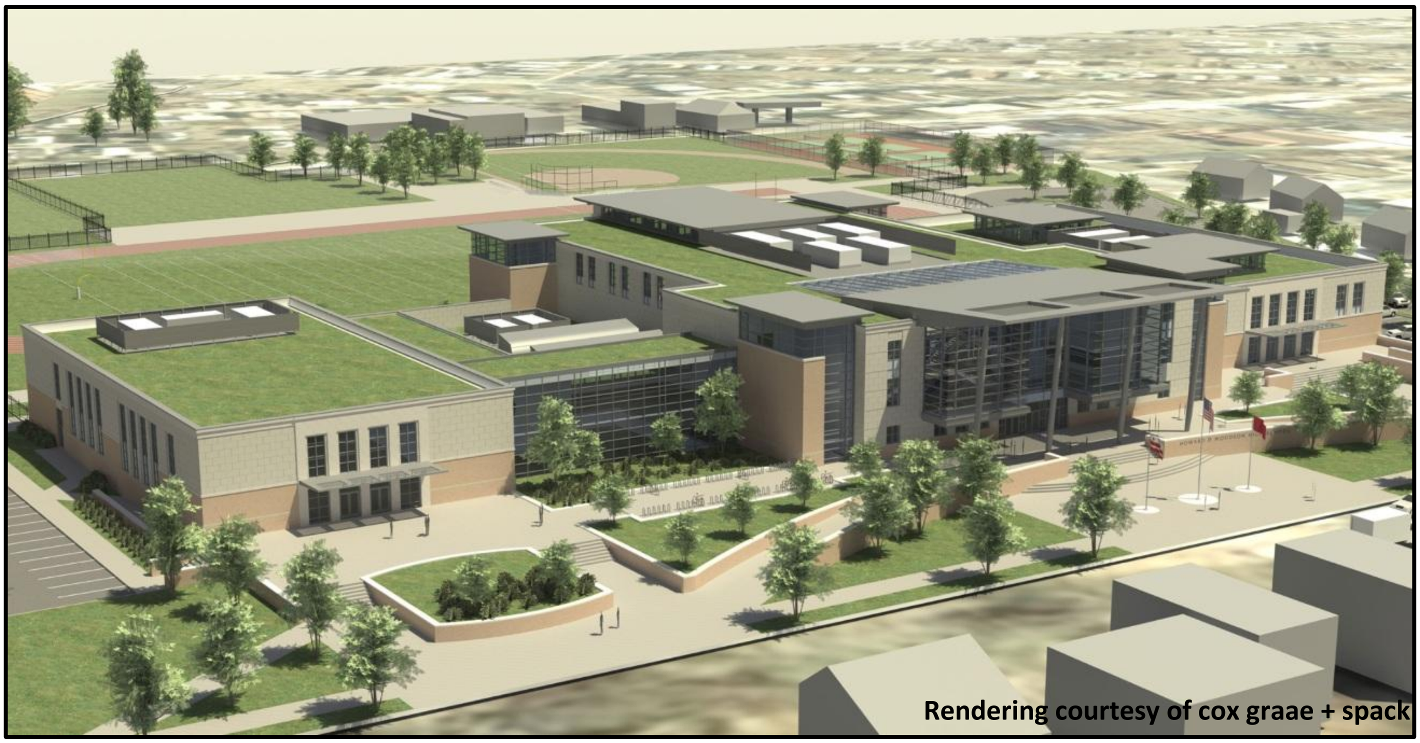
HD WOODSON HIGH SCHOOL

Construction Project Management



FINAL REPORT

Prepared For:
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Construction Option
April 7, 2011

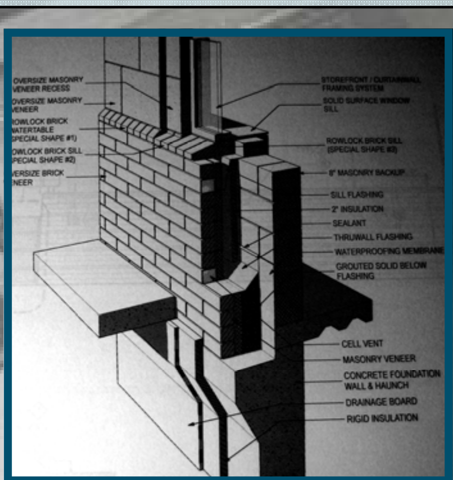
HD Woodson Senior High School

PROJECT TEAM

<u>Owner</u>: District of Columbia Public Schools
<u>Design-Builder</u>: HESS Construction + Engineering Services
<u>Architect</u>: cox graae +spack
<u>Associate Architect</u>: SHW Group
<u>Civil Engineer</u>: Wiles Mensch
<u>Landscape</u>: EDAW|AECOM
<u>Structural</u>: ADTEK
<u>M/E/P</u>: Setty and Associates International, PLLC

BUILDING STATISTICS

<u>Function</u>: Complete High School Facility
<u>Size</u>: 266,000 SF
<u>Stories</u>: 3 above grade, 1 below
<u>Construction</u>: September 2009—November 2011
<u>Delivery Method</u>: Design-Build w/ CM at Risk




Rendering courtesy of cox graae + spack

ARCHITECTURE

<u>Purpose</u>: New High School facility to replace the former High School at the same location
<u>Spaces</u>: 2 Gymnasiums, Natatorium, Auditorium, Classrooms, Admin Spaces and Outdoor Sports Facilities
<u>Material</u>: Brick, Precast Banding, Masonry Panels, Aluminum Panels and Storefront Style Glass Curtain Walls

STRUCTURAL

<u>Main Floors</u>: Ordinary Steel Construction with Concentrically braced frames.
<u>Roof</u>: metal decking on Open Web Steel Truss
<u>Foundation</u>: Spread Footings on Structural Fill or Undisturbed Earth

ELECTRICAL

<u>Power Distribution</u>: Two Switchboards 3,000A 480/277V 3PH 4W
Step Down Transformers: Multiple per floor for 208/120V Loads

MECHANICAL

<u>Ventilation</u>: Dedicated Outdoor Air System with VAV's
<u>Heating Loads</u>: Gas Fired Parallel Boilers supply AHU's and Reheat Coils at VAV's
<u>Cooling Loads</u>: Cooling tower with 2 Dual Centrifugal Chillers supply AHU's and DOAS/VAV System
<u>Natatorium</u>: Standalone Dehumidification Unit

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http://www.engr.psu.edu/ae/thesis/portfolios/2011/nwd5013/index.html

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EXECUTIVE SUMMARY

The following report contains information and analyses related to HD Woodson Senior High School located in Washington, DC. The initial sections contain background information and data pertaining to the project, followed by four analyses created to theoretically study the Constructability, Schedule Acceleration and Value Engineering of a construction project. The framework for this report is created by the Architectural Engineering Senior Capstone Thesis course sequence.

Analysis One: Maximizing BIM Investment

The use of Building Information Modeling, BIM, on HD Woodson High School was an effective way to facilitate trade coordination. Using BIM assisted in coordinating the large amount of MEP systems in areas confined by low floor to structure heights and the desire to eliminate field clashes of these components. While this decision was one great way to coordinate MEP Systems there are many uses that can make BIM efforts more beneficial. Building Information Modeling can be much more than a 3-D clash detecting model if the goals and uses are defined early on in a project. This critical industry issue of high initial costs associated with BIM can be justified if the end results and valuable inputs of Building Information Modeling are maximized. This topic was a Critical Industry discussion at the PACE Roundtables.

Analysis Two: Optimizing Value Engineering

Analysis two looks at some possible Value Engineering (VE) Solutions to clear the hurdle of "LEED" elements being excluded from the VE Process. The green roof will be at the center of this analysis and investigation into the impacts of the green roof on other building systems. Value Engineering that dismisses LEED elements can unknowingly overlook cost effective benefits that can add real value and reduce total project costs and schedule.

Analysis Three: Alternative Exterior Wall Assemblies

Exterior enclosure is a major schedule risk to the projects timely completion. The current design for the exterior walls is exterior masonry panels with CMU backing. Issues that come from use of a CMU wall are its duration, weather impacts, cleanliness and ability for changes and acceleration during MEP rough in. Analysis three will develop and evaluate two alternate assemblies. The path to this topic began with a site visit, during which the masons were laying block and having to lift the blocks over the conduits stubbed up out of the walls.

Analysis Four: Alternative Steel Truss Construction

The transportation of steel trusses, for the gymnasium at HD Woodson High School, became extremely challenging. Multiple trusses over 100 feet long had to be transported from Delmar Delaware to NE Washington DC, roughly 112 miles, with police escorts and at great stress and expense to the project team. This topic was derived from a conversation with the project team about the truss transportation.

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Special thanks to my F**am**il**y**, Friends and Classmates for helping **a**nd supporting me throughout the last five years, more than they will ever know.

PROJECT BACKGROUND

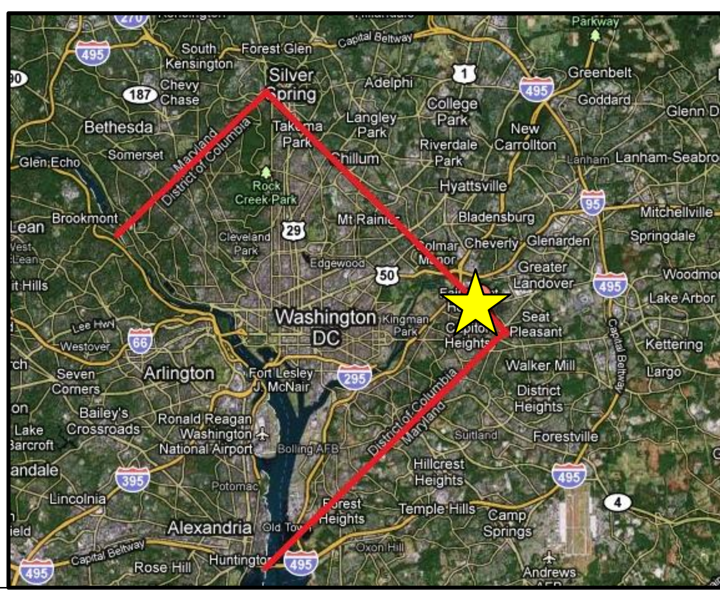
Project Introduction

HD Woodson Senior High School will be a 230,130 gross square foot new high school facility to accommodate up to 900 students in grades 9 through 12. The facility is designed around a developing trend in high schools that are focused on Science, Technology, Engineering and Mathematics (STEM). This newly developed STEM Concept allows students to learn in a very practical and hands-on manner. The STEM requirements allow for integral design of classroom and laboratory spaces. An emphasis on using the most current classroom technologies is present at HD Woodson High School. Classrooms will use interactive smart board technology and each student will have a personal laptop computer.

The actual building facility of HD Woodson Senior High School will be striving to achieve LEED Gold Certification upon completion under the LEED for Schools program by the US Green Building Council. Green Roof technology and highly reflective EPDM roofing membrane will assist in achieving critical LEED Points. An elaborate rain and grey water system will also be used to reduce run-off and conserve water. A Baysaver system will be used to filter all other run-off water.

In addition to the high tech classrooms, the facility construction also includes a competition gymnasium, auxiliary gymnasium, natatorium, auditorium, cafeteria, football field, eight lane all-weather track, throwing areas, high jump and triple jump areas, softball field and press boxes.

The facility is a project of the DC Public Schools (DCPS). Internal to DCPS it is the first totally new facility that the Office of Public Education Facilities Modernization (OPEFM) is overseeing. The former facility on the location was deemed no longer fit for use by the faculty and community prior to demolition. This is DCPS's first school design focused on the STEM concept and the new facility is scheduled to be open for the 2011-2012 school years.



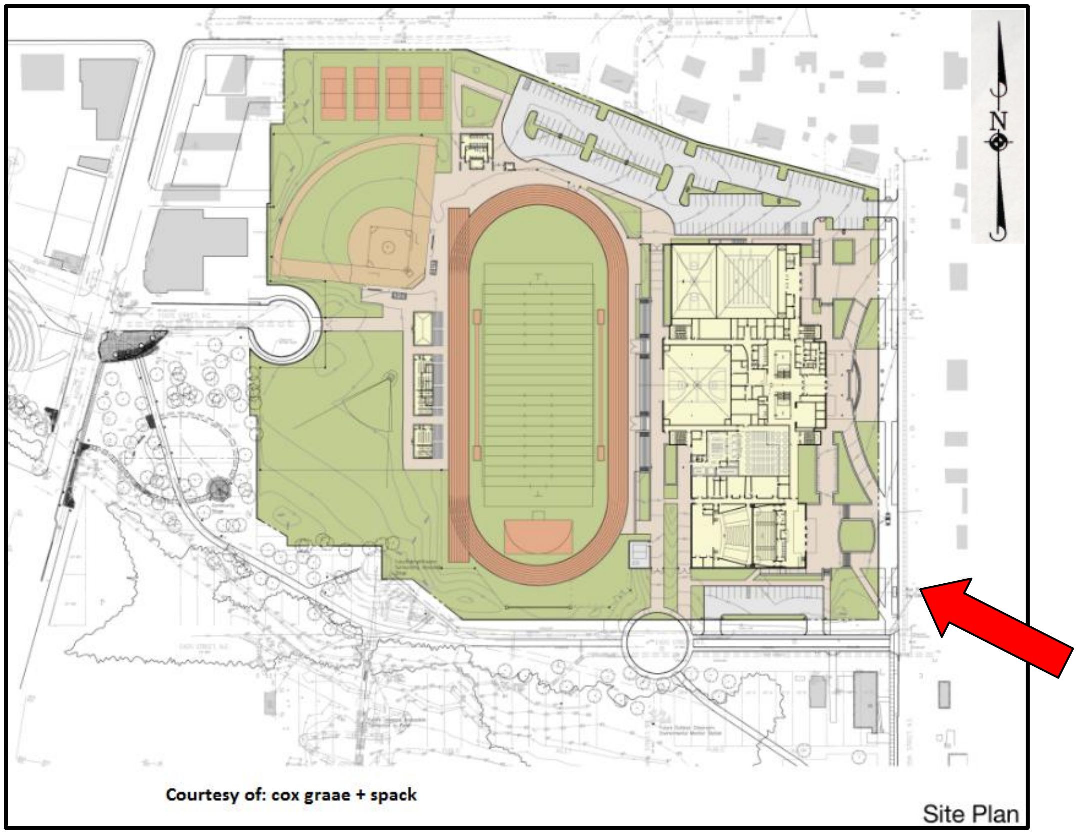


Figure 1: Overall site development plan

Figure 2: View as indicated by red arrow in Figure 1 (Courtesy cox graae + spack)

Client Information

District of Columbia Public Schools (DCPS) is the client for Howard D. Woodson High School. This school is the first totally new facility that is being coordinated by the Office of Public Education Facilities Modernization (OPEFM) within DCPS. Howard D. Woodson High School opened originally in 1972. Prior to demolition, a nine story white tower was located on the site. The tower was surrounded by a tennis court, long and triple jump track, pole vault track, football field and parking area. After 30 years of operation the faculty, students and community deemed it was no longer feasible to be in use.

The school has been carefully designed to meet a new concept created to focus on Science, Technology, Engineering and Math (STEM). The building is also designed to achieve LEED Gold under USGBC LEED for Schools. The owner is set on having the school open for the 2011-2012 school year. They are being progressive and ambitious by implementing rain water harvesting and grey water capturing for re-use in certain plumbing fixtures. The overall concept that DCPS is really excited about on this project is that it will be their first STEM School, and built to restore the community pride surrounding the site. Portions of the school will be open to the public after hours and for special events (i.e. gymnasium, natatorium, and outdoor facilities) by doing this the DCPS assists in achieving LEED rating as well as expanding community outreach. (Considered Mixed facility use for LEED)

The owner will be satisfied with the completion of HD Woodson High School if it meets their $103 million budget, opens for the 2011-2012 school year, is LEED Gold Certified and meets STEM requirements. They have already included the mayor of DC and the director of DCPS in ceremonies on the site, proving that this facility is highly regarded and public in the District of Columbia.

ARCHITECTURE

Design and Functional Components

HD Woodson Senior High School is a new facility that will consist of three building sections or bays separated by fire walls. The Center Building has four levels and features a gymnasium with bleacher seating along with ancillary space. A Fitness Area, Health Area, Student Dining, Student Commons, Classrooms and Administrative Offices and serves as the main entrance to the building.

To the South lies a single story auditorium with mezzanine seating. Ancillary space is also provided around the auditorium. Music classrooms are also in the South Building.

North of the Center Building is a three level auxiliary Gymnasium with bleachers and ancillary spaces. A Natatorium with Mezzanine seating is also provided along with ancillary spaces. Classrooms, Administrative Offices, a School Store and Bookstore are in the North Building as well.

The lower level of the school contains the gymnasiums, natatorium, associated spaces and mechanical rooms. The entry level is where the auditorium, in south section, with cafeteria and common areas adjacent. Directly opposite the main entry are the administrative offices in the Center with the natatorium entrance and mezzanine in the north section. The entrance space is defined from the interior with staircases in an open space that extends from the lower level to a large skylight, 4 stories up, allowing natural light through the entire building.

The two upper floors include four distinct "learning communities." Each is configured to support the STEM system of learning. Integrated classrooms provide flexible arrangements and allow for the use of a central integrated learning suite and conferencing area surrounding a collaborative learning space. Additionally, a media center on the second level, near the main entrance off the center bay, is intended to offer community use. The purpose is to reflect the culture of the learning in a shared learning environment through the use of technology.

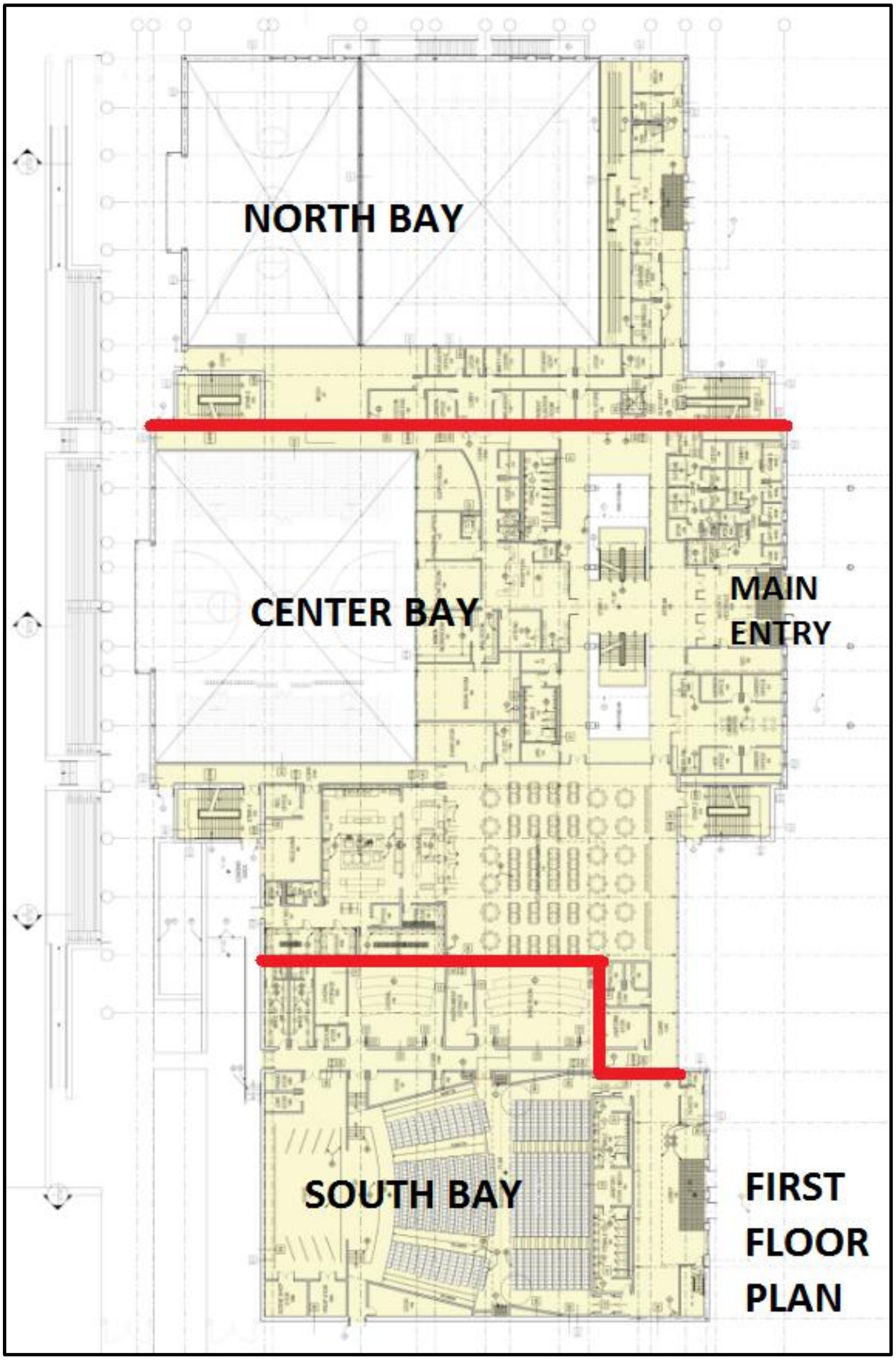


Figure 3: First Floor Plan with fire wall and bay designations (Courtesy cox graae + spack)

Building Envelope

Materials will include Brick around the bottom of the building up to a precast banding. The banding will serve as a transition to oversized masonry panels. Aluminum Cladding is also used for exterior walls and overhang spaces. Storefront style Glass Walls will also be used throughout HD Woodson High School. One of the main features of the building will be its Metal Canopy that extends over the Main Entry.

Figure 4: Rendered view of main entrance (Courtesy of cx graae + spack)

Figure 5: Rendered rear of facility, aerial view (Courtesy cox graae + spack)

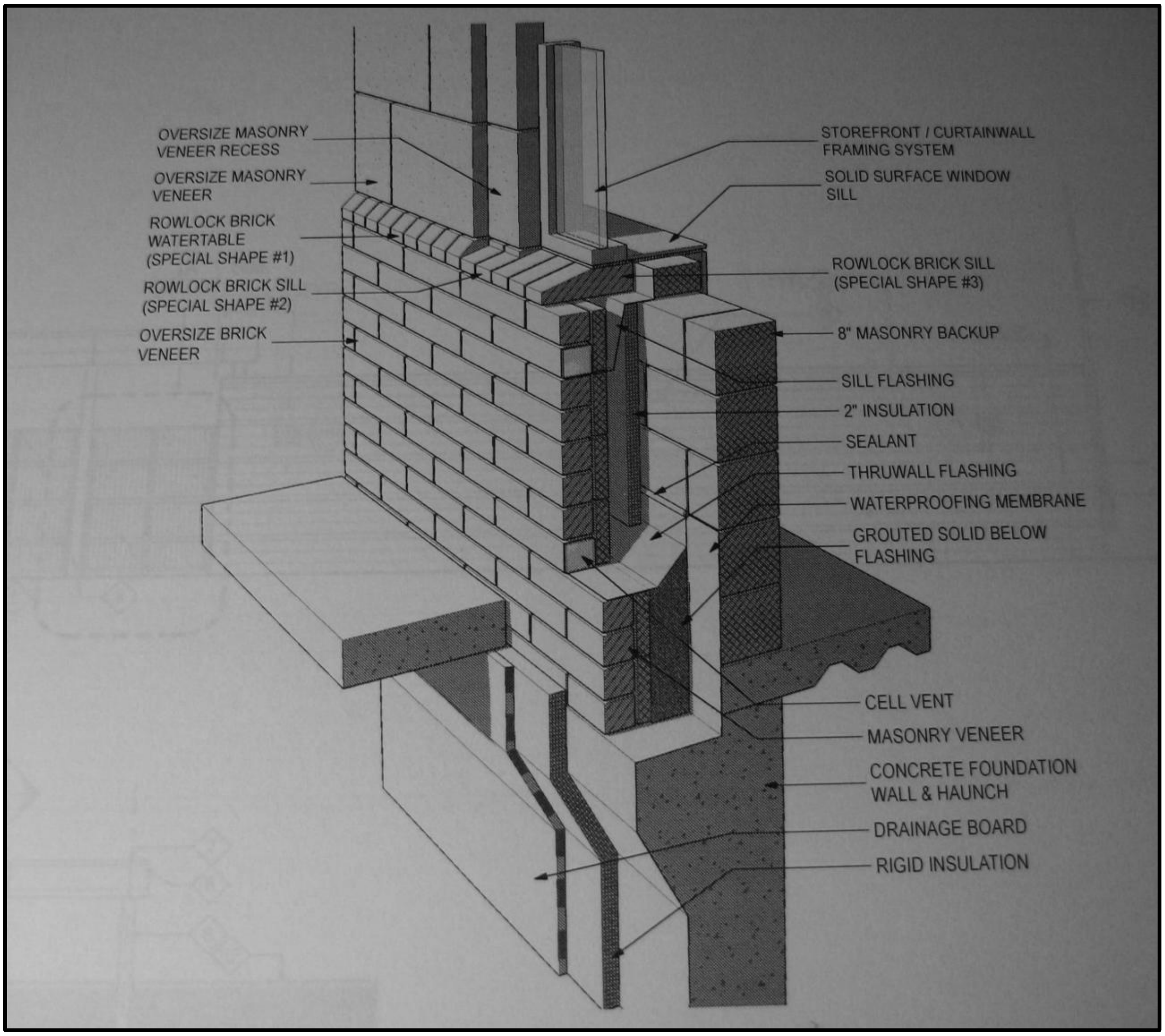


Figure 6: Building Envelope Cut-Away Perspective

PROJECT DELIVERY SYSTEM

The original project was arranged to be a Design-Build with CM at Risk. Through conversations with involved parties, the project has morphed into a more traditional Design-Bid-Build delivery. The original delivery method was chosen to allow the project to begin development prior to completion of all Construction Documents. To allow for completion on time and satisfy the wants from the owner in the time desired created a scenario that would be best fit by the Design-Build with CM at Risk Delivery Method.

