PENNSTATE

Architectural Engineering

Senior Thesis - Final Report

by

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Construction Management Option

on

Taylor Hall – George Mason University

Advisor: Dr. Ed Gannon Date: April 9, 2014

Balfour Beatty Construction

GEORGE MASON UNIVERSITY

Gensler

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Executive Summary

This document serves as a proposal of the research work that is to be completed during the Spring 2014 semester and serves as a contract with the Architectural Engineering faculty of Pennsylvania State University. Four construction related analyses will be conducted on Taylor Hall, a 70,000 SF dormitory housing 295 freshmen students at George Mason University in Fairfax, VA. In addition to the depth analyses, two non-construction related breadth analyses will investigate further issues with a related depth.

The largest analysis pertains to the addition of a green roof above a multi-purpose room on the first floor of the dorm. Since GMU is making a large stride towards sustainability and educating its students in such practices, the green roof was an important feature of the building to the owner. Because of budget restraints, the green roof was the first item to be removed from the building. Research will be done to see how expensive a green roof addition would be and how the installation of the system would affect the critical path of construction. A structural breadth would be done to investigate if the current structural system would allow such an installation and what would be needed for added reinforcement if it doesn't.

The current structural system in place uses prefabricated load bearing cold-formed stud walls and is said to be a quicker alternative compared to a concrete structural system. Since this system is typically intended for larger buildings and has been causing issues with permit approval, the novel idea of stick-built framing will be analyzed for application as Taylor Hall's structural system. This will involve schedule and cost analysis in a comparison of the systems.

Considering job-site and student safety, an idea will be specifically applied to Taylor Hall through the implementation of a façade re-design. This re-design will raise sill heights to reduce the appropriate

OSHA recommended fall safety height and analyze the cost implications of this application. In addition, a specific job-site tour itinerary and recommendation plan will be developed to assist in maintaining student safety throughout the construction process.

As the critical industry issue analysis, "Prevention through Design" will be researched and investigated for application to Taylor Hall. This is especially important due to its practicality it this particular application and the fact that students are accessing the job site weekly for tours. In addition to the research done on fall prevention through design, an architectural breadth will be completed to analyze the Mechanical access points throughout Taylor Hall for safe height access and security measures to insure safety from student tamper.

To finalize the report is a short conclusion outlining the work that will be completed in the next semester. Attached is a schedule of when each analysis will be completed along with an assigned grading weight based on the complexity of each topic.

Ultimately, each topic works towards achieving the goals of the owner and will create ideas that may be used on future campus projects and dormitories. Those goals being:

- Increase the awareness for sustainable design and ideas
- Reduce the cost of construction while maintain quality
- Investigate new ways to increase job-site safety
- Reduce the risk of injury for construction workers, future students, and maintenance personnel

Technical Analyses

Green Roof Addition

Taylor Hall, being a green building and an educational opportunity to teach freshman about sustainability, was originally intended to include a green roof above a first floor multi-purpose room. It is important to the owner that George Mason University strives towards a green future with its buildings, but after the building was set to be over budget, it was the first item to be eliminated.

Green roofs provide several benefits to the building, including water run-off elimination, reduction of glare into the above rooms, and insulation properties for the space below it. For this building in particular, the green roof provides a learning opportunity for the students who reside inside it. After learning from the design-builder that it was removed from the original design, it provided an opportunity to investigate how adding the green roof would affect the bottom line of the project.

The addition of the green roof over the multi-purpose room would be analyzed for cost and schedule implications by completing a detailed estimate and schedule of installation. Information would be pulled from literature sources as well as interviews with Balfour Beatty Construction team members who have experience with green roof installation.

In addition to the aforementioned analyses, a breadth topic analysis will investigate the current structural components supporting the roof to see if it can adequately support a green roof system without further reinforcement. This will be discussed further in the Appendix.

Expected outcomes from this analysis are that the green roof can be completed without affecting the critical path of Taylor Hall and will create the educational and sustainable environment desired by the owner. This will, however, come with a price which may or may not be offset pending the results of the technical analysis topic.

Stick-Built Framing vs. Infinity Structural System

One of the original value engineering ideas implemented on the project was the replacement of the concrete structural system with an Infinity Structural System. The Infinity Structural System is comprised of load bearing, cold formed metal stud walls that are prefabricated off site and installed at a relatively quick rate. These walls support a special metal deck that has more surface area for load bearing and a standard concrete slab to top off each elevation.

Through an interview with specialty sub-contractor, Miller & Long, the Infinity Structural System can be set in place at a rate nearly three times faster than a concrete structural system. A secondary interview with a Balfour Beatty Construction superintendant conversely stated that it actually causes more problems than it solves and that it takes roughly the same time as a concrete system.

The owner is partial to the Infinity Structural System due to its recent application and success on another campus project nearing completion, but given the scale of application, it may not have been the best choice for Taylor Hall. Furthermore, because of its complex design, the system is causing critical delays as permit approvals are log jamming further construction.

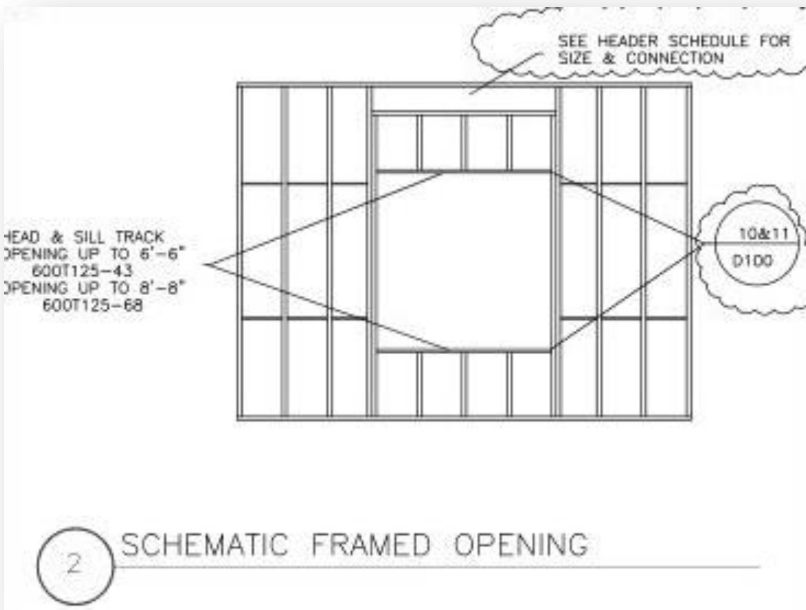
A popular topic in the DC metropolitan area, and another value engineering proposal for Taylor Hall, included the use of a prefabricated wood framing structural system, commonly referred to as "stick-built" construction. This system is primarily used for residential applications and buildings not exceeding 5 stories in height, nominating Taylor Hall as a perfect use of this system.

Since the system is prefabricated similarly to the Infinity Structural System, but does not included concrete pours on decks, the schedule reduction characteristics of stick-built construction will be analyzed. Secondly, the cost of the stick-built system will be compared to the current system. These will be done by completing a cost estimate of system replacement and gathering scheduling data via interviews from specialty sub-contractors currently using stick-built construction methods. A cost and schedule comparison will be presented to conclude the analysis.

Based on research already completed, the benefits of the stick-built structural system are predicted to outweigh the benefits of the Infinity Structural System, especially when considering its application. These benefits will be primarily in schedule reduction rather than cost since it is still prefabricated.

Façade Re-design for Prevention through Design Application

Since Taylor Hall is a project at a public university that is consistently in the news, it is critical to maintain the highest standards of safety in any campus event. The risk of a serious injury or death from a fall on a job site is one of the top four accidents to occur yearly according to OSHA. That being said, it is vital to minimize the risk of falling at all costs



Above: A potential schematic of the Infinity Structural System's exterior wall.

Because Taylor Hall uses the Infinity Structural System, it is plausible to propose that raising the sill height to the OSHA regulated height for fall safety would assist in reducing the risk of falling on a job site. This will, however, surely come with a cost. The cost of raising the sill height for all elevated openings of Taylor Hall will be analyzed and the details behind fall safety's importance to George Mason University will be detailed.

Furthermore, an investigation into student interaction with the job site will be completed. This will specifically be done by reviewing the current tour itinerary and providing a detailed list of suggestions on how to implement a safer student interaction, especially in regards to the risk of falling.

Prevention through Design (Critical Industry Research)

After the attendance of the PACE Roundtable break-out session in early November, titled Prevention through Design, it was decided that it was particularly necessary for Taylor Hall to incorporate this emerging industry topic. Prevention through design, or PTD, is safety conscience design incorporated into the project to protect workers during the construction phase, the inhabitants of the building, and the facility maintenance personnel who will need to access controls of the building.

From the roundtable discussion, the main problem preventing this topic from being included in every project's contract is as follows: Prevention through design is not commonly incorporated into many projects primarily due to the insufficiency in knowledge of safety related issues from a design professional's prospective and the lack of involvement of construction team and facility managers in the design phase of a project.

Taylor Hall is a perfect application of PTD for several reasons. Since Taylor Hall utilizes a Design-Build delivery system and GMU has a department of facility maintenance in place already, the design of the building can be altered to suit their needs for safety. Secondly, it is particularly of importance for George Mason University to have a safe job site due to weekly tours given to students and knowing that the dorm will house freshman students, who may not be in the most responsible age group when it comes to concern for safety.

The goal of incorporating PTD in Taylor Hall is to create a safer environment for construction workers, future students, and maintenance personnel. This will be done by researching common application ideas and their general effectiveness in preventing injury.

With this research topic comes the addition of an architectural breadth to see how the new safety features will affect the appearance of the building. This is detailed further in the Appendix.

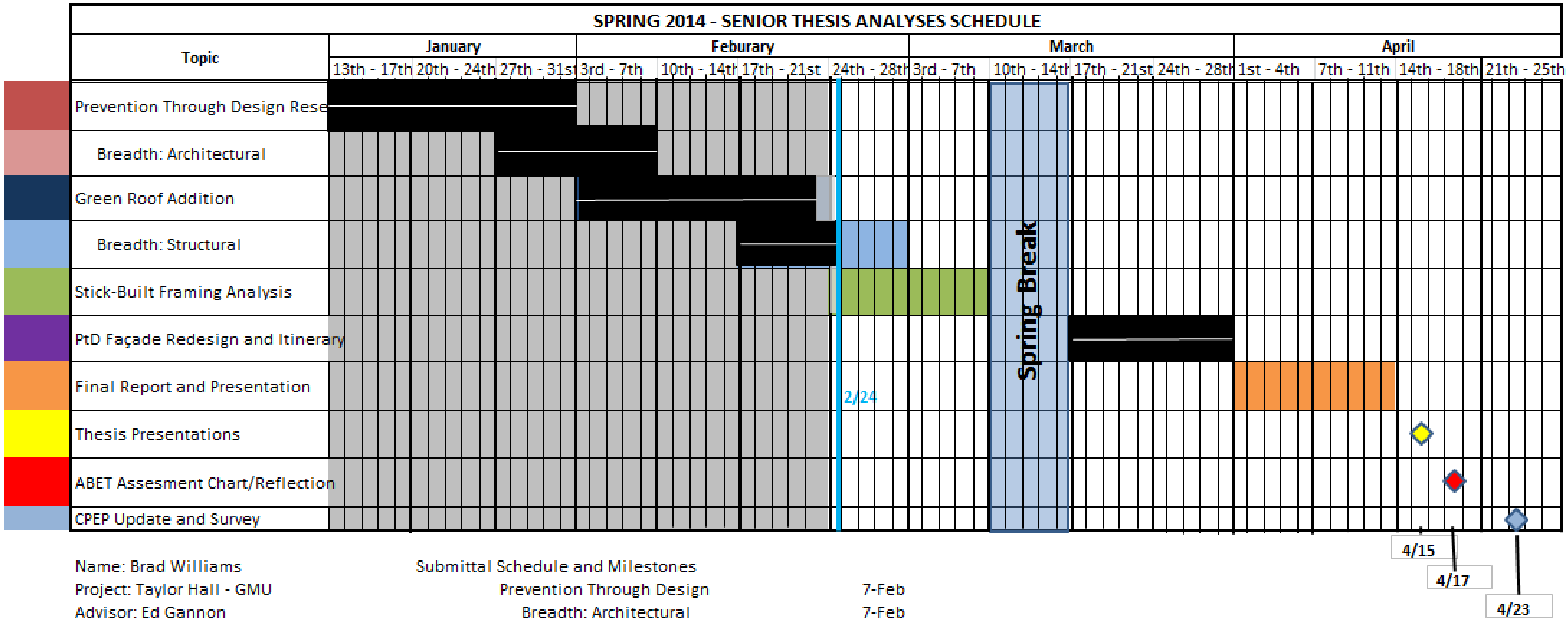
Conclusion

Through the four analyses mentioned in this paper, it is believed that George Mason University will have better building in place through value-added decisions, safer construction practices and design, and more constructible options for installation of critical path items. This will help ensure the owner's continued investment of interest in hiring Balfour Beatty Construction as a Design-Builder of construction manager for their projects on campus.

The above analyses and later mentioned breadth analyses will be accomplished over the course of the Spring 2014 semester and weighted based on the complexity of research and time involved in completion of each. Below is an outline and schedule of when the analyses will be completed and how they are to be weighted.

Overview of Grading Weights

Analysis (*Including Breadth*)	**Percentage of grade**	**Start Date**	**Completion Date**
Green Roof Addition *Structural Breadth*	25%	2-3-2014	2-19-2014
Stick-Built Framing Comparison	25%	2-24-2014	3-7-2014
Façade Re-design for Prevention through Design Application	15%	3-18-2014	3-29-2014
Prevention through Design *Architectural Breadth*	35%	1-13-2014	1-31-2014



Name: Brad Williams
Project: Taylor Hall - GMU
Advisor: Ed Gannon
Option: Construction
Date: 2/24

Submittal Schedule and Milestones

Prevention Through Design	7-Feb
Breadth: Architectural	7-Feb
Green Roof Addition	21-Feb
Breadth: Structural	28-Feb
Stick-Built Framing Analysis	7-Mar
PtD Façade Redesign and Itinerary	28-Mar
Final Report and Presentation	11-Apr
Thesis Presentations	16-Apr
ABET Assesment Chart/Reflection	25-Apr
CPEP Update and Survey	25-Apr

Breadth Topics

Structural: Multi-purpose Room Structural Analysis for Green Roof Application

Within the depth analysis looking into the addition of a green roof, a breadth topic will analyze the structural integrity of the roof below it. This will specifically show whether the current structural system of the roof of the first floor multi-purpose room (K-series Joists) is capable of supporting the future addition of a green roof without further reinforcement. An investigation to metal decking, beam sizing and footing sizing will also be conducted as necessary. Existing structural members, including columns and footings, will be resized if they are deemed inadequate for the new load. If further structural reinforcement is required, the spacing of the joists, columns, and footings will be altered. If changes are to be made based on my investigation, a cost analysis of structural system upgrades will be calculated so that the desired green roof can be applied.

This analysis will be done by accessing notes from AE 404, CE 397 and by performing a simple structural analysis of the system in place with the new dead loads of the vegetation. Using beam tables K-Series Joists and RS Means, new reinforcement can be sized and priced to meet the necessary load requirements. Concluding the investigation, a report of any structural changes will be presented along with any associated cost changes.

Architectural: Investigation of Mechanical equipment access for the incorporation of Prevention through Design

In order to decrease the risk of falls for workers and future maintenance staff, the mechanical equipment access points throughout the building and mechanical room will be analyzed. Considering factors such as access height, the use of a ladder in a high traffic area, and ease of access in general, high risk locations will be investigated and new solutions for relocation will be proposed. To be considered for relocation, access points must be greater than 8 feet above the finished floor level since anything greater will require a ladder. Access points in the entrance and common areas will also be considered due to their proximity to high volumes of moving students. Having easily accessible maintenance locations for mechanical equipment will greatly relieve pressure on George Mason University staff and further influence Prevention through Design. The findings of this investigation, along with any mechanical access modifications (marked on drawings), will be presented in a report.

Interview Questions Draft for Prevention through Design:

Balfour Beatty Construction – Assistant Project Manager

(1) Q: What current fall risks do you see with the design of Taylor Hall?

(2) Q: What fall protection methods are being applied to the façade of Taylor Hall during construction?

(3) Q: How many students are accessing the site during a given week?

(4) Q: How many construction workers access a standard dorm room during the course of a week?

(5) Q: What path do you typically take students into the building when giving tours?

(6) Q: How close do students typically get to a wall surface or ledge during the tours? OR Rate students fall exposure on a scale of 1 to 10 during a typical tour.

Depth and Breadth Analyses

Analysis 1: Prevention through Design: The Pinnacle of Construction Safety

Within today's construction industry, rules are set in place with the construction worker's safety placed above all. Organizations such as OSHA (Occupational Safety and Health Administration) have laid down standards to protect the workforce in nearly every aspect of the jobsite. Yet even with all these regulations in place, the construction industry accounts for more work related accidents than any other occupation at 19.6% of all work related deaths in 2012. (United States Department of Labor)

Not only are those deaths a devastating burden for families to live with, but work related deaths account for nearly $128 billion to $155 billion in indirect costs annually (Schulte). Particularly within the construction industry, these work related accidents go far beyond fiscal loss and can often lead to low worker moral, mental illnesses, insurance hikes, and litigation.

With each injury and/or death in the workplace, new ideas emerge to curb the elements causing the most risk. Research organizations such as the National Institute for Occupational Safety and Health (NIOSH) and the Center for Disease Control and Prevention (CDC) have pinpointed in recent studies that an abundant 37% of these work related injuries are directly caused by poor design (Heidel). Upon discovering this, the idea of Prevention through Design (PtD) was conceived.

According to the National Institute for Occupational Safety and Health, Prevention through Design is defined as the following.

> *The practice of anticipating and "designing out" potential occupational safety and health hazards and risks associated with new processes, structures, equipment, or tools, and organizing work, such that it takes into consideration the construction, maintenance, decommissioning, and disposal/recycling of waste material, and recognizing the business and social benefits of doing so.*

The idea of Prevention through Design can be easily applied to the construction industry in a theoretical sense due to the product that is being produced. Safety must be taken into consideration during the process of construction, for future maintenance by the owner's personnel, and for any future occupants of the building. Even at the end of a building's life, safety must be considered in how it is to be deconstructed and disposed of, especially if they contain hazardous materials such as asbestos. With statistics clearly showing that injury risk is by far associated with design and that the construction industry has the highest risk of all work related industry, incorporating it into the construction process makes the most sense for this novel idea.

What do the Industry Leaders think?

After attending the 22nd Annual Partnership for Achieving Construction Excellence (PACE) Roundtable held at Penn State University, several ideas and issues were brought into the discussion. The breakout session, facilitated by Architectural Engineering professor Robert Leicht, helped bring up a debate about the key concerns of industry leading professionals about the topic. Expanding on several of the issues brought up, there is room for analysis.

Firstly, it was brought to the conference's attention that the design community is not particularly, or lacking knowledge of, construction related risks associated with common design principles applied to buildings. Although designers are not solely responsible for what occurs on a job site, the design or layout may inhibit construction safety personnel from creating an injury conscious environment. One example of would be the obstruction or inability to safely direct an egress route in the case of a building fire. For this to be avoided, it was suggested that construction managers be incorporated into the building process early in the design phase. Having a facility manager of the building be present would even further optimize this process. Knowing that this is not always possible, especially if an owner has already fast tracked a design, further examples were needed.

The topic of sliding Prevention through Design into the contract was suggested so that, even during the design phase, architects and designers would be held liable for evaluating their designs for potential risks. It was mentioned that architects are already liable for safety after occupancy, but such contractual language injections would require early collaboration and engage them in construction safety conversations.

With internal investigations as mentioned above, there would also need to be an independent third party review of the design. Currently, the UK has a design safety review board system that requires reviews and approval of each design and alteration. This idea would regulate the process throughout the design's life from early reviews to final walkthroughs. Because of this, it was noticed that European design firms have hired safety review specialists to assist in the design process. It was widely agreed upon that Prevention through Design would not be accepted into the industry until some sort of regulatory process, similar to what has worked in the UK, is applied within the United States.

One option that was personally intriguing was the integration of a third party review committee similar to that of LEED (Leadership in Energy and Environmental Design). This would essentially be a scorecard-like system that incorporates common injury prone design flaws within categories concerning all parties involved. (Ex: Owners, occupants, maintenance, and construction workers.) The owner would have a goal of achieving different levels of safety within the building and would be rewarded in ways including, but not limited to, tax breaks and insurance cuts. With incentive on the table, Prevention through Design will be eased into the industry until it becomes such standard practice that it isn't even a question when the design is being initiated.

Application to Taylor Hall, George Mason University

The idea of Prevention through Design is of particular interest to major universities because of several reasons. First of all, PtD is an “everyone wins” application when it comes to safety. Reducing risk of injury wherever possible is fiscally beneficial to all parties involved because of insurance cost reductions. (Risley)

Secondly, the public image of a company is greatly improved by incorporating PtD. Particularly of importance on a university scale, where everything that happens is under a media microscope; this can greatly reduce the risk of putting the public image in jeopardy. If for some reason a fatality were to occur on a campus, the owner and the contractor would most likely have a marred image for quite some time and would lose business.

For the Taylor Hall project at George Mason University, it is not only important to create a safe environment to incoming freshmen students, but also for the current students that access the site for tours on a daily basis. After talking with our Contractor Safety Coordinator, John Risley, from Penn State University, I discovered that PtD not only creates a safer environment for the students, but it makes their lives more convenient. John mentioned that with common PtD practices, essential equipment can be accessed much quicker and more safely than before, resulting in quicker response times to student problems.

With Taylor Hall being a Design-Build project, it provides a perfect opportunity to incorporate Prevention through Design into the earliest design considerations of the project. Having a safety conscience owner with a safety conscience design-builder should result in an optimized process for construction safety. Over the next few sections, several ideas for PtD integration will be briefly discussed and reviewed for constructability.

Popular Ideas

The first idea for PtD integration increases safety on the job site and cuts the schedule and increases quality simultaneously. Taylor Hall uses a prefabricated and panelized structural system known as an *Infinity Structural System*. Prefabrication allows for wall partitions to be constructed off site in a dry, indoor environment. This means that it is not only constructed at a much more reasonable height, without the risk of falling, but it reduces the risk of mistakes that commonly occur when workers are under a tight schedule in the field. By reducing the amount of time that workers are building up in the air, the overall risk of falling is also reduced.

Once a floor is completed and poured, it is required that cables or temporary barrios be placed between 39”- 45” above the floor level. That cable must be able to withstand 200 lbs of horizontal force to ensure that nothing breach its fall stopping ability. Even once exterior wall partitions are set in place, these fall safety measurements must still be set in place, causing hours of preparatory work. Often times, this secondary fall safety measure is done by adding a temporary 2x4 at the required height above the typical sill height.

With the second idea, the time and material required to revisit each exterior wall panel would be eliminated. It would even remain safer for the future inhabitants who may find themselves’ opening the windows often. This is simply accomplished by raising the sill height of the original façade design to 39” above the finished floor. Depending on the height and number of windows in a given building, this would not only significantly reduce the fall risk, but safe time and material.

The third general idea is also related to fall statistics, which will be examined further on. After several interviews, it has been widely mentioned that the roof is the greatest risk of falling from a building. This is due to many factors, some of which being its height above ground, a lack of a significant parapet, having a pitch, and lacking in tie-off locations. Since this is such a risk prone area of the building, the safest way to reduce the risk of falling would be to have a flat roof with a 39" parapet and plenty of tie-off points for window cleaning etc. Taylor Hall, however, must abide by several BCOM architectural and appearance standards and has a standard shingled and pitched roof. The easiest way to minimize risk in this situation would be to design in strategic tie-off locations to allow for safe window cleaning while not affecting the aesthetic features of the building. Taylor Hall already has an exceptionally safe mechanical penthouse which allows for a closed in access point not requiring common roof access.

Lastly, an idea frequented by industry professionals is to the benefit of the owner and future maintenance personnel. By lowering mechanical access points, or making them easier to access in general, the fall risk is decreased. Facility managers and maintenance often require ladders to reach key mechanical controls. Furthermore, access to such controls must be done late at night when an area will not be congested by students. By relocating the height of mechanical equipment access and making conscience decisions about potential foot traffic, risk of falling can be reduced. Although the risk may seem miniscule, safety must never be overlooked. This idea will be investigated further in a breadth.

Analysis 2: Façade Re-design and Implementation of Prevention through Design

When looking at the greatest risk reduction potential for the construction process and future building inhabitants, the window sill height addition is, by far, the most practical. By simply restructuring the façade appearance by raising the sill height and placing them as early as possible, construction workers will be significantly safer when installing MEP rough-in within the interior.

According to OSHA, the most significant of the "fatal four" causes of work-related deaths was falling, a whopping 36%. (United States Department of Labor) By eliminating this risk, 278 more lives would have been saved in 2012 alone. This risk is most prevalent within the construction site because of the exposure to wide-open elevated surfaces, but it extends beyond the buildings construction. With Taylor Hall's residents being freshmen, with new freedoms and fewer boundaries, it is important to consider their safety, even when windows are set in place. By raising the sill height, the ability for a student to fall out the window or even sit on the sill, is significantly reduced.

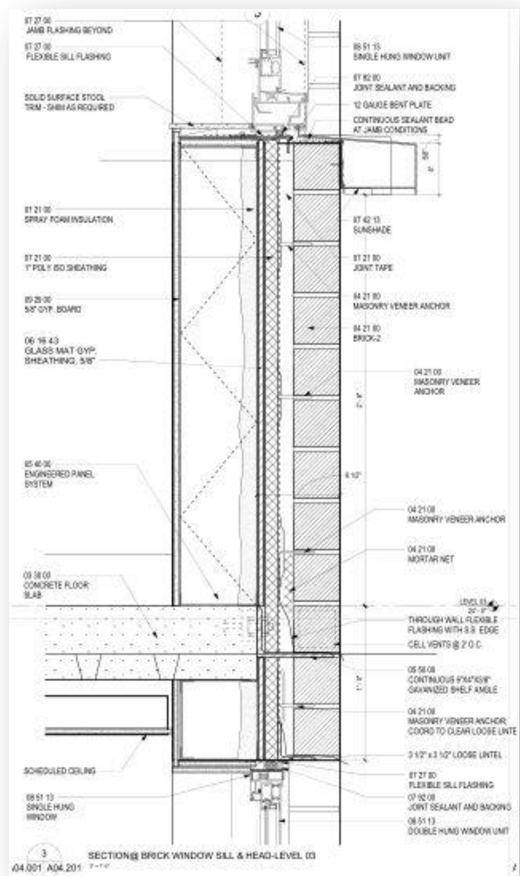


Figure 2: Typical unit window sill assembly

To accomplish this, the design of the prefabricated façade panels for each dorm unit would require a sill height lift. Since the panels are to be manufactured off site and delivered as a whole, they could be set in-place immediately and effectively eliminate the need for long-term fall protection cables to be set in place. Secondly, the size of the window would have to be shortened to accommodate the change. The current sill height (before finishes) is 36 ⅝" and the required height is a minimum of 39” according to OSHA.

Because of the size change, the cold form steel would need to be extended the menial 2 ⅜.” The connection between the brick and the window would not be affected because of the “sun shade” that is applied at sill height (This can be seen in the detail above). Cost of finishing material would not significantly change, however, the window dimensions would be changed from 5’ 10 ½” x 4’ 0” to 5’ 8 ⅛” x 4’ 0.”

To accomplish this change of the design, it would be most simple to layer two additional lengths of 4” metal stud at the window sill. Based on each opening being 5’, the below table accounts for each unit opening and stairwells. Pricing was found to be $100.92 per 10’ section and labor costs are assumed to not change. Total building cost change would be $17,156.40 or 0.107%.

Cost Change by Raising Sill Height by 3”

Floor	Number of 5’ Openings	Total Distance of 4” metal stud	Cost
1	32	320 LF	$3,229.44
2	46	460 LF	$4,642.32
3	46	460 LF	$4,642.32
4	46	460 LF	$4,642.32
		TOTAL COST	**$17,156.40**

With the most substantial cost implication being the above mentioned window size reduction, it would be safe to conclude that the cost of implementing this Prevention through Design would be an incredibly inexpensive way to reduce the risk of falling on the job site. In fact, this would be a value added initiative because of the work hours saved from installing control cables at correct height, visibility, and tension required by OSHA (permitting that the panel installation sequence allows this).

To extend its fall protection benefits beyond the construction workers, the sill height addition will also be of value to the students who are regularly visiting the job site. Although, I was not able to obtain specific tour itineraries or hard data on the number of students who access different areas of the building, I can offer a short list of suggestions on how to best mitigate job site risk during said tours. This is seen below.

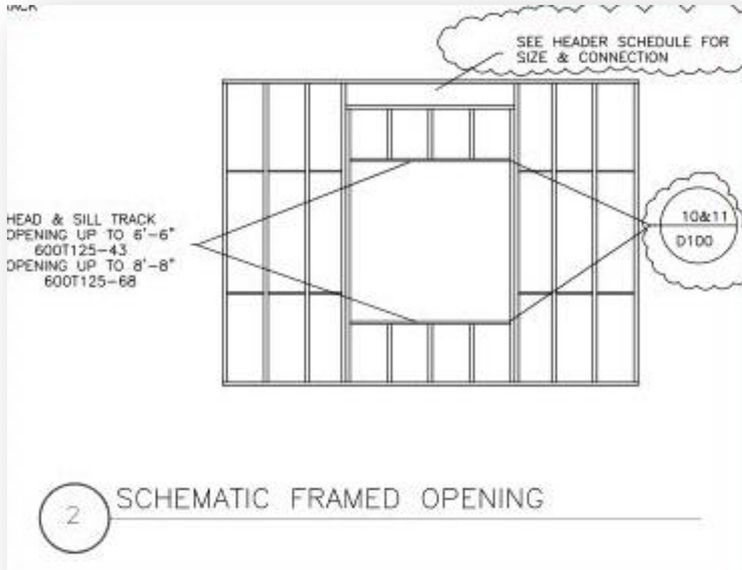


Figure3: A potential schematic of the Infinity Structural System's exterior wall.

Suggestions for job site tour risk reduction:

- Keep tour sizes under 5 people. In larger groups, it is easier to lose track of student's attention and there is a larger risk of tripping and congestion in small areas.

- Require that students wear all PPE that would regularly be required on a job site. This includes a hard hat, safety glasses, highly visible vests, steel toed boots, and gloves (if required)

- Ask that students do not use their cell phones. Use of cell phones during a tour leads to distraction from speaker and from the surrounding environment, resulting in a higher risk of tripping or head hitting.

- Direct the tour in areas where work is either completed or construction is not heavily occurring. This will reduce risk of falling objects, obstructed pathways, or congested work environments.

- Only use metal stairways that have been poured or have wooden inlays. This helps to greatly reduce trip hazards.

- When showing students the study lounge areas and common rooms on the upper floors (have curtain walls), stay at least 10 feet from the ledge. This will ensure that the fall protection methods in place will not be tested if a student were to be bumped.

- Do not take students on any floors that do not have the raised sill height façade partitions in place yet. By avoiding areas that are not yet prepared for construction safety, you are significantly reducing risk.

Each of the above ideas are based on personal experience with job site student tours as well as an interview with Penn State University – Office of Physical Plant's Contractor Safety Coordinator, Jonathan Risley. From the interview (attached in the appendix), It was mentioned that applying tour suggestions is on a project by project basis. For example, projects that will be highly visited and toured by students and athletes should have appropriate PPE on site for tours, but less popular projects may require less PPE simply because of the expense of purchasing extra. To compensate for not requiring some forms of PPE (such as steel toe shoes or gloves), tours can take place during off hours (past 4pm) and/or by requiring something that identifies them as a non-construction worker so that those who are performing work are extra conscious about their safety. By applying each of these ideas to the typical tour, the students will be able to experience the job site atmosphere in an educational and safe manner.

In conclusion, the raising of the sill height, combined with the implementation of the suggested safety requirements, would significantly reduce the risk of falling on a job site. The roughly $17,000 cost of this change is menial compared to the cost of losing one's life, the cost of insurance premium hikes, the cost of an EMR loss, and potential litigation. Furthermore, the intangible cost of reputation damage could potentially amount to a future loss of business. Considering this, the small addition can be viewed as a sort of insurance to assure the liveliness and good health of the workers, the university, and the construction firm.

Architectural Breadth: Investigation of Mechanical Access Points

Since the construction personnel and students are accounted for in the above mentioned PtD ideas, it would only be appropriate to also incorporate safety conscious design for facility maintenance staff. This is to be done by incorporating the mechanical access point height analysis.

For this investigation, each mechanical access point will be located and assessed for how safe it is. The criteria to what is "not safe" will be assumed to be anything over 8' (requiring a ladder) and anything in a high traffic area (common room, lobby, or multipurpose room). This will lead to a concise list of problematic areas for fall risk in the future and short list of recommendations on how to mitigate those risks.

Since falling is the number one cause of work related deaths, it is important to reduce that risk at all costs. At the PACE conference held in November, several facility managers mentioned the importance to incorporate fall safe designs with the owners and maintenance workers in mind. Upholding those interests of the owners, the use of a ladder to access mechanical equipment should be minimized where possible.

Based on an interview with Penn State University's Contractor Safety Coordinator, the most common access points are needed at large mechanical equipment rooms. Most valves and essential equipment, particularly in university buildings, are in locked or restricted areas to evade wandering students who may put themselves in danger. In older buildings, it was common to have a mechanical access point via a permanent ladder (sometimes 10' of higher off the ground[4]). But to completely avoid the risk of students using these ladders or mechanical maintenance falling, it is best to access them via a stairway.

Knowing this, the mechanical equipment rooms will be investigated for how easily they can be reached by trained professionals and if a ladder is needed. Secondly, the common Fan Coil Units located in each dorm will be analyzed for ease of access since the filters are to be replaced annually. Finally, the mechanical pent house will be analyzed for ease of access and ability to conduct maintenance without a ladder.

Mechanical Room

Beginning with the first floor mechanical room's accessibility from an architectural standpoint, it appears the room is properly protected from wandering students. As seen in the plan below, the mechanical room is only accessible via a maintenance corridor that is locked to students. The room also opens to the outside for purposes of equipment replacement in the future, meaning the ease of mechanical equipment replacement is adequate.

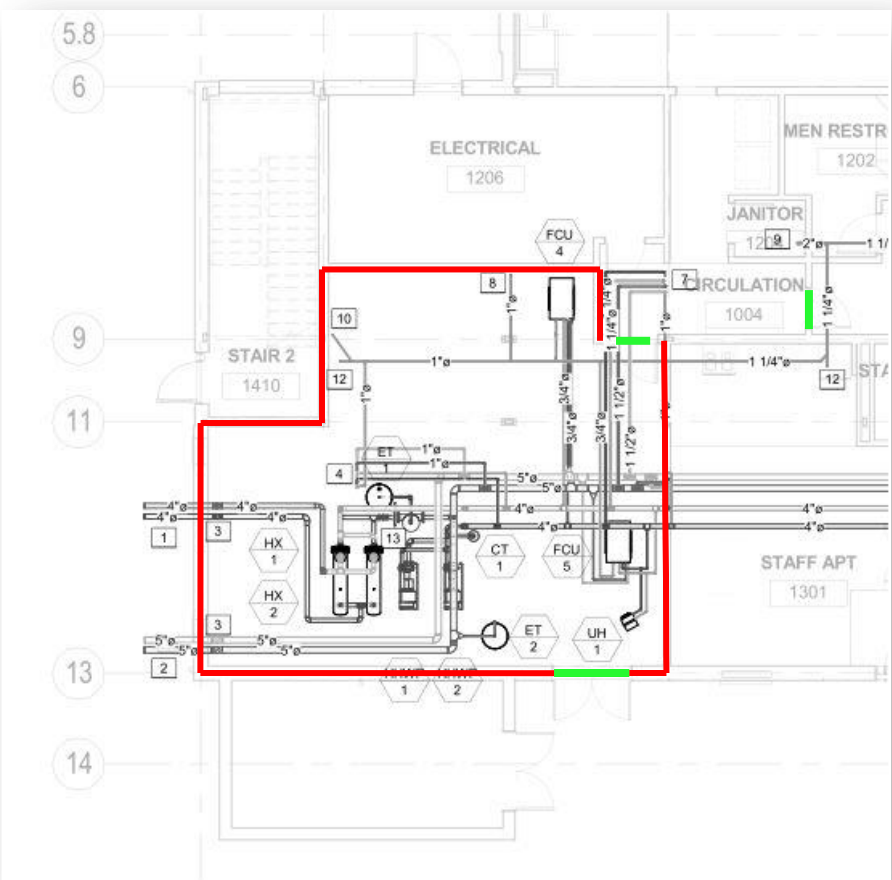


Figure 4: In this mechanical room plan, the red lines identify the boundaries of the room and the green lines identify doors that are restricted to authorized personnel only. This means that all mechanical equipment is safe from tamper.

Now that it has been established that this area of mechanical equipment will be free from any potential student tampering, we must find out if its components are below 8' in elevation. Any piece of equipment below the stated height above floor level infers that it can be reached without the use of a ladder. This effectively reduces any falling hazard. To do this, the schematic drawing will be referenced.

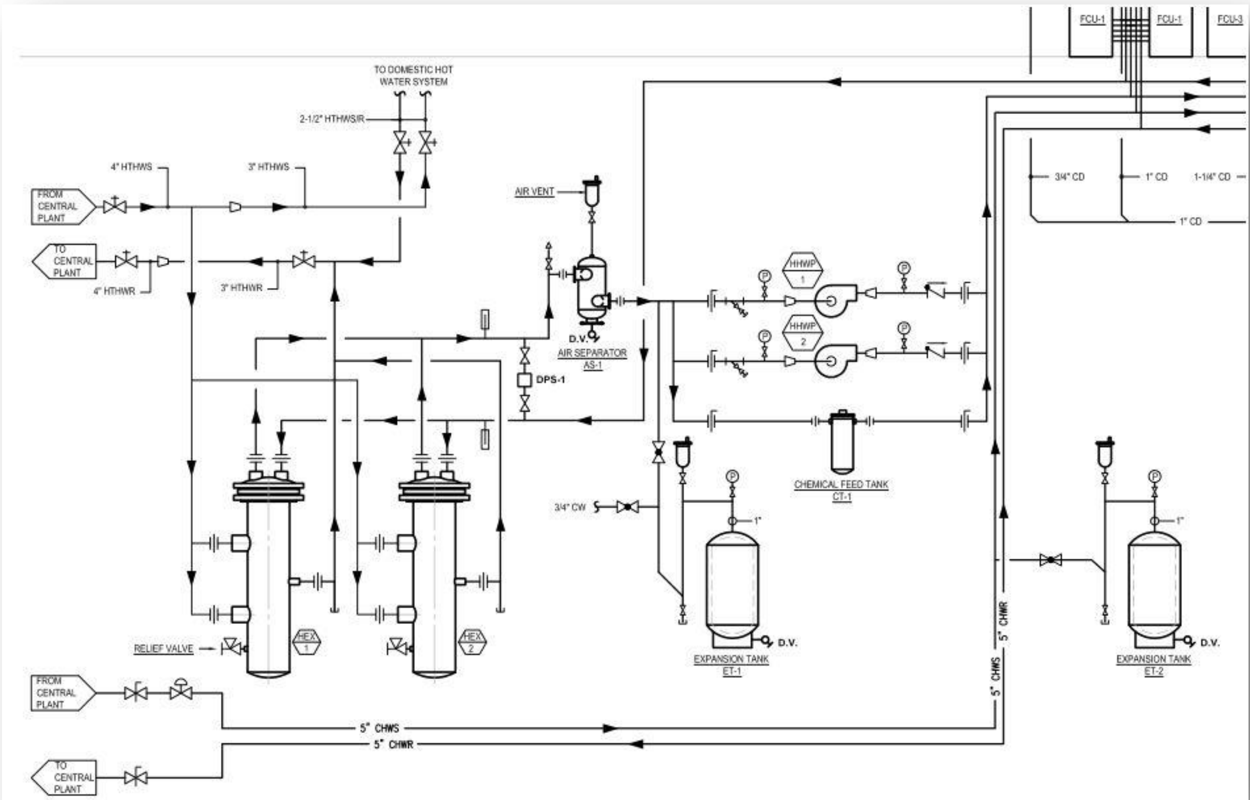


Figure 5: Schematic diagram of the mechanical room

It is stated that the incoming supply of High Temperature Hot Water (supply and return) as well as the Chilled Water (supply and return) enter the building at the left of the above diagram. Since they enter the building below grade, they are immediately risen to "ceiling level." Ceiling level of the neighboring rooms are 8' 6", 8' 9" in the corridor, and 10' 0" in the main lobby. With the 4' change in elevation between the upper and lower first floor, the 8' 6" corridor height of the upper level becomes

12’ 6” AFF (above finished floor) for the lower level. Since the floor to floor height for is 14’ 0” and the highest ceiling for the first floor is 12’ 6”, it is to be assumed that the pipes immediately rise to at least 13’ AFF. Luckily, any valves that will need to be accessed on the lines can be placed on the risers to and from the equipment, allowing for plenty of clearance within the 8’ limit.

