will cost more
No, it is unfamiliar territory
Not Sure
Other

9. Design-assist; your opinion on these aspects in terms of applicability. (i.e. in design development "Average" means no benefit during this phase for DA)

	Worst	Bad	Average/Indifferent	Good	Excellent	N/A
Conceptual/Planning Phase	8.7% (2)	0.0% (0)	13.0% (3)	**60.9% (14)**	8.7% (2)	8.7% (2)
Schematic Design Phase	0.0% (0)	8.7% (2)	4.3% (1)	**65.2% (15)**	13.0% (3)	8.7% (2)
Design Development Phase	0.0% (0)	0.0% (0)	4.3% (1)	**56.5% (13)**	30.4% (7)	8.7% (2)
Construction Documents Phase	0.0% (0)	4.3% (1)	8.7% (2)	**47.8% (11)**	26.1% (6)	13.0% (3)
Constructability	0.0% (0)	0.0% (0)	8.7% (2)	**43.5% (10)**	39.1% (9)	8.7% (2)
Change Order Prevention	0.0% (0)	0.0% (0)	13.0% (3)	**60.9% (14)**	17.4% (4)	8.7% (2)

From the results one can assume that there is a great general pull towards using design-assist on a project that is in a situation like the Moore Building Addition. An average number will be used to quantify the results, by multiplying each response with the percentage of professionals that had agreed with it. For example, for question 3, the formula would be:

(0.6538*10)+(0.0769*30)+(0.0769*50)+(0.0385*70)=15.385%

Results Averaged

Question	Average
3. How much more (or less) effective is a design-assist contract (generally) in terms of schedule reduction than a typical contract?	15.385%
4. How much more (or less) effective is a design-assist contract for structural steel in terms of schedule reduction than a typical contract?	15.769%
5. How much more (or less) effective is a design-assist contract (generally) in terms of cost reduction than a typical contract?	10.388%
6. How much more (or less) effective is a design-assist contract for structural steel in terms of cost reduction than a typical contract?	8.462%
7. How would you quantify the risk involved with taking on a design-assist contract as opposed to holding a typical contract with a steel subcontractor, as a percentage of the contract value?	13.88%

Table 3-2: *Results Averaged*

The results shown in table 3-2 can be further

Final Analysis			
Item	**% Average increase/decrease**	**Original Quantity**	**Increase/(Savings)**
Schedule Impact	15.769%	71 Days (from design to delivery of structural steel)	(12 work days)
Cost Impact	8.462%	$1.28M (structural steel only)	($108,162.03)
Risk Involved	13.88%	$26.1M	($3.62M)

Table 3-3: *Results Averaged*

As shown in table 3-3 the savings are clear using conservative numbers. This is because each number interval has a twenty percent interval, and only the midpoint was considered for each. And, although this sounds like a bad design for a survey, the maximum was reached that the survey allowed.

Also, as can be shown in table 3-2, the design-assist contract type was very suitable in all phases of construction, with many professionals accepting its use and its benefits.

Professional Opinions

Some of the survey results were in the form of text, and so, some of the recommendations have been considered; first many thought it to be necessary to have buy-in by the owner for a successful project. This is because the owner must be organized and determined when it comes to a different contract type, and the owner's response is crucial. This is mainly because the design-assist contract is one that must be established very early, and being only marginally late defeats the purpose, so finding a subcontractor to hire in the beginning stages is necessary and will take owner input.

There is also speculation that there is a sort-of "exponential" effect to allowing the design-time reduction (as calculated) to be only a small amount of the schedule savings in the long run. Although mentioned several times, the effect cannot be measured.

The reduction in cost also seems not to be directed towards a decrease in steel contract but mostly by the reduction in change orders, and changes to design that may become costly. This is because the steel would have lots of time to be "perfected" or come close to a final design very early. There would be collaboration by the fabricator and erector as well to aid in the design, which would be the reason why this is possible. Also, another very highly contributing factor to savings would be the ability to design connections in advance, allowing savings to be realized in that sense.

Another interesting point brought up by one of the participating professionals is that the purchase of steel earlier would allow its price to be constant (like buying a stock!), which would offset its future cost and allow savings in that sense as well. This is a very interesting point that is rarely raised.

Finally, the most important aspect is to select "trustworthy" or credible contractors in order to make sure that the project goes as smooth as possible. Selecting based on low prices, for example, would probably lead to much less desired results.

Conclusion & Recommendation

To conclude, the final impact that would be seen from the use of a design-assist contract with the steel fabricator, are notable. There is a risk involved with the entire operation, and that risk had been quantified as part of the entire project's value. This means that the failure of the design-assist to meet the time required of the original design would probably end up costing the project a significant amount.

All of the quantities used in the final portion were based on consensus rather than take the most voted-for value, just to add or remove a necessary amount based on the input of the industry professionals.

Moreover, there are many points that point to a design-assist contract with the steel fabricator, all in order to reduce the schedule time of the main critical path item of the project and allow the project to finish early, even if only by roughly two weeks.

With the funding being the only factor involved with the inability to hire a design-assist contractor for the structural steel, the final recommendation would be to – should time reverse itself and OPP found themselves in the past – pursue this contract type. The barrier is one that can be easily overcome in the realms of OPP as funding is available from many sources at any given time, and for a project that is already under-budget, even the losses could cover the risk or borrowing from a different entity.

The whole idea of introducing design-assist is to be able to complete the structural steel earlier than it would be now. The exact time that it will save cannot be solid, but based on the consensus of those who answered the survey, there will be at least twelve days of schedule reduction. Simply said, there is a stronger opinion that points towards there being benefits than not. There have been those who have seen losses in schedule time due to a design-assist contract, although most design-assist contracts were performed for the mechanical or electrical portions of the building. Very few professionals had direct experience with structural steel DA contracts. And, although the results are not entirely based on the survey results, the survey results do complete the picture, in a sense that they affirm what had been discussed earlier in the report.

Analysis IV: BIM through AE (Critical Industry Issue)

The Office of Physical Plant has been expanding its use of BIM by recently writing guidelines, contract language and leading the way in terms of the implementation of BIM. However, they need lots of help to generate models of all the buildings on campus and utilize them for all sorts of BIM applications.

Proposed Solution

As has been requested before, the OPP would like, through the AE department at Penn State, to utilize some of the classes in the AE course in order to produce BIM models for some existing buildings. The collaboration of the two entities would not only be beneficial to the OPP but also to the students partaking in the classes.

Possible Drawbacks to Solution

Some of the drawbacks may be rooted in the inexperience of the students in creating models at some of the earlier stages of their college life. This may emanate through models with insufficient detail, and lack of other details as well as the possibility that some of the more "slacking students" produce completely inadequate models.

Methodology

- Research requirements of a model by OPP's standards, and what is useful and what isn't.
- Research which classes may be available to take on BIM model producing and the experience of students required in order to ensure decent models are produced.
- Conduct interviews to understand the typical problems with this approach and where there would be lost time and money.
- Determine which level students are better suited to produce what type of models; architectural vs trades.
- Research the amount of money that would come into the department due to this collaboration and how this would affect the AE program as well as possible incentives for very knowledgeable and experienced students to get paid in order to privately create models.

Resources/Tools

- Professor Paul Bowers PSU
- Dr. Ed Gannon OPP/PSU
- Dr. David Riley PSU
- Mr. John Bechtel OPP
- Colleen Kasprzack OPP/PSU
- Other PSU and OPP BIM professionals involved

Expected Outcome

The expected outcome is that there is a very realistic and possible method to intertwine some of the classes at PSU AE with the production of models that can be used to benefit the OPP and university as well as the students through real BIM exposure.

Performed Research and Analysis

The most important part of this analysis was getting information from all parties involved or those that would potentially be involved with such a project. This would include people from OPP's side as well as people from the Architectural Engineering Department, and those involved with the process, the implementation as well as those involved with the finances and revenues generated from the process itself.

Office of Physical Plant

The first step was to determine what the "client" wants. This means asking questions and later using that information to create a concept that will suit both parties. This required the input of OPP personnel in order to fully understand what is expected of the AE department.

The Office of Physical Plant are currently creating and developing a Building Information Modeling (BIM) master plan, or a guide, that will help keep all BIM related activities and processes equivalent, to a certain extent, and allow all projects that originate from within the university to hold many key components common. Covered topics may include, but are not limited to, the software used to model buildings, certain information inputs and how exactly to analyze the data.

Trial and Error

As of recently, there had been a trial (by OPP) to produce BIM models through the PSU-AE department in order for OPP to utilize them for their purposes (discussed later). Some of these models met all quality control expectations and were geographically accurate in that they represented, to a certain degree, the actual buildings' [being modeled] component locations. These include columns, windows, mechanical equipment and such.

The other side of this equation consisted of some almost useless models, which meant that nothing was gained nor lost. And, in between were models that could, through minor work, be useable. Small issues like floating doors and inconsistencies with other "objects" in software like Autodesk Revit were not uncommon. This is mainly due to the relative inexperience of the students who modeled the buildings, and these students were primarily "2nd year" AE students who have either never used or had little experience with Autodesk Revit.

The Students and the Class

Before understanding the requirements and all the details involved, the students must be examined; this means understanding their capabilities and incentive to work. In this case it also means using resources wisely as well as having a bit of luck.

Students who are working through AE all go through several classes in a universal fashion, and one of the main classes in focus is AE222. This is an introductory class taught by professor Paul Bowers, and allows students to experience 3D modeling as it relates to the construction industry. Usually, students in this stage have no intention of backing out of the program but some do. So, most students are already convinced of their major and knowing the "higher" standards required of students in order to enter the major, most will be more committed to their classes and their performance; this is key.

The students are, by the time they reach 2nd year, a little overwhelmed by their workload, and are probably going to need incentive in order to create models that will benefit both themselves and can be used by OPP. This means that a set of standards must be clear to these students in order for them to be able to perform. This would prevent confusion.

What is OPP Looking For?

The Office of Physical Plant is looking for useable models. This does not mean that they expect a model that has been created by a professional, but a model that can be altered slightly, or not at all, and be used for their purposes. These models would need to be evaluated by OPP staff and verified with typical landmarks in order to ensure relative compatibility with the existing buildings.

Although the trial and error has not been a resounding success in the past with this approach, it is still a very viable option as it is now clear that a plan must be put in place before setting off to do this type of collaboration.

The types of things that the OPP are interested in are, among the modeling of existing buildings, modeling renovations. This requires renovations block plans, which can be provided by OPP. The same goes for existing structures whose block plans are all available. In total there are a little over 425 projects that need to be modeled, and although some may take much shorter time than others, they need to be done.

In order for these models to be modeled, there must be guidelines and standards that are required in order to deem a specific model useable, or not. This is crucial to the success of the project, as without guidelines, nothing can be quantified in a reasonable manner; it would be one guess against another in determining if a model would or would not meet criteria. In fact, having gone through a trial period, the issues involved with the trials would best be used as a guideline for making a guideline! For example, the knowledge that floating objects does not render a model useless is a good tool to help evaluate a model that suffers from floating objects in several locations. However, it may be extremely important the 2D drawings be very accurate, whilst the 3D is an added benefit and a learning tool (explained later).

Value

The next question to be addressed is the value of a model. How one evaluates this is very important, as there is more than one answer.

Typically, a 3D model can cost anywhere from $20K to $40K for an architect to produce, but with an influx of information that must be input into a BIM model, the cost can rise to as much as $100K (Bechtel). Simply put, a 3D model is simply that: a 3D model of a building that shows structure, enclosure, M.E.P. and possible textures. However, a BIM Model is much vaster, and includes information on, mostly, the mechanical, electrical and plumbing equipment. The idea is to be able to point and click at any object and retrieve all relevant data of it, including its manufacturing facility to its specifications. This eliminates the need for separate data sheets and submittal forms and centralizes all information into one, albeit large, model file.

In summary, a typical model *could* be assumed to be worth $30K, for a normal sized building, and although this is a generalization, this is what will be used as a value for a model with no information tied to it. A typical model, with information tied to it would cost a total of $70K (assumed as well). This will be used to quantify results.

The Ultimate Goal

In order to fully understand the OPP side of the deal, one must be extremely clear on the intent of the project. For OPP, the ultimate goal is to be able to use the BIM models for maintenance, facility management, and enterprise management system, preventative maintenance, ordering items and equipment and all categories that fall under the aforementioned (Gannon).

Preventative Maintenance and Maintenance

This is the consistent and constant caring for and maintaining of equipment to make sure that equipment is operating within acceptable standards, in order to prevent incipient failures or to prevent major issues or defects from occurring. A BIM model can streamline this process by providing information in one centralized location, allowing for ease of access. Finally, digital checklists can be integrated into this process similar to how commissioning would work, and allow for instant information retrieval and submission. In other words, management does not have to dig for anything.

Facility Management and Enterprise Management System

Also known as asset management systems, the current form is Maximo in OPP, and is already used to streamline the work-orders and such with maintenance. It is a system designed for OPP's needs but is not proprietary. The way that these systems would be further developed in the presence of full BIM models is not by simply replacing them, but by actually integrating the entire system; again, a centralized model that holds all/most information.

The recent developments in this portion of the BIM development phase at OPP includes a collaboration between OPP and a hardware/software developer to combine the asset management software (maximo) with the BIM models for total information centralization.

Added Benefits

Some of the added benefits that *could* be used but would not be deal-breakers include an integrated B.A.S. (Building Automation System), space management and operational management. Operational management means things like figuring out how long it takes to clean, for example, a typical room. This would, in theory, be able to create a very information-wealthy model, whose aim is not to overwhelm, but to make sure all required information is available at any one given time. Cloud computing would become a more viable option in the future, but for now, these are the main added benefits.

OPP Guidelines

For the AE department to know what is acceptable or not with these models, there must be a set of rough guidelines to help clarify all the dos and don'ts. The first thing to be known is that the models *do not* need to be 100% exact to the last detail. In fact, that is not what is being pursued out of this project. In order for a model to be useable, it must be representative of the spaces allotted (i.e. a 100SF room should be about 100SF ±1SF). The spaces should have the ability to, in plan-view, look very similar to the actual drawings, which could be provided by OPP.

With a 3D model that looks quite similar to the drawings provided by OPP, the model instantly becomes useable. Walls, doors, and windows should be accounted for but specific materials do not need to be input into the model, as that can be fixed by appropriate personnel.

Since a push for a much more elaborate mechanical plan is desired, the best situation would be 80-90% accurately model. Also, with quality control being an issue for the modeling process, there would need to be some type of qualitative approach to determining the usability of the modeled ductwork, electrical work, etc. of the models.

In summary, OPP would like models to come out of the AE department, but they are not very picky about every last detail. In fact, they are more focused on getting what is offered, but would like there to be a little more added if it both benefits OPP and the student, as ultimately, the students' main priority is learning, so if nothing is to be learned, this whole idea is instantly wasteful!

Penn State AE Faculty

The second entity in this operation is the faculty of the AE Department. In particular those whose classes would provide the bridge required to produce the models. Their willingness to participate and their knowledge and vision of what a class is and should be teaching is what will determine the next set of guidelines to aid in the design of a suitable course in which both parties will benefit from, with absolutely no cost to the student, as their education is prime in the AE department.

Another Side to the Story

Previously mentioned, there was a trial done in the past in order to help create models for OPP through Professor Paul Bower's AE222 class. In the eyes of Mr. Bowers, this was a fairly successful trial with some students performing below average (as OPP saw) and some exceeding expectations. Models like that of IST were created and were up to standard. They included structural as well as other building components and the building representation was fairly accurate. However, that was one year ago in the spring of 2010, and the AE222 class has shifted back to looking for house models to do from the internet.

Bang for Your Buck

Most important to the AE department is to provide the students with a learning environment that is suitable and promotes their learning. Whether they benefitted OPP by creating models that accomplished the goal of promoting learning was an added benefit. However, it was not foreseen that creating the models would cost the AE department. In fact, that was counter-productive. There was a roadblock that stopped the project dead in its tracks, which was a cost of $1/Sheet for the drawings of the buildings that would be modeled, and this was simply not feasible for the AE department (Bowers).

In summary, assuming 5 groups worked on the drawings of different buildings, and each building consisted of 500 sheets, that would come to a grand total of $2,500 per semester and $5K per year to create these models. This was simply not appealing and made no sense whatsoever, especially since the final product was going to the OPP, who was purportedly going to pay for these models.

To say the least, it was probably lack of communication, lack of guidelines, and lack of a formal agreement that resulted in this, as it seemed to the observer that neither of the parties fully understood what the other party wanted.

Guidelines for Developing this Project

For AE222, Professor Bowers has a clear idea in his head of how it is to progress and develop. Some of the things he wants for his students are universal, regardless of the modeling abilities of the students. They are as follows:

- Every student that partakes in AE222 should have an equal learning opportunity in learning (i.e., every student should be exposed to the same exact material and not have each student performing a single task in order to be brought together as one final product)

- Tedious tasks like modeling fittings and couplings are not beneficial from a learning standpoint, and do not promote learning, but waste time
- Students cannot be made to keep re-doing models until they are up to OPP standards, but they are expected to perform at a certain level (at C grade or above).

Some of the concerns with this approach is that some students, when matched up together, may produce exceptional drawings, but the class's focus is not simply that. Ideally, the class should support 5 groups of 5, all with their own project being done and coordinating amongst themselves so that each student gets an opportunity to experience all levels of the modeling process, from lighting, mechanical, structural, enclosures and electrical and lighting. This is a tall order and requires a well-designed approach in order to be fulfilled. A key stressing point is that tedious work is not beneficial to the students and is not the goal of AE222.