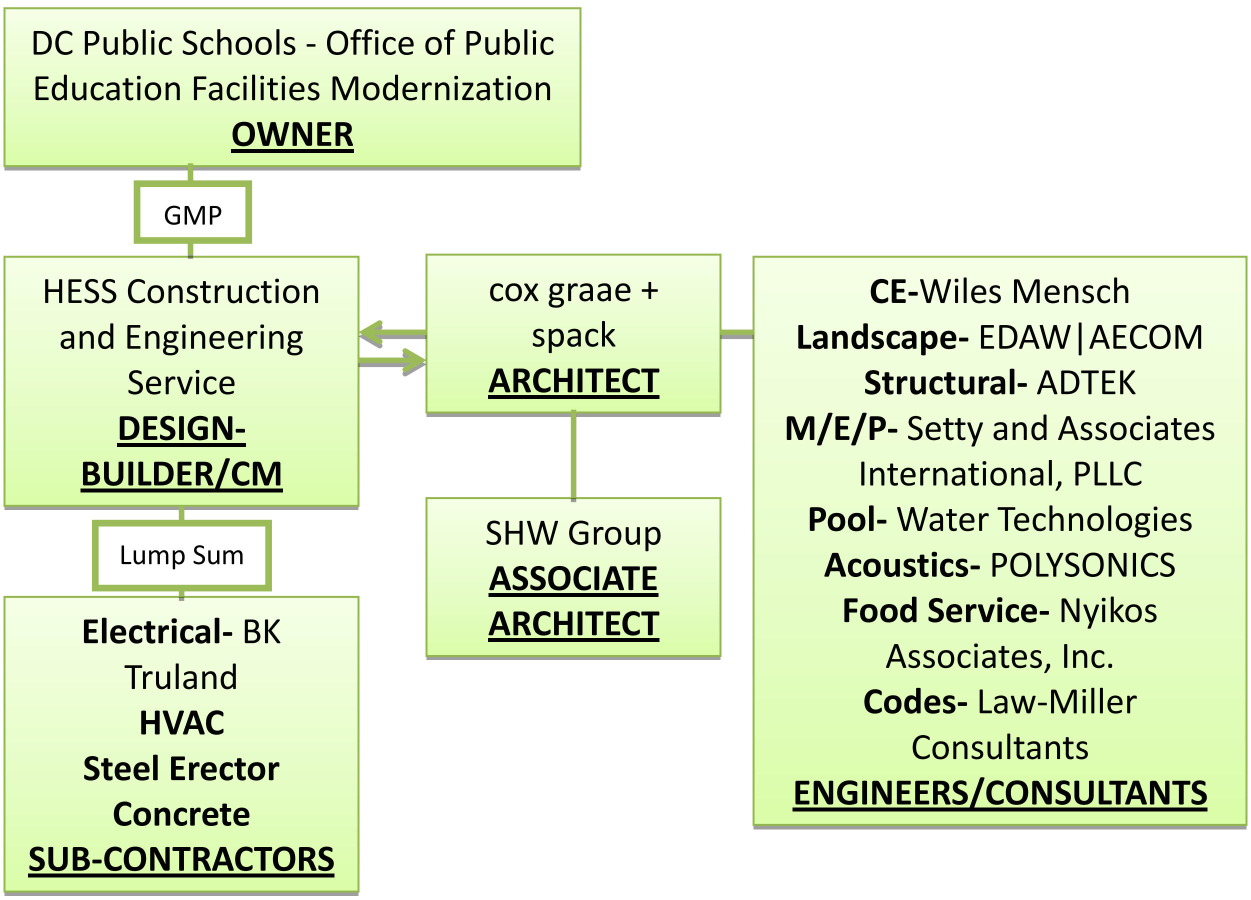


Figure 7: HD Woodson High School Organizational Chart

PROJECT SCHEDULE SUMMARY

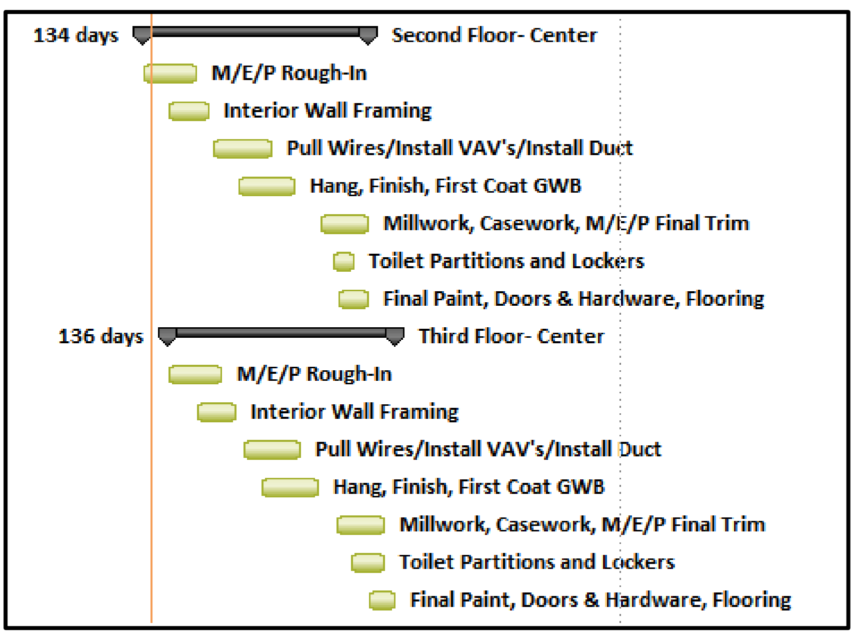
Schedule Overview

The total project is scheduled to take 528 Days. This does not include pre-design demolition. Substructure is projected to last 164 days, superstructure will take 127 days and the rough-in and finish timeline is 143 days. Building closeout includes testing for LEED point verification and other testing and balances, as well as final punch list work. Final completion is expected to be November 23, 2011. See Gantt chart Summary Schedule Appendix A.

Foundation, Structure, Finishes Narrative

The foundations will be constructed one of two ways on the site depending on the location and loading. Higher load areas will require geopiers to be constructed under the footings to create a high load bearing capacity. The rest of the site and outbuildings will use spread footings. The one exception will be the pool location; this area will involve the installation of sheeting and shoring, a mud mat, and special water-proofing of the Pool Structure inside and out.

Structurally the building will be erected in three segmented sections separated by fire rated barriers. The Substructure and Superstructure will both follow similar sequence paths. The Center Section and core of the building will always lead followed by the North Section and then the South. By segmenting the schedule throughout the process crews will be able to be of smaller sizes and more productive, if other trades have already moved out of a particular area prior to the next starting its work. There are however a number of trades that will require tight collaboration to achieve success on this project. The primary example being, the Electrical Contractor and Masonry Contractor as many block walls will need to be roughed in while being constructed. The Rough-in and finish schedule will follow a similar sequence by starting in the Center, progressing to the North and then finishing in the South Building.



PROJECT COST EVALUATION

Construction Cost	Source	Construction Cost per SF
$ 39,564,992	D4 Cost Estimating	$ 171.92
$ 49,120,500	R.S. Means	$ 213.44
$ 89,000,000	Actual	$ 386.74

Table 1: Square foot estimates summary

The total project has a budget of $103 million and building cost of $89 million. The actual building cost per square foot was calculated to be $387. In Table 1, a comparison to the parametric estimate created using D4 Cost Estimating can be seen; the estimates created in my research appear to be low. I feel that the reason for this difference in cost can be justified. The actual building cost considers the many amenities and sport facilities created for HD Woodson High School. In D4 it is strictly looking at square foot and a comparable size building. HD Woodson is a revolutionary design for a High School focusing on the use of technology and striving for LEED Gold Certification. Also HD Woodson HS involves the construction of an auditorium, competition gymnasium, auxiliary gymnasium, natatorium and multiple outdoor sports facilities.

The estimate using Cost works (RS Means) has resulted in an estimate of $49.1 million. The revisions made to the base square foot price include: adjusting to appropriate story height and perimeter as well as some additional amenities. The large differences can be accounted for in the differences in the design of the project compared to other high school facilities. RS Means square foot cost data cannot account for the many amenities included in the actual construction costs of HD Woodson High School.

System	System Cost	% of Total	Cost per SF
Mechanical	$14,000,000*	16	$ 60.83
Electrical	$10,960,000	12	$ 47.62
Structural	$ 3,900,000*	4	$ 16.95

Table 2: MEP and structural cost estimates summary *Estimated Values

SITE CONDITIONS

Figure 8, below shows the existing site and surrounding building structures prior to demolition. The following two pages are further detailed drawings of the existing site conditions. Figure 10 shows roads, vehicular and pedestrian pathways around the site. More details on the existing utility locations can be found on Figure 11.

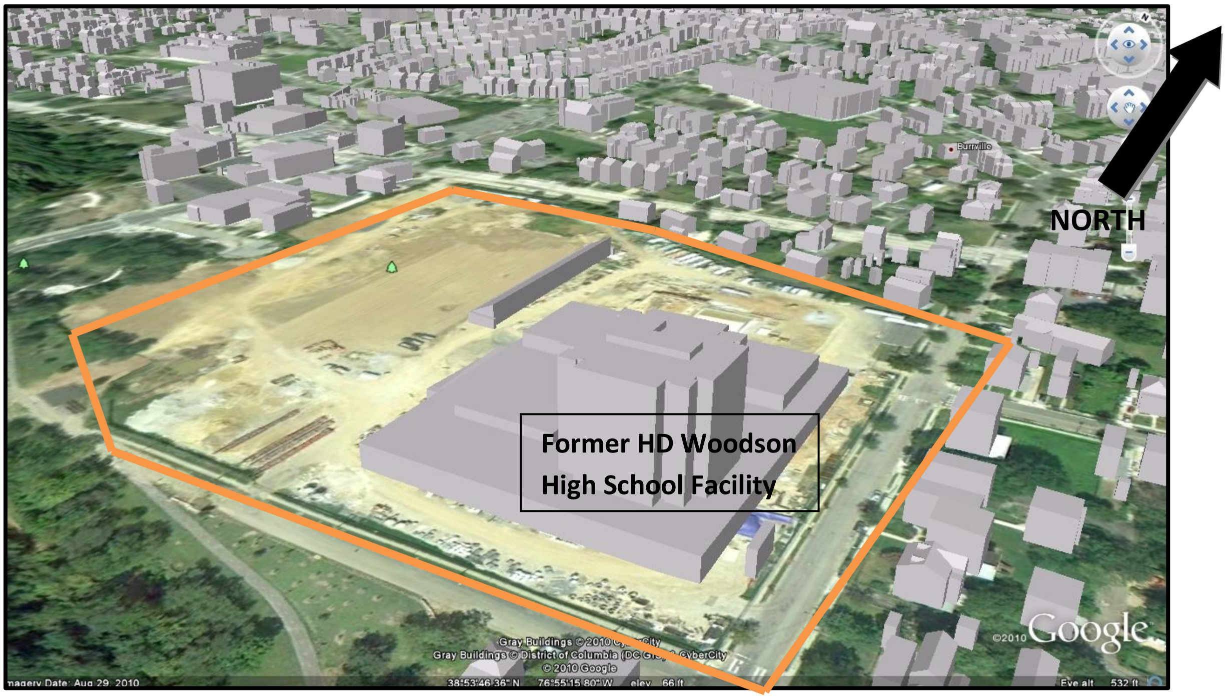


Figure 8: Existing site prior to demolition (Courtesy cox graae + spack)

Figure 9: View after Demolition from 55th and EADS Intersection (Courtesy Google Maps)

Figure 10: Site plan with ingress/egress and surrounding streets

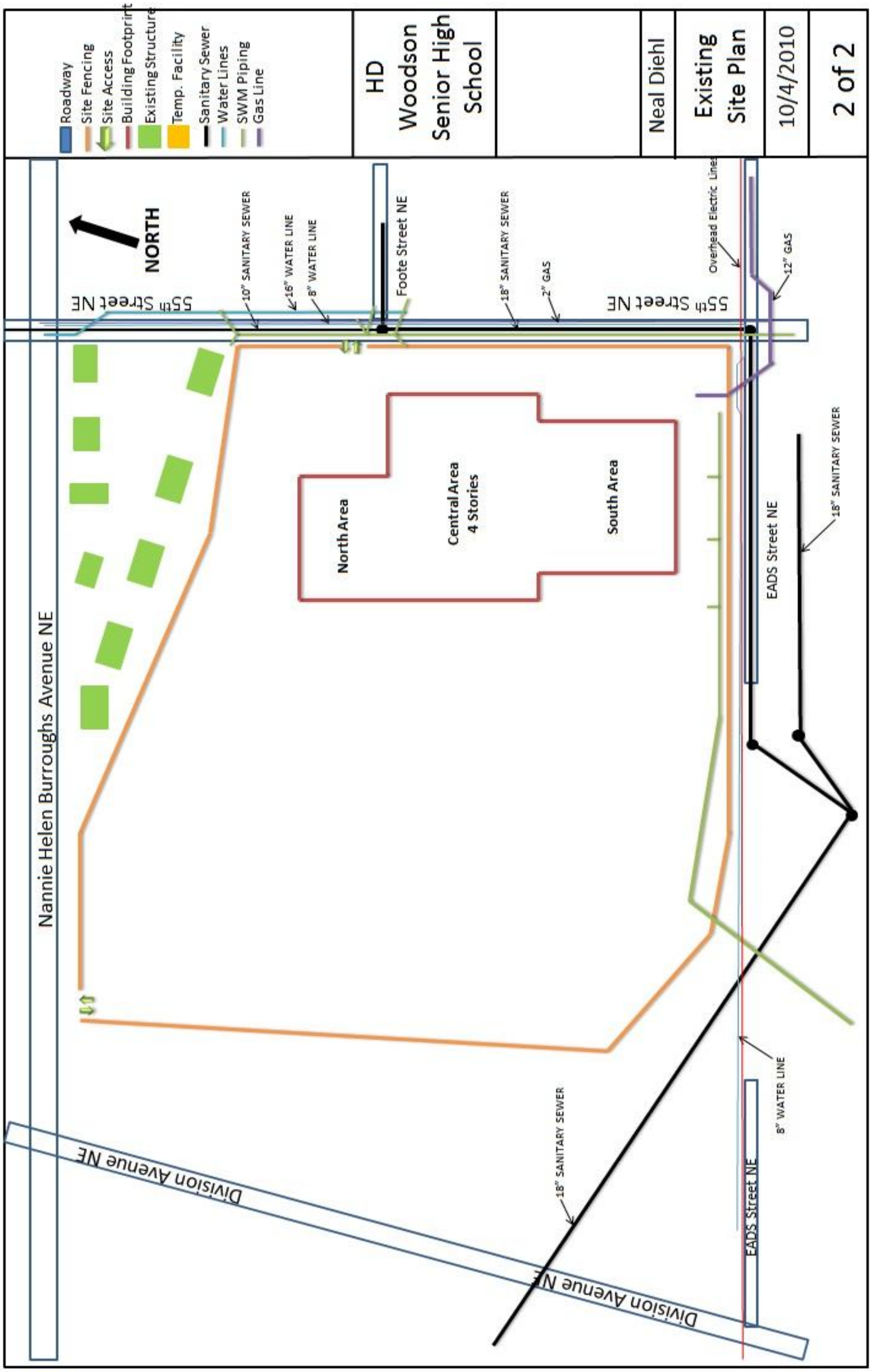


Figure 11: Site plan with underground utility locations

LOCAL CONDITIONS

Typically in the Washington DC region the preferred method of construction is cast in place concrete. It is interesting that the structural system is mainly ordinary steel construction. With building height not being a design limitation, in respect to maximizing number of floors this may have factored into the method chosen.

The site allows limited on-site parking and street parking is available for overflow parking. The surrounding area is mostly residential and street parking will provide sufficient parking spaces during construction.

Many construction recycling companies are available to the DC area, from Aggregate on site recycling to sorting and hauling services. The concrete from the existing facility was recycled during demolition, before the Design-Build Process started.

Subsurface and site conditions from the demolition posed a hazard to the surrounding area due to the groundwater level and large holes on the site. Certain areas ranged from 6 to 14 feet below grade and contained up to 10 feet of water. The soil bearing capacity does not require anything more than the use of geo-piers in certain locations. Spread footings are sufficient in most areas and for detached structures around sports facilities.

LEED CONSIDERATIONS

The High School is currently projected to meet LEED Gold under LEED for Schools Program. This rating will be achieved by focusing on Indoor Air Quality and Optimizing Energy Performance. A large portion of the roof (over 40%) will be extensive green roof gardens, while the remaining areas will be a highly reflective EPDM roofing material. The complete LEED Scorecard can be seen in Appendix A, however a summary can be seen below in Table 3.

LEED 2009 for Schools New Construction and Major Renovations			
Category	**Points Planned to be Earned**		
	Yes	**Maybe**	**No**
Sustainable Site	16	3	5
Water Efficiency	9	2	0
Energy and Atmosphere	12	0	20
Materials and Resources	6	1	6
Indoor Environmental Quality	16	0	1
Innovation and Design Process	2	1	3
Regional Priority Credits	0	0	0
TOTAL	61	7	35
	GOLD = 60 to 79 points		

Table 3: LEED Scorecard Summary

ANALYSIS 2: OPTIMIZING VALUE ENGINEERING

Problem Identification

Analysis two looks at some possible Value Engineering (VE) Solutions to clear the hurdle of "LEED" elements being excluded from the VE Process. The green roof will be at the center of this analysis and investigation onto the impacts of the green roof on other building systems. Value Engineering that dismisses LEED elements can unknowingly overlook cost effective benefits that can add real value and reduce total project costs and schedule.

Research Goal

To identify the costs and impacts on other systems associated with elimination of the green roof. To develop a way to ensure that the LEED points can still be claimed to achieve LEED Gold at a lower cost and within a shorter duration. Determine the possible missed opportunities that occur when LEED elements are not properly evaluated during the total project Value Engineering Process.

Analysis 2 Introduction

This analysis started with an investigation into the green roof. The properties of the green roof analyzed included: cost, thermal efficiency, storm water storage capacity, weight, and construction duration. Upon investigation into these properties, the impacts of eliminating the green roof on other systems were considered. The storm water retention of the green roof will affect the greywater system sizing and capacity. Weight reduction provides potential for a reduction of the steel framing members, which will be studied as a breadth topic. Thermal properties of the green roof system are very complex and will require careful and creative considerations. Construction duration for the roof system can be reduced dramatically. Finally, cost will be studied with changes and impacts of the other systems to determine the viability of eliminating the green roof. To conclude this analysis taking LEED certification, Value Engineering and Schedule Reduction into consideration will determine the risks and opportunities associated with Optimizing Value Engineering.

Green Roof Background

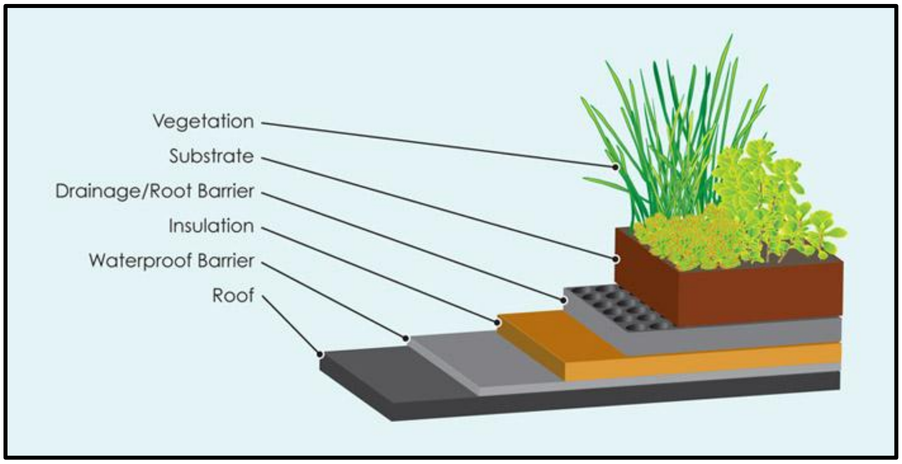


Figure 12: Simplified Extensive Green Roof Example

HD Woodson High School's design incorporates and extensive green roof as part of the roof system. Extensive green roof is an innovative use of the thermal and moisture properties associated with soil and plant life material to create a sustainable feature in many modern day construction projects. This particular type of green roof, extensive, provides capacity of only up to 6" of soil on top of the roof. In Figure 12, a simplified diagram of the extensive green roof utilized at HD Woodson is shown to allow the visualization of a basic extensive green roof assembly.

The soil medium layer as designed is planned to be four inches and the system selected for use allows the base layer of the assembly to be insulation directly on Concrete, which is not typical for most green roof assemblies. The detailed assembly designed specifically for HD Woodson High School is shown in Figure 13.

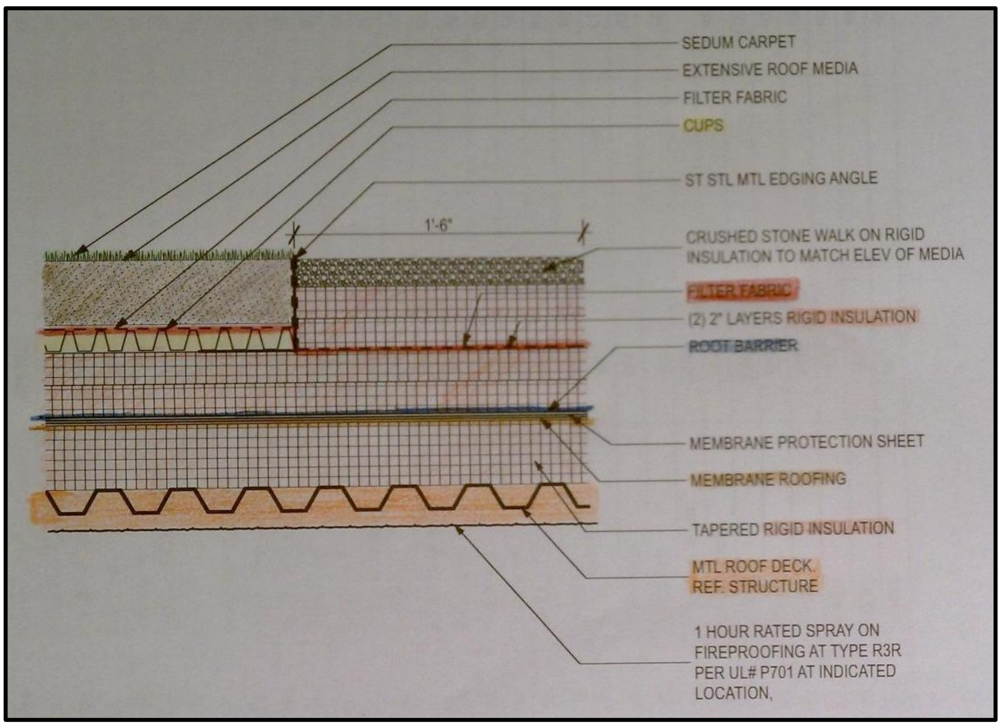


Figure 13: Detailed Actual Extensive Green Roof Assembly

Green roofs provide many advantages and disadvantages that must all be considered when deciding if it is a suitable option for a roofing assembly. A few advantages to green roofs are: storm water management properties, acts as a thermal mass, ability to clean the air and possible long term energy savings. Some disadvantages are: high initial costs, increased roof dead loads, maintenance concerns and costly repairs if required. Some of these pros and cons associated with green roofs will be discussed further in the following sections. The green roof designed will cover 45,502 sf with an additional 31,648 sf draining onto the green roof area. A total of 77,150 sf of roof area runoff will be controlled by the green roof. The 31,648 sf and the area that drains onto the green roof will be an EPDM reflective roofing materials, 55,904 sf.

Green Roof Estimate

The green roof estimate was generated by first looking at case studies of green roof costs in the DC Region. The use of six case studies resulted in $25.57 per square foot for the green roof installation. Table 4 shows the case studies and the average cost per square foot costs. This cost did not include the waterproofing membrane so an additional $2.50 per square foot will be added in order to account for this cost. The total cost per square foot that will be used to compare the green roof system costs to replacement with reflective EPDM will be $ 28.07 per square foot. The cost used for EPDM price per square foot was researched and the range for installed Reflective EPDM roofing is $ 3.00 to $ 4.50 per square foot. With the green roof being at the higher end of national averages for installation costs, the $ 4.50 cost per square foot for reflective EPDM roofing will be used.

Washington DC Green Roof Case Studies			
Building	Square Feet (SF)	Cost	Cost per SF
Anacostia Gateway Building	10,500	$ 250,000	$ 23.81
United States DOT Headquarters	68,000	$ 720,000	$ 10.59
DC Dept. of Parks and Recreation	5,400	$ 120,000	$ 22.22
Latin American Montessori Bilingual Charter School	2,682	$ 79,290	$ 29.56
Service Employees International Union Hdqrts	Not provided	Not provided	$ 35.00
US Dept. of Interior- Main Interior Building	6,495	$ 209,526	$ 32.26
Case Study Average			**$ 25.57**
Cost Used for Estimate			**$ 28.07**

Table 4: DC Region Green Roof Case Studies

Green Roof Cost Estimate		Reflective EPDM Roofing	
$ per Square Foot	$ 28.07	$ 4.50	$ per Square Foot
Square Feet	45,502	45,502	Square Feet
TOTAL	**$ 1,277,240**	**$ 204,760**	TOTAL
Potential Savings	**$ 1,072,480**		

Table 5: Green roof vs. EPDM Roofing Costs

Durations and Schedule Reduction Scenario

The current schedule allowed 60 days for the installation of the green roof on all three bays of the building. 21 for the Center, 20 for the North and 19 for the South, however, the actual green roof, or plant material installation is not on the critical path of the project. The waterproof membrane is the critical portion of the roof enclosure, which will still be the same or a similar process for the EPDM reflective roofing membrane.

Thermal Property Considerations

Thermal properties of a green roof are very complex and difficult to quantify. The R-value of soil can be taken into account, though it is poor, it does not represent accurately all the benefits that the green roof thermally provides. The R-value does not take into account the thermal mass that the soil provides to the construction assembly, creating a longer period of time for heat to transfer to or from the conditioned space. However, this report does not allow the time and depth needed to take this into account while comparing thermal properties; it is an important note to make about the system, but was not accounted for in the alternative design proposal. Equally as important to note about the EPDM roofing membrane is its reflective properties that are not taken into account in this proposal as well.

The as-is design of the green roof has a combined R-value of 43. The alternative assembly being proposed will provide an R-value of 50 and become consistent with the EPDM reflective roofing material. Table 6: R and U value Assembly comparisons. Table 6 breaks down the assembly of the green roof system and alternative system by R-value. However, when looking into these systems further the Solar Reflectance and Emmittance should be taken into account, it was not included in this report.

Green Roof		Alternative Assembly	
	R-Value	R-Value	
Sedum Carpet	0	0	EPDM Roof Membrane
Extensive Roof Medium	1.25		
(2) 2" Layers Rigid Ins.	20	20	(2) 2" Layers Rigid Ins.
Tapered Ins. Average	21.6 (average)	21.6	Tapered Ins. Average
Cementitious FP (1HR)	0	8.33	Blazeshield II FP
TOTAL R-value	42.85	49.93	Total R-value
U value (1/R)	0.02334	0.02003	U value (1/R)

Table 6: R and U value Assembly comparisons

To determine roughly the amount of BTU/hr that will be transferred through the 45,502 sf of green roof the winter extreme and summer extreme temperatures were used to calculate heat transfer per hour. In order to calculate the heat transferred through the green roof area and potential savings ASHRAE Handbook Fundamentals 2009 was used to determine winter and summer extreme temperatures. These numbers were used to calculate Change in Temperature from one side of the assembly to the other according to the corresponding indoor design temperature. The additional R-value is gained by a proposed Fireproofing system that provides an R of 3.33 per inch and 2.5 inches are required for the 1 hour rating on the underside of the metal decking. The product is Blazeshield II and can be installed for 10 to 15 % less than the typical cementitious Spray-on Fireproofing, appendix B Shows the product data sheets.

Design Temperatures and Heat Transfer					
	U Value	**Season**	**Indoor Design Temperature**	**Outdoor Temp. (Reagan Int. Airport)**	**Change in Temperature (ΔT)**
Green Roof	0.02334	Winter[1]	70	16.3	53.7
A= 45,502 sf	0.02334	Summer[2]	75	94.3	19.3
$Q = U * A\Delta T$ (BTU/hour)		Q^1=57024			
		Q^2=20494			
Alternative	0.02003	Winter[1]	70	16.3	53.7
A= 45,502 sf	0.02003	Summer[2]	75	94.3	19.3
$Q = U * A\Delta T$ (BTU/hour)		Q^1=48943			
		Q^2=17590			

Table 7: Heat Transfer by Season

Greywater and Potable Water System Impacts

Another LEED designed element at HD Woodson High School is the Greywater reuse system. The removal of the green roof will have a large impact on this system. One of the benefits to the green roof was its ability to retain storm water, filtering it and releasing it slowly. However, the Greywater system is another system that assists in Storm Water Management. Part of considering the removal of the green roof was the impacts on other systems. In order to Optimize Value Engineering, redundancy of systems to solve the same problem may not always be the best solution. By expanding the capacity and uses of the greywater system can provide more than assistance in Storm Water Management.