Equipment located within this mechanical room are the following:

- UH 1 – 19,950 MBH capacity Hydronic Water Unit Heater
- HX 1 and 2 – 3,942 MBH capacity Heat Exchangers (shell and tube)
- ET 1 and 2 – 21.7 gallon (ea.) Expansion Tanks
- HHWP 1 and 2 – 265 GPM Hot Water Pumps (primary and back-up)
- AS 1 – Air Separator

Each of the above mentioned mechanical equipment are specified to be floor mounted with the exception of the Unit Heater (UH -1) which is specified to be 9’ AFF. Because the majority of equipment and their associated control valves are run by a BAS (Building Automation System) this room is considerably safe. The only equipment to be accessed by ladder would be the unit heater which won’t be in use other than the rare times that the room is to be occupied.

In summary, the first floor mechanical room is safely distant from any unwanted access by students, the door to the exterior provides quick and safe equipment replacement if needed in the future, and the height at which the equipment must be accessed is well below 8’ with only a small heater requiring a ladder.

Common FCU Access in Dorm Unit

Since fan coil units contain filters that must be replaced roughly every 12 months, each unit must be readily accessible during summer hours for replacement and maintenance. As seen highlighted in the document below, there is an FCU in each dormitory room making it the most common FCU type in the building and most likely the one needing the most maintenance.

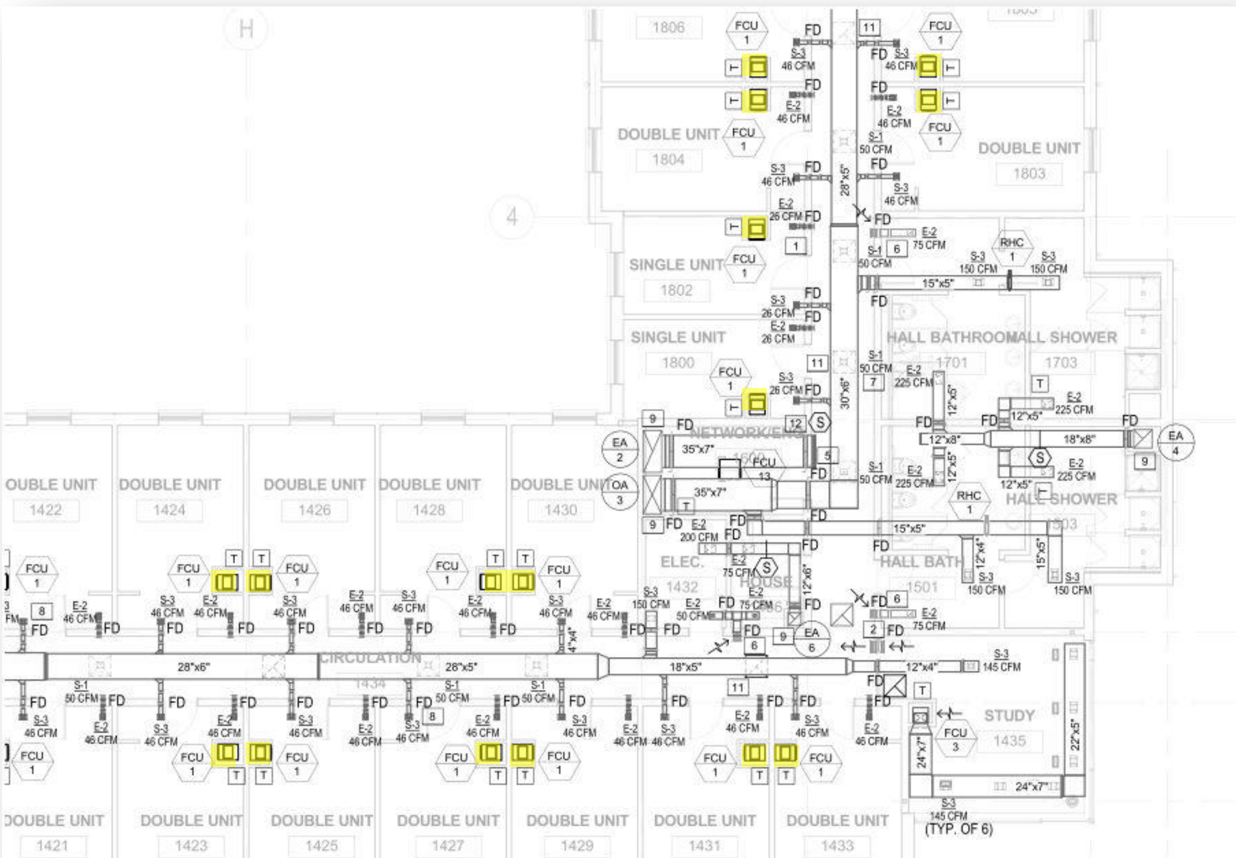


Figure 6: All dormitory FCUs are highlighted in yellow on the mechanical plan above.

There are two types of FCU depending on weather it is a single, double, or triple unit. Single and double units have a fan operating at 337 CFM max and triple units can reach 407 CFM of conditioned air. According to specifications these fan coil units are mounted in the vertical position in an area where the ceiling height is only 8’ 6” AFF. It is assumed based on the location of these units that they are in-accessible to students and require a special tool for maintenance, but it is still important that these units be located below the ceiling height so that a ladder is not required.

According to the architectural plans, these FCUs are placed in a closet like structure near the entrance of the room. They are to be accessed facing the interior of the room, which is helpful in cutting down maintenance time since no furniture requires moving. They are composed of an intake grill, filter, cooling coil, heating coil, temperature monitor, and then a fan to drive the air. This is shown in the diagram below.

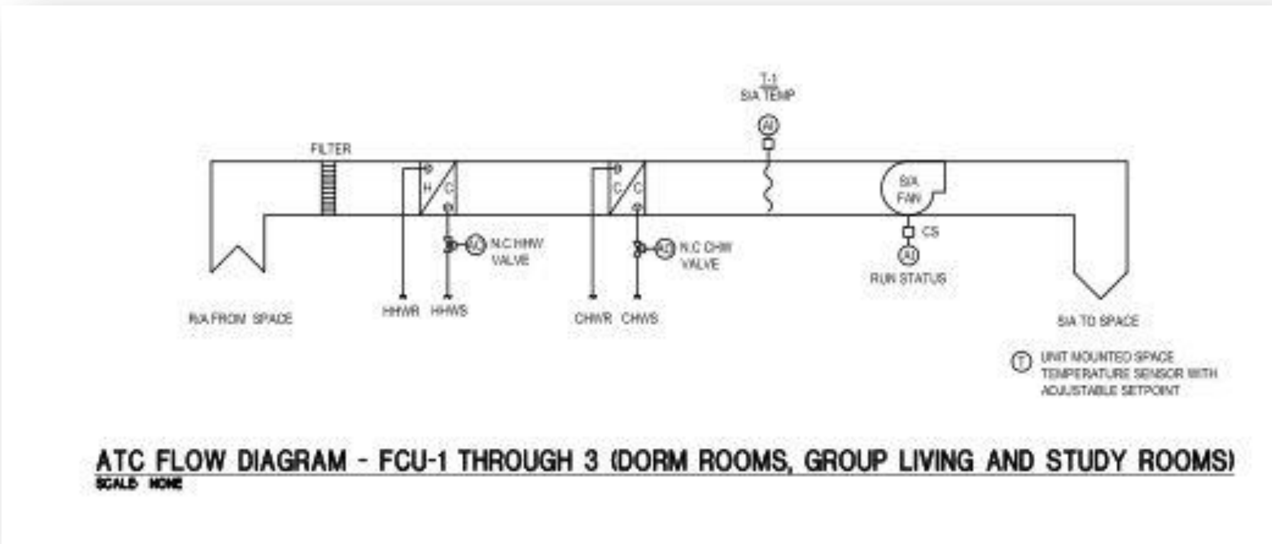


Figure 7: Schematic flow diagram for the common FCU in Taylor Hall

The diagram below shows a more specific image of where each component is located within the dormitory closet. Based on the knowledge that the floor to ceiling height is 8' 6", the height of the filter can be derived. As shown on the diagram, that height must be assumed to be the height of the unit access panel. According to the below diagram, that access panel is roughly 3' 5". This value was found by doing a simple ratio of heights.

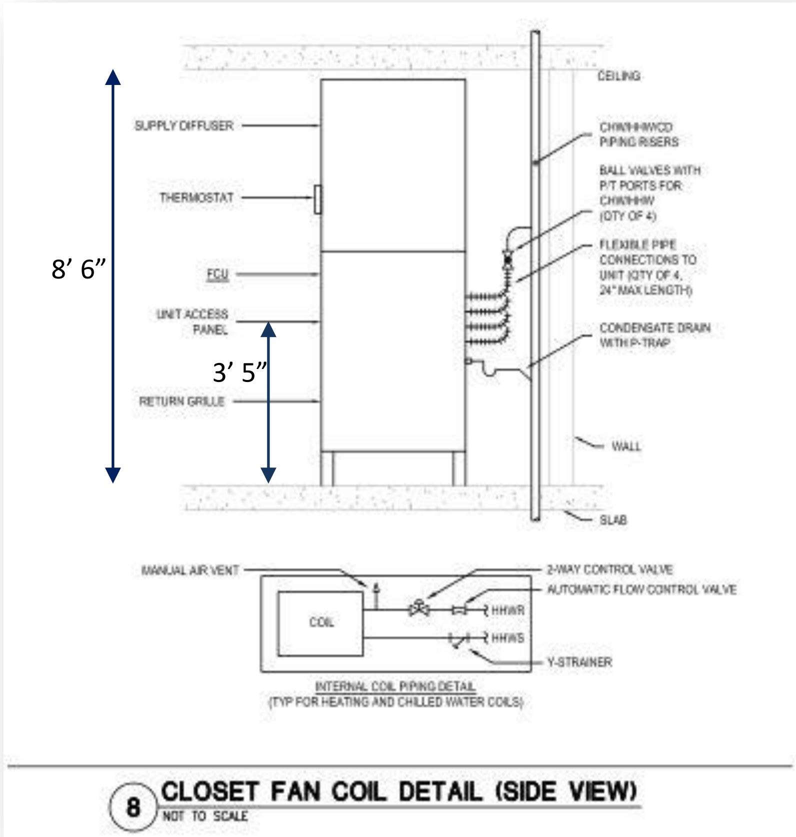


Figure 8: Elevation of the typical dormitory FCU location with floor-to-floor height and floor-to-access height noted.

Since this is the most common FCU in the building which needs yearly maintenance, having the access point below necessary height for a ladder is not only time effective, but also dramatically reduces the risk of falling. It is clear that facility maintenance conscious design played a role in the placement and orientation of this fan coil unit. In summary, this common mechanical access point is protected from student interference and considered very safe for maintenance personnel.

Mechanical Pent House

On the fifth floor of the building is a mechanical penthouse with a single 26,500 CFM capacity air handling unit. The unit feeds the entire building with fresh air and helps to cut down on energy consumption with the use of an enthalpy wheel. With the building going for LEED certification, and requiring MERV 7 and 13 filters in doing so, the unit will need to be accessed frequently.

Considering access, the fifth floor can be accessed via stairwell or elevator. Students, however, will not be able to gain access to the fifth floor due to a special key needed to operate the elevator controls for that floor and the stairwell has a locked door at the top of it. This means that the buildings' air supply is safe from any misconduct.

After my interview with Penn State Contractor Safety Coordinator, John Risley, the true value of this design was not realized. Most rooftop air handling units must be accessed through rooftop doors, requiring tie-offs if the unit is within 15' of the buildings edge (assuming < 39" parapet). Secondly, replacing components and filters of those units can be a time intensive activity since each part must be carried through a stairwell and fit through a standard doorframe. Luckily, Taylor Hall has an extremely efficient access advantage, letting maintenance access the closed in room via elevator.

Investigating the accessibility of each component, it is easily noticed that the air handling unit is reachable without a ladder. Included in the specifications, a clause states that each segment of the unit must include an access door for maintenance. In the below diagrams, the air handling unit plan and location are shown with their respective elevations.

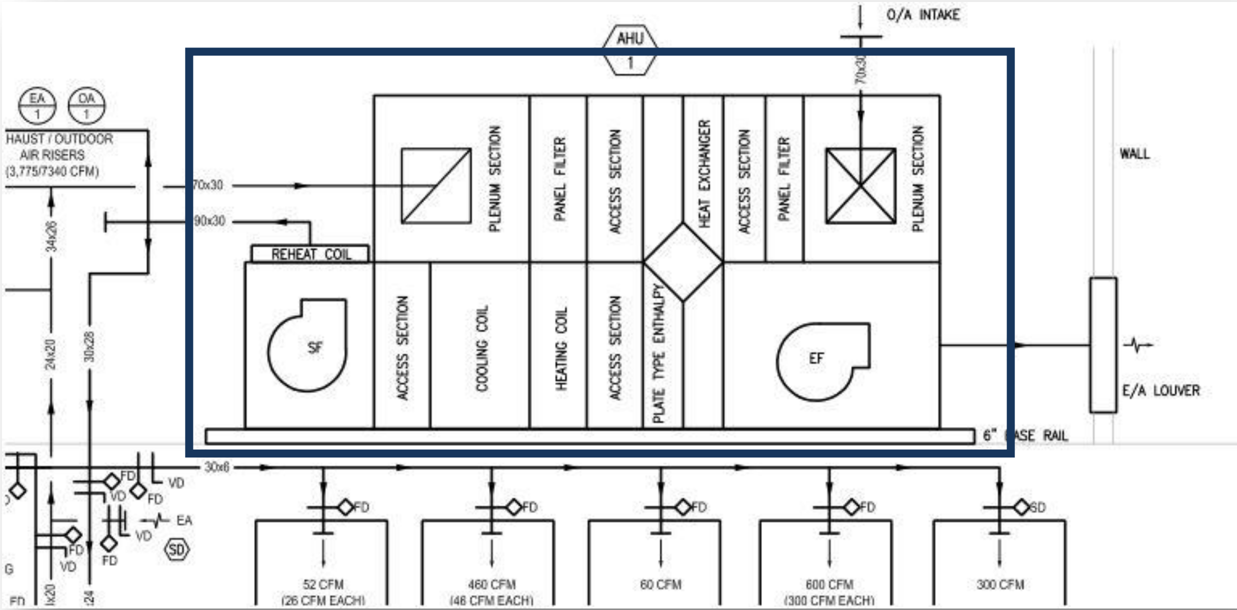


Figure 9: Schematic diagram of the rooftop AHU (highlighted with the navy box).

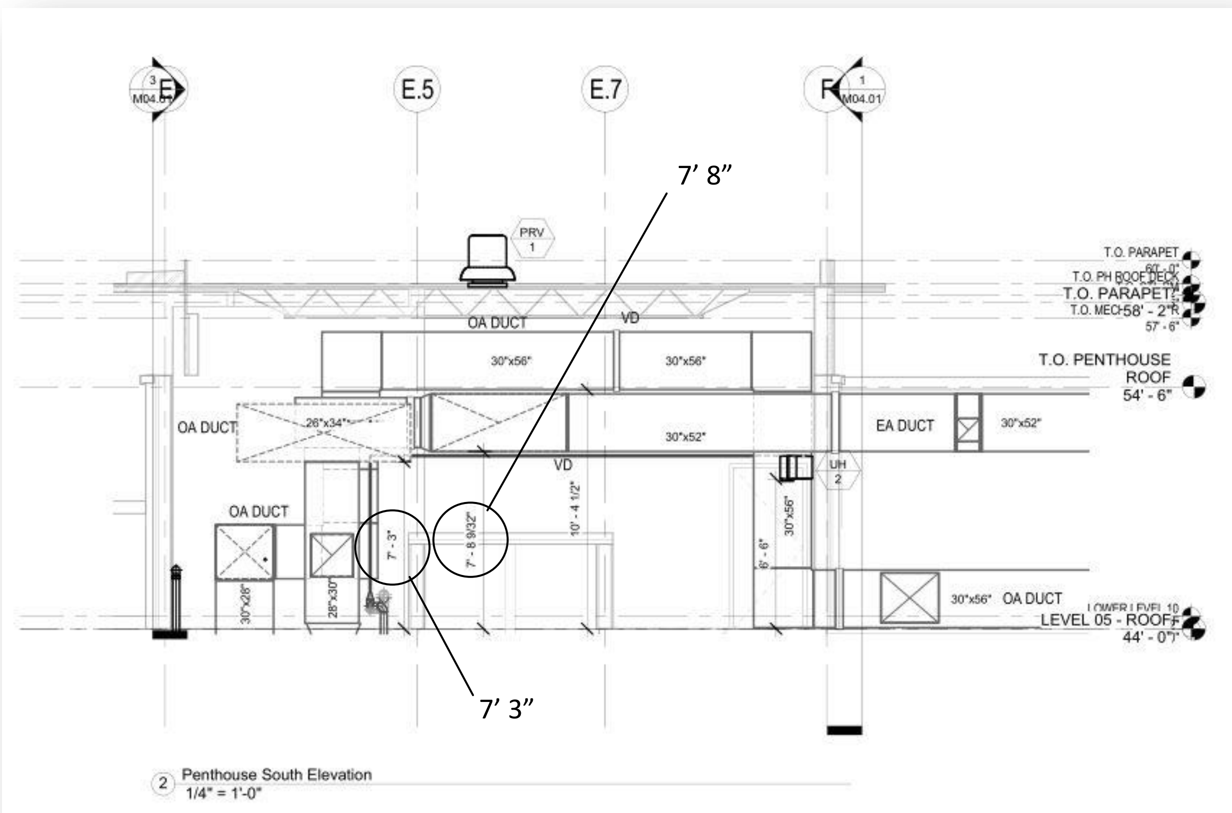


Figure 10: Elevation of the mechanical pent house with height of duct work noted.

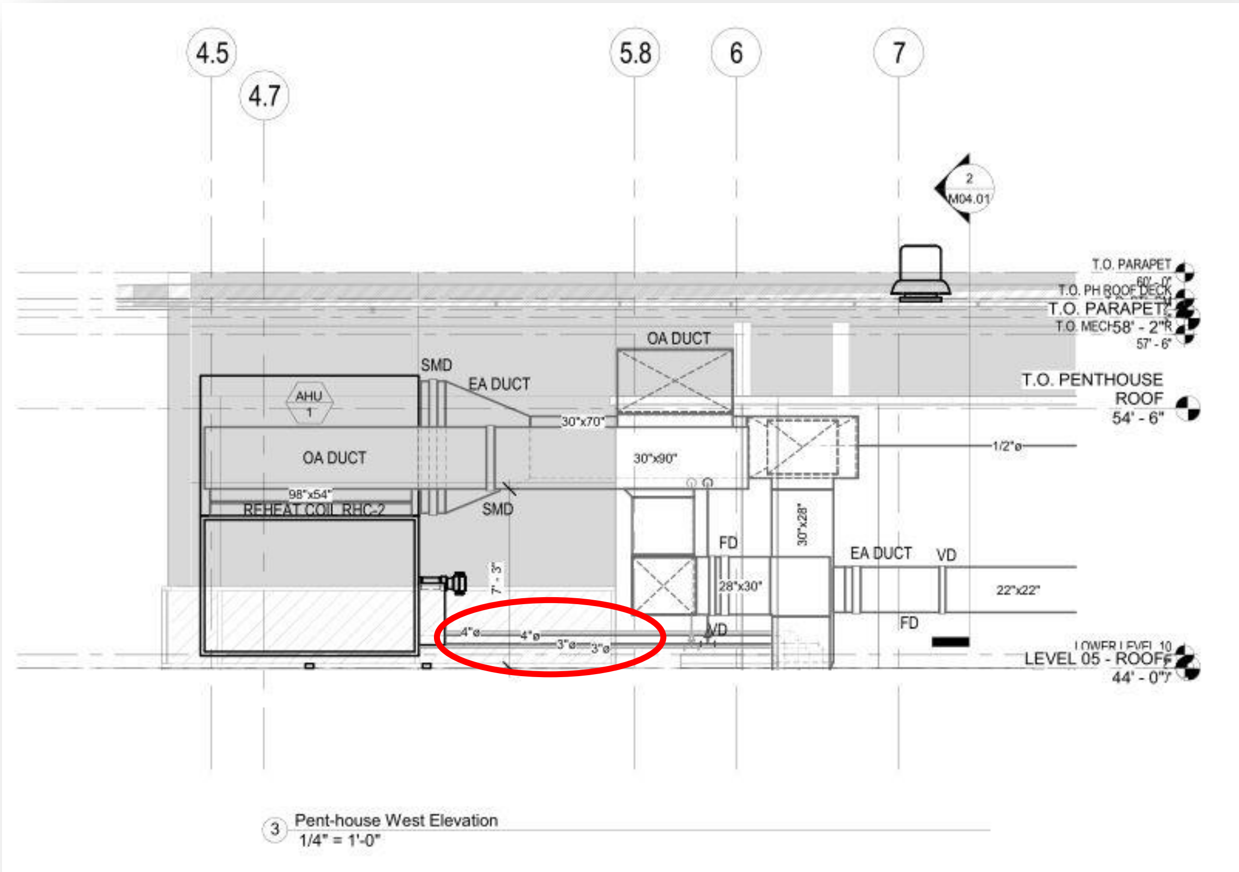


Figure 11: West Elevation of the mechanical pent house with the red circle noting a low lying hazard.

Each component of the air handling unit is below the access height needed that would require a ladder. This is, of course, assuming that the access point for the upper half of the air handling unit (where the two filters are located) is reachable from the 7' 3". All other control components of the air handling unit are accessible and readable from the ground, making it completely safe to operate.

Upon reviewing the elevations of the mechanical penthouse, a potential safety hazard was discovered. Although it is not a fall safety issue, the trip hazard caused by the 4" and 3" pipes feeding the reheat coil highlighted in red above, it is equally import to highlight the issue. To combat this issue, the most cost effective solution would be to paint the pipes a florescent yellow or make it highly visible in some way. Rerouting the pipes is not feasible due to the manufacturing specifications of the air handling units.

In addition to the air handling unit, its associated duct work and water feeds, is a small cabinet unit heater located 6’ 4 ⅞” AFF in the rear of the room. This unit heater is used only when the room is occupied and can be easily accessed since it below 8’ in elevation.

In conclusion of this breadth investigation, all three mechanical access categories are to be deemed considerably safe. Each are limited to restricted access only, keeping students away from attempting to tamper with mechanical equipment. Based on the architectural layout of each, maintenance personnel should be able to efficiently conduct their work with ease. Finally, nearly all mechanical components researched within the scope of this investigation are at or below 8’ in elevation, which means ladders will not be required on the job site and the fall safety risk is effectively mitigated.

Analysis 3: Green Roof Addition

When it was originally stated that Taylor Hall of George Mason University was to achieve LEED Silver status and become a step forward for the University's future sustainable efforts, the idea of a green roof was initially brought up. Due to budget concerns, it was decided that the small green roof not be included in the current construction plan. This analysis will determine the actual cost and schedule implications of adding a 3" green roof over top of the currently designed multi-purpose room on the ground level. Preceding the cost analysis is a review of the benefits and specific needs of a green roof. Finally, a breadth investigation will determine if the current design can sufficiently support the addition of a 3" green roof.

What is a Green Roof

A green roof is essentially a vegetated surface covering a roof. They range in depth of growth media and the types of plants that they can produce. These plant types are determined by the needs of the owner and are typically local species of plants that are low-maintenance and able to endure the elements they may encounter. Short, brush-like, vegetation on green roofs are referred to as extensive green roofs.

For owners that want to further engage their building users into the green roof, intensive green roofs offer many more plant species. These green roofs can allow users to walk about them and may even feature grown of harvestable species. Though, they are typically more attractive, they are high maintenance, high cost, require irrigation systems, special support systems, and are not favorable for a dorm application.

Figure 12: A fully grown comprehensive green roof (omni-ecosystems.com)

Recently, a third type of green roof has been developed to provide a wider variety of plants similar to an intensive green roof, while maintaining the low maintenance, lower cost, and overall physical properties of an extensive green roof. This is achieved by incorporating a more natural variety of plants, those that would support each other in a symbiotic relationship found in a meadow. A special type of growing media allows for low saturated weights and drainage properties of standard green roofs that are twice as thick. (*Beyond Extensive and Intensive*.)

Benefits of a Green Roof

Green roofs provide many benefits to the owner of a building. The rewards of a green roof are not only environmental, but fiscal in the long term. Specifically for a building on a college campus like George Mason University, these benefits can be recognized by students, faculty, and the public to provide even further value.

The main advantage of a green roof is to more effectively manage storm water. Green roofs can absorb anywhere from the first ½” to ¾” of rainfall in a storm and can further reduce runoff rate by 65%. (*GSA)* By adding layers of media for water to travel through, said runoff can be slowed by up to 3 hours.

This is especially important for flash-flood style events and areas where there are potentials for combined-sewer overflows.

Particularly on larger applications, building owners can see a significant energy cost reduction in areas with green roofs. This is because they add thermal mass to the buildings top layer where most energy escapes (savings of 13-33% according to *GSA*). A roof's heat retention ability is increased, but the majority of savings are seen during summer months when cooling costs can be reduced. This is done through a cooling effect known as evapotranspiration combined with a lower heat gain coefficient. According to the GSA's Green Roof Benefits and Challenges Analysis, there are varying results across the world and a more concrete study is currently underway. Nonetheless, with energy costs on the rise this is a step in the positive direction.

One of the more overlooked qualities of green roofs, which is of particular importance to applications such as Taylor Hall, is the longevity of the roof system. Although more regular maintenance is required, the life time of a green roof is much greater than T.P.O. and EPDM roof applications. This is due to the green roof's ability to shield the waterproof membrane from damage by debris and UV radiation. The actual payback period and economic outlook of a green roof application will be examined briefly later in the report.

Green roofs offer many other benefits for the owner and the environment, some of which are currently being researched by the U.S. General Services Administration (GSA.)

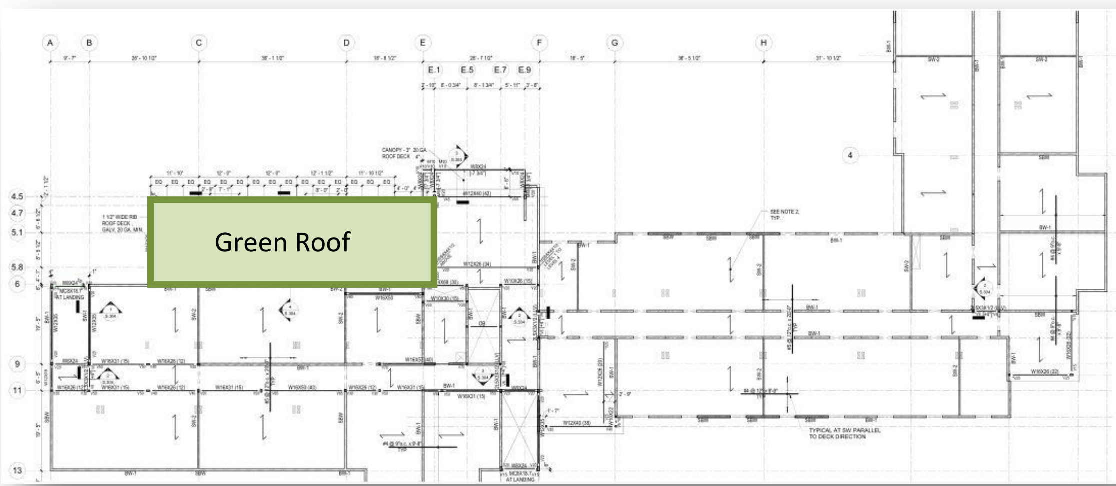
- Biodiversity and Habitat introduction
- Urban heat island reduction
- Urban agriculture (intensive)
- Acoustic improvements
- Air quality improvement
- Aesthetics and quality of life.
- Job creation and economic benefit
- Increased resale value

Taylor Hall's Green Roof

Applying a green roof to Taylor Hall fits well with, and complements, the building's existing sustainable design. Since the intention of the sustainable attributes extends beyond environmental and financial benefits to educational benefits, the green roof would allow yet another opportunity for the freshmen inhabitants to discover "green" opportunities.

The green roof location would be above the multipurpose room on the ground floor. This is depicted in the diagram at the bottom of this page. Because of its accessible location for maintenance and installation, the location is more safe and cost effective than a full roof application. Furthermore, since the location extrudes itself from the main building, it is easily in viewing range of the common room of each floor near the elevator lobby. This is important to maintain the roof's educational purposes.

Figure 13: The green rectangle below shows the 1,310 SF green roof area for Taylor Hall



Since the green roof was originally value engineered out of the building, it would make sense that the application be compatible with the existing roof system and structure so that it can be installed at a later time. The current roof structure of the multipurpose room is a standard metal deck with 4" of insulation and a T.P.O. membrane. This can be seen in the diagram below.

It should also be noted that the green roof must be adaptable to the drainage system currently in place. This issue is easily mitigated by covering the existing primary drain and lowering the level of the emergency drain guard on the T.P.O. roof. Due to drainage principles of green roofs, the roof drains will only be in use when the system is fully saturated.

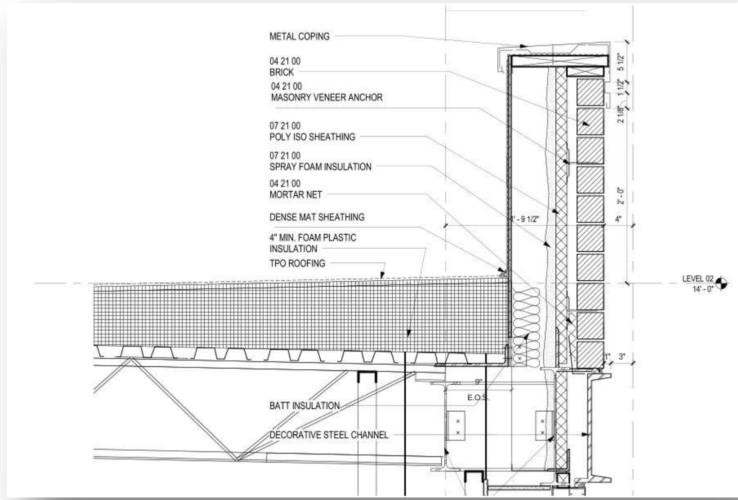


Figure 14: Roof edge detail

Since the green roof will be applying a load when it is fully saturated, the current system in place must be able to hold the dead load associated with a new green roof. This will be examined in a Structural Breadth analysis attached to this section.

Considering all the factors above, the best option for installation would be a shallow, low weight, and cost effective green roof. The Omni Ecosystem Infinity Growth Medium 3" system is a suitable option because of its low weight (15 PSF fully saturated), great drainage characteristics (water retention of an equivalent 5" deep green roof), and its ease of installation (1'x1' trays, installing up to 5000 SF in a single day). Through investigating different types of green roofs, this was also found to be the ideal system for post-construction installation. Better yet, it is considered a low maintenance comprehensive style green roof, meaning it will be aesthetically pleasing for the students and financially pleasing for the University.

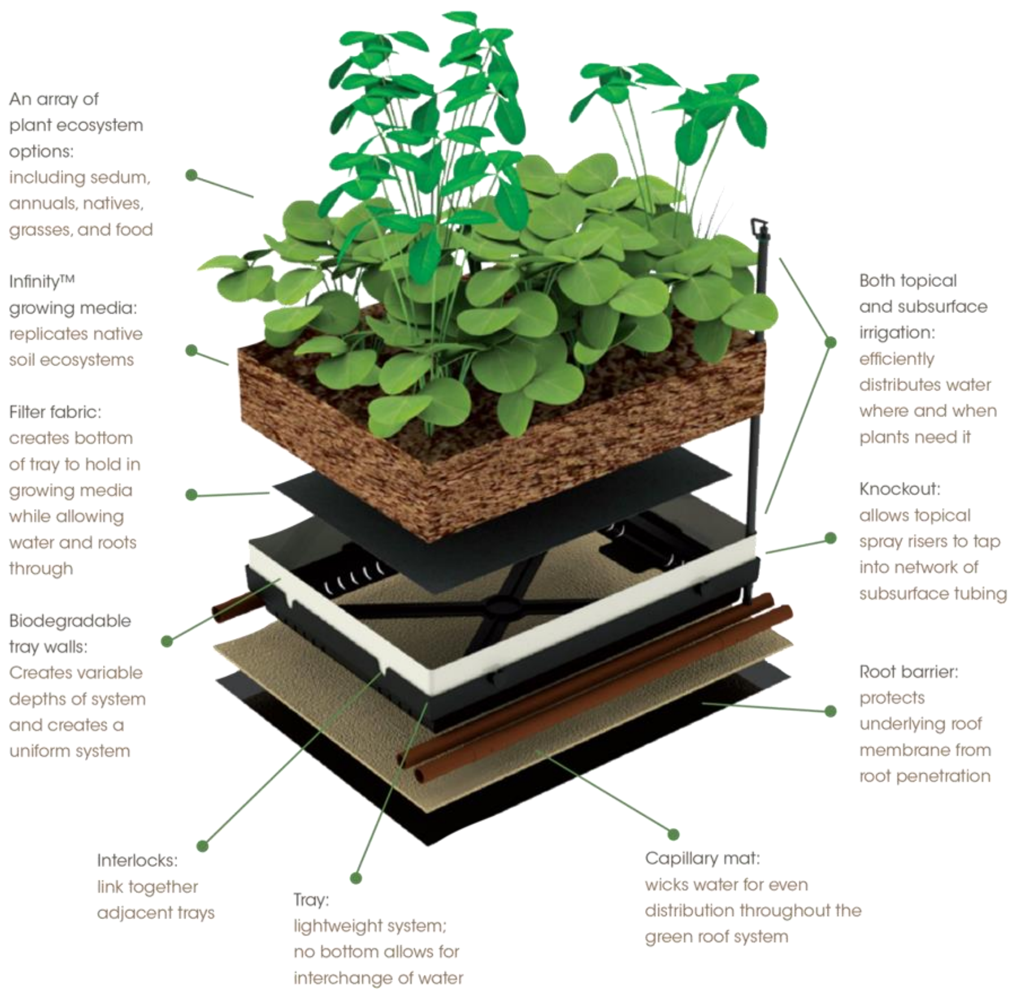


Figure 15: Overview of the Omni-Ecosystem 3" Infinity Green Roof (omni-ecosystems.com)

Schedule and Cost Implications of the Omni-Ecosystem Green Roof

Schedule Addition

As mentioned above, the Omni Green Roof system is the best possible option for the post construction application desired by owner. The area of the green roof is only 1,310 SF, meaning that it well below the average installation of a green roof but still a feasible application since it is partially for educational purposes.

The Omni Green Roof system consists of trays that require light irrigation, about 15 liters per day for the entire 1,310 SF roof. Because of this, a small copper pipe will have to be drawn from chilled water system directly on the interior wall. This will attach to the irrigation system in place. Installation is completed in three easy steps according to the manufacturer's specifications.

Steps (According to Omni-Ecosystems.com)

1. Roll out root barrier and capillary mat
2. Connect irrigation system
3. Set trays in place

Since the area is below the 5000 SF daily limit and the materials lift will only need to access the first level, it is safe to assume that the green roof can be installed in as little as one day (pending weather delays). In terms of the comprehensive system growing, the Omni system claims to arrive on site vegetated. This means that the green roof can be fully operational shortly after installation. It is safe to conclude that the installation time is so miniscule that it will have no impacts on the schedule, especially since it is not a critical path item.

Cost Addition

Specific pricing information could not be obtained from Omni-Ecosystems, but several educated assumptions have taken place to achieve the most accurate estimation. Firstly, all costs discussed in this section are under the assumption that the existing roof structure is not to be estimated and that the existing T.P.O. membrane with heat welds is to remain. It is also assumed that irrigation system attachments are included in the cost of the green roof, due to the majority of irrigation components delivered with the green roof system.

Consulting the RS Means Green Buildings Cost Data for 2014, there was no option for either a tray system or a 3" system. Furthermore, the Omni system incorporates a novel growing medium that isn't accounted for in the RS Means system. Because the growing medium has the same physical properties of a 5" soil green roof (according to Omni-Ecosystems.com) it is best to assume the cost values of a 6" soil green roof covering (item number 3100 in section B3010 125 Green Roofs). This value is verified by a secondary source for the cost data in this evaluation, The U.S. General Services Administration's Cost and Benefits Analysis of Green Roofs.

Below is table illustrating the proximity of the estimates through RS Means and the average premium for the DC green roof addition according to GSA. In this case it is more favorable to side with the higher cost value from RS Means. The above values from GSA were derived from interpolating the values provided for 5,000 and 10,000 SF roofs.

Interpolated Cost Estimation Comparison ($/SF)

	Basic Roof $	GR Premium	Material	Labor	O&P	Location Factor	TOTAL
RS MEANS			$7.40	$3.65	$3.57	$0.924	$13.51
GSA	$1.89	$11.59					$13.48

Based on the cost per square foot of $13.51 and the size of the roof being 1,310 SF, the official estimate of the Omni-Ecosystem 3" green roof application to Taylor Hall will cost **$17,696.63.** This is a substantial but very fair investment based on current market averages.

Cost/Benefit Analysis

There are several costs and benefits that are associated with green roofs. In most cases, the heightened yearly maintenance costs compared to normal roofs is paid off by the value added by the green roof. When looking at Taylor Hall's green roof, the interpolation of the standard 4 person-hours per 1000 SF per year comes out to a mere 5.24 hours of maintenance per year.

Cost of maintenance includes the cost of materials and labor of replacement parts. The 50-year cost of maintenance for Taylor Hall's roof using this value would be $18.25/SF. This value is quite high because typically smaller areas are harder to maintain and often an indicator that the green roof is located at a higher floor. Though this value was derived with data from the Washington, DC area, it is higher than what the actual cost of maintenance for Taylor Hall would be. Secondly, the Omni-Ecosystem 3" tray system dramatically reduces replacement costs due to the reuse of the irrigation, tray, and growth medium. The value of $18.25/SF over 50 years assumes that it is a built in place system without the use of trays. Therefore, it is safe to say that the actual value would be much less than this.

There are many benefits to having a green roof that exist to help offset that cost (mentioned previously). Although they are all vital to the value of the green roof, the most tangible values are energy savings from heating and cooling, and the slowing of storm water runoff (for reduction of infrastructure upgrades and/or storm water fee's). The averages for these values were found in the analysis by the GSA for the average green roof and have now been interpolated for Taylor Hall's roof size. Since the Omni-System is only 3" deep but provides the same water absorption of a 5" green roof, it is assumed that these numbers are accurate. The 50-year added value for Taylor Hall's green roof would be $11.37/SF for storm water reduction and $6.47/ SF for energy savings.

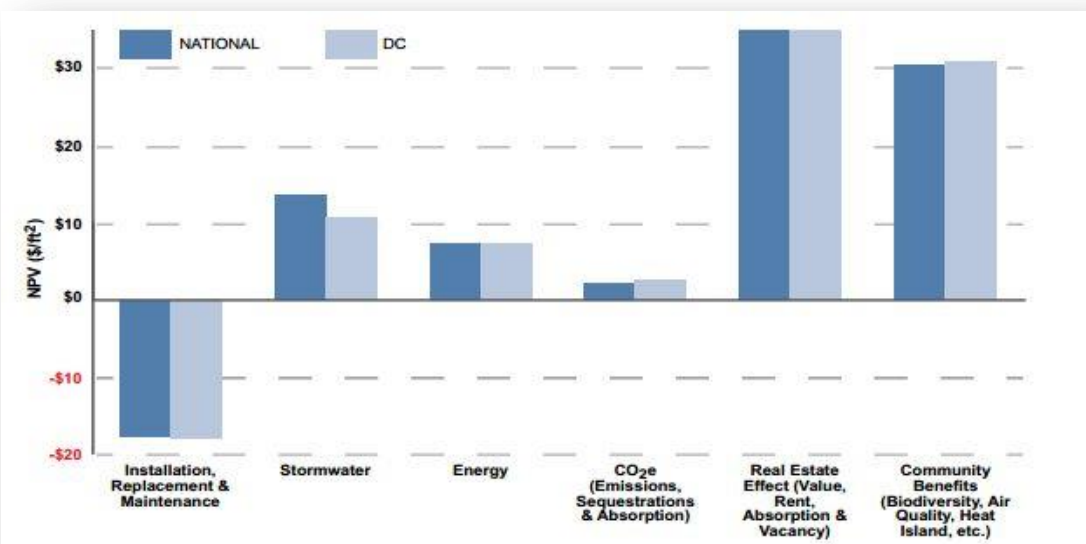


Figure 16: Cost/Benefit Analysis results from a study conducted by the GSA for national and DC averages.