Finally, it was brought forth that new forms of integration have been in the works, and this may be the missing link; using full building drawings. The new form of integration was performed in the recent 300 level classes, as a way to allow students to learn the integration process side-by-side with all the classes in the same semester (minus structural class). The benefit is that from class-to-class the students can relate all building processes. This has value to the OPP/AE dilemma!

Putting the Information Together

In an effort to determine the best route for both parties to go so that they both see a benefit is to find requirements by both, and determine which ones can and cannot be fulfilled.

Rating Scale

OPP Wants	Minimum	AE Can Provide		
3D Model	4+	3+		
Structural	3+	2+		
Enclosure	3+	3+	Scale	
Mechanical	4+	2+	0	No Model
Lighting	3+	2+	1	Model Needs Most Work
Electrical	4+	2+	2	Model Needs A lot of Work
Plumbing	4+	2+	3	Model Needs Some Work
Fittings	1+	0-1	4	Model Needs Little Work
Details	1+	0-1	5	Model is Perfect

Table 4-1: *Rating Scale*

Table 4-1 shows the relation of what is desired from OPP and what the AE department can realistically provide. Fittings and details are rated at 0-1 because they are a tedious item for students to model and represent little-to-no value from an educational standpoint. Plumbing, mechanical and lighting are the greatest focus of the OPP and if anything, they would want these to be modeled as best as possible.

The First Idea

In the end, those at OPP need to obtain 3D models should they arrive from a professional's office or the students at PSU AE. And whilst doing this work in class during learning is a great idea, modeling small things and being repetitive with them (like fittings, nuts, bolts etc) may defeat the learning goal of this. So, as a suggestion, it would make most sense to have a secondary modeling entity that would do all the tedious modeling, once the students have modeled the main part of the building.

The first idea was to have 2nd year AE students model all components of the building and then have the 4th year students perform more detailed parts of their work on the building. These may include things like lighting, mechanical and electrical being refined by 4th year students. So, although the model will still not be perfect, it would become much more useable; all major equipment would have a space and designated model to represent them, minus small fittings and, essentially, the nails on the board!

However, this idea is not as easy as it seems. A lot of the work now is removed from the original scope and there is a great amount of work that is generally not required in those classes, but may still be beneficial, like inputting information for certain equipment.

A Refined Approach

The first idea is a bit more general to allow one to start thinking "outside the box." This, however, is not sufficient. A plan must be put into place, and one that can be adapted for real use within the two entities.

Classes

The 2nd year class always spoken about is AE222, whilst the 4th year class is AE444. Both of these classes are taught by Paul Bowers, and are the greatest learning tool for modeling besides 4th year studio, which is reserved for creative thinking. So, that class would be best left to the architecture department to use to enhance the innovative thinking of the AE student. Given models to model in a class such as 4th year studio would defeat the entire purpose of the whole project.

Shortcomings

In AE222, the first proposal would have been to have 5 groups each focused on one portion of the building. So, for example, group A would consist of 5 students creating an electrical model, whilst group B would start producing the mechanical and so on, until all groups would gather in a fashion similar to that of a BIM coordination meeting, and bring all the parts of the project together. This seems very idealistic, especially if you assume that each group is made up of students willing to pursue that option that they are modeling for. However, this overly-simplified idea has its flaws; first of all, you cannot determine what each student wants to do especially during the 2nd year. Secondly, every group of students learns a completely different thing. They are not all exposed to the same material and this is simply not what the AE department wants.

The second approach would be the exact same idea, except divided into groups of 5, where each member models one portion of the building, all to be brought together by the same group. This, although done previously (speaking from experience), exposes the students to each other's models in order to coordinate between one another. At that level in college, very few students would completely retain the knowledge required to benefit from all the different types of modeling. This means that although the two previous approaches are not ideal, they are quite useful.

Dual-Benefit Option 1: A Simple Approach

The first option, which is much more focused on a quicker production of a model, is the approach that students in AE222 are grouped into groups of 5, as usual, and each group is responsible for a system of each floor. The main idea is that there must first be 5 floors to the building, or a building would need to be split up into portions that would need to be placed back together into one final model. The main idea is that, for example, group A perform the mechanical, lighting and electrical, structural and enclosure for the first floor and the rest of the groups do the same for their allotted floor or even their section. This would be brought together to form an entire model in the final stages of the project.

NOTE: Dual-Benefit refers to approach based on a direct communication between OPP and the AE department, and not the student directly. Do not confuse with Internship approach.

Challenges

The main challenges would be how to distribute the building, especially since some floors might be less demanding than others. Also, to coordinate with students that have very limited knowledge of the subject may be a challenge.

Benefits

The main benefits of this approach are that the entire project is contained in one class, and the models can be produced on a semester basis, whilst also exposing every student to all options of modeling and allowing them to figure out on their own what they like more or less.

Dual-Benefit Option 2: Dealing with Details

The second option is what may be called a fully integrated approach. It is based on the idea that the model-producing can stretch into 3rd year and even 4th year. This would be achieved by allowing the same students in AE222 to create models similar to those created in option 1, but with much less time devoted to simply creating models, and more time focused on the rest of the class. This means that although each floor is created, to a certain extent, with all the components, there is no need to put it all together… yet.

With BIM becoming a much bigger industry focus, proper exposure is key to differentiating students. The way this can be done, in order to have students that have simply seen and done all portions of the BIM process at one point or another, is by attempting to take all classes that require students to model new structures (e.g. AE311 modeling rooms for lighting purposes, AE309 modeling an acoustical room) and using the time to do that, to instead model portions related to the class. So, let's assume that building A has all 5 floors modeled but they are all separate. These would be logical events to occur:

1. The model would be further enhanced by adding lighting fixtures in AE311 and performing the rest of the class accordingly. In the second portion of AE311, electrical equipment can be added and analyzed with some data input where necessary.
2. The model would be further enhanced for inputting mechanical equipment data for at least a few of the mechanical equipment in AE310
3. The model would be tested for reverberation times and such in AE309, and allow the students to optimize the rooms (which could become an added benefit!)
4. The model would be then put together in coordinated BIM-meeting-setting in AE372. This would be the coordination of all trades to find clashes, fix them and learn the process first-hand!
5. Finally, since now AE308 is in the spring for most students, the members can be analyzed for deflection etc. when modeling in STAAD as opposed to modeling arbitrary buildings.
6. If time is not an issue, AE444 can be used to turn these buildings into movie subject, and allow for decent renders to occur, as well as placing them geographically on a central map. Also items like textures can be added to some portions like the facades, in order to complete the package.

The idea is simple, but it focuses on as much exposure as possible whilst preventing the focus of the classes from being all on the BIM portion. It allows portions to be done in each class, but in a relative manner.

Challenges

One major challenge here is that buildings must be carefully selected in order to be beneficial. Also, buildings with very sophisticated systems may be tough to model and will fall through in these classes. What this entails is that a selected building must meet certain criteria in order for it to be useful to the students. Although just an assumption, this may drop the available projects that can be done from the total of 400+ to less than 50. Also, coordinating the models' progression through two entire years may be a tough process, and one that requires extensive management.

There may be "anomalies" with students who arrive in the spring and try and catch up, which may expose them to a mix of classes where they may have to sacrifice the singular process of seeing a model from beginning to end, although this would not be too much of a sacrifice. The reason this is a challenge is that there is a very important value to seeing the project's entire life cycle from beginning to end. It would definitely take away from the learning experience to jump from project to project, but the "harm" would be minimal considering that assimilating into a new group would not be a tough part and can be accommodated.

BPY (Buildings per Year)

The amount of buildings that can be produced each year, or cycle of three years, is debatable. This first item to consider is that no two buildings are equal, and whilst there may be two 5-story buildings, one might require very little modeling effort due to repetitiveness and size, whilst the other may take a much longer time. In order to make the process more efficient, a SF requirement would need to be made in order to determine, based year to year, how many groups are needed to perform the modeling process without interfering with their workloads in a detrimental manner, as the goal is not to overload the students; this is not their job.

It is very difficult for one to simply assume what would be a necessary building size, and the only true measure would be through trial and error. However, since a building as large as the IST building was produced by the last class to take this project, the threshold is large. Also, a larger project may require an entire class to participate in the "floor-to-floor idea" (the idea that each group takes on a system on each floor, allowing every student exposure to all the systems), while a set of smaller projects (for example 5 small buildings) can be appropriately divided to allow each student the same exposure to all systems by alternating between each system on an individual level as opposed to groups created from an entire class. These are the two extremes. Typically, the goal will be to achieve a consistent SF for the entire class.

Liquidity

Returning to the assumption that the amount of projects that are usable would fall from 400+ to only 50, and assuming that every three years, five projects would be produced, that gives the entire project an estimated life of thirty years. Whilst this may sound very limited there are more assumptions to be made; assuming that each three year model would be up to a very high standard (3D model, with most systems including some data inputs into the models), there may be upwards of $60K allocated for each model. In other words, every three years the PSU AE department would earn $300K, or close to $100K every single year.

The returns would not be seen until the third year, after which each following year would produce an income for the department. Undoubtedly, each project would be evaluated differently, and whilst the proposed earnings above may seem good, they are in fact optimistic. However, that is not to say that they are unrealistic, as they do hold great value to OPP and their ultimate goal as part of a larger system and the savings they would ultimately generate are probably a large factor in OPP's investment in them.

Monetary Challenges

Models produced can be assumed to have an average value of $60K±10K. The margin is large, but it is important to realize that the money generated cannot be considered a constant. This is especially true when investing the money into something constant such as hiring a new staff-member. It is instantly appealing, but the large risk involved with this volatile project puts such investments at risk, especially if the project does not deliver; there is always a risk involved.

The reason why every year, as certain SF should be targeted is to keep the income more of a constant, and allow the project to be very systematic and allow all errors to be ironed out throughout the project's life. For example, if the SF target was 250,000SF, the buildings may come in sizes of five 50,000SF buildings, one 250,000SF building (not many of those!) or any combination that comes within a reasonable range of the target. That would allow the above argument that each model come in at $60K to be somewhat invalidated, and may be the reason to start a cost/SF for modeling.

Process and Design

This section will cover a possible course design, by attempting to simplify all data presented above, with some more information that can be deemed useful.

AE222

This class, instructed by Paul Bowers is the primary candidate for the models and the syllabus has been examined in order to determine what would be consistent with the material that it intends to teach and what may not be. From the syllabus, this is what is required in terms of 3D modeling:

"Create the following, utilizing the latest version of Revit and AutoCAD in accordance to the National CAD Standards:"

Requirements	Relates to OPP Models? (Yes/No/Possibly)
a. BIM Model	Y
b. Floor Plans	Y
c. Elevations	Y
d. Exterior Wall Section	P
e. Building Sections	P
f. Floor Plan/s with Lighting, Electrical, HVAC, Plumbing	Y
g. Reflected Ceiling Plan	Y
h. Title Block	P
i. Roof Plan	Y
j. Foundation Plan	Y
k. Structural Plan	Y
l. Site Plan (Parking, Landscape, Zoning)	Y

m. Stairs	Y
n. Details	Y
o. Schedules (Room, Door, Window, Lintel, etc.)	Y

Table 4-2: *AE222 Requirements*

The course clearly covers a lot of what is being asked for by OPP and it would only make sense to incorporate the two for the benefits that both parties will receive.

A direct inclusion of the topics that are required in AE222 is not established in the 300 level courses, but the design will cover the basic requirements.

Process Method

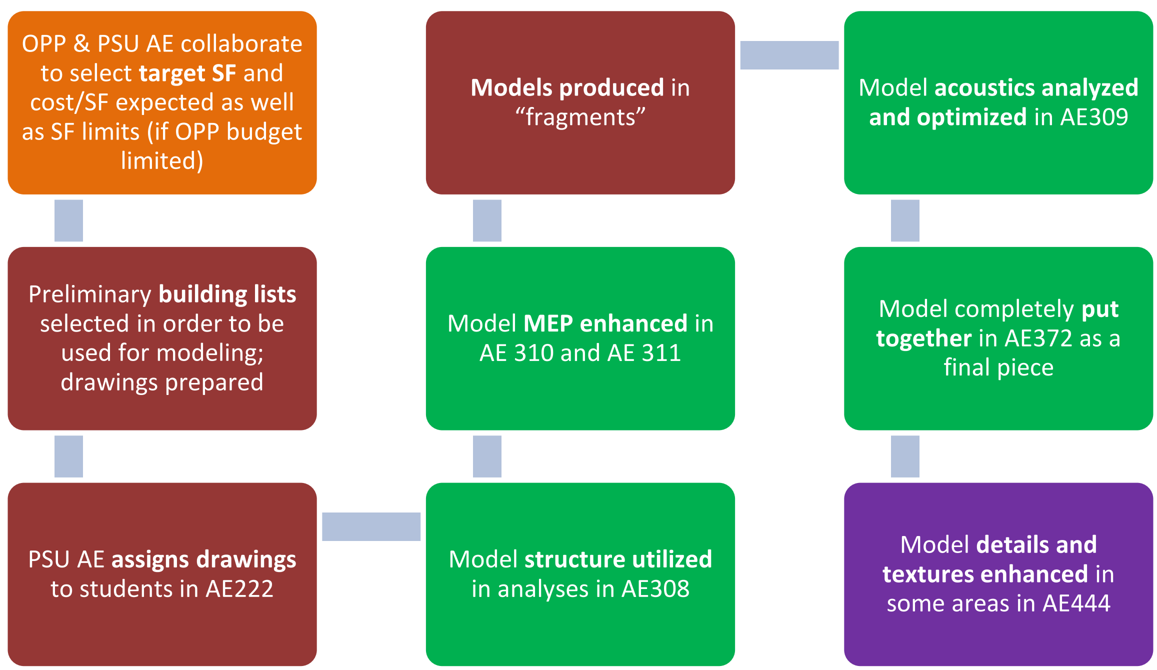


Figure 4-1: *BIM Process*

The process outlined in *figure 10* shows a simplified method of starting at zero and ending with a product. Its idea is based on a model that can be expanded at each stage in order to make each stage more efficient. This can then be further improved to remove or even replace stages to realize the process' full potential.

Trial and Error

This process requires trial and error in order to become a feasible, sustainable and beneficial project. Every process must undergo analysis in order to remove small design errors. For example, in order to determine an appropriate SF count, both historical data on earlier projects, as well as new data can be used and combined to determine the average square footage that a typical class can successfully model without jeopardizing their education. The most important point, as stressed over and over is that the most important factor to realize is that any part of the project that takes away from the educational aspect is immediately removed from the design and process. It is important to always keep in mind that this project is not designed to simply create models for OPP's sole benefit, but rather a much more complex approach to designing a process that allows the project to essentially "hit two birds with one stone" by allowing students to benefit from all the same educational characteristics of the modeling process whilst creating a model that is not only useable by OPP, but first by the students in a number of courses that allows them to be exposed to the most cutting edge and be on the frontlines of the new wave of BIM integration. This idea requires close monitoring and an efficient trial and error process that allows itself to become more and more streamlined as time passes.

BIM Information

In order to further understand the benefits of BIM, one must understand the components and portions of BIM that make it what it is and allow its use to be efficient.

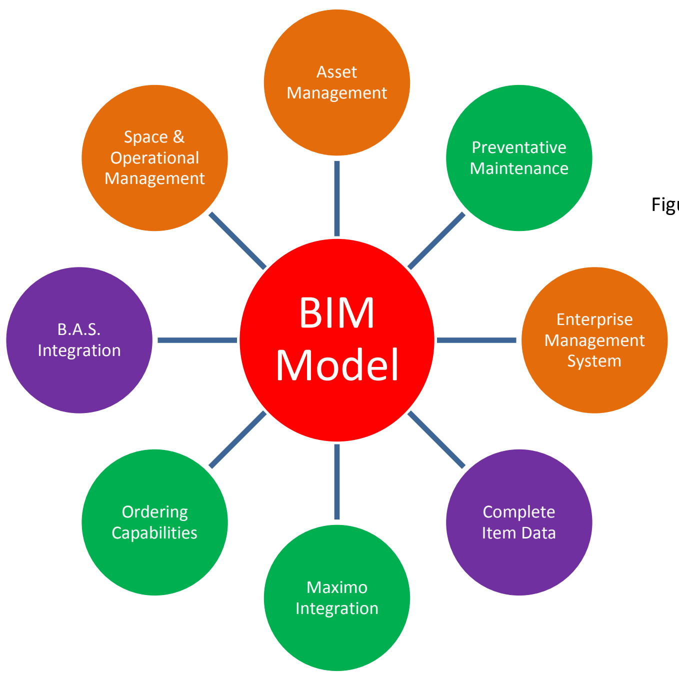


Figure 4-4: *BIM Model Relationship Chart*

Figure 4-4 shows the different things that can be done using a true BIM model, since BIM is often mistaken for simple 3D models; It is, by definition, the integration of a 3D model with information that pertains to the building itself.

What Isn't BIM?

One particular issue is that many professionals and owners do not know what is not considered BIM and why. As mentioned earlier, BIM is not simply a 3D model, as that is simply a 3D model and not a BIM model! The reason is that the model is a visual representation, but one that cannot be used to aid in design or integration processes. It also does not aid in the construction process, so it is practically just visual. Another point is a model with objects whose sizes and parameters cannot be changed, is one that is not considered to be a BIM model.

BIM for Owners (Eastman)

BIM is often talked about in a sense that is advantageous to the constructors and fabricators and subcontractors and all entities involved with construction except for the owner. The owner is usually left out of the equation except in terms of visual representations for "pitches." The BIM tools used are actually catered to those entities and not the owner.