Upon investigation into the total water supply and management, both potable and non-potable as well as Storm Water, a number of interesting discoveries were made. The first being the redundancy of the green roof and greywater system, secondly the grey water system and conventional plumbing both required for toilet flushing. Toilet flushing also contributes the highest demand for the sizing of the water main coming to the building from the street. The next few sections will explain and justify, in terms of water use, the removal of the green roof, expansion of the greywater system, greywater and trickle tank concept for toilet flushing, as well as downsizing the main water line from the street.

Green Roof Storm Water Storage Capacities

An advantages that will be lost when removing the green roof will be its ability to retain water, filter it and release it slowly. The water storage capacity of the roof is calculated using the Area, Voids ratio of the soil and the thickness. The Total Capacity of the green roof was 6,006 cf, or 44,928 gallons. Using the short cut routing method an engineer on the project determined that the maximum volume that would be required during either a 2 year or 15 year storm event would be 3,540 cf and 4,656 cf respectively. This means that the system had well over the required capacity for a 15 year rain event.

Green Roof Storage Volume Capacity			
Square Footage	Voids Ratio (%)	Thickness of Soil (ft)	Storage Volume (cubic feet)
45,502	0.4	0.33	6,006

Table 8: Green Roof Storage Volume

In addition to the green roof area controlling drainage for 45,502 sf, there is also a portion of the roof that drains onto the green roof. 31,648 sf of EPDM roof area drains onto the green roof making the total area of roof drainage controlled by green roof 77,150 sf, or 76%.

Greywater System Design Considerations

The current greywater system has a capacity of 30,000 gallons, or 4,011 cf. Two tanks make up this storage capacity, one a 10,000 gallon tank and the other a 20,000 gallon tank. This is not enough capacity to satisfy the replacement of the green roof entirely. Therefore an additional 20,000 gallon tank will need to be installed, increasing the total system capacity to 50,000 gallons or, 6,685 cf. In addition to the current design of the greywater system tanks and pumps another change can add real value to this project. By adding a main line into the tanks and automatic controls that will never allow the tanks to fall below a minimal level required for all toilet flushing, the redundancy of the plumbing system can be eliminated. The concept of slowly filling the tanks as needed when storm water and greywater re-use systems are not providing enough to make the system usable, the ability to downsize the potable water main becomes possible. By maintaining a minimal level in the tanks and using the system for toilet flushing.

The current design for the water main coming into the building was based on the criteria in Table 9. 5,355 gallons per minute were designed for toilet and urinal flushing, while only 394 gallons per minute make up the rest of the domestic water demand.

Fixture	GPM/fixture	# of Fixtures	GPM
Faucet (kitchen sink)	2.2	56	123
Faucet (lavatory)	1.5	118	177
Shower	2.5	23	58
Faucet (Utility Sink)	4	9	36
Urinal (flush)	35	29	1015
Toilet (flush valve)	35	124	**4340**
TOTAL GPM			**5749**
Total Toilet Flushing			**5,355**

Table 9: Water Main Design Criteria

This large portion of water demand will be able to be met entirely by combing the expansion of the greywater/rain storage collection with a smaller water main connection to slowly fill the storage tanks and act as buffers for this large demand. The plumbing engineer would have to study the possibility of downsizing the water main upon proposal of this system. If the water main can be reduced after looking at demand for fire suppression systems and worst case scenarios for the buffer tanks getting minimal rainfall amounts. The location of the tank will be to the right of the current location of the grey water tanks. Figure 13 shows the original design and location of the two water storage tanks under the parking lot at the south of the complex. To the east or right of the tank is where the additional proposed 20,000 gallon tank will also be installed. Table 10 displays a breakdown of estimated additional costs of installing the additional tank.

Additional 20,000 Gallon Storage Tank Costs		
	Impact on Schedule	Cost
Added Excavation	2 Day	$ 15,000
Tank (20,000 gal)		$ 10,000
Additional Plumbing	1 day for connections	$ 1,000 allowance
TOTAL		**$ 26,000**

Table 10: Added Storage Tank Costs

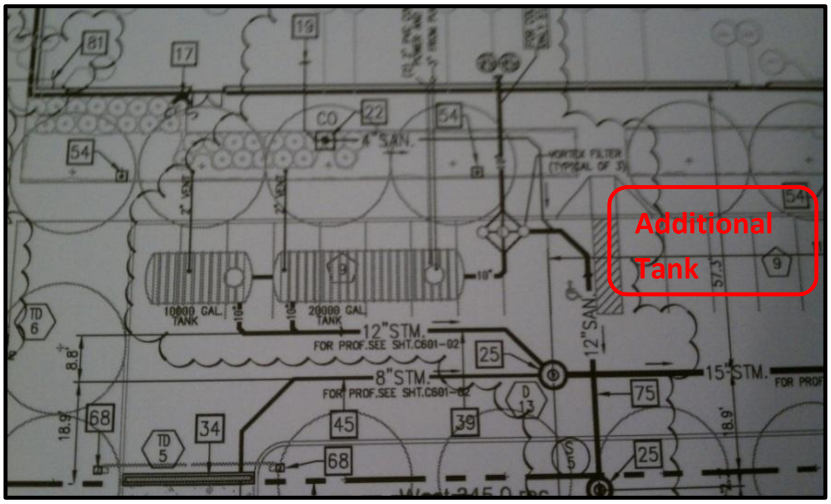


Figure 14: Original Design and Location of Greywater Tanks

Expected Rainfall

Table 11, shows the average monthly rainfall in the DC area. These averages were used to determine how much rain water can be expected to be collected per month. The rainiest month provides on average 8,049 gallons per day. With a storage capacity increased to 50,000 gallons the ability to significantly reduce the amount of potable water being used for toilet flushing is greatly reduced.

Average Monthly Rainfall from 1971 to 2010 Reagan Airport					
	Inches	Feet	Roof Area	CF	Gallons
January	3.21	0.268	101406	27,126	202,917
February	2.63	0.219	101406	22,225	166,253
March	3.60	0.300	101406	30,422	227,571
April	2.77	0.231	101406	23,408	175,103
May	3.82	0.318	101406	32,281	241,478
June	3.13	0.261	101406	26,450	197,860
July	3.66	0.305	101406	30,929	231,363
August	3.44	0.287	101406	29,070	217,456
September	3.79	0.316	101406	32,027	239,581
October	3.22	0.268	101406	27,211	203,549
November	3.03	0.253	101406	25,605	191,539
December	3.05	0.254	101406	25,774	192,803
MAX	3.82		MAY	32,281	241,478
MIN	2.63		FEB	22,225	166,253
AVERAGE	3.28			27,711	207,289
TOTAL				332,527	2,487,473

Table 11: Average Monthly Rainfall

Effects on LEED Criteria

By removing the green roof the potential to lose thermal efficiency may become difficult depending on how much the mechanical system designed, relied on the thermal mass of the green roof. In order to combat this issue, the proposal to use a higher R-Value spray on fire proofing is suggested. The impact on cost for this spray on fireproofing is minimal and claims to be at a 10% to 20% reduction of normal cementitious spray on fireproofing. If additional insulation for the green roof area, 45,502 sf, is needed an additional 2 2" layers for rigid insulation would cost under $80,000. That price can be cut in have if only a single layer is required per the mechanical engineer's recommendation.

Water efficiency points will also not be affected due to the green roof removal, if the expansion of the grey water system is implemented. The two systems, while quite different, work to combat the same problems of rapid discharged storm water and water use efficiency.

Structural Breadth- Impacts of Removing Green Roof

By removing the Green Roof the Dead load is significantly decreased on the structural steel roof framing members. This breadth analysis will evaluate the potential to downsize the steel members in a roof section over the south building, above the auditorium between columns K-11 to 15 and H-11 to 15. Figure 15 below shows the original design of a roof structural bay. Girder A and Beam B will be analyzed for potential reduction due to green roof deletion. The W 21x44 beams are only partially shown to indicate the tributary area for Girder A.

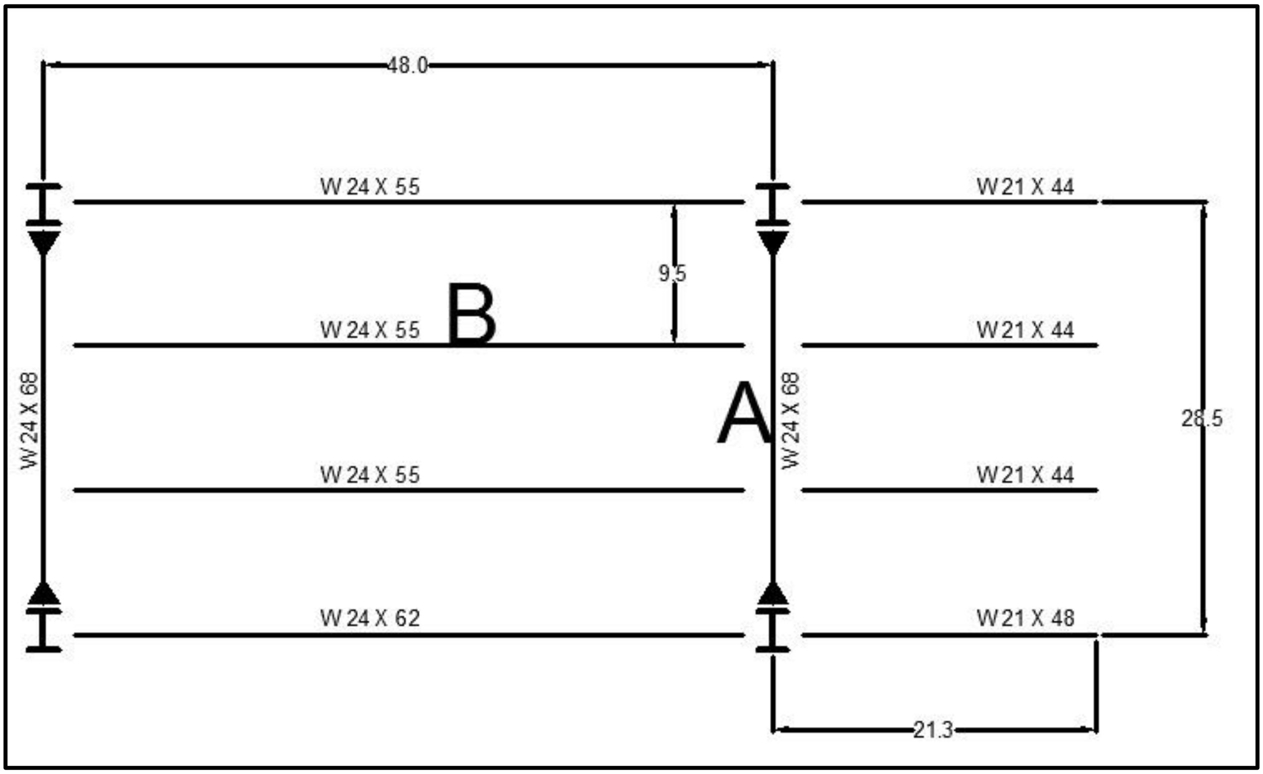


Figure 15: Roof Framing Members Original Design

Beam Design Loads and Reduction

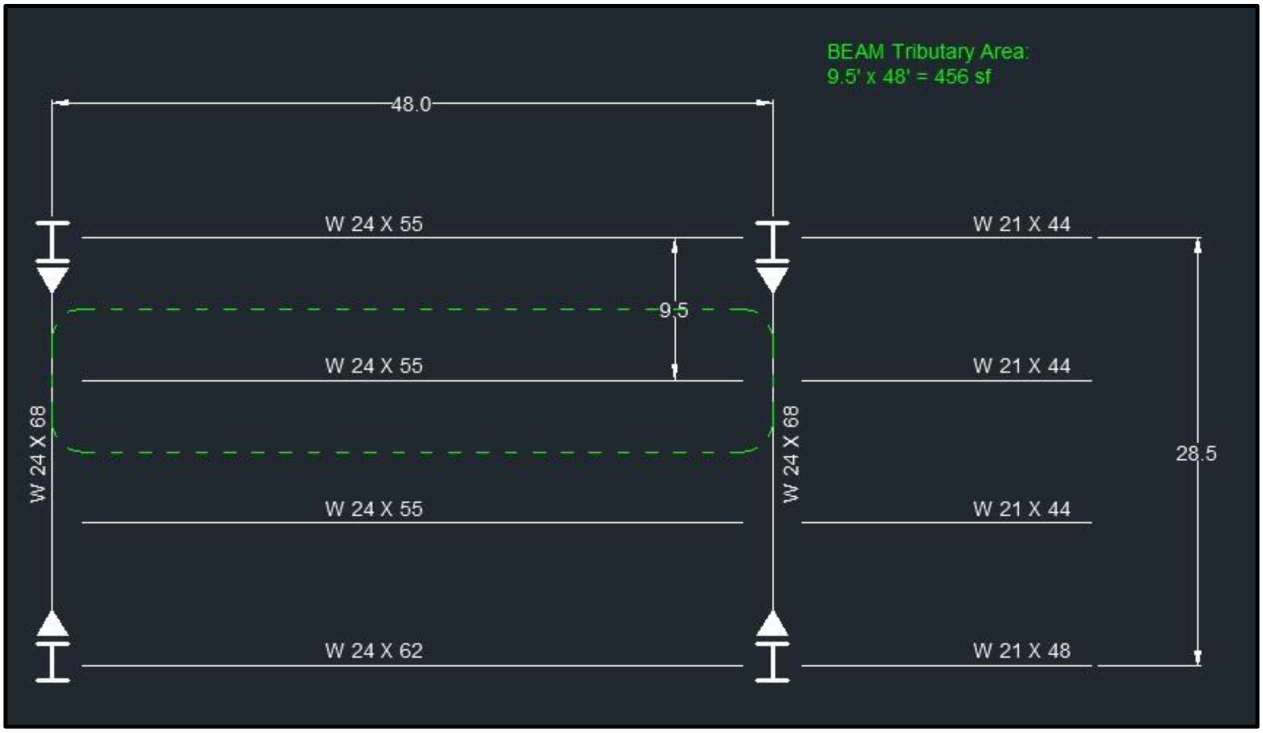
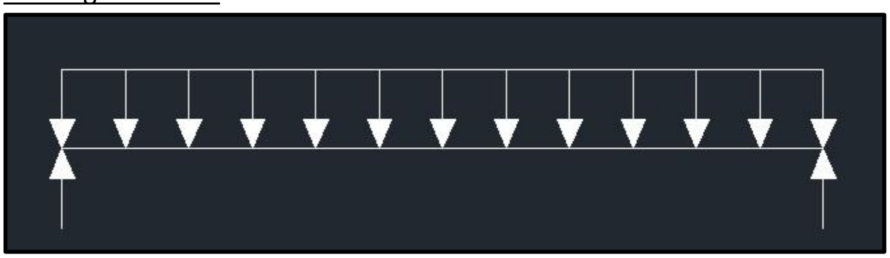


Figure 16: Beam B Tributary Area and Original Member Sizes

Loading Condition



W 24x55 Loading Calculations

Factored Load: 1.2(30 PSF + 30 PSF) + 1.6(21) = 105.6 PSF

Load (PLF): 105.6 PSF x 9.5’ (width of Trib. Area) = 1003.2 PLF (1.003 KLF)

Load per Support: (1.003 KLF x 48’) / 2 Supports = 24.072 kips (at each support)

Bending Moment: $w_u l^2/8$ = (1.003 KLF) x $(48')^2/8$ = 288.9 kip-ft.

W 24x55 Max Bending Moment: **503 > 288.9 (57%) OK**

Deflection Calculations

Load: 60 PSF + 21 PSF = 81 PSF, 81 PSF x 9.5’ = 769.5 PLF

Deflection: $(5wl^2) / (384EI)$ = 5(769.5 PLF)$(48')^4$(1728 Conversion) / [(384)(29,000,000)(1350)= 2.34”

Max Allowable Deflection Total Load: L/240 = [48’ x (12”/1’)]/240 = **2.4”>2.34” OK**

<u>Reduced Load Calculations</u>

Factored Load: 1.2(30 PSF) + 1.6(21) = 69.6 PSF

Load (PLF): 69.6 PSF x 9.5' (width of Trib. Area) = 661.2 PLF (.661 KLF)

Load per Support: (.661 KLF x 48') / 2 Supports = 15.87 kips (at each support)

Bending Moment: $w_u l^2/8$ = (.661 KLF) x $(48')^2/8$ = 190.4 kip-ft.

Maintain 57% for unknown factors: 190.4 + 57% = 299 kip-ft.

W 21x44 Max Bending Moment: **358 kip-ft. > 299**

W 18x40 Max Bending Moment: **294 kip-ft. «» 299**

<u>Reduced Load Deflection Calculations</u>

W 21x44

Load: 30 PSF + 21 PSF = 51 PSF, 51 PSF x 9.5' = 484.5 PLF

Deflection: $(5wl^2)$ / (384EI) = 5(484.5 PLF)$(48')^4$(1728 Conversion) / [(384)(29,000,000)(843)= 2.36"

Max Allowable Deflection Total Load: L/240 = [48' x (12"/1')]/240 = **2.4">2.36" OK**

W 18x40

Load: 30 PSF + 21 PSF = 51 PSF, 51 PSF x 9.5' = 484.5 PLF

Deflection: $(5wl^2)$ / (384EI) = 5(484.5 PLF)$(48')^4$(1728 Conversion) / [(384)(29,000,000)(612)= 3.26"

Max Allowable Deflection Total Load: L/240 = [48' x (12"/1')]/240 = **2.4"<3.26" NOT OK**

In the bay studied the W24x55 can be reduced to W21x44 and the W21x44 beams to the right of the bay can be reduced to W18x40s. The calculations for this second reduction can be found in Appendix C. The reason these beams were analyzed was to allow the reduction of the Girder A. The reduced beams are shown in Figure 17 with the possibility to resize the Girder to be investigated in the rest of the Structural Breadth.

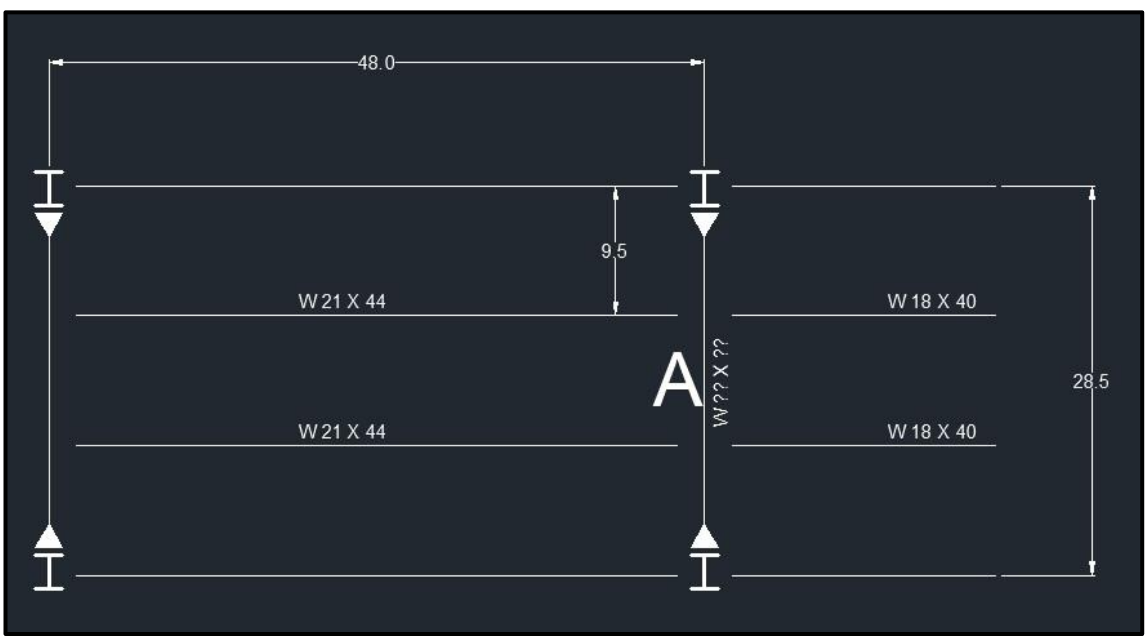


Figure 17: Reduced Beam Designations Influencing Girder A

Girder Design Loads and Reduction

In order to re-size Girder A an investigation into the existing design was first done to explore the possibility of downsizing at all. Figure 18 Displays the Tributary Area and design of the steel members with the green roof loads accounted for.

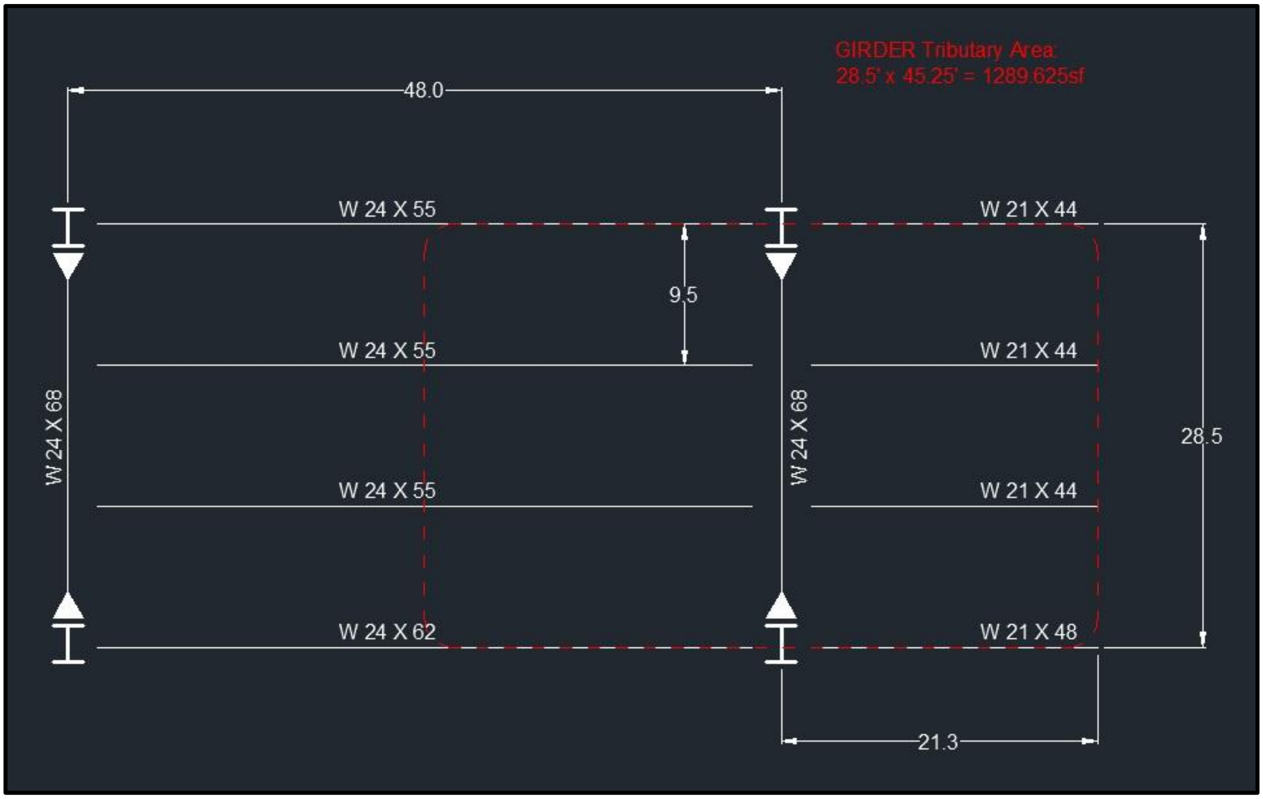


Figure 18: Girder A Tributary Area with Original Member Sizes

<u>W 24x68 Loading Calculations</u>

Factored Load: 1.2(30 PSF + 30 PSF) + 1.6(21) = 105.6 PSF

Additional Self Weight of Connecting Beams: 105.6 + 3.5 PSF = 109.1 PSF

Load (PLF): 109.1 PSF x 45.25’ (width of Trib. Area) = 4936.8 PLF (4.94 KLF)

Load per Support: (4.94 KLF x 28.5’) / 2 Supports = 70.4 kips (at each support)

Bending Moment: $w_u l^2/8$ = (4.94 KLF) x $(28.5')^2/8$ = 501.6 kip-ft.

W 24x68 Max Bending Moment: **664 kip-ft. > 501.6 kip-ft. OK** (75%)

<u>Deflection Calculations</u>

Load: 60 PSF + 21 PSF = 81 PSF, 81 PSF x 45.25’ = 3,665.25 PLF

Deflection: $(5wl^2) / (384EI)$ = 5(3665.25 PLF)$(28.5')^4$(1728 Conversion)/[(384)(29,000,000)(1830) = 1.03”

Max Allowable Deflection Total Load: L/240 = [28.5’ x (12”/1’)]/240 = **1.43”>1.03” OK**

<u>Reduced Load Calculations</u>

Factored Load: 1.2(30 PSF) + 1.6(21) = 69.6 PSF

Additional Self Weight of Connecting Beams: 69.6 + 2.96 PSF = 72.6 PSF

Load (PLF): 72.6 PSF x 45.25' (width of Trib. Area) = 3285.2 PLF (3.285 KLF)

Load per Support: (3.285 KLF x 28.5') / 2 Supports = 46.8 kips (at each support)

Bending Moment: $w_u l^2/8$ = (3.285 KLF) x $(28.5')^2/8$ = 333.5 kip-ft.

Maintain 75% for unknown factors: 333.5 + 75% = 416.9 kip-ft.