After establishing our 50-year cash flow generated by the green roof, we can find the NPV (Net Present Value) which assists in finding the IRR (Internal Rate of Return). The IRR is essentially the rate of the return that would be needed to make the Net Present Value equal to zero. In other words, this is the rate that determines if the investment will provide a positive return. Using the values above, before alteration from the overestimate of maintenance, balance out to a 50-year loss of $0.41/SF, or $537. This is assuming the many other positive values of a green roof are not included since they are often dependant on how highly it is valued by the owner. Having a NPV of -$0.41 yields an IRR of an interpolated 4.21%. In turn, the ROI (Return on Investment) comes out to 196%. That means that for every $1 invested today, the green roof will be worth $0.96 in today's money, 50 years from now.

This may seem like a dismal outlook for an investor, but when looking at the use of a green roof for Taylor Hall, the feasibility takes a new turn. As a reminder, those values only account for two of the many positives that a green roof can add to a project and the maintenance estimate is quite high for this particular application and system. Something to consider is the educational benefits of the green roof addition, the reduction of CO_2 emissions, and the added value of the building if it were to ever be sold. These are all real, quantifiable values that can be interpolated to add to the positive cash flow in the analysis. The 50-year values of education and community improvements, reduction in CO_2, and added Real Estate value are $30.90/SF, $2.60/SF, and $105.93/SF respectively (values accumulated by GSA analysis and interpolated for Taylor Hall).

Considering these figures, the net cost of the green roof over 50-years would be $18.25/SF and the value added would be $157.27/SF. Therefore, the investment appreciates at a rate of $2.78/SF/Year. Assuming the GSA's values for educational and community benefits are linearly related to size, Taylor Hall's green roof would pay for itself in 4.17 years. Conversely, by interpolating the GSA's payback period findings, Taylor Hall would pay off its investment in 6.7 years. Either way 4.2 to 6.7 years till full payback is immensely more valuable than that of a standard membrane roof due to its replacement needs.

In conclusion, the value added by a green roof installation on Taylor Hall's multipurpose room would be a wise investment on the part of George Mason University. The Omni-Ecosystems Infinity 3" green roof system has proven to be the perfect combination of structural favorability, low maintenance, and high aesthetic value. The installation would take just one day and the estimated cost would be roughly $17,700. The payback would conservatively take place during the first 6.7 years and the green roof would create profit for the following 43.3 year amounting to roughly $182,000 based on a 50 year life span. Whether it be installed for aesthetes, performance, or purely educational purposes, the green roof of the multipurpose room would provide value to Taylor Hall.

Structural Breadth: Structural evaluation of Potential Green Roof

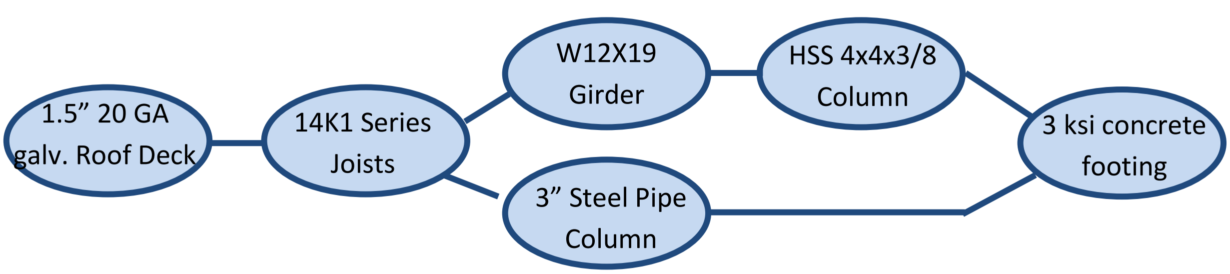
With weight added by the green roof, it is important to ensure that the structure below will be able to withstand the new dead load addition without additional reinforcement. This analysis will investigate the structural loads encountered by each component in the load path of the green roof; from the metal deck it sits on, all the way to the soil beneath the footing. The current roof system of the multipurpose room consists of metal roof deck, steel joists, steel girders, steel posts, and steel columns. One entire bay's components will be analyzed to see if anything fails. If any additional reinforcement is needed, it will be added to the cost of the green roof.

Weight of Taylor Hall's Green Roof

Specifications from Omni-Ecosystem's 3" green roof specify that the system will add 15 PSF at full saturation, the time when the roof with be at its heaviest. This is on the lighter side when it comes to the common range of green roofs, which is 15-30 PSF, most likely because of the patented growing medium made to simulate up to 5" of dirt at a low weight.

Without the green roof installed, the live load of the roof is 30 PSF, dead load is 17 PSF, and the snow load is 30 PSF (conservative). After standard factoring (1.6L + 1.2D + 0.5S) the load before installation is 81 PSF. After the added weight of the 15 PSF saturated green roof system, this weight jumps to 99 PSF. This is the value which will be used in this analysis.

Figure 17: Load path diagram showing the order in which components encounter the roof's load bearing down upon it.



Metal Deck

The metal deck in place was specified as 1.5" 20GA galvanized steel roof deck. For analysis purposes, I chose Vulcraft 1.5B20, which fits the specifications. The following points of analysis are values obtained from Vulcraft's product catalog's vertical load table and dimensions taken from the structural drawings, which are located in the appendix of this analysis.

Load Analysis for Metal Deck

Point of Analysis	Allowable	Actual (GR)	Actual (no GR)	Pass or Fail
Max span	6' 6"	4'	4'	Pass
Max uniform load	159 PSF	99 PSF	81 PSF	Pass

Joists

In a single bay (12' wide) there are two 14K1 series joists to support the metal deck. They are spaced evenly and support 4' of metal deck per linear foot each. If the 99 PSF factored load is distributed over this width, the load on each linear foot of joist would be 396 PLF compared to the original roof's 324 PLF. Each joist extends the width of the multipurpose room, which is 19'. Using a standard LRFD chart for determining maximum loading on K-series joists, the below table was developed to determine if the support would be sufficient.

Load Analysis for K-Series Joists

Point of Analysis	Allowable	Actual (GR)	Actual (no GR)	Pass or Fail
Max Load	472 PLF	401.2 PLF*	329.2 PLF*	Pass

*Includes joist self weight of 5.2 lbs/ft

Girder

Containing the outer edge of the multipurpose room's roof is a W12X19 steel girder that is 12' in length. Using the PLF loads on the girders from above and half of the 19' span of the room, there will be two equally spaced 3.8 kip point loads on the girder (4' from either column connection). Previous to the addition of the green roof, the point loads would amount to 3.1 kips each. The beam will also experience a uniform load of 19 PLF, which is its self weight. Maximum moment, maximum shear, and maximum deflection were calculated and compared in the table below. The maximum shear allowable between the girder and each column is rated for 20 kips according to the structural drawings. Detailed calculations can be found in the appendix of this section.

Load Analysis for W12X19 Girder

Point of Analysis	Allowable	Actual (GR)	Actual (no GR)	Pass or Fail
Max Shear	20 kips	3.9 kips	3.2 kips	Pass
Max Moment	85.5 kip-ft	15.9 kip-ft	13.1 kip-ft	Pass
Max Deflection	0.24 in.	$1.35\text{x}10^{-21}$ in.	$1.15\text{x}10^{-21}$ in.	Pass

Steel Post

The interior side of the joist is supported by the patented Infinity Structural System. According to the drawing the joist's point loads are located on an SBW (Shear Bearing Wall). Since each prefabricated wall panel is different, a specific design of this wall could not be found. Elsewhere in the building, 3" steel posts support minor loads and from floors above, especially around openings under bearing walls. It is assumed that there is also a 3.5" steel post directly under each of the K-Series joists, that it is equal to the height of the floor (like the wall) and that is laterally braced by other components of the wall. This would make sense, as the 3.5" steel post would likely be concealed in the 4" thick wall. By researching bearing axial loads, the below information was found regarding the maximum axial load allowed on such a steel post (14' in length, 3" interior diameter, 3.5" exterior diameter).

Load Analysis for 3.5" Steel Post Column @ 14' in length

Point of Analysis	Allowable	Actual (GR)	Actual (no GR)	Pass or Fail
Max Axial Load	16 kips	3.9 kips	3.2 kips	Pass

Column

On either side of the 12' girder is an HSS steal column. The dimensions of the column are 4"x4"x3/8" and it is 13' in height due to the slope of the roof over the 19' width of the multipurpose room. Since only one bay is being analyzed, only one column will be analyzed since the opposing bay will equal the load. The affective area of the column equates to 114 SF. The factored load of this area is featured in the table below, with and without the green roof. Also included in the table are the LRFD maximum axial load allowable for this particular column and its dimensions.

Load Analysis for 4"x4"x3/8" HSS @ 13' in length

Point of Analysis	Allowable	Actual (GR)	Actual (no GR)	Pass or Fail
Max Axial Load	87 kips	11.3 kips	9.2 kips	Pass

Footings and Soil Bearing

Since it is a strip footing on each side of the multipurpose room, it is assumed that the affective area of the footing is equivalent to the width for a particular column. Therefore, the dimensions of the footing are 4'x4'x1.5'. The strip footing is reinforced by four evenly spaced #4 bars in the lengthwise direction and have a #6 ever 12" laying perpendicular to that. Since this is the actual reinforcement currently installed, it is assumed that the minimum area of steel for shrinkage and temperature are already met. It is also assumed that the soil property of the site has an allowable load of 2 Kips/SF, which is based on bore hole results before construction.

Since there are certain spacing requirements based on the column size, the size of the base plate must be 13" x 13" at a minimum. The shear force for the footing based on those dimensions, require a depth of steel reinforcement that would allow a minimum footing height of 9.75". The absolute minimum area of steel reinforcement based on this factor is 0.12 in^2/ft. All calculations are included in the appendix for further details. The table below summarizes the findings of the footing analysis.

Load Analysis for Concrete Footing and Soil Bearing

Point of Analysis	Allowable	Actual (GR)	Actual (no GR)	Pass or Fail
Depth (Shear)	>10"	18"	18"	Pass
Minimum Steel Rebar Area	0.12 in^2/ft.	0.218 in^2/ft.	0.218 in^2/ft.	Pass
Soil Bearing Capacity	2.0 K/SF	0.71 K/SF	0.56 K/SF	Pass

In conclusion, each component in the load path of the green roof addition can support the additional 15 PSF that it adds. The allowable load in every situation allowed for a green roof up to twice the weight of the Omni-Ecosystems 3" comprehensive green roof. The first structural component to be compromised in a load increase would be the K-Series joist, which are able to support a green roof up to 32.7 PSF. For this application, however, each member maintains its structural integrity with an appropriate factor of safety, making the Omni 3" green roof a great candidate for the Taylor Hall application.

Analysis 4: Stick-Built Framing vs. Infinity Structural System

Early in the design phase of Taylor Hall, the structural system of choice was up for debate. The main candidates at play were concrete frame, load bearing stud walls with steel framing, and stick-build (timber) framing. Since this was a schedule given project, the decision was made to utilize an Infinity Structural System, a prefabricated load bearing stud wall system with minimal steel framing. George Mason University was partial to the system due to its success on other campus applications.

The Infinity Structural System uses specially designed metal decks to allow a more even load distribution on to cold-formed metal stud walls. These stud walls, depending on their function, can also have cross bracing for shear forces. Schedule acceleration factors also reside in the choice for Infinity, as one specialty sub-contractor mentioned that up to 24,000 SF of floor area can be placed in a single week.

However, despite the efficiency of the structural design, some members of the industry have mentioned that it causes more trouble than it is worth. Specifically when coordinating the MEP system penetrations early on in a Design-Build delivery system. It was mentioned that after considering all the delays involved with integrating the MEP systems, the Infinity system would be no faster than concrete for Taylor Hall's size and would come at a higher price.

The third option, stick-built construction, may have proven to be a happy medium for this type and size of building. This is especially due to the recent boom of stick built construction in the Washington D.C. metropolitan area.

Why Stick-Built Framing?

Now that the building industry is seeing a rise in activity, areas like Washington D.C. are developing at extremely high rates. These rates have driven property owners to accelerate schedules as quickly as possible. By spending less time during the construction process, money is saved on paying construction loans, which are still quite expensive with banks still weary of the economic times. There are several options for quicker construction processes but many have found wood-frame construction to be the most cost effective and novel idea, especially given recent breakthroughs on wood frame fireproofing technology. A CEO of a D.C. area developer, Jim Butz, mentioned that "As banks start dipping their toe back into the construction loan market, wood-frame is where they'll start generally speaking" (Return to Wood).

Figure 18: A personally taken picture of the early stages of a stick-built multi-family housing project.

Secondly, wood frame construction works particularly well with the regions height limitations. An act passed in 1899 limits construction heights to 90' within the District, which typically equates to 7 or 8 stories. Being too low to be considered a "high-rise," steel frame construction wouldn't particularly make economic sense. This is one of the reasons the area has popularly used concrete framing, but with new technology, light gauge framing has emerged as the economical champion of this specific height range.

Light gauge metal framing, like the Infinity structural system can be built easily constructed off site and quickly set into place, making the construction site safer and cleaner since materials don't need to be stored as vast other options. Cold-formed steel systems can also be built all the way up to the current District height limit of 90', an option stick-built construction does not have.

Current regulations only allow up to 5 stories of purely stick-built construction. This can be amplified to 6 total stories with the popular addition of a concrete plateau on the ground floor. With a total height option of 6 floors, wood framing has reached enough of a market share in the region to catch the eye of developers who may not require the maximum height of 90'. This is especially the case for multi-family and residential housing projects that need to be constructed as quickly as possible to minimize the payback period.

Now that light gauge steel and wood framing are making an impact in the area, people are debating which system is better. When dealing strictly with the numbers, RS. Means will show that light gauge wood framing is slightly less expensive than the similar steel framing. In terms of total building cost, the wood frame building can cost an average of $20 /SF less when compared to metal frame nationally. This is seen in the table below using data collected by Greatergreaterwashington.org.

RS. Means Cost Comparison by Structural System

Price per SF	Building Fireproofing Type	System Type
$139.01	Type II	Mid-rise, Light-Gauge Steel
$119.77	Type III	Mid-rise, Wood Frame w/Fire Resistant Walls

Fire Resistance Ability of Wood Framing

As seen in the table above, the wood framed building's ability to withstand fire also plays a large factor in a designer's choice of which light-gauge system to use. Type III construction is described as "Mixed noncombustible and combustible including frames and heavy timber (HT)" by the National Fire Protection Association (NFPA) and allows for Residential buildings, such as Taylor Hall, to be built to a height of 4 stories or 55'. Taylor Hall happens to be just under that requirement at 4 residential floors and a total building height of 54'. Despite the qualification, doubt still exists regarding the safety of wooden structures.

Luckily, technological breakthroughs have allowed wood products to achieve competitive fire rating values. These products are known as FRT, or Fire-Retardant Treated, and must meet a 2 hour rating for exterior and load bearing walls for the building class type that Taylor Hall falls into. Higher fire resistant flooring must also accompany the exterior wall and any opening, as seen in this picture (right) that was taken at a personal site visit this past July.

Figure 19: A picture taken at a stick-built multi-family residential building. Notice the higher resistant wood along the exterior wall.

A second wood assembly technology known as CLT, or Cross-Laminated Timber, has proven to be extremely effective for both fire resistance and strength relative to its weight. This type of plywood is not yet recognized by the NFPA, but is widely thought to be accepted in the 2015 updated code.

Schedule Acceleration

Like light weight metal framing, such as the Infinity system used at Taylor Hall, stick-built framing sections can be prefabricated off-site in a similar fashion. The benefits of this are as follows:

- Reduction in falling hazard. Sections constructed at a safe height.
- Increase in quality. The products are likely prefabricated indoors and in a more livable environment.
- Reduced site usage. Since the segments are installed almost instantaneously, they will not be taking up any storage space on site
- Ease of installation. With larger sections, less time has to be spent on minor details that can be fabricated off-site.

With the ability for stick-built frames and trusses to be prefabricated, it is assumed that the schedule will not be affected if Taylor Hall were to hypothetically change to this structural option.

Cost Comparison: Infinity Structural System vs. Stick-Built Framing

With cost being a major concern for the Taylor Hall project, it is critical that the most economical system is used. Already assuming that both the Infinity system and stick-built framing will be prefabricated off site in roughly equal amounts of time, this decision comes down to direct costs associated with material and labor.

In Technical Assignment II, a detailed structural estimate was done on Taylor Hall, resulting in a total value equivalent to $15.50/SF. This, however, was very distant from second opinions on the system. Technical Assignment I (which can be found in the Appendix with Technical Assignment II) found that RS Means square foot estimation found the light-gauge steel cost to be $19.98/SF, but it did not account for the patented assembly system or prefabrication costs. After consulting a specialty contractor with significant experience with the Infinity Structural System, it was concluded that the cost per square foot would be near $23.00, however after an interview with the construction team it was mentioned that the structural elements accounted for roughly $30.00/SF of the total building cost. Though a wide variety of values have been found for this system and accurate pricing was not available specifically from Infinity, it will be assumed that the cost is $23.00/SF for this analysis. This would place the total cost for the Infinity Structural System at $1,611,311.

Because the RS Means Square Foot estimate was most accurate to the assumed actual cost for light-gauge steel framing, it will also be used as the method in which the stick-built system is estimated. This is done by breaking the stick-built system into three types of estimates: one for the roof, one for the actual wall partitions, and one for the joists and girders.

Starting with the roof, it was found that a wood truss would have to span exactly 49’ 10-1/2” with the 2” overhang on each side of Taylor Hall. In order to maintain the same appearance, a 5:12 slope will be maintained for the roof and it is assumed that the truss spacing is 24” O.C. Given the criteria, the total cost per square foot of roof was determined to be $7.04. Using the footprint of the roof (16,820 SF) and a slope pitch multiplier (1.083) the total roof area was found to be 18,216 SF, bringing the sub-total cost to $128,240.64

The core of the building, being composed of wood framed walls, is second to be estimated. Based on a similar wall construction to what currently exists with the Infinity System, RS Means was able to find a square foot value of the building. The wall structure is as follows: 5/8” Drywall/ Resilient Channel/ 2x4 @ 16” O.C. (Assumed)/ Resilient Channel/ 5/8” Drywall. The cost for walls of this system was estimated to be $8.75/SF bringing this sub-total to $612,998.75.

Lastly, the wooden joists and girders are what will ultimately hold up the floors above the walls. It is assumed that this value also accounts for supplementary studs or columns to assist in the support of the mentioned girders. It was also assumed that the typical bay of Taylor Hall is 15’ x 15’ due to simplicity and the wide jump of bay sizes in RS Means. Different girder/joist combinations are different for different loading areas of the building, but because the majority of the building has a SDL of 20 PSF and an LL of 40 PSF that the next highest floor type would be most suitable for estimation. This ended up being 75 PSF of superimposed load, which would cover most areas of the building (other than stairways and mechanical rooms). This level of loading requires 8”x16” and 4”x16” girders combined with 2”x8” joists spaced evenly at 16”. The total load of the system is 90 PSF after the weight of these components are factored in. Given this scenario, RS Means estimated that the square foot cost would be $17.48, bringing the sub-total to $1,224,596.36.

Overall Cost of Stick-Built System

Part of System	Price
Wooden Roof Trusses/Sheathing	$128,240.64
Wooden Framing	$612,998.75
Wooden Joists/Girders	$1,224,596.36
TOTAL COST	**$1,965,835.75**
TOTAL ($/SF)	**$28.06**

The initial reaction when adding these three components together shows that the Stick-Built System would be about $5 per square foot more costly for the average location in the United States. However, because of the D.C. Metropolitan area's unique use of this type of system, the location factor for 2014 significantly reduces that cost. This can be seen in the table below.

Overall Cost of Stick-Built System (Adjusted for Fairfax, VA 2014)

Part of System	Price
TOTAL COST	**$1,965,835.75**
TOTAL ($/SF)	**$28.06**
Location Adjustment Multiplier (2014 Woodwork costs in Fairfax, VA)	**78.3**
ADJUSTED TOTAL COST ($/SF)	**$21.97**

At just $21.97/SF, the cost of the stick-built structural system would save George Mason a total of $72,158.71. To put that number in perspective, it would be more than enough money to pay for the green roof addition mentioned in the previous analysis. It would also cover that green roof's entire life cycle cost of maintenance and replacement after 50 years.

Though the Infinity Structural System has proven to be similarly cost affective and has equivalent abilities to accelerate the schedule, the stick-built framing may have provided a better option for Taylor Hall economically. With stick-built construction on the rise in Northern Virginia and D.C., technologies for wood fire protection emerging, and the sustainability aspect of using wood instead of cold-formed steel, George Mason University and similar owners in the region may consider stick-built construction in the future.

Conclusion

In conclusion of my senior thesis analysis of Taylor Hall, I have successfully fulfilled the expectations set forth by my proposal. Throughout the four analyses, important information was developed regarding the topics of safety, sustainability, and cost/schedule improvements. In addition to the analyses, two breadth investigations were completed to assist in the explanation of the particular analysis.

In the critical industry research analysis of Prevention through Design, it was discovered why there are issues in the design phase of buildings and how important it is that team work is involved early in the process to influence safety conscious design. In the same theme, a re-design analysis was performed to apply a raise in sill height on Taylor Hall wall openings to increase fall safety. Furthermore, interviews were conducted to gain information about how Taylor Hall construction staff might make the site safer for the weekly tours of George Mason University students. Lastly, a breadth analysis was performed to investigate the mechanical access points within Taylor Hall. This was done to assure safety of future maintenance staff.

Pertaining to sustainability, it was originally an idea to include a green roof surface on the Multi-purpose room of Taylor Hall. An analysis was performed to find the total cost and schedule implications related to adding a specific type of green roof. A cost/benefit analysis found a positive internal rate of return when considering the educational, storm water, energy, and CO_2 emissions. A breadth analysis was also done to assure that the current structure in place could support the new saturated dead load associated with the green roof.

The last analysis is also in relation to an emerging industry trend, stick-built frame construction. Taylor Hall had considered using this prefabricated wooden system but opted with the Infinity Structural System. A cost analysis was done comparing the two systems and found that stick-built would actually be applicable to Taylor Hall due to its height and use. It was found that for the stick-built framing actually would have been less expensive for the Fairfax area where Taylor Hall is located. Better yet, this could have been completed using the same schedule as the Infinity Structural System because of the advantage brought by prefabrication.

Each of the separate investigations has proven to be mutually beneficial for the owner and the construction staff, especially regarding the safety topics. The green roof brings great educational benefits to a university that values sustainability and simultaneously provides a great fiscal return on investment. Finally, while it is an emerging style in the area, it is proven that stick-built construction may prove to be a more cost effective system when compared to other prefabricated systems. Considering these investigations, George Mason University will surely continue to construct the best buildings in the Northern Virginia area and maintain an excellent safety and sustainability record while doing so.

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Appendix

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Analysis 2 – Façade Re-design and Implementation of Prevention through Design.

Interview Dialog Notes- John Risley

Q: What makes prevention through design particularly important to a university?

A: Depending on the project and who is paying for the insurances, like a university, reducing injuries will provide a cost benefit. Public image and reputation are also large factors since negative publicity can't be avoided in the case a large incident. Lifecycle approach, we want to build a building that designs out potential risks and reduces maintenance in the long run. Maintenance is quite expensive; nearly ten times the cost of what it would cost to change something during the design phase. PSU is preparing to put PTD into affect with the new Stiedle renovation. The main idea is to get rid of the problems before the problems become apparent.

Q: How is it beneficial to students specifically?

A: If a component fails, it should theoretically take less time for maintenance to get in and fix it. HVAC units, on a rooftop, that are less than 15' from the edge require tie-offs, which take more time. Strategically placing AHUs cut that time. We strive for Best Value (Total Value) Design for higher quality products.

Q: How is it beneficial to your maintenance personnel?

A: Allowing them to work more efficiently is a plus. This occurs when components are easier to access and easier to maintain. Less time spent acquiring/renting special lifts or equipment for access with PtD. Pegula, for example, on the club level in the kitchen, has an HVAC access in the wall which prevents the need for access from the floor below. The Multi-sport roof access, north entrance, has a special stairway from within a mechanical room which means no ladders are needed to get up there with tools and parts. Always go with a stairway instead of a ladder wherever possible.

Q: When letting students take tours, what do you feel are the most important things to remember when directing them through the job site?

A: Currently Penn State has no written policy regarding on site tours. PPE is step one. Anything to identify who the visitors are (to make it obvious) and to make sure the contractor has a schedule and tour itinerary in place are critical. It is important not to delay the project but still want to educate the students. Some universities don't require steel toe boots and some projects have limited extras on site, but not enough for all students. For now, it mainly up to the contractor.

Q: when analyzing maintenance safety and fall protection methods for occupancy, what are the key mechanical aspects to investigate? Where would access doors be best placed?

A: It depends on the piece of equipment; really, some access doors need small sub access (like a hand door). Access to air handlers is in hallway with permanent ladder, but it is preferred to have it behind a door or locked so students don't climb it. The attic space of Sparks building for example, has a ladder where you could be up to 10' off the floor, but with a cage. Most are locked up so students aren't curious.

Analysis 3 – Multi-purpose room Green Roof Addition (with Structural Breadth)

VERTICAL LOADS FOR TYPE 1.5B

No. of Spans	Deck Type	Max. SDI Const. Span	Allowable Total (Dead + Live) Uniform Load (PSF) Span (ft.-in.) C. to C. of Support										
			5'-0	5'-6	6'-0	6'-6	7'-0	7'-6	8'-0	8'-6	9'-0	9'-6	10'-0
1	B 24	4'-8	66	52	42	36	30	27	24	21	20		
	B 22	5'-7	91	71	57	47	40	34	30	27	24	22	20
	B 21	6'-0	104	81	64	53	44	38	33	29	26	24	22
	B 20	6'-5	115	89	71	58	48	41	36	31	28	25	23
	B 19	7'-1	139	107	85	69	57	48	41	36	32	29	26
	B 18	7'-8	162	124	98	79	65	55	47	41	36	32	29
	B 16	8'-8	206	157	123	99	81	68	58	50	44	39	34
2	B 24	5'-10	126	104	87	74	64	55	47	41	36	32	29
	B 22	6'-11	102	85	71	61	52	46	40	35	32	28	26
	B 21	7'-4	118	97	82	70	60	52	46	41	36	33	29
	B 20	7'-9	132	109	91	78	67	59	51	46	41	36	33
	B 19	8'-5	154	127	107	91	79	69	60	53	48	43	39
	B 18	9'-1	174	144	121	103	89	78	68	60	54	48	44
	B 16	10'-3	219	181	152	130	112	97	86	76	68	61	55
3	B 24	5'-10	130	100	79	65	54	45	39	34	31	27	25
	B 22	6'-11	128	106	89	76	65	57	50	44	39	34	31
	B 21	7'-4	147	122	102	87	75	65	56	49	42	38	34
	B 20	7'-9	165	136	114	97	84	72	61	53	46	41	36
	B 19	8'-5	193	159	134	114	98	84	71	61	53	47	41
	B 18	9'-1	218	180	151	129	111	96	81	69	60	52	46
	B 16	10'-3	274	226	190	162	140	119	100	85	73	64	56

Notes: 1. Load tables are calculated using sectional properties based on the steel design thickness shown in the Steel Deck Institute (SDI) Design Manual.
2. Loads shown in the shaded areas are governed by the live load deflection not in excess of 1/240 of the span. A dead load of 10 PSF has been included.
3 ** Acoustical Deck is not covered under Factory Mutual

Figure 1: Roof loading table from Vulcraft

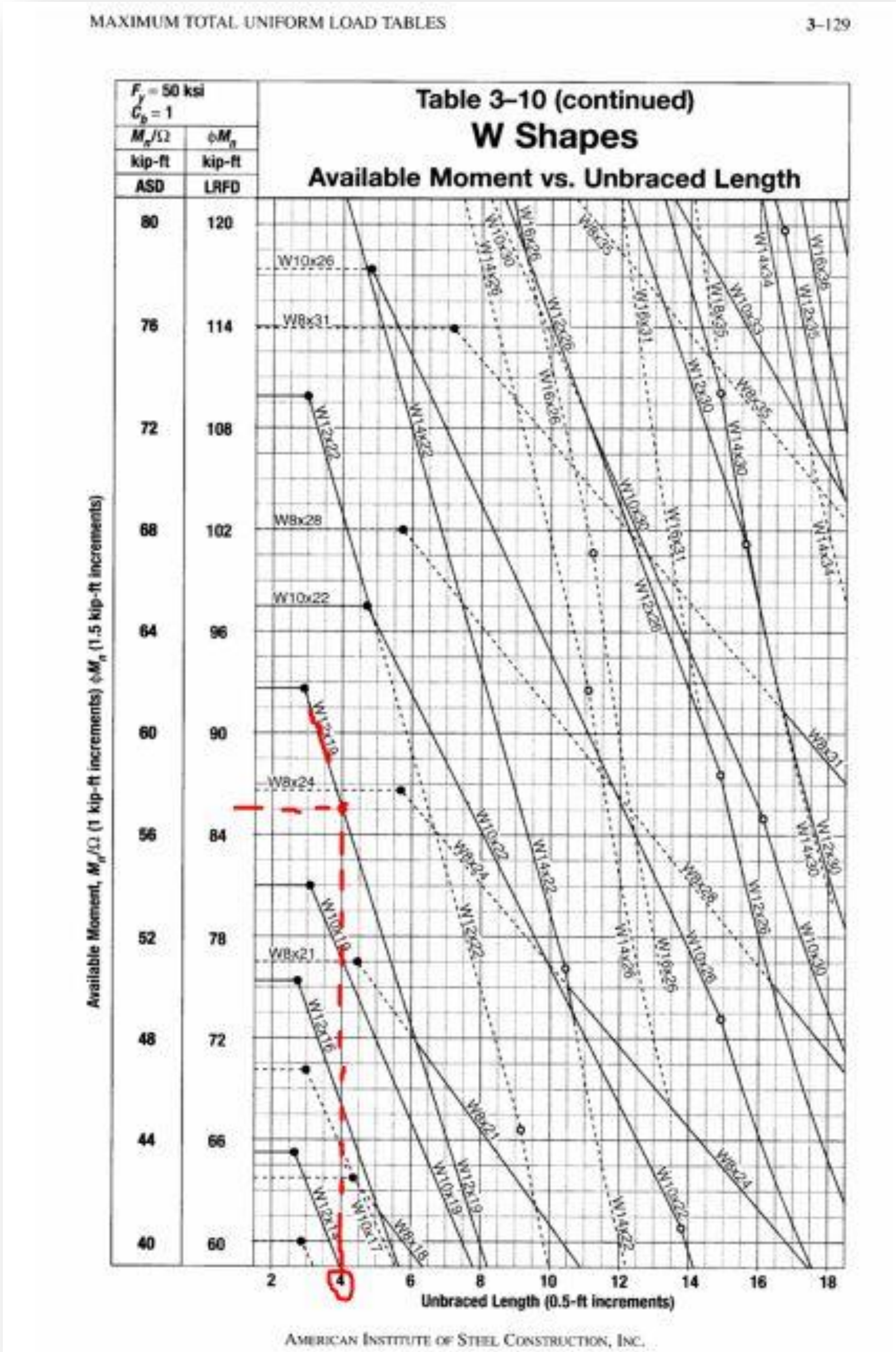
LRFD

STANDARD LOAD TABLE FOR OPEN WEB STEEL JOISTS, K-SERIES
Based on a 50 ksi Maximum Yield Strength - Loads Shown in Pounds per Linear Foot (plf)

Joist Designation	8K1	10K1	12K1	12K3	12K5	14K1	14K3	14K4	14K6	16K2	16K3	16K4	16K5	16K6	16K7	16K9
Depth (in.)	8	10	12	12	12	14	14	14	14	16	16	16	16	16	16	16
Approx. Wt (lbs./ft.)	5.1	5.0	5.0	5.7	7.1	5.2	6.0	6.7	7.7	5.5	6.3	7.0	7.5	8.1	8.6	10.0
Span (ft.) ↓																
8	825 550															
9	825 550															
10	825 480	825 550														
11	798 377	825 542														
12	666 288	825 455	825 550	825 550	825 550											
13	565 225	718 363	825 510	825 510	825 510											
14	486 179	618 289	750 425	825 463	825 463	825 550	825 550	825 550	825 550							
15	421 145	537 234	651 344	814 428	825 434	766 475	825 507	825 507	825 507							
16	369 119	469 192	570 282	714 351	825 396	672 390	825 467	825 467	825 467	825 550	825 550	825 550	825 550	825 550	825 550	825 550
17		415 159	504 234	630 291	825 366	592 324	742 404	825 443	825 443	768 488	825 526	825 526	825 526	825 526	825 526	825 526
18		369 134	448 197	561 245	760 317	528 272	661 339	795 397	825 408	684 409	762 456	825 490	825 490	825 490	825 490	825 490
19		331 113	402 167	502 207	681 269	472 230	592 287	712 336	825 383	612 347	682 386	820 452	825 455	825 455	825 455	825 455
20		298 97	361 142	453 177	613 230	426 197	534 246	642 287	787 347	552 297	615 330	739 386	825 426	825 426	825 426	825 426
21			327 123	409 153	555 198	385 170	483 212	582 248	712 299	499 255	556 285	670 333	754 373	822 405	825 406	825 406
22			298 106	373 132	505 172	351 147	439 184	529 215	648 259	454 222	505 247	609 289	687 323	747 351	825 385	825 385
23			271 93	340 116	462 150	321 128	402 160	483 188	592 226	415 194	462 216	556 252	627 282	682 307	760 339	825 363
24			249 81	312 101	423 132	294 113	367 141	442 165	543 199	381 170	424 189	510 221	576 248	627 269	697 298	825 346
25						270 100	339 124	408 145	501 175	351 150	390 167	469 195	529 219	576 238	642 263	771 311
26						249 88	313 110	376 129	462 156	324 133	360 148	433 173	489 194	532 211	592 233	711 276
27						231 79	289 98	349 115	427 139	300 119	334 132	402 155	453 173	493 188	549 208	658 246
28						214 70	270 88	324 103	397 124	279 106	310 118	373 138	421 155	459 168	510 186	612 220
29										259 95	289 106	348 124	391 139	427 151	475 167	570 198
30										241 86	270 96	324 112	366 126	399 137	444 151	532 178
31										226 78	252 87	304 101	342 114	373 124	415 137	498 161
32										213 71	237 79	285 92	321 103	349 112	388 124	466 147

Figure 2: LRFD loading diagram for K-Series Joists

Figure 3: Allowable Girder Loading from US. Steel Design Manual.



Load Bearing Capacity of Standard Steel Pipe Columns
(36 KSI Yield)

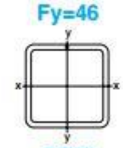
Nominal Dia. (in.)	Outside Dia. (in.)	Wall Thickness (in.)	Weight (lb./ft.)	Allowable Load in Thousands of Pounds — Unsupported Column Length (ft.)*				
				6	8	10	12	14
3	3.50	0.216	7.58	38	34	28	22	16
3-1/2	4.00	0.226	9.11	48	44	38	32	25
4	4.50	0.237	10.79	59	54	49	43	36
5	5.563	0.258	14.62	83	78	73	68	61
6	6.625	0.280	18.97	110	106	101	95	89

* The above loads are the allowable loads for a column in which the load acts downward along the longitudinal axis of the column. For other designs, such as a column with a side load consult with an engineer for the proper size. When in doubt consult with an engineer.

Figure 4: Steel Pipe Column Loading table.