One of the biggest issues with BIM models is that typically, once the building is constructed, the model is not updated. This causes the model's value to drop exponentially as its use is done and no longer is it needed or useful. This actually creates a dilemma; to update or not. The value in this may not actually be realized instantly, and may cost a lot up-front, which is the case for the analysis at hand.

With facility management being one of the most important parts of the BIM models to OPP, one must consider the actual benefits. So firstly, the models are a long term investment in that they are not forgotten and "left to rot." The models must always be monitored and done so to reflect changes in the buildings systems and geometry. That being said, the gains are very noticeable even from day 1 or the system being in operation. Inefficiencies due to activities like maintenance and labor entering data by paper and filling out forms and inputting data at a later time in a computer can be entirely eliminated. There will be no need to have anybody hired to collect and enter data; instead the laborers can do this directly to the BIM model. In turn, this can be all viewed by the owner (OPP) in one single location to streamline the process. In other words, the models will pay for themselves eventually.

The most important point to gain from this is that using a BIM model is going to have benefits, but it also comes with commitment and the need for the owner to supervise the process and ensure a quality product results from this.

Keeping it Real!

Being realistic is the most important part of this project, and while the aforementioned class design may be appealing, there are some major flaws in it.

Firstly, the program does not look at the problem in which students are almost literally “forced” to carry out this project. The fact that the entire design of the class emanated from the two parties involved benefitting does not mean that this should take away any benefits that are already being realized in the current situation for the students. So, this means that the students should not have their education be force-infused with the OPP project to make models, no matter how profitable and beneficial they are. In fact, just the opposite needs to happen (discussed later).

Secondly, the modeling scenario presented in “A Refined Approach” is very optimistic and relies heavily on all things going well. The issue with this is that there is little or no room for things to go awry, and if a model does not come out well from second year, the students will need to deal with it throughout third year as well. This is less than ideal, but also very likely, as the students who make the models are not all experts and not all is interested in the modeling aspect of architectural engineering. And as things stand now, not every student that graduates from the program is, or needs to have intensive knowledge of the modeling process.

Finally, in order to address these issues, students need to be in control of what they are learning to some degree. So, the fact that what they are doing is producing a product quite literally, is a bit of a weird position to be in, especially when that may not be their interest.

Real Expectations

Considering that the OPP’s current as-built drawings are a little outdated, the modeling of buildings may be a challenge. Some M.E.P. systems may not be accurate, and may not be able to be represented in a fashion that satisfies either party. There will be a lot of wasted time gathering drawings and information and whilst this seems like a quick-fix, it is not. Some models may not have all required drawings, while some may. Finding these drawings may be a new issue altogether as there is quite a few buildings whose drawings are very old, and may need special attention when being handed to students.

Moreover, the expectation that students would be able to model M.E.P. in a manner that is useful is “expecting a lot” and may be a setback to the OPP in terms of a sunk cost. In other words, OPP’s time investment as well as possible monetary investment in the project may not be realized when unfinished models, or unusable models are produced; there must be enough control over what is being asked for, as well as incentive.

The Solution

The solution might seem like an "all-inclusive deal" but it is not. It is merely a better method of looking at this entire project, and understanding the ultimate needs of all parties involved. The risks involved with taking on a project like this when the end result is actually a product, is high. The whole idea focuses on the need for models and the ability of OPP to "exploit" the position it is in, in a sense that they are hitting two birds with one stone (instead of paying a higher premium at a specialized company).

Accuracy

In order to have this work, students CANNOT be expected to model more than just the exterior and architectural components. In other words, the most valuable portion that can be realistically modeled by students in a 200 level course in AE, is the exterior and interior walls of the building, with some façade details. Essentially, this is what they learn anyway, and the model being produced would not affect their learning.

Internship Approach

Although this seems like a very simple idea, an internship would be a very attractive method of producing models, and is so very many very good reasons.

- The students who perform well modeling in the 200 level classes can be selected based on known performance, which can drastically reduce the time necessary to identify possible candidates.
- The incentive to work and both be paid as an intern, as well as have it shown on a resume is great for any student.
- OPP would have total control over the required content of the models, and can easily monitor the process and have a hand in their investment; this is much more appealing than "hoping for the best."
- The process can easily be flexible and accommodate students' needs, as well as the ability for students to work either in a specific location or in any campus lab.

There are drawbacks as well to this approach as well, with the most noteworthy being the fact that the AE program will receive very minimal earnings from the process. Since this should not be a political debate, that shouldn't be a problem as the opportunity of exposing students to a working environment is much more beneficial to them than producing a product with little incentive, for another entity's use.

Off Limits

One final point to consider is that there may be quite a few buildings on campus whose drawings cannot be accessed for security reasons, and that may not hinder progress, but would possibly require more debate as to how they would be handled. A simple starting point would be to only model the façade and exterior walls, with not information provided on anything else in the building.

Conclusion

To conclude, *table 4-3* shows the possible risks and benefits of the modeling process if the in-class approach was taken.

Risks and Benefits of the Process Method

Benefits	Risks
Models provided to OPP	May be detrimental to education
Income provided to PSU AE	May be extremely time consuming
Students exposed to mechanical BIM modeling	May relocate focus of classes
Students exposed to lighting/electrical BIM modeling	Possible failure of 2-3 year process if not coordinated well enough
Students exposed to structural BIM modeling	Models not updated lose value
Students exposed to BIM coordination and management processes	

Table 4-3: *Risks and Benefits of the Process Method*

With technology changing rapidly before our eyes, getting students in the habit of using the tools provided by the industry is a way of setting them apart from the rest of the graduates in this field. The ability to enter the market with years of experience with these tools is not only an added benefit to the students, but to the industry as a whole; it promotes the efficiency of these processes and allows the students to become leaders. This is perpetuated by their knowledge of the systems that they design, as they are not only experts in the 3d coordination and integration aspect, but can also perform all that they learn in theory and apply it to real-life-applications.

The advantage to OPP is that they will receive models that can only get better with time, as the process will get more efficient and become a dedicated learning tool for the professors at PSU AE, whilst allowing the models to be used by a separate entity in a manner that benefits both. The foreseeable benefits are endless, but the process must be closely monitored and controlled to ensure the main goals are always kept at hand, preventing the process from turning into something that it was not intended to be; a job.

Recommendation

In this particular case, despite the effort to realize the potential of a class that will serve the students and the university, the project is unfeasible. It is true that if all external factors are very highly controlled and all students produce to their best potential, the process may be very successful. However the risk is high considering the real situation. The need for many external factors to all be in harmony is too much of a risk and shows that the approach is extremely optimistic. The factors include:

- Up-to-date models required for all systems
- Very quick Reponses to any queries about the drawings as not to waste-students time looking for information to be provided
- Students must perform at a high standard for all approaches to work
- Access to drawings must be immediate (finding out midway in the project that certain drawings are missing would be very wasteful to the student)

Whilst the factors are just a few, they are enough to deter from having the 2nd year students modeling for an external cause. This is not to say that the success of the project (no internship) is impossible, but it is highly unlikely as it depends on more than one factor greatly outside both parties' (PSUAE and OPP) control.

Finally, it is very wise to consider the internship approach. This is an overly-simplified solution, but without the resources and time to continue to study the "dual-benefit" approach, one cannot come to a solid conclusion. However, based on the information provided and the research conducted, there is a lot of conflicting ideas within both entities, with no clear boundaries drawn on what exactly is wanted/expected from either entity. And with control being one of the most important issues, the only way to fully control the product is to directly pay for it. Although it may not seem fair for AE PSU to "give up" its students to work outside its boundaries, there are clear benefits to that.

LACCD e7

The LACCD (Los Angeles Community College District) employs an internship program that benefits the university through internship works. It operates under very similar principles and allows students internship opportunities that benefit the university. One of these programs, called e7 studio (e7studio.net) does what is very similar to what PSU wishes to achieve. Although communication was limited with this entity during research, the success of this project is very realistic.

Final Words

In a final conclusion, the most effective approach at based on information provided and received within this report, the most viable option for the problem statement at hand is to employ an internship based approach.

Final Conclusion

To conclude this thesis report, it is important to note some of the lessons that have been learned as a result of this research, which would not have been learned otherwise.

Analysis I

In this analysis, it was determined that asbestos is a major contributor to issues and problems when dealing with renovation work on buildings that were built before the 1980s. It is a crucial part of the project to understand the health risks involved with asbestos and not to underestimate the importance of its removal.

There is also the concern of demolition, and that demolition is not necessarily dealing with charges and explosives. In fact, it may be a carefully choreographed event in which a crane and other heavy-duty equipment are used to tear down a building.

In terms of the Moore Building Addition, it would be advised to tread cautiously when selecting one method over the other, as delays in the project may occur due to unforeseen circumstances. Also, the risk of not shortening the schedule is high considering the short timeframe of the project.

Analysis 2

One important piece of information learned is that there are many variables that go into the selection of a new design. It is not a simple task to simply take a given design and adapt it for use with a new façade. In the case of the Moore Building Addition, it would be best to consider a precast façade system as the savings in time are extremely high. Also, there may be savings in other areas due to the high reduction of on-site crowdedness. It is without a doubt, a very appealing route to go with for this building.

Analysis 3

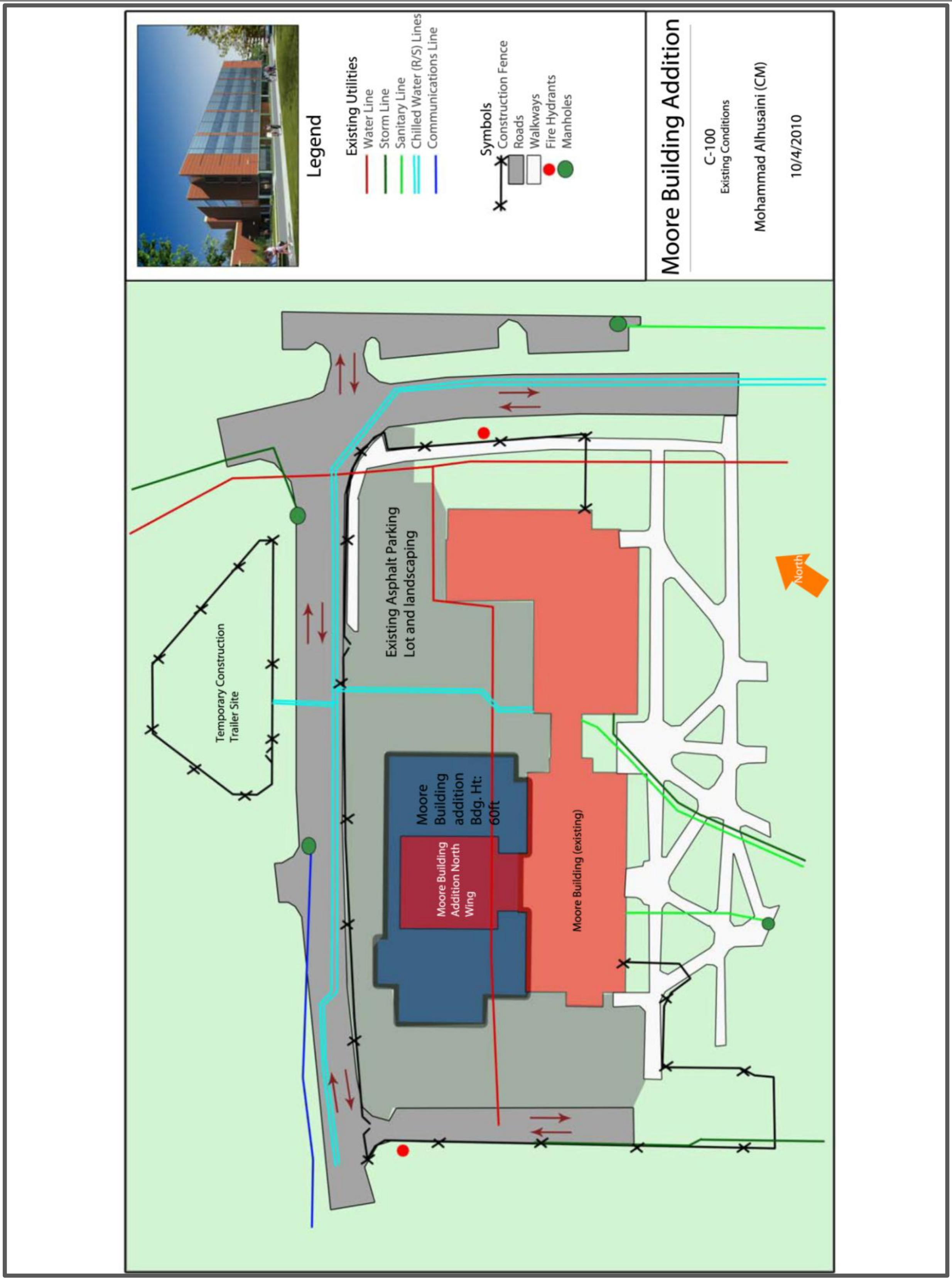
In researching design-assist as a possible contract type, one of the most important lessons learned was that there is an inherent lack of communication between key people involved in some projects. For one, the information provided as to the structure of the projects was differing from two separate entities in the physical plant.

It is also almost impossible to quantify ideas with no comparable data; surveys are a very helpful tool in this situation.

Analysis 4

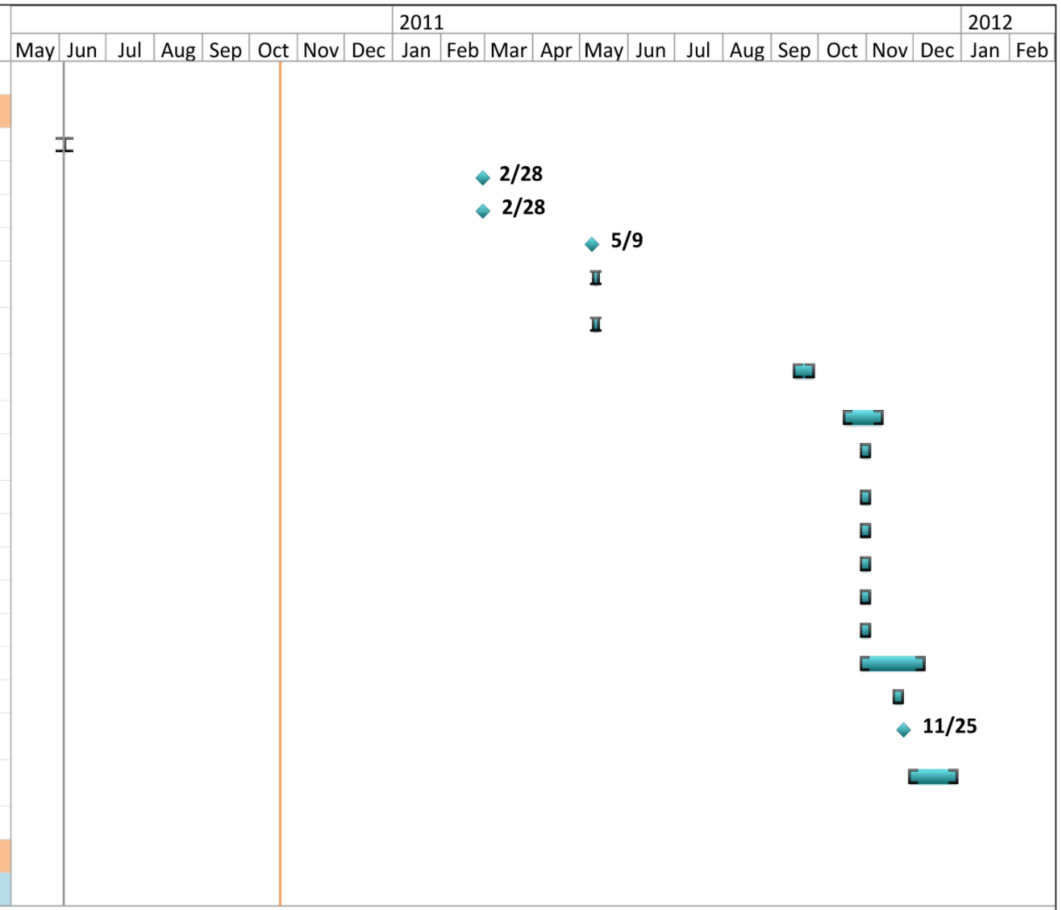
In the last analysis, the most important lesson learned is that the answer that may be most useful may also be the simplest. It may not always be that the complex route is the one to provide the best results. Although it may, the time available made it hard to delve deep enough to find out just that. However, based on the research, the internship route looks the most promising.