W 21x55 Max Bending Moment: **473 kip-ft. > 416.9 kip-ft.**

W 18x55 Max Bending Moment: **420 kip-ft. > 416.9 kip-ft.**

Reduced Load Deflection Calculations

W 21x55

Load: 30 PSF + 21 PSF = 51 PSF, 51 PSF x 45.25' = 2307.8 PLF

Deflection: $(5wl^2)$ / (384EI) = 5(2307.8 PLF)$(28.5')^4$(1728 Conversion) / [(384)(29,000,000)(1140)= 1.04"

Max Allowable Deflection Total Load: L/240 = [28.5' x (12"/1')]/240 = **1.43">1.04" OK**

W 18x55

Load: 30 PSF + 21 PSF = 51 PSF, 51 PSF x 45.25' = 2307.8 PLF

Deflection: $(5wl^2)$ / (384EI) = 5(2307.8 PLF)$(28.5')^4$(1728 Conversion) / [(384)(29,000,000)(890)= 1.34"

Max Allowable Deflection Total Load: L/240 = [28.5' x (12"/1')]/240 = **1.43">1.33" OK**

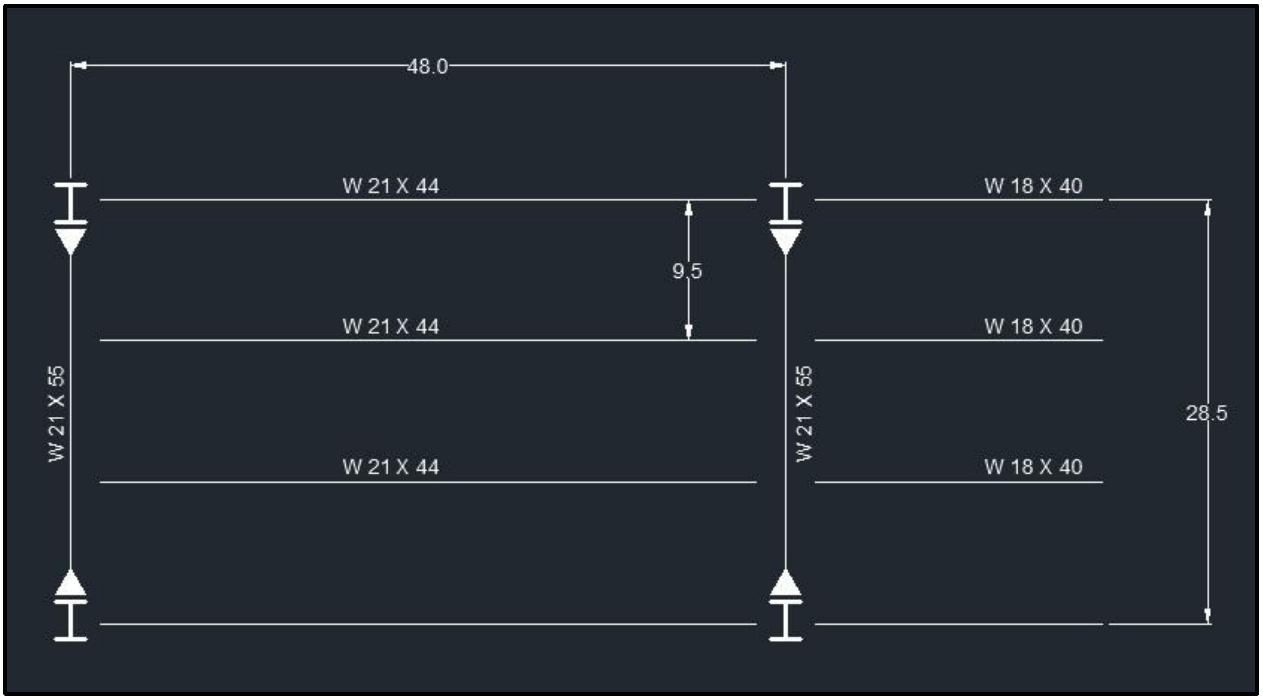


Figure 19: Resized Beams and Girders

Figure 19 shows the reductions able to be made to the structural steel with the deletion of the green roof loads. On average each the beams were able to be reduced by 16%. Upon verification by the structural engineer on the project a reduction of all steel that was originally under green roof area could be reduced by 16% by weight. Removing the green roof would result in the 44% of originally designed roof structure reducing its structural steel member total weight by 16 to 18 tons and saving nearly $50,000.

Optimizing Value Engineering Conclusion

Analyzing and expanding the Value Engineering Process at HD Woodson High School in this analysis yielded three important points. Excluding designated LEED elements from the VE Process poses a risk to improve the building while reducing costs. Removing a green roof can add benefits that outweigh the advantages it provides. Greywater systems and rainwater harvesting are viable ways to reduce water usage and waste. Overall the VE Options discussed throughout Analysis 2 has the ability to save $1,096,000 while not adding any time to the overall project schedule.

VE Option	Cost
Green Roof Deletion	$ 1,072,480
Additional 20,000 gal. tank	**$ 26,000**
Reduced Roof Steel Members	$ 50,000
TOTAL	**$ 1,096,000**

Table 12: Value Engineering Cost Summary

ANALYSIS 3: ALTERNATIVE EXTERIOR WALL ASSEMBLIES

Problem Identification

The exterior enclosure is a major schedule risk to the projects timely completion. The current design for the exterior walls is exterior masonry panels with CMU backing. Issues that come from use of a CMU wall are its duration, weather impacts, cleanliness and ability for changes and acceleration during MEP rough in. The weather is directly related with CMU construction. When the temperatures reach a certain point it must either be completely shut down or costly temporary heat and tents must be used. The process also tends to clutter a site and requires vigilant “house cleaning” efforts. It also makes the MEP rough in cumbersome, especially the in-wall electrical conduits. The path to this topic began with a site visit, during which the masons were laying block and having to lift the blocks over the conduits stubbed up out of the walls.

Research Goal

To develop and chose a more jobsite friendly and efficient exterior enclosure wall assembly, that has potential to accelerate the schedule and eliminate risk of delaying the exterior enclosure construction. The impact of the alternative system must also provide little to no impact to the architecture, while maintaining or improving the material properties and their impact on other building systems.

Analysis 3 Introduction

The analysis of alternative exterior wall assembly options includes comparison of cost, schedule time, thermal properties, through a Mechanical Breadth study, and feasibility. The two alternatives that will be assessed are an innovative product, Metal Stud Crete, and regular metal stud system. Both these options are only being assessed to replace the CMU Back Up portions of the exterior wall. The square footage of this area is 62,050 square feet. After the two systems are analyzed a summary and recommendation will be made.

Original Design - CMU Back Up

The original design documents call for a regular CMU Wall Back Up with the 4" Precast exterior finish on 62,050 square feet of exterior wall at HD Woodson High School. Reasons for proposing to change this element are the schedule risks associated with masonry construction, the need for integrated and simultaneous construction with multiple trades and reduction of on-site congestion.

The project team allowed 90 days for the CMU wall exterior enclosure to be completed. The begin date starting in the center bay was September 23, 2010 and end on November 2, 2010. The North Bay was schedule for October 18, 2010 to December 23, 2010 and the south bay from December 16, 2010 to January 21, 2010. The risk with laying CMU walls during the winter can be great. When the ambient temperature drops below 40 degrees F additional precautions must start to be implemented. More drastic measures are required as the temperature drops lower, starting with simply having to heat the mortar to having to heat the CMU Blocks or even to the need to "tent" the areas under construction. This comes with a large price tag and decreased efficiency.

Laying CMU walls and simultaneously installing conduits and boxes for electrical and other components is not an efficient process. The two crews working together can become frustrated with the other and matching pace with another trade will always require one of the trades to progress slower than typically accepted. This risk of feuding trade contractors, and decreased efficiency make the use of CMU Back Up walls questioned as the best solution.

CMU Construction processes tend to clutter a site and increase the costs of general cleaning and maintenance of an organized safe site. The use of scaffolding can begin to limit safe site and building access. Safety concerns do not allow workers to be near the base of the scaffold limiting the amount of work that can be done in a specific area of the site. The mortar mixing stations along with stockpiles of material require a sizable area. Cutting masonry units creates dust, and tripping hazards raising safety risks and concerns. Broken and cut-off pieces of the CMU blocks also require continuous clean up. Storing of CMU on site also can take up a large area.

An excellent solution to reduce or eliminate all or most of these issues is desirable. This analysis will consider Metal Stud Crete's innovative system and standard stud metal stud wall systems for alternative solutions.

Metal Stud Crete®

Metal Stud Crete System is a structural, composite wall panel system combining regular hard rock concrete, approximately two inches thick, on exterior side, constructed as a composite with standard light-gauge steel framing on the interior. Metal Stud Crete's patented structural, composite shear connector bonds these two to create a load bearing, wall designed to carry floor and roof loads and rapidly enclose a building. For HD Woodson High School the Metal Stud Crete is being proposed as an alternative to the exterior CMU Backup walls. Metal Stud Crete can be prefabricated within 500 miles of any site in the United States. Pricing information was found by contacting Earl Corporation; the company that makes Metal Stud Crete, for the DC Region an average of $ 32 per square foot was given. This price includes Prefabrication, Transportation and Erection. Below, the prefabrication process of the precast panels is shown, photos and typical details, courtesy of Earl Corporation.

Metal stud framing, welded wire fabric and shear connectors laid out on casting beds.

Concrete being poured between stud cavities, leaving stud, (interior) exposed for ease of rough-ins, insulation and gypsum wallboard hanging.

Lifting the Panels out of the Beds to be stacked on the trucks for transportation.

Unloading panels on a site for installation.

Erecting panels to provide exterior enclosure and interior wall framing.

An example of interior view after erection, prior to rough-in and insulation.

Metal Stud Crete and LEED

Metal Stud Crete also qualifies for a number of LEED Credits. They use a large portion of recycled content and regional materials to construct lighter weight pre-cast panels that offer innovation and opportunities to increase building envelope efficiency.

Materials and Resources:

Recycled Content MR 4.0

Regional Materials MR 5.0

Energy & Atmosphere

Steel Stud Cavities allow for variety of insulations

Innovation & Design Process

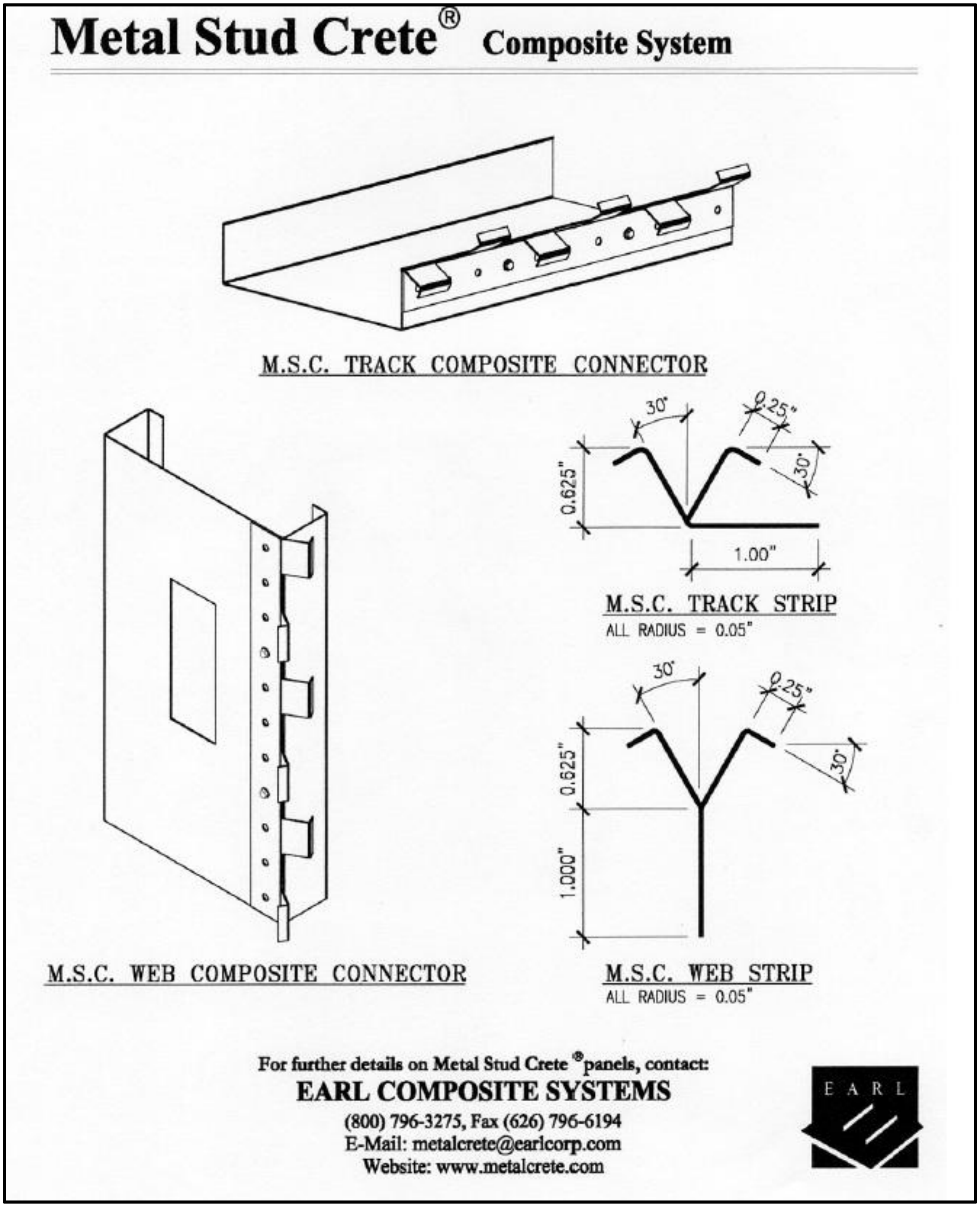
Exceptional Performance

-Resource Conservation (65% concrete and reinforcing steel

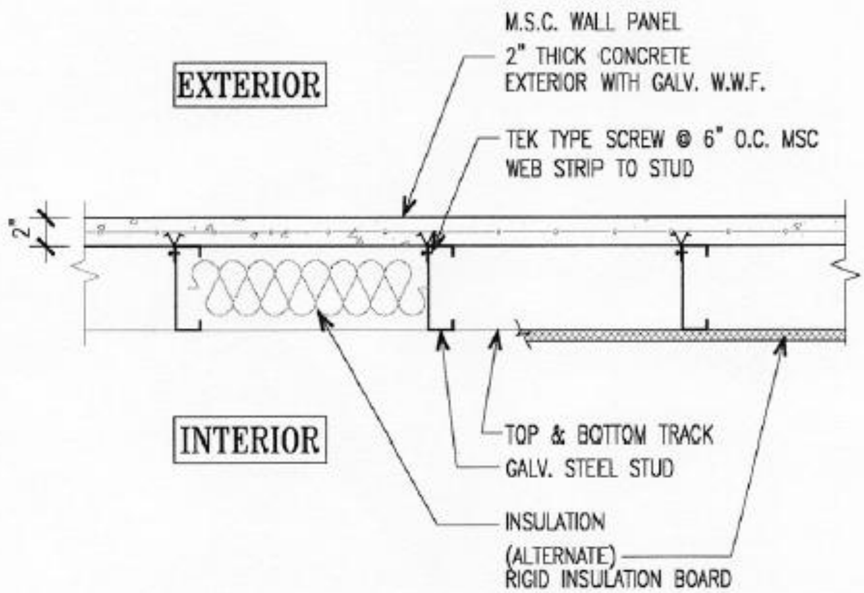
-Conserve resources in Structure (Reduced Dead Load on Foundation)

Typical Metal Stud Crete Details

A number of typical details are provided by Earl Corporation to assist in explaining their product function and design. Two options are shown for attaching the composite connection to the studs, either a face flange is screwed to the stud or a flange is screwed to the slide of the stud. The final design and shop drawings would be done in a collaborative effort with Earl Corporation. The exterior finish would also need to be approved by the architect on the project, a very similar look to the oversized precast can be achieved.


Metal Stud Crete® Composite System
M.S.C. TRACK COMPOSITE CONNECTOR
30°
0.25"
30°
0.625"
1.00"
M.S.C. TRACK STRIP
ALL RADIUS = 0.05"
30°
0.25"
30°
0.625"
1.000"
M.S.C. WEB COMPOSITE CONNECTOR
M.S.C. WEB STRIP
ALL RADIUS = 0.05"
For further details on Metal Stud Crete ®panels, contact:
EARL COMPOSITE SYSTEMS
(800) 796-3275, Fax (626) 796-6194
E-Mail: metalcrete@earlcorp.com
Website: www.metalcrete.com
E A R L

Metal Stud Crete® Composite System



M.S.C. WALL – PLAN VIEW

1" = 1'-0"

For further details on Metal Stud Crete® panels, contact:

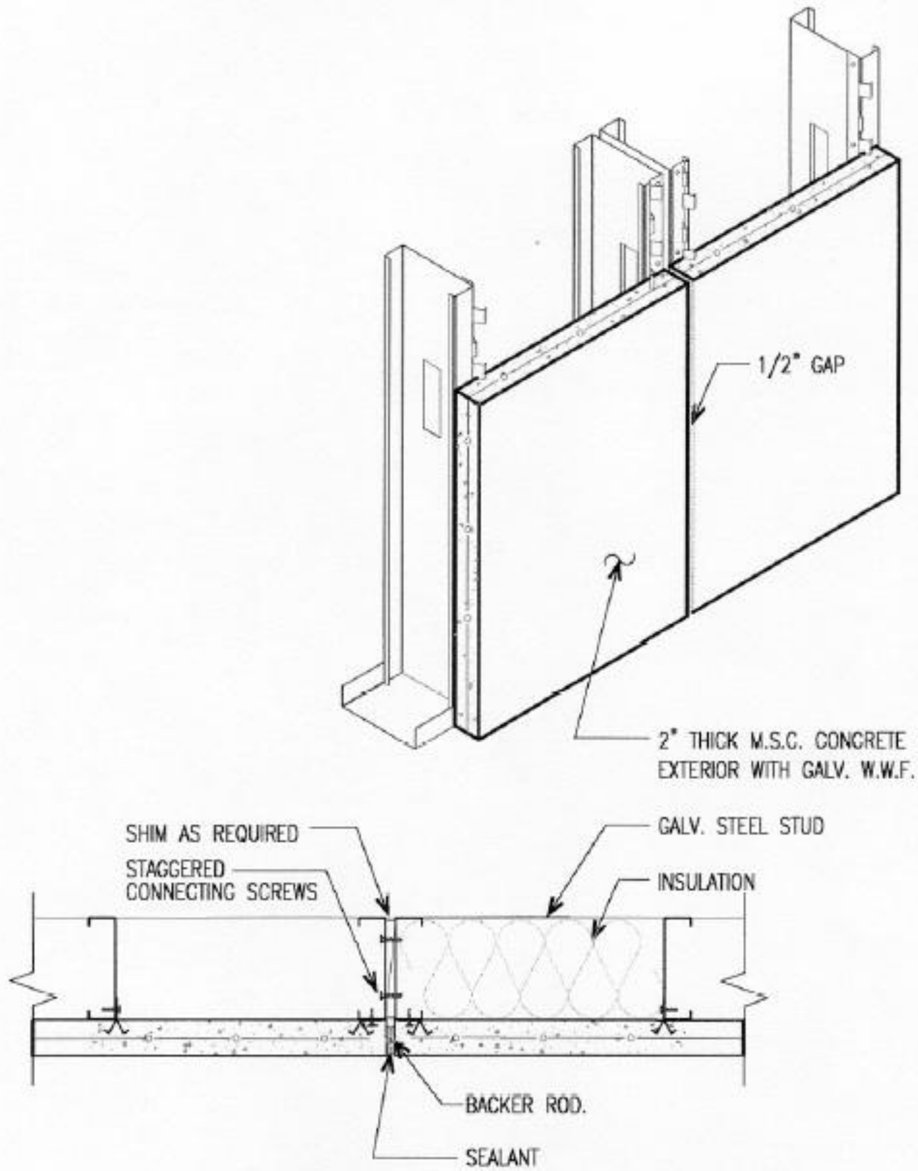
EARL COMPOSITE SYSTEMS

(800) 796-3275, Fax (626) 796-6194

E-Mail: metalcrete@earlcorp.com

Website: www.metalcrete.com

Metal Stud Crete® Composite System



TYPICAL IN-LINE BUTT JOINT

N.T.S.

For further details on Metal Stud Crete® panels, contact:

EARL COMPOSITE SYSTEMS

(800) 796-3275, Fax (626) 796-6194

E-Mail: metalcrete@earlcorp.com

Website: www.metalcrete.com

Schedule and Cost of Metal Stud Crete System

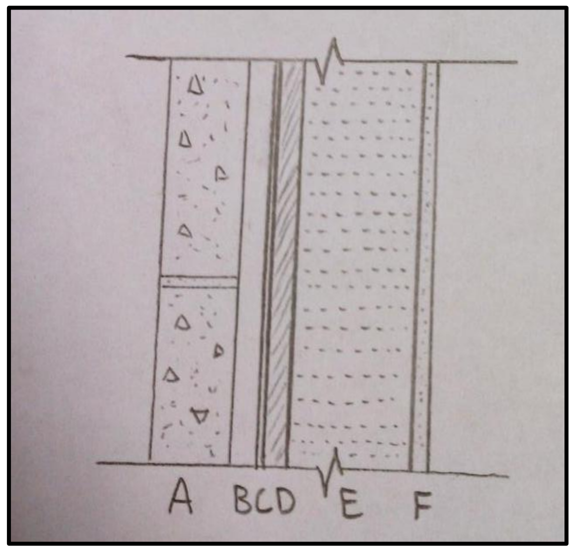
To evaluate the cost of the Metal Stud Crete System, a conversation with a representative of Earl Corporation took place. During the conversation a verbal statement, for the DC Region, on average the panels cost $32 per square foot. This price includes pre-casting of concrete walls at one of their locations within 500 miles of the site, transportation to the site and erection of the panels. The price did not include insulation, so an additional phone conversation with NOVA Spray Foam Insulation, LLC, a DC Metropolitan region spray foam services company was utilized to obtain spray foam information and pricing. And additional $2.40 was added per square foot for open cell foam on the interior, making the total $34.40 per square foot. Total system cost is estimated at $ 2,134,520.

Projected on site erection time for the panels is 17 days. Compared to the original 90 day duration, this product will provide an 80% reduction in this portion of the project. 60 of those original days were on the critical path. There will be an added lead time that can be accounted for that would not exist with the CMU backup system. Besides the direct impact of the affected 62,050 SF of CMU Composite walls other aspects of the building rough-ins and finishes will also be affected. The in-wall electrical rough-in was originally done in conjunction with the masons laying the block. This is a slower process and increases difficulty of CMU Masonry Construction, ultimately making it less efficient.

Regular Metal Stud Back Up

The alternative of using metal stud framing was also identified as a possible option for schedule acceleration and envelope efficiency improvement. An assembly consisting of 25 GA. 6 inch studs, open cell spray foam, 1 inch fiberglass board and the originally designed architectural precast panels. Advantages of using this system include the ability to increase the speed of enclosing the exterior envelope. Flexibility is increased with possibly changes after installation, prior to precast exterior installation. Also the rough in process for other trades, such as electrical will be increased. The ability to allow trades to follow one another will result in an increased efficiency for both trades and avoid potential conflicts that may arise. Coordination prior to the exterior Back Up walls are installed can be shortened for in wall items, as the metal studs allow increased ability for field adjustments after being enclosed.

6" Metal Stud Back Up for 4" Architectural Precast Concrete



Schedule and Cost of Regular Metal Stud Back Up

The estimated cost of the assembly was calculated at $28.00 per square foot, equaling a total of $1,737,400. This cost includes the stud walls, fiberglass board, insulation and precast masonry. It does not include any general conditions costs.

The expected duration for this system will reduce the originally allotted time by 30%. 60 days has been estimated as the duration needed to install this system. The lead times will not be of major concern with this assembly; the materials are typically stocked items at local suppliers.

Alternative Systems Cost Comparisons

Alternative System Cost Comparisons					
	Area (SF)	Assembly $/SF	Estimated Cost	Cost Difference	Duration (days)
CMU Back Up	62050	$ 12.94	$ 802,927	-	90
Metal Stud Crete	62050	$ 34.40	$ 2,134,520	$ 1,331,593	17
Regular Stud Walls	62050	$ 28.00	$ 1,737,400	$ 934,473	60

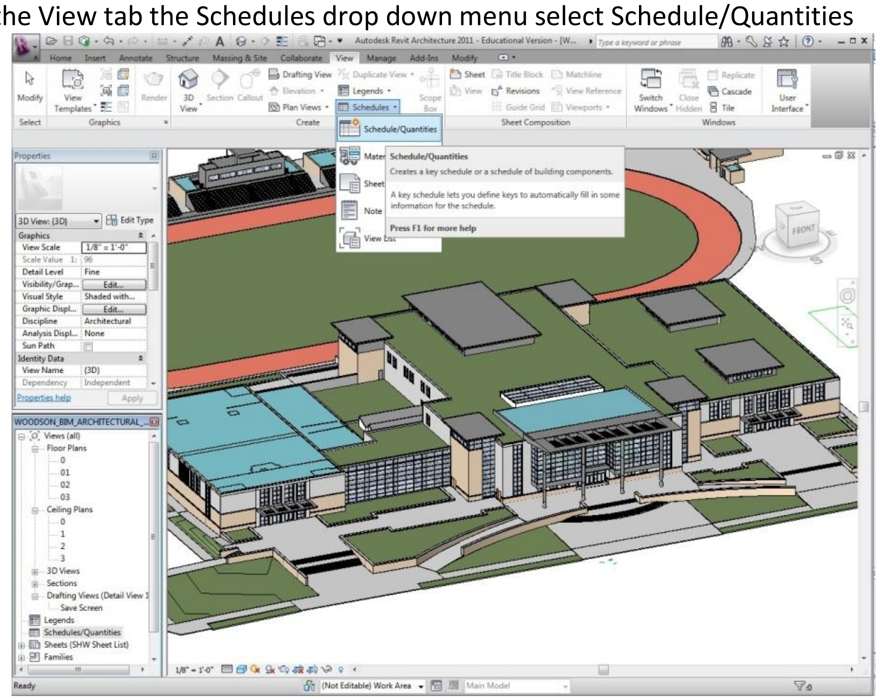
Table 13: Alternative Wall Assemblies Comparison

The originally designed CMU assembly was estimated to be the lowest cost version for the wall assembly itself, but it also has the longest duration. The middle price was $ 1,737,400 with a reduction in schedule time by 30 days. The most expensive assembly is the Metal Stud Crete system that also takes the least amount of time, allowing for the possibility of reducing general conditions cost significantly on the overall project this option begins to be a more realistic figure.

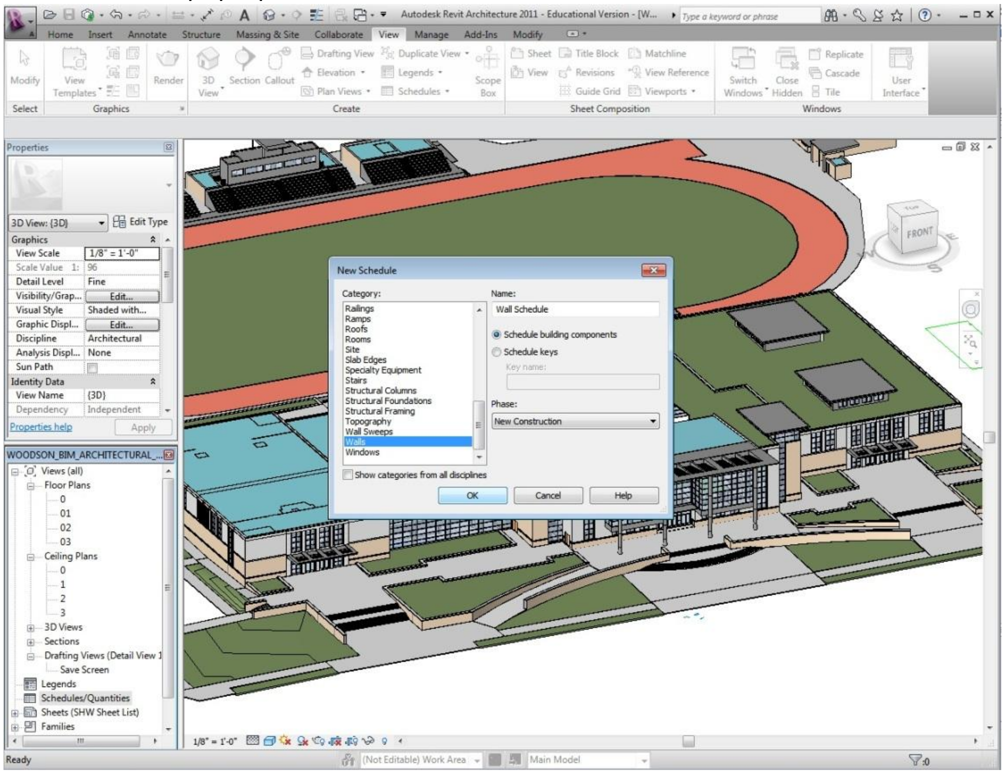
BIM Influence on Analysis 3 Alternative Exterior Wall Systems

The effective uses of BIM used to assist in analysis three are Electronic Quantity Takeoff for estimating using Revit Architectural Model and Revit MEP to analyze alternative wall assemblies could effect on the mechanical systems. Screen shots and descriptions of how the exact CMU exterior composite walls are below. By using the Revit model to calculate electronically the exterior CMU walls many hours of hand takeoffs and calculations were avoided. The ability to quickly have an accurate square footage for estimating allows more time to be focused on selecting viable options and creative problem solving.

