CAMPUS SQUARE BUILDING

1426 North Third Street, Harrisburg, PA.

Andrew Martin
Construction Management

Final Thesis Report
April 7, 2010
Dr. Chris Magent

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Campus Square Building

Harrisburg, PA

Owner: GreenWorks Development
Architect: Ganflec Architects & Engineers
Civil: Kairos Design Group and Edward G. Black & Assoc.
Structural: Gannett Fleming
Mechanical: McClure Company
Electrical: G.R. Sponaugle
Plumbing: Enginuity LLC
CM: Wohlsen Construction Company

Project Information and Architectural Features

-75,000 SF Mixed Use Space- Retail/Office/Educational
-Construction Dates (Core & Shell): June 2008 – August 2009
-4 Stories Above Grade, Mechanical Basement Space
-Cost: $9,000,000
-Delivery Method: Design/Build
-LEED Gold Certification (LEED-CS v2.0)

Structural

-Steel moment resisting frame with composite beam and deck floor system
-Red brick façade with metal stud back-up and aluminum frame storefront
-5" 4000 PSI concrete slab-on-grade with Thickened spread footings supporting pier system

Mechanical

-46 Well - Closed Loop Geothermal System
-Each well was drilled to 450 feet deep to achieve the cooling/heating load for the building
-Fully flexible water source heat pump system with wireless automatic temperature controls and energy recovery
-Centralized gas fired water heater in basement
-Low flow water closets and faucets with automatic sensors
- Waterless urinals (up to 40,000 gallons reduced annually)

Electrical

-Integrated building management system
-47 kW photovoltaic solar system
-Three Invertors on the roof and basement,
-Six batteries in basement as backup power
-Wireless thermostats at heat pumps, reducing wiring and field waste

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http://www.engr.psu.edu/ae/thesis/portfolios/2010/arm5056/index.html

Acknowledgements

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- Craig Fleischmann

KERR Interior Systems Ltd. & Composite Building Systems Inc.

- Darryl Wiebe

Family and Friends

Executive Summary

This senior thesis report provides background information for the Campus Square building, along with in-depth research and analyses of the construction and technical aspects of the project.

As part of the critical industry research in this thesis, applicable exterior wall systems were researched as potential additions to Campus Square as a means to make the building more sustainable and energy efficient. The results of the research concluded with many thermally advantageous wall systems and materials which could be applied to Campus Square; as well as constructability issues which must be overcome to ensure the system's success. However, the physical location of the building negated the performance of these technologies due to the lack of solar availability because of the orientation of the structure. Fortunately, the benefits of prefabrication, and EIFS technologies were applied to the following analysis portions of this report.

To further analyze incorporating a prefabricated exterior wall system, this second analysis applied the lessons learned in the critical industry research about wall systems to Campus Square. Cost analysis performed showed that a prefabricated wall system would have an increased initial cost of $430,500 more than the wall system used for the project. However, the construction schedule was reduced by 9-weeks. This shorter construction schedule allows for tenants to move into the building, and for GreenWorks to begin profiting off of the leased space.

The third analysis of this thesis focused on the thermal efficiency of a prefabricated wall system, compared to the as-built method, as well as the curtain wall system. This was performed using heat loss calculations to compare the thermal losses during peak design temperatures. The data proved that a well constructed prefabricated system would reduce the overall thermal loss and gains throughout the year. The savings in operational costs due to the increased thermal efficiency of the building envelope would further mitigate the initial price increase of the wall assembly.

The fourth and final analysis of this thesis report included a structural redesign of the connections required to fasten the prefabricated panels to the superstructure. Through the use of QuickClips™, a product developed by Dietrich Metal Framing, a simple solution was discovered. The clops allow for a simple, yet durable structural connection. Furthermore, the clips could be welded to the steel studs of the prefabricated walls prior to their delivery on-site. This reduces the amount of on-site time which would be spent connecting the panels to the superstructure.

Project Information

The Campus Square Building is a four story, mixed-use building located in Harrisburg, Pennsylvania. Construction on the core and shell was completed August 2009, and tenant fit-outs began November 2009. The 75,000 square foot building received a LEED® Gold certification for the core and shell, as it hosts a closed loop geothermal system, a photovoltaic solar system on the roof, as well as many other sustainable features.