LRFD Columns
Square HSS

Design Axial Strength in kips (ϕ=0.85)



Nominal Size	4 x 4						3 1/2 x 3 1/2				
Wall Thickness	1/2	3/8	5/16	1/4	3/16	1/8	3/8	5/16	1/4	3/16	1/8
Weight Per Foot	21.63	17.27	14.83	12.21	9.42	6.46	14.72	12.70	10.51	8.15	5.61
Design Wall Thickness	0.465	0.349	0.291	0.233	0.174	0.116	0.349	0.291	0.233	0.174	0.116
	F_y = 46 ksi										
Effective length KL in feet: 0	235	187	160	132	101	69	160	138	114	88	60
2	231	184	158	130	99	68	156	134	111	86	59
3	225	179	154	127	97	67	151	131	108	83	57
4	218	174	150	123	95	65	145	125	104	80	55
5	208	167	144	119	91	63	137	119	99	77	53
6	198	159	137	113	87	60	128	112	93	72	50
7	185	150	129	107	83	57	119	103	87	68	47
8	172	140	121	101	78	54	108	95	80	62	43
9	159	129	113	94	73	51	98	86	73	57	40
10	145	119	104	87	67	47	87	77	65	51	36
11	131	108	95	79	62	43	76	68	58	46	32
12	117	97	86	72	56	40	66	60	51	41	29
13	103	87	77	65	51	36	57	51	44	36	25
14	90	77	68	58	46	32	49	44	38	31	22
15	79	67	60	51	41	29	43	39	33	27	19
16	69	59	53	45	36	26	38	34	29	24	17
17	61	52	47	40	32	23	33	30	26	21	15
18	55	47	42	36	28	20	30	27	23	19	13
19	49	42	37	32	25	18	27	24	21	17	12
20	44	38	34	29	23	16	24	22	19	15	11
21	40	34	31	26	21	15	22	20	17	14	10
22	37	31	28	24	19	14			16	12	9
23	34	29	25	22	17	12					
24		26	23	20	16	11					
25				18	15	10					
26						10					
27											

Figure 5: LRFD Loading Table for Square HSS Columns

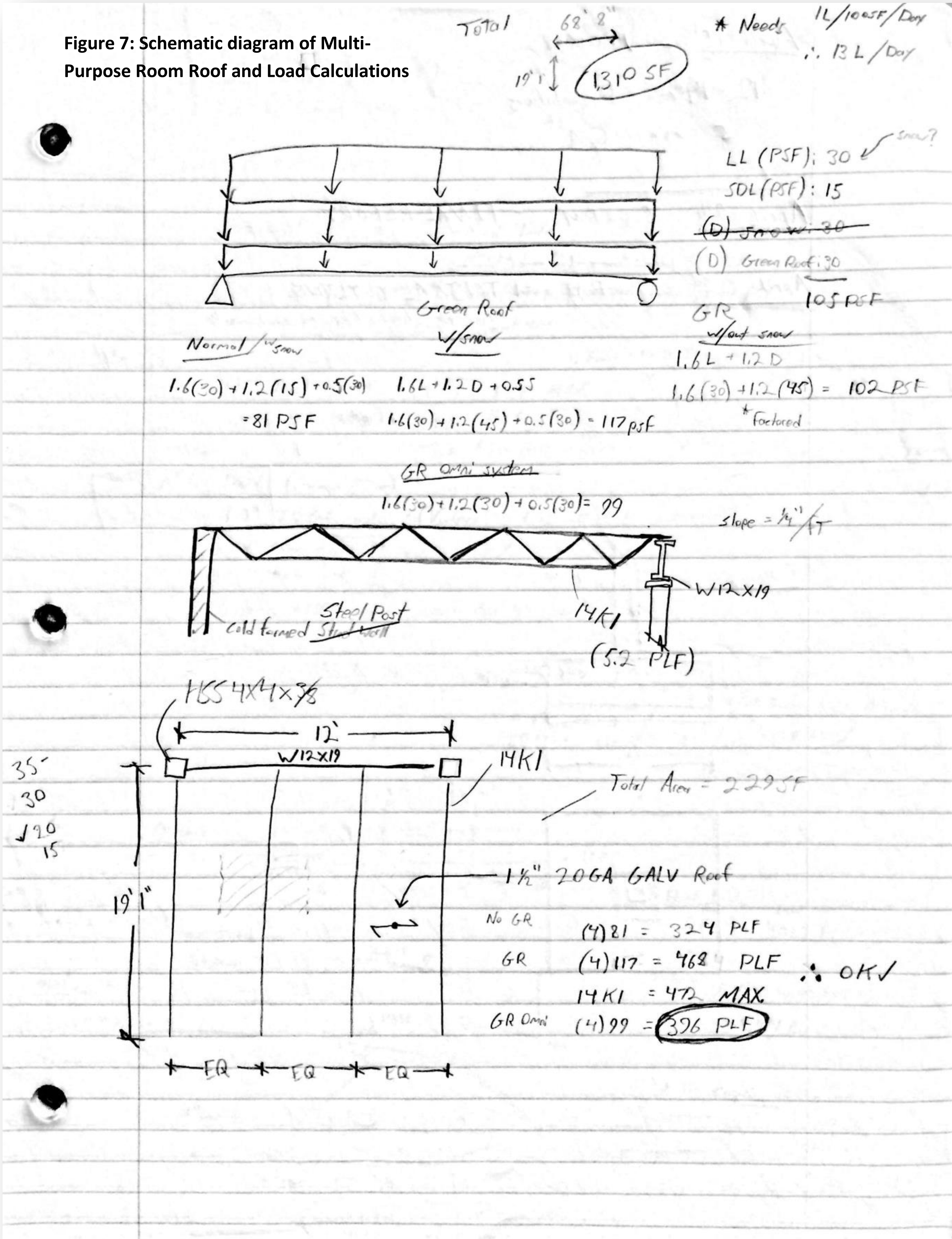
SOIL BEARING CAPACITY

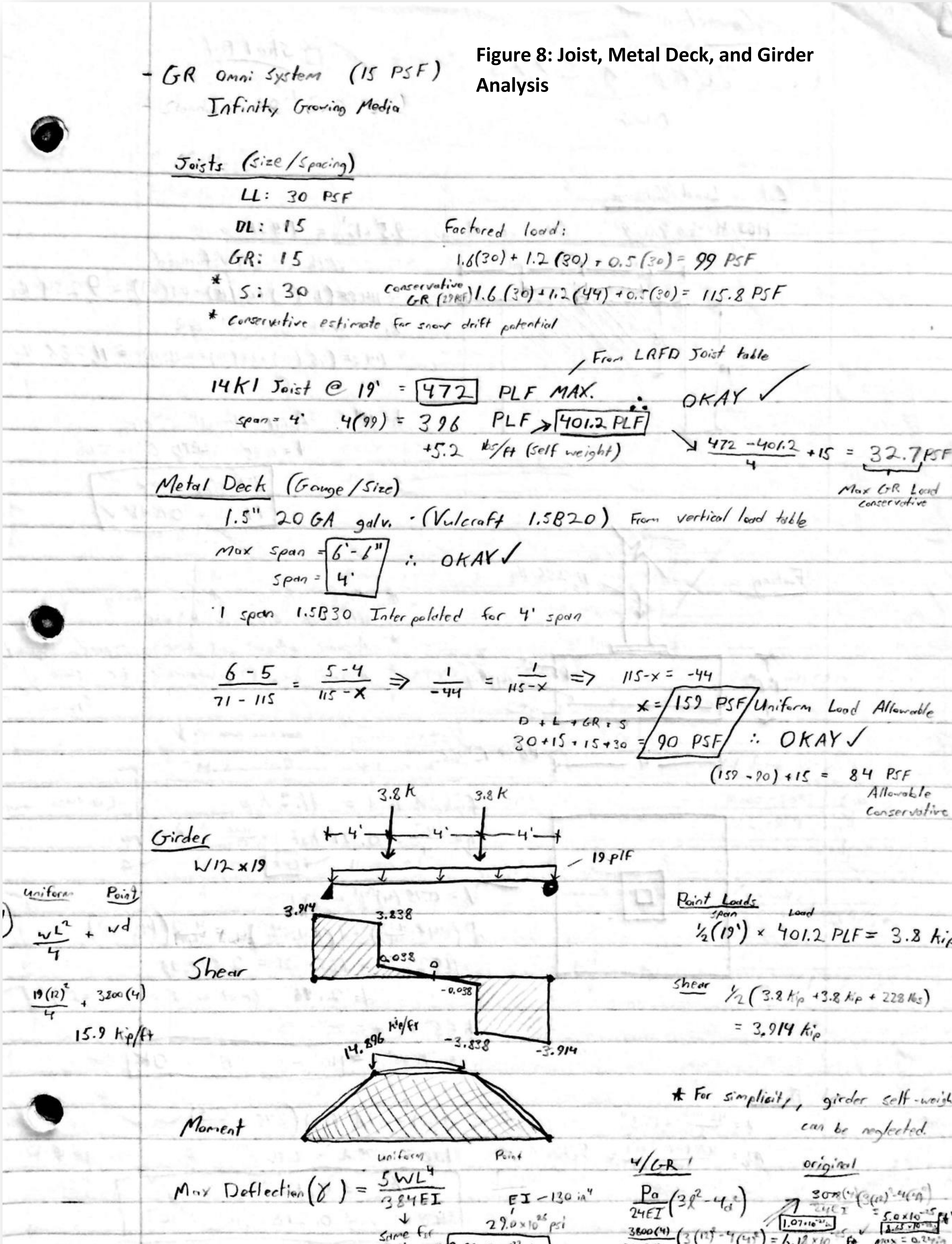
TABLE 1804.2
ALLOWABLE FOUNDATION AND LATERAL PRESSURE

Class of Materials	Allowable Foundation Pressure (psf)[d]	Lateral Bearing (psf/f below natural grade)[d]	Lateral Sliding	
			Coefficient of friction[a]	Resistance (psf)[b]
1. Crystalline bedrock	12,000	1,200	0.70	—
2. Sedimentary and foliated rock	4,000	400	0.35	—
3. Sandy gravel and/or gravel (GW and GP)	3,000	200	0.35	—
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	2,000	150	0.25	—
5. Clay, sandy clay, silty clay, clayey silt, silt and sand silt (CL, ML, MH and CH)	1,500[c]	100	—	130

Figure 6: Soil Bearing Capacity Table

Figure 7: Schematic diagram of Multi-Purpose Room Roof and Load Calculations





- GR Omni System (15 PSF)
  Infinity Growing Media

Joists (Size/Spacing)

LL: 30 PSF
DL: 15
GR: 15
* S: 30

Factored load:
1.6(30) + 1.2 (30) + 0.5 (30) = 99 PSF
conservative GR (29 PSF) 1.6 (30) + 1.2 (44) + 0.5(30) = 115.8 PSF

* Conservative estimate for snow drift potential

From LRFD Joist table
14K1 Joist @ 19' = 472 PLF MAX. ∴ OKAY ✓
span = 4'   4(99) = 396 PLF → 401.2 PLF
+5.2 lbs/ft (self weight)
(472 − 401.2)/4 + 15 = 32.7 PSF
Max GR Load conservative

Metal Deck (Gauge/Size)

1.5" 20 GA galv. · (Vulcraft 1.5B20) From vertical load table
Max span = 6'-6"
span = 4'
∴ OKAY ✓

1 span 1.5B30 Interpolated for 4' span

(6 − 5)/(71 − 115) = (5 − 4)/(115 − x) ⇒ 1/(−44) = 1/(115 − x) ⇒ 115 − x = −44
x = 159 PSF Uniform Load Allowable
D + L + GR + S
30 + 15 + 15 + 30 = 90 PSF ∴ OKAY ✓
(159 − 90) + 15 = 84 PSF Allowable Conservative

Girder
W12x19

3.8 k, 3.8 k; 4' – 4' – 4'; 19 plf

Uniform + Point
wL²/4 + wd
19(12)²/4 + 3800(4)
15.9 kip/ft

Point Loads
½(19') × 401.2 PLF = 3.8 kip

Shear
½ (3.8 kip + 3.8 kip + 228 lbs)
= 3,914 kip

Shear: 3.914, 3.838, 0.038, 0, −0.038, −3.838, −3.914

Moment: 14.896 kip/ft

* For simplicity, girder self-weight can be neglected.

Max Deflection (γ) = 5WL⁴/384EI (uniform)
EI − 130 in⁴
29.0 × 10⁶ psi
Same for Both = 2.82 × 10⁻²² in.

Point: 4/GR: Pa/24EI (3l² − 4a²)
3800(4)/24EI (3(12)² − 4(4)²) = 6.12 × 10⁻⁵ ft
original: 30 × (4)(3(12)² − 4(4)²)/24EI = 5.0 × 10⁻⁵ ft ✓
1.07 × 10⁻²¹ ... 1.63 × 10⁻²³ ... max = 0.24 in

Figure 8: Joist, Metal Deck, and Girder Analysis

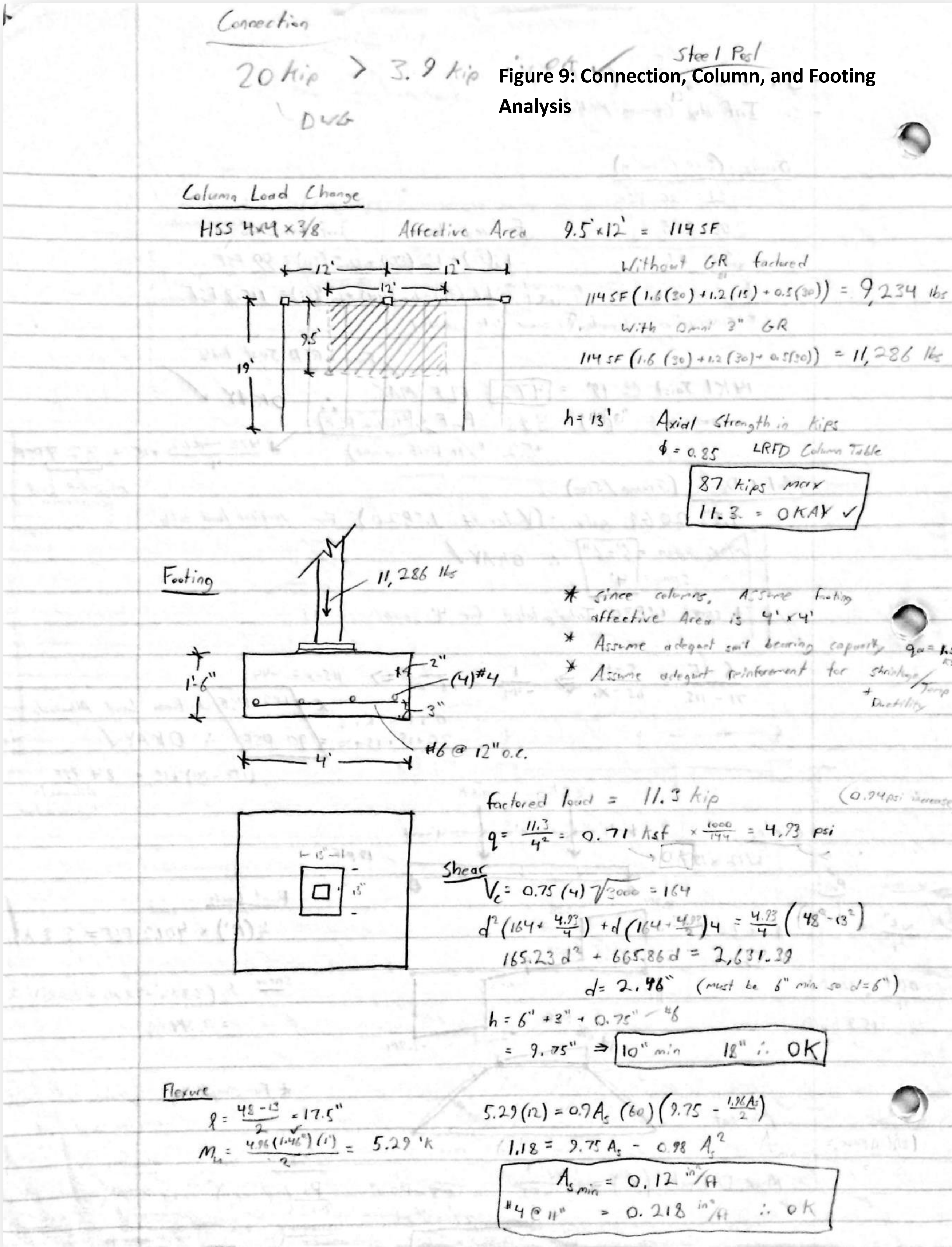


Figure 9: Connection, Column, and Footing Analysis

Figure 10: Green Roof Cost/Benefit Analysis

DC Cost Data

Initial Premium

$$\frac{10{,}000 - 5{,}000}{9.5 - 10.7} = \frac{5{,}000 - 1{,}310}{10.7 - x}$$

(−) $x = \$11.59/SF$

Net Present Value of Installation, Replacement & Maintenance (50-year)

$$\frac{10{,}000 - 5{,}000}{17.9 - 18.1} = \frac{5{,}000 - 1{,}310}{18.1 - x}$$

(−) $x = \$18.25/SF$

NPV Stormwater

$$\frac{10{,}000 - 5{,}000}{10.5 - 11.0} = \frac{5{,}000 - 1{,}310}{11.0 - x}$$

(+) $x = \$11.37/SF$

NPV Energy

$$\frac{50{,}000 - 10{,}000}{8.3 - 6.8} = \frac{10{,}000 - 1{,}310}{6.8 - x}$$

(+) $x = \$6.47/SF$

NPV − $0.41/SF

Internal Rate of Return

$$NPV = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n}$$ (cash flow)

$$0 = -11.59 + \frac{-.0082}{(1+r)^{50}}$$

$$\frac{50{,}000 - 10{,}000}{4.7 - 4.3} = \frac{10{,}000 - 1{,}310}{4.3 - r}$$

$r = 4.21\%$

Real Estate Value

$$\frac{10{,}000 - 5{,}000}{88.2 - 98.4} = \frac{5{,}000 - 1{,}310}{98.4 - x}$$

$x = \$105.93/SF$

Payback

$$\frac{50{,}000 - 10{,}000}{6 - 6.6} = \frac{10{,}000 - 1{,}310}{6.6 - n}$$

$n = 6.7$ years

Community

$30.9/SF

Return on Investment

$$\frac{50{,}000 - 10{,}000}{209 - 198} = \frac{10{,}000 - 1{,}310}{198 - x}$$

$x = 196\%$

CO_2e

$2.6/SF

Net 50-year

+ $157.27/SF
− $18.25/SF
$139.02/SF / 50

= $2.78/SF/year

Actual Pay off

$$\frac{11.59}{2.78} = 4.17 \text{ years}$$

Analysis 4: Stick-Built vs. Infinity Structural System

Figure 11: Square foot cost analysis of Stick-Built construction vs. Infinity System

Roof: Stick-Built vs. Infinity System

From Tech II

	$/SF
Total $1,086,434.97	$15.50
RS Means	$19.98
Infinity	$23.00
Original from BBC	$30.00

TOTAL

Roof = $128,240.64

Int. Frame = $612,998.75

Joists/Girders = $1,224,596.36

$1,965,835.75

= $28.06/SF × Fairfax, VA factor (78.3) Wood work

= $21.97/SF

∴ Saving $72,158.71

Stick Built

- Wood Roof

Wood truss 5" 12 slope, 24" O.C. (Assumed *)

Span is 45' 10.5" + 4' lip → 49' 10.5"

- 44' to 60' span

Materials	Installation	Total
4.43	2.61	7.04

Slope pitch multiplier (5 in 12) = 1.083

Roof Area (flat) = 16,820 SF

(pitch) = 18,216 SF

Sub-Total = $128,240.64

- Wood Partitions *

5/8" Drywall / Res. channel / 2×4 @ 16" O.C. / Res. chanel / 5/8" Drywall | 1-½" Fiberglass

Materials	Installation	Total
2.10	6.65	8.75

Floor Area (Net) = 70,057

Sub-Total = $612,998.75

- Joists/Girders

	SDL	LL	
Residential Load =	20	40	= 60 / Majority
Stairs (Max) =	SDL 20	LL 100	= 120

Sub-Total = $1,224,596.36

* Assume 15' × 15' Bay

Superimposed Load = 75 PSF

Girder	Joists	Total Load
8×16 4×16	2×8 @ 16	90

Floor Area (Net) = 70,057

Materials	Installation	Total
12.60	4.88	17.48

Brad Williams
Faculty Consultant: Ed Gannon
Architectural Engineering – Construction Management
Building Statistics – Part 1
8/30/13

GENERAL BUILDING DATA

Building Name: Taylor Hall, George Mason University
Location and Site: Campus of George Mason University
10444 Presidents Park Drive
Fairfax, VA
Building Occupant Name: George Mason University
Occupancy Type: Dormitory, New Construction
Mixed Use:
R-1/R-2: Residential - Dormitory
R-2: Residential – Apartment
A-3: Assembly
S-2: Storage
B: Business
Size (SF): 70,057 GSF
Number of stories above grade: 4
Primary Project Team:
Owner: George Mason University
CM: Balfour Beatty Construction (www.balfourbeattyus.com)
Architect: Gensler (www.gensler.com)
Structural Engineer: Thornton Tomasetti (www.throntontomasetti.com)
Civil Engineer: Paciulli, Simmons & Associates (www.psaltd.com)
MEP Engineer: Encon Group (www.encongroup.com)
Dates of Construction: May ’13 – June ‘14
Overall Project Cost: $16,000,000
Delivery Method: Design-Build (with competitive bid)

ARCHITECTURE

Architectural design function: The building will function as a freshman dorm building and is intended to be separated into different communities or groups (See figure 1) of rooms with several study and congregation areas. The ground floor will a multi-purpose common room, staff apartments, a full laundry room, a housing office, group living rooms, and bathrooms, in addition to mechanical, electrical, and sprinkler rooms.

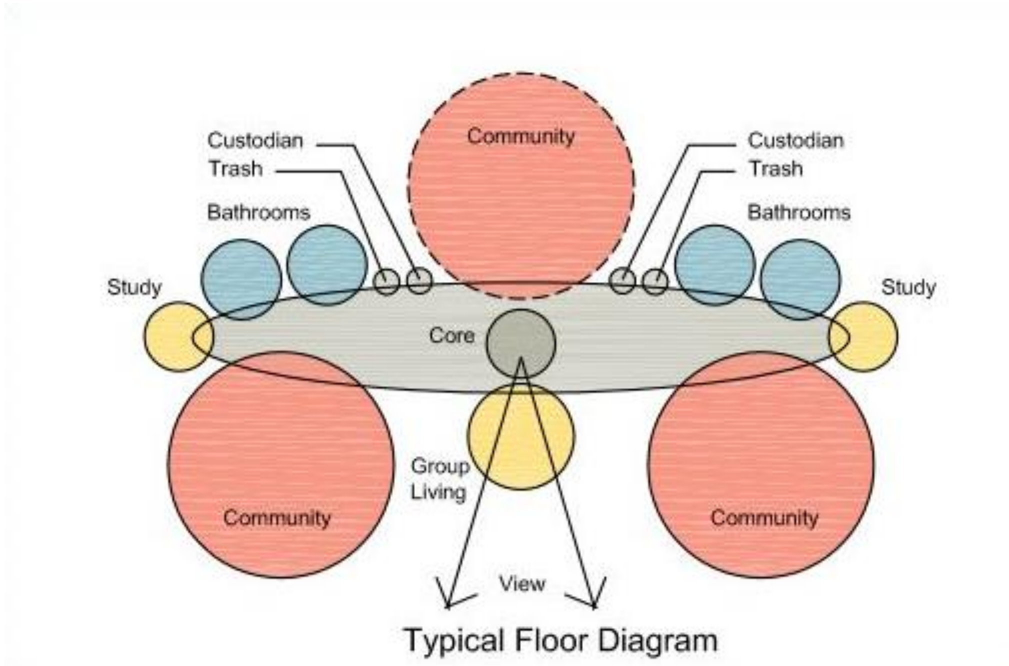


Figure 1. Floor Diagram representation from George Mason University's Request for Proposal

Major Codes:

General:
- ICC International Building Code (IBC) – 2009
- The Americans with Disabilities Act Accessibility Guidelines "ADAAG "– 2004
- CC. USGBC LEED 2009 for New Construction and Major Renovations
- National Fire Protection Association (NFPA) – 2007

Mechanical:
- ASHRAE Standard 62-2010 Ventilation for Acceptable Indoor Air Quality
- ICC International Mechanical Code (IMC) – 2009
- ASHRAE Standard 90.1-2010 Energy Standard for Buildings Except Low-Rise Residential Buildings

Electrical:
- National Electrical Code (NEC) – 2008
- ICC International Energy Conservation Code (IECC) – 2009
- National Electrical Code/NFPA 70 – 2008

Plumbing:
- ICC International Plumbing Code (IPC) – 2009

Zoning: Must maintain 100' tree buffer (save area) between site and Roberts Rd per University tree protection agency. Must maintain silt fences to trap job-site runoff from nearby stream 350' south of site.

Historical requirements of the building: BCOM must approve that the design meets regulations and verify that it matches the design of the surrounding buildings. Traditionally, GMU has a very modern Architecture type.

BUILDING ENCLOSURE

The typical building façade is a weep holed running-bond brick face with an air space, followed by 2" polyisocyanurate building insulation, moisture barrio, spray foam insulation, 6" metal studs, and 2 layers of 5/8" GWB. In some cases there are insulated composite metal panels installed in place of the brick. There are aluminum storefront segments in the multipurpose rooms and on the first floor with both vision glass and spandrel glass. These aluminum storefronts have thermal barrios within them to avoid the creation of a heat bridge. Frosted glass is also used in bathroom areas.

The roofing system is the standard applied to surrounding buildings, as required from BCOM. It is an asphalt shingle system attached to a self-adhering, high-temperature rubberized asphalt underlayment. In areas not covered by the self adhering underlayment, a felt underlayment is to be used. This is attached to blocking and substrate insulation on metal decking.

SUSTAINABILITY FEATURES

The building is expected to meet or exceed DEB Notice 121510 (Virginia Energy Conservation and Environmental Standards) and will exceed 2006 IECC energy standards. It is also expected to implement Green Building educational features, that monitor and display live building power consumption to help influence conservation of energy. Enthalpy Plate Heat exchangers are used in the rooftop air handling unit which help to precondition the incoming outside air. This system is also a variable speed system to slow down air production when the building is in low occupancy. These steps help to reduce energy usage. Combined with usage of local materials, daylighting strategies, low emitting materials, and site sustainability features, the building is currently tracking 58 LEED points and is expected to easily obtain LEED Silver certification.

Structural

Taylor Hall's structural system makes use of the patented Infinity Structural System with the intention of schedule acceleration. After talking with a representative from a major specialty contractor who installs the system, this method can be erected a little more than 3 times faster than a standard concrete building.

The foundation of the building consists of shallow footings, as deep as 3' -4'. Column footings reach dimensions as high as 13'x 13'. Each of the bearing a shear walls on the first floor have their slabs thickened to 1' deep and 2' wide on center. The standard slab on grade thickness is 5" for Taylor Hall.

One interesting feature is the elevation change in the slab on grade. Near the elevator pit, the deepest excavation on site (-10'), there is a 4' elevation difference between the living "community" of the ground floor and the common rooms, office, and laundry room areas.

The superstructure is composed of HSS columns, with a variety of sizes and thickness ranging from 3/8" to ½". The columns are spliced at the second story and reach a total height from 40' to 56'. A variety of beams are used to support the Infinity slab system, but not nearly as much as a typical steel frame building would have. The 10'-25' W12's in Taylor Hall only accumulate to 18.3 tons of steel.

Infinity Structural System's in place make use of load bearing, shear bearing, and load/shear bearing cold – formed walls. These walls are panelized into an average of 10' segments and prefabricated off site. Depending on their application and load, they have 3 5/8" and 5 5/8" thick walls that are 16" off center, and 12" in some areas requiring more bearing. The metal decking is a patented dovetail pattern 20 gage metal, which allows for maximum contact area with the load bearing stud walls. The system is completed with 4" of normal weight concrete slab on deck with 1.5 lbs per SF of reinforcement. Maximum spans using this system allow for columns to be placed as far as 28' apart.

Mechanical

Taylor Hall's mechanical system consists of a hydronic heating system that feeds individual units which heat incoming air. The system is tied into the campus' high temperature hot water system and through two heat exchangers located in the mechanical room. This converts transfers heat to the buildings' low temperature hot water system for distribution. The temperature drop from heat exchange to the furthest unit is 30 degrees Fahrenheit.

The building is fed from one rooftop air handling unit. The unit feeds the building with 23,500 CFM of 100% Outside Air. Incoming air is preconditioned with an enthalpy wheel for heat recovery and energy savings. The air feeds 3 vertical risers which are then distributed to living areas. For keeping a positive pressure in the building, the exhaust air is less powerful and is taken through above-ceiling plenums in the corridors. Bathrooms have their own exhaust air vent stacks and exhaust fans.

Electrical

Taylor Hall has a total electrical load of 1200A and is fed from a transformer just north of the site. Through underground duct banks, 2 480/277 V 3-phase busses feed the building. After passing through a main switchboard, distribution cables feed 3 panels per floor for residential units. Conduit for each room is run through the concrete slabs on deck. Other electrical loads, such as the elevators and mechanical equipment, have their own electrical panels. The building has a designated diesel powered emergency generator on the exterior of the building to fully power the building in the case of a power outage.

Plumbing

Each floor within Taylor Hall has 2 group bathrooms, each consisting of men's and women's rooms. In each bathroom, there are 3 lavatories, 3 water closets, 2 standard showers, and a handicap shower. Each floor also has an individual 3 unit bathroom for the resident associate. The ground floor has one extra group bathroom with 2 water closets and lavatories per gender for the multipurpose room. All waste is tied directly into the campus sewage system located west of the site.

Taylor Hall

George Mason University
Fairfax, VA

Technical Assignment 1

Executive Summary

Brad Williams
Construction Management
Faculty Consultant: Ed Gannon

Technical Assignment 1
September 16, 2013

<u>Executive Summary</u>

Taylor Hall is a freshman dormitory located at George Mason University's main campus in Fairfax, VA. The 70,057 GSF facility will house 295 students and will be located in the south eastern corner of campus. George Mason University has been growing rapidly since the 1960's and has taken pride in exuding excellence through a unique brand of building style. Each building's architecture is carefully planned to knit students into distinct communities and intertwine nature with protected open spaces. Taylor Hall is expected to maintain this tradition in every way possible.

Because of university's transition from a commuter campus to a full time student campus, the need for housing has been critical in the past few years. In 2012, the university added a total of 1200 beds through two new dormitories on the north end of campus, but the demand continued. The addition of 295 beds in the southern end of campus will house freshman students near "President's Park" and "Liberty Square," other student residential communities.

The current cost is set to be $16 million and there is a very strict schedule to complete the building by the fall of 2014. The building is made to integrate students into a collaborative atmosphere through two "communities" brought together by common areas and group living rooms. This was portrayed in Taylor Hall as two wings of rooms with group living areas, study lounges, and large bathrooms on each wing. The ground floor of the building has a laundry room, a common room for games and entertainment, and a housing office. George Mason's standards include the goal of LEED Silver, which makes for a healthy and cost efficient lifestyle that will benefit both the university and its' students.

The delivery method is Design – Build with a competitive bid process based on design, schedule, and cost. Each general contractor manages an architect to create a design that would fit George

Mason's requests in a cost effective manner. After a short list is created, University and The Commonwealth of Virginia officials pick the design that most accurately reflects the culture of the university, its surrounding buildings, and fits the budget set forth. Luckily, Balfour Beatty Construction had already made a great impression on university officials upon the recent completion of The Mason Inn, a $55 million hotel and conference center.

Upon winning the bid, Balfour Beatty quickly assembled a team of talented individuals that had previously worked on George Mason's campus and were familiar with the area. By putting this team together, the university would feel safe knowing that they understood the standards and protocols well and could integrate construction with campus life in the safest way possible.

The project delivery team expanded as the design phase continued. Since the project was fast-tracked, the foundation was in place before the working drawings were approved for a handful of trades. As part of the Design-Build structure, Balfour Beatty managed both the Architect and the sub-contractors performing the work.

The site had already been drilled for core samples and the geotechnical reports noted fair soil properties for a building. Since the building location in south-east campus was part of the university's master plan, the nearby utilities were set to accommodate a residential building with around 300 students. The only utilities needed would be telecom to be trenched in from the nearby Patriot Circle. A 500 kVa transformer due north of the site provides temporary electricity during construction will provide permanent power after construction. The dorm's location is also very close to the campus hot and cold water system, needed for the mechanical and plumbing systems. Critical site constraints are the protection of the trees to the east of the site and a stream that is roughly 375' south of the site. These tree's will serve as a natural noise buffer between the dorm and Robert's Road while the stream serves as an artery for campus nature preserves and cannot be polluted.

The structural system of the dormitory is a steel frame with slabs on metal decks. Column footings and the elevator shaft mark the extent of excavation needed in the shallow foundations. There will be no basement in the dormitory. The superstructure is comprised of HSS steel columns and load bearing cold-formed steel walls. Prefabricated concrete shear walls provide for further structural support and fire barriers. This structural system allows for the most efficient layout of dormitory spaces while saving valuable time compared to using a concrete super structure.

Heating in the dorm comes from the provided campus high temperature hot water (HTHW) system. These pipes enter two heat exchangers inside the mechanical room to provide heat for the building's low temperature hot water (LTHW) system which provides 120 degree Fahrenheit heat to all terminal units with a 30 degree temperature differential. For redundancy, there is a backup suction pump to move the water through the building to each ran coil, VAV reheat coil, cabinet unit heater, radiators, and an AHU.

The rooftop AHU is a 100% outside air system and is equipped with an energy saving plate type enthalpy heat exchanger for preconditioning. Since the health of the students is a high priority for GMU, MERV 7 and MERV 13 filters are used in the rooftop unit. The unit provides 70 degree air to vertical risers, through the corridor, to VAV boxes and to individual units. The air handling unit is fed from the campus chilled water system (runs parallel to the HTHW) which provides 48 degree water to the building.

The transformer on the north end of the site provides power which is step down to 120/208V 3-phase, 4-wire power after it enters the building's main electrical room. Each floor is equipped with a distribution panel and branch circuits are set in the concrete floors. Energy-saving lighting systems and occupancy sensors help to optimize the power consumption of Taylor Hall during off-season periods.

The expected load of the building is 1200 A and an education display in the lobby will display live building statistics for energy consumption to raise conservation awareness.

Standard running-bond brick makes up the majority of the façade for Taylor Hall. In congregation and study areas, located on each floor and lobby, a curtain wall system is in place to maximize sunlight penetration. These large glass areas are also present in stairwells and frosted glass is featured in the bathrooms. The north facing storefront on the ground floor's common room helps to cut down on energy consumption and fits in with the modern look of the near-by Liberty Square. BCOM must approve all architectural plans to ensure that the building "fits in" with its surrounding buildings. This is the same for all state funded institutional buildings in Virginia.

Table 1. Construction Cost Comparison

	RS Means	Actual	% Difference
HVAC **Plumbing**	$ 38.66	$ 40.00	(3.35%)
Fire Protection	$ 3.58	$ 2.90	23.5%
Electrical	$ 17.38	$ 20.50	(15.2%)
Structural	$ 19.98	$ 30.00	(33.4%)
Construction Cost	$ 157.01	$ 157.02	0%
TOTAL PROJECT	$ 199.81	$ 228.39	(12.5%)

It was quite clear that, because of its intended use, this building must adhere to a strict schedule base on freshman move-in day. Because of this, the project's preliminary structure and excavation were beginning to be put in place before all shop-drawings were received or working drawings approved. Cost was also a factor for the University, but it appears that fast-tracking the project may have driven the price up quite a bit. In the above table, you can see the difference between the predicted costs per square foot (per RS Means) and the actual cost per square foot. Although the construction cost is nearly identical, I believe that the 12.5% difference in building price is due in-part to the acceleration of the schedule.

With a talented project team familiar with GMU's building traditions and an innovative design team, this highly efficient living area will provide a healthy and memorable first-year experience to incoming freshmen. As George Mason's main campus continues to expand, more dormitories will surely pave the ways of growth and uphold the university's traditions in constructing excellent buildings.

Taylor Hall

George Mason University
Fairfax, VA

Technical Assignment 1
Summary Slides

Brad Williams
Construction Management
Faculty Consultant: Ed Gannon

Technical Assignment 1
September 16, 2013

Introduction

Taylor Hall, George Mason University, located in Fairfax, VA

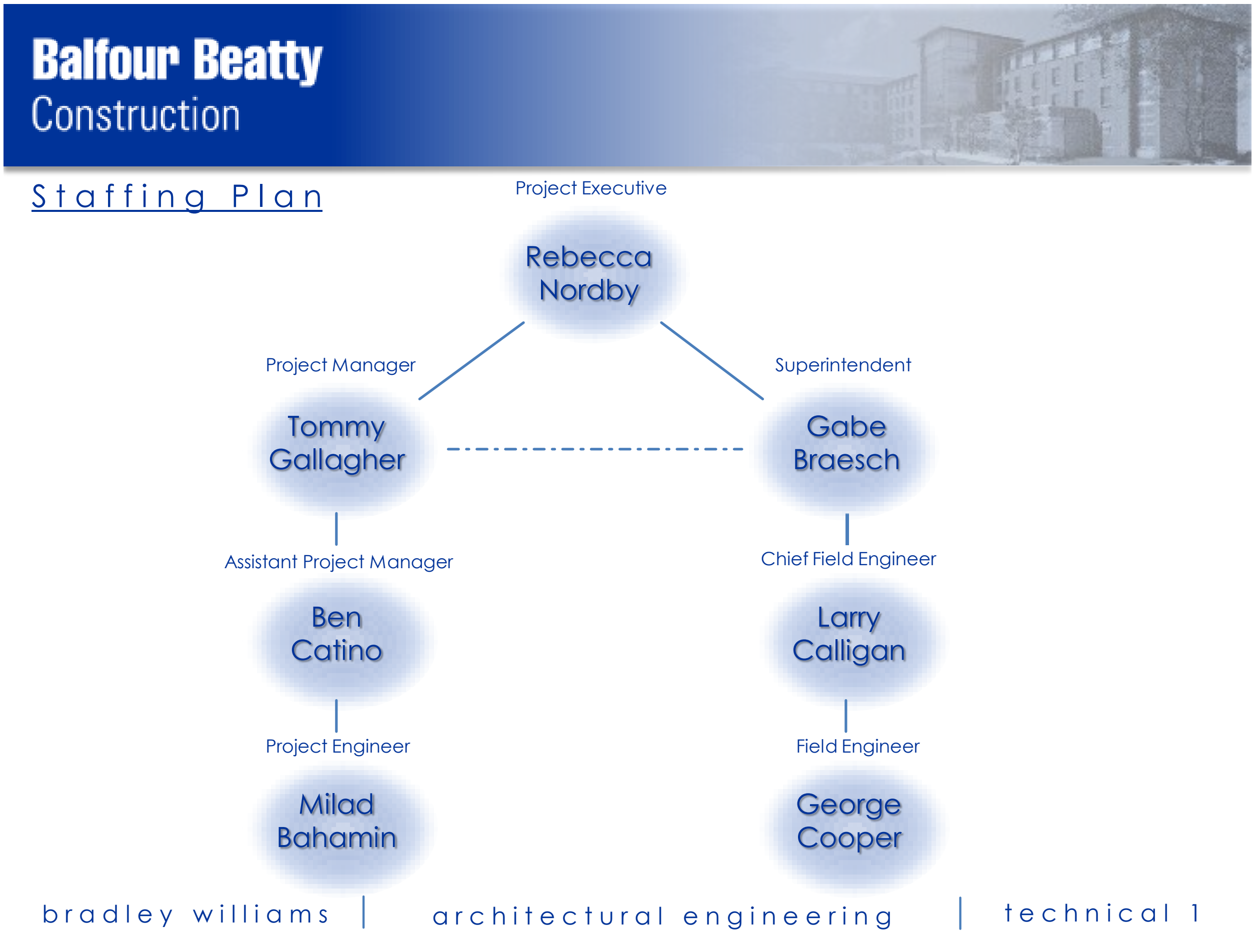
- Freshman dorm to hold 295 students
- LEED Silver
- $16 Million
-

Client Information

Photos from gmu.edu

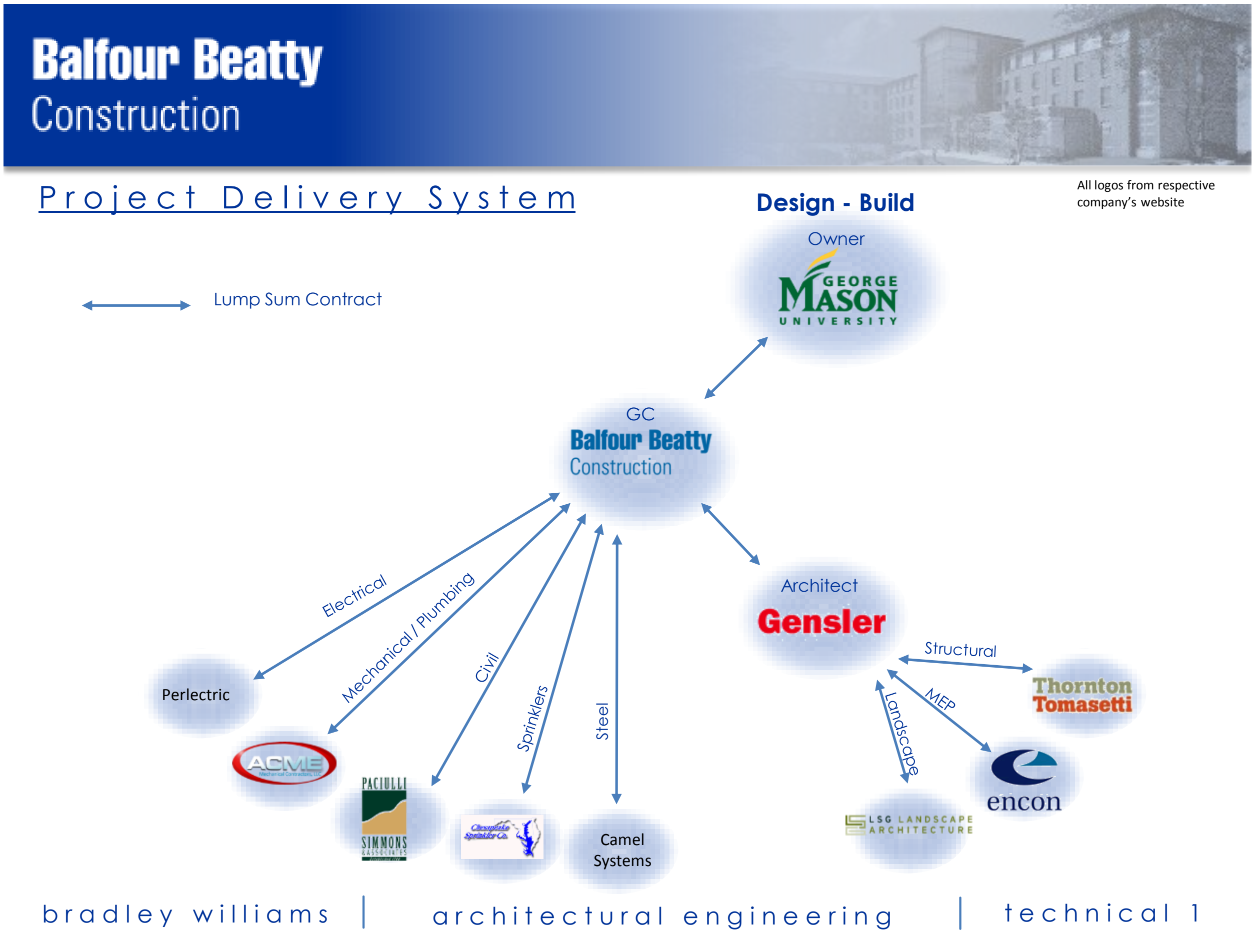
Client Information

- Expanding campus since 1960
- Values woodland “buffer zones” and open congregational spaces
- Has a very modern architecture and state of the art buildings
- Has roughly 3 construction projects underway on campus at any given time, just like Penn State
- BBC recently finished the $55 Million Mason Inn Hotel and conference center
- Project team moves down the street to build the new freshman dormitory for the rapidly growing campus.



Staffing Plan

- The same management personnel from the Mason Inn project were kept together because of their knowledge of George Mason's construction standards and orders of operation.
- Knowledge of how to manage campus construction operations, dealing with student-construction interaction, and adherence to a tight construction schedule.



Project Delivery System

- Design – Build project hosted by George Mason University and the Commonwealth of Virginia
- GMU put out an RFP and GC's managed design teams to complete a competitive design to meet the request and a proposal to compete with other designs.
- Decision was design and cost based
- GC manages subcontractors and architect

Balfour Beatty
Construction

Existing Conditions

• Student/Faculty parking lot

• Geotechnical reports; mostly Silty Clay (ML); no high-plasticity soils or ground water

• No interference with student traffic flow

• Half parking lot still accessible

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Existing Conditions

- Building to be placed in a student/faculty parking lot on the south-east boarder of campus.
- Geotechnical reports showed favorable building conditions, mostly silty-clay. No signs of high-plasticity soils or ground water.
- GMU values the buffer zone and has strict tree protection policies in place
- Current site utilities were designed to accommodate a building in the area, as per the master plan
- Underground electric in red (light poles in parking lot), storm water in aqua, and water main in blue dots.
- Building to be the same height as neighboring Liberty Square
- New utilities include an underground telecom line and ties into nearby water main, HTHW (High Temp. hot water), CWS (Chilled water system) and electricity from nearby transformer
- Site plan will not hinder student flow on campus due to all classes being north of site. Construction delivery easily integrates with existing road loop.