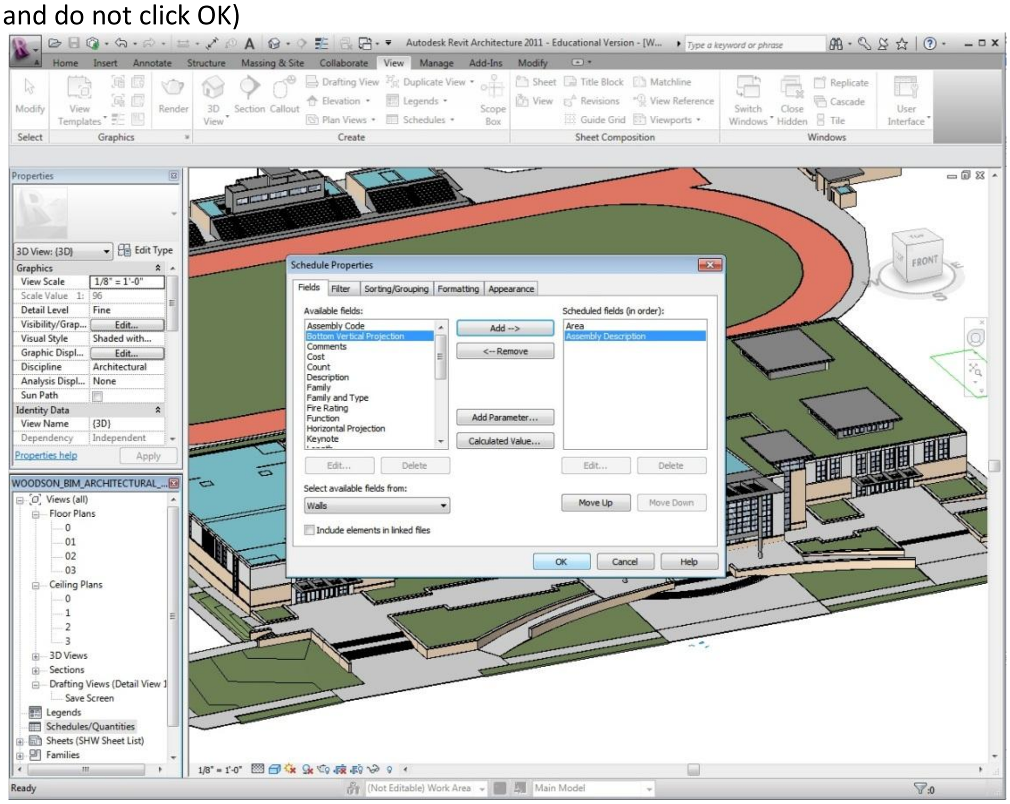
<u>Step 1:</u> Under the View tab the Schedules drop down menu select Schedule/Quantities



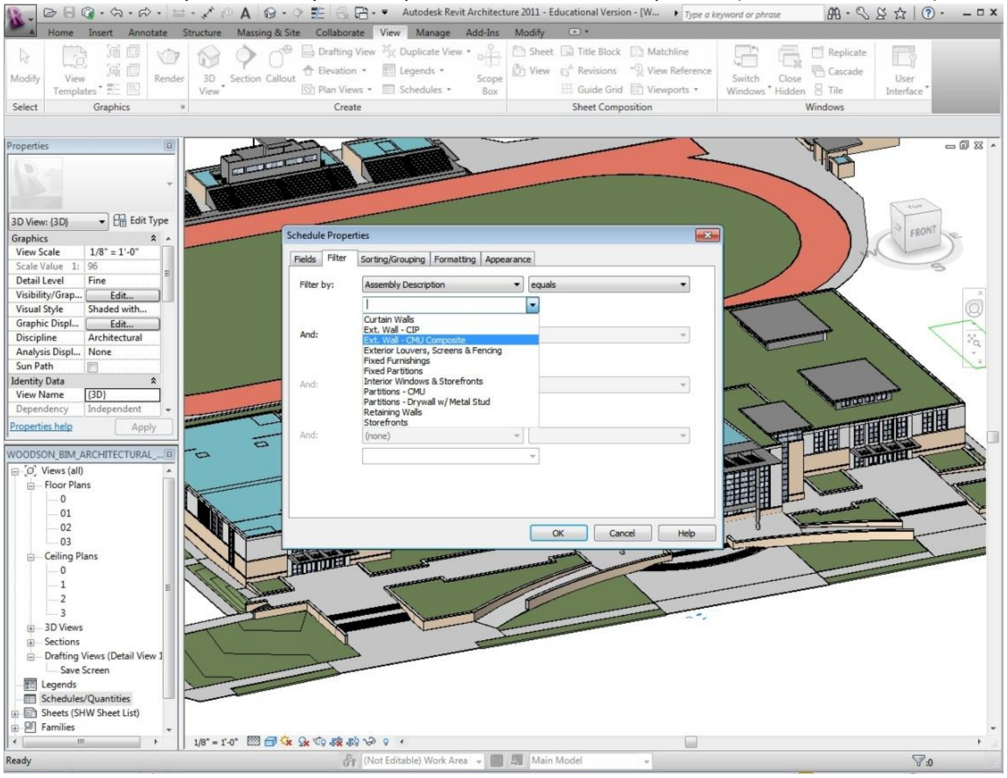
Step 2: On New Schedule pop-up select Walls in left hand menu and Click OK



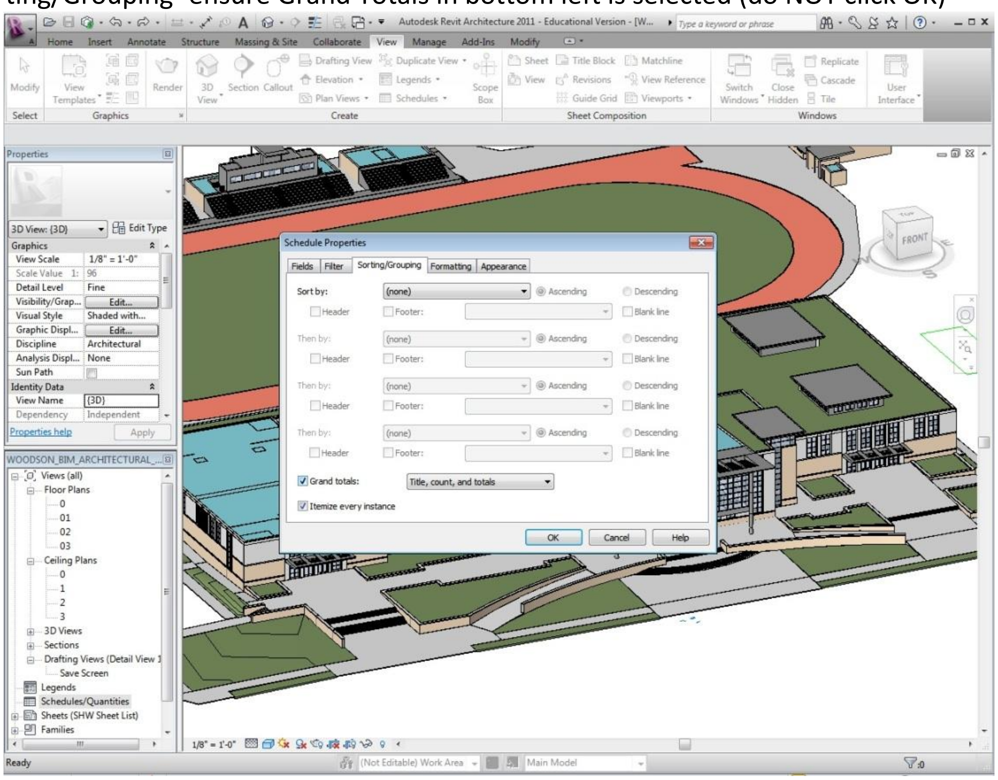
Step 3: Schedule Properties window- Fields Tab- Select, Assembly Description (click Add), Select Area, (click add and do not click OK)



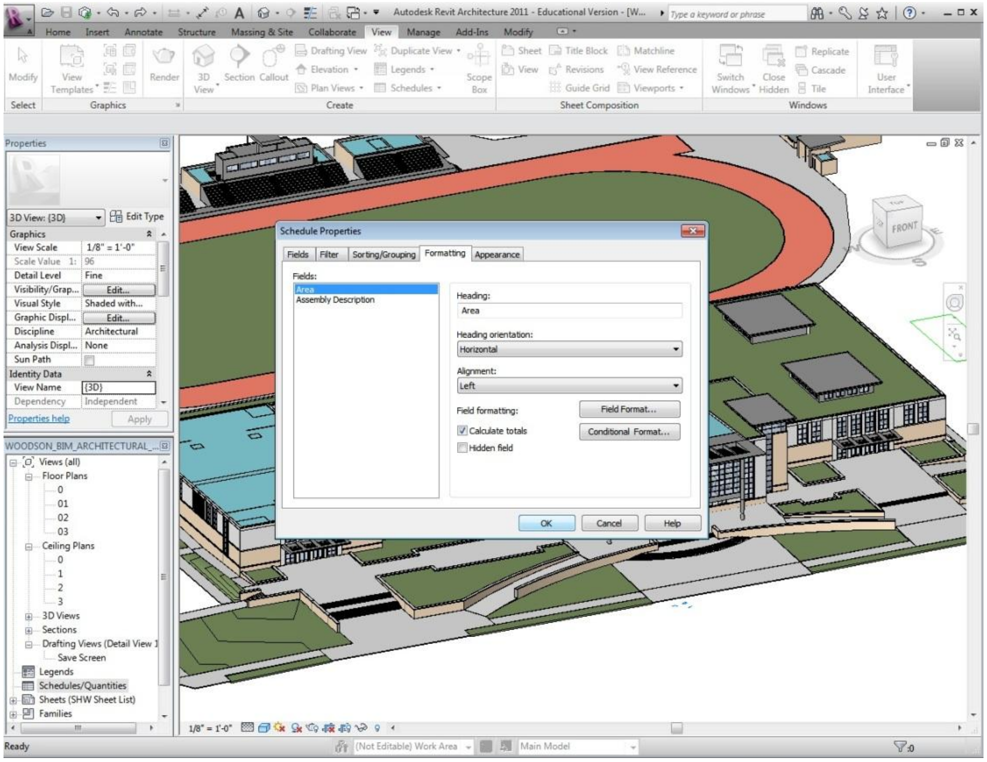
Step 4: Filter Tab- Filter by: Assembly Description- Ext. CMU Composite (do NOT click OK)



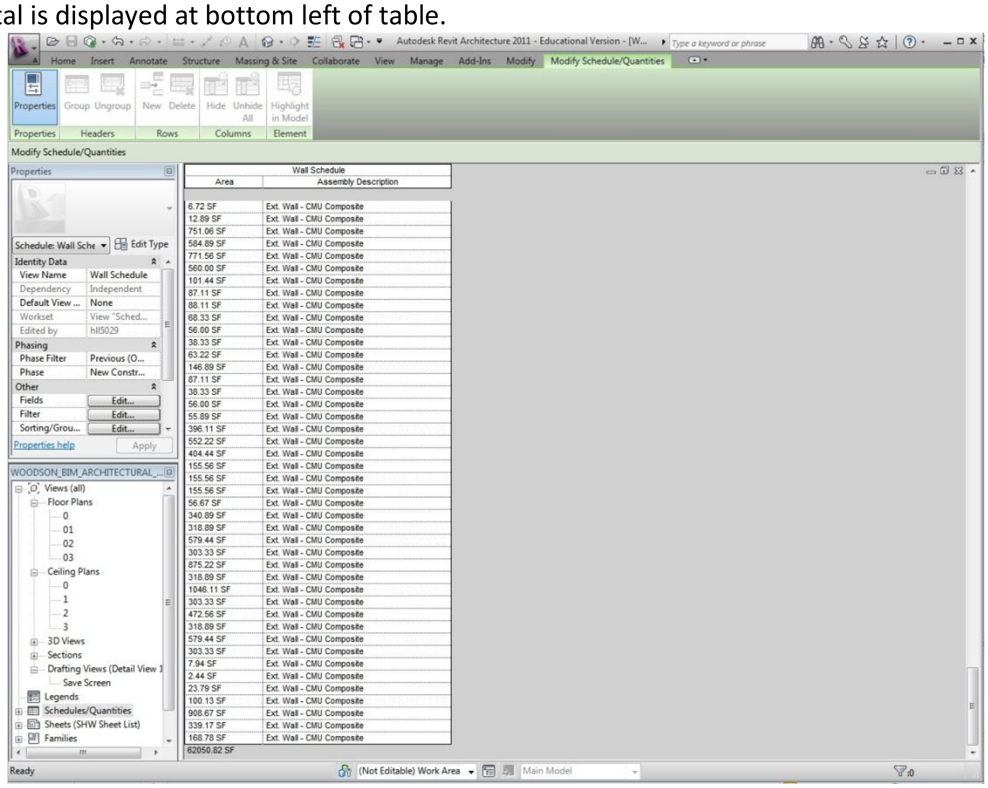
Step 5: Sorting/Grouping- ensure Grand Totals in bottom left is selected (do NOT click OK)



Step 6: Formatting Tab- Select Area on Left, check Calculate Totals, click OK

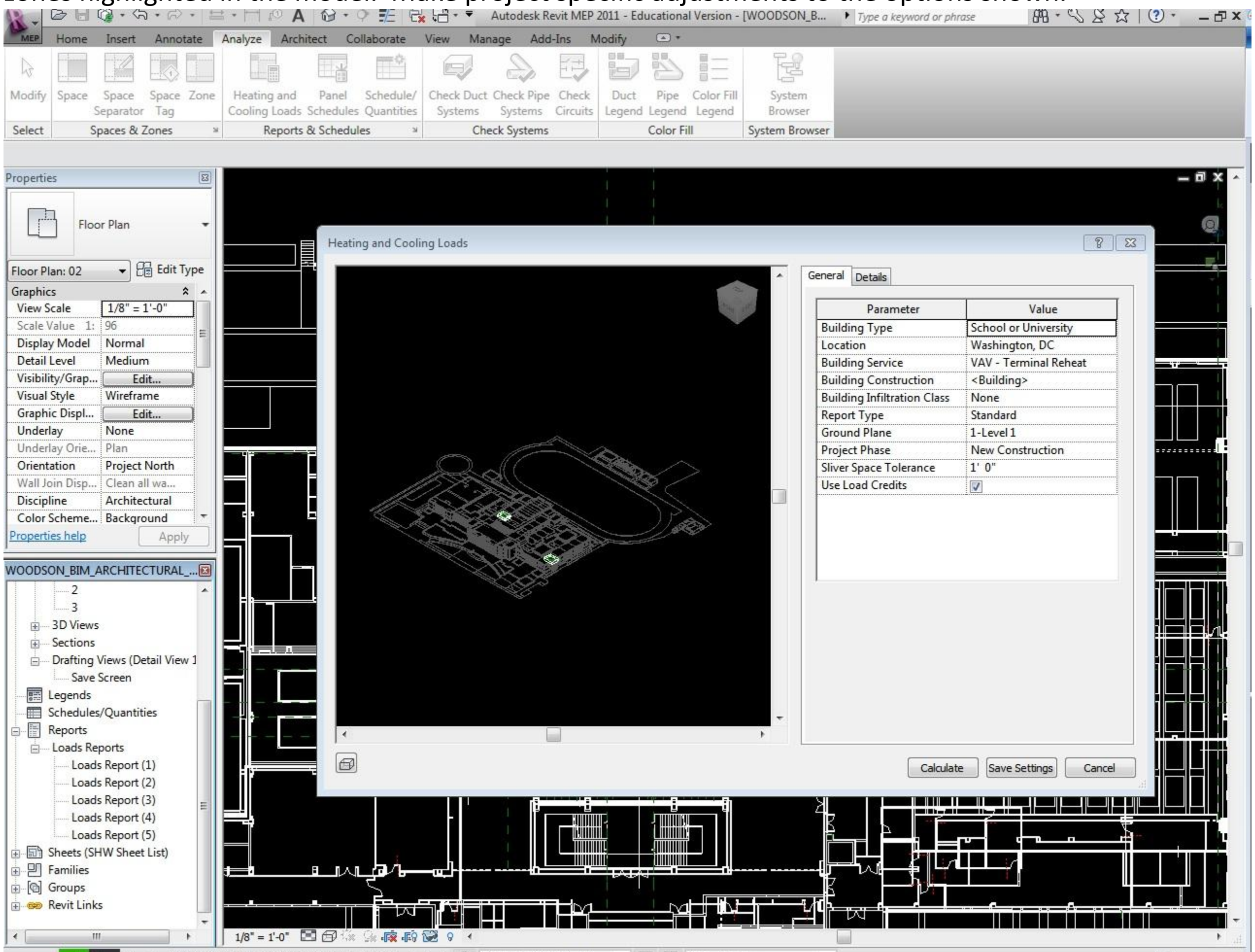


Step 7: Total is displayed at bottom left of table.

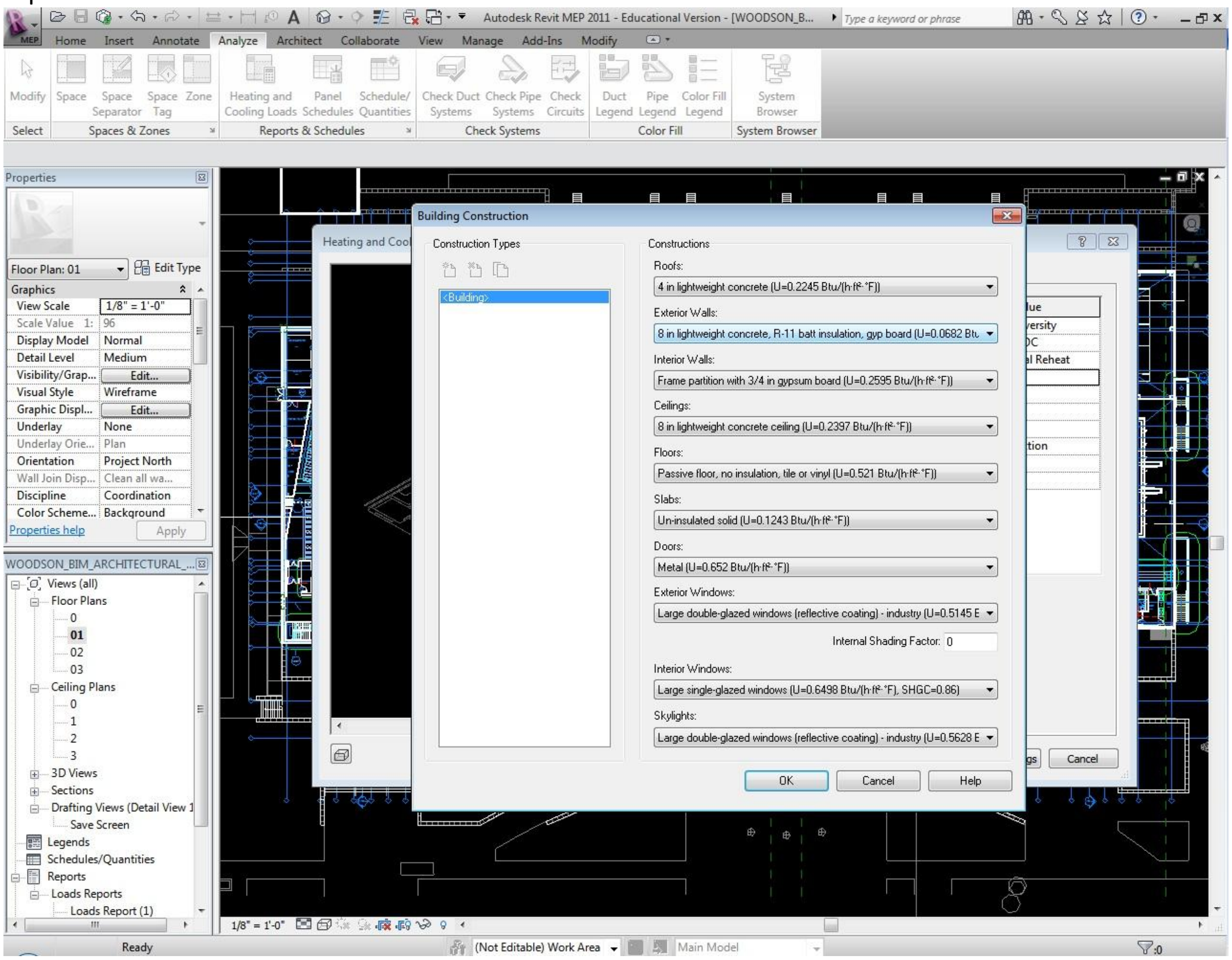


Building Information Modeling also was essential in the Mechanical Breadth Study. By opening the Revit Architectural Model in Revit MEP the loads in selected spaces were analyzed to determine the effects on the Mechanical System Load when changing the exterior wall construction type. Below is a simplified process that was used for each wall type to allow comparison.

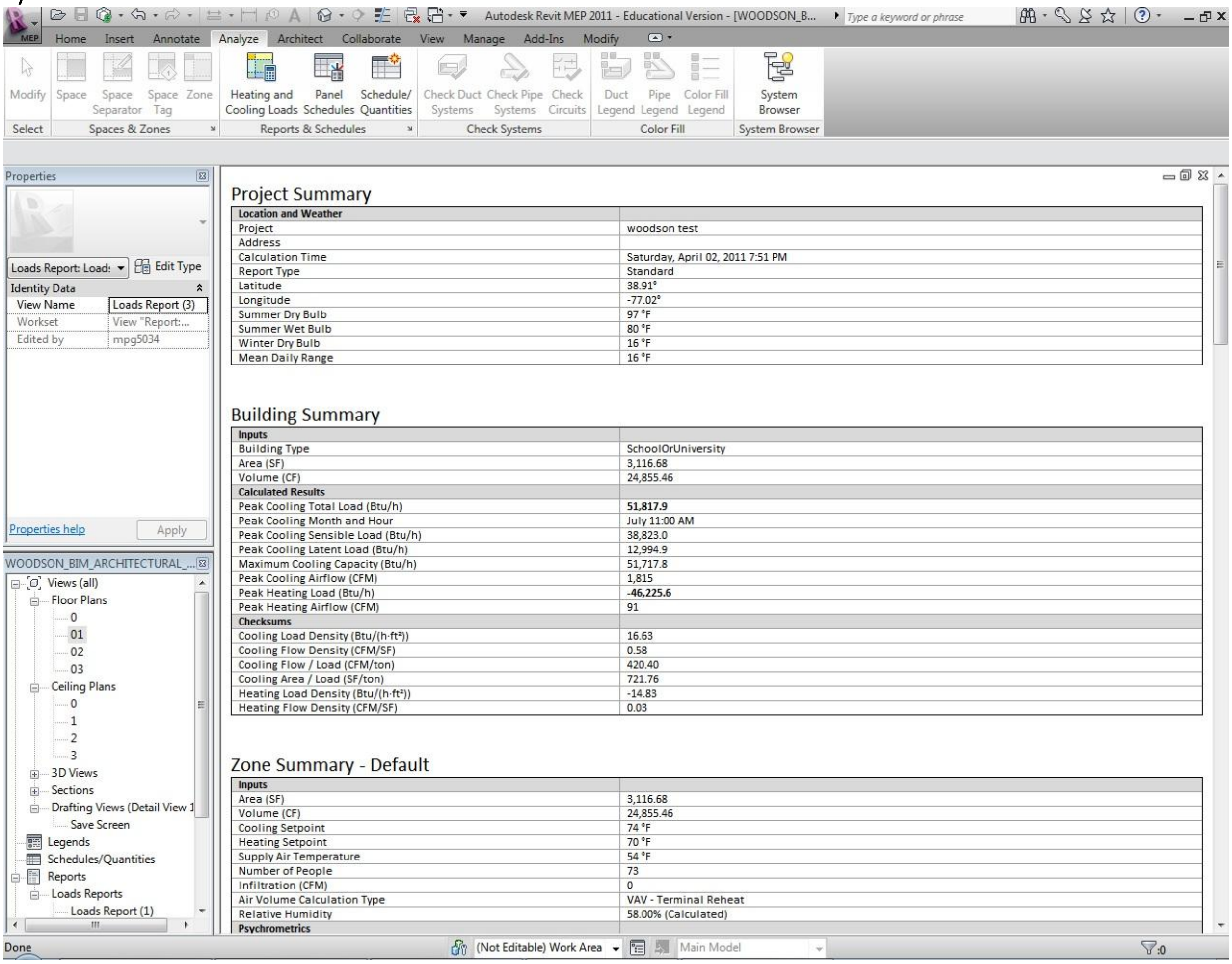
Step 1: After defining the Zones to be calculated on the floor plans, select the Analyze Tab. Under the Analyze tab Select Heating and Cooling Loads. The Window shown below will appear with the two zones highlighted in the model. Make project specific adjustments to the options shown.



<u>Step2:</u> Under the Building Construction Label options select the small box to the right to further define specific system components; this is where the wall types will be changed for each report. In this case the Exterior Walls is what is changed. The exact description is not always an option, so the nearest U value is used for analysis. Select OK when finished defining parameters and select Calculate to generate report.



Step 3: The Report Summary will appear. At the Bottom of the page the Zones are summarized and specific contributions to the loads are calculated. By repeating this process with the three different exterior wall types a comparison will be able to be made to determine the effects on the mechanical system.



Thermal Property Considerations – Mechanical Breadth

In order to demonstrate mechanical breath a comparison of wall assembly effects on the building mechanical system loads was calculated. The R and U values were calculated for the original CMU walls and the two alternatives. The U value was then used to determine the Q (BTU/hr) through the wall assemblies. This value will then be used to calculate the potential impact on the Mechanical System load using BIM in the form of Revit MEP. Refer to BIM Influences on Analysis 3 for the detail on how the loads were determined for comparison.

The original system has 2" of closed cell spray foam on the exterior of the CMU wall, between the precast and CMU. The other two assemblies have been selected using open cell spray foam on the interior side between the stud cavities. Open cell and closed cell spray foams have a few differences that are important to know when deciding the location in the assembly and application desired. They both provide very good air sealing and low air infiltration compared to fiberglass batt and cellulose insulation. The reason for selecting the open cell for the alternative systems is the exposure factors and the cost. The closed cell is overkill for the space and the insulation will be well protected in both alternatives. Closed cell can also add a slight increase in wall strength.