Appendix A – Existing Conditions Site Layout


Legend
Existing Utilities
Water Line
Storm Line
Sanitary Line
Chilled Water (R/S) Lines
Communications Line
Symbols
Construction Fence
Roads
Walkways
Fire Hydrants
Manholes
Moore Building Addition
C-100
Existing Conditions
Mohammad Alhusaini (CM)
10/4/2010
Temporary Construction Trailer Site
Existing Asphalt Parking Lot and landscaping
Moore Building addition Bdg. Ht: 60ft
Moore Building Addition North Wing
Moore Building (existing)
North

Appendix B – Detailed Project Schedule

ID	Task Name	Duration	Start
1			
2	**MILESTONES**		
3	GROUND BREAKING CEREMONY	1 day	Fri 6/4/10
4	PERMANENT POWER	0 days	Mon 2/28/11
5	BUILDING DRY-IN WEST	0 days	Mon 2/28/11
6	BUILDING DRY-IN NORTH & EAST	0 days	Mon 5/9/11
7	PREFUNCTIONAL TESTING FOR AIR SIDE	5 days	Mon 5/9/11
8	PREFUNCTIONAL TESTING FOR CHILLED WATER	5 days	Mon 5/9/11
9	PREFUCNTIONAL TESTING FOR HOT WATER SYSTEM	10 days	Thu 9/15/11
10	TEST AND BALANCE	20 days	Mon 10/17/11
11	FIRE PROTECTION FINAL INSPECTION	5 days	Fri 10/28/11
12	ACCESSIBILITY FINAL INSPECTION	5 days	Fri 10/28/11
13	ENERGY FINAL INSPECTION	5 days	Fri 10/28/11
14	MECHANICAL FINAL INSPECTION	5 days	Fri 10/28/11
15	ELECTRICAL FINAL INSPECITON	5 days	Fri 10/28/11
16	PLUMBING FINAL INSPECTION	5 days	Fri 10/28/11
17	FUNCTIONAL TESTING	30 days	Fri 10/28/11
18	BUILDING FINAL INSPECTION	5 days	Fri 11/18/11
19	PROJECT SUBSTANTIAL COMPLETION	0 days	Fri 11/25/11
20	PUNCHLIST AND COMMISSIONING	24 days	Mon 11/28/11
21			
22	**CONSTRUCTION**		
23	**SITEWORK**		

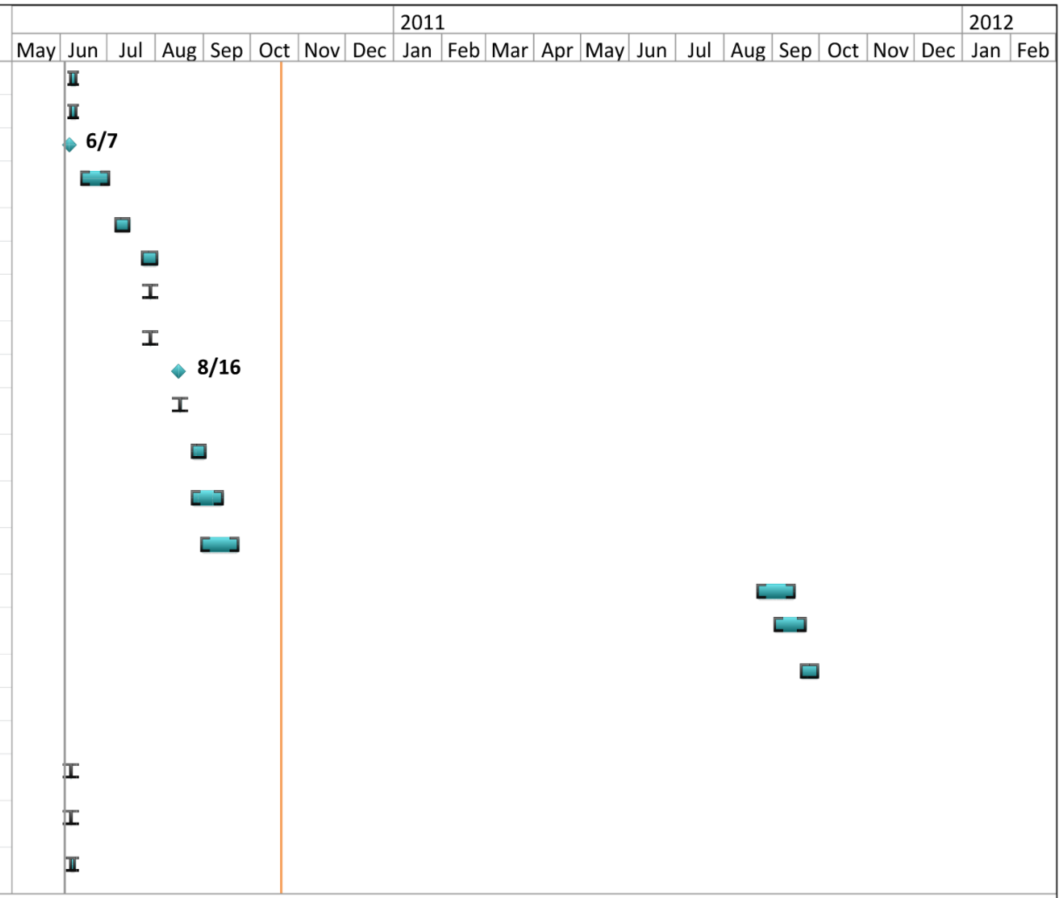


Project: FULL SCHEDULE
Date: Thu 10/21/10

Task	External Milestone	Manual Summary Rollup
Split	Inactive Task	Manual Summary
Milestone	Inactive Milestone	Start-only
Summary	Inactive Summary	Finish-only
Project Summary	Manual Task	Deadline
External Tasks	Duration-only	Progress

Page 1

ID	Task Name	Duration	Start
24	INSTALL SITE FENCING	5 days	Mon 6/7/10
25	TREE REMOVAL	5 days	Mon 6/7/10
26	CLOSE ALLEY	0 days	Mon 6/7/10
27	INSTALL CHILLED WATER LINES (ALLEY)	15 days	Mon 6/14/10
28	INSTALL WATER LINES (ALLEY)	8 days	Tue 7/6/10
29	INSTALL STORM SEWER (ALLEY)	7 days	Fri 7/23/10
30	INSTALL TEMPORARY WATER HEATERS	2 days	Wed 7/28/10
31	RESTORE ALLEY	2 days	Wed 7/28/10
32	REOPEN ALLEY	0 days	Mon 8/16/10
33	RELOCATE SITE FENCE & CLOSE MOORE/CEDAR PKG LOT	2 days	Mon 8/16/10
34	INSTALL TEMP. CA PIPING (SITE & BASEMENT)	8 days	Tue 8/24/10
35	INSTALL TEMP. STEAM PIPING (SITE & BASEMENT)	15 days	Tue 8/24/10
36	INSTALL PERMANENT SITE UTILITES	19 days	Mon 8/30/10
37	INSTALL SITE CONCRETE	19 days	Mon 8/22/11
38	INSTALL SITE LIGHTING/ELECTRICAL	15 days	Fri 9/2/11
39	INSTALL LANDSCAPING	10 days	Mon 9/19/11
40			
41	ABATEMENT & DEMOLITION		
42	PREP 3RD FLOOR ASBESTOS ABATEMENT	2 days	Mon 6/7/10
43	PREP CRAWL SPACE ASBESTOS ABATEMENT	2 days	Mon 6/7/10
44	ASBESTOS ABATEMENT CONTAINMENT SET-UP	4 days	Mon 6/7/10

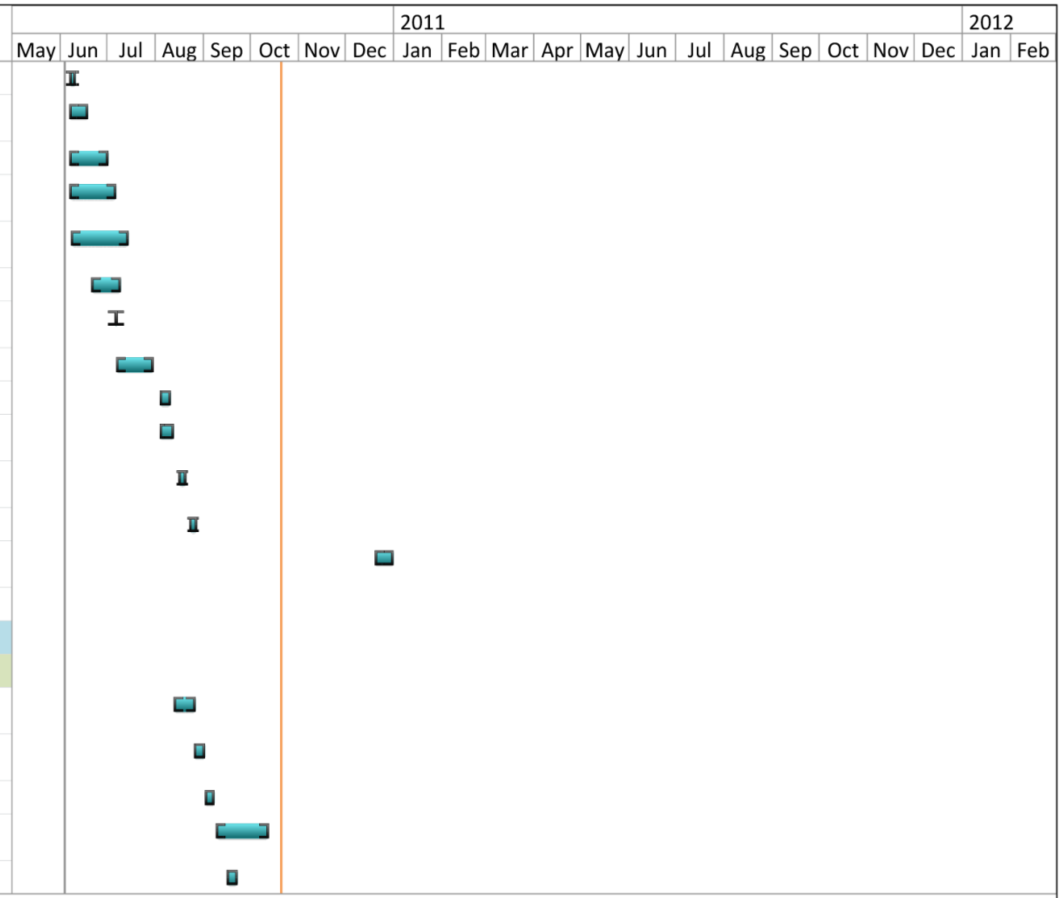


Project: FULL SCHEDULE
Date: Thu 10/21/10

Task	External Milestone	Manual Summary Rollup
Split	Inactive Task	Manual Summary
Milestone	Inactive Milestone	Start-only
Summary	Inactive Summary	Finish-only
Project Summary	Manual Task	Deadline
External Tasks	Duration-only	Progress

Page 2

ID	Task Name	Duration	Start
45	PREP 2N FL ASBESTOS ABATEMENT	4 days	Mon 6/7/10
46	ASBESTOS ABATEMENT EXTERIOR PANEL REMOVAL	10 days	Mon 6/7/10
47	ASBESTOS ABATEMENT TRANSITE	19 days	Mon 6/7/10
48	ASBESTOS ABATEMENT 3RD FL THEN SERVER	22 days	Mon 6/7/10
49	ASBESTOS ABATEMENT CRAWL SPACE	27 days	Tue 6/8/10
50	ASBESTOS ABATEMENT 2ND FL	15 days	Mon 6/21/10
51	PREP 4TH FL ASBESTOS ABATEMENT	2 days	Tue 7/6/10
52	ASBESTOS ABATEMENT 4TH FL	18 days	Wed 7/7/10
53	DEMO 1ST FL INTERIOR WALLS	5 days	Wed 8/4/10
54	DEMO WEST ELEVATION BRICK EXTERIOR	7 days	Wed 8/4/10
55	DEMO NORTH ELEV BRIC EXTERIOR	5 days	Mon 8/16/10
56	DEMO EAST ELEV BRICK EXTERIOR	5 days	Mon 8/23/10
57	EXISTING MOORE BSMT ASBESTOS ABATEMENT	10 days	Mon 12/20/10
58			
59	**BUILDING CONSTRUCTION**		
60	**STRUCTURE THRU SLOCURE**		
61	EXCAV WEST BASEMENT & SHORE /UNDERPIN EXISTING STEEL	10 days	Fri 8/13/10
62	DEMO SLABS AND AREAWAY WALLS & WEST GRADE BEAMS	5 days	Thu 8/26/10
63	STABILIZE EXCAVATION	4 days	Thu 9/2/10
64	F/R/P BSMT FOOTINGS/WALLS - WEST	24 days	Thu 9/9/10
65	BELOW SLAB EXCAVATION	5 days	Thu 9/16/10

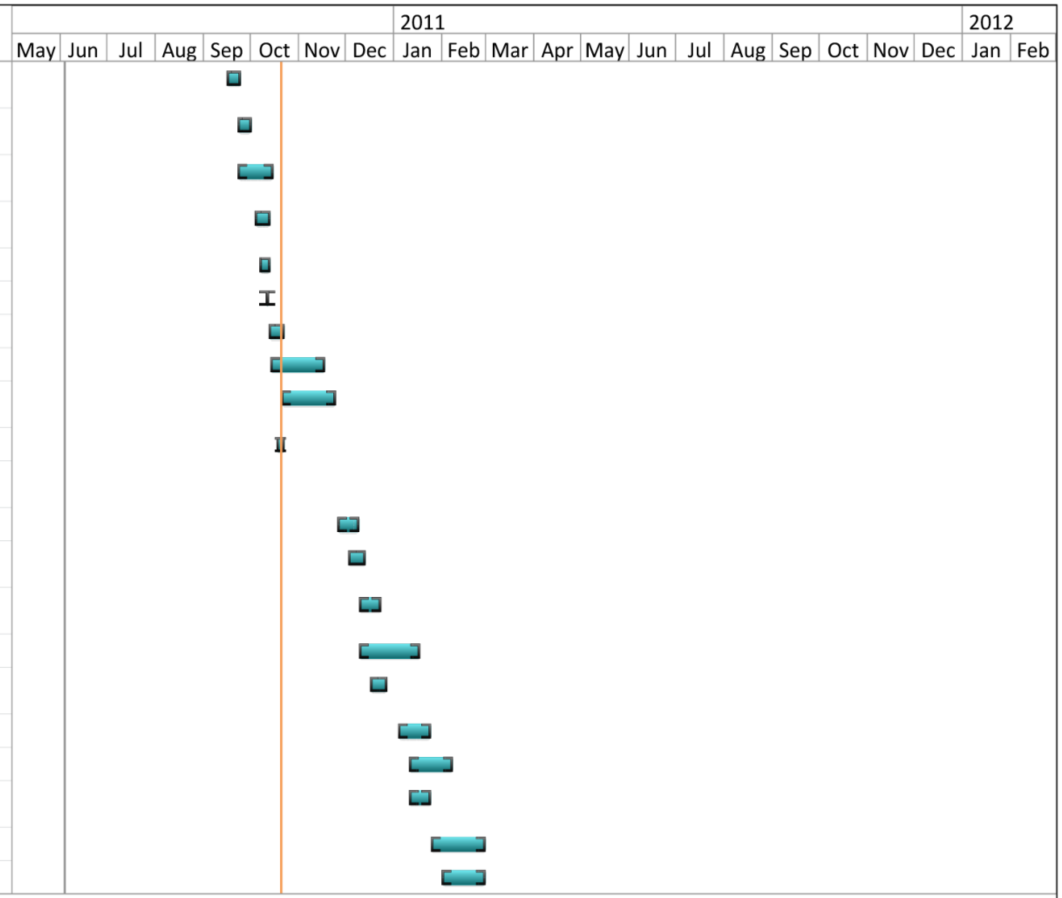


Project: FULL SCHEDULE
Date: Thu 10/21/10

Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress

Page 3

ID	Task Name	Duration	Start
66	BELOW SLAB ELECTIRCAL - WEST & EAST	7 days	Thu 9/16/10
67	BELOW SLAB PLUMBING - WEST & EAST	7 days	Thu 9/23/10
68	F/R/P FOOTINGS/WALLS NORTH & EAST	17 days	Thu 9/23/10
69	FLOOR DRAINS, EXCAV SITE SANITARY, BACKFILL PIPING	8 days	Mon 10/4/10
70	CANTILEVER GRADE BEAM	5 days	Thu 10/7/10
71	INSTALL SITE SANITARY PIPING	2 days	Mon 10/11/10
72	BASEMENT WATER PROOFING	8 days	Wed 10/13/10
73	ERECT STEEL WEST TO EAST	25 days	Thu 10/14/10
74	DECKING/DETAIL/IN SLAB PREP WEST TO EAST	25 days	Thu 10/21/10
75	BASEMENT SLAB ON GRADE WEST	5 days	Mon 10/18/10
76	SLAB ON DECK POURS -WEST 5 LEVELS	10 days	Mon 10/26/20
77	SLAB ON GRADE NORTH & EAST	10 days	Fri 11/26/10
78	BACKFILL FOUNDATION WALLS - WEST	7 days	Fri 12/3/10
79	SLAB ON DECK POURS - N&E 4 LEVELS	10 days	Fri 12/10/10
80	SOFP - WEST NORTH AND EAST	27 days	Fri 12/10/10
81	BACKFILL FOUNDATION WALLS - NORTH AND EAST	7 days	Fri 12/17/10
82	ROOFING - WEST	15 days	Tue 1/4/11
83	MASONRY - WEST	20 days	Tue 1/11/11
84	EXT FRAMING AND SHEATHING - NORTH & EAST	10 days	Tue 1/11/11
85	ROOFING - NORTH AND EAST	25 days	Tue 1/25/11
86	CURTAINWALL - WEST	20 days	Tue 2/1/11