Building Systems Summary

Structural	CIP Concrete	Precast Concrete	Mechanical	Electrical	Masonry	Curtain Wall

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Building Systems Summary

-Structural

Steel frame with HSS columns, designed to maximize space; load bearing cold formed steel walls and precast concrete shear walls

-CIP Concrete

Shallow footings and an elevator pit are the deepest pours on the project. Slab on deck system for floors 2-4.

-Precast Concrete

Precast structural concrete shear walls to maximize space and time. Early coordination needed to form wall penetrations in the right locations.

-Mechanical

Heating system fed from campus high temperature hot water system. Goes through a heat transfer to a building low temperature system to feed unit radiators and terminal units. Cooling from campus chilled water system which works in conjunction with a rooftop AHU with 100% Outside Air. The AHU has a heat recovery system in place and provides 5 CFM per person for dorm rooms.

-Electrical

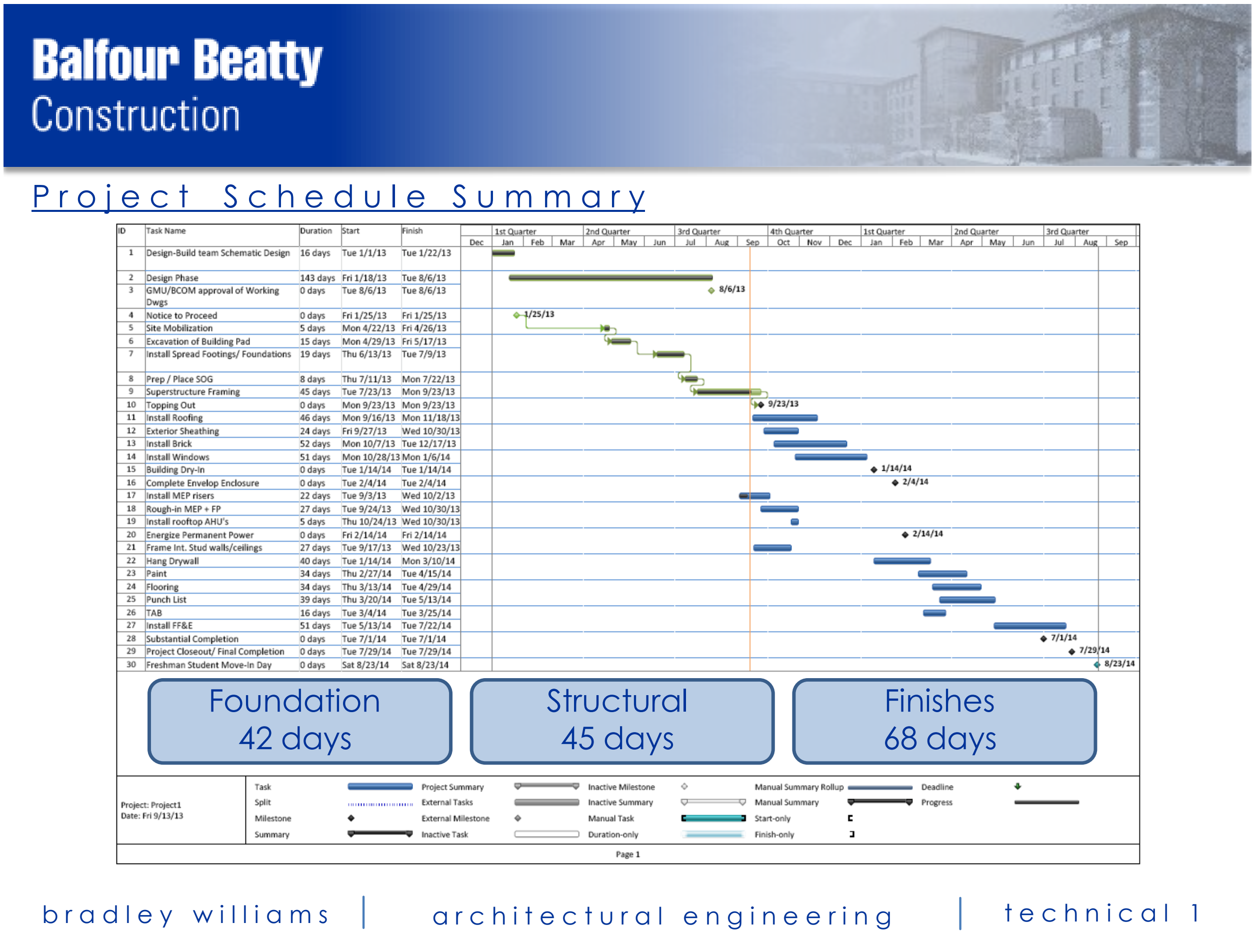
Near-by 500kVa transformer provides power to the site and building. Step down transformers located in the building and panels located on each floor. Branch circuits are located in-slab and building load is expected to be 1200A. There is a diesel fuel emergency generator to back up system.

-Masonry walls

Façade is composed of a standard running-bond brick. It makes up roughly 60% of the face of the building.

-Curtain wall

There are aluminum storefronts making up approximately 30% of the façade. These are located in the elevator areas/group living rooms, stairwells, and ground floor common room.



ID	Task Name	Duration	Start	Finish
1	Design-Build team Schematic Design	16 days	Tue 1/1/13	Tue 1/22/13
2	Design Phase	143 days	Fri 1/18/13	Tue 8/6/13
3	GMU/BCOM approval of Working Dwgs	0 days	Tue 8/6/13	Tue 8/6/13
4	Notice to Proceed	0 days	Fri 1/25/13	Fri 1/25/13
5	Site Mobilization	5 days	Mon 4/22/13	Fri 4/26/13
6	Excavation of Building Pad	15 days	Mon 4/29/13	Fri 5/17/13
7	Install Spread Footings/ Foundations	19 days	Thu 6/13/13	Tue 7/9/13
8	Prep / Place SOG	8 days	Thu 7/11/13	Mon 7/22/13
9	Superstructure Framing	45 days	Tue 7/23/13	Mon 9/23/13
10	Topping Out	0 days	Mon 9/23/13	Mon 9/23/13
11	Install Roofing	46 days	Mon 9/16/13	Mon 11/18/13
12	Exterior Sheathing	24 days	Fri 9/27/13	Wed 10/30/13
13	Install Brick	52 days	Mon 10/7/13	Tue 12/17/13
14	Install Windows	51 days	Mon 10/28/13	Mon 1/6/14
15	Building Dry-In	0 days	Tue 1/14/14	Tue 1/14/14
16	Complete Envelop Enclosure	0 days	Tue 2/4/14	Tue 2/4/14
17	Install MEP risers	22 days	Tue 9/3/13	Wed 10/2/13
18	Rough-in MEP + FP	27 days	Tue 9/24/13	Wed 10/30/13
19	Install rooftop AHU's	5 days	Thu 10/24/13	Wed 10/30/13
20	Energize Permanent Power	0 days	Fri 2/14/14	Fri 2/14/14
21	Frame Int. Stud walls/ceilings	27 days	Tue 9/17/13	Wed 10/23/13
22	Hang Drywall	40 days	Tue 1/14/14	Mon 3/10/14
23	Paint	34 days	Thu 2/27/14	Tue 4/15/14
24	Flooring	34 days	Thu 3/13/14	Tue 4/29/14
25	Punch List	39 days	Thu 3/20/14	Tue 5/13/14
26	TAB	16 days	Tue 3/4/14	Tue 3/25/14
27	Install FF&E	51 days	Tue 5/13/14	Tue 7/22/14
28	Substantial Completion	0 days	Tue 7/1/14	Tue 7/1/14
29	Project Closeout/ Final Completion	0 days	Tue 7/29/14	Tue 7/29/14
30	Freshman Student Move-In Day	0 days	Sat 8/23/14	Sat 8/23/14

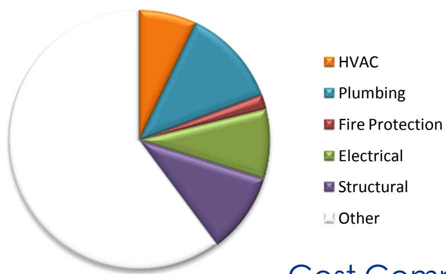
Project Schedule Summary

- There's a total of13 months of construction, driven by student semesters.
- Ground breaking in May '13 and Substantial completion at the end of June '14
- Foundation and excavation will take 42 days
- Superstructure will take 45 days
- Finishes will take 68 days

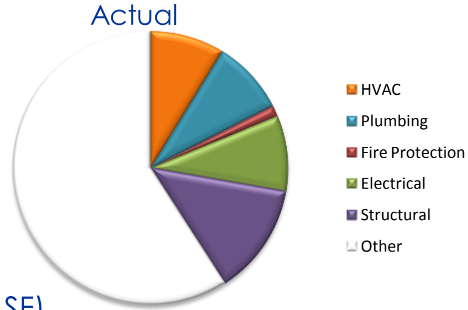
Balfour Beatty
Construction

Project Cost Evaluation

RS Means



Actual



Cost Comparison ($ / SF)

	RS Means	Actual	% Difference
HVAC	$ 14.26	$ 40.00	(3.35%)
Plumbing	$ 24.40		
Fire Protection	$ 3.58	$ 2.90	23.5%
Electrical	$ 17.38	$ 20.50	(15.2%)
Structural	$ 19.98	$ 30.00	(33.4%)
Construction Cost	$ 157.01	$ 157.02	0%
TOTAL PROJECT	$ 199.81	$ 228.39	(12.5%)

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Project Cost Evaluation

- Compared to RS Means data, the actual costs were relatively high. The cost of fire protection, however, was less than predicted by RS Means.
- The construction costs were nearly identical, possibly because of fees associated with fast tracking the project.
- Overall project cost was 12.5% higher than RS Means prediction.

Taylor Hall

George Mason University
Fairfax, VA

Technical Assignment 2

Brad Williams
Construction Management
Faculty Consultant: Ed Gannon

Technical Assignment 2
October 16, 2013

Executive Summary

The purpose of Technical Report 2 is to analyze and report critical schedule and cost data for our buildings. It is also for discovering and analyzing potential constructability and site concerns associated with the project. Finally, the analysis of an emerging trend is explained and shown how it will positively affect the building construction process.

For Taylor Hall, the schedule is the most critical item of concern for the owner. This is because there is a set date on which 295 students will call it their home. To ensure that the project stays on schedule, entire systems have been decided upon purely due to their ability to accelerate the schedule. (ie. The Infinity Structural System, said to be three times faster than concrete.) Through the analysis of critical path items, it can be seen that achieving the substantial completion after only 295 days of construction is very possible.

Secondly to schedule, the owner is concerned with cost. With a strict budget, it is important to include the most efficient and sustainable equipment and procedures available. This will not only help to cut down on upfront cost, but building maintenance and life cycle cost. An assembly estimate of the buildings primary mechanical, electrical, and plumbing systems allow for a more accurate building cost analysis. It was found that the MEP total estimate is within roughly $8 per square foot of the projected cost.

With schedule being a primary concern and cost second, the structural system has an integral role to the owner. The Infinity Structural System utilizes prefabrication of load bearing stud walls to accelerate the schedule of the superstructure by three-fold. It has been said that up to 24,000 SF of structure can be erected in 5 days. However, this patented system comes with a price.

According to a detailed structural system estimate completed in this report, the cost per square foot of the Infinity Structural System was roughly $15.50. This was achieved after several assumptions were made about the cost of design and prefabrication of the panelized stud walls. From a sub-contractor source, the cost per square foot of the Infinity System in the DC area ranges between $19 and $23, but the original cost information obtained shows a $30/SF cost. This information can be used to analyze weather this system's cost outweighs its ability to accelerate the schedule.

General Conditions estimates, including staffing, insurance and bonding, fee, and temporary facilities fees indicate how schedule can directly impact price. Since the project is a "Design-Build" management model, the project team must work together long before arriving on-site to model and discover potential schedule and budge hazards before they happen. Because of this, the GC estimate comes in at just over 13% of the total project cost.

Site plans at different stages of construction are made to help show how the campus will interact with Taylor Hall and how the project team will have to monitor the space usage closely. In the site plans contained in this report, the excavation phase, structural erection phase, and completion stage of the building are shown. It was found that the site has ample space for construction activities to take place, but has some critical constraints from the north and eastern boundaries of the site and that water runoff management is important on the southern side of the site.

With so much preconstruction focus from the job team, certain areas were discovered that may lead to speed bumps in the already tight schedule. These constructability concerns pertaining to the Infinity Structural system and it's interaction with other trades are weighed against their ability to negatively affect the schedule. They will require an immense amount of attention during the construction phase, but with proper communication and planning, all should run smoothly.

Finally, the project's LEED accreditation is analyzed to see what goals the owner has in obtaining the Silver certification. The highlights for each category in achieving the 58 points reflect George Mason University's sustainability plan and help to maintain healthy students, a healthy environment, and a cost efficient life cycle. These required points are similar to that which Penn State University requires of their new buildings on campus.

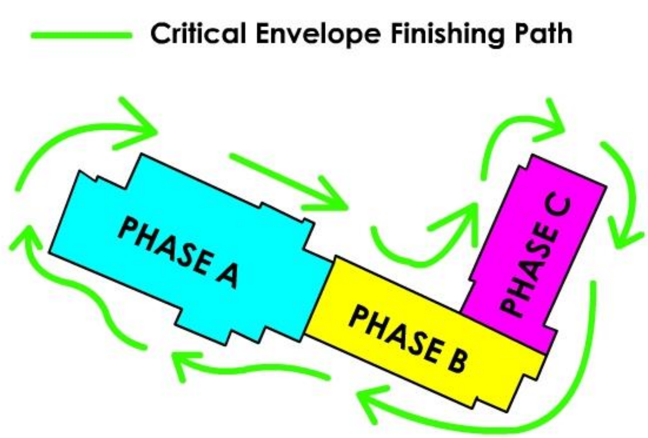
Technical Report 2 will help me in my future analyses of Taylor Hall by providing baselines of comparison for which I will measure changes that I may institute in the future. By looking into the key constituents that affect the cost, schedule and overall success of the project, I have learned valuable assets in brainstorming potential ideas for improvement.

Primavera P6 Project Schedule

A condensed schedule of 180 line items has been created based on trade and type of work. This schedule can be seen in Appendix A. With this particular type of schedule, cost loading and evaluation can be done in further technical reports where alternative systems may be presented. With a Total Project Duration of 404 days and a Construction Duration of only 295 days (assuming ground breaking to substantial completion) the project is already very efficient with its schedule.

The schedule mentions Areas A, B, C, and also mentions areas where the skin and envelope of the building are to be worked on at a given time. I've developed the following graphic to help visualize the process per floor for the superstructure and envelope systems.

Figure 1. Phase and Flow Diagram



Since the Taylor Hall project is a student dormitory, the schedule is the primary concern of the owner. For the project to best adhere to the schedule, the critical path items must be a priority for the construction team long before they take the field. The following critical path items hold the ability to make or break the project due to the short construction period.

The submission, approval, and fabrication of rebar are critical to when the building can begin taking shape. Since Balfour Beatty (the Design-Builder) is also the concrete subcontractor, this process can be carried out rather quickly and with ease.

Other than the procurement period, the under-slab preparation is a critical path item that must be happen before the project can continue. This is because it precedes the pouring of the slab on grade, another critical path item. While the under-slab rough-in is occurring, concrete work can already be ongoing with strip and bearing footings.

Since the roof is a critical path item on nearly every building (as it is on this one), getting to the roof is equally as important. This means that installing the Infinity Structural panels the whole way up the building are on the critical path before placing the cold formed trusses and decking of the roof system. Once the roof is in place, the building is dried in.

The next critical landmark in the schedule is when the building is 100% enclosed. This means that the scaffolding, sheathing, brick, and window installation are all critical path items. When the building is fully enclosed and protected from the elements, finishes can begin to be installed in the building.

Going along with the finishes, drywall installation is a critical path item immediately following building enclosure since certain drywalls can be ruined by water. The finishing process of sanding, priming, and painting these drywall segments is critical to the project being completed on time.

The last, and arguably most important, critical path item is the final building inspections and fire alarm testing. These are the most important because the C of O (Certificate of Occupancy) completely relies on the passing of these permit closeout inspections. It is also important to realize that pre-testing is required so that actual fire alarm testing runs smoothly to avoid multiple visits from the fire marshal, which could be weeks apart.

Project Estimates

MEP- Assemblies Estimate

An assemblies estimate for the electrical, mechanical, and plumbing systems were conducted using RS Means Online Assemblies Estimating calculator. The detailed reports and raw calculations/takeoffs are located in Appendix B and show the work done to come up with the numbers. No assumptions were needed for the Assemblies estimates, but conversion calculations were completed to find values not found on the drawings.

Below are tables detailing the groups and values within each of the assemblies' estimates. For comparison purposes, the cost per square foot of each assembly was also calculated.

Mechanical Assemblies Estimate Summary

Group Name	Price
Large Hydronic Heating System – 70,057 SF	**$ 570,964.55**
20,300 CFM, 50.75 ton, Rooftop AHU for College Dorm	**$ 1,411,648.55**
MECHANICAL TOTAL	**$ 1,982,613.10**
SF COST	**$28.30 /SF**

Electrical Assemblies Estimate Summary

Group Name	Price
Switchgear	**$ 32,644.65**
Panels	**$ 193,777.25**
Air Conditioning	**$ 20,316.53**
Fire Detection and Alarm System	**$ 113,386.80**
Underground Service Installation	**$ 61,146.00**
Telecom	**$ 101,930.99**
Lighting	**$ 331,369.61**
Receptacles	**$ 215,074.99**
Switches	**$ 42,034.20**
ELECTRICAL TOTAL	**$ 1,111,681.02**
SF COST	**$15.87 /SF**

Plumbing Assemblies Estimate Summary

Group Name	Price
3 Fixture Bathrooms, 2 Walls of Plumbing	**$ 34,968.65**
Water Closets	**$ 123,896.76**
Showers	**$ 203,958.44**
Lavatories	**$ 69,311.04**
Electric Water Coolers	**$ 6,112.65**
Electric Water Heaters	**$ 96,682.80**
Drinking Fountains	**$ 11,850.60**
Roof Drains	**$ 9,828.45**
PLUBMING TOTAL	**$ 556,609.39**
SF COST	**$7.95 /SF**

Compared to SF estimates completed in technical assignment 1, the overall MEP system cost does not differ greatly. From RS Means, the MEP costs were combined to be $56.04 /SF. This is slightly more than the assemblies estimate above, which equals $52.12 /SF. Actual building cost per SF numbers for MEP systems summed to $60.50. This difference may be due to the addition of special additives, such as an economizer on the AHU and in-slab rough in for branch circuiting throughout the floors.

Individually, however, the numbers differ greatly when compared to the actual and SF estimate costs. The below table illustrates the variations between estimates and system.

Cost Comparison for MEP Systems by Estimate Type ($/SF)			
System	**Square Foot**	**Assembly**	**Actual**
Mechanical	$14.26	$28.30	$15.00
Electrical	$17.38	$15.87	$20.50
Plumbing	$24.40	$7.95	$25.00
TOTAL	$56.04	$52.12	$60.50

Clearly there is something about the plumbing system in the building that is accounting for a much larger cost than that estimated by assembly. The opposite can be said for the mechanical system in place. This may be because of the hyrdonic heating system and heat exchanger was put under the mechanical system estimate and may have been under the plumber's scope of work for this particular project.

Structural - Detailed Estimate

The detailed structural system estimate was done within the RS Means Online program and the attached report in Appendix B shows the detailed breakdown. All numbers were taken off within Bluebeam Revu and measured accordingly. Interpolation was also needed in cases where items did not show up in the estimate. All interpolation calculations can be seen on the scratch notes in Appendix B and they are represented on the detailed estimate with a code "SS" followed by a number. Only Total cost with O&P values were interpolated.

Several assumptions were made during the course of the estimate. The assumptions pertaining to the Infinity Structural System are educated guesses based on my questioning of Bob McDaniel from Miller + Long, a sub-contractor specializing in installing the system. I was not able to obtain real cost data or shop drawings for the walls since it is a patented system and was only provided with very basic information.

- **Waste:** 5% waste on concrete materials
- **Reinforcement:** 3 lb/SF reinforcement on concrete SOG and 1.5 lb/SF reinforcement for SOMD. (per interview with sub-contractor)
- **Connections:** (4) ¾" diameter, 2" length bolts per steel member. 5% waste on bolts
- **Formwork:** 4.5 SFCA/LF of exterior wall (from footing calculation)
- **Infinity System: Prefabricated, load bearing stud walls**
    - 15% increase for shear wall components
    - 25% increase for shear bearing wall components
    - 50% increase on labor for prefabrication
    - 12" OC, 18 ga., 3-5/8" wide, 10' high walls for standard bear wall
    - Floors 2-4 have identical framing plans

The following table provides a summary of the estimate by group name. For a more detailed estimate, please reference the generated project report in Appendix B.

Cost Summary for Detailed Structural Estimate

Group Name	Total Cost
Slab on Grade	**$ 8,589.72**
Strip Footings	**$ 7,392.92**
Slab on Metal Deck	**$ 18,060.38**
Concrete Material	**$ 142,053.60**
Metal Deck (Roof and Floor)	**$ 227,753.34**
Roof Trusses	**$ 25,151.56**
K-Series Joists	**$ 3,788.79**
Bearing and Shear Stud Walls (Infinity System)	**$ 234,675.08**
Footings	**$ 32,427.92**
Bearing Plates	**$ 3,445.83**
Columns	**$ 64,897.99**
Beams	**$ 68,144.42**
Concrete Reinforcement + Galvanized	**$ 103,170.05**
Curb Edging	**$ 94,349.92**
Concrete Curing	**$ 5,182.39**

Bolts/Connections	**$**	**2,840.05**
Concrete Formwork	**$**	**44,511.02**
TOTAL STRUCTURAL SYSTEM		**$1,086,434.97**

The total cost of $1,086,434.97 comes out to roughly $15.50 per square foot of building space. According to my Square Foot estimate from the previous technical report, the building should have a structural square foot cost of $19.98. I believe this difference is due to the fact that RS Means assumes that there are many more load bearing steel members which are much more costly than cold-formed metal walls.

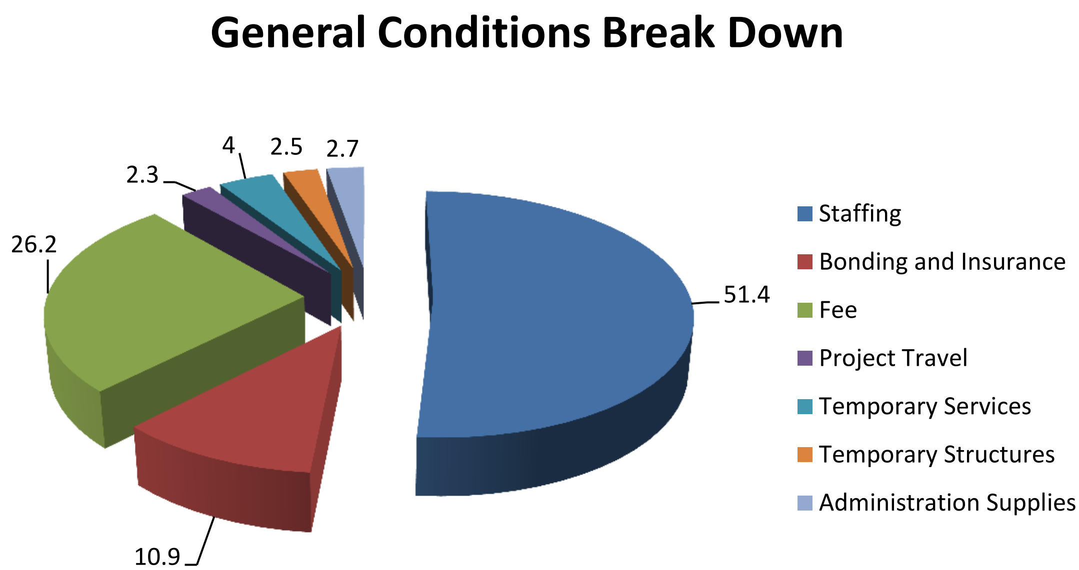
After my conversation with a specialist sub-contractor, I learned that the Infinity system should actually cost more than that of RS Means due to prefabrication costs. Per conversation with Miller + Long, the cost per square foot should be roughly $23. This means that the Infinity System's load bearing walls must come with a very high design, preconstruction, and delivery price.

Furthermore, the sub-contractor's estimate of $23/SF does not coordinate with the original $30/SF estimate that was received from the Design-Builder for Technical Assignment 1. This may be due to a late change in structural design (October 9th) due to the building being slightly over budget.

(Complete cost breakdown available in appendix B)

General Conditions Estimate

The general conditions estimate overview below shows the percentages of each component of the estimate. The estimate, in total, makes up 13.3% of the total construction cost and accounts for all necessary expenses that may take place during the project.



The Staffing plan shown in the next section correlates with the staffing plan presented in Tech 1 and the salary information was derived from industry average salaries under the assumption of a 40 hour work week. It is also assumed that staffing costs include Employee Benefits Expense (EBE) which consist of health care (18%), paid time off (10%), taxes and insurance (10%), 401k/profit sharing (7%), and on the job training for an intern (3%).

General Conditions Estimate							
			Material		Labor		
Description	**Quantity**	**Units**	**$/ Unit**	**Total**	**$/Hr**	**Total**	**Total**
Project Manager	57	WK			118	269040	$ 269,040.00
Superintendant	53	WK			115	243800	$ 243,800.00
Asst. Project Manager	53	WK			90	190800	$ 190,800.00
Asst. Superintendant	53	WK			85	180200	$ 180,200.00
Project Engineer	52	WK			65	135200	$ 135,200.00
Project Executive 25%	57	WK			138	78660	$ 78,660.00
Total							**$ 1,097,700.00**
Administration Supplies	*						**$ 57,500.00**
Temporary Structures	*						**$ 54,100.00**
Temporary Services	*						**$ 84,478.50**
Project Related Travel	*						**$ 50,000.00**
SUB TOTAL FOR COSTS							**$ 1,343,778.50**
"Fee" (Overhead and Profit)							
a) Offerer's Fixed Fee in Dollars							**$ 560,000.00**
b) Fixed Fee as percent of "cost of work"							**3.5%**
Insurance and Bonds	1.45%						**$ 232,000.00**
BASELINE TOTAL GENERAL CONDITIONS AND FEE							**$ 2,135,778.50**

The fee for the project was set at 3.5% of the total building cost, in accordance with Means data. Insurance and performance bonding is assumed to be 0.75 % and 0.70% of the total project cost respectively.

All data for Temporary Services, Structures, Project Travel and Administrative Supplies were based on averages used on previous projects and in-class assignments for estimating (AE472) and have been adjusted for the Fairfax area. The durations and amounts of each activity were set in place based on 12 months of construction.

The estimate may be slightly higher than a typical project would expect. This may be because of the extensive pre-construction work needed to compete for the project. Planning associated with the pre-fabrication and extremely tight schedule may also lead to slight general conditions inflation.

Temporary Conditions and Expenses							
			Material		Labor		
Description	Quantity	Units	$/ Unit	Total	$/ Unit	Total	Total
Administration Supplies							
Office Supplies	12	MO	300	3600			$ 3,600.00
Office Equipment	1	LS	Already Present				$ -
Office Furniture	1	LS	Already Present				$ -
Copying / Blueprinting Specifications	1	LS		50000			$ 50,000.00
Fax Machine	1	LS	Already Present				$ -
Miscellaneous Safety Equipment	1	LS		1500			$ 1,500.00
Postage	12	MO	100	1200			$ 1,200.00
Site Fire Extinguishers	15	EA	Already Present				$ -
Expendable Small Tools	12	MO	100	1200			$ 1,200.00
Computer Equipment / Software	1	LS	Already Present				$ -
Subtotal							**$ 57,500.00**
Temporary Structures							
Scaffolding	12	MO	1200	14400			$ 14,400.00
Job Office / Trailer	12	MO	1500	18000			$ 18,000.00
Construction Fence	13	MO	900	11700			$ 11,700.00
Trailer Set-up	1	LS		5000			$ 5,000.00
Trailer Utilities Usage Cost	12	MO	By Owner				$ -
Temporary Signage	5	EA	1000	5000			$ 5,000.00
Subtotal							**$ 54,100.00**
Temporary Services							
Toilets	12	MO	800	9600			$ 9,600.00
Drinking Water / Ice	12	MO	200	2400			$ 2,400.00
Progress Photos	12	MO	250	3000			$ 3,000.00
Radios/ Phones/ Nextel	7	EA	1800	12600			$ 12,600.00
Security	1	LS		4500			$ 4,500.00
Dumpster and Trash Removal	13	MO	1200	15600			$ 15,600.00
Final building clean-up	72,057	SF	0.5	36028.5			$ 36,028.50
Snow Removal	1	LS		750			$ 750.00
Subtotal							**$ 84,478.50**
Project Related Travel							
Signage	1	LS	By Owner				$ -
Professional Survey			By Owner				$ -
Testing & Inspections			By Owner				$ -
Topping Out		EA					$ -
Business Promotion		LS					$ -
Visit Subcontractors	1	LS		15000			$ 15,000.00
Vehicle Milage	20,000	Miles	0.5	10000			$ 10,000.00
Auto Allowances	1	LS		10000			$ 10,000.00
Job Site Travel	1	LS		12500			$ 12,500.00
Temporary Living Expense	1	LS		2500			$ 2,500.00
Subtotal							**$ 50,000.00**
Total							**$ 246,078.50**

Site Plans throughout Construction

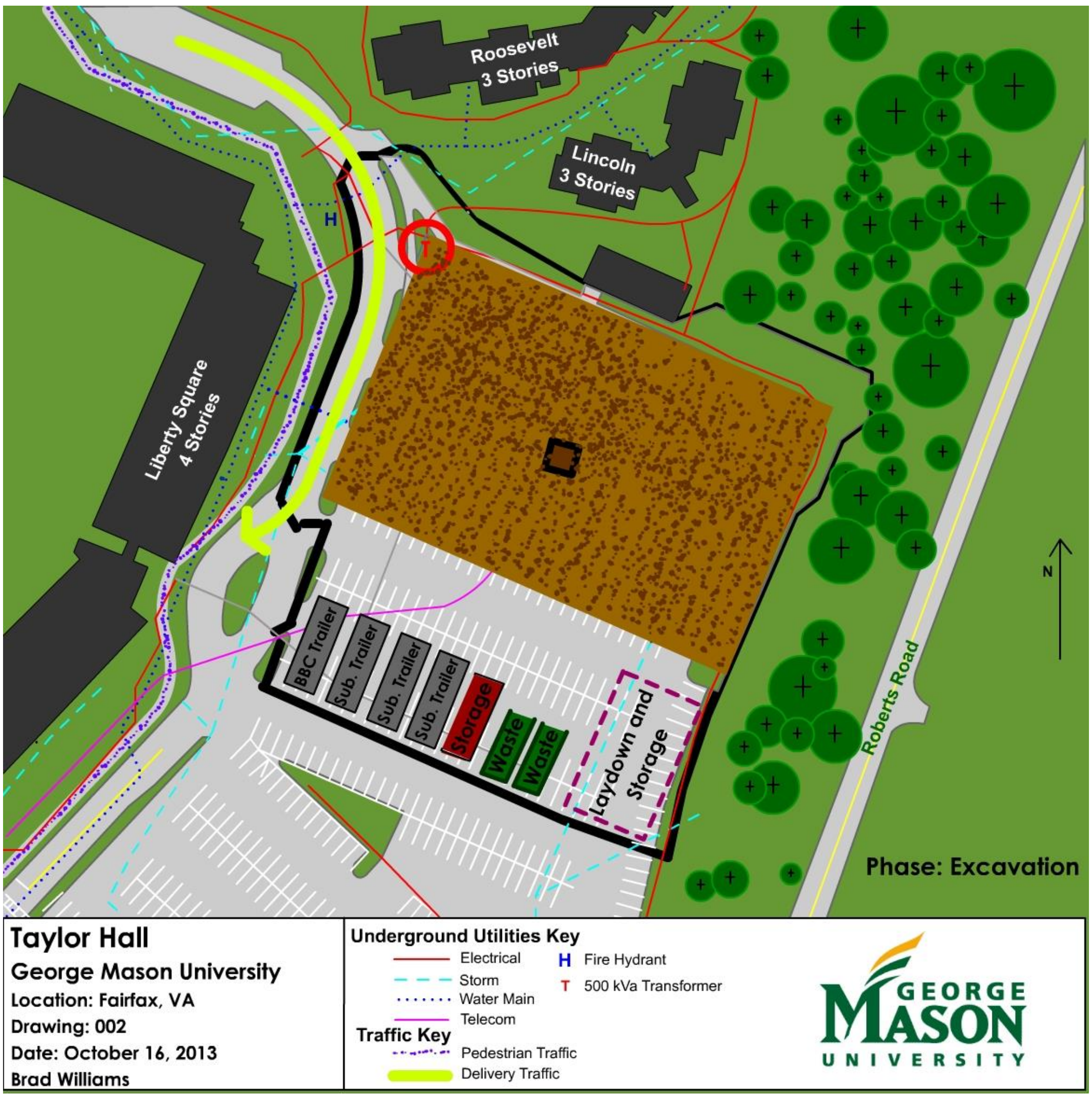
Existing Conditions

As mentioned in the previous Technical Report, the existing conditions are a faculty/student parking lot on the south eastern boarder of George Mason University's campus in Fairfax, VA. The site was proposed as a potential building location when developing the campus's Master Plan, so all utility tie-ins are already available and capable of supporting the new 295 bed dormitory.

In the above plan, it is clear that site delivery and traffic flow will be well maintained and student traffic should not be a problem since all classroom buildings are north or north-west of the site. It is also important to not the construction site is constrained by a greenhouse to the north of the site and a 100’ tree buffer to the west of the site. These boundaries may not be crossed or obstructed by any construction activity.

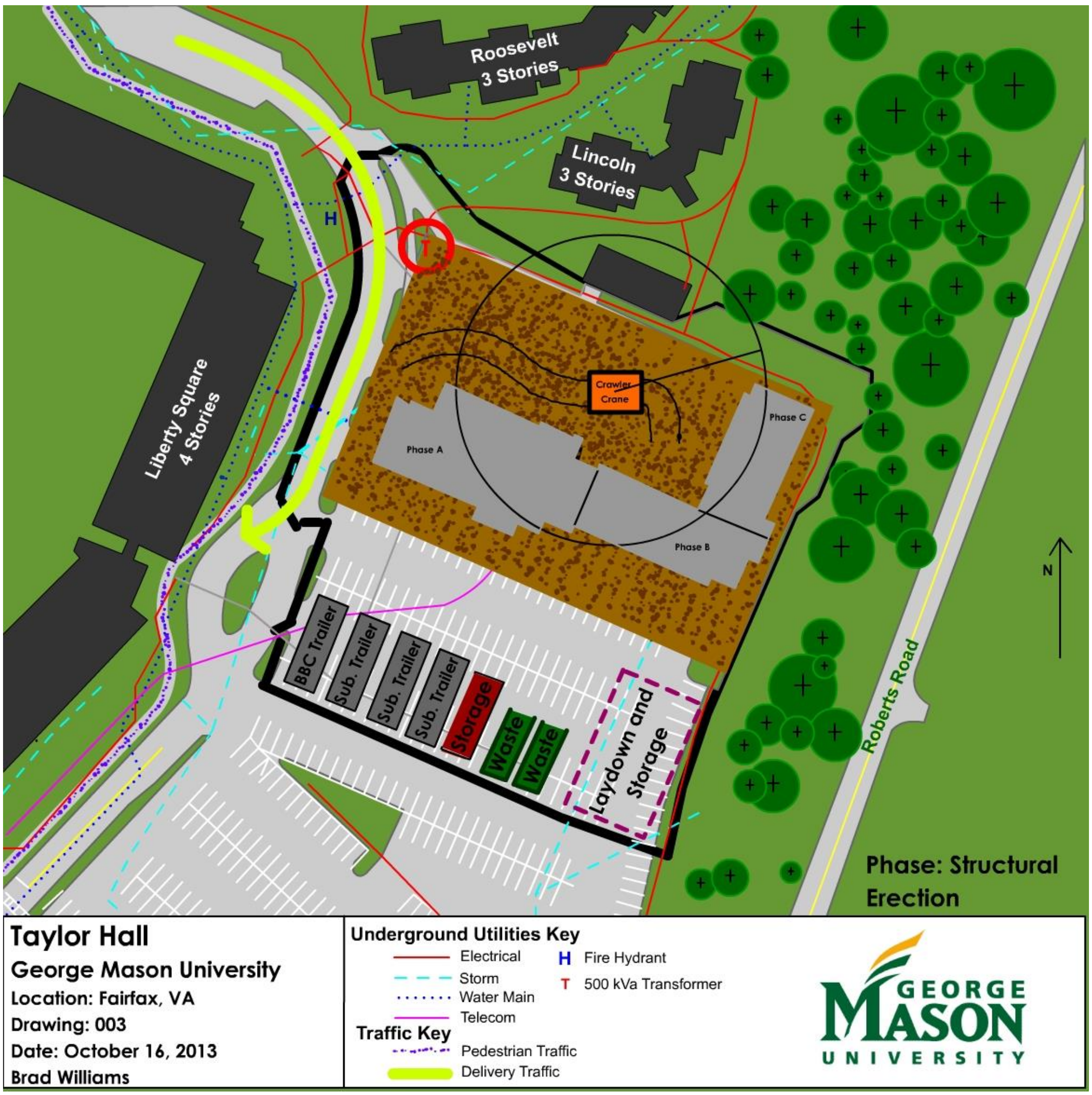
Excavation

The site is set in an existing parking lot, so there is ample room for temporary trailers, storage, waste containment, and delivery layout in the south end of the site. The excavation will take place after removing a portion of the parking lot noted above. On the above drawing, the black square indicates the elevator pit, which is the deepest excavation on the project. All other footings and strip footings are less than 5' below grade.



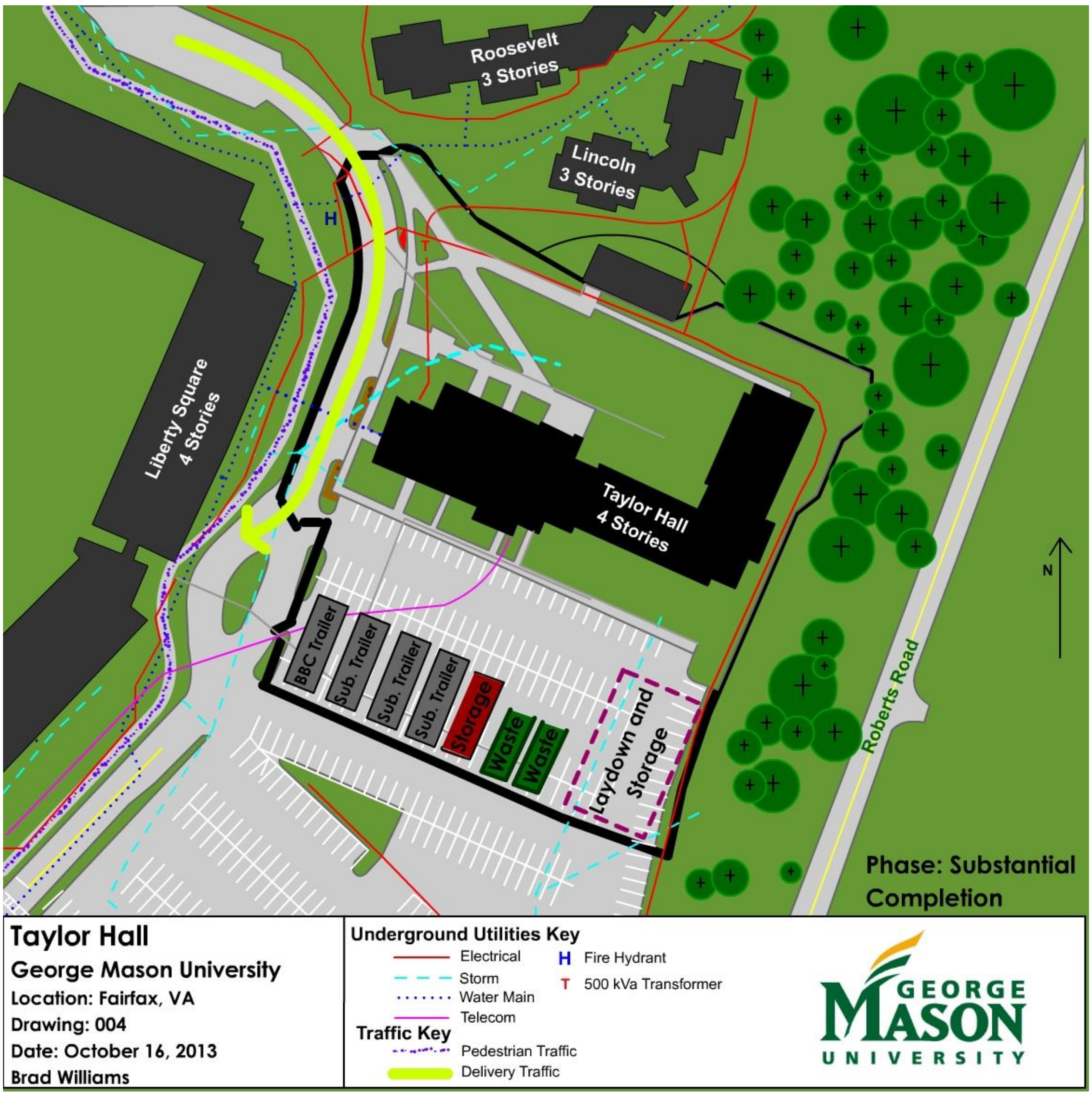
Superstructure Erection

In the above graphic representing the superstructure erection phase, you can see the building footprint represented by the gray concrete slab. The erection of the structure will take place in 3 phases (A, B, and C) and are noted above. Prefabricated load bearing stud walls, columns, and beams will be placed with a crawler crane which will have the mobility to easily relocate if a lift is outside the range.