Open Cell vs. Closed Cell Spray Foam		
	Open Cell	**Closed Cell**
Cost per Board Foot (1"x12"x12")	$ 0.60	$ 1.50
R-Value per inch	**3.5**	**6.0**
Typical Exposure/Durability	Softer feeling and weaker, air fills voids in tiny cells that aren't completely closed (Usually towards interior side of assembly for protection)	Gas filled tiny cells are able to resist water vapor and moisture infiltration (Can be applied closer to exterior or below grade, and roofing application)
Density	Medium (1.75 - 2.25 lbs/ft^3)	Low (0.4 - 1.2 lbs/ft^3)

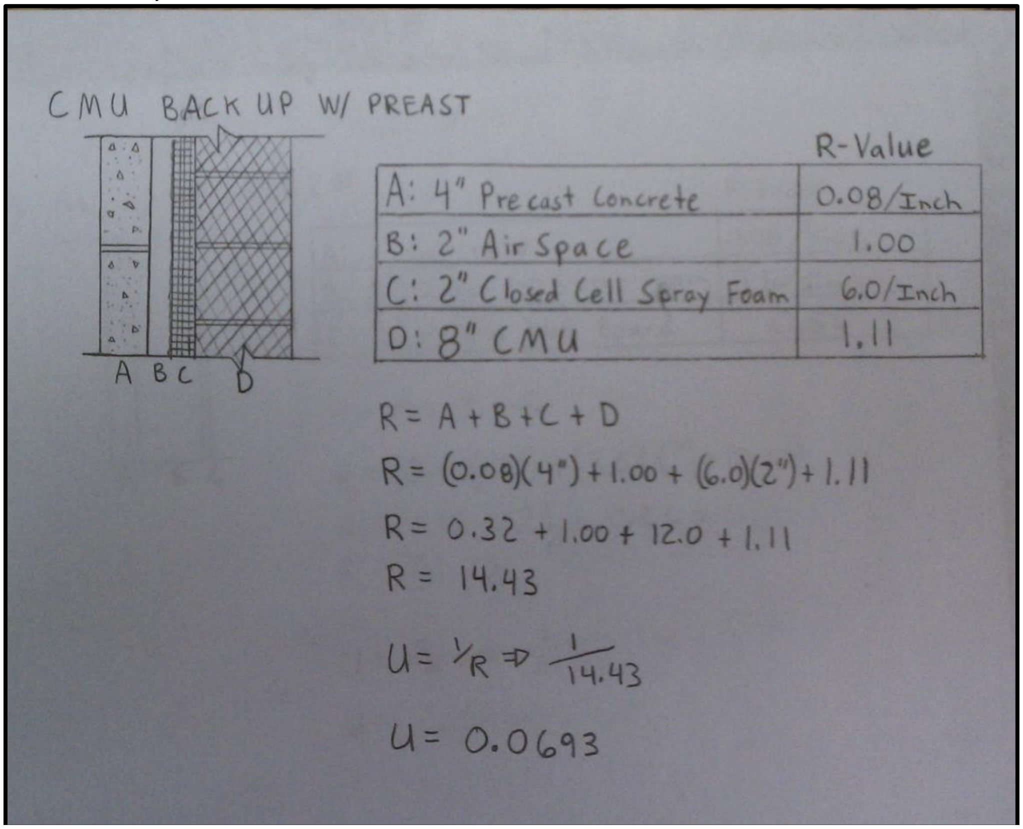
Table 14: Open Cell vs. Closed Cell Spray Foam

The R and U value are the basis of comparison for the mechanical breadth. These calculations were done by hand and the results are summarized below as well as the individual calculations.

Wall Assembly Options R and U Values		
	R	U
Original CMU	14.43	0.0693
Metal Stud Crete	21.72	0.04604
Metal Stud Framing	26.88	0.0372

Table 15: R and U value Comparisons

Original CMU Assembly



CMU BACK UP W/ PREAST

	R-Value
A: 4" Precast Concrete	0.08/Inch
B: 2" Air Space	1.00
C: 2" Closed Cell Spray Foam	6.0/Inch
D: 8" CMU	1.11

$R = A + B + C + D$

$R = (0.08)(4") + 1.00 + (6.0)(2") + 1.11$

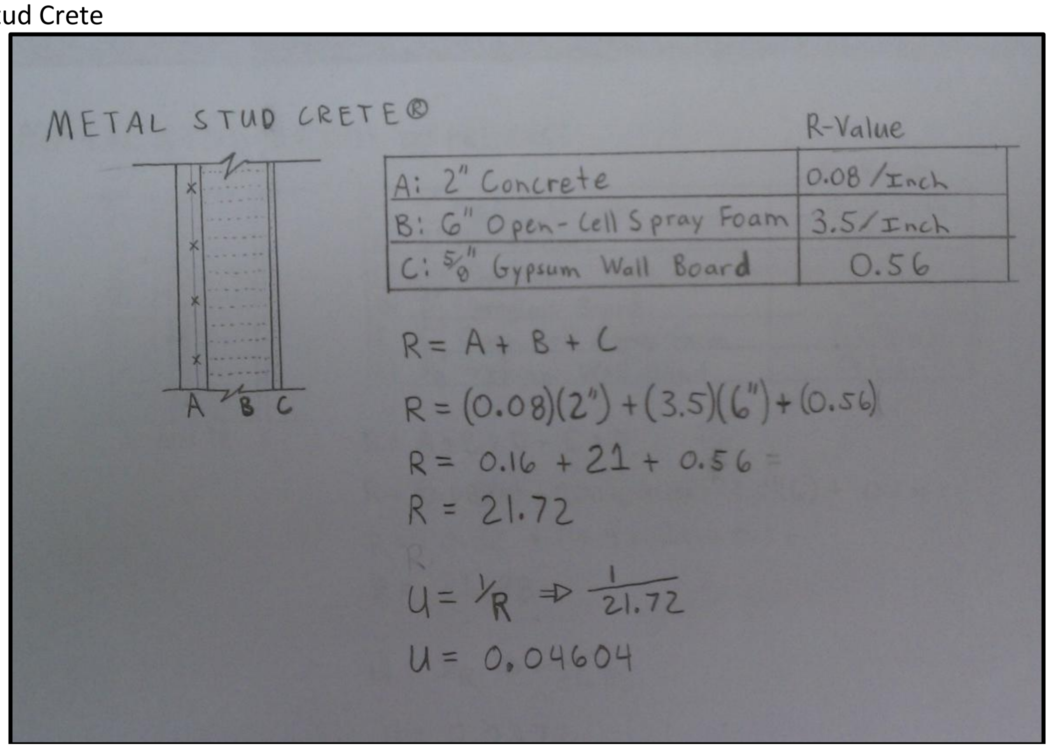
$R = 0.32 + 1.00 + 12.0 + 1.11$

$R = 14.43$

$U = 1/R \Rightarrow \frac{1}{14.43}$

$U = 0.0693$

Metal Stud Crete



METAL STUD CRETE®

	R-Value
A: 2" Concrete	0.08 /Inch
B: 6" Open-Cell Spray Foam	3.5/Inch
C: 5/8" Gypsum Wall Board	0.56

$R = A + B + C$

$R = (0.08)(2") + (3.5)(6") + (0.56)$

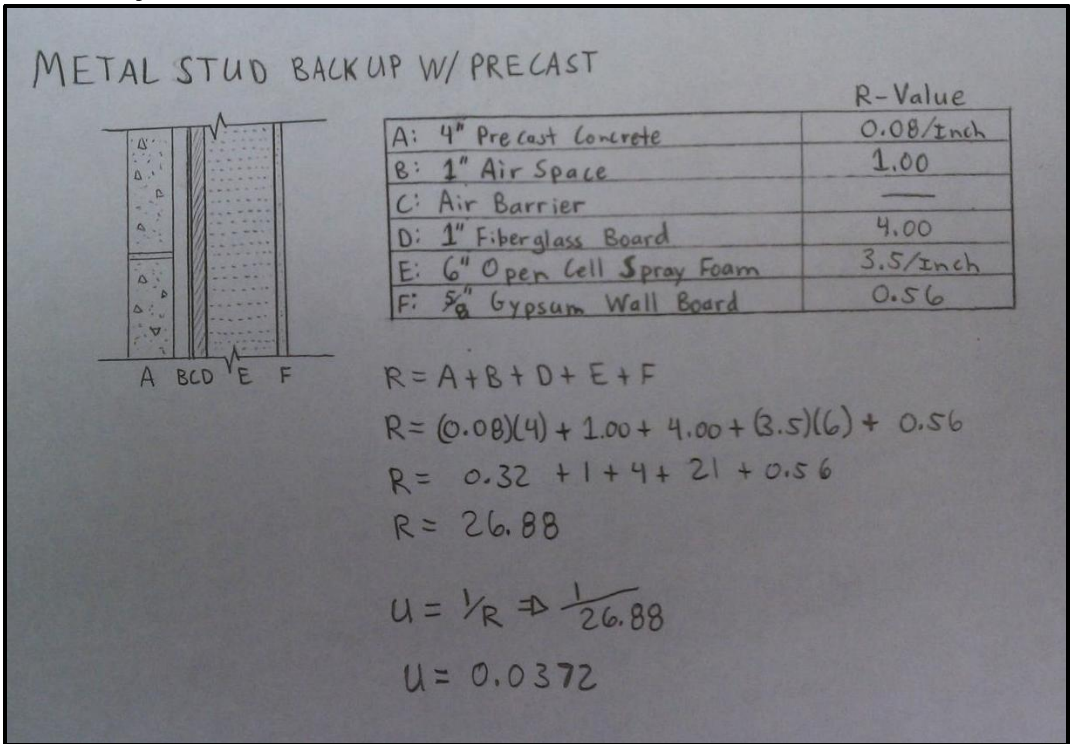
$R = 0.16 + 21 + 0.56$

$R = 21.72$

$U = 1/R \Rightarrow \frac{1}{21.72}$

$U = 0.04604$

Metal Stud Framing



Heating and Cooling Loads Comparison

The two alternate systems proposed for exterior wall assemblies reduce the load on the mechanical system. The load contributed by the exterior walls is reduced. This load differential is not a significant change and will not add cost of upgrading the mechanical system; however it is recommended that the Mechanical Engineer be consulted for potential downsizing and verification upon alternative wall assembly selection. The three walls are compared in Table 16 and Table 17.

Space 1 - Heating and Cooling Load Comparisons						
	Cooling			Heating		
	Loads BTU/hr	% of Total	Cooling Savings	Loads BTU/hr	% of Total	Heat Savings
Original CMU Back Up	19	0.14%		36.6	0.26%	
Metal Stud Crete	12.5	0.09%	6.5	24.6	0.17%	12
Metal Stud Back Up	10.3	0.08%	8.7	20.3	0.14%	16.3

Table 16: Space 1 Load Comparisons

Space 2 - Heating and Cooling Load Comparisons						
	Cooling			Heating		
	Loads BTU/hr	% of Total	Cooling Savings	Loads BTU/hr	% of Total	Heat Savings
Original CMU Back Up	22.4	0.14%		48.8	0.29%	
Metal Stud Crete	11.8	0.07%	10.6	32.7	0.19%	16.1
Metal Stud Back Up	9.8	0.06%	12.6	27.1	0.16%	21.7

Table 17: Space 2 Load Comparisons

Overall the exterior wall enclosure accounts for less than 1% of the space load. 90% of the space loads are contributed by the Occupants, Lighting and Power (computers). However comparisons of the exterior walls are still advantageous. Table 18 shows the Zone Summary for Space 1, a third floor classroom with exterior wall exposure to the South. The total cooling load (BTU/hour) is 19 or 0.14% and heating load (BTU/hour) is 36.6, 0.26%. This report is for the CMU Back Up walls or the basis on which the alternate system would need to improve upon. The other space summaries can be found in Appendix D.

Original CMU Assembly- Space 1 (3rd floor class Room Exterior Wall facing South)				
Components	Cooling		Heating	
	Loads (Btu/h)	Percentage of Total	Loads (Btu/h)	Percentage of Total
Wall	19	0.14%	36.6	0.26%
Window	1,075.50	7.92%	1,261.10	8.92%
Door	0	0.00%	0	0.00%
Roof	208.7	1.54%	560.2	3.96%
Skylight	0	0.00%	0	0.00%
Partition	0	0.00%	0	0.00%
Infiltration	0	0.00%	0	0.00%
Lighting	2,504.10	18.43%	-2,504.10	-17.71%
Power	3,130.10	23.04%	-3,130.10	-22.14%
People	6,646.10	48.93%	-6,646.10	-47.01%
Plenum	0	0.00%		
Total	**13,583.50**	**100%**	**-10,422.30**	**100%**

Table 18: Typical Heating and Cooling Load Summary by Zone

CMU vs. Metal Stud Electrical Rough In

An important aspect of changing wall types to consider is the electrical in-wall rough-in. There are many differences in the rough-in process to analyze. The CMU rough-in process is more time consuming and more expensive for both material and labor. In order to rough-in CMU walls EMT conduit must be used. Typical when EMT is used 10' sections are able to be installed, however; when used in CMU walls 3' sections are installed, in the vertical direction, as an assembly working in conjunction with the masons. Wires would then also have to be pulled through the conduits as well. When discussing this topic with the electrical sub-contractor labor and costs were discussed, based on a 10' section with a single device. The cost of devices will not vary but the CMU assembly is significantly longer time and at a higher cost. The labor rate for rough in is very contingent on the Masons as well. The comparison below shows best case scenario for rough-in.

Metal Stud walls and the specifications at HD Woodson HS allow for the use of MC Cable. MC Cable is a flexible metal conduit with wire already in it. The process is much simpler and allows for a faster rough-in. The cable can be pulled in many directions and snake through much easier, with supports every 4'. Both assembly comparisons include the boxes and box supports. The possibility to save $ 8.50 per 10' device and rough-in assembly and a labor saving of half an hour exists.

Electrical Rough-in CMU vs. Metal Studs		
	CMU Walls (EMT + Wire)	Metal Studs (MC Cable)
Material Assembly (10' section)	$ 16.50	$ 8.00
Labor	1.5 hours (best case)	1 hour

Table 19: Electrical Rough-in Comparison

Alternative Exterior Wall Assemblies Conclusion

By establishing the baseline characteristics and properties of the originally design CMU Back Up exterior wall assemblies and developing two alternatives to eliminate risks and improve the over quality of the project a viable solution was found. The Metal Stud Crete is recommended to replace the CMU Back Up assembly.

The Metal Stud Crete, while being the most expensive of the three options discussed it also provides the best solutions to eliminate schedule risk and site congestion. The improvement in the thermal envelope are also notable, though the existing design was very good system to compare to. The ability to have all on site construction completed for the exterior walls in less than 20 days, with the exception of caulk joints, saves on general conditions and reduced safety risk. The added benefit of rough in of MEP systems through metal stud walls is also a huge benefit.

Using BIM assisted in developing these alternatives, by providing valuable data and calculations in a very short period of time. The ability to do quantity takeoffs and mechanical system load analysis allowed for better and faster decision making on alternative designs that add value to projects.

ANALYSIS 4: ALTERNATIVE STEEL TRUSS CONSTRUCTION

Problem Identification

Transportation of specialized construction materials can be a difficult and arduous task. The transportation of steel trusses, for the gymnasium at HD Woodson High School, became extremely challenging. Multiple trusses over 100 feet long had to be transported from Delmar Delaware to NE Washington DC, roughly 112 miles, with police escorts and at great stress and expense to the project team. This topic was derived from a conversation with the project team about the truss transportation.

Research Goal

The goal of this analysis will be to analyze the feasibility of splicing the trusses to allow easier transportation and risk savings. Determine if it is possible to reduce the transportation risk by suggesting the truss be spliced to reduce overall shipping length. While erection time and site assembly may increase, the time needed to carefully plan and expense of shipping can be greatly reduced.

Analysis 4 Introduction

To develop Analysis four the feasibility and splice locations will be discussed as well as difference in transportation concerns. The most important aspect for determining feasibility will be the erection and on site assembly for the truss. A plan will need to be developed to assist in space coordination and laydown area to assemble and erect the truss on site. Schedule impacts will also be discussed.

Single Piece Truss Discussion

There are a number of advantages and dis advantages to transporting and erecting the truss in a single piece. Advantages include single truck for each truss, single pick to erect truss, on site labor and construction is minimized for steel fabrication, low residual stress risk. Disadvantages are the length makes transportation more challenging and at a higher cost due to special load requirements, restrictions and escorts. The risk associated with the transportation of a steel member this large is also very high. A viable solution would reduce these risks while maintaining the advantages.

The single member allows for the minimum schedule time and risk to the steel erection sequence. The trusses are supporting two floors above the gymnasium that are supported by the trusses. The location of two columns, on one of trusses is potentially an issue with splicing the truss together in the field. One of the single piece trusses, T-5, is shown in Figure 20. The location of the columns supported of one of the trusses is shown in Figure 22. There are two different trusses the T-4 and T-5, the differences are mostly in the length, for this analysis, the principles should still apply.

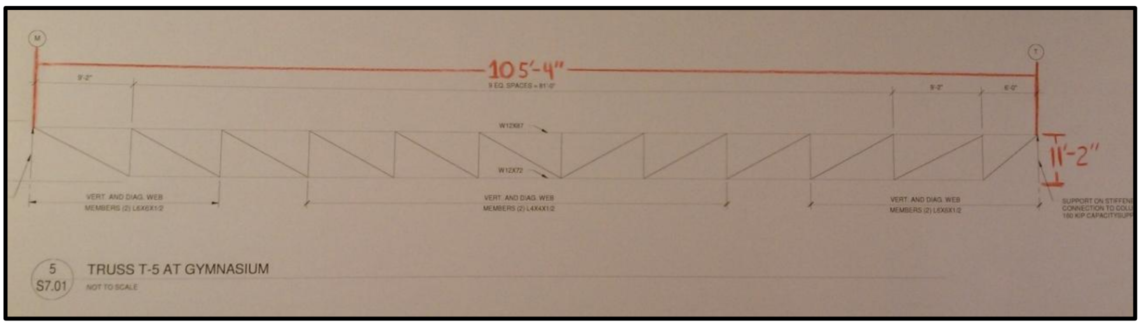


Figure 20: Truss T-5

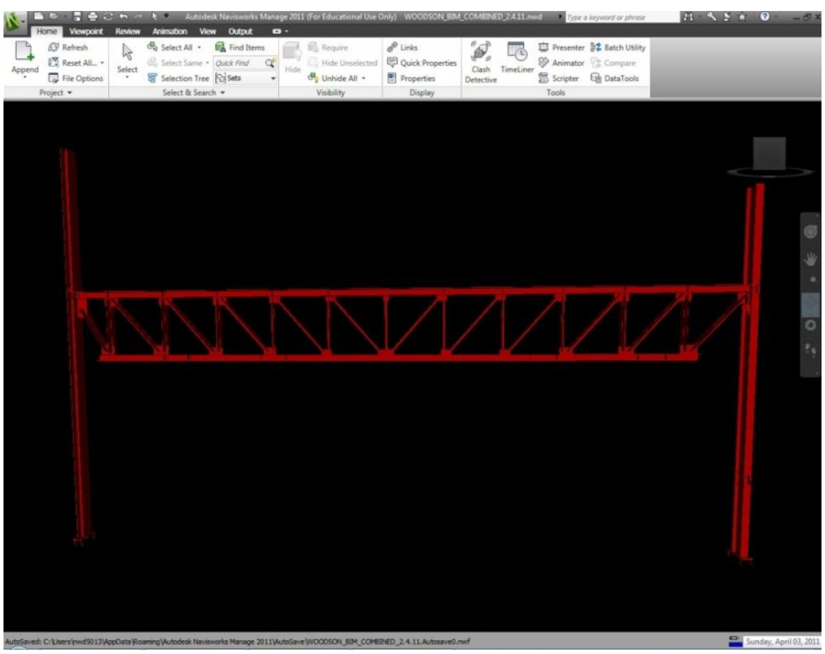


Figure 21: Truss T-5 in Navisworks Fully Coordinated Model (Courtesy HESS Construction + Engineering Services)

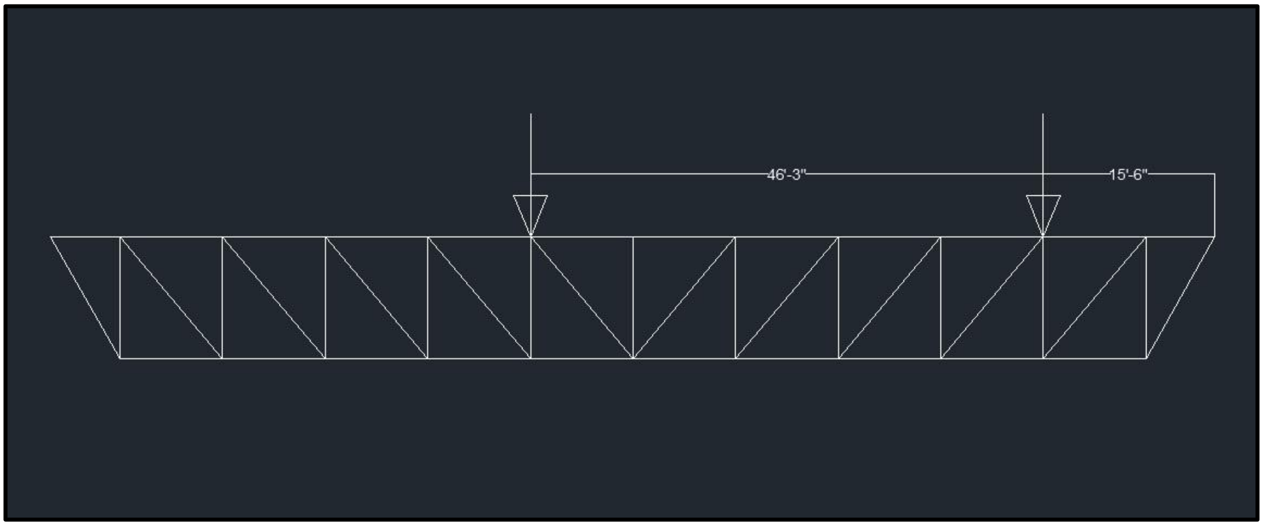


Figure 22: Single truss with Column Locations Indicated by Arrows

Spliced Truss Options Discussion

In order to splice the truss in an appropriate location and ensure proper design the structural engineer would have to be consulted. The following discussion would only apply if the design was approved by the proper engineer.

Through a consultation with a fellow AE Structural option student, the suggested locations found in Figure 23. The web members of the truss are welded L Sections or W Section members, and the welds indicate moment resistance in the Webs. The moment is the lowest crossing through the center of the web members. This is why the truss is suggested to be spliced at the locations indicated. An increase in Web member may be necessary as well as a stiffener plate to transfer the moment. The maximum distance away from the joint is also desired to make the strongest joint possible.

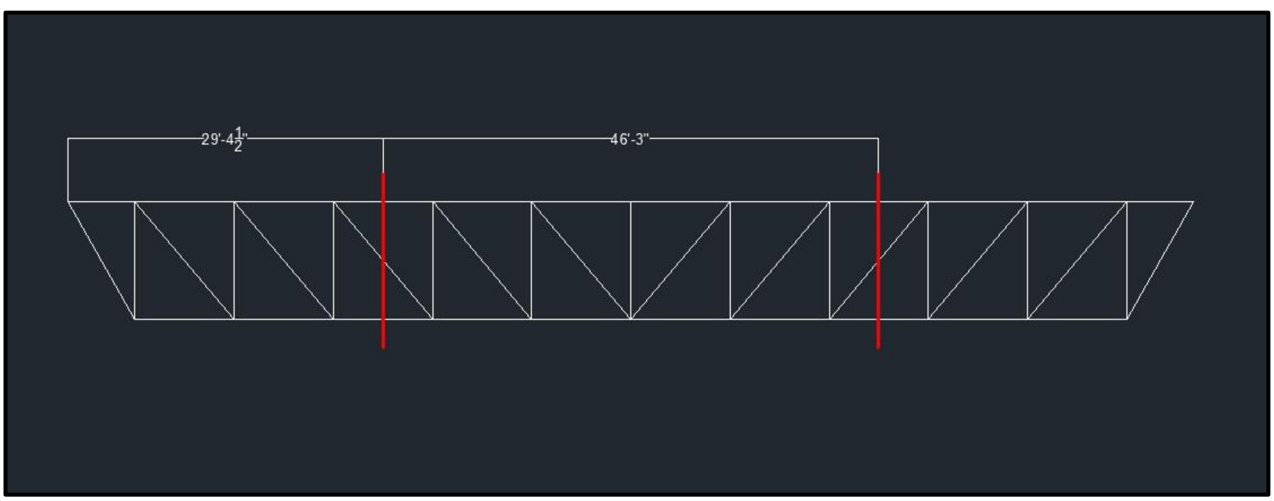


Figure 23: Suggested Splice Locations

Transportation

The costs for transportation are typically priced by ton per mile. The loads even when spliced would still be considered an unusual load and prices can typically range from $ 105 to $ 150 a ton per mile. If police escorts are required costs could reach up to $ 175 a ton per mile. The best case scenario would allow shipping to still use the same number of loads as there are trusses and reduce overall length to eliminate police escorts. The main points to consider when determining the transportation of the trusses will be the length, overhang, weight, width and height. Each state has different rules, regulations and permit requirements.

Delaware Regulations

Legal Loads

Length	60' (53' trailer)
Overhang	3' front, 5' rear
Weight	80,000 lbs. (20,000 per axle)
Width	8'-6"
Height	Not Specified

Routine Transport Permits (Typical 5 day permit for $10)

Length up to 100'

Overhang over 5'

Weight GVW up to 120,000 lbs.

Width up to 14'

Height up to 15'

Escort Vehicle Requirements

Width over 12' requires 1, over 14' requires 2, over 15' requires Police escort

Length Over 100' requires 1 car, over 110' requires 2 cars, over 120' requires Police Escort

Height not required unless permit requires

Restrictions

Travel allowed from Sunrise to Sunset

Maryland Regulations

Legal Loads

Length	65' (48' trailer, 53' allowed only on Interstate)
Overhang	3' front, 6' rear
Weight	80,000 lbs. (20,000 per axle)
Width	8' on non-Highway, 8'-6" on Highway
Height	13'-6"

Routine Transport Permits (Typical 5 day permit for $30)

Length up to 120'

Weight GVW up to 110,000 lbs.

Width up to 16’
Height up to 16’

Escort Vehicle Requirements
Width over 13’ requires 1, over 14’ requires 2
Length over 120’ requires 1 car
Height over 16’
Weight over 110,000 lbs.

Restrictions
Travel allowed Monday thru Friday 1/2 hour prior to sunrise and ½ hour after sunset, until noon on Saturday. If over 12’ width, travel can only occur from 9 to noon on Saturday.

Washington, D.C. Regulations

Legal Loads

Length	40’ (other than a bus, or combined length over 55’)
Weight	80,000 lbs. (20,000 per axle)
Width	8’-6”
Height	13’-6”

Routine Transport Permits
Single Trip: $30.00 one way of $50.00 round-trip
Single Trip Permit Required when:
Total Length is over 70’
Total Height is over 13’-6”
Total Width is over 8’-6”
Gross weight on any single axle exceeds 21,000 lbs.

Restrictions
Allow one week for Single haul Permits, as a specific route will be designated based on size and weight

Permits will be required in all states the trusses will be passing through at a minimum a routine permit will be required and escort vehicles. The trusses being spliced will be able to be shipped with a maximum length of 47’ allowing a normal length trailer to be used. Except for DC a permit should not be required if a low trailer is able to be used. The height will then become the restricting factor in the transportation.