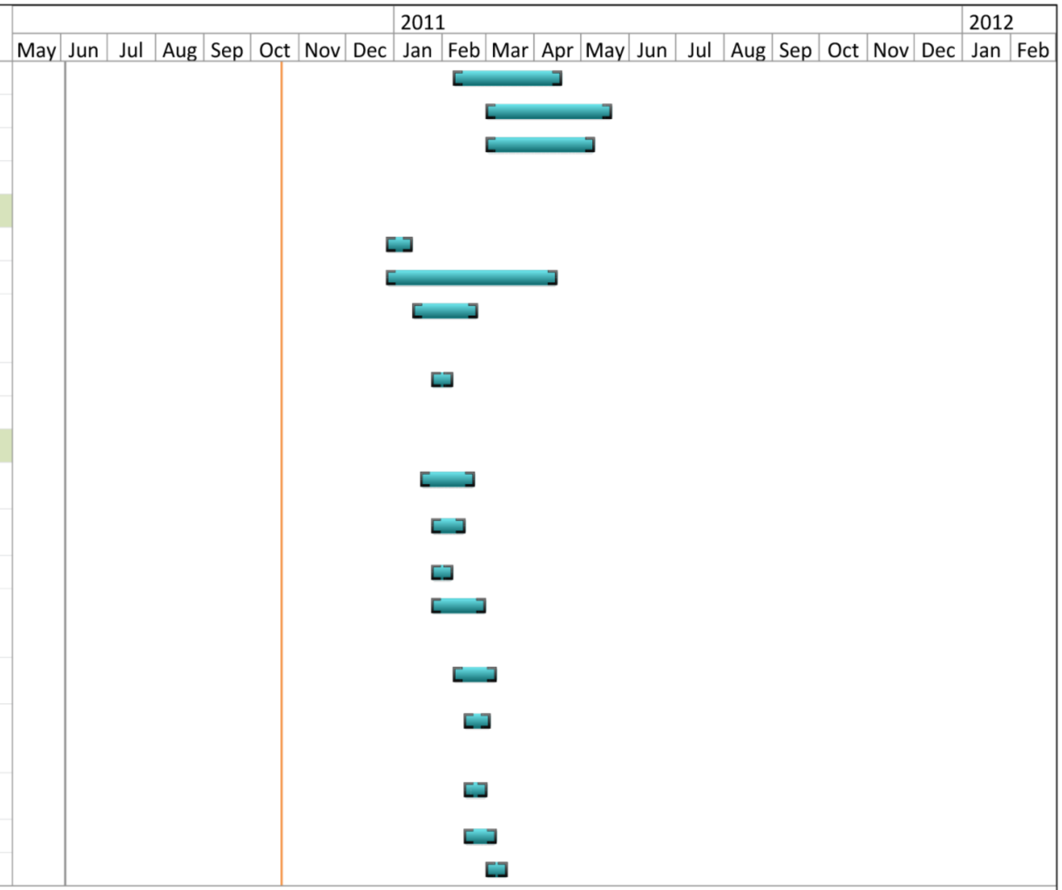


Project: FULL SCHEDULE
Date: Thu 10/21/10

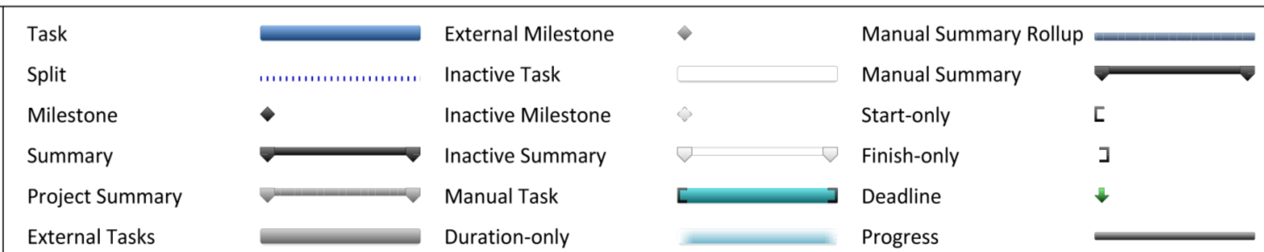
Task	External Milestone	Manual Summary Rollup
Split	Inactive Task	Manual Summary
Milestone	Inactive Milestone	Start-only
Summary	Inactive Summary	Finish-only
Project Summary	Manual Task	Deadline
External Tasks	Duration-only	Progress

Page 4

ID	Task Name	Duration	Start
87	MASONRY - NORTH AND EAST	50 days	Tue 2/8/11
88	INSTALL ELEVATOR EQUIPMENT	59 days	Tue 3/1/11
89	CURTAINWALL - NORTH AND EAST	50 days	Tue 3/1/11
90			
91	**BASEMENT**		
92	SANITARY/STORM RI	13 days	Mon 12/27/10
93	BSMT MER RI & RISERS	80 days	Mon 12/27/10
94	BSMT PUMPS/SEWAGE/DOMESTIC WTR/WATER HEATERS	30 days	Thu 1/13/11
95	BSMT FIRE PROTECTION	10 days	Tue 1/25/11
96			
97	**1ST FLOOR**		
98	FLOOR LAYOUT/TRACK/STUD FRAMING & INSTALL	25 days	Tue 1/18/11
99	FLOOR STORM PIPING/SANITARY RI/DRAINS	16 days	Tue 1/25/11
100	FIRE PROTECTION RI	10 days	Tue 1/25/11
101	O/H ELECTRICAL ROUGH IN & ELECTRICAL IN-WALL STUD ROUGH-IN	25 days	Tue 1/25/11
102	HVAC PIPING RI/DUCTWORK INSTALL	20 days	Tue 2/8/11
103	IN-WALL DOMESTIC WATER RI/OH DOMESTIC WATER RI/REC WATER RI	13 days	Tue 2/15/11
104	WALL INSULATION/HANG DRYWALL	11 days	Tue 2/15/11
105	INSTALL FAN COIL UNITS	15 days	Tue 2/15/11
106	DUCT/PIPE INSULATION	10 days	Tue 3/1/11



Project: FULL SCHEDULE
Date: Thu 10/21/10



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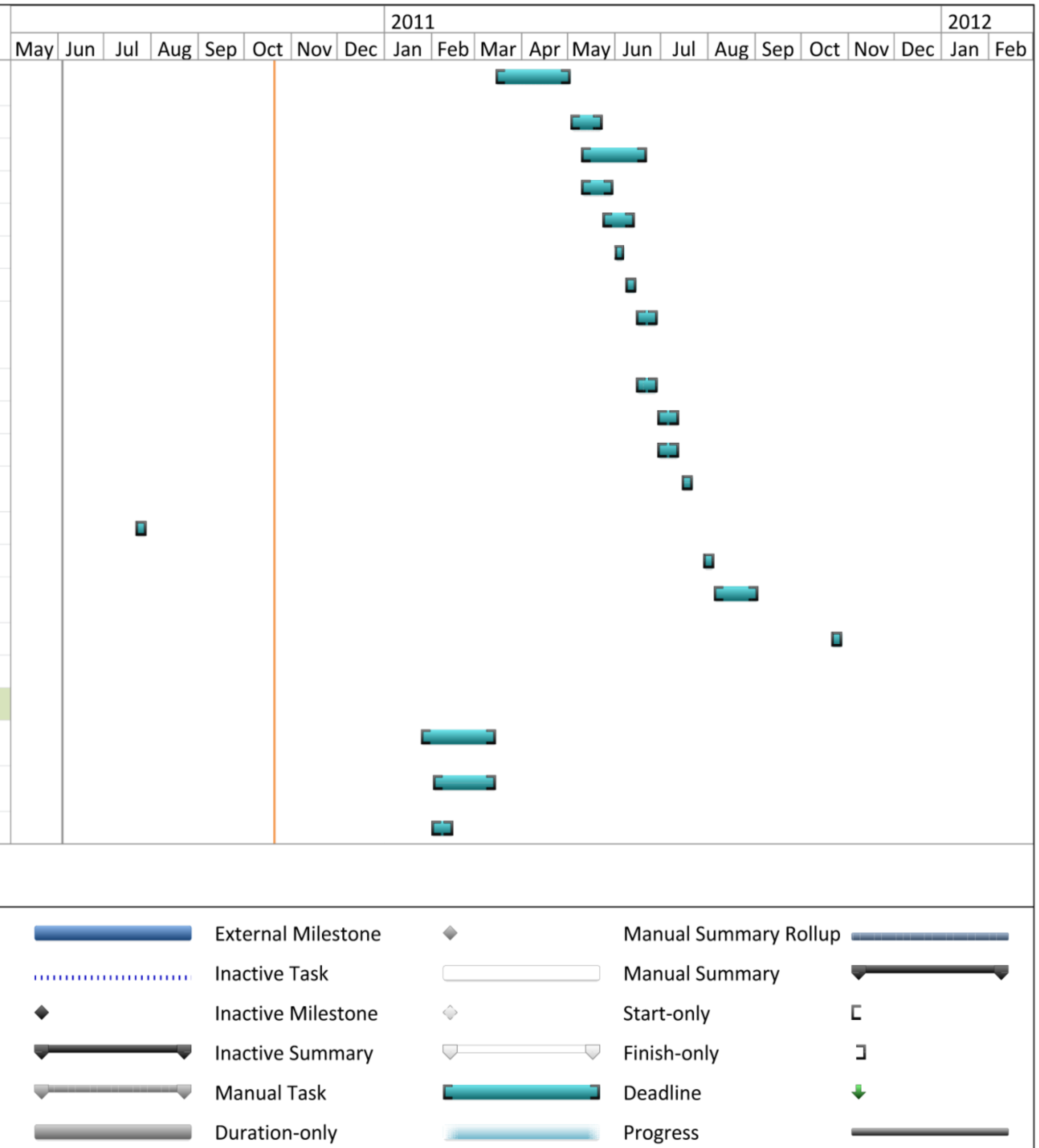
ID	Task Name	Duration	Start
107	FRAME/HANG/TAPE & FINISH DRYWALL	35 days	Tue 3/15/11
108	PRIME/PAINT WALLS & CEILINGS	15 days	Tue 5/3/11
109	INSTALL ACOUSTIC GRID & TILE	31 days	Tue 5/10/11
110	CERAMIC TILE	15 days	Tue 5/10/11
111	LIGHT FIXTURES	15 days	Tue 5/24/11
112	FIRE PROTECTION TRIM	4 days	Wed 6/1/11
113	INSTALL PLUMBING FIXTURES	5 days	Wed 6/8/11
114	INSTALL TOILET PARTITIONS/TOILET & BATH ACCESSORIES	10 days	Wed 6/15/11
115	FINISH PAINT & WALL COVERING	10 days	Wed 6/15/11
116	INSTALL CARPET/BASE	10 days	Wed 6/29/11
117	ELECTRICAL DEVICES & TRIM	10 days	Wed 6/29/11
118	INSTALL WOOD DOORS / HARDWOOD	5 days	Fri 7/15/11
119	PAIN TOUCHUPS	5 days	Thu 7/22/10
120	FINAL CLEANING	5 days	Fri 7/29/11
121	PUNCHLISTS (IN-HOUSE/ARCH/WORKOFF)	21 days	Fri 8/5/11
122	INSTALL FURNITURE	5 days	Fri 10/21/11
123			
124	**2ND FLOOR**		
125	FLOOR LAYOUT/TRACK/STUD FRAMING & INSTALL	35 days	Tue 1/25/11
126	FLOOR STORM PIPING/SANITARY RI/DRAINS	29 days	Wed 2/2/11
127	FIRE PROTECTION RI	10 days	Tue 2/1/11



Project: FULL SCHEDULE
Date: Thu 10/21/10

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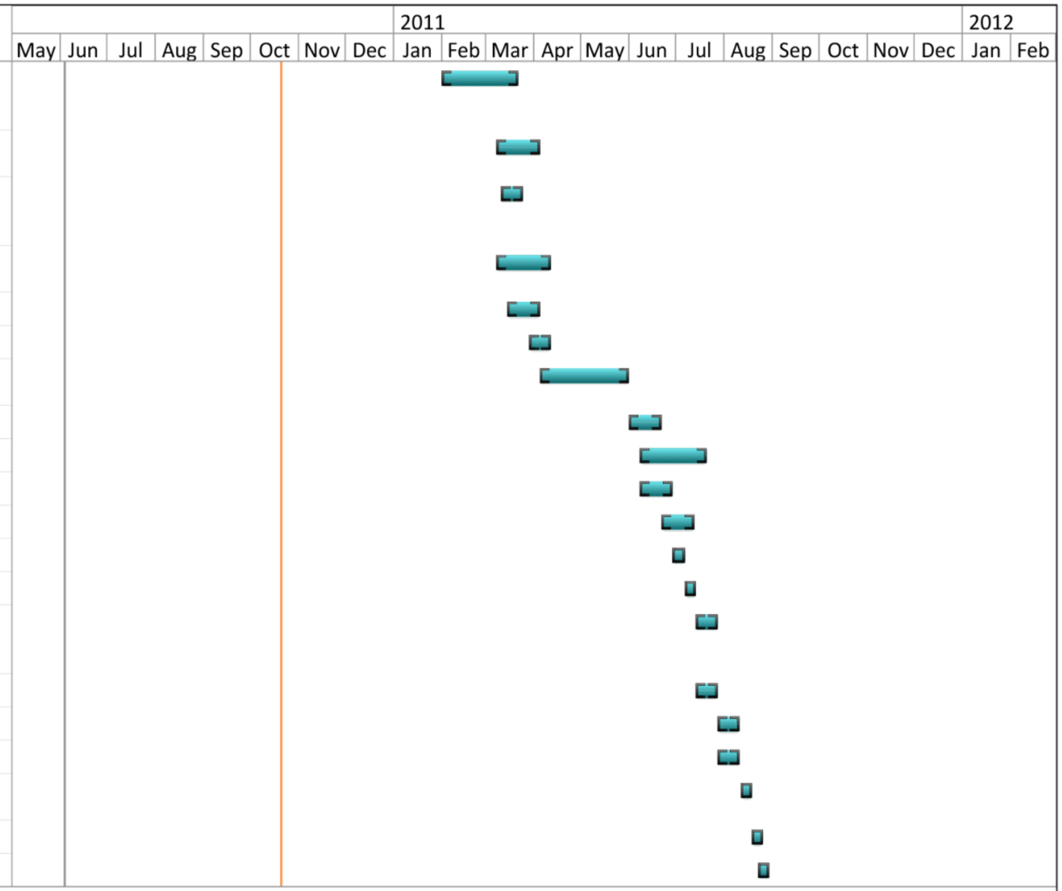
ID	Task Name	Duration	Start
128	O/H ELECTRICAL ROUGH IN & ELECTRICAL IN-WALL STUD ROUGH-IN	35 days	Tue 2/1/11
129	HVAC PIPING RI/DUCTWORK INSTALL	20 days	Tue 3/8/11
130	IN-WALL DOMESTIC WATER RI/OH DOMESTIC WATER RI/REC WATER RI	10 days	Fri 3/11/11
131	WALL INSULATION/HANG DRYWALL	25 days	Tue 3/8/11
132	INSTALL FAN COIL UNITS	15 days	Tue 3/15/11
133	DUCT/PIPE INSULATION	10 days	Tue 3/29/11
134	FRAME/HANG/TAPE & FINISH DRYWALL	41 days	Tue 4/5/11
135	PRIME/PAINT WALLS & CEILINGS	15 days	Wed 6/1/11
136	INSTALL ACOUSTIC GRID & TILE	31 days	Wed 6/8/11
137	CERAMIC TILE	15 days	Wed 6/8/11
138	LIGHT FIXTURES	15 days	Wed 6/22/11
139	FIRE PROTECTION TRIM	6 days	Wed 6/29/11
140	INSTALL PLUMBING FIXTURES	5 days	Thu 7/7/11
141	INSTALL TOILET PARTITIONS/TOILET & BATH ACCESSORIES	10 days	Thu 7/14/11
142	FINISH PAINT & WALL COVERING	10 days	Thu 7/14/11
143	INSTALL CARPET/BASE	10 days	Thu 7/28/11
144	ELECTRICAL DEVICES & TRIM	10 days	Thu 7/28/11
145	INSTALL WOOD DOORS / HARDWOOD	5 days	Fri 8/12/11
146	PAIN TOUCHUPS	5 days	Fri 8/19/11
147	FINAL CLEANING	5 days	Tue 8/23/11



Project: FULL SCHEDULE
Date: Thu 10/21/10

Task	External Milestone	Manual Summary Rollup
Split	Inactive Task	Manual Summary
Milestone	Inactive Milestone	Start-only
Summary	Inactive Summary	Finish-only
Project Summary	Manual Task	Deadline
External Tasks	Duration-only	Progress