Completion

This site plan represents the final completion stage of the building. With sidewalks in place, you can see the building easily tie-in with the network of walkways already present on campus. Once construction has ended and trailers are removed, the parking lot will be restored and used by faculty and students.



Constructability Concerns

When planning for the construction phase of the building, it is important to analyze how the major systems will come together in the field. This helps avoid the potential mishap later in the construction phase which could lead to schedule and cost implications. Throughout my research of Taylor Hall, I've found 3 major areas that may require special attention during the design phase and construction phase of a building. The phase planning of the pre-fabricated structural walls, coordination of wall penetrations, and the project completion date are critical areas specific to this project.

Infinity Structural System

Taylor Hall uses a patented structural system that is based around panelized, pre-fabricated cold formed walls. The walls are built to bear structural load as well as shear loads and sometimes both. When considering other structural systems, this was favored due to its schedule acceleration abilities. After talking with a representative (Bob McDaniel) from Miller and Long, it was mentioned that they could place up to 24,000 SF of building structural system in only 5 days. This does, however, come with a pretty significant price.

Early in the design phase of the building, it must be determined which walls are load bearing walls and which are not. This is not only important for the prefabrication department, but for phase planning. Though made of roughly the same components, the prefabricated shear and bearing walls must be in place before the metal decking of the next floor is laid out. Non load bearing walls, on the other hand, are placed after the next slab on metal deck is poured.

Designated bearing walls, shear walls, and shear-bearing walls have a significant lead time and must be designed long before foundation work has begun. It is important for the management team to coordinate this with the building schedule so that the right wall segments are being delivered in time to be lifted into place. Without proper coordination, specific designed walls may end up being placed in an improper location.

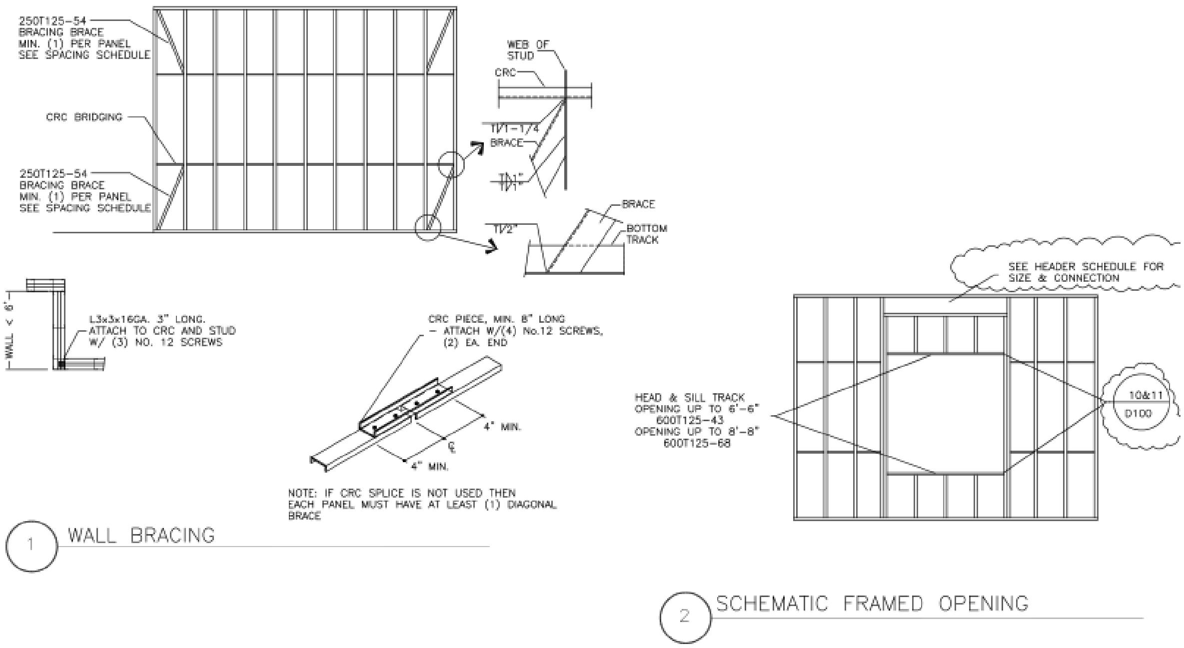


Figure 2. From Structural Sub drawings C200. It is the only hint of Bearing Wall components/design shown from the Infinity System.

After talking with Bill Moyer, Vice President of Davis Construction, on the topic of Infinity Structural Systems, he mentioned a second constructability concern to me. Without proper phasing of where the structural system is to be put in place, you may end up with exposed MEP risers and branches. Since the framing is set in place so quickly and significant time is spent laying out electrical branch conduit on the decking before the next slab is poured, mechanical and plumbing trades are routinely scheduled to install risers and branch distributions before the slab is poured. This has happened on several projects in the Northern Virginia and DC area and has lead to some contamination of systems when the slab is poured.

Other than improper installation procedures, to achieve LEED IEQc3.1 (Indoor Air Quality Management Plan – During Construction), it is required to provide a signature confirming all duct work remained dry and covered during construction. The above-mentioned constructability concern may put this credit in jeopardy.

Coordination of Wall Penetrations

Due to the majority of the structural system being prefabricated, it is absolutely critical for trades to coordinate plans early in the design process. The long lead times required for panel prefabrication mean that plumbing, electrical, and mechanical penetrations need to be finalized long before construction begins.

When the structural panels arrive on site, they will not allow for large penetrations to be relocated. Small penetrations however may have more space when penetrating the structural stud walls. By increasing communications between subcontractors early on, an efficient design to minimize wall penetrations can be developed to allow for more flexibility when the construction phase begins in the field.

Project Completion Date

Like most universities, George Mason wishes to have a completed building ready for occupancy for a new school year. It has been quite clear that the entire project is schedule driven so that the move-in date of the new freshman students is not delayed. Several critical path items may require special attention to adhere to the schedule.

The Infinity Structural System, being on the critical path, has a major role in how the remainder of the project will be on schedule. By avoiding the previously mentioned constructability concerns, this one may also be avoided. Secondly, early coordination and keeping good communication on the site may help to eliminate tension on such a tight schedule. Without many float days, there are not too many areas on the schedule for acceleration later on.

Industry Leading Practice - LEED

LEED (Leadership in Energy and Environmental Design) is a program intended to recognize efforts in designing and constructing sustainably buildings. LEED accredited buildings may be more energy efficient, healthier to live in, use local and recycled materials, and have low impact on the surrounding environment. Taylor Hall is currently set to achieve 58 points in the LEED version 3 scoring system, allowing the building to reach LEED Silver certification (George Mason University Standard).

Sustainable Sites

The first category is "Sustainable Sites" and is intended to manage impact on the surrounding environment, control population density, provide occupants with nearby alternative transportation, and to decrease the heat island affect. The category has 26 possible points with 1 prerequisite (Construction Activity Pollution Prevention). In accordance with George Mason's Sustainability Plan, most of these points are required. Taylor Hall is expected to earn 20 of these points with the possibility of one additional point.

Water Efficiency

"Water Efficiency" is a category which aims to reduce the waste of water, manage an efficient site design in terms of water control, and to encourage innovative design. Out of the possible 10 points, Taylor Hall will be earning 3 by reducing the water usage by 35%.

George Mason University has a very specific construction site water management plan due to the protection of several tree and wildlife buffers on campus. The site water management plan is of particular importance to the Taylor Hall site for concerns of contaminating a nearby (< 300') creek that flows off campus.

Energy and Atmosphere

The "Energy and Atmosphere" category scores projects based on their abilities to optimize energy performance and to turn to on-site renewable energy as a resource. Due to the costs involved with optimizing the energy performance of the building, Taylor Hall is only expected to earn 9 points (with a possibility of 4 more) out of a possible 33 points. The majority of these 9 points come from enhanced commissioning and refrigerant management, however, the building will meet energy standards set forth by the University and optimize energy performance by 19%. This will be accomplished, in-part, due to the enthalpy heat recovery wheel to pre-condition the outside air entering the building.

Materials and Resources

"Materials and Resources" is a category intending to manage construction waste, encourage the use of local materials, use recycled materials, and use of rapidly renewable resources or certified wood. Of the 14 possible points, Taylor Hall will be earning 7 points with a large emphasis on construction waste management, recycled content of materials, and the use of materials harvested and manufactured within 500 miles. This is easily done with the amount of concrete plants and steel mills in the acceptable radius.

Indoor and Environmental Air Quality

The "Indoor and Environmental" Category exists to maintain the health of the building's future occupants by reducing volatile organic compounds, increasing ventilation and filtration of air, and providing a comfortable and controllable environment. Luckily, most flooring, sealants, and paints are made to comply with allowable VOC limits and the replacement of MERV 13 filters has become standard practice before occupancy. Of the 15 possible points, the building will earn 10 with the possibility of 2 additional points. This score heavily reflects George Mason University's intentions of providing its students with a top notch living environment.

Innovation and Design Process / Regional Priority

The final categories of LEED certification are "Innovation and Design Process" and "Regional Priority." These credit categories encourage the use of having a LEED Accredited Professional on the project team and allow for a variety of options for gaining points. For one of the points, the building will be fit out with a display panel in the lobby showing live building statistics on energy consumption in the hopes that it might influence savings. Taylor Hall will be gaining 7 points from the two categories. The 6 Innovative practices are listed below and are worth 1 point each.

- Green Housekeeping
- Environmental Pest Control
- Green Landscape Management
- Low Mercury Bulbs
- Green Education
- LEED Accredited Professional

University Plan Comparison

In comparison to Penn State University's LEED Policy on buildings, Taylor Hall would be considered going above the Penn State standard. When reviewing the PSU LEED scorecard and counting a "mandatory" as a "yes" and a "significant" as a "maybe, yes" it is only required for Penn State buildings to obtain 27 points. Similarly to GMU's plan, PSU also heavily emphasizes the points within the Indoor Air Quality category to maintain the health of its students. Penn State's plan seems to heavily consider price when assigning points, however, many points listed as "minimal" effort can be achieved for little to no price increase.

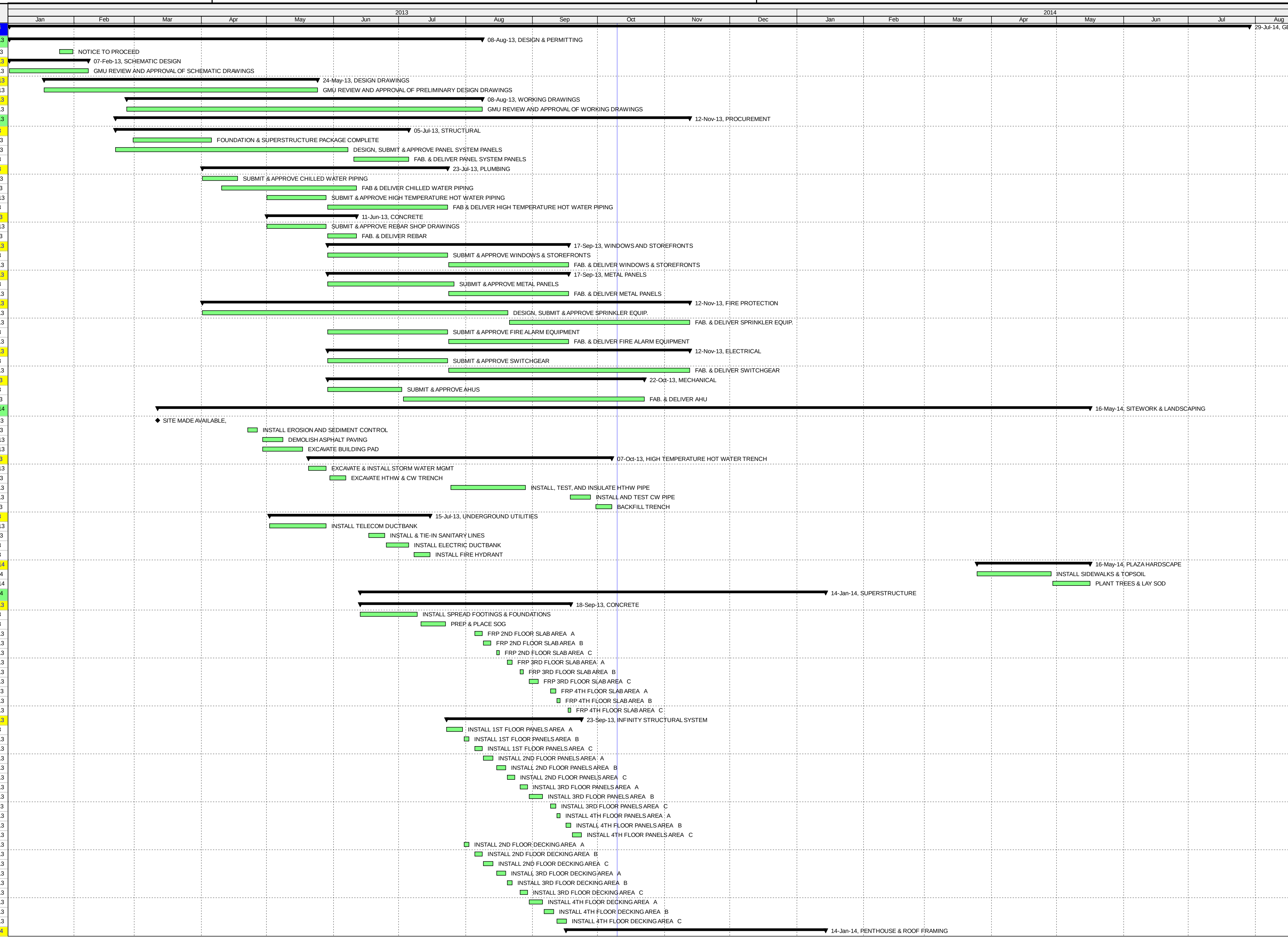
George Mason University strives for excellence in the field of sustainability and feels that obtaining LEED Silver certification is of the utmost importance. With such a young and growing campus, the opportunity for "green" innovation is present and Taylor Hall will be taking full advantage of it by earning 58 points.

v(see appendix C for LEED scorecard for Taylor Hall)

Appendix A:

Primavera Project Schedule

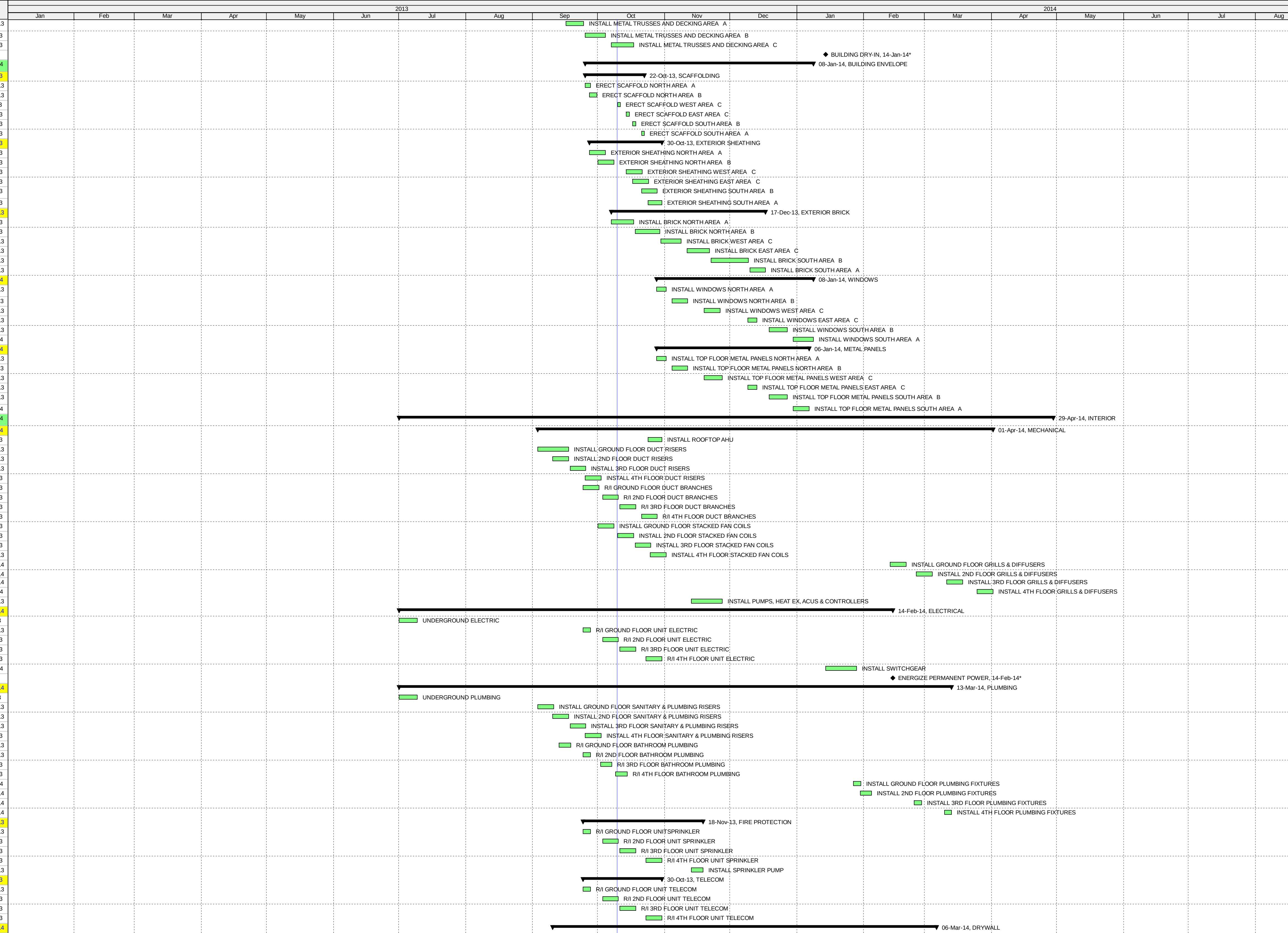
Activity ID	Activity Name	Original Duration	Start	Finish
GEORGE MASON UNIVERSITY - TAYLOR HALL		404	02-Jan-13	29-Jul-14
DESIGN & PERMITTING		155	02-Jan-13	08-Aug-13
A1000	NOTICE TO PROCEED	5	25-Jan-13	31-Jan-13
SCHEMATIC DESIGN		27	02-Jan-13	07-Feb-13
A1010	GMU REVIEW AND APPROVAL OF SCHEMATIC I	27	02-Jan-13	07-Feb-13
DESIGN DRAWINGS		91	18-Jan-13	24-May-13
A1020	GMU REVIEW AND APPROVAL OF PRELIMINARY	91	18-Jan-13	24-May-13
WORKING DRAWINGS		117	25-Feb-13	08-Aug-13
A1030	GMU REVIEW AND APPROVAL OF WORKING DF	117	25-Feb-13	08-Aug-13
PROCUREMENT		187	20-Feb-13	12-Nov-13
STRUCTURAL		96	20-Feb-13	05-Jul-13
A1038	FOUNDATION & SUPERSTRUCTURE PACKAGE	27	28-Feb-13*	05-Apr-13
A1040	DESIGN, SUBMIT & APPROVE PANEL SYSTEM P	77	20-Feb-13	07-Jun-13
A1100	FAB. & DELIVER PANEL SYSTEM PANELS	19	10-Jun-13	05-Jul-13
PLUMBING		80	01-Apr-13	23-Jul-13
A1050	SUBMIT & APPROVE CHILLED WATER PIPING	13	01-Apr-13	17-Apr-13
A1055	FAB & DELIVER CHILLED WATER PIPING	44	10-Apr-13	11-Jun-13
A1070	SUBMIT & APPROVE HIGH TEMPERATURE HOT	19	01-May-13	28-May-13
A1075	FAB & DELIVER HIGH TEMPERATURE HOT WAT	39	29-May-13	23-Jul-13
CONCRETE		29	01-May-13	11-Jun-13
A1080	SUBMIT & APPROVE REBAR SHOP DRAWINGS	19	01-May-13	28-May-13
A1090	FAB. & DELIVER REBAR	10	29-May-13	11-Jun-13
WINDOWS AND STOREFRONTS		78	29-May-13	17-Sep-13
A1110	SUBMIT & APPROVE WINDOWS & STOREFRON	39	29-May-13	23-Jul-13
A1120	FAB. & DELIVER WINDOWS & STOREFRONTS	39	24-Jul-13	17-Sep-13
METAL PANELS		78	29-May-13	17-Sep-13
A1130	SUBMIT & APPROVE METAL PANELS	42	29-May-13	26-Jul-13
A1140	FAB. & DELIVER METAL PANELS	39	24-Jul-13	17-Sep-13
FIRE PROTECTION		159	01-Apr-13	12-Nov-13
A1150	DESIGN, SUBMIT & APPROVE SPRINKLER EQUI	100	01-Apr-13	20-Aug-13
A1155	FAB. & DELIVER SPRINKLER EQUIP.	59	21-Aug-13	12-Nov-13
A1160	SUBMIT & APPROVE FIRE ALARM EQUIPMENT	39	29-May-13	23-Jul-13
A1190	FAB. & DELIVER FIRE ALARM EQUIPMENT	39	24-Jul-13	17-Sep-13
ELECTRICAL		118	29-May-13	12-Nov-13
A1170	SUBMIT & APPROVE SWITCHGEAR	39	29-May-13	23-Jul-13
A1180	FAB. & DELIVER SWITCHGEAR	79	24-Jul-13	12-Nov-13
MECHANICAL		103	29-May-13	22-Oct-13
A1200	SUBMIT & APPROVE AHUS	25	29-May-13	02-Jul-13
A1210	FAB. & DELIVER AHU	78	03-Jul-13	22-Oct-13
SITEWORK & LANDSCAPING		304	11-Mar-13	16-May-14
A1220	SITE MADE AVAILABLE	0		11-Mar-13
A1230	INSTALL EROSION AND SEDIMENT CONTROL	5	22-Apr-13	26-Apr-13
A1240	DEMOLISH ASPHALT PAVING	8	29-Apr-13	08-May-13
A1250	EXCAVATE BUILDING PAD	15	29-Apr-13	17-May-13
HIGH TEMPERATURE HOT WATER TRENCH		98	20-May-13	07-Oct-13
A1260	EXCAVATE & INSTALL STORM WATER MGMT	6	20-May-13	28-May-13
A1270	EXCAVATE HTHW & CW TRENCH	6	30-May-13	06-Jun-13
A1280	INSTALL, TEST, AND INSULATE HTHW PIPE	25	25-Jul-13	28-Aug-13
A1290	INSTALL AND TEST CW PIPE	8	18-Sep-13	27-Sep-13
A1300	BACKFILL TRENCH	6	30-Sep-13	07-Oct-13
UNDERGROUND UTILITIES		51	02-May-13	15-Jul-13
A1310	INSTALL TELECOM DUCTBANK	18	02-May-13	28-May-13
A1320	INSTALL & TIE-IN SANITARY LINES	6	17-Jun-13	24-Jun-13
A1330	INSTALL ELECTRIC DUCTBANK	8	25-Jun-13	05-Jul-13
A1340	INSTALL FIRE HYDRANT	6	08-Jul-13	15-Jul-13
PLAZA HARDSCAPE		39	25-Mar-14	16-May-14
A1350	INSTALL SIDEWALKS & TOPSOIL	25	25-Mar-14*	28-Apr-14
A1360	PLANT TREES & LAY SOD	14	29-Apr-14*	16-May-14
SUPERSTRUCTURE		149	13-Jun-13	14-Jan-14
CONCRETE		68	13-Jun-13	18-Sep-13
A1390	INSTALL SPREAD FOOTINGS & FOUNDATIONS	18	13-Jun-13	09-Jul-13
A1400	PREP & PLACE SOG	8	11-Jul-13	22-Jul-13
A1620	FRP 2ND FLOOR SLAB AREA A	4	05-Aug-13	08-Aug-13
A1630	FRP 2ND FLOOR SLAB AREA B	2	09-Aug-13	12-Aug-13
A1640	FRP 2ND FLOOR SLAB AREA C	2	15-Aug-13	16-Aug-13
A1650	FRP 3RD FLOOR SLAB AREA A	3	20-Aug-13	22-Aug-13
A1660	FRP 3RD FLOOR SLAB AREA B	2	26-Aug-13	27-Aug-13
A1670	FRP 3RD FLOOR SLAB AREA C	2	30-Aug-13	03-Sep-13
A1680	FRP 4TH FLOOR SLAB AREA A	3	09-Sep-13	11-Sep-13
A1690	FRP 4TH FLOOR SLAB AREA B	2	12-Sep-13	13-Sep-13
A1700	FRP 4TH FLOOR SLAB AREA C	2	17-Sep-13	18-Sep-13
INFINITY STRUCTURAL SYSTEM		44	23-Jul-13	23-Sep-13
A1410	INSTALL 1ST FLOOR PANELS AREA A	6	23-Jul-13	30-Jul-13
A1420	INSTALL 1ST FLOOR PANELS AREA B	3	31-Jul-13	02-Aug-13
A1430	INSTALL 1ST FLOOR PANELS AREA C	4	05-Aug-13	08-Aug-13
A1440	INSTALL 2ND FLOOR PANELS AREA A	3	09-Aug-13	13-Aug-13
A1450	INSTALL 2ND FLOOR PANELS AREA B	3	15-Aug-13	19-Aug-13
A1460	INSTALL 2ND FLOOR PANELS AREA C	4	20-Aug-13	23-Aug-13
A1470	INSTALL 3RD FLOOR PANELS AREA A	4	26-Aug-13	29-Aug-13
A1480	INSTALL 3RD FLOOR PANELS AREA B	4	30-Aug-13	05-Sep-13
A1490	INSTALL 3RD FLOOR PANELS AREA C	3	09-Sep-13	11-Sep-13
A1500	INSTALL 4TH FLOOR PANELS AREA A	2	12-Sep-13	13-Sep-13
A1510	INSTALL 4TH FLOOR PANELS AREA B	3	16-Sep-13	18-Sep-13
A1520	INSTALL 4TH FLOOR PANELS AREA C	3	19-Sep-13	23-Sep-13
A1530	INSTALL 2ND FLOOR DECKING AREA A	3	31-Jul-13	02-Aug-13
A1540	INSTALL 2ND FLOOR DECKING AREA B	4	05-Aug-13	08-Aug-13
A1550	INSTALL 2ND FLOOR DECKING AREA C	3	09-Aug-13	13-Aug-13
A1560	INSTALL 3RD FLOOR DECKING AREA A	3	15-Aug-13	19-Aug-13
A1570	INSTALL 3RD FLOOR DECKING AREA B	3	20-Aug-13	22-Aug-13
A1580	INSTALL 3RD FLOOR DECKING AREA C	4	26-Aug-13	29-Aug-13
A1590	INSTALL 4TH FLOOR DECKING AREA A	4	30-Aug-13	05-Sep-13
A1600	INSTALL 4TH FLOOR DECKING AREA B	3	06-Sep-13	10-Sep-13
A1610	INSTALL 4TH FLOOR DECKING AREA C	3	12-Sep-13	16-Sep-13
PENTHOUSE & ROOF FRAMING		84	16-Sep-13	14-Jan-14



Actual Level of Effort | Remaining Work | ◆ Milestone
Actual Work | Critical Remaining Work | summary

TASK filter: All Activities

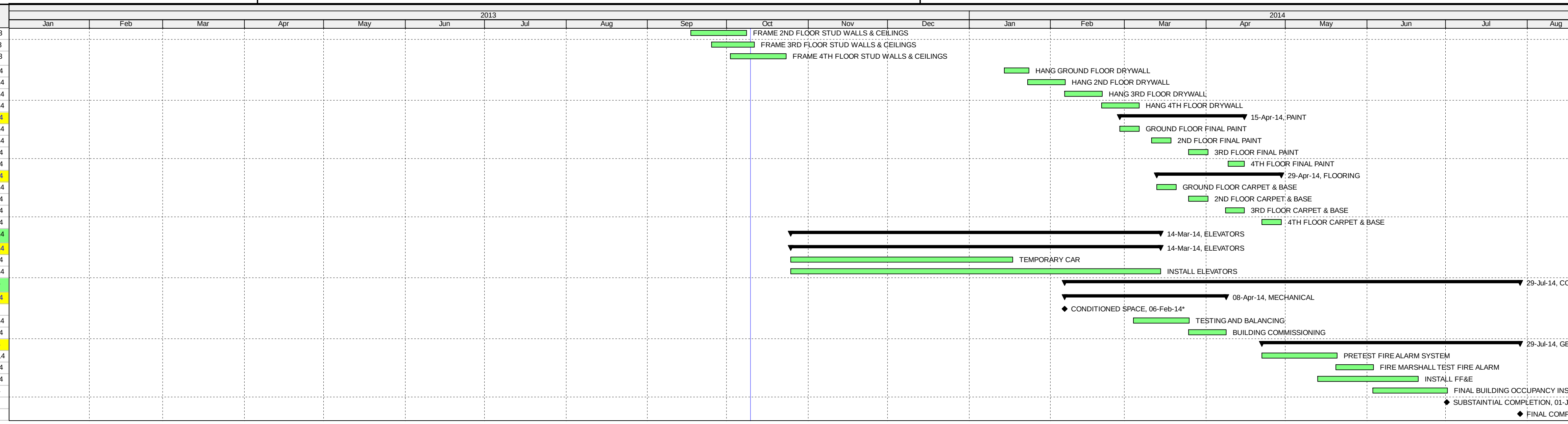
Activity ID	Activity Name	Original Duration	Start	Finish
A1710	INSTALL METAL TRUSSES AND DECKING AREA	7	16-Sep-13	24-Sep-13
A1720	INSTALL METAL TRUSSES AND DECKING AREA	8	25-Sep-13	04-Oct-13
A1730	INSTALL METAL TRUSSES AND DECKING AREA	9	07-Oct-13	17-Oct-13
A1740	BUILDING DRY-IN	0	14-Jan-14*	
BUILDING ENVELOPE		74	25-Sep-13	08-Jan-14
SCAFFOLDING		20	25-Sep-13	22-Oct-13
A1750	ERECT SCAFFOLD NORTH AREA A	3	25-Sep-13	27-Sep-13
A1760	ERECT SCAFFOLD NORTH AREA B	2	27-Sep-13	30-Sep-13
A1770	ERECT SCAFFOLD WEST AREA C	2	10-Oct-13	11-Oct-13
A1780	ERECT SCAFFOLD EAST AREA C	2	14-Oct-13*	15-Oct-13
A1790	ERECT SCAFFOLD SOUTH AREA B	2	17-Oct-13*	18-Oct-13
A1800	ERECT SCAFFOLD SOUTH AREA A	2	21-Oct-13*	22-Oct-13
EXTERIOR SHEATHING		24	27-Sep-13	30-Oct-13
A1810	EXTERIOR SHEATHING NORTH AREA A	6	27-Sep-13	04-Oct-13
A1820	EXTERIOR SHEATHING NORTH AREA B	6	01-Oct-13	08-Oct-13
A1830	EXTERIOR SHEATHING WEST AREA C	6	14-Oct-13*	21-Oct-13
A1840	EXTERIOR SHEATHING EAST AREA C	6	17-Oct-13*	24-Oct-13
A1850	EXTERIOR SHEATHING SOUTH AREA B	6	21-Oct-13*	28-Oct-13
A1860	EXTERIOR SHEATHING SOUTH AREA A	5	24-Oct-13*	30-Oct-13
EXTERIOR BRICK		51	07-Oct-13	17-Dec-13
A1870	INSTALL BRICK NORTH AREA A	9	07-Oct-13	17-Oct-13
A1880	INSTALL BRICK NORTH AREA B	8	18-Oct-13*	29-Oct-13
A1890	INSTALL BRICK WEST AREA C	8	30-Oct-13*	08-Nov-13
A1900	INSTALL BRICK EAST AREA C	9	11-Nov-13*	21-Nov-13
A1910	INSTALL BRICK SOUTH AREA B	11	22-Nov-13*	09-Dec-13
A1920	INSTALL BRICK SOUTH AREA A	6	10-Dec-13*	17-Dec-13
WINDOWS		51	28-Oct-13	08-Jan-14
A1930	INSTALL WINDOWS NORTH AREA A	5	28-Oct-13*	01-Nov-13
A1940	INSTALL WINDOWS NORTH AREA B	6	04-Nov-13*	11-Nov-13
A1950	INSTALL WINDOWS WEST AREA C	6	19-Nov-13*	26-Nov-13
A1960	INSTALL WINDOWS EAST AREA C	5	09-Dec-13*	13-Dec-13
A1970	INSTALL WINDOWS SOUTH AREA B	6	19-Dec-13*	27-Dec-13
A1980	INSTALL WINDOWS SOUTH AREA A	8	30-Dec-13*	08-Jan-14
METAL PANELS		49	28-Oct-13	06-Jan-14
A1990	INSTALL TOP FLOOR METAL PANELS NORTH AF	5	28-Oct-13*	01-Nov-13
A2000	INSTALL TOP FLOOR METAL PANELS NORTH AF	6	04-Nov-13*	11-Nov-13
A2010	INSTALL TOP FLOOR METAL PANELS WEST ARE	7	19-Nov-13*	27-Nov-13
A2020	INSTALL TOP FLOOR METAL PANELS EAST ARE	5	09-Dec-13*	13-Dec-13
A2030	INSTALL TOP FLOOR METAL PANELS SOUTH AF	6	19-Dec-13*	27-Dec-13
A2040	INSTALL TOP FLOOR METAL PANELS SOUTH AF	6	30-Dec-13*	06-Jan-14
INTERIOR		213	01-Jul-13	29-Apr-14
MECHANICAL		149	03-Sep-13	01-Apr-14
A2050	INSTALL ROOFTOP AHU	5	24-Oct-13*	30-Oct-13
A2060	INSTALL GROUND FLOOR DUCT RISERS	11	03-Sep-13	17-Sep-13
A2061	INSTALL 2ND FLOOR DUCT RISERS	6	10-Sep-13	17-Sep-13
A2062	INSTALL 3RD FLOOR DUCT RISERS	6	18-Sep-13	25-Sep-13
A2063	INSTALL 4TH FLOOR DUCT RISERS	6	25-Sep-13*	02-Oct-13
A2070	R/I GROUND FLOOR DUCT BRANCHES	6	24-Sep-13	01-Oct-13
A2071	R/I 2ND FLOOR DUCT BRANCHES	6	03-Oct-13	10-Oct-13
A2072	R/I 3RD FLOOR DUCT BRANCHES	6	11-Oct-13*	18-Oct-13
A2073	R/I 4TH FLOOR DUCT BRANCHES	6	21-Oct-13*	28-Oct-13
A2080	INSTALL GROUND FLOOR STACKED FAN COILS	6	01-Oct-13	08-Oct-13
A2081	INSTALL 2ND FLOOR STACKED FAN COILS	6	10-Oct-13	17-Oct-13
A2082	INSTALL 3RD FLOOR STACKED FAN COILS	6	18-Oct-13*	25-Oct-13
A2083	INSTALL 4TH FLOOR STACKED FAN COILS	6	25-Oct-13*	01-Nov-13
A2090	INSTALL GROUND FLOOR GRILLS & DIFFUSER:	6	13-Feb-14*	20-Feb-14
A2091	INSTALL 2ND FLOOR GRILLS & DIFFUSERS	6	25-Feb-14*	04-Mar-14
A2092	INSTALL 3RD FLOOR GRILLS & DIFFUSERS	6	11-Mar-14*	18-Mar-14
A2093	INSTALL 4TH FLOOR GRILLS & DIFFUSERS	6	25-Mar-14*	01-Apr-14
A2210	INSTALL PUMPS, HEAT EX, ACUS & CONTROLLI	11	13-Nov-13*	27-Nov-13
ELECTRICAL		160	01-Jul-13	14-Feb-14
A1380	UNDERGROUND ELECTRIC	6	01-Jul-13	09-Jul-13
A2110	R/I GROUND FLOOR UNIT ELECTRIC	4	24-Sep-13	27-Sep-13
A2111	R/I 2ND FLOOR UNIT ELECTRIC	6	03-Oct-13	10-Oct-13
A2112	R/I 3RD FLOOR UNIT ELECTRIC	6	11-Oct-13*	18-Oct-13
A2113	R/I 4TH FLOOR UNIT ELECTRIC	6	23-Oct-13*	30-Oct-13
A2240	INSTALL SWITCHGEAR	11	14-Jan-14*	28-Jan-14
A2250	ENERGIZE PERMANENT POWER	0	14-Feb-14*	
PLUMBING		180	01-Jul-13	13-Mar-14
A1370	UNDERGROUND PLUMBING	6	01-Jul-13	09-Jul-13
A2100	INSTALL GROUND FLOOR SANITARY & PLUMBII	6	03-Sep-13	10-Sep-13
A2101	INSTALL 2ND FLOOR SANITARY & PLUMBING R	6	10-Sep-13	17-Sep-13
A2102	INSTALL 3RD FLOOR SANITARY & PLUMBING R	6	18-Sep-13	25-Sep-13
A2103	INSTALL 4TH FLOOR SANITARY & PLUMBING R	6	25-Sep-13	02-Oct-13
A2190	R/I GROUND FLOOR BATHROOM PLUMBING	4	13-Sep-13	18-Sep-13
A2191	R/I 2ND FLOOR BATHROOM PLUMBING	4	24-Sep-13	27-Sep-13
A2192	R/I 3RD FLOOR BATHROOM PLUMBING	4	02-Oct-13	07-Oct-13
A2193	R/I 4TH FLOOR BATHROOM PLUMBING	4	09-Oct-13	14-Oct-13
A2200	INSTALL GROUND FLOOR PLUMBING FIXTURE:	4	27-Jan-14*	30-Jan-14
A2300	INSTALL 2ND FLOOR PLUMBING FIXTURES	4	30-Jan-14*	04-Feb-14
A2310	INSTALL 3RD FLOOR PLUMBING FIXTURES	4	24-Feb-14*	27-Feb-14
A2360	INSTALL 4TH FLOOR PLUMBING FIXTURES	4	10-Mar-14*	13-Mar-14
FIRE PROTECTION		40	24-Sep-13	18-Nov-13
A2120	R/I GROUND FLOOR UNITSPRINKLER	4	24-Sep-13	27-Sep-13
A2121	R/I 2ND FLOOR UNIT SPRINKLER	6	03-Oct-13*	10-Oct-13
A2122	R/I 3RD FLOOR UNIT SPRINKLER	6	11-Oct-13*	18-Oct-13
A2123	R/I 4TH FLOOR UNIT SPRINKLER	6	23-Oct-13*	30-Oct-13
A2230	INSTALL SPRINKLER PUMP	4	13-Nov-13*	18-Nov-13
TELECOM		27	24-Sep-13	30-Oct-13
A2130	R/I GROUND FLOOR UNIT TELECOM	4	24-Sep-13	27-Sep-13
A2270	R/I 2ND FLOOR UNIT TELECOM	6	03-Oct-13	10-Oct-13
A2320	R/I 3RD FLOOR UNIT TELECOM	6	11-Oct-13*	18-Oct-13
A2370	R/I 4TH FLOOR UNIT TELECOM	6	23-Oct-13*	30-Oct-13
DRYWALL		126	10-Sep-13	06-Mar-14
A2140	FRAME GROUND FLOOR STUD WALLS & CEILII	11	10-Sep-13	24-Sep-13