Project costs associated with the completion of the core and shell was approximately $9 million with a GMP contract between Wohlsen Construction Company and GreenWorks Development. The project delivery method used was design/build.

Project Summary Schedule

Sitework & Foundations

The Campus Square site is located on an existing gas station, and required tank removal and soil remediation before excavation began. Once the demolition of gas station and soil remediation were complete, sitework could begin for the new construction. Additionally, the building utilizes a geothermal mechanical system which required well drilling before footer excavation could take place in order to find optimum well placement. Concrete piers were poured in the same area as the geothermal well field, taking special consideration as to not disturb the geothermal wells. Foundations for the superstructure were poured in between the two well fields on either side of the mechanical basement space. Throughout construction, site utilization was very important in considering sequencing due to confined sight limitations, as well as existing utility interference

Superstructure

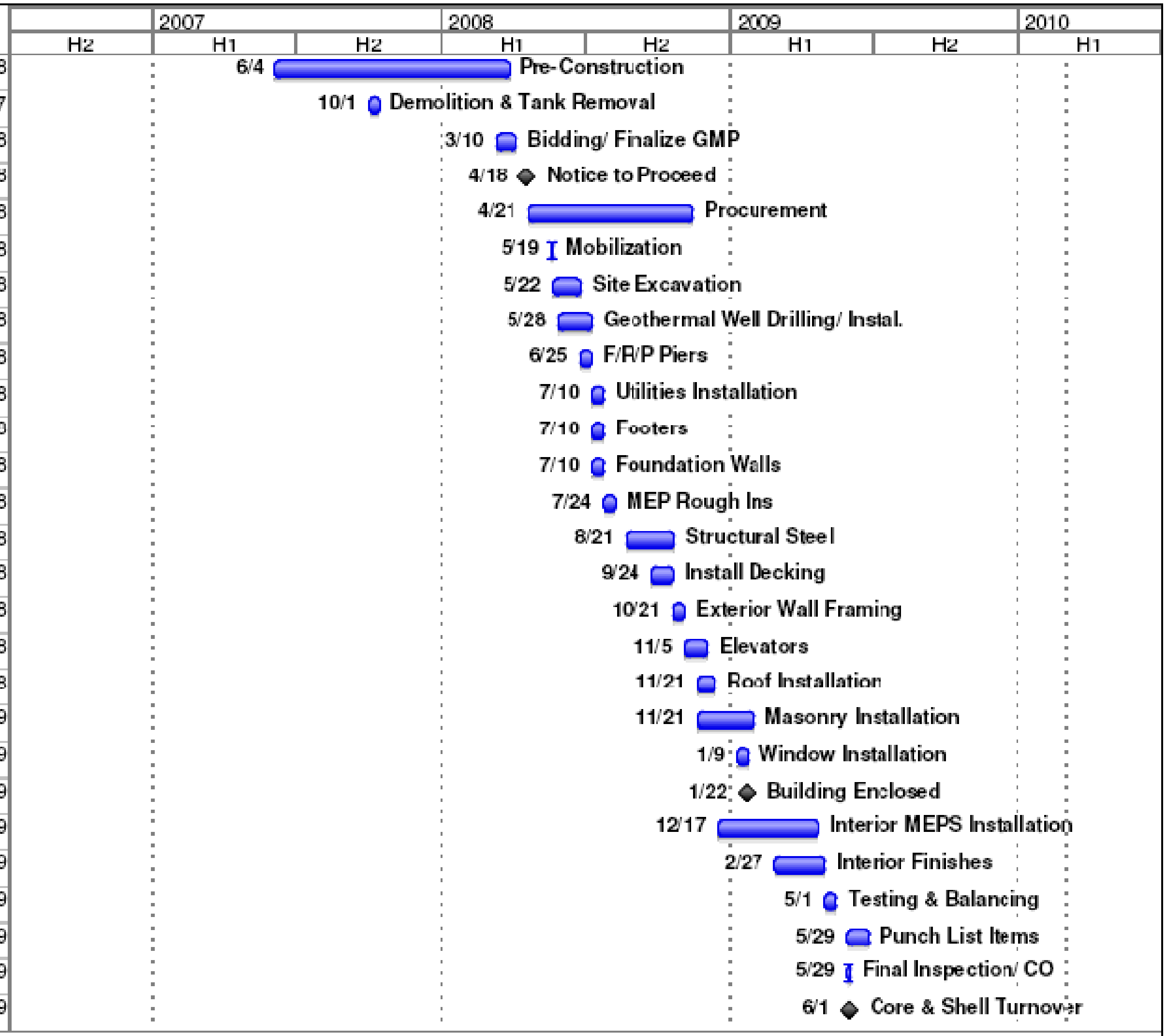
Structural steel began once underground MEP work was completed. Because the building is only 4-stories in height, a mobile crane was used in order to efficiently place the columns and beams. A 150 ton hydraulic crane was strategically placed on the south side of the site in order to hoist material deliveries efficiently, without disrupting workflow. Installation of the composite deck began once all overhead steel work was completed. Concrete for the slab-on-grade and metal decking would be poured once all steelwork was inspected. Enclosure work, including roof installation, exterior framing, masonry, curtain wall and windows required additional sequencing consideration due to existing power lines running along one of the sides of the building. Coordination between the General Contractor and the power company was required to sequence powering off the lines while work was being performed near them.