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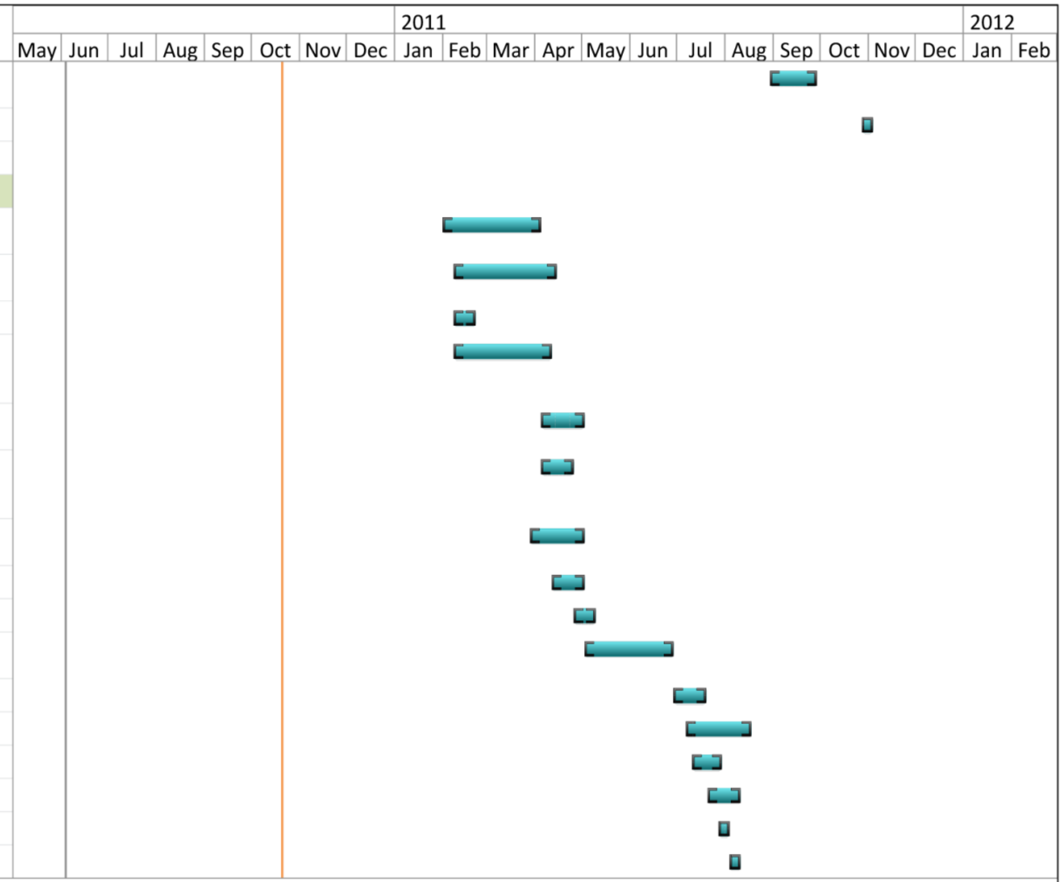
ID	Task Name	Duration	Start
148	PUNCHLISTS (IN-HOUSE/ARCH/WORKOFF)	22 days	Tue 8/30/11
149	INSTALL FURNITURE	5 days	Fri 10/28/11
150			
151	**3RD FLOOR**		
152	FLOOR LAYOUT/TRACK/STUD FRAMING & INSTALL	45 days	Tue 2/1/11
153	FLOOR STORM PIPING/SANITARY RI/DRAINS	48 days	Tue 2/8/11
154	FIRE PROTECTION RI	10 days	Tue 2/8/11
155	O/H ELECTRICAL ROUGH IN & ELECTRICAL IN-WALL STUD ROUGH-IN	45 days	Tue 2/8/11
156	HVAC PIPING RI/DUCTWORK INSTALL	20 days	Tue 4/5/11
157	IN-WALL DOMESTIC WATER RI/OH DOMESTIC WATER RI/REC WATER RI	15 days	Tue 4/5/11
158	WALL INSULATION/HANG DRYWALL	25 days	Tue 3/29/11
159	INSTALL FAN COIL UNITS	15 days	Tue 4/12/11
160	DUCT/PIPE INSULATION	10 days	Tue 4/26/11
161	FRAME/HANG/TAPE & FINISH DRYWALL	41 days	Tue 5/3/11
162	PRIME/PAINT WALLS & CEILINGS	15 days	Wed 6/29/11
163	INSTALL ACOUSTIC GRID & TILE	30 days	Thu 7/7/11
164	CERAMIC TILE	15 days	Mon 7/11/11
165	LIGHT FIXTURES	15 days	Thu 7/21/11
166	FIRE PROTECTION TRIM	5 days	Thu 7/28/11
167	INSTALL PLUMBING FIXTURES	5 days	Thu 8/4/11



Project: FULL SCHEDULE
Date: Thu 10/21/10

Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress

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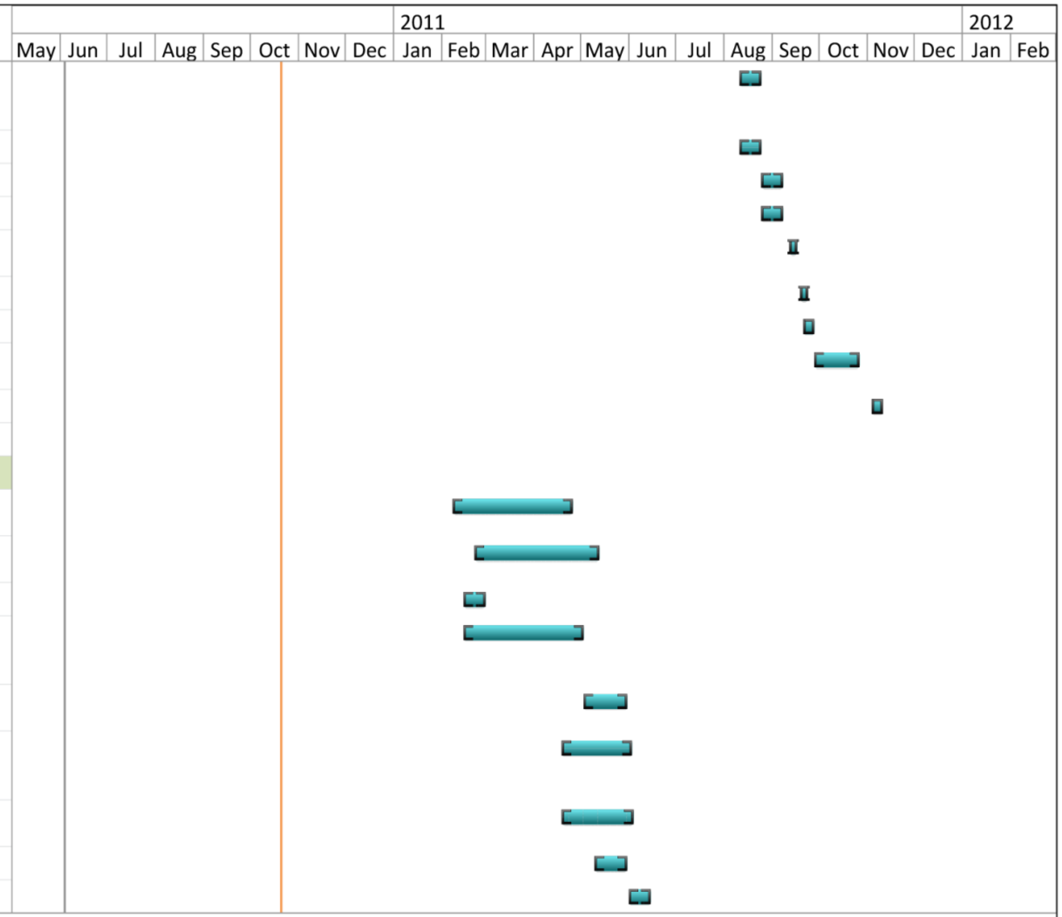
ID	Task Name	Duration	Start
168	INSTALL TOILET PARTITIONS/TOILET & BATH ACCESSORIES	10 days	Thu 8/11/11
169	FINISH PAINT & WALL COVERING	10 days	Thu 8/11/11
170	INSTALL CARPET/BASE	10 days	Thu 8/25/11
171	ELECTRICAL DEVICES & TRIM	10 days	Thu 8/25/11
172	INSTALL WOOD DOORS / HARDWOOD	5 days	Mon 9/12/11
173	PAIN TOUCHUPS	5 days	Mon 9/19/11
174	FINAL CLEANING	5 days	Wed 9/21/11
175	PUNCHLISTS (IN-HOUSE/ARCH/WORKOFF)	21 days	Wed 9/28/11
176	INSTALL FURNITURE	5 days	Fri 11/4/11
177			
178	**4TH FLOOR**		
179	FLOOR LAYOUT/TRACK/STUD FRAMING & INSTALL	55 days	Tue 2/8/11
180	FLOOR STORM PIPING/SANITARY RI/DRAINS	58 days	Tue 2/22/11
181	FIRE PROTECTION RI	10 days	Tue 2/15/11
182	O/H ELECTRICAL ROUGH IN & ELECTRICAL IN-WALL STUD ROUGH-IN	55 days	Tue 2/15/11
183	HVAC PIPING RI/DUCTWORK INSTALL	20 days	Tue 5/3/11
184	IN-WALL DOMESTIC WATER RI/OH DOMESTIC WATER RI/REC WATER RI	33 days	Tue 4/19/11
185	WALL INSULATION/HANG DRYWALL	34 days	Tue 4/19/11
186	INSTALL FAN COIL UNITS	15 days	Tue 5/10/11
187	DUCT/PIPE INSULATION	10 days	Wed 6/1/11



Project: FULL SCHEDULE
Date: Thu 10/21/10

Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress

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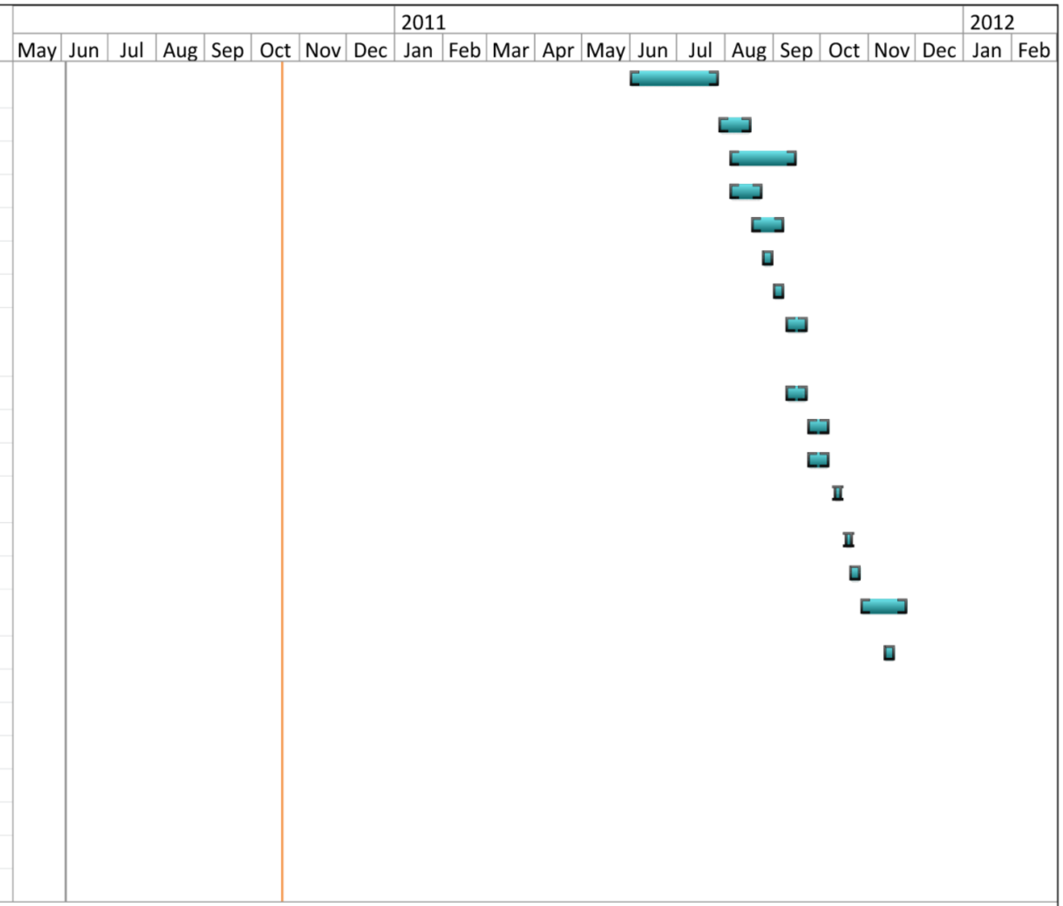
ID	Task Name	Duration	Start
188	FRAME/HANG/TAPE & FINISH DRYWALL	41 days	Wed 6/1/11
189	PRIME/PAINT WALLS & CEILINGS	15 days	Thu 7/28/11
190	INSTALL ACOUSTIC GRID & TILE	31 days	Thu 8/4/11
191	CERAMIC TILE	15 days	Thu 8/4/11
192	LIGHT FIXTURES	15 days	Thu 8/18/11
193	FIRE PROTECTION TRIM	5 days	Thu 8/25/11
194	INSTALL PLUMBING FIXTURES	5 days	Thu 9/1/11
195	INSTALL TOILET PARTITIONS/TOILET & BATH ACCESSORIES	10 days	Fri 9/9/11
196	FINISH PAINT & WALL COVERING	10 days	Fri 9/9/11
197	INSTALL CARPET/BASE	10 days	Fri 9/23/11
198	ELECTRICAL DEVICES & TRIM	10 days	Fri 9/23/11
199	INSTALL WOOD DOORS / HARDWOOD	5 days	Mon 10/10/11
200	PAIN TOUCHUPS	5 days	Mon 10/17/11
201	FINAL CLEANING	5 days	Thu 10/20/11
202	PUNCHLISTS (IN-HOUSE/ARCH/WORKOFF)	22 days	Thu 10/27/11
203	INSTALL FURNITURE	5 days	Fri 11/11/11
204			
205			
206			
207			
208			
209			
210			



Project: FULL SCHEDULE
Date: Thu 10/21/10

Task · Split · Milestone · Summary · Project Summary · External Tasks · External Milestone · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · Deadline · Progress

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Appendix C – Material Take-Offs and Detailed Structural Estimate

Spread Footings									
	Footing Size								Formwork
Mark	Length, L (ft)	Width, W (ft)	Thickness (in)	Bottom Reinforcing Each Way		QTY of Type	Volume ft3	Volume CY	SFCA
F50	5	5	12	7 #4		1	25	0.93	20.00
F70	7	7	24	6 #8		1	98	3.63	56.00
F80	8	8	24	6 #7		3	384.00	14.22	192.00
F90	9	9	24	10 #6		3	486.00	18.00	216.00
F100	10	10	24	9 #7		9	1800.00	66.67	720.00
F110	11	11	26	8 #8		3	786.50	29.13	286.00
F120	12	12	27	10 #8		2	648.00	24.00	216.00
F130	13	13	29	12 #8		7	2858.92	105.89	879.67
F140	14	14	31	11 #9		5	2531.67	93.77	723.33
F150	15	15	33	12 #9		2	1237.50	45.83	330.00
F10080	8	10	24	9 #7		0	0.00	0.00	0.00
F11080	8	11	26	8 #8		3	572.00	21.19	247.00
F13070	7	13	29	12 #8		1	219.92	8.15	96.67
F13090	9	13	29	12 #8		1	282.75	10.47	106.33
F14080	8	14	31	11 #9		2	578.67	21.43	227.33
F120100	10	12	27	10 #8		2	540.00	20.00	198.00
F130100	10	13	29	12 #8		1	314.17	11.64	111.17
F150100	10	15	33	12 #9		1	412.50	15.28	137.50
						Total	13775.58	510.21	4763.00

Strip Footing							Formwork
Mark	Length, L (ft)	Width, W (ft)	Thickness (ft)		Volume ft3	Volume CY	SFCA
2,3,6,4	195.266	2.167	1.000		423.076	15.669	850.485
2 (First Floor)	260.500	2.167	1.000		564.417	20.904	1133.167
5,8	93.083	1.500	1.000		139.625	5.171	282.250
				Total	1127.117	41.745	2265.901

SOG						Formwork
Mark	Area (ft2)	Thickness (ft)	Perimeter	Volume ft3	Volume CY	SFCA
SOG1	5970.491	0.500	288.333	2985.246	110.565	144.167
SOG2 (Strip)	283.877	0.417	276.167	118.282	4.381	115.069
SOG2	5285.972	0.417	459.250	2202.488	81.574	191.354
			Total	5306.016	196.519	450.590

Slab on Deck						Formwork
Mark	Area (ft2)	Thickness (ft)	Perimeter	Volume ft3	Volume CY	SFCA
S1 (first floor)	5970.491	0.375	288.333	2238.934	82.923	108.125
S1 (second floor)	11305.271	0.375	832.333	4239.477	157.018	312.125
S1 (third floor)	11306.271	0.375	832.333	4239.852	157.032	312.125
S1 (fourth floor)	11306.271	0.375	832.333	4239.852	157.032	312.125
S1 (low roof)	2418.979	0.375	341.458	907.117	33.597	128.047
S1 (high roof)	11306.271	0.375	832.333	4239.852	157.032	312.125
			Total	20105.083	744.633	1484.672

Foundation Wall							Formwork
Mark	Length, L (ft)	Width, W (ft)	Thickness (ft)		Volume ft3	Volume CY	SFCA
4,5,6,8 (Basement)	298.083	1.167	5.000		1738.819	64.401	2992.500
2 (First Floor)	260.500	1.167	4.850		1473.996	54.592	2538.167
				Total	3212.815	118.993	5530.667

Piers							Formwork
Mark	Length, L (ft)	Width, W (ft)	Cumul. Depths (ft)		Volume ft3	Volume CY	SFCA
P1	2.000	2.000	69.000		276.000	10.222	552.000
P2	1.167	2.000	14.500		33.833	1.253	91.833
				Total	309.833	11.475	643.833

GRADE BEAMS							Formwork
Mark	Length, L (ft)	Width, W (in)	Depth (in)		Volume ft3	Volume CY	SFCA
GB1	19.280	24.000	36.000		115.677	4.284	127.677
GB2	10.814	24.000	36.000		64.885	2.403	76.885
				Total	180.562	6.687	204.562

TOTAL			
Volume of Concrete		Area of Formwork	Metal Decks
Ft3	CY	SFCA	SF
43836.448	1630.260	15343.225	53613.555