Actual Level of Effort | Remaining Work | ◆ Milestone
Actual Work | Critical Remaining Work | summary

TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Start	Finish
A2141	FRAME 2ND FLOOR STUD WALLS & CEILINGS	16	17-Sep-13	08-Oct-13
A2142	FRAME 3RD FLOOR STUD WALLS & CEILINGS	13	25-Sep-13	11-Oct-13
A2143	FRAME 4TH FLOOR STUD WALLS & CEILINGS	16	02-Oct-13	23-Oct-13
A2150	HANG GROUND FLOOR DRYWALL	8	14-Jan-14*	23-Jan-14
A2280	HANG 2ND FLOOR DRYWALL	11	23-Jan-14*	06-Feb-14
A2330	HANG 3RD FLOOR DRYWALL	11	06-Feb-14*	20-Feb-14
A2380	HANG 4TH FLOOR DRYWALL	11	20-Feb-14*	06-Mar-14
PAINT		34	27-Feb-14	15-Apr-14
A2160	GROUND FLOOR FINAL PAINT	6	27-Feb-14*	06-Mar-14
A2170	2ND FLOOR FINAL PAINT	6	11-Mar-14*	18-Mar-14
A2340	3RD FLOOR FINAL PAINT	6	25-Mar-14*	01-Apr-14
A2390	4TH FLOOR FINAL PAINT	5	09-Apr-14*	15-Apr-14
FLOORING		34	13-Mar-14	29-Apr-14
A2180	GROUND FLOOR CARPET & BASE	6	13-Mar-14*	20-Mar-14
A2290	2ND FLOOR CARPET & BASE	6	25-Mar-14*	01-Apr-14
A2350	3RD FLOOR CARPET & BASE	6	08-Apr-14*	15-Apr-14
A2400	4TH FLOOR CARPET & BASE	6	22-Apr-14*	29-Apr-14
ELEVATORS		99	25-Oct-13	14-Mar-14
ELEVATORS		99	25-Oct-13	14-Mar-14
A2410	TEMPORARY CAR	59	25-Oct-13*	17-Jan-14
A2420	INSTALL ELEVATORS	99	25-Oct-13*	14-Mar-14
COMMISSIONING & INSPECTIONS		123	06-Feb-14	29-Jul-14
MECHANICAL		44	06-Feb-14	08-Apr-14
A2430	CONDITIONED SPACE	0	06-Feb-14*	
A2440	TESTING AND BALANCING	16	04-Mar-14*	25-Mar-14
A2450	BUILDING COMMISSIONING	11	25-Mar-14*	08-Apr-14
GENERAL BUILDING		70	22-Apr-14	29-Jul-14
A2460	PRETEST FIRE ALARM SYSTEM	21	22-Apr-14*	20-May-14
A2470	FIRE MARSHALL TEST FIRE ALARM	11	20-May-14*	03-Jun-14
A2480	INSTALL FF&E	29	13-May-14*	20-Jun-14
A2490	FINAL BUILDING OCCUPANCY INSPECTIONS	21	03-Jun-14*	01-Jul-14
A2500	SUBSTAINTIAL COMPLETION	0	01-Jul-14*	
A2510	FINAL COMPLETION	0	29-Jul-14*	



Actual Level of Effort | Remaining Work | ◆ Milestone
Actual Work | Critical Remaining Work | summary

TASK filter: All Activities

Appendix B:

Construction Project Estimates

GMU Taylor Hall - HVAC

Data Release :Year 2013 Quarter 3 **Assembly Cost Estimate**

Quantity	Assembly Number	Sourc	SubCo	Description	Unit	Material O&P	Installation O&P	Total O&P	Ext. Material O&P	Ext. Installation O&P	Ext. Total O&P	Labor Type	Data Release	Zip Code	Notes
70057	M1	U		70,057 Interpolated Large Hydronic Heating System	S.F.	$ 8.15	$ -	$ 8.15	$ 570,964.55	$ -	$ 570,964.55	USER	Year 2013 Quarter 3		
70057	M2	U		20,300 CFM, 50.75 ton Rooftop AHU for a college dorm, interpolated	Ea.	$ 20.15	$ -	$ 20.15	$ 1,411,648.55	$ -	$ 1,411,648.55	USER	Year 2013 Quarter 3		
								Total	**$ 1982613.10**	**$ .00**	**$ 1982613.10**				

GMU Taylor Hall

Data Release :Year 2013 Quarter 3 **Assembly Cost Estimate**

Quantity	Assembly Number	Sourc	SubCo	Description	Unit	Material O&P	Installation O&P	Total O&P	Ext. Material O&P	Ext. Installation O&P	Ext. Total O&P	Labor Type	Data Release	Zip Code	Notes
70057	1	U		Recepticles, 14.5 per 1000 SF	S.F.	$ 3.00	$ 0.07	$ 3.07	$ 210,171.00	$ 4,903.99	$ 215,074.99	USER	Year 2013 Quarter 3		
70057	2	U		Wall Switch per. SF. 2.85 per 1000 SF	S.F.	$ 0.60	$ -	$ 0.60	$ 42,034.20	$ -	$ 42,034.20	USER	Year 2013 Quarter 3		
1	I3	U		Panelboard, 4 wire w/conductor & conduit, NEHB, 120/208 V, 800 A, 1 stories, 25' horizontal.	Ea.	$19,308.29	$ -	$ 19,308.29	$ 19,308.29	$ -	$ 19,308.29	USER	Year 2013 Quarter 3		
1	D50102400580			Switchgear installation, incl switchboard, panels & circuit breaker, 277/480 V, 1200 A	Ea.	$25,751.40	$ 6,893.25	$ 32,644.65	$ 25,751.40	$ 6,893.25	$ 32,644.65	OPN	Year 2013 Quarter 3		
3	D50102502000			Panelboard, 4 wire w/conductor & conduit, NQOD, 120/208 V, 225 A, 1 stories, 25' horizontal		$ 3,657.30	$ 2,449.25	$ 6,106.55	$ 10,971.90	$ 7,347.75	$ 18,319.65	OPN	Year 2013 Quarter 3		
1	D50102504040			Panelboard, 4 wire w/conductor & conduit, NEHB, 277/480 V, 100 A, 1 stories, 25' horizontal		$ 3,481.95	$ 2,121.00	$ 5,602.95	$ 3,481.95	$ 2,121.00	$ 5,602.95	OPN	Year 2013 Quarter 3		
3	D50102501020			Panelboard, 4 wire w/conductor & conduit, NQOD, 120/208 V, 100 A, 1 stories, 25' horizontal		$ 1,703.40	$ 1,691.75	$ 3,395.15	$ 5,110.20	$ 5,075.25	$ 10,185.45	OPN	Year 2013 Quarter 3		
1	D50102502080			Panelboard, 4 wire w/conductor & conduit, NQOD, 120/208 V, 400 A, 1 stories, 25' horizontal		$ 5,185.35	$ 3,787.50	$ 8,972.85	$ 5,185.35	$ 3,787.50	$ 8,972.85	OPN	Year 2013 Quarter 3		
2	I4	U		Panelboard, 4 wire w/conductor & conduit, NEHB, 277/480 V, 225 A, 4 stories	Ea.	$12,007.35	$ -	$ 12,007.35	$ 24,014.70	$ -	$ 24,014.70	USER	Year 2013 Quarter 3		
1	I5	U		Panelboard, 4 wire w/conductor & conduit, NQOD, 277/480 V, 250 A, 1 stories	Ea.	$ 9,493.53	$ -	$ 9,493.53	$ 9,493.53	$ -	$ 9,493.53	USER	Year 2013 Quarter 3		
2	I6	U		Panelboard, 4 wire w/conductor & conduit, NQOD, 277/480 V, 100 A, 4 stories	Ea.	$ 6,961.50	$ -	$ 6,961.50	$ 13,923.00	$ -	$ 13,923.00	USER	Year 2013 Quarter 3		
3	I7	U		Panelboard, 4 wire w/conductor & conduit, NQOD, 120/208 V, 225 A, 4 stories	Ea.	$ 9,348.65	$ -	$ 9,348.65	$ 28,045.95	$ -	$ 28,045.95	USER	Year 2013 Quarter 3		
3	I8	U		Panelboard, 4 wire w/conductor & conduit, NEHB, 120/208 V, 225 A, 3 stories	Ea.	$ 8,267.95	$ -	$ 8,267.95	$ 24,803.85	$ -	$ 24,803.85	USER	Year 2013 Quarter 3		
3	I9	U		Panelboard, 4 wire w/conductor & conduit, NEHB 120/208 V, 225 A, 2 stories	Ea.	$ 7,187.25	$ -	$ 7,187.25	$ 21,561.75	$ -	$ 21,561.75	USER	Year 2013 Quarter 3		
2	I10	U		Panelboard, 4 wire w/conductor & conduit, NEHB, 120/208 V, 100 A, 4 stories	Ea.	$ 4,772.64	$ -	$ 4,772.64	$ 9,545.28	$ -	$ 9,545.28	USER	Year 2013 Quarter 3		
70057	D50202100240			Fluorescent fixtures recess mounted in ceiling, 2 watt per SF, 40 FC, 10 fixtures @40 watt per 1000 SF	S.F.	$ 1.52	$ 3.21	$ 4.73	$ 106,486.64	$ 224,882.97	$ 331,369.61	OPN	Year 2013 Quarter 3		
70057	D50201400200			Central air conditioning power, 1 watt	S.F.	$ 0.07	$ 0.22	$ 0.29	$ 4,903.99	$ 15,412.54	$ 20,316.53	OPN	Year 2013 Quarter 3		
70.06	I11	U		Telecom/Data connection per 1000 S.F, 5.18 connections	Ea.	$ 1,454.91	$ -	$ 1,454.91	$ 101,930.99	$ -	$ 101,930.99	USER	Year 2013 Quarter 3		
2	D50309100440			Communication and alarm systems, fire detection, non-addressable, 100 detectors, includes outlets, boxes, conduit and wire	Ea.	$21,242.40	$35,451.00	$ 56,693.40	$ 42,484.80	$ 70,902.00	$ 113,386.80	OPN	Year 2013 Quarter 3		
1	D50101301250			Underground service installation, includes excavation, backfill, and compaction, 100' length, 4' depth, 3 phase, 4 wire, 277/480 volts, 1200 A w/groundfault switchboard	Ea.	$48,096.00	$13,050.00	$ 61,146.00	$ 48,096.00	$ 13,050.00	$ 61,146.00	OPN	Year 2013 Quarter 3		
								Total	**$ 757304.77**	**$ 354376.25**	**1111681.02**				

GMU Taylor Hall Plumbing

Data Release :Year 2013 Quarter 3 **Assembly Cost Estimate**

Quantity	Assembly Number	Sourc	SubCo	Description	Unit	Material O&P	Installation O&P	Total O&P	Ext. Material O&P	Ext. Installation O&P	Ext. Total O&P	Labor Type	Data Release	Zip Code	Notes
5	D20109264680			Bathroom, three fixture, 2 wall plumbing, water closet, corner bathtub & lavatory, stand alone	Ea.	$ 4,865.73	$2,128.00	$ 6,993.73	$ 24,328.65	$ 10,640.00	$ 34,968.65	STD	Year 2013 Quarter 3		
16	D20101201760			Water closets, battery mount, wall hung, side by side, first closet	Ea.	$ 2,038.00	$ 748.16	$ 2,786.16	$ 32,608.00	$ 11,970.56	$ 44,578.56	STD	Year 2013 Quarter 3		
30	D20101201800			Water closetss, battery mount, wall hung, side by side, each additional water closet, add	Ea.	$ 1,936.10	$ 707.84	$ 2,643.94	$ 58,083.00	$ 21,235.20	$ 79,318.20	STD	Year 2013 Quarter 3		
28	D20107101600			Shower, stall, baked enamel, molded stone receptor, 32" square	Ea.	$ 1,808.73	$ 748.16	$ 2,556.89	$ 50,644.44	$ 20,948.48	$ 71,592.92	STD	Year 2013 Quarter 3		
14	D20107102100			Shower, handicap with fixed and handheld heat, control valves,grab bar & seat	Ea.	$ 6,139.48	$3,315.20	$ 9,454.68	$ 85,952.72	$ 46,412.80	$ 132,365.52	STD	Year 2013 Quarter 3		
51	D20103101640			Lavatory w/trim, vanity top, PE on CI, 18" round	Ea.	$ 718.40	$ 640.64	$ 1,359.04	$ 36,638.40	$ 32,672.64	$ 69,311.04	STD	Year 2013 Quarter 3		
3	D20108201880			Water cooler, electric, wall hung, dual height, 14.3 GPH	Ea.	$ 1,477.55	$ 560.00	$ 2,037.55	$ 4,432.65	$ 1,680.00	$ 6,112.65	STD	Year 2013 Quarter 3		
6	D20108101920			Drinking fountain, 1 bubbler, wall mounted, non recessed, stainless steel, no back	Ea.	$ 1,553.98	$ 421.12	$ 1,975.10	$ 9,323.88	$ 2,526.72	$ 11,850.60	STD	Year 2013 Quarter 3		
3	D20202402020			Electric water heater, commercial, 100< F rise, 200 gal, 120 KW 490 GPH	Ea.	$30,570.00	$1,657.60	$ 32,227.60	$ 91,710.00	$ 4,972.80	$ 96,682.80	STD	Year 2013 Quarter 3		
3	D20402106200			Roof drain, steel galv sch 40 threaded, 4" diam piping, 10' high	Ea.	$ 2,088.95	$1,187.20	$ 3,276.15	$ 6,266.85	$ 3,561.60	$ 9,828.45	STD	Year 2013 Quarter 3		
								Total	**$ 399988.59**	**$ 156620.80**	**556609.39**				

GMU Taylor Hall Structural

Data Release : Year 2 **Unit Cost Estimate**

Quantity	LineNumber	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total	Mat. O&P	Labor O&P	Equip. O&P	Total O&P	Ext. Mat. O&P	Ext. Labor O&P	Ext. Equip. O&P	Ext. Total O&P	Labor Type	Data Release
5.04	051223174500	Column, structural tubing, square, 4" x 4" x 1/4" x 12'-0", incl shop primer, cap & base plate, bolts	E2	58	0.97	Ea.	$217.80	$ 46.17	$ 26.84	$ 290.81	$ 1,097.71	$ 232.70	$ 135.27	$ 1,465.68	$ 239.07	$ 78.73	$ 29.38	$ 347.18	$ 1,204.91	$ 396.80	$ 148.08	$ 1,749.79	STD	Year 2013 Quarter 3
30.54	051223175600	Column, structural tubing, rectangular, 8" x 4" x 3/8" x 12'-0", incl shop primer, cap & base plate, bolts	E2	54	1.04	Ea.	$481.18	$ 49.57	$ 28.36	$ 559.11	$ 14,695.24	$ 1,513.87	$ 866.11	$ 17,075.22	$ 526.76	$ 84.56	$ 31.40	$ 642.72	$ 16,087.25	$ 2,582.46	$ 958.96	$ 19,628.67	STD	Year 2013 Quarter 3
17.31	SS1	Column, structural tubing, square, 4' x 4" x 3/8" x 12'. Interpolated		0	0	Ea.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 390.58	$ -	$ -	$ 390.58	$ 6,760.94	$ -	$ -	$ 6,760.94	USER	Year 2013 Quarter 3
1.2	SS2	Column, structural tubing, square 4" x 4" x 1/2" x 12'. Interpolated		0	0	Ea.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 694.36	$ -	$ -	$ 694.36	$ 833.23	$ -	$ -	$ 833.23	USER	Year 2013 Quarter 3
8.13	SS3	Column, structural tubing, square, 6" x 4" x 3/8"		0	0	Ea.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 535.39	$ -	$ -	$ 535.39	$ 4,352.72	$ -	$ -	$ 4,352.72	USER	Year 2013 Quarter 3
3.57	SS4	Column, structural tubing, square, 8" x 4" x 1/2" x 12'. Interpolated		0	0	Ea.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 925.52	$ -	$ -	$ 925.52	$ 3,304.11	$ -	$ -	$ 3,304.11	USER	Year 2013 Quarter 3
12.18	SS5	Column, structural tubing, rectangular, 8" x 4" x 1/4". Interpolated		0	0	Ea.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 424.20	$ -	$ -	$ 424.20	$ 5,166.76	$ -	$ -	$ 5,166.76	USER	Year 2013 Quarter 3
3.88	SS6	Column, structural tubing, rectangular, 10" x 6" x 5/8" x 14'. Interpolated.		0	0	Ea.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,612.14	$ -	$ -	$ 1,612.14	$ -	$ -	$ -	$ 6,255.10	USER	Year 2013 Quarter 3
12.41	SS7	Column, structural tubing, rectangular 12" x 4" x 3/8" x 14'		0	0	Ea.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 971.17	$ -	$ -	$ 971.17	$ 12,052.22	$ -	$ -	$ 12,052.22	USER	Year 2013 Quarter 3
7.48	SS8	Column, structural tubing, rectangular, 12' x 4" x 1/4" x 14'. Interpolated		0	0	Ea.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 640.97	$ -	$ -	$ 640.97	$ 4,794.46	$ -	$ -	$ 4,794.46	USER	Year 2013 Quarter 3
264.85	051223750360	Structural steel beam or girder, 100-ton project, 1 to 2 story building, W8x24, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	550	0.1	L.F.	$ 34.95	$ 4.85	$ 2.81	$ 42.61	$ 9,256.51	$ 1,284.52	$ 744.23	$ 11,285.26	$ 38.49	$ 8.31	$ 3.09	$ 49.89	$ 10,194.08	$ 2,200.90	$ 818.39	$ 13,213.37	STD	Year 2013 Quarter 3
9.5	051223750700	Structural steel beam or girder, 100-ton project, 1 to 2 story building, W10x22, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.09	L.F.	$ 31.91	$ 4.45	$ 2.57	$ 38.93	$ 303.15	$ 42.28	$ 24.42	$ 369.84	$ 34.95	$ 7.63	$ 2.84	$ 45.42	$ 332.03	$ 72.49	$ 26.98	$ 431.49	STD	Year 2013 Quarter 3
37.06	051223750720	Structural steel beam or girder, 100-ton project, 1 to 2 story building, W10x26, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.09	L.F.	$ 37.48	$ 4.45	$ 2.57	$ 44.50	$ 1,389.01	$ 164.92	$ 95.24	$ 1,649.17	$ 41.53	$ 7.63	$ 2.84	$ 52.00	$ 1,539.10	$ 282.77	$ 105.25	$ 1,927.12	STD	Year 2013 Quarter 3
214.75	051223751520	Structural steel beam or girder, 100-ton project, 1 to 2 story building, W12x35, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	810	0.07	L.F.	$ 50.65	$ 3.30	$ 1.90	$ 55.85	$ 10,877.09	$ 708.68	$ 408.03	$ 11,993.79	$ 55.72	$ 5.64	$ 2.10	$ 63.46	$ 11,965.87	$ 1,211.19	$ 450.98	$ 13,628.04	STD	Year 2013 Quarter 3
243.17	051223752700	Structural steel beam or girder, 100-ton project, 1 to 2 story building, W16x26, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	1000	0.06	L.F.	$ 37.48	$ 2.67	$ 1.54	$ 41.69	$ 9,114.01	$ 649.26	$ 374.48	$ 10,137.76	$ 41.53	$ 4.57	$ 1.70	$ 47.80	$ 10,098.85	$ 1,111.29	$ 413.39	$ 11,623.53	STD	Year 2013 Quarter 3
71.46	051223752900	Structural steel beam or girder, 100-ton project, 1 to 2 story building, W16x31, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	900	0.06	L.F.	$ 45.08	$ 2.96	$ 1.71	$ 49.75	$ 3,221.42	$ 211.52	$ 122.20	$ 3,555.14	$ 49.64	$ 5.05	$ 1.88	$ 56.57	$ 3,547.27	$ 360.87	$ 134.34	$ 4,042.49	STD	Year 2013 Quarter 3
38.79	051223753120	Structural steel beam or girder, 100-ton project, 1 to 2 story building, W16x50, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	800	0.07	L.F.	$ 72.43	$ 3.33	$ 1.93	$ 77.69	$ 2,809.56	$ 129.17	$ 74.86	$ 3,013.60	$ 79.52	$ 5.73	$ 2.13	$ 87.38	$ 3,084.58	$ 222.27	$ 82.62	$ 3,389.47	STD	Year 2013 Quarter 3
65.83	033053403825	Structural concrete, in place, spread footing (3000 psi), 1 C.Y. to 5 C.Y., includes forms(4 uses), Grade 60 rebar, concrete (Portland cement Type I), placing and finishing	C14C	43	2.6	C.Y.	$208.23	$ 93.41	$ 0.77	$ 302.41	$ 13,707.78	$ 6,149.18	$ 50.69	$ 19,907.65	$ 229.37	$ 143.45	$ 0.84	$ 373.66	$ 15,099.43	$ 9,443.31	$ 55.30	$ 24,598.04	STD	Year 2013 Quarter 3
26.88	033053403850	Structural concrete, in place, spread footing (3000 psi), over 5 C.Y., includes forms(4 uses), Grade 60 rebar, concrete (Portland cement Type I), placing and finishing	C14C	75	1.49	C.Y.	$189.20	$ 53.38	$ 0.44	$ 243.02	$ 5,085.70	$ 1,434.85	$ 11.83	$ 6,532.38	$ 208.23	$ 82.57	$ 0.49	$ 291.29	$ 5,597.22	$ 2,219.48	$ 13.17	$ 7,829.88	STD	Year 2013 Quarter 3
11.1	SS9	Structural steel beam, W10X30, Interpolated		0	0	L.F.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 58.90	$ -	$ -	$ 58.90	$ 653.79	$ -	$ -	$ 653.79	USER	Year 2013 Quarter 3
76.63	SS10	Structural steel beam, W12X19, Interpolated		0	0	L.F.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 37.27	$ -	$ -	$ 37.27	$ 2,856.00	$ -	$ -	$ 2,856.00	USER	Year 2013 Quarter 3
131.13	SS11	Structural Steel Beam, W12X40, Interpolated		0	0	L.F.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 71.60	$ -	$ -	$ 71.60	$ 9,388.91	$ -	$ -	$ 9,388.91	USER	Year 2013 Quarter 3
11.29	SS12	Structural Steel Beam, W14X68, Interpolated		0	0	L.F.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 116.26	$ -	$ -	$ 116.26	$ 1,312.58	$ -	$ -	$ 1,312.58	USER	Year 2013 Quarter 3
16.38	SS13	Structural Steel Beam, W14x132, Interpolated		0	0	L.F.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 220.21	$ -	$ -	$ 220.21	$ 3,607.04	$ -	$ -	$ 3,607.04	USER	Year 2013 Quarter 3
21	SS14	Structural Steel Beam, W16X57, Interpolated		0	0	L.F.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 98.60	$ -	$ -	$ 98.60	$ 2,070.60	$ -	$ -	$ 2,070.60	USER	Year 2013 Quarter 3
70	051223650450	Steel plate, structural, for connections & stiffeners, 3/4" T, shop fabricated, incl shop primer		0	0	S.F.	$ 40.52	$ -	$ -	$ 40.52	$ 2,836.40	$ -	$ -	$ 2,836.40	$ 44.57	$ -	$ -	$ 44.57	$ 3,119.90	$ -	$ -	$ 3,119.90	STD	Year 2013 Quarter 3
5.5	051223650500	Steel plate, structural, for connections & stiffeners, 1" T, shop fabricated, incl shop primer		0	0	S.F.	$ 53.69	$ -	$ -	$ 53.69	$ 295.30	$ -	$ -	$ 295.30	$ 59.26	$ -	$ -	$ 59.26	$ 325.93	$ -	$ -	$ 325.93	STD	Year 2013 Quarter 3
277.2	033105701950	Structural concrete, placing, continuous footing, shallow, pumped, includes leveling (strike off) & consolidation, excludes material	C20	150	0.43	C.Y.	$ -	$ 13.59	$ 5.27	$ 18.86	$ -	$ 3,767.15	$ 1,460.84	$ 5,227.99	$ -	$ 20.85	$ 5.82	$ 26.67	$ -	$ 5,779.62	$ 1,613.30	$ 7,392.92	STD	Year 2013 Quarter 3
282	033105704350	Structural concrete, placing, slab on grade, pumped, up to 6" thick, includes leveling (strike off) & consolidation, excludes material	C20	130	0.49	C.Y.	$ -	$ 15.68	$ 6.08	$ 21.76	$ -	$ 4,421.76	$ 1,714.56	$ 6,136.32	$ -	$ 23.77	$ 6.69	$ 30.46	$ -	$ 6,703.14	$ 1,886.58	$ 8,589.72	STD	Year 2013 Quarter 3
637.5	033105701400	Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes leveling (strike off) & consolidation, excludes material	C20	140	0.46	C.Y.	$ -	$ 14.55	$ 5.67	$ 20.22	$ -	$ 9,275.63	$ 3,614.63	$ 12,890.25	$ -	$ 22.10	$ 6.23	$ 28.33	$ -	$ 14,088.75	$ 3,971.63	$ 18,060.38	STD	Year 2013 Quarter 3
1256	033105350150	Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, sand, Portland cement (Type I) and water, delivered, excludes all additives and treatments		0	0	C.Y.	$102.53	$ -	$ -	$ 102.53	$ 128,777.68	$ -	$ -	$ 128,777.68	$ 113.10	$ -	$ -	$ 113.10	$ 142,053.60	$ -	$ -	$ 142,053.60	STD	Year 2013 Quarter 3
2762	051223201000	Curb edging, structural steel angle w/ anchors, on concrete forms, 12.3 plf, 6" x 4", shop fabricated	E4	250	0.13	L.F.	$ 20.21	$ 6.27	$ 0.59	$ 27.07	$ 55,820.02	$ 17,317.74	$ 1,629.58	$ 74,767.34	$ 22.29	$ 11.23	$ 0.64	$ 34.16	$ 61,564.98	$ 31,017.26	$ 1,767.68	$ 94,349.92	STD	Year 2013 Quarter 3
66.2	032110500700	Reinforcing steel, average price, cut, bent and delivered, A615, grade 60, material only		0	0	Ton	$971.00	$ -	$ -	$ 971.00	$ 64,280.20	$ -	$ -	$ 64,280.20	$ 1,068.10	$ -	$ -	$ 1,068.10	$ 70,708.22	$ -	$ -	$ 70,708.22	STD	Year 2013 Quarter 3
66.2	032113100150	Galvanized coating, for reinforcing steel, add to fabricated & delivered price of uncoated reinforcing		0	0	Ton	$446.66	$ -	$ -	$ 446.66	$ 29,568.89	$ -	$ -	$ 29,568.89	$ 490.36	$ -	$ -	$ 490.36	$ 32,461.83	$ -	$ -	$ 32,461.83	STD	Year 2013 Quarter 3
175.14	033913500015	Curing, burlap, 7.5 oz., 4 uses assumed	2 Clab	55	0.29	C.S.F.	$ 14.80	$ 8.59	$ -	$ 23.39	$ 2,592.07	$ 1,504.45	$ -	$ 4,096.52	$ 16.33	$ 13.26	$ -	$ 29.59	$ 2,860.04	$ 2,322.36	$ -	$ 5,182.39	STD	Year 2013 Quarter 3
51818	053113505300	Metal floor decking, steel, non-cellular, composite, galvanized, 2" D, 20 gauge	E4	3600	0.01	S.F.	$ 2.19	$ 0.45	$ 0.04	$ 2.68	$ 113,481.42	$ 23,318.10	$ 2,072.72	$ 138,872.24	$ 2.40	$ 0.81	$ 0.04	$ 3.25	$ 124,363.20	$ 41,972.58	$ 2,072.72	$ 168,408.50	STD	Year 2013 Quarter 3
1394	053123502600	Metal roof decking, steel, open type B wide rib, galvanized, under 50 Sq, 1-1/2" D, 20 gauge	E4	3865	0.01	S.F.	$ 2.45	$ 0.42	$ 0.04	$ 2.91	$ 3,415.30	$ 585.48	$ 55.76	$ 4,056.54	$ 2.70	$ 0.76	$ 0.04	$ 3.50	$ 3,763.80	$ 1,059.44	$ 55.76	$ 4,879.00	STD	Year 2013 Quarter 3
18216	053123502100	Metal roof decking, steel, open type B wide rib, galvanized, under 50 sq., 1-1/2" D, 22 gauge	E4	4500	0.01	S.F.	$ 2.10	$ 0.36	$ 0.03	$ 2.49	$ 38,253.60	$ 6,557.76	$ 546.48	$ 45,357.84	$ 2.31	$ 0.64	$ 0.04	$ 2.99	$ 42,078.96	$ 11,658.24	$ 728.64	$ 54,465.84	STD	Year 2013 Quarter 3
323	052119100180	Open web bar joist, K Series, 40-ton job lots, 14K3, 6.0 plf, spans up to 30', shop fabricated, incl shop primer, horizontal bridging	E7	1500	0.05	L.F.	$ 5.26	$ 2.66	$ 1.23	$ 9.15	$ 1,698.98	$ 859.18	$ 397.29	$ 2,955.45	$ 5.77	$ 4.61	$ 1.35	$ 11.73	$ 1,863.71	$ 1,489.03	$ 436.05	$ 3,788.79	STD	Year 2013 Quarter 3
86	054413601160	Roof truss, using galv LB metal studs, fink (W) or King Post type, 5:12 to 8:12 pitch, 18 ga x 4" chords, 32' span, excl erection, bridging & bracing, fabrication only of trusses on-site	2 Carp	8	2	Ea.	$140.97	$ 89.19	$ -	$ 230.16	$ 12,123.42	$ 7,670.34	$ -	$ 19,793.76	$ 155.70	$ 136.76	$ -	$ 292.46	$ 13,390.20	$ 11,761.36	$ -	$ 25,151.56	STD	Year 2013 Quarter 3
395	050523102200	Bolt, hex head, plain steel, 3/4" dia x 2" L, A307, incl nut & washer	1 Sswk	120	0.07	Ea.	$ 1.18	$ 3.31	$ -	$ 4.49	$ 466.10	$ 1,307.45	$ -	$ 1,773.55	$ 1.29	$ 5.90	$ -	$ 7.19	$ 509.55	$ 2,330.50	$ -	$ 2,840.05	STD	Year 2013 Quarter 3
6278	031113455000	C.I.P. concrete forms, footing, spread, plywood, 1 use, includes erecting, bracing, stripping and cleaning	C1	305	0.1	SFCA	$ 1.81	$ 3.32	$ -	$ 5.13	$ 11,363.18	$ 20,842.96	$ -	$ 32,206.14	$ 1.99	$ 5.10	$ -	$ 7.09	$ 12,493.22	$ 32,017.80	$ -	$ 44,511.02	STD	Year 2013 Quarter 3
7181	Infinity	partition, galv. LB studs, 18ga x 3-5/8" W studs 16" O.C. x 10' H. Pre-fabricated		0	0	L.F.	$ 10.05	$ 9.36	$ -	$ 19.41	$ 72,169.05	$ 67,214.16	$ -	$ 139,383.21	$ 11.05	$ 21.63	$ -	$ 32.68	$ 79,350.05	$ 155,325.03	$ -	$ 234,675.08	USER	Year 2013 Quarter 3
Total											**$608698.77**	**$177163.10**	**$14399.22**	**$800261.09**					**$726811.12**	**$337628.94**	**$15739.81**	**$1086434.97**		

Electrical - Assemblies Estimate

	Size	Voltage	Qty
Switchboard	1200 A	480Y/277 V	1
Panel HDP	225 A	480Y/277 V	1
Panel LDP1	800 A	208Y/120 V	1
Panel HLP	400 A	208Y/120 V	1
Panel ESBH	250 A	480V/277 V	1
Panel ELSH	100 A	480V/277 V	1
Panel LP1	225 A	208Y/120 V	2
Panel ESBP	400 A	208Y/120 V	1
Panel ELSP	100 A	208Y/120 V	1
Panel LP2	225 A	208Y/120 V	3
Panel LP3	225 A	208Y/120 V	3
Panel LP4	225 A	208Y/120 V	3
Panel HP4	225 A	480Y/277 V	1
Panel GP4	100 A	208Y/120 V	1
Panel ELSH4	100 A	480Y/277 V	1
Panel ESBH4	100 A	480Y/277 V	1
Panel LR	225 A	208Y/120 V	1
Panel ELSP4	100 A	208Y/120 V	1
Panel ESBP4	100 A	208Y/120 V	1
Panel LC	100 A	208Y/120 V	1

* = Interpolation on following page

Summary

Ch.	Qty			
1	(1)	1200 A	277 V	
4	(2)	225 A	277 V	*
1	(1)	800 A	120 V	* Interpolate
1	(1)	400 A	120 V	
1	(1)	250 A	277 V	*
2 or 4 / 1 or 1	(3)	100 A	277 V	*
3 ea.	(4)	225 A	120 V	*
2 or 4 / 3 or 1	(5)	100 A	120 V	*

x = $17,508.29

Receptacles

	Qty	x	# of rooms	Σ
Typ. Single Room	4		22	88
Typ. Double Room	5		126	630
Typ. Triple Room	6		7	42
Corridor	25		3	75
Hall Bathroom	2		14	28
Study	4		7	28
Group Living	5		4	20
Housing	3		3	9
Single Bath	1		4	4
1st Floor Corridor (Up)	12		1	12
Multi-Purpose Room	15		1	15
Janitor	3		1	3
1st Floor Restrooms	1		2	2
1st Floor Corridor (Low)	10		1	10
Office	4		1	4
Staff Apt.	19		1	19
Laundry	23		1	23
				1,016

Total Rec. = 1,016
Total SF = 70,057
= 14.5 per 1000 SF

*Interpolation

$$\frac{16.5-14.5}{3.25-x} = \frac{16.5-10}{3.25-1.68} \qquad x = \$3.07/SF$$

Switches

*Assume 1 switch/room

200 rooms

$$\frac{200 \text{ switches}}{70{,}057} = 2.85 \frac{\text{switches}}{\text{KSF}}$$

$$\frac{5.0-2.85}{1.12-x} = \frac{5.0-2.5}{1.12-0.52} \qquad x = \$0.60/SF$$

A 225 A 277/480 V

$\frac{5-4}{13,088.05 - x} = \frac{5-1}{13,088.05 - 8765.25}$ X = $12,007.35 (2)

B 250 A 277/480 V

$\frac{400-250}{13,865.20 - x} = \frac{400-225}{13,865.20 - 8765.25}$ x = $9,493.53 (1)

C 100 A 277/480 V

$\frac{5-4}{7414.35 - x} = \frac{5-1}{7414.35 - 5602.95}$ x = $6,961.50 (2)

D 225 A 120/208 V

$\frac{5-4}{10,429.35 - x} = \frac{5-1}{10,429.35 - 6,106.55}$ x = $9,348.65 (3)

$\frac{5-3}{"} = \frac{5-1}{"}$ x = $8,267.95 (3)

$\frac{5-2}{"} = \frac{5-1}{"}$ x = $7,187.25 (3)

E

100 A 120/208 V

$\frac{5-4}{5231.80 - x} = \frac{5-1}{5231.80 - 3395.15}$ X = $4,772.64 (2)

Lighting

$\frac{70,057}{4}$ = 17,514.25 SF/Floor

Fluorescent Fixtures/Floor = 148

$\frac{148}{17,514.25}$ = 0.00845 Fixtures/SF

$\frac{8.45}{1000 SF}$ x

E-Generator (Diesel)

30 HP × 746 W/HP = 22,380 W (22 kW)

AC

50 HP Supply

50 HP Exhaust

100 HP × $\frac{746 W}{HP}$ = 74,600 W

$\frac{74,600 W}{70,057 SF}$ = W/SF

Fire detection

Conservative estimate of 200 detectors (199 rooms)

Telecom

17 ▽ per floor public area + 1 per student in rooms

$\frac{363 telecom}{70,057}$ = 5.18 telecom/1000 SF

Interpolate

$\frac{6-5.18}{1667.71 - X} = \frac{6-4}{1667.71 - 1148.88}$

X = $1,454.91/M.S.F.