On Site Assembly and Erection of Three Piece Trusses

In order to assemble the truss a level and open area will be needed. Gymnasium footprint below where the trusses will be going could work for this space. The deliveries can enter the site via EADS St. to the south and driving in a single direction around the building. Figure 24, shows the designated area for the truss delivery and on site fabrication/assembly area. By assembling the trusses on site, in the area designated with the access road running between the fabrication area and the gymnasium, the crane will be able to swing the trusses into place without having to walk the trusses. The temporary pad will require a level area and temporary supports to allow the trusses to be assembled quickly.

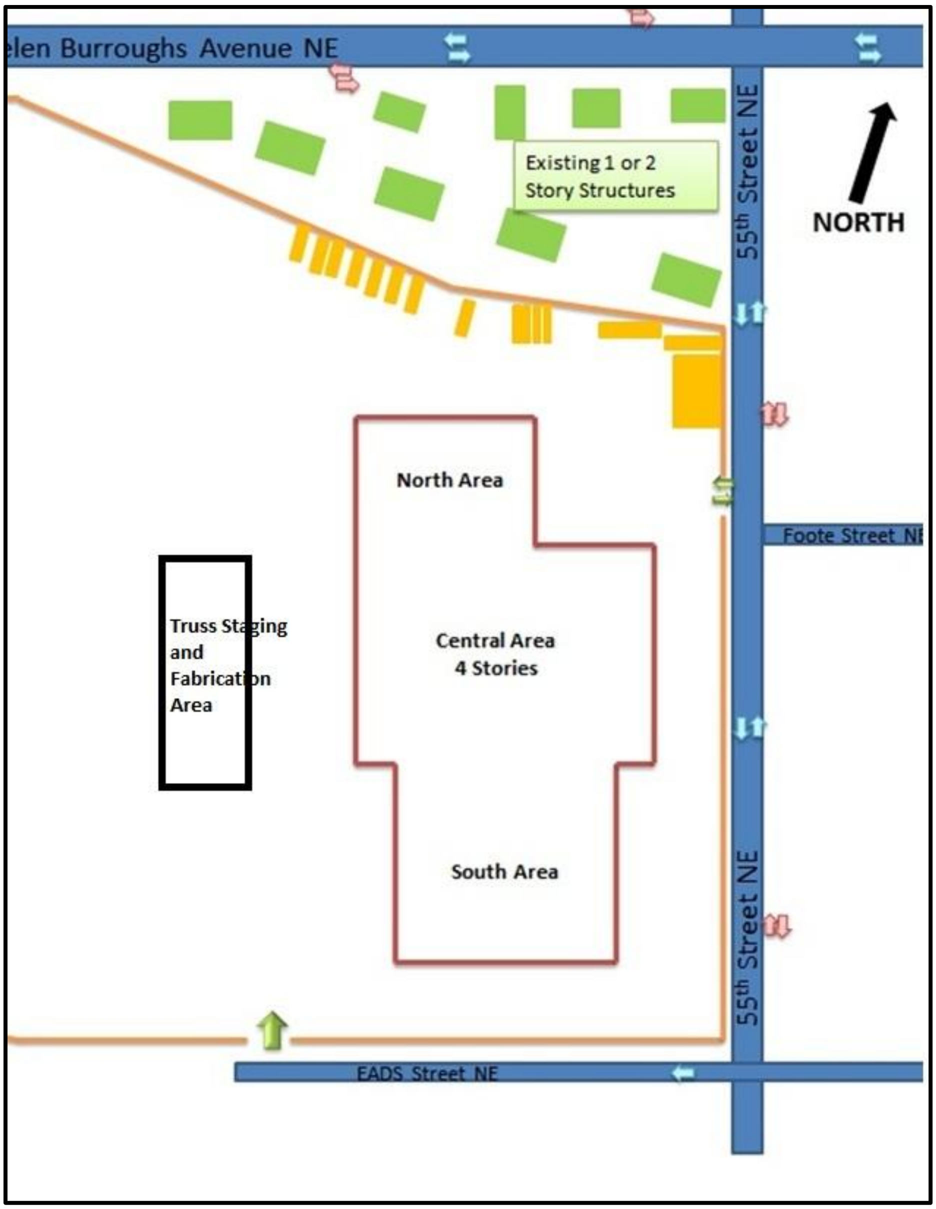


Figure 24: Truss Delivery and Fabrication Area

Schedule Impacts of On-site Truss Assembly

The erection time of the trusses will increase causing an issue if they were to be delivered as originally scheduled. The trusses would have to be coordinated and approved earlier to allow time for site assembly. Risk is elevated of losing schedule time due to weather factors by fabricating on site. The on-site fabrication time would take up to 2 days for each truss as opposed to delivering the trusses and erecting the same day of arrival. The gym trusses are on the critical path with 5 days allotted beginning August 10, 2010. The added risk of not just delaying the trusses but the remaining steel sequence is a big risk.

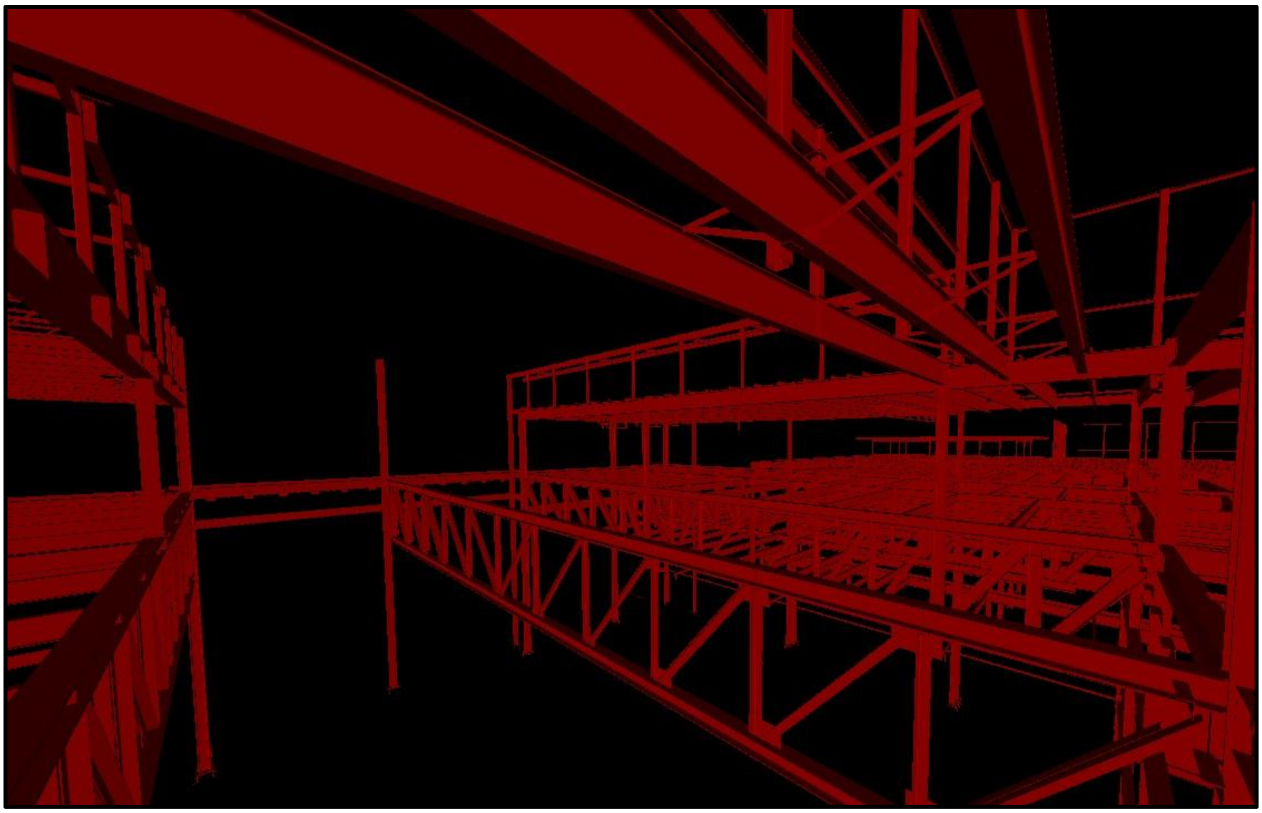


Figure 25: View from Floor above Gymnasium during Steel Erection (Courtesy HESS Construction + Engineering Services)

Alternative Truss Assembly Conclusion

The proposal to splice the trusses is not recommended. There are a number of reasons why this recommendation is being made. The difficulty of assembling the members on site and schedule risk does not outweigh the little or no cost savings that may have been possible. Removing a process from a controlled environment, especially steel fabrication increases cost, difficulty and time. The weather poses the risk of losing a day or multiple days on erection time for the gymnasium trusses, which would be unacceptable.

FINAL CONCLUSIONS

The analyses conducted on HD Woodson Senior High School over the previous year, have developed and considered alternative options that improve upon the original design and construction plan. The final report serves as the culmination of these analyses and a source of ideas for future projects. The findings and investigations are not intended in any way to find flaws or perceived mistakes in the actual project. The suggestions and concepts developed are theoretical and solely for the purpose of the senior thesis capstone course.

Building Information Modeling can be a very valuable tool and process in building construction. Through the Building Information Modeling Execution Planning Guide, developed at Penn State, allows the maximum value to be achieved with BIM. The HD Woodson High School Project Team used BIM effectively on the project.

Value Engineering is the process that includes developing and evaluating alternative construction methods and techniques to add value to a project. In Analysis two the suggestion of LEED elements being excluded from the value engineering process explores a potential situation if the green roof was included in the value engineering process. Through removal of the green roof, increasing the R-Value of the roof assembly and expanding the greywater system, value was theoretically added through a cost savings and reduction of Potable water use in the operation of the building. Additionally the green roof load on the structure will be removed allowing the size and weight of the steel framing members to be reduced.

Alternative Exterior Wall Assemblies were explored and two options were developed to compare to the original system. The recommendation of the Metal Stud Crete system was made. This system, while initially costing less can provide serious schedule acceleration for the exterior enclosure. It will also provide a reduction of loading on the mechanical system from the exterior walls.

Alternative Truss Assembly explored the opportunity to splice the 100+ feet trusses used over the gymnasium. While structurally the trusses would most likely be able to be splice with minor modifications, from a constructability stand point it does not make sense to do this. Splicing would simplify transportation however, the on-site assembly and schedule risk do not provide enough justification to remove a process from a controlled environment and increase risk.

These analyses and breadth topics have allowed a study into how building system assemblies and construction techniques can affect other systems of a building. Through Building information modeling alternative designs and options can be explored quickly and efficiently, allowing more opportunities and options to be explored.

REFERENCES

ASI Spray Insulation Professionals. (2011). (Blazeshield II). Retrieved March 2011, Fireproofing + Thermal Insulation=Energy Savings and Protection: http://www.asispray.com.

Border, T. (2011, April 4). Transportation Cost Information. (N. Diehl, Interviewer)

Clark, P. (2011, March 29). Metal Stud Crete-Earl Corporation. (N. Diehl, Interviewer)

Computer Integrated Construction Research Program. (2010). (Version 2.0 Guide and Templates). Building Information Modeling Project Execution Planning Guide.

District of Columbia Department of Energy. (2011). (Green Roof Case Studies). Retrieved March 2011, Green Roofs in the District - Showcase Projects: http://ddoe.dc.gov/ddoe.

EPDM Roofing Association. (2011). (Multiple articles and Data). Retrieved March 2011: http://www.edpmroofs.org.

Gamino, T. (2011, April 5). Electrical Rough in Informtion. (N. Diehl, Interviewer)

Greensulate. (2011). (Green Roof Diagram and Research). Retrieved March-April 2011, What is a Green Roof?: http://www.greensulate.com.

Metal Stud Crete. (2011). (Typical Details and General Information). Retrieved March 2011: http://www.metalcrete.com.

Greensulate. (2011). (Green Roof Diagram and Research). Retrieved March-April 2011, What is a Green Roof?: http://www.greensulate.com.

Wideloadshipping.com. (2011). (Shipping Restrictions). Retrieved March -April 2011, State Regulations: http://www.wideloadshipping.com.

APPENDIX A

Total Project Schedule Summary Gantt Chart

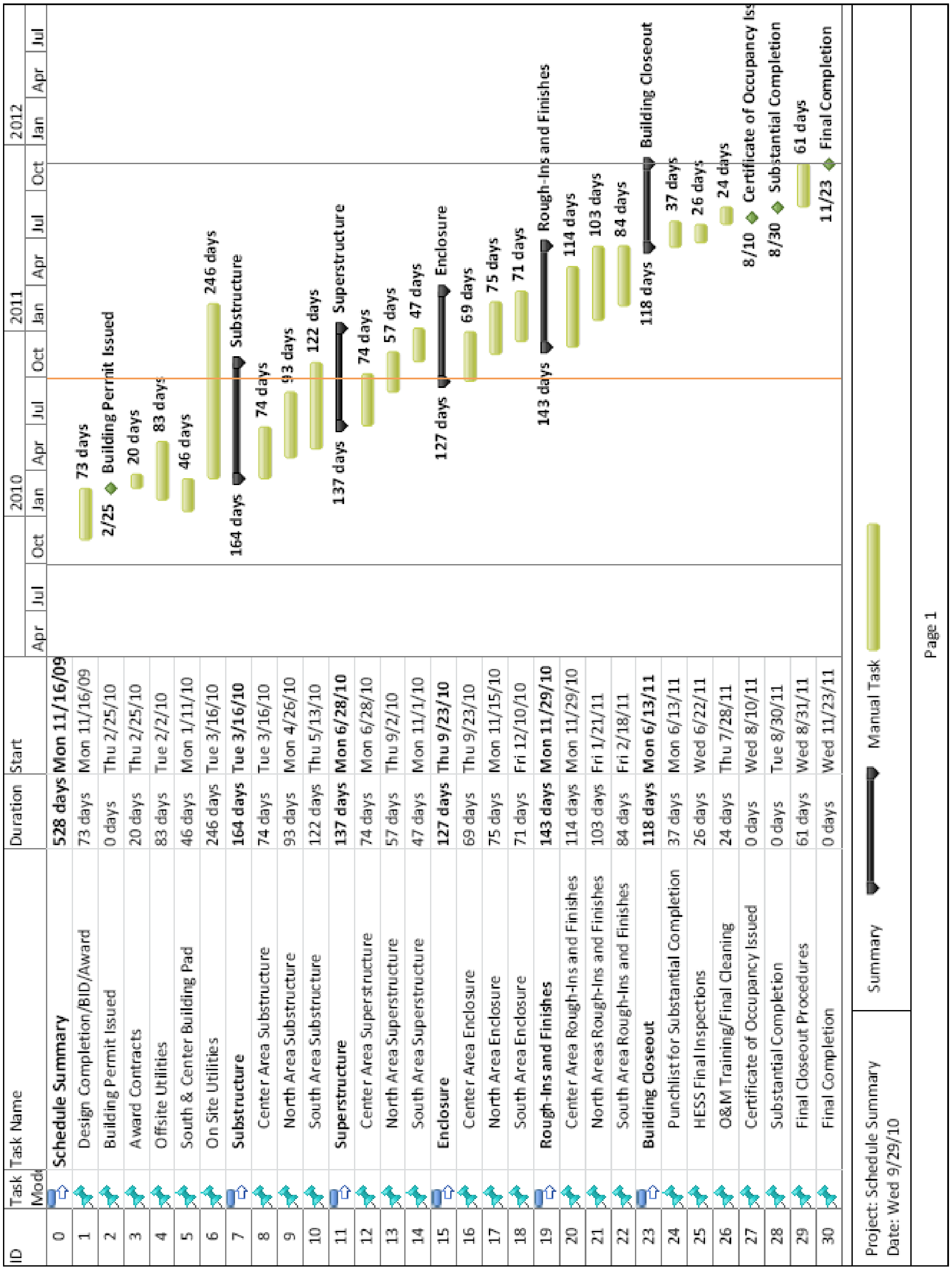


Figure 26: Schedule Summary

LEED Scorecard for Original Design

LEED 2009 for Schools New Construction and Major Renovations

Project Checklist

Project Name

Date

Y	?	N			
16	3	5		**Sustainable Sites**	Possible Points: 24
Y	?	N			
Y			Prereq 1	Construction Activity Pollution Prevention	
Y			Prereq 2	Environmental Site Assessment	
		1	Credit 1	Site Selection	1
4			Credit 2	Development Density and Community Connectivity	4
		1	Credit 3	Brownfield Redevelopment	1
4			Credit 4.1	Alternative Transportation—Public Transportation Access	4
1			Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Roon	1
	2		Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Ve	2
2			Credit 4.4	Alternative Transportation—Parking Capacity	2
		1	Credit 5.1	Site Development—Protect or Restore Habitat	1
		1	Credit 5.2	Site Development—Maximize Open Space	1
	1		Credit 6.1	Stormwater Design—Quantity Control	1
1			Credit 6.2	Stormwater Design—Quality Control	1
		1	Credit 7.1	Heat Island Effect—Non-roof	1
1			Credit 7.2	Heat Island Effect—Roof	1
1			Credit 8	Light Pollution Reduction	1
1			Credit 9	Site Master Plan	1
1			Credit 10	Joint Use of Facilities	1
9	2			**Water Efficiency**	Possible Points: 11
Y			Prereq 1	Water Use Reduction—20% Reduction	
4			Credit 1	Water Efficient Landscaping	2 to 4
2			Credit 2	Innovative Wastewater Technologies	2
2	2		Credit 3	Water Use Reduction	2 to 4
1			Credit 3	Process Water Use Reduction	1
12		20		**Energy and Atmosphere**	Possible Points: 33
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
7		11	Credit 1	Optimize Energy Performance	1 to 19
		7	Credit 2	On-Site Renewable Energy	1 to 7
2			Credit 3	Enhanced Commissioning	2
1			Credit 4	Enhanced Refrigerant Management	1
2			Credit 5	Measurement and Verification	2
		2	Credit 6	Green Power	2
6	1	6		**Materials and Resources**	Possible Points: 13
Y			Prereq 1	Storage and Collection of Recyclables	
		2	Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 2
		1	Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Element	1
2			Credit 2	Construction Waste Management	1 to 2
				Materials and Resources, Continued	
Y	?	N			
		2	Credit 3	Materials Reuse	1 to 2
2			Credit 4	Recycled Content	1 to 2
2			Credit 5	Regional Materials	1 to 2
		1	Credit 6	Rapidly Renewable Materials	1
	1		Credit 7	Certified Wood	1
16		1		**Indoor Environmental Quality**	Possible Points: 19
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
Y			Prereq 3	Minimum Acoustical Performance	
1			Credit 1	Outdoor Air Delivery Monitoring	1
1			Credit 2	Increased Ventilation	1
1			Credit 3.1	Construction IAQ Management Plan—During Construction	1
1			Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
4			Credit 4	Low-Emitting Materials	1 to 4
1			Credit 5	Indoor Chemical and Pollutant Source Control	1
1			Credit 6.1	Controllability of Systems—Lighting	1
1			Credit 6.2	Controllability of Systems—Thermal Comfort	1
1			Credit 7.1	Thermal Comfort—Design	1
1			Credit 7.2	Thermal Comfort—Verification	1
1			Credit 8.1	Daylight and Views—Daylight	1 to 3
		1	Credit 8.2	Daylight and Views—Views	1
1			Credit 9	Enhanced Acoustical Performance	1
1			Credit 10	Mold Prevention	1
2	1	3		**Innovation and Design Process**	Possible Points: 6
	1		Credit 1.1	Innovation in Design: Specific Title	1
		1	Credit 1.2	Innovation in Design: Specific Title	1
		1	Credit 1.3	Innovation in Design: Specific Title	1
		1	Credit 1.4	Innovation in Design: Specific Title	1
1			Credit 2	LEED Accredited Professional	1
1			Credit 3	The School as a Teaching Tool	1
				Regional Priority Credits	Possible Points: 4
			Credit 1.1	Regional Priority: Specific Credit	1
			Credit 1.2	Regional Priority: Specific Credit	1
			Credit 1.3	Regional Priority: Specific Credit	1
			Credit 1.4	Regional Priority: Specific Credit	1
61	7	35		**Total**	Possible Points: 110

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

Figure 27: LEED Scorecard for Original Design

APPENDIX B

Blazeshield II

BLAZE-SHIELD® II

Spray-Applied Fire Resistive Material

CAFCO® BLAZE-SHIELD® II is a portland cement based spray-applied fire resistive material (SFRM) designed to provide fire resistive ratings for structural steel and concrete in commercial construction.

Applied directly to deck, steel beams, columns or concrete surfaces, the outstanding value and proven fire resistive performance of BLAZE-SHIELD II make it an excellent choice for concealed commercial environments.

BLAZE-SHIELD II is applied exclusively by CAFCO licensed and trained contractors. Our technical staff works closely with building team members to meet all fire protection needs.

Code Compliances

CAFCO BLAZE-SHIELD II satisfies the requirements of the following:

- IBC—International Building Code
- SBCCI—Southern Building Code Congress International (Report No. 9423E)
- ICBO—International Conference of Building Officials (Report No. 1244)
- BOCA—Building Officials and Code Administrators International
- New York City—MEA
- NBC—National Building Code of Canada, Sections 2.5, 3.1.5, and 3.1.7

Major Specifications

BLAZE-SHIELD II complies with the requirements of the following specifications:

- General Services Administration (GSA): AIA/SC/GSA: 07811
- Department of the Navy NAVFACENGCOM Guide Specification NFGS 07810, Sprayed-On Fireproofing
- Veterans Administration (VA): H-08-1
- U.S. ARMY Corps of Engineers. CEGS-07811
- U.S. Environmental Protection Agency (EPA): Regulation 40
- Construction Specification Canada (CSC) TEK-AID

Fire Test Performance

CAFCO BLAZE-SHIELD II has been extensively tested for fire endurance by Underwriters Laboratories, Inc. (UL) and Underwriters Laboratories of Canada (ULC) in accordance with ASTM E119 (UL 263, CAN/ULC-S101).

These tests have resulted in ratings of up to 4 hours for:

- Floor Assemblies
- Beams
- Joists
- Columns
- Roof Assemblies
- Walls and Partitions

BLAZE-SHIELD II has also been tested in accordance with ASTM E84 and CAN/ULC-S102 and has the following Surface Burning Characteristics:

Flame Spread..................0
Smoke Developed 0

Thermal Properties

The unique formulation of CAFCO® BLAZE-SHIELD® II makes it a very effective thermal insulator. This benefit is important in reducing heat loss, particularly when applied to the underside of a roof deck. The R-value added by BLAZE-SHIELD II may allow a reduction in roof insulation.

Product	Conductivity (k)*	Resistance (R/inch)
BLAZE-SHIELD II	0.30 BTU in/hr ft² °F @ 75°F (0.043 W/mK @ 24°C)	3.33

*When tested in accordance with ASTM C518

Acoustical Properties

As an efficient sound-absorbing material, BLAZE-SHIELD II adds value to the fire protection application in areas where high-noise levels are anticipated. Typical acoustical performance is as follows:

Product	Thickness	Base	NRC Rating*
BLAZE-SHIELD II	1/2 inch (13 mm)	Deck & Beam	0.75
BLAZE-SHIELD II	1 inch (25 mm)	Solid	0.75

*When tested in accordance with ASTM C423

Physical Performance

Characteristic	ASTM Method	Standard Performance*	Tested Performance**
Density	E605	15 pcf (240 kg/m³)	16 pcf (256 kg/m³)
Combustibility	E136	Noncombustible	Noncombustible
Cohesion/Adhesion	E736	150 psf (7.2 kPa)	360 psf (17.2 kPa)
Deflection	E759	No Cracks or Delaminations	No Cracks or Delaminations
Bond Impact	E760	No Cracks or Delaminations	No Cracks or Delaminations
Compressive Strength	E761	750 psf (35.9 kPa)	2,380 psf (114 kPa)
Air Erosion Resistance	E859	Less than 0.025 g/ft² (0.27 g/m²)	0.000 g/ft² (0.000 g/m²)
Corrosion Resistance	E937, Mil. Std. 810	Does Not Promote Corrosion of Steel	Does Not Promote Corrosion of Steel
Sound Absorption	C423		0.75 NRC, 1/2" (13mm) onto deck and beam

.* Standard performance based on General Services Administration AIA/SC/GSA/07811 except for density, which is based on UL. Refer to UL design for density requirement.

** Values represent independent laboratory tests under controlled conditions

BLAZE-SHIELD II Guide Specification

PART 1 – GENERAL

1.1 Work Included

1.1.1 Provide all labor, materials, equipment and services necessary for, and incidental to, the complete and proper installation of all spray-applied fire resistive material and related work as shown on the drawings or where specified herein, and in accordance with all applicable requirements of the Contract Documents.

1.1.2 The material and installation shall conform to the applicable building code requirements and the requirements of all authorities having jurisdiction.

1.2 Quality Assurance

1.2.1 Work shall be performed by a firm with expertise in the installation of fire protection or similar materials. This firm shall be licensed or otherwise approved by the spray-applied fire resistive material manufacturer.

1.2.2 Before proceeding with the fire protection work, approval of the proposed material thicknesses and densities shall be obtained from the architect and other applicable authorities having jurisdiction.

1.3 Related Sections

1.3.1 Section 05100 - Structural Steel.
1.3.2 Section 05300 - Metal Decking.
1.3.3 Section 07200 - Insulation.
1.3.4 Section 07270 - Firestopping.
1.3.5 Section 07812 - Intumescent Coatings.
1.3.6 Section 09200 - Lath and Plaster.
1.3.7 Section 09900 - Painting.

1.4 References

A. ASTM E84 - Surface Burning Characteristics of Building Materials.
B. ASTM E119 - Fire Tests of Building Construction and Materials.
C. ASTM E136 - (Noncombustibility) Behavior of Materials in a Vertical Tube Furnace at 750ºC.
D. ASTM E605 - Thickness and Density of Sprayed Fire-Resistive Materials Applied to Structural Members.
E. ASTM E736 - Cohesion/Adhesion of Sprayed Fire-Resistive Materials Applied to Structural Members.
F. ASTM E759 - Effect of Deflection of Sprayed Fire-Resistive Materials Applied to Structural Members.
G. ASTM E760 - Effect of Impact on Bonding of Sprayed Fire-Resistive Materials Applied to Structural Members.
H. ASTM E761 - Compressive Strength of Sprayed Fire-Resistive Materials Applied to Structural Members.
I. ASTM E859 - Air Erosion of Sprayed Fire-Resistive Materials Applied to Structural Members.
J. ASTM E937 - Corrosion of Steel by Sprayed Fire-Resistive Materials Applied to Structural Members.
K. CAN/ULC-S101 - Standard Methods of Fire Tests of Building Construction and Materials.
L. CAN/ULC-S102 Steiner Tunnel Test.
M. CAN4-S114 Standard Test Method for Determination of Noncombustibility in Building Materials.

1.4.1 Underwriters Laboratories, Inc. (UL) Fire Resistance Directory.

1.4.2 Underwriters Laboratories of Canada (ULC) List of Equipment and Materials.

1.4.3 Uniform Building Code Standard No. 7-6 (current edition): Thickness and Density Determination for Spray-Applied Fire Protection.

1.4.4 AWCI Publication: Technical Manual 12-A Standard Practice for the Testing and Inspection of Field Applied Sprayed Fire-Resistive Materials; an Annotated Guide.

1.5 Submittals

1.5.1 Manufacturer's Data: Submit manufacturer's specifications, including certification as may be required to show material compliance with Contract Documents.