Steel Beams

Beam Type	Total Length (ft)	Weight (PLF)	Total Member Weight (lb)
W16X40	103.333	40	4133.333
W16X36	478.583	36	17229.000
W14X22	165.500	22	3641.000
W14X34	42.000	34	1428.000
W12X14	167.042	14	2338.583
W24X62	19.667	62	1219.333
W24X68	9.833	68	668.667
W14X34	21.083	34	716.833
W14X43	21.333	43	917.333
W16X67	49.667	67	3327.667
W16X26	81.000	26	2106.000
W10X12	21.333	12	256.000
W12X19	24.000	19	456.000
W21X44	0.000	44	0.000
W16X45	0.000	45	0.000
W21X83	0.000	83	0.000
W21X73	0.000	73	0.000
W16X57	0.000	57	0.000
W8X35	0.000	35	0.000
W16X31	0.000	31	0.000
		TOTAL	38437.750

Total

Beam Type	Total Length (ft)	Weight (PLF)	Member Weight (lb)
W21X48	11.083	48	532.000
W10X12	80.083	12	961.000
W12X14	63.000	14	882.000
W8X21	10.667	21	224.000
W21X44	103.500	44	4554.000
W14X22	73.667	22	1620.667
W18X40	40.333	40	1613.333
W16X45	40.333	45	1815.000
W10X26	19.667	26	511.333
		TOTAL	12713.333

Total

Beam Type	Total Length (ft)	Weight (PLF)	Member Weight (lb)
W16X40	251.583	40	10063.333
W16X36	613.500	36	22086.000
W14X22	648.083	22	14257.833
W14X34	0.000	34	0.000
W12X14	105.333	14	1474.667
W24X62	0.000	62	0.000
W24X68	0.000	68	0.000
W14X34	42.000	34	1428.000
W14X43	0.000	43	0.000
W16X67	71.667	67	4801.667
W16X26	262.083	26	6814.167
W10X12	46.500	12	558.000
W12X19	0.000	19	0.000
W21X44	465.417	44	20478.333
W16X45	21.083	45	948.750
W21X83	21.000	83	1743.000
W21X73	56.167	73	4100.167
W16X57	223.250	57	12725.250
W8X35	161.792	35	5662.708
W16X31	17.333	31	537.333
		TOTAL	107679.208

TOTAL BEAM WEIGHT	
lb	Tons
158830.292	79.415

Steel Columns			
Total			
Beam Type	Total Length (ft)	Weight (PLF)	Total Member Weight (lb)
W10X33	652.125	33	21520.125
W12X65	224.000	65	14560.000
W12X72	132.708	72	9555.000
W10X45	211.500	45	9517.500
W10X39	169.917	39	6626.750
W12X58	157.500	58	9135.000
W10X77	41.500	77	3195.500
W10X68	116.000	68	7888.000
W10X54	74.500	54	4023.000
W10X49	365.000	49	17885.000
W12X40	250.625	40	10025.000
W12X53	58.000	53	3074.000
W10X60	29.000	60	1740.000
		TOTAL (lbs)	**118744.875**
		TOTAL (tons)	**59.372**

Steel Bracing			
Total			
Beam Type	Total Length (ft)	Weight (PLF)	Total Member Weight (lb)
HSS7X7X1/4	374.9963	22.4200	8407.4175
HSS8X8X1/4	289.9619	25.8200	7486.8157
HSS8X8X5/16	149.3689	31.8400	4755.9042
HSS6X6X1/4	66.6155	19.0200	1267.0260
		TOTAL (lbs)	**21917.163**
		TOTAL (tons)	**10.959**

Cost Estimate Report CostWorks RSMeans

Unit Detail Report

State College,
PA, 16802
Year 2010 Quarter 3

Date: 15-Oct-10

Moore Building Addition Concrete

Prepared By:
Mohammad alhussaini
PSU

LineNumber			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 03 Concrete							
031113000000			Structural Cast-In-Place Concrete Forming	0.00			$0.00
031113050010			FORMS, BUY OR RENT	0.00			$0.00
031113050100			C.I.P. concrete forms, aluminum, smooth face, buy, 6" x 8', includes material only	15,343.23	SFCA	$30.31	$465,053.15
032200000000			Welded Wire Fabric Reinforcing	0.00			$0.00
032205000000			Uncoated Welded Wire Fabric	0.00			$0.00
032205500010			WELDED WIRE FABRIC	0.00			$0.00
032205500030			Welded wire fabric, from recycled materials	0.00			$0.00
032205500050			Welded wire fabric, sheets	0.00			$0.00
032205500300			Welded wire fabric, sheets, 6 x 6 - W2.9 x W2.9 (6 x 6) 42 lb. per C.S.F., A185	570.00	C.S.F.	$65.15	$37,135.50
033105000000			Normal Weight Structural Concrete	0.00		$0.00	$0.00
033105300010			CONCRETE, FIELD MIX	0.00			$0.00
033105350300			Structural concrete, ready mix, normal weight, 4000 PSI, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments	1,630.26	C.Y.	$94.81	$154,564.95
033105701400			Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes strike off & consolidation, excludes material	744.63	C.Y.	$24.72	$18,407.33
033105701450			Structural concrete, placing, elevated slab, with crane and bucket, less than 6" thick, includes strike off & consolidation, excludes material	744.63	C.Y.	$46.47	$34,603.10
033105701950			Structural concrete, placing, continuous footing, shallow, pumped, includes strike off & consolidation, excludes material	41.75	C.Y.	$23.14	$965.98
033105702650			Structural concrete, placing, spread footing, pumped, over 5 C.Y., includes strike off & consolidation, excludes material	510.21	C.Y.	$23.14	$11,806.26
033105703250			Structural concrete, placing, grade beam, pumped, includes strike off & consolidation, excludes material	6.69	C.Y.	$19.32	$129.19
033105704350			Structural concrete, placing, slab on grade, pumped, up to 6" thick, includes strike off & consolidation, excludes material	196.52	C.Y.	$26.67	$5,241.16
033105705300			Structural concrete, placing, walls, direct chute, 15" thick, includes strike off & consolidation, excludes material	118.99	C.Y.	$17.83	$2,121.65

PSU

University Park,
PA, 16802
Year 2010 Quarter 3

Date: 14-Oct-10

Unit Detail Report

Cost Estimate Report CostWorks RSMeans

Moore Building Addition Steel

Prepared By:
Mohammad alhussaini
PSU

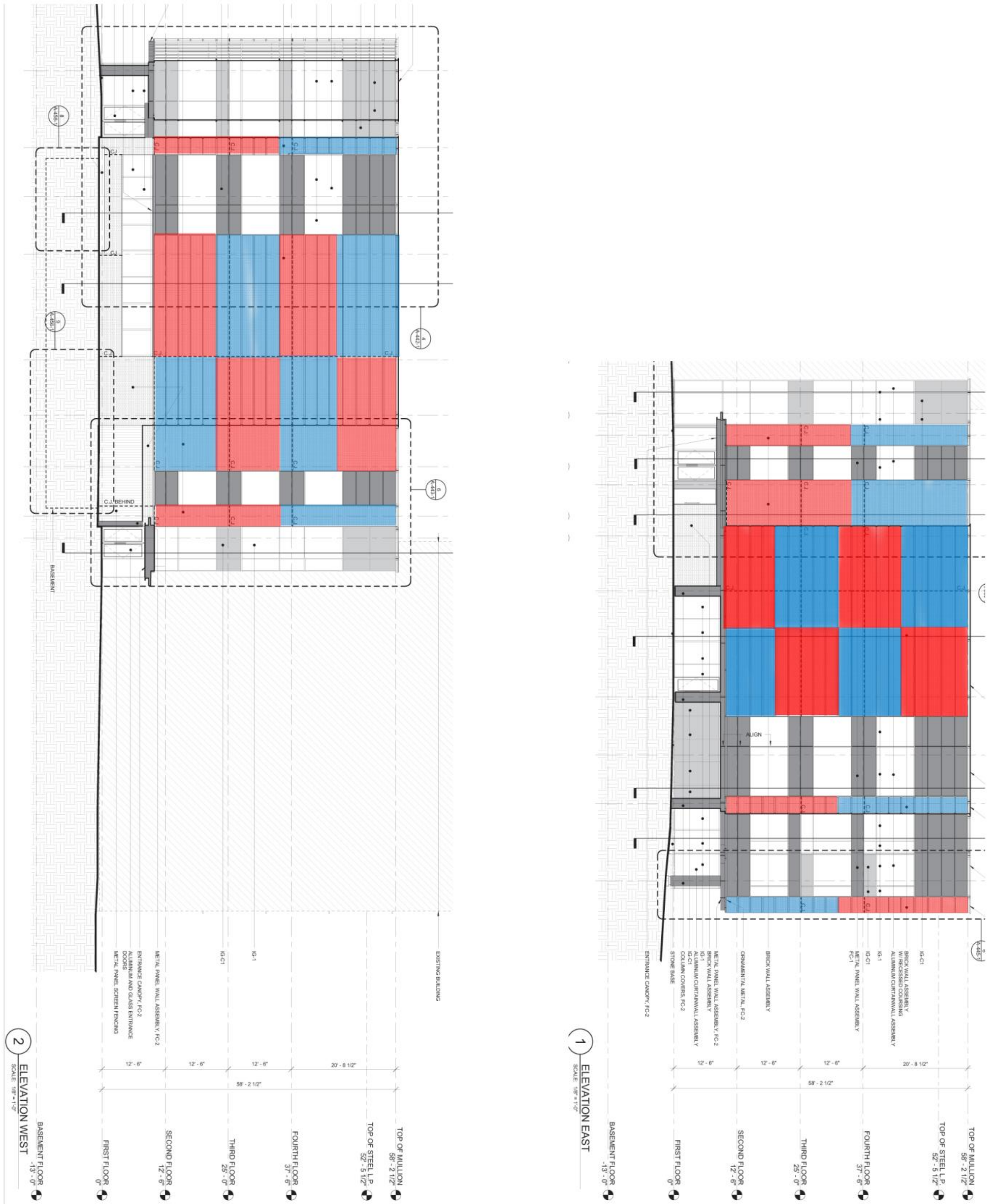
LineNumber			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 05 Metals							
050513506000			Paints and protective coatings, galvanizing structural steel in shop, over 20 tons, hot dip	150.00	Ton	$427.17	$64,075.50
051223170010			COLUMNS, STRUCTURAL	0.00			$0.00
051223170015			Columns, structural steel, made from recycled materials	0.00			$0.00
051223174600			Column, structural tubing, 8" x 8" x 3/8" x 14'-0", incl shop primer, cap & base plate, bolts	63.00	Ea.	$750.47	$47,279.61
051223176850			Column, structural, 2-tier, W8x31, A992 steel, incl shop primer, splice plates, bolts	652.13	L.F.	$42.15	$27,487.07
051223176900			Column, structural, 2-tier, W8x48, A992 steel, incl shop primer, splice plates, bolts	615.63	L.F.	$61.73	$38,002.53
051223176950			Column, structural, 2-tier, W8x67, A992 steel, incl shop primer, splice plates, bolts	543.00	L.F.	$83.53	$45,356.79
051223177000			Column, structural, 2-tier, W10x45, A992 steel, incl shop primer, splice plates, bolts	381.42	L.F.	$58.30	$22,236.61
051223177050			Column, structural, 2-tier, W10x68, A992 steel, incl shop primer, splice plates, bolts	116.00	L.F.	$84.82	$9,839.12
051223177200			Column, structural, 2-tier, W12x87, A992 steel, incl shop primer, splice plates, bolts	41.50	L.F.	$106.70	$4,428.05
051223177350			Column, structural, 2-tier, W14x74, A992 steel, incl shop primer, splice plates, bolts	132.71	L.F.	$91.68	$12,166.67
051223750010			STRUCTURAL STEEL MEMBERS	0.00			$0.00
051223750015			Structural steel members, made from recycled materials	0.00			$0.00
051223750120			Structural steel member, 100-ton project, 1 to 2 story building, W6x15, A992 steel, shop fabricated, incl shop primer, bolted connections	336.00	L.F.	$28.87	$9,700.32
051223750140			Structural steel member, 100-ton project, 1 to 2 story building, W6x20, A992 steel, shop fabricated, incl shop primer, bolted connections	0.00	L.F.	$34.49	$0.00
051223750350			Structural steel member, 100-ton project, 1 to 2 story building, W8x21, A992 steel, shop fabricated, incl shop primer, bolted connections	11.00	L.F.	$35.77	$393.47
051223750500			Structural steel member, 100-ton project, 1 to 2 story building, W8x31, A992 steel, shop fabricated, incl shop primer, bolted connections	18.00	L.F.	$48.42	$871.56
053113500015			Metal floor decking, steel, made from recycled materials	0.00			$0.00

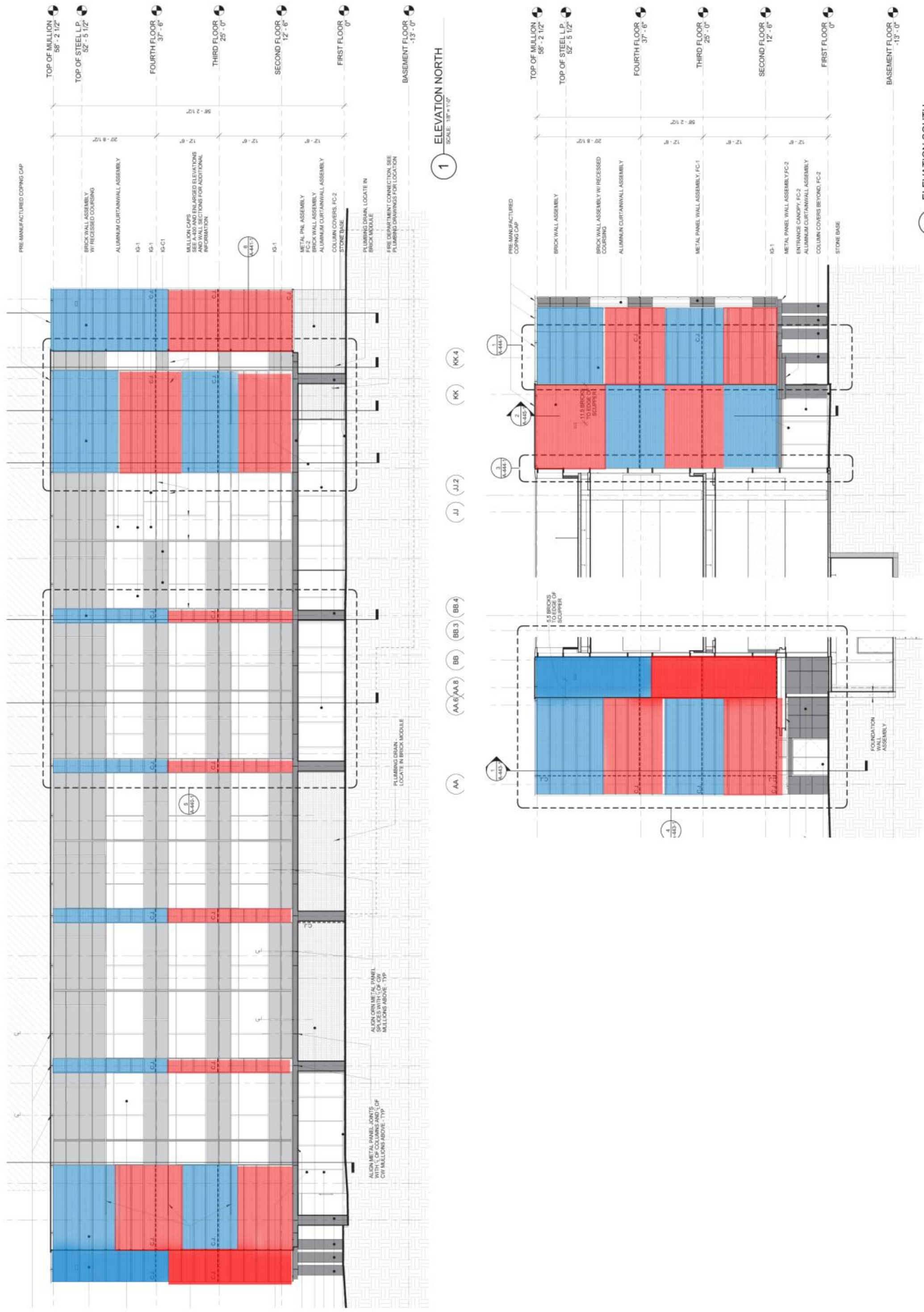
LineNumber			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
053113505400			Metal floor decking, steel, non-cellular, composite, galvanized, 2" D, 18 gauge	53,613.56	S.F.	$2.99	$160,304.53
Division 05 Subtotal							**$661,384.49**