140

Plumbing

Fixtures	W.C. #	Shower Stalls #	Bath tubs #	HC Shower #	Lavatories #	Water coolers #	Drinking FTN. #
1st Floor	3	2	0	1	3		
	3	2	0	1	3		
	2 / 2½	2	2	0	2 +4		
2nd Floor	3	2	0	1	3	1	2
	3	2	0	1	3		
	3	2	0	1	3		
	3	2	0	1	3		
	1	1	1	0	1		
3rd Floor	3	2	0	1	3	1	2
	3	2	0	1	3		
	3	2	0	1	3		
	3	2	0	1	3		
	1	1	1	0	1		
4th Floor	3	2	0	1	3	1	2
	3	2	0	1	3		
	3	2	0	1	3		
	3	2	0	1	3		
	1	1	1	0	1		

Mechanical

* Interpolation (Heating Hydronic System)

$$\frac{111{,}700 - 70{,}057}{7.33 - x} = \frac{111{,}700 - 57{,}700}{7.33 - 2.39} \qquad x = \$8.15/SF$$

* Interpolation (Rooftop Air Handling Unit)

$$20{,}300 \text{ CFM} \times \frac{1 \text{ ton}}{400 \text{ CFM}} = 50.75 \text{ ton unit}$$

$$\frac{95.83 - 57.50}{19.37 - 20.03} = \frac{57.50 - 50.75}{20.03 - x} \qquad x = \$20.15/SF$$

Structural Estimate

*Footings

Mark	Size L	Size W	Size H	CF	CY	Qty.	Sub total CY	Formwork SFCA	Sub-Total SFCA
CF1	4'	4'	1.5'	24	0.89	卌 卌 卌	13.35	24	360
CF2	4'	4'	2'	32	1.19	卌 卌 卌 卌	23.8	32	640
CF3	5'	5'	2'	50	1.85	II	3.7	40	80
CF4	6'	6'	1.5'	54	2.00	IIII	8	36	144
CF5	6'	6'	2'	72	2.67	卌	13.35	48	240
CF6	7'	7'	2'	98	3.63	I	3.63	56	56
CF7	11'	11'	2'	242	8.96	III	26.88	88	264
						TOTAL CY	92.6		1784 SFCA

Formwork (Slab, Piers, Footings)

SFCA = 5"/LF + 4.5'/LF of Exterior + 1784

= 5/12(914') + 4.5(914) + 1784

= 6278 SFCA plywood

Infinity System

Spans up to 27'

*Base Plates

3/4" thick

		SF
21"×21"	卌 I	18.38
17"×17"	卌 卌 III	26.10
13"×13"	卌 卌 I	12.91
15"×15"	卌 I	9.38
12"×12"	III	3

} 70 SF

1" thick

17×17 II — 4 SF

1.5" thick

12"×12" I — 1 SF

*Columns

Column		Dim.	Qty	L
C1	HSS	4 × 4 × 3/8	(1)	13' 9 3/8" ✓
C2	HSS	4 × 4 × 3/8	(5)	12' 6 7/8" ✓
C3	HSS	4 × 4 × 3/8	(1)	14' 3 1/8" ✓
C4	HSS	6 × 4 × 3/8	(1)	14' 3 1/8" ✓
C5	HSS	6 × 4 × 3/8	(1)	14' 3 1/8" ✓
C6	HSS	4 × 4 × 3/8	(1)	14' 3 1/8" ✓
C7	HSS	4 × 4 × 3/8	(1)	14' 3 1/8" ✓
C8	HSS	8 × 4 × 3/8	(1)	14' 3 1/8" ✓
C9	HSS	8 × 4 × 3/8	(1)	14' 3 1/8" ✓
C10	HSS	8 × 4 × 3/8	(1)	14' 3 1/8" ✓
C11	HSS	6 × 4 × 3/8	(1)	14' 3 1/8" ✓
C12	HSS	6 × 4 × 3/8	(1)	14' 3 1/8" ✓
C13	HSS	6 × 4 × 3/8	(1)	14' 3 1/8" ✓
C14	HSS	8 × 4 × 3/8	(1)	14' 3 1/8" ✓
C15	HSS	8 × 4 × 3/8	(1)	14' 3 1/2" ✓
C16	HSS	6 × 4 × 3/8	(1)	14' 3 1/8" ✓
C17	HSS	4 × 4 × 1/2	(1)	14' 2 7/8" ✓
C18A	HSS	8 × 4 × 3/8	(2)	32' 3 1/4" ✓
C19A	HSS	8 × 4 × 3/8	(1)	32' 3 1/2" ✓
C19B	HSS	8 × 4 × 1/4	(1)	17' 5 3/8" ✓
C18B	HSS	8 × 4 × 1/4	(1)	17' 5 3/8" ✓
C20A	HSS	12 × 4 × 3/8	(1)	32' 3 1/2 ✓
C20B	HSS	12 × 4 × 1/4	(1)	17' 5 3/8" ✓
C21A	HSS	12 × 4 × 3/8	(1)	32' 3 1/4" ✓
C21B	HSS	12 × 4 × 1/4	(1)	17' 5 3/8"
C22A	HSS	12 × 4 × 3/8	(1)	27' 3 1/2" ✓
C22B	HSS	12 × 4 × 1/4	(1)	17' 5 3/8" ✓
C23A	HSS	12 × 4 × 3/8	(1)	27' 3 1/2 ✓
C23B	HSS	12 × 4 × 1/4	(1)	17' 5 3/8" ✓

Columns Cont.		Dim	Qty	L	
C24A	HSS	8×4×3/8	(1)	23' 3 1/2"	✓
C24B	HSS	8×4×1/4	(1)	17' 5 3/8"	✓
C25A	HSS	8×4×3/8	(1)	24' 3 1/2"	✓
C25B	HSS	8×4×1/4	(1)	17' 5 3/8"	✓
C26A	HSS	12×4×3/8	(1)	27' 3 1/2"	✓
C26B	HSS	12×4×1/4	(1)	17' 5 3/8"	✓
C27A	HSS	12×4×3/8	(1)	27' 3 1/2"	✓
C27B	HSS	12×4×1/4	(1)	17' 5 3/8"	✓
C28A	HSS	8×4×3/8	(1)	27' 3 1/2"	✓
C28B	HSS	8×4×1/4	(1)	17' 5 3/8"	✓
C29A	HSS	8×4×3/8	(1)	27' 3 1/2"	✓
C29B	HSS	8×4×1/4	(1)	17' 5 3/8"	✓
C30A	HSS	8×4×3/8	(1)	23' 3 1/2"	✓
C30B	HSS	8×4×1/4	(1)	17 5 3/8"	✓
C31A	HSS	4×4×3/8	(1)	23' 3 1/2"	✓
C31B	HSS	4×4×1/4	(1)	17 5 3/8"	✓
C32A	HSS	4×4×3/8	(1)	9' 2 3/4"	✓
C32B	HSS	4×4×3/8	(1)	8' 10 1/2"	✓
C32C	HSS	4×4×1/4	(1)	9' 0 1/2"	✓
C33	HSS	6×4×3/8	(1)	12' 0 7/16"	✓
C34	HSS	8×4×3/8	(1)	13' 0 3/16"	✓
C35A	HSS	4×4×3/8	(1)	23' 3 1/2"	✓
C35B	HSS	4×4×1/4	(1)	16' 11 5/8"	✓
C36A	HSS	4×4×3/8	(1)	23' 6 1/4"	✓
C36B	HSS	4×4×1/4	(1)	16' 11 5/8"	✓
C37A	HSS	8×4×1/2	(1)	12' 10 3/4"	✓
C37B	HSS	8×4×1/2	(1)	29' 11 3/8"	✓
C38A	HSS	10×6×5/8	(1)	27' 2 1/4"	✓
C38B	HSS	8×4×3/8	(1)	29' 9 3/4"	✓
C39A	HSS	10×6×5/8	(1)	27' 2 1/4"	✓
C39B	HSS	8×4×3/8	(1)	29' 11 3/8"	✓

Beams	Dim	L	Qty
B1	W12×19	14' 7 3/8"	(1) ✓
B2A	W12×19	7' 11"	(1) ✓
B2B	W12×19	7' 11"	(1) ✓
B3	W12×19	16' 2 1/2"	(1) ✓
B4	W12×19	15' 6 1/2"	(1) ✓
B5	W12×19	8' 5 7/8"	(1) ✓
B6	W16×26	12' 10 1/16"	(1) ✓
B7	W16×50	18' 7"	(1) ✓
B8	W16×26	8' 9"	(1) ✓
B9	W16×31	13' 10 1/2"	(1) ✓
B10	W16×26	11' 9"	(1) ✓
B11	W16×31	14' 11 1/2"	(1) ✓
B12	W16×50	20' 2 1/2"	(1) ✓
B13	W16×26	7' 11 1/2"	(1) ✓
B14	W16×31	14' 9 3/4"	(1) ✓
B15	W16×31	13' 11 1/4"	(1) ✓
B16	W16×26	11' 9"	(1) ✓
B17	W16×31	13' 10 1/2"	(1) ✓
B18	W12×40	18' 5 1/2"	(3) ✓
B19	W16×26	15' 1 3/8"	(4) ✓
B20	W12×35	17' 10 3/4"	(6) ✓
B21	W12×35	17' 10 3/4"	(6) ✓
B22	W8×24	8' 9"	(24) ✓
B23	W16×57	21' 0"	(1) ✓
B24	W12×40	21' 6 1/2"	(2) ✓
	L 3×3×3/8	20' 6 1/2"	(1) ✓
B25	W16×26	21' 2 1/2"	(2) ✓
B26	W14×132	16' 4 1/2"	(1) ✓
B27A	W12×40	16' 3 1/2"	(1) ✓
B27B	W12×40	16' 4 1/2"	(1) ✓
B29	W10×26	5' 0"	(2) ✓
B30	W12×40	21' 8 1/2"	(1) ✓
B31	W16×26	18' 3"	(1) ✓
B32	W10×22	2' 4 1/2"	(4) ✓
B33	W16×26	15' 5 1/2"	(3) ✓
B33A	W16×26	15' 5 1/2"	(1) ✓
B34	W10×30	11' 1 1/4"	(1) ✓
B35	W10×26	9' 1/4"	(3) ✓
B36	W14×68	11' 3 1/2"	(1) ✓
B37	W12×19	5' 11 1/4"	(1) ✓
B38	W8×24	25' 10"	(1) ✓
B39	W8×24	5' 11 7/8"	(2) ✓
B40	W8×24	8' 6 1/4"	(2) ✓

18.3 ton
+50% Material
+25% Labor

Interpolation for Columns Price

*Assume 4×4 HSS Columns Prices are dependent on thickness (Area). ∴ $ 1/2 thickness is 2× $ 1/4

4×4×1/2 × 12' = $694.36 ea
4×4×3/8 × 12' = $390.58 ea

* 8"×4"×3/8" = 9 in²
6"×4"×3/8" = 7.5 in² = 16.7% Δ → 642.72 · (1 − .167) → $535.39 ea.

* 9 in²
8"×4"×1/2" = 12 in² = 4/9 = 44% Δ → 642.72 × 1.44 → $925.52 ea

* 9 in²
8"×4"×1/4" = 6 in² 3/9 = 33% Δ → 642.72 × (1 − .33) → $424.20 ea

* 10"×6"×5/8" = 20 in²
10"×6"×3/8" = 12 in² 8/12 = +66% $971.17 × 1.66 = $1612.14 ea (14')
14'

* 12"×4"×3/8" = 12 in² ∴ = $971.17 / 14' ea.
12"×4"×1/4" = 8 in² 4/12 = −33%
∴ = $640.97 / 14' ea.

Interpolations Cont.

1) W10 x 30

$$\frac{33-30}{64.08-x} = \frac{33-26}{64.08-52} \qquad x = \$58.90/LF$$

2) W12 x 19

$$\frac{22-19}{42.08-x} = \frac{22-16}{42.08-32.46} \qquad x = \$37.27/LF$$

3) W12 x 40

$$\frac{50-40}{87.87-x} = \frac{50-35}{87.87-63.46} \qquad x = \$71.60/LF$$

4) W14 x 68

$$\frac{74-68}{125.28-x} = \frac{74-53}{125.28-92.45} \qquad x = \$116.26/LF$$

5) W14 x 132

$$W14 \times 120 + \left(\frac{132-120}{120} \times 100\%\right)$$

$$200.19 \times 1.10 = \$220.21/LF$$

6) W16 x 57

$$\frac{67-57}{114.84-x} = \frac{67-50}{114.84-87.38} \qquad x = \$98.60/LF$$

Roof truss Pre-fab

341' 7" of ridge line

1 truss / 4' = 86 trusses spanning 31'

Stud Walls

h = 10'

Rebar

3 lbs/SF × 18,239 SF = 54,717 lbs

1.5 lbs/SF × 51,818 SF = 77,727 lbs

$$\frac{132,444 \text{ lbs}}{2000} = \boxed{66.2 \text{ ton}}$$

K-Series Joists

14K1 19' 1" span × 17 = [323 LF]

w 1½", Galv, 20 ga. Deck

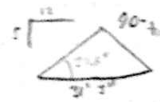
Deck

[1,394 SF]

Roof

Misc. Lange = 1½", Galv, 20 ga

Roof = 1½", Galv, 22 ga



$90 - \tan^{-1}\left(\frac{12}{5}\right) = 22.6°$

$\cos 22.6 = \frac{31.25'}{x}$

$x = 33.8'$

Slabs

same Area's as below

2" Dovetail 20 GA

[51,818 SF]

$\frac{33.8-31.25}{31.25} = 8.3\%$ ↑ from norm. Areas [18,216 SF]

Slab on Deck (4" slab)

Floor	2	16,820 SF	5606.7 CF
	3	16,820 SF	5606.7 CF
	4	16,652 SF	5495.2 CF
	Penthouse	1,526 SF	503.6 CF
			17,212.0 CF

17,212.0 CF / 27 = [637.5 CY]

+ L 6×6×⅜ on entire exterior

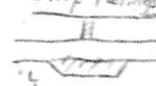
└ 914 LF × 3 → [2742']

Slab on Grade

t = 5" A = 18,239 SF

CF = 7599.58 ~ 7600/27 = [281.5 CY]

Strip Footings



1.) $(.5' \times 2') + .5'^2 = 1.25 \; CF/LF$ Interior Bearing Wall

2.) Exterior Bearing Wall = $(3' \times 1.5') + (2' \times .66') = 5.82 \; CF/LF$

3.) Elevation Change = $(4' \times 1.5') + (5' \times 1') = 11 \; CF/LF$

Type	LF	
Interior BW	(1112' 10" × 1.25)/27	= 51.5 CY
Exterior BW	(914' 3" × 5.82)/27	= 197.1 CY
Elevation Ch.	(70' 1" × 11)/27	= 28.6 CY
	Total	= [277.2 CY]

* ASSUME 5% Waste on Concrete Material

* ASSUME 3 lb/SF Reinforcement on concrete SOG, 1.5 lb/SF on Decks

* ASSUME (4) ¾" dia. 2" L Bolts per Member + 5% waste

* Assume 4.5 SFCA / LF of exterior wall

Infinity Structures

Load Bearing Cold Formed Panelized Walls

* Assume: 15% increase for shear wall
25% increase for shear bearing wall
50% increase Labor Pace for pre fabrication
12" OC, 18 ga., 3-5/8" wide, 10' high walls
Floors 2-4 are identical

1st Floor:

	LF		Sub total
BW (Bearing Wall)	1000' 7" × 1	=	1000.58
SW (Shear Wall)	265' 8" × 1.15	=	305.51
SBW (Shear Bearing Wall)	414' 7" × 1.25	=	518.23

2nd Floor (×3)

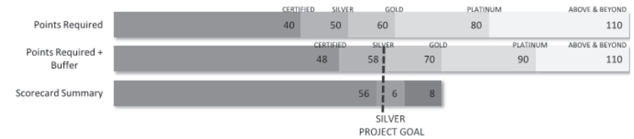
BW	1,033' 10" × 3 = 3101.5' × 1	=	3101.50
SW	243' 5" × 3 = 730.25' × 1.15	=	839.79
SBW	377' 5" × 3 = 1132.25' × 1.25	=	1415.31
			7180.92 LF

Appendix C:

Taylor Hall LEED Scorecard

LEED Dashboard- GMU Housing VIII-B

4/30/2013



Category	Identifier	Credit	Points Available	Submission	Ultimately Responsible For Documentation	Y (56)	MY (6)	MN (8)	N
Sustainable Sites	**SSp1**	**Construction Activity Pollution Prevention**	**0**	**C**	**Contractor**	R			
	SSc1	Site Selection	1	D	Civil	1			
	SSc2	Development Density and Community Connectivity	5	D	Architect	5			
	SSc3	Brownfield Redevelopment	1	D	Civil				1
	SSc4.1	Alternative Transportation - Public Transportation Access	6	D	Architect	6			
	SSc4.2	Alternative Transportation - Bicycle Storage and Changing Rooms	1	D	Architect				1
	SSc4.3	Alternative Transportation - Low-Emitting and Fuel-Efficient Vehicles	3	D	Architect	3			
	SSc4.4	Alternative Transportation - Parking Capacity	2	D	Architect	2			
	SSc5.1	Site Development - Protect or Restore Habitat	1	C	Landscape Designer				1
	SSc5.2	Site Development - Maximize Open Space	1	D	Landscape Designer	1			
	SSc6.1	Storm water Design - Quantity Control	1	D	Civil	1			
	SSc6.2	Storm water Design - Quality Control	1	D	Civil			1	
	SSc7.1	Heat Island Effect - Non-roof	1	C	Landscape Designer		1		
	SSc7.2	Heat Island Effect - Roof	1	D	Architect	1			
	SSc8	Light Pollution Reduction	1	D	MEP				1
Water	**WEp1**	**Water Use Reduction**	**R**	**D**	**MEP**	R			
	WEc1a	Water-Efficient Landscaping - Reduce by 50%	2	D	Landscape Designer			2	
	WEc1b	Water-Efficient Landscaping - Reduce by 100%	2	D	Landscape Designer				2
	WEc2	Innovative Wastewater Technologies	2	D	MEP				2
	WEc3a	Water Use Reduction - 30%	2	D	MEP	2			
	WEc3b	Water Use Reduction - 35%	1	D	MEP	1			
	WEc3c	Water Use Reduction - 40%	1	D	MEP			1	
Energy & Atmosphere	**EAp1**	**Fundamental Commissioning of Building Energy Systems**	**R**	**C**	**Commissioning Agent**	R			
	EAp2	**Minimum Energy Performance**	**R**	**D**	**MEP**	R			
	EAp3	**Fundamental Refrigerant Management**	**R**	**D**	**MEP**	R			
	EAc1	Optimize Energy Performance	19	D	MEP	4	1	1	13
	EAc1a	Optimize Energy Performance (12% New / 8% Renovation)	1	D	MEP	1			
	EAc1b	Optimize Energy Performance (14% New / 10% Renovation)	1	D	MEP	1			
	EAc1c	Optimize Energy Performance (16% New / 12% Renovation)	1	D	MEP	1			
	EAc1d	Optimize Energy Performance (18% New / 14% Renovation)	1	D	MEP	1			
	EAc1e	Optimize Energy Performance (20% New / 16% Renovation)	1	D	MEP		1		
	EAc1f	Optimize Energy Performance (22% New / 18% Renovation)	1	D	MEP			1	
	EAc1g	Optimize Energy Performance (24% New / 20% Renovation)	1	D	MEP				1
	EAc1h	Optimize Energy Performance (26% New / 22% Renovation)	1	D	MEP				1
	EAc1i	Optimize Energy Performance (28% New / 24% Renovation)	1	D	MEP				1
	EAc1j	Optimize Energy Performance (30% New / 26% Renovation)	1	D	MEP				1
	EAc1k	Optimize Energy Performance (32% New / 28% Renovation)	1	D	MEP				1
	EAc1l	Optimize Energy Performance (34% New / 30% Renovation)	1	D	MEP				1
	EAc1m	Optimize Energy Performance (36% New / 32% Renovation)	1	D	MEP				1
	EAc1n	Optimize Energy Performance (38% New / 34% Renovation)	1	D	MEP				1
	EAc1o	Optimize Energy Performance (40% New / 36% Renovation)	1	D	MEP				1
	EAc1p	Optimize Energy Performance (42% New / 38% Renovation)	1	D	N/A				1
	EAc1q	Optimize Energy Performance (44% New / 40% Renovation)	1	D	N/A				1
	EAc1r	Optimize Energy Performance (46% New / 42% Renovation)	1	D	MEP				1
	EAc1s	Optimize Energy Performance (48% New / 44% Renovation)	1	D	N/A				1
	EAc2	On-Site Renewable Energy	7	D	MEP				7
	EAc2a	On-Site Renewable Energy (1%)	1	D	MEP				1
	EAc2b	On-Site Renewable Energy (3%)	1	D	MEP				1
	EAc2c	On-Site Renewable Energy (5%)	1	D	N/A				1
	EAc2d	On-Site Renewable Energy (7%)	1	D	N/A				1
	EAc2e	On-Site Renewable Energy (9%)	1	D	N/A				1
	EAc2f	On-Site Renewable Energy (11%)	1	D	N/A				1
	EAc2g	On-Site Renewable Energy (13%)	1	D	N/A				1
	EAc3	Enhanced Commissioning	2	C	Commissioning Agent	2			
	EAc4	Enhanced Refrigerant Management	2	D	MEP	2			
	EAc5	Measurement and Verification	3	C	MEP	1			2
	EAc6	Green Power	2	C	Client - Optional		2		
Materials & Resources	**MRp1**	**Storage and Collection of Recyclables**	**R**	**D**	**Architect**	R			
	MRc1.1a	Maintain Interior Structural Components (55% Reuse)	1	C	N/A				1
	MRc1.1b	Maintain Interior Structural Components (75% Reuse)	1	C	N/A				1
	MRc1.1c	Maintain Interior Structural Components (95% Reuse)	1	C	N/A				1
	MRc1.2	Maintain Interior Nonstructural Components (50% Reuse)	1	C	N/A				1
	MRc2a	Construction Waste Management Divert 50% from Disposal	1	C	Contractor	1			
	MRc2b	Construction Waste Management Divert 75% from Disposal	1	C	Contractor	1			
	MRc3.1a	Materials Reuse - 5% Reuse	1	C	Contractor				1
	MRc3.1b	Materials Reuse - 10% Reuse	1	C	Contractor				1
	MRc4a	Recycled Content - 10% of Content	1	C	Contractor	1			
	MRc4b	Recycled Content - 20% of Content	1	C	Contractor	1			
	MRc5a	Regional Materials - 10% Manufactured	1	C	Contractor	1			
	MRc5b	Regional Materials - 20% Manufactured	1	C	Contractor	1			
	MRc6	Rapidly Renewable Materials - 2.5%	1	C	Contractor				1
	MRc7	Certified Wood -50% FSC	1	C	Contractor	1			
Indoor Environmental Quality	**IEQp1**	**Minimum Indoor Air Quality Performance**	**R**	**D**	**MEP**	R			
	IEQp2	**Environmental Tobacco Smoke (ETS) Control**	**R**	**D**	**Architect**	R			
	IEQc1	Outdoor Air Delivery Monitoring	1	D	MEP		1		
	IEQc2	Increased Ventilation	1	D	MEP		1		
	IEQc3.1	Indoor Air Quality Management Plan - During Construction	1	C	Contractor	1			
	IEQc3.2	Indoor Air Quality Management Plan - Before Occupancy	1	C	Contractor			1	
	IEQc4.1	Low-Emitting Materials - Adhesives and Sealants	1	C	Contractor	1			
	IEQc4.2	Low-Emitting Materials - Paints and Coatings	1	C	Contractor	1			
	IEQc4.3	Low-Emitting Materials - Flooring Systems	1	C	Contractor	1			
	IEQc4.4	Low-Emitting Materials - Composite Wood and Agrifiber Products	1	C	Contractor	1			
	IEQc5	Indoor Chemical and Pollutant Source Control	1	D	MEP				1
	IEQc6.1	Controllability of Systems - Lighting	1	D	Architect	1			
	IEQc6.2	Controllability of Systems - Thermal Comfort	1	D	MEP	1			
	IEQc7.1	Thermal Comfort - Design	1	D	MEP	1			
	IEQc7.2	Thermal Comfort - Verification	1	D	Architect	1			
	IEQc8.1a	Daylight and Views - Daylight75% of Spaces	1	D	Lighting Designer			1	
	IEQc8.2	Daylight and Views - Views for Seated Spaces	1	D	Architect	1			
Innovation	IDc1.1	Green Housekeeping	1	C	Client	1			
	IDc1.2	Environmental Pest Control	1	C	Client	1			
	IDc1.3	Green Landscape Management	1	C	Client	1			
	IDc1.4	Low Mercury Bulbs	1	C	Contractor	1			
	IDc1.5	Green Education	1	C	Client	1			
	IDc2	LEED® Accredited Professional	1	C	Architect	1			
Regional	RPc1	SSc4.1	1	D	Architect	1			
	RPc2	SSc5.1	1	C	Landscape Designer				1
	RPc3	SSc6.2	1	D	Civil			1	
	RPc4	WEc2	1	D	MEP				1
	RPc5	EAc1o	1	D	MEP				1
	RPc6	EAc2a	1	D	MEP				1

56 6 8
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△	Date	Description
	05.03.2013	PRELIMINARY DESIGN RESUBMISSION
	07.12.2013	PRELIMINARY DESIGN SUBMISSION 2
	07.12.2013	SITE UTILITIES RESUBMISSION
	07.12.2013	FOUNDATION SUBMISSION

Seal/Signature

Project Name
SHENANDOAH HOUSING VIIIB TAYLOR HALL

Project Number
09.2043.000
BCOM Code: 247-17570-002

Description
LEED SCORECARD

Scale

147

G00.020

Bradley Williams
Construction Option
11/15/2013
Advisor: Ed Gannon

Technical Assignment 3

Taylor Hall – George Mason University

Photo Courtesy of Gensler

Executive Summary

Within this report, a variety of topics are discussed that will encourage creative thoughts when choosing topics to research with Taylor Hall this upcoming spring. After conducting an interview with a representative of the project team, specific issues with the façade of the building and BCOM approval are analyzed on how they affect the schedule and critical path of the building. With each issue comes an area for improvement and ideas on how the schedule can be accelerated if needed.

Since cost is a key concern for the owner, value engineering methods used on Taylor Hall were discussed. Furthermore, the ideas not implemented will provide good bases to spur my research and add value to the project for the owner. One peculiar area of research could be the controversial and troublesome Infinity Structural System.

Lastly, this report contains information gathered from the PACE roundtable on November 6th. Breakout sessions involving "Prevention through Design" and "Efficient Delivery of Facility Management Information" provided insight on how we can better our designs to improve safety and how we create an effective vehicle to house pertinent information for the owner's facility maintenance personnel. Concluding the PACE roundtable was a small group discussion on specific ideas we could potentially look at for the next thesis segment, the presentation of research topics.

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Project Manager Interview

Having learned that my Project Manager and point-of-contact is no longer with the company, I interviewed the most senior leadership on the jobsite available. The Assistant Project Manager that I contacted will remain my contact for the entirety of the project, although he had admitted that he was not on the job at the time when the following issues were discussed.

In the following sections of the paper, I will discuss issues critical to the Taylor Hall project specifically pertaining to the schedule and value engineered items. These issues may, and hopefully will, lead to potential study areas that could be used for depth studies and further breadth studies in non-construction management related areas.

Project Schedule

When examining the schedule, it is clear that building dry-in is a critical issue after the structural system is in place. Without building dry-in, interior trades and finishes can't be completed in a timely manner. Current plans show the façade work rotating around the building for each floor up to the roof with several material types.

Via my interview with APM Ben, he had mentioned specific concern for the metal panel system on the façade. The metal panels are located above window height on the top floor and the entire elevation of a small area near the building entrance. This has apparently caused problems with BCOM (Bureau of Capital Outlay Management) design approval, which is needed to continue with the building since George Mason University is a public institution and there are tight restrictions on appearance. Ben had mentioned that this delay in approval is partially due to the Design-Build delivery method chosen and the loss of key team members.

The biggest risks to not completing the project on time are delaying the building dry-in. As the project enters the winter months, weather delays will become more prevalent and could damage the schedule. Although the façade brings the biggest schedule risk, it also leaves room for improvement and optimization.

Acceleration of the façade completion could potentially lead to quicker installation of finishes in the building. One area of focus may be the implementation of a short interval production schedule (SIPS) to ensure this is done as quickly as possible. As mentioned above, the jobsite can only operate as fast as BCOM approves the designs, so there is also a potential to accelerate in areas where designs are approved and straightforward.

Risks associated with the above mentioned ideas are having too many trades work in the same area and running into stagnant periods waiting for design approval. If the façade is closed in quicker than expected and a space utilization plan by trade is not established, there is a potential for conflicts with work flow. It was also mentioned that accelerating the schedule might lead to a point of construction where designs have yet to be approved by BCOM.

In conclusion, it was clear in my interview that the primary concerns for the schedule included BCOM design approval delays and the closing-in of the façade. The BCOM design approval delays can potentially be combated with a different project delivery method and the façade schedule could be optimized with the utilization of a short interval production schedule due to the repetitiveness of the façade around the building.

Value Engineering

Because each of the projects presented to George Mason University were over budget, value engineering played a key role in bringing down the cost of the building. Balfour Beatty Construction presented a total of 77 value engineering and value added ideas to George mason with 20 of the being accepted and several of which were implemented in the job.

The primary value engineering move was the removal of the concrete structural system and the implementation of the Infinity Structural System (discussed in previous reports). At first this move was a great idea because it was apparently less expensive when compared to the concrete structural system. Another implemented VE was the removal of closet doors in each unit, leading to significant price reductions. Both of these topics help to reduce the cost of the building without reducing the value, a primary concern for the owner.

The following is a list of value engineering items that were discussed but not implemented in the project for one reason or another. Each of these has potential to reduce costs and/or schedule of the building and can be looked into for a research topic.

Value Engineering Idea	Reason for not implementing it
• Increasing the beds to SF ratio	- Site space limitations
• 4 pipe mechanical system to 2 pipe	- Easier maintenance since campus already used a 4 pipe system
• Stick-built structural system	- Emerging trend and lack of experience
• Green roof above multi-purpose room	- To be completed by students later on
• Rainwater harvesting	- No grey water lines/Campus irrigation already in place
• Cement board instead of metal panels	- BCOM wanted metal panels
• Flat roof instead of pitched roof	- BCOM wanted a pitched roof

In conclusion, most of the value engineering topics that were considered were minor so the design of the building was not altered in any major way. This is due to BCOM's strict overseeing that the façade looks the same as the surrounding buildings. Because of this, any value engineering issues I propose to look into should be on the interior of the building unless it doesn't dramatically alter the façade.

Due to the project being over budget, a major value engineering idea would be beneficial to the owner. Personally, I think the potential value may be hidden within changing the Infinity Structural System due the complications with BCOM approval and the questionable application of such a system on a building of this scale.

Critical Industry Issues

Prevention through Design

The idea of prevention through design revolves around encouraging and educating architects to the needs of a safe work environment for the construction phases of a building. Secondly, the consideration of the safety of future maintenance personnel should be implemented early in the design phase. The goal is to reduce the risk of a building, from the construction phase to occupation.

Some examples of prevention through design include sill heights of 48" to reduce fall hazards during construction, the lowering of control panels so that future maintenance personnel won't need large ladders to access them, and smart design when looking at slopes and directions of roof pitches to mitigate potential ice fall locations.

It was determined during the roundtable discussion that it should be added to the contract that architects consider these safety criteria in their designs and that we have dedicated, third party, reviewers to assess the safety of a building. One idea even mentioned the integration of a checklist similar to LEED so that common areas of improvement become so standard that they are second nature to architects.

Implementing PTD on the Taylor Hall project could simply include the altering of window sill heights to 48" and a re-configuration of the schedule to place exterior cold formed frames sooner to prevent fall hazards. Other considerations may include incorporation of tie-off locations in the roof to allow for safe maintenance, prefabrication of duct work, or lower access to HVAC controls.

Key contacts from the roundtable who displayed exceeding knowledge in the field were Professor Leicht from Penn State University and Jason Reece from Balfour Beatty. Both exhibited interesting ideas on how to bring PTD into the industry in an efficient way.

Efficient Delivery of Facility Management Information

This roundtable discussed the various ways we handover project closeout information and documents to the owners. Current methods of doing this include programs such as New Forma and Cobie, as well as BIM models. The issue resides in knowing what information is valuable to the owner and will the owner's maintenance personnel know how to use the current technologies.

Due to the variety of different perspectives at the roundtable, the discussions brought up very important information about the problems at this stage of construction. Currently, project teams assemble bundles of information digitally, most of which isn't needed by the owner. Furthermore, it was brought to the roundtables attention that many maintenance workers still prefer hard copy plans and specs in comparison to digital copies.

Two key solutions were discussed, both of which will lead to easier turnover of material when construction phase closes. The main goal is to find information that is needed/wanted by the owner and then to find an affective vehicle to deliver that information in a useful and simple way. This can be done on the part of the owner by requiring specific information that they know will be useful in the future, reducing the amount of clutter material that will never be referenced. Secondly, it would be optimum to hand over an easy to use program that helps maintenance find the required information as quickly as possible, being much easier than giving them a BIM model with links to different things.

This can be applied specifically to the Taylor Hall project by looking into what the owner's O&M, close-out, and warranty specifications are so that the project team can deliver the necessary information in clear and concise fashion. Since the owner is an established university, there are already very standard requirements regarding these documents. In this case, a BIM model will be handed over and has been proven valuable to the university.

Key contacts that gained from this discussion were Ed Gannon and Craig Dubler, being the facilitators of the roundtable as well as having knowledge of what is needed from the owner's perspective. Mike Arnold, from the Diocese of Pittsburgh, also had valuable information regarding what is valuable to the owner's facility management personnel.

Feedback from Industry Roundtable

Following the industry roundtable, the breakout session helped each student gain a one-on-one opinion about their thesis projects from industry professionals. I sat with Jason Reece with Balfour Beatty Construction and discussed potential areas of research.

The first topic of research mentioned was the value of the Infinity Structural System. The depth would analyze if this specific structural system was appropriate for a building of this scale and if the cost/schedule benefits were substantially better than a concrete system. Jason also mentioned that it could be valuable to do an energy analysis to see if any of the mechanical or electrical systems could be optimized with green techniques (like daylighting) without altering the façade and involving BCOM design review.

Other topic ideas mentioned were looking into the benefit of a PPP (Public-Private Partnership), which was recently used on another George Mason University project, and the implementation of a SIPS schedule to drive the critical path items on the building.

Suggested resources for the project would be Jason Reece and Andreas Phelps, both from the research and development department of Balfour Beatty Construction. They would be able to provide valuable information on emerging industry trends and would have the knowledge to determine if they are useful on a project such as Taylor Hall.

(Please see Appendix for PACE Roundtable forms)

Appendix

The 22nd Annual PACE Roundtable

Session 1-A:

Prevention through Design

Facilitator: Leicht **Room 203**

Questions

- How aware is the design community of the impact they have on construction safety?
- How is safety typically approached during the design and preconstruction process?
- What examples of improving safety during design have you seen?
- What opportunities exist to improve / increase the focus of design on safety issues?
- What concerns or issues might prevent designers or owners from considering safety in the design process?
- What could be done to begin influencing this process?

Notes

(PTD)

- Design community not aware
- Construction needs to influence design
- Permanent Safety
  - Building Process Safety
    - Design-Build projects do it better
    - Gets Safety Staff involved
    - Cranes
    - Vaccuume/Extinguisher tube riser for construction
    - Construction Egress needs emphasis

- Contractor's Safety Program helps a lot because it works above what the owner wants (if owner doesn't care)
- Design Changes to influence safety during
  - Maintenace Tower made more accessible so less ladders are used.
  - Awnings over entrances sloped to avoid ice falling.
  - Window washing system that adds to a more efficient design by bracing curtain wall.
  - window sill being 48" off floor
  - Incorporation / Prefabrication of tie-offs in design for Facility Mgmt and construction
- Architect is liable for safety issues during occupancy but dont mind much about during construction
- Not engaged in safety conversations.

** Contractual language is key - toss PTD in there and describe collaboration requirements
- early costs could save/will save in the long run

UK - Possible design safety review - required in Europe
- Risk assesment/Regulation
- can regulate process (review/walkthrough)
- can't usually regulate design (every design is unique)

Design Firms need to hire safety review specialists because knowledge base isn't their

Prefab
- Positive
  - Quality
  - Less man hours
  - shop is safer than site
  - fast
- Negative
  - Heavier lifts
  - Dangerous lifts
  - More Logistics

Session ends at 10:30 am

Total Value Design

Make Safety a design evaluation point

Scoring System

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Session 2-B:

Efficient Delivery of Facility Management Information

Facilitator: **Gannon / Dubler** **Room 211**

Questions

- What inefficiencies exist now for transferring information between phases effectively
- What information needs to be turned over for facility management?
- What takes the most time and effort to compile and transfer?
- What relationships or contracts may be hampering the process for efficient transfer of information?
- What workflows would be high value to define more clearly and make repeatable?
- What infrastructure or tool support is needed to make these workflows consistent and interoperable?

Notes

-New Forma
-Cobie

- FM Info needs to be collected during design
- Define Owner
- "Maximo" defines work needed to be done.
- Best Possible thing is BIM model with O&M's attached with live statistics. Complete Bldg. Mg

- Find Info that's wanted then find effective vehichle

- Look into Long term owner issues
  - "Total Cost of ownership" Carpet vs. Terrazzo example.
  (Initial cost + Maintenance cost + Replacement Cost) Life Cycle

FM
- Asset Management
- Space Management
- Building Automation System/controls
- Renovations
- Energy
- Engineering
- Maps GIS

Session ends at 2:30 pm

The 22nd Annual PACE Roundtable

Industry Member: Jason Reece

Key Feedback: *Which research topic is most relevant to industry? What is the scope of the*

*- Value of Infinity System
  - Is it appropriate
    - Schedule / Cost / Safety
    - Ability to alter design
    - why did they choose it?
    - Cost / Benefit analysis

*- Energy Analysis
  - BCOM requirements
  - what Value Engineerings could save on buget / Not change design

*- Public Private Partnership to increase #'s of Beds

*- Energy Reduction vs. Daylighting
  - optimization
  - Mech Load / shading

*- Crew Planning / SIPS / Phasing
  - Schedule Driven

Suggested Resources: *What industry contacts are needed? Is the information available?*

- GMU Maintence personell
- Andreas Phelps
- Jason Reece

> Research / Development BBC

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Bradley Williams
Construction Option
12/4/2013
Advisor: Ed Gannon

Current Project Issues

At the Taylor Hall construction project site, there are several areas that have had a noticeable negative impact on the construction process, schedule and budget. Just to recap, Taylor Hall is a 70,000 SF freshman dormitory housing 295 students and is located at George Mason University's main campus in Fairfax, VA. The project is set to cost $16,000,000 and is to be completed in just 12 months.

As predicted earlier, the Infinity Structural System is beginning to cause issues on the job site. This is mainly due to the late approval of BCOM and GMU staff. Without a design approved, the job cannot move forward with this critical path item. The complexity of the Infinity Structural System and the size of the application have been questioned since the original decision to value engineering them into the project compared to the original concrete structure.

On the same topic of owner approval, there have been several issues with the metal panels near the entrance of the building and how it ties into the curtain wall and the brick veneer. This material has come under architectural fire due to its relatively modern look when compared to neighboring buildings. Other than the delayed approval because of aesthetics, there also seems to be some constructability concerns with how it will be fit into the façade installation schedule since building dry-in can't be extended any further.

Many value engineering ideas were presented to the owner, but due to strict approval boundaries of BCOM, only few were added into the building. With the project being over budget already, and the late approval of designs, the project team is faced with difficult daily decisions to continue working without approved drawings or risk delaying the project. One example of this is the decision to not include a green roof in the construction because it was thought to delay the project.

On top of the above mentioned, the project team and owner have recently lost key personnel involved in the project, making it even more difficult to make executive decisions on these issues.

Potential Points of Analysis

The following potential points for analysis in the spring 2014 semester will include focus areas in Value Engineering, Schedule Acceleration, Constructability Review, or be a research on a Critical Construction Issue. Potential breadths for research are highlighted below where applicable.

Green Roof Addition

Since sustainability is a key concern of the owner and a green roof was originally intended to be installed over the miscellaneous use room on the ground floor, I feel it would be appropriate to do an in depth research on the topic. The depth would analyze the cost and schedule implications of the addition of the green roof and data would be collected by interviewing specialty subcontractors from the region as well as experienced project management personnel.

Furthermore, this depth could lead to a potential for a structural breadth investigation to see if the current steel joist roof would be able to support the loads associated with the green roof. This could also include a mechanical breadth to investigate the thermal and moisture protection that would need to be added with the green roof in place to insure there are no leaks.

Stick Built Structural System

Due to the complexity that the Infinity Structural System has brought with it, it was suggested that a stick built framing system could provide a more efficient and cost effective structural system. The depth would include analyses on cost and schedule implications as well as constructability. Using a stick built structural system was one of the original options considered when value engineering out the concrete structural design, so it would be interesting to compare the decision to go with the Infinity Structural System with this up and coming method of construction in the DC metropolitan area.

Prefabricated Brick Veneers

Since the installation of the brick on the exterior of the building is a critical path item and this is a schedule-driven project, it would be logical to find an effective way to accelerate installation. One way of doing this may be through prefabricated or tilt-up panels which incorporate "thin bricks" set in a grout and polymer like panel. The depth could include a cost vs. benefit analysis by incorporating labor and prefabrication costs and its reduction in the critical path schedule. Secondly, constructability can be analyzed since the site is congested and a crane would be needed at this later point in construction.

In terms of breadths, this research could include an envelope analysis looking into the new systems thermal and moisture protection performance compared to the original design. An Architectural breadth could potentially investigate how this new façade system would affect the appearance of the building and it's tie-ins with other materials such as the metal panels and curtain walls.

Prevention through Design

For the critical industry issue and research topic, I believe it would be valuable to look into how special design tactics could increase safe construction and future maintenance of the building. Since this is a public project and is under a watchful eye of students on a daily basis, it is increasingly important to maintain a safe project site. Through my research of common site safety and facility maintenance errors, I could develop design change proposals that could increase the overall safety of the project to ensure that Balfour Beatty's Zero Harm initiative is taken advantage of in its fullest potential.

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BRADLEY T. WILLIAMS

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OBJECTIVE

To begin my professional career as a full time employee of a construction management firm

EDUCATION

The Pennsylvania State University — **University Park, PA**

Bachelor of Architectural Engineering – Construction Management Option — **Spring - 2014**
Five year professional degree – ABET accredited
GPA: 3.04/4.00

Sede di Roma – Penn State Study Abroad Program — **Rome, Italy**

- Earned 12 credits of Architectural and Ancient Structural Design courses in Italy — **Summer - 2012**

WORK EXPERIENCE

Internship – Balfour Beatty Construction, Embassy Suites Hotel — **Fairfax, VA**

- Managed RFI documents, an 8500 item punch list, and subcontractor close-out requirements — **Summer - 2013**
- Began assembling Operation and Maintenance manuals and warranties for the owner
- Responsible for LEED documentation collection, submittal to LEED Online, and the accreditation of the project

Hershey Entertainment and Resorts — **Hershey, PA**

- Served as a Foods Clerk, Special Facilities Lifeguard, and Room Service Attendant — **2004 - 2012**
- Supervised and prepared food for large catering groups; Worked with a team of first responders on several serious medical emergencies

Engineering Research – Energy Opportunities Inc., Seven Group, and KCBA Architects — **2006 - 2009**

- Designed clerestory lighting scenarios using a parabolic solar atrium to reduce lighting load by up to 92%
- Helped design the façade of a new high school to be energy efficient based on results and worked with the building committee to influence sustainability
- Awarded by the National Collegiate Inventors and Innovators Alliance for the novel design at the INTEL International Science and Engineering Fair 2008

SKILLS

- Autodesk Constructware
- Autodesk BIM 360 Field
- Revit Architecture
- AutoCAD
- Primavera P6
- Microsoft Office

ACTIVITIES & AWARDS

Awards

Henry J. and Florence K. Anderson Memorial Scholarship in Engineering — **2010 - 2012**
Russel H. Herman, Senior, Scholarship in Engineering from the College of Engineering — **2009 - 2012**
Boy Scouts of America – Eagle Scout Rank — **2000 - 2009**
National Society of Professional Engineers award winner — **2008 - 2009**
National Junior Science and Humanities Symposium; 5th place in Engineering — **2008**
INTEL International Science and Engineering Fair – NCIIA Award — **2008**

Activities

Alpha Tau Omega Fraternity, National Leadership Development Fraternity. — **2010 - 2014**
Alpha Tau Omega – THON Chair, House Manager, Greek Week Chair, Alternative Fundraising Chair — **2010 - 2014**

- Assisted the organization in raising $1,333,000 over the past 4 years to help children fight cancer
- Lead 200 students to raise $368,000 in under 140 days for THON 2013 (current Greek Life record)

Student Partnership for Achieving Construction Excellence — **2012 - 2014**
Penn State Sailing Club — **2011 - 2014**

References available upon request