Finishes

Due to economic conditions, tenants were not established for the building until the core and shell portion of the project was nearly turned over to the owner. Therefore, finishes within the building did not require as long of a duration due to the open floor plan. However, a “parade-of-trades” was utilized in completing the interior work for each floor. Additionally, throughout the construction process, special documentation and coordination was needed in the LEED certification process.

Please view the project schedule summary on the next page.

ID	Task Name	Duration	Start	Finish
1	Pre-Construction	213 days	Mon 6/4/07	Wed 3/26/08
2	Demolition & Tank Removal	10 days	Mon 10/1/07	Fri 10/12/07
3	Bidding/ Finalize GMP	20 days	Mon 3/10/08	Fri 4/4/08
4	Notice to Proceed	0 days	Fri 4/18/08	Fri 4/18/08
5	Procurement	150 days	Mon 4/21/08	Fri 11/14/08
6	Mobilization	3 days	Mon 5/19/08	Wed 5/21/08
7	Site Excavation	25 days	Thu 5/22/08	Wed 6/25/08
8	Geothermal Well Drilling/ Instal.	31 days	Wed 5/28/08	Wed 7/9/08
9	F/R/P Piers	10 days	Wed 6/25/08	Tue 7/8/08
10	Utilities Installation	10 days	Thu 7/10/08	Wed 7/23/08
11	Footers	10 days	Thu 7/10/08	Wed 7/23/08
12	Foundation Walls	10 days	Thu 7/10/08	Wed 7/23/08
13	MEP Rough Ins	10 days	Thu 7/24/08	Wed 8/6/08
14	Structural Steel	44 days	Thu 8/21/08	Tue 10/21/08
15	Install Decking	19 days	Wed 9/24/08	Mon 10/20/08
16	Exterior Wall Framing	10 days	Tue 10/21/08	Mon 11/3/08
17	Elevators	20 days	Wed 11/5/08	Tue 12/2/08
18	Roof Installation	15 days	Fri 11/21/08	Thu 12/11/08
19	Masonry Installation	50 days	Fri 11/21/08	Thu 1/29/09
20	Window Installation	10 days	Fri 1/9/09	Thu 1/22/09
21	Building Enclosed	0 days	Thu 1/22/09	Thu 1/22/09
22	Interior MEPS Installation	90 days	Wed 12/17/08	Tue 4/21/09
23	Interior Finishes	45 days	Fri 2/27/09	Thu 4/30/09
24	Testing & Balancing	10 days	Fri 5/1/09	Thu 5/14/09
25	Punch List Items	20 days	Fri 5/29/09	Thu 6/25/09
26	Final Inspection/ CO	2 days	Fri 5/29/09	Mon 6/1/09
27	Core & Shell Turnover	0 days	Mon 6/1/09	Mon 6/1/09



Campus Square
Project Summary Schedule

Task | Rolled Up Task | External Tasks
Progress | Rolled Up Milestone | Project Summary
Milestone | Rolled Up Progress | Group By Summary
Summary | Split | Deadline

Building Systems Summary

Structural Steel

Campus Square is a 4-story building, implementing a structural steel moment resisting frame, with a composite beam and deck floor system and joist and deck system at the roof. A 150