Appendix D – General Conditions Estimate

General Conditions Estimate							
Activity	Quantity	Units	Unit Labor	Total Labor	Unit Material Cost	Total Material Cost	Total Cost
PRIMARY PERSONNEL							
Project Executive	610.00	MHR	140.00	85,400.00			$85,400.00
Project Manager	3,800.00	MHR	90.00	342,000.00			$342,000.00
Project Superintendent	3,800.00	MHR	90.00	342,000.00			$342,000.00
Project Engineer	3,800.00	MHR	50.00	190,000.00			$190,000.00
						TOTAL	**$959,400.00**
SUPPORT STAFF							
Secretary	3,800.00	MHR	35.00	133,000.00			$133,000.00
Scheduling Manager	500.00	MHR	90.00	45,000.00			$45,000.00
Safety Engineer	500.00	MHR	50.00	25,000.00			$25,000.00
MEP Support	350.00	MHR	90.00	31,500.00			$31,500.00
						TOTAL	**$234,500.00**
OFFICE EXPENSES/OH & Temporary Utilities							
Living Expenses	10.00	MONTHLY			3,000.00	30,000.00	$30,000.00
Moving Expenses	1.00	LS			15,000.00	15,000.00	$15,000.00
Travel/Parking (STAFF)	1.00	LS			0.00	0.00	$0.00
Office Set-Up	1.00	LS	1,500.00	1,500.00	250.00	250.00	$1,750.00
Contractors Office	10.00	MONTHLY			1,600.00	16,000.00	$16,000.00
Contractors Office Furnishings	1.00	LS			3,000.00	3,000.00	$3,000.00
Clean Office	10.00	MONTHLY			255.00	2,550.00	$2,550.00
Telephone Set-Up	1.00	LS			310.00	310.00	$310.00
Telephone Service	15.00	MONTHLY			285.00	4,275.00	$4,275.00
Cell Phones	15.00	MONTHLY			270.00	4,050.00	$4,050.00
Computers & Supplies	2.00	EA			1,750.00	3,500.00	$3,500.00
Copy Machine	1.00	EA			6,000.00	6,000.00	$6,000.00
Copy Machine Maintenance	12.50	MONTHLY			300.00	3,750.00	$3,750.00
Potable Water	5.00	MONTHLY			200.00	1,000.00	$1,000.00
Safety Equipment	1.00	LS			2,000.00	2,000.00	$2,000.00
Mail and Postage	15.00	MONTHLY			350.00	5,250.00	$5,250.00
Constructware Usage FEES	12.50	MONTHLY			850.00	10,625.00	$10,625.00
First Aid	25.00	MONTHLY			150.00	3,750.00	$3,750.00
Office Supplies	20.00	MONTHLY			300.00	6,000.00	$6,000.00
Photographs	22.50	MONTHLY			100.00	2,250.00	$2,250.00
Plans & Specs	1.00	LS			25,000.00	25,000.00	$25,000.00
BIM Services	1.00	ALLOW	40,000.00	40,000.00	0.00	0.00	$40,000.00
Internet Set-Up	1.00	LS			1,000.00	1,000.00	$1,000.00
Internet Service	7.50	MONTHLY			250.00	1,875.00	$1,875.00
General Clean-Up	1.00	ALLOW	25,000.00	25,000.00	0.00	0.00	$25,000.00
Printers	1.00	EA			750.00	750.00	$750.00
Temporary Power Set-Up	1.00	LS			12,500.00	12,500.00	$12,500.00
Temporary Power Service	22.50	MONTHLY			2,000.00	45,000.00	$45,000.00
Temporary Sanitation Set-Up	1.00	LS			3,000.00	3,000.00	$3,000.00
Temporary Sanitation Service	1.00	MONTHLY			50.00	50.00	$50.00
						TOTAL	**$214,685.00**
						CUM. TOTAL	**$1,408,585.00**

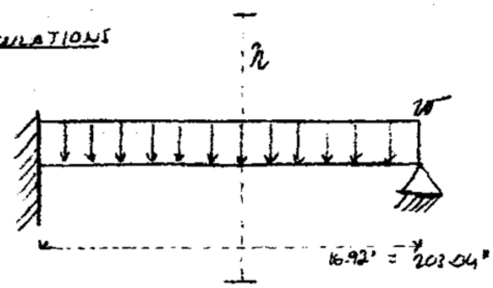
Appendix E – Visual Representation of Façade Panels


ELEVATION WEST
ELEVATION EAST
BASEMENT FLOOR -13' - 0"
FIRST FLOOR 0"
SECOND FLOOR 12' - 6"
THIRD FLOOR 25' - 0"
FOURTH FLOOR 37' - 6"
TOP OF STEEL LP 52' - 5 1/2"
TOP OF MULLION 58' - 2 1/2"
58' - 2 1/2"


ELEVATION NORTH
ELEVATION SOUTH

Appendix F – Structural Calculations and Details

UNIFORM LOAD CALCULATIONS



BRICK FACADE (8")
6" · 40 PSF
4" · 6 PSF INSULATION

PRECAST FACADE (8")
6" · 43 PSF
2" · 1.5 psf INSULATION

2nd & 3rd FLOORS:

BRICK FACADE: $w = (12.5')(40\,psf + 6\,psf) = 575\,plf$

$575\,plf \left(\frac{1\,kip}{1000\,lbs}\right)\left(\frac{1\,ft}{12\,in}\right) = \underline{0.04792\ kip/in}$

PRECAST FACADE: $w = (12.5')(43\,psf + 1.5\,psf) = 556.25\,plf$

$= \underline{0.04635\ kip/in}$

4th FLOOR:

BRICK FACADE: $w = (16.605')(46\,psf) = 763.83\,plf$

$= \underline{0.06365\ kip/in}$

PRECAST FACADE: $w = (16.605')(44.5\,psf) = 738.9225\,plf$

$= \underline{0.06158\ kip/in}$

HIGH ROOF

BRICK FACADE: $w = (10.355')(46\,psf) = 476.33\,plf$

$= \underline{0.03969\ kip/in}$

PRECAST FACADE: $w = (10.355')(44.5\,psf) = 460.7975\,plf$

$= \underline{0.03839\ kip/in}$

Beam Combined Axial and Bending Stresses Summary

Beam	L/C	Length (ft)	Max Comp Stress (psi)	Max Comp d (ft)	Max Comp Corner	Max Tens Stress (psi)	Max Tens d (ft)	Max Tens Corner
2	1:2ND & 3RD F	16.920	7.92E+3	8.460	1	-7.95E+3	8.460	3
	2:4TH FLOOR	16.920	646.790	16.920	1	-601.377	16.920	3
	3:ROOF FACA	16.920	51.224	16.920	1	-52.601	16.920	3
3	1:2ND & 3RD F	16.920	7.6E+3	8.460	1	-7.56E+3	8.460	3
	2:4TH FLOOR	16.920	1.24E+3	16.920	1	-1.34E+3	16.920	3
	3:ROOF FACA	16.920	166.272	16.920	1	-150.340	16.920	3
4	1:2ND & 3RD F	16.920	1.43E+3	16.920	1	-1.43E+3	16.920	3
	2:4TH FLOOR	16.920	9.43E+3	8.460	1	-9.37E+3	8.460	3
	3:ROOF FACA	16.920	453.460	16.920	1	-478.020	16.920	3
5	1:2ND & 3RD F	16.920	355.252	16.920	1	-374.294	16.920	3
	2:4TH FLOOR	16.920	1.1E+3	16.920	1	-1.11E+3	16.920	3
	3:ROOF FACA	16.920	6.53E+3	8.460	1	-6.52E+3	8.460	3
9	1:2ND & 3RD F	12.500	2.19E+3	12.500	3	-2.32E+3	12.500	1
	2:4TH FLOOR	12.500	4.78E+3	12.500	1	-1.64E+3	12.500	3
	3:ROOF FACA	12.500	1.27E+3	0.000	1			
12	1:2ND & 3RD F	12.500	1.96E+3	12.500	3			
	2:4TH FLOOR	12.500	2.57E+3	12.500	1			
	3:ROOF FACA	12.500	848.975	0.000	1			
13	1:2ND & 3RD F	12.500	1.34E+3	0.000	1			
	2:4TH FLOOR	12.500	1.73E+3	0.000	1			
	3:ROOF FACA	12.500	703.801	12.500	1			
14	1:2ND & 3RD F	12.500	1.39E+3	0.000	3	-1.24E+3	0.000	1
	2:4TH FLOOR	12.500	3.51E+3	0.000	1	-19.557	0.000	3
	3:ROOF FACA	12.500	1.74E+3	12.500	1			
16	1:2ND & 3RD F	20.710	895.385	0.000	3	-865.187	0.000	1
	2:4TH FLOOR	20.710	306.331	0.000	3	-214.973	0.000	1
	3:ROOF FACA	20.710	1.72E+3	0.000	1			
17	1:2ND & 3RD F	20.710	560.849	20.710	3	-585.699	20.710	1
	2:4TH FLOOR	20.710	1.7E+3	20.710	3	-1.77E+3	20.710	1
	3:ROOF FACA	20.710	2.03E+3	20.710	1	-114.582	20.710	3
18	1:2ND & 3RD F	12.500	2.02E+3	0.000	1			
	2:4TH FLOOR	12.500	1.35E+3	0.000	1			
	3:ROOF FACA	12.500	850.559	0.000	1			
19	1:2ND & 3RD F	12.500	1.58E+3	0.000	1			
	2:4TH FLOOR	12.500	1.05E+3	0.000	1			
	3:ROOF FACA	12.500	662.265	0.000	1			

Beam Maximum Axial Forces

Distances to maxima are given from beam end A.

Beam	Node A	Length (ft)	L/C		d (ft)	Max Fx (kip)
2	1	16.920	1:2ND & 3RD F	Max -ve		
				Max +ve	0.000	-0.297
			2:4TH FLOOR	Max -ve	0.000	0.425
				Max +ve		
			3:ROOF FACA	Max -ve		
				Max +ve	0.000	-0.013
3	5	16.920	1:2ND & 3RD F	Max -ve	0.000	0.403
				Max +ve		
			2:4TH FLOOR	Max -ve		
				Max +ve	0.000	-0.889
			3:ROOF FACA	Max -ve	0.000	0.149
				Max +ve		
4	7	16.920	1:2ND & 3RD F	Max -ve	0.000	0.022
				Max +ve		
			2:4TH FLOOR	Max -ve	0.000	0.508
				Max +ve		
			3:ROOF FACA	Max -ve		
				Max +ve	0.000	-0.230
5	9	16.920	1:2ND & 3RD F	Max -ve		
				Max +ve	0.000	-0.124
			2:4TH FLOOR	Max -ve		
				Max +ve	0.000	-0.037
			3:ROOF FACA	Max -ve	0.000	0.087
				Max +ve		
9	6	12.500	1:2ND & 3RD F	Max -ve		
				Max +ve	0.000	-0.728
			2:4TH FLOOR	Max -ve	0.000	18.481
				Max +ve		
			3:ROOF FACA	Max -ve	0.000	11.121
				Max +ve		
12	1	12.500	1:2ND & 3RD F	Max -ve	0.000	13.545
				Max +ve		
			2:4TH FLOOR	Max -ve	0.000	17.452
				Max +ve		
			3:ROOF FACA	Max -ve	0.000	11.014
				Max +ve		
13	2	12.500	1:2ND & 3RD F	Max -ve	0.000	13.104
				Max +ve		
			2:4TH FLOOR	Max -ve	0.000	17.958
				Max +ve		
			3:ROOF FACA	Max -ve	0.000	11.056
				Max +ve		
14	5	12.500	1:2ND & 3RD F	Max -ve	0.000	0.728
				Max +ve		

Beam Maximum Axial Forces Cont...

Beam	Node A	Length (ft)	L/C		d (ft)	Max Fx (kip)
			2:4TH FLOOR	Max -ve	0.000	16.929
				Max +ve		
			3:ROOF FACA	Max -ve	0.000	10.950
				Max +ve		
16	7	20.710	1:2ND & 3RD F	Max -ve	0.000	0.147
				Max +ve		
			2:4TH FLOOR	Max -ve	0.000	0.444
				Max +ve		
			3:ROOF FACA	Max -ve	0.000	10.761
				Max +ve		
17	8	20.710	1:2ND & 3RD F	Max -ve		
				Max +ve	0.000	-0.147
			2:4TH FLOOR	Max -ve		
				Max +ve	0.000	-0.444
			3:ROOF FACA	Max -ve	0.000	11.310
				Max +ve		
18	1	12.500	1:2ND & 3RD F	Max -ve	0.000	26.649
				Max +ve		
			2:4TH FLOOR	Max -ve	0.000	17.705
				Max +ve		
			3:ROOF FACA	Max -ve	0.000	11.035
				Max +ve		
19	2	12.500	1:2ND & 3RD F	Max -ve	0.000	26.649
				Max +ve		
			2:4TH FLOOR	Max -ve	0.000	17.705
				Max +ve		
			3:ROOF FACA	Max -ve	0.000	11.035
				Max +ve		

Beam Maximum Moments

Distances to maxima are given from beam end A.

Beam	Node A	Length (ft)	L/C		d (ft)	Max My (kip`in)	d (ft)	Max Mz (kip`in)
2	1	16.920	1:2ND & 3RD F	Max -ve	0.000	0.000	16.920	44.747
				Max +ve	0.000	0.000	8.460	-653.978
			2:4TH FLOOR	Max -ve	0.000	0.000	0.000	0.000
				Max +ve	0.000	0.000	16.920	-51.442
			3:ROOF FACA	Max -ve	0.000	0.000	0.000	0.000
				Max +ve	0.000	0.000	16.920	-4.279
3	5	16.920	1:2ND & 3RD F	Max -ve	0.000	0.000	16.920	103.149
				Max +ve	0.000	0.000	8.460	-624.777
			2:4TH FLOOR	Max -ve	0.000	0.000	0.000	0.000
				Max +ve	0.000	0.000	16.920	-106.191
			3:ROOF FACA	Max -ve	0.000	0.000	0.000	0.000
				Max +ve	0.000	0.000	16.920	-13.049
4	7	16.920	1:2ND & 3RD F	Max -ve	0.000	0.000	0.000	0.000
				Max +ve	0.000	0.000	16.920	-118.128
			2:4TH FLOOR	Max -ve	0.000	0.000	16.920	247.691
				Max +ve	0.000	0.000	8.460	-774.865
			3:ROOF FACA	Max -ve	0.000	0.000	0.000	0.000
				Max +ve	0.000	0.000	16.920	-38.390
5	9	16.920	1:2ND & 3RD F	Max -ve	0.000	0.000	0.000	0.000
				Max +ve	0.000	0.000	16.920	-29.768
			2:4TH FLOOR	Max -ve	0.000	0.000	0.000	0.000
				Max +ve	0.000	0.000	16.920	-90.057
			3:ROOF FACA	Max -ve	0.000	0.000	16.920	55.718
				Max +ve	0.000	0.000	8.460	-532.289
9	6	12.500	1:2ND & 3RD F	Max -ve	0.000	0.000	12.500	117.136
				Max +ve	0.000	0.000		
			2:4TH FLOOR	Max -ve	0.000	0.000		
				Max +ve	0.000	0.000	12.500	-166.742
			3:ROOF FACA	Max -ve	0.000	0.000	12.500	4.224
				Max +ve	0.000	0.000	0.000	-17.213
12	1	12.500	1:2ND & 3RD F	Max -ve	0.000	0.000	12.500	46.016
				Max +ve	0.000	0.000		
			2:4TH FLOOR	Max -ve	0.000	0.000	0.000	1.043
				Max +ve	0.000	0.000	12.500	-61.605
			3:ROOF FACA	Max -ve	0.000	0.000		
				Max +ve	0.000	0.000	0.000	-1.024
13	2	12.500	1:2ND & 3RD F	Max -ve	0.000	0.000	0.000	43.980
				Max +ve	0.000	0.000	12.500	-1.269
			2:4TH FLOOR	Max -ve	0.000	0.000	12.500	10.163
				Max +ve	0.000	0.000	0.000	-52.486
			3:ROOF FACA	Max -ve	0.000	0.000		
				Max +ve	0.000	0.000	12.500	-4.164
14	5	12.500	1:2ND & 3RD F	Max -ve	0.000	0.000	0.000	46.016
				Max +ve	0.000	0.000		

Beam Maximum Moments Cont...

Beam	Node A	Length (ft)	L/C		d (ft)	Max My (kip¯in)	d (ft)	Max Mz (kip¯in)
			2:4TH FLOOR	Max -ve	0.000	0.000	12.500	9.108
				Max +ve	0.000	0.000	0.000	-61.605
			3:ROOF FACA	Max -ve	0.000	0.000		
				Max +ve	0.000	0.000	12.500	-21.552
16	7	20.710	1:2ND & 3RD F	Max -ve	0.000	0.000	0.000	30.760
				Max +ve	0.000	0.000		
			2:4TH FLOOR	Max -ve	0.000	0.000	0.000	9.108
				Max +ve	0.000	0.000	20.710	-0.000
			3:ROOF FACA	Max -ve	0.000	0.000		
				Max +ve	0.000	0.000	0.000	-21.552
17	8	20.710	1:2ND & 3RD F	Max -ve	0.000	0.000	20.710	29.768
				Max +ve	0.000	0.000	0.000	-0.992
			2:4TH FLOOR	Max -ve	0.000	0.000	20.710	90.057
				Max +ve	0.000	0.000		
			3:ROOF FACA	Max -ve	0.000	0.000		
				Max +ve	0.000	0.000	20.710	-55.718
18	1	12.500	1:2ND & 3RD F	Max -ve	0.000	0.000	12.500	0.000
				Max +ve	0.000	0.000	0.000	-0.767
			2:4TH FLOOR	Max -ve	0.000	0.000	12.500	0.000
				Max +ve	0.000	0.000	0.000	-1.043
			3:ROOF FACA	Max -ve	0.000	0.000	0.000	1.024
				Max +ve	0.000	0.000	12.500	0.000
19	2	12.500	1:2ND & 3RD F	Max -ve	0.000	0.000	0.000	0.767
				Max +ve	0.000	0.000	12.500	0.000
			2:4TH FLOOR	Max -ve	0.000	0.000	0.000	1.043
				Max +ve	0.000	0.000		
			3:ROOF FACA	Max -ve	0.000	0.000	12.500	0.000
				Max +ve	0.000	0.000	0.000	-1.024

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