1.5.2 Test Data: Independent laboratory test results shall be submitted for all specified performance criteria.

1.6 Delivery, Storage and Handling

1.6.1 Deliver materials to the project in manufacturer's unopened packages, fully identified as to trade name, type and other identifying data. Packaging shall bear the UL and ULC labels for fire hazard and fire-resistance classifications.

1.6.2 Store materials above ground, in a dry location, protected from the weather. Damaged packages found unsuitable for use should be rejected and removed from the project.

1.7 Project Conditions

1.7.1 When the prevailing outdoor temperature at the building is less than 40° F (4° C), a minimum substrate and ambient temperature of 40° F (4° C) shall be maintained prior to, during, and a minimum of 24 hours after application of spray-applied fire resistive material. If necessary for job progress General Contractor shall provide enclosures with heat to maintain temperatures.

1.7.2 General Contractor shall provide ventilation to allow proper drying of the spray-applied fire resistive material during and subsequent to its application.

1.7.2.1 In enclosed areas ventilation shall not be less than 4 complete air changes per hour.

1.8 Sequencing/Scheduling

1.8.1 All fire protection work on a floor shall be completed before proceeding to the next floor.

1.8.2 The Contractor shall cooperate in the coordination and scheduling of fire protection work to avoid delays in job progress.

PART 2 – PRODUCTS

2.1 Acceptable Manufacturers. The spray-applied fire resistive material shall be manufactured under the CAFCO® brand name, by authorized producers.

2.2 Materials

2.2.1 Materials shall be BLAZE-SHIELD® II, (UL/ULC designation: Type II) applied to conform to the drawings, specifications and following test criteria:

2.2.1.1 Deflection: When tested in accordance with ASTM E759, the material shall not crack or delaminate when the non-concrete topped galvanized deck to which it is applied is subjected to a one time vertical centerload resulting in a downward deflection of 1/120th of the span.

2.2.1.2 Bond Impact: When tested in accordance with ASTM E760, the material shall not crack or delaminate from the concrete topped galvanized deck to which it is applied.

2.2.1.3 Cohesion/Adhesion (bond strength): When tested in accordance with ASTM E736, the material applied over uncoated or galvanized steel shall have an average bond strength of 150 psf (7.2 kPa).

2.2.1.4 Air Erosion: When tested in accordance with ASTM E859, the material shall not be subject to losses from the finished application greater than 0.025 grams per sq. ft. (0.27 grams per square meter).

2.2.1.5 Compressive Strength: When tested in accordance with ASTM E761, the material shall not deform more than 10 percent when subjected to a crushing force of 750 psf (35.9 kPa).

2.2.1.6 Corrosion Resistance: When tested in accordance with ASTM E937, the material shall not promote corrosion of steel.

2.2.1.7 Noncombustibility: When tested in accordance with ASTM E136 or CAN4-S114, the material shall be noncombustible.

2.2.1.8 Surface Burning Characteristics: When tested in accordance with ASTM E84 or CAN/ULC-S102, the material shall exhibit the following surface burning characteristics:
Flame Spread..........0
Smoke Developed.....0

2.2.1.9 Density: When tested in accordance with ASTM E605, the material shall meet the minimum individual and average density values as listed in the appropriate UL / ULC design or as required by the authority having jurisdiction.

2.2.2 The material shall have been tested and classified by Underwriters Laboratories, Inc. (UL) or Underwriters Laboratories of Canada (ULC) in accordance with the procedures of UL 263 (ASTM E119) or CAN/ULC-S101.

2.2.3 Spray-applied fire resistive materials shall be applied at the approved minimum thickness and density to achieve the following ratings:
Floor assemblies ___hr.
Roof assemblies ___hr.
Beams ___hr.
Girders ___hr.
Columns ___hr.
Joists ___hr.

2.2.4 Potable water shall be used for the application of spray-applied fire resistive materials.

2.2.5 Spray-applied fire resistive materials shall be free of all forms of asbestos, including actinolite, amosite, anthophyllite, chrysotile, crocidolite and tremolite. Material manufacturer shall provide certification of such upon request.

PART 3 – EXECUTION

3.1 Preparation

3.1.1 All surfaces to receive fire protection shall be free of oil, grease, loose mill scale, dirt, paints/primers or other foreign materials which would impair satisfactory bonding to the surface. Manufacturer shall be contacted for procedures on handling primed/painted steel. Any cleaning of surfaces to receive spray-applied fire resistive material shall be the responsibility of the General Contractor or Steel Erector, as outlined in the structural steel or steel deck section.

3.1.2 Clips, hangers, supports, sleeves and other attachments to the substrate are to be placed by others prior to the application of spray-applied fire resistive materials.

3.1.3 The installation of ducts, piping, conduit or other suspended equipment shall not take place until the application of spray-applied fire resistive material is complete in an area.

3.1.4 The spray-applied fire resistive material shall only be applied to steel deck which has been fabricated and erected in accordance with the criteria set by the Steel Deck Institute.

3.1.5 When roof traffic is anticipated, as in the case of periodic maintenance, roofing pavers shall be installed as a walkway to distribute loads.

3.2 Application

3.2.1 Equipment, mixing and application shall be in accordance with the manufacturer's written application instructions.

3.2.2 The application of spray-applied fire resistive material shall not commence until certification has been received by the General Contractor that surfaces to receive spray-applied fire resistive material have been inspected by the applicator and are acceptable to receive spray-applied fire resistive material.

3.2.3 All unsuitable substrates must be identified and made known to the General Contractor and corrected prior to application of the spray-applied fire resistive material.

3.2.4 Spray-applied fire resistive material shall not be applied to steel floor decks prior to the completion of concrete work on that deck.

3.2.5 The application of spray-applied fire resistive material to the underside of roof deck shall not commence until the roofing is completely installed and tight, all penthouses are complete, all mechanical units have been placed, and after construction roof traffic has ceased.

3.2.6 Proper temperature and ventilation shall be maintained as specified in 1.7.1, 1.7.2 and 1.7.2.1.

3.2.7 Provide masking, drop cloths or other suitable coverings to prevent overspray from coming in contact with surfaces not intended to be sprayed.

3.2.8 CAFCO® BOND-SEAL (Type EBS) adhesive shall be applied as per the appropriate UL/ULC fire resistance design and manufacturer's written recommendations.

3.3 Repairing and Cleaning

3.3.1 All patching of and repair to spray-applied fire resistive material, due to damage by other trades, shall be performed under this section and paid for by the trade responsible for the damage.

3.3.2 After the completion of the work in this section, equipment shall be removed and all surfaces not to be sprayed shall be cleaned to the extent previously agreed to by the applicator and General Contractor.

3.4 Inspection and Testing

3.4.1 The spray-applied fire resistive material shall be tested for thickness and density in accordance with one of the following procedures: ASTM E605 - Standard Test Method of Sprayed Fire-Resistive Materials Applied to Structural Members. AWCI - Technical Manual 12-A Standard Practice for the Testing and Inspection of Field Applied Sprayed Fire-Resistive Materials an Annotated Guide.UBC Standard No. 7-6 - Thickness and Density Determination for Spray-Applied Fire Protection.

Product Availability

CAFCO Spray-Applied Fire Resistive Materials are available to trained, licensed contractors around the world from strategically located production and distribution points in the U.S., Canada, Mexico, Europe and the Pacific Basin.

For Further Information

ISOLATEK INTERNATIONAL is registered with the AIA Continuing Education System (AIA/CES)

For Further Information CAFCO® Technical and Sales Representatives are always available to lend assistance. Additional printed materials, including Material Safety Data Sheets, and other product literature, are available upon request. For more information about our CAFCO® line of sprayed fire protection, thermal and acoustical treatments, SprayFilm™ Intumescent Coatings, and CAFCO-BOARD™ or for the name of the Sales Representative in your area, please contact:

In the United States: Isolatek International, Stanhope, New Jersey Tel: 800.631.9600 Fax: 973.347.9170
In Mexico & Central America: Cafco Mexico S.A. de C.V., Mexico D.F. Tel: 52.55.5254.6683 Fax: 52.55.5531.7826
In Andean Countries: Cafco Andina S.A., Santiago, Chile Tel: 562.378.5120 Fax: 562.378.5121
In Canada: Cafco Industries, Toronto, Ontario Tel: 888.873.0003 Fax: 416.679.2933

For more detailed product information, visit our website at
www.cafco.com or contact us at cafco@isolatek.com

ISOLATEK INTERNATIONAL

2/03

APPENDIX C

Structural Breadth- Hand Calculations and Self Weights

W 21 x 44 (To Right of Bay studied) - Effect Girder sizing

WITH GREEN ROOF LOADS

Tributary Area: 9.5' x 42' = 399 SF

Original Design (Incl. Green Roof)

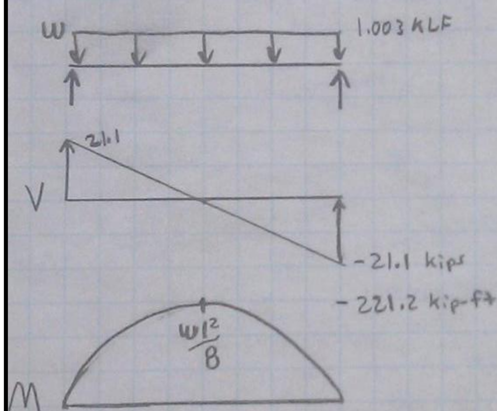
Factored Load: 1.2(60) + 1.6(21) = 105.6 PSF

LOAD: 105.6 PSF x 9.5' = 1003.2 PLF (1.003 k LF)

LOAD PER Support: (1.003 kLF)(42')/2 = 21.1 kips

Bending Moment: $w_u l^2/8$ = (1.003)(42²)/8 ⇒ 221.2 kip-ft

W 21 x 44 Max Moment = 358 > 221.2 (ok) (61% unknowns)



DEFLECTION CHECK:

60 PSF + 21 PSF = 81 PSF

81 x 9.5' = 769.5 PLF

$5wL^2/384EI$

$\frac{5(769.5)(42')^4(1728)}{384(29{,}000{,}000)(843)} = 2.2''$

Max Allowable deflection:

$\frac{L}{240} = \frac{42 \times 12}{24} \Rightarrow 2.1''$

2.1" ≈ 2.2"

Reduced Load Calcs.

NO GREEN ROOF LOADS

Factored Load:

$1.2(30) + 1.6(21) = 69.6$ PSF

LOAD: $69.6(9.5) = 661.2$ PLF (.661 KLF)

LOAD Per Support: $= (.661)(42')/2 \Rightarrow 13.9$ kips (@ each Support)

BENDING MOMENT: $w_u L^2/8 = (.661)(42')^2/8 = 145.8$ kip-ft

Maintain 61% for unknowns $= 145.8 \times 1.61 = 234.8$ kip-ft

W18x40	Max Moment = 294	$I_4 = 612$	ok, check deflection
W16x40	Max Moment = 274	$I_4 = 518$	
W18x35	Max Moment = 249	$I_4 = 510$	

Max allowable deflection (Total Load)

$$\frac{L}{240} = \frac{42' \times \frac{12}{1}}{240} = 2.1''$$

$$\frac{5wl^4}{384EI}$$

LOAD $= 30 + 21 = 51$ PSF $\times 9.5' = 484.5$ PLF

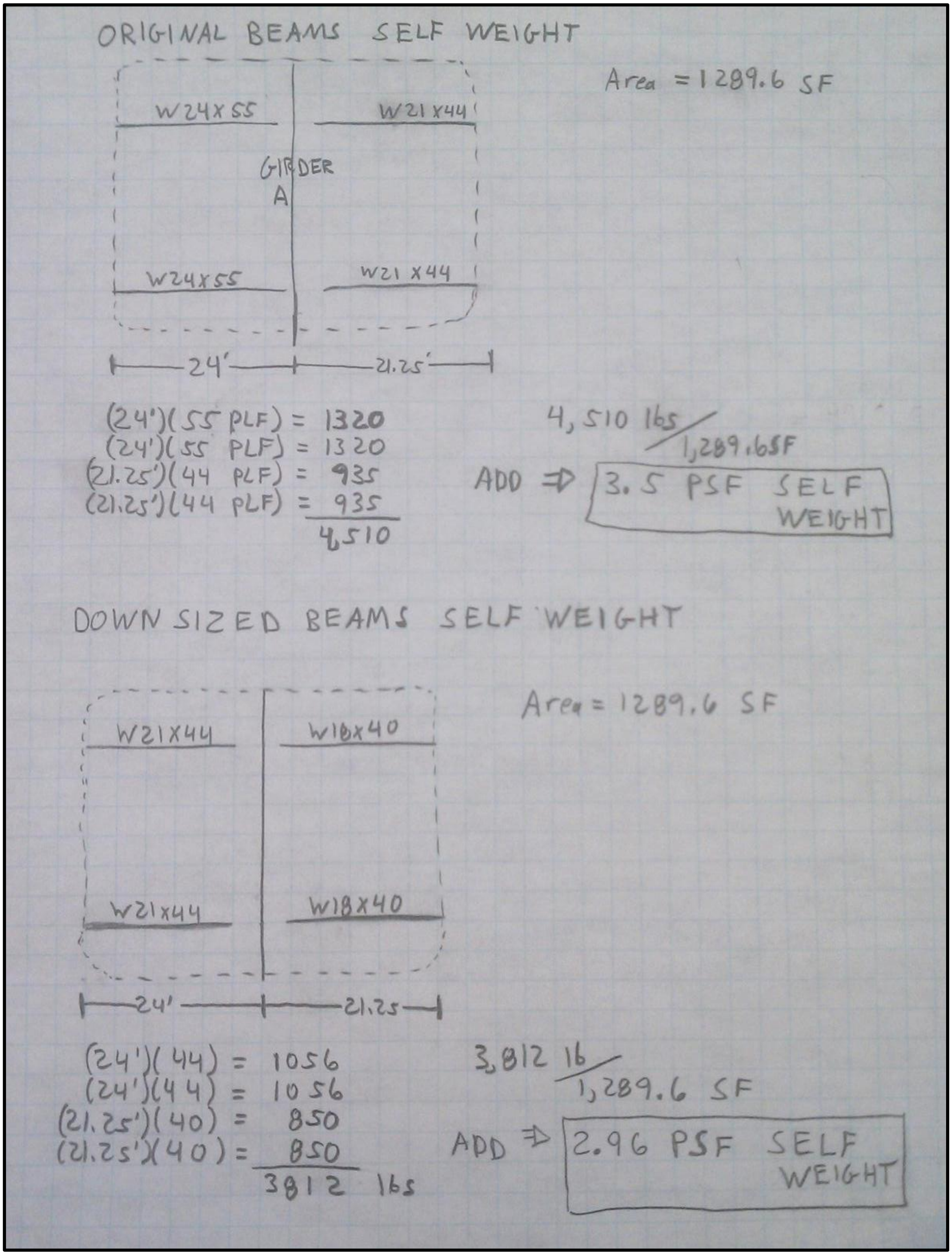
W18x40

$$\frac{5(484.5)(42')^4(1728)}{(384)(29{,}000{,}000)(612)} = 1.9'' < 2.1'' \text{ (OK)}$$

W16x40

$$\frac{5(484.5)(42')^4(1728)}{384(29{,}000{,}000)(518)} = 2.26'' \text{ (NOT OK)}$$

W18x35 — (NOT OK) $\Rightarrow I_4 = 510 < 514$


ORIGINAL BEAMS SELF WEIGHT
W24X55
W21X44
GIRDER A
W24X55
W21X44
24'
21.25'
Area = 1289.6 SF
(24')(55 PLF) = 1320
(24')(55 PLF) = 1320
(21.25')(44 PLF) = 935
(21.25')(44 PLF) = 935
4,510
4,510 lbs / 1,289.6 SF
ADD ⇒ 3.5 PSF SELF WEIGHT
DOWN SIZED BEAMS SELF WEIGHT
W21X44
W18X40
W21X44
W18X40
24'
21.25
Area = 1289.6 SF
(24')(44) = 1056
(24')(44) = 1056
(21.25')(40) = 850
(21.25')(40) = 850
3812 lbs
3,812 lb / 1,289.6 SF
ADD ⇒ 2.96 PSF SELF WEIGHT

APPENDIX D

Mechanical Breadth- Space Heating and Cooling Load Summaries

CMU Back Up

Space Summary - Space1	
Inputs	
Area (SF)	775.41
Volume (CF)	6,170.61
Wall Area (SF)	55
Roof Area (SF)	46.12
Door Area (SF)	40.08
Partition Area (SF)	0
Window Area (SF)	45.31
Skylight Area (SF)	0
Lighting Load (W)	930
Power Load (W)	1,163
Number of People	18
Sensible Heat Gain / Person (Btu/h)	250
Latent Heat Gain / Person (Btu/h)	200
Infiltration Airflow (CFM)	0
Space Type	School or University (inherited from building type)
Calculated Results	
Peak Cooling Load (Btu/h)	**13,583.50**
Peak Cooling Month and Hour	July 10:00 AM
Peak Cooling Sensible Load (Btu/h)	10,341.80
Peak Cooling Latent Load (Btu/h)	3,241.70
Peak Cooling Airflow (CFM)	495
Peak Heating Load (Btu/h)	**-10,422.30**
Peak Heating Airflow (CFM)	64

Original CMU Assembly- Space 1 (3rd floor class Room Exterior Wall facing South)				
Components	**Cooling**		**Heating**	
	Loads (Btu/h)	**Percentage of Total**	**Loads (Btu/h)**	**Percentage of Total**
Wall	**19**	**0.14%**	**36.6**	**0.26%**
Window	1,075.50	7.92%	1,261.10	8.92%
Door	0	0.00%	0	0.00%
Roof	208.7	1.54%	560.2	3.96%
Skylight	0	0.00%	0	0.00%
Partition	0	0.00%	0	0.00%
Infiltration	0	0.00%	0	0.00%
Lighting	2,504.10	18.43%	-2,504.10	-17.71%
Power	3,130.10	23.04%	-3,130.10	-22.14%
People	6,646.10	48.93%	-6,646.10	-47.01%
Plenum	0	0.00%		
Total	**13,583.50**	**100%**	**-10,422.30**	**100%**

Space Summary - Space 2

Inputs	
Area (SF)	954.46
Volume (CF)	7,601.26
Wall Area (SF)	73.14
Roof Area (SF)	48.68
Door Area (SF)	37.79
Partition Area (SF)	0
Window Area (SF)	60.24
Skylight Area (SF)	0
Lighting Load (W)	1,145
Power Load (W)	1,432
Number of People	23
Sensible Heat Gain / Person (Btu/h)	250
Latent Heat Gain / Person (Btu/h)	200
Infiltration Airflow (CFM)	0
Space Type	School or University (inherited from building type)
Calculated Results	
Peak Cooling Load (Btu/h)	**15,434.20**
Peak Cooling Month and Hour	July 10:00 AM
Peak Cooling Sensible Load (Btu/h)	11,443.90
Peak Cooling Latent Load (Btu/h)	3,990.20
Peak Cooling Airflow (CFM)	562
Peak Heating Load (Btu/h)	**-12,173.40**
Peak Heating Airflow (CFM)	80

Original CMU Assembly- Space 2 (2nd floor class Room-Exterior Wall facing North)

Components	Cooling		Heating	
	Loads (Btu/h)	Percentage of Total	Loads (Btu/h)	Percentage of Total
Wall	**22.4**	**0.14%**	**48.8**	**0.29%**
Window	701.3	4.54%	1,676.80	9.98%
Door	0	0.00%	0	0.00%
Roof	220.3	1.43%	591.3	3.52%
Skylight	0	0.00%	0	0.00%
Partition	0	0.00%	0	0.00%
Infiltration	0	0.00%	0	0.00%
Lighting	2,902.50	18.81%	-2,902.50	-17.27%
Power	3,628.10	23.51%	-3,628.10	-21.59%
People	7,959.70	51.57%	-7,959.70	-47.36%
Plenum	0	0.00%		
Total	**15,434.20**	**100%**	**-12,173.40**	**100%**

Metal Stud Crete

Space Summary - Space 1	
Inputs	
Area (SF)	775.41
Volume (CF)	6,170.61
Wall Area (SF)	55
Roof Area (SF)	46.12
Door Area (SF)	40.08
Partition Area (SF)	0
Window Area (SF)	45.31
Skylight Area (SF)	0
Lighting Load (W)	930
Power Load (W)	1,163
Number of People	18
Sensible Heat Gain / Person (Btu/h)	250
Latent Heat Gain / Person (Btu/h)	200
Infiltration Airflow (CFM)	0
Space Type	School or University (inherited from building type)
Calculated Results	
Peak Cooling Load (Btu/h)	**13,642.20**
Peak Cooling Month and Hour	July 10:00 AM
Peak Cooling Sensible Load (Btu/h)	10,400.50
Peak Cooling Latent Load (Btu/h)	3,241.70
Peak Cooling Airflow (CFM)	501
Peak Heating Load (Btu/h)	**-10,434.40**
Peak Heating Airflow (CFM)	64

Metal Stud Crete - Space 1 (3rd floor class Room Exterior Wall facing South)				
Components	**Cooling**		**Heating**	
	Loads (Btu/h)	**Percentage of Total**	**Loads (Btu/h)**	**Percentage of Total**
Wall	**12.5**	**0.09%**	**24.6**	**0.17%**
Window	1,140.70	8.36%	1,261.10	8.93%
Door	0	0.00%	0	0.00%
Roof	208.7	1.53%	560.2	3.97%
Skylight	0	0.00%	0	0.00%
Partition	0	0.00%	0	0.00%
Infiltration	0	0.00%	0	0.00%
Lighting	2,504.10	18.36%	-2,504.10	-17.73%
Power	3,130.10	22.94%	-3,130.10	-22.16%
People	6,646.10	48.72%	-6,646.10	-47.05%
Plenum	0	0.00%		
Total	**13,642.20**	**100%**	**-10,434.40**	**100%**

Space Summary - Space 2

Inputs	
Area (SF)	954.46
Volume (CF)	7,601.26
Wall Area (SF)	73.14
Roof Area (SF)	48.68
Door Area (SF)	37.79
Partition Area (SF)	0
Window Area (SF)	60.24
Skylight Area (SF)	0
Lighting Load (W)	1,145
Power Load (W)	1,432
Number of People	23
Sensible Heat Gain / Person (Btu/h)	250
Latent Heat Gain / Person (Btu/h)	200
Infiltration Airflow (CFM)	0
Space Type	School or University (inherited from building type)
Calculated Results	
Peak Cooling Load (Btu/h)	**16,003.90**
Peak Cooling Month and Hour	July 10:00 AM
Peak Cooling Sensible Load (Btu/h)	12,013.70
Peak Cooling Latent Load (Btu/h)	3,990.20
Peak Cooling Airflow (CFM)	587
Peak Heating Load (Btu/h)	**-12,815.20**
Peak Heating Airflow (CFM)	79

Metal Stud Crete - Space 2 (2nd floor class Room Exterior Wall facing North)

Components	Cooling		Heating	
	Loads (Btu/h)	Percentage of Total	Loads (Btu/h)	Percentage of Total
Wall	**11.8**	**0.07%**	**32.7**	**0.19%**
Window	655.8	4.10%	1,676.80	9.63%
Door	0	0.00%	0	0.00%
Roof	220.3	1.38%	591.3	3.40%
Skylight	0	0.00%	0	0.00%
Partition	0	0.00%	0	0.00%
Infiltration	0	0.00%	0	0.00%
Lighting	3,082.30	19.26%	-3,082.30	-17.70%
Power	3,852.90	24.07%	-3,852.90	-22.12%
People	8,180.80	51.12%	-8,180.80	-46.97%
Plenum	0	0.00%		
Total	**16,003.90**	**100%**	**-12,815.20**	**100%**

Metal Stud Back Up

Space Summary - Space 1

Inputs	
Area (SF)	775.41
Volume (CF)	6,170.61
Wall Area (SF)	55
Roof Area (SF)	46.12
Door Area (SF)	40.08
Partition Area (SF)	0
Window Area (SF)	45.31
Skylight Area (SF)	0
Lighting Load (W)	930
Power Load (W)	1,163
Number of People	18
Sensible Heat Gain / Person (Btu/h)	250
Latent Heat Gain / Person (Btu/h)	200
Infiltration Airflow (CFM)	0
Space Type	School or University (inherited from building type)
Calculated Results	
Peak Cooling Load (Btu/h)	**13,640.10**
Peak Cooling Month and Hour	July 10:00 AM
Peak Cooling Sensible Load (Btu/h)	10,398.40
Peak Cooling Latent Load (Btu/h)	3,241.70
Peak Cooling Airflow (CFM)	501
Peak Heating Load (Btu/h)	**-10,438.60**
Peak Heating Airflow (CFM)	64

Metal Stud Back Up - Space 1 (3rd floor class Room Exterior Wall facing South)

Components	Cooling		Heating	
	Loads (Btu/h)	Percentage of Total	Loads (Btu/h)	Percentage of Total
Wall	**10.3**	**0.08%**	**20.3**	**0.14%**
Window	1,140.70	8.36%	1,261.10	8.93%
Door	0	0.00%	0	0.00%
Roof	208.7	1.53%	560.2	3.97%
Skylight	0	0.00%	0	0.00%
Partition	0	0.00%	0	0.00%
Infiltration	0	0.00%	0	0.00%
Lighting	2,504.10	18.36%	-2,504.10	-17.73%
Power	3,130.10	22.95%	-3,130.10	-22.16%
People	6,646.10	48.73%	-6,646.10	-47.06%
Plenum	0	0.00%		
Total	**13,640.10**	**100%**	**-10,438.60**	**100%**

Space Summary - Space 2

Inputs	
Area (SF)	954.46
Volume (CF)	7,601.26
Wall Area (SF)	73.14
Roof Area (SF)	48.68
Door Area (SF)	37.79
Partition Area (SF)	0
Window Area (SF)	60.24
Skylight Area (SF)	0
Lighting Load (W)	1,145
Power Load (W)	1,432
Number of People	23
Sensible Heat Gain / Person (Btu/h)	250
Latent Heat Gain / Person (Btu/h)	200
Infiltration Airflow (CFM)	0
Space Type	School or University (inherited from building type)
Calculated Results	
Peak Cooling Load (Btu/h)	**16,001.90**
Peak Cooling Month and Hour	July 10:00 AM
Peak Cooling Sensible Load (Btu/h)	12,011.60
Peak Cooling Latent Load (Btu/h)	3,990.20
Peak Cooling Airflow (CFM)	587
Peak Heating Load (Btu/h)	**-12,820.80**
Peak Heating Airflow (CFM)	79

Metal Stud Back Up- Space 2 (2nd floor class Room-Exterior Wall facing North)

Components	Cooling		Heating	
	Loads (Btu/h)	Percentage of Total	Loads (Btu/h)	Percentage of Total
Wall	**9.8**	**0.06%**	**27.1**	**0.16%**
Window	655.8	4.10%	1,676.80	9.63%
Door	0	0.00%	0	0.00%
Roof	220.3	1.38%	591.3	3.40%
Skylight	0	0.00%	0	0.00%
Partition	0	0.00%	0	0.00%
Infiltration	0	0.00%	0	0.00%
Lighting	3,082.30	19.26%	-3,082.30	-17.70%
Power	3,852.90	24.08%	-3,852.90	-22.13%
People	8,180.80	51.12%	-8,180.80	-46.99%
Plenum	0	0.00%		
Total	**16,001.90**	**100%**	**-12,820.80**	**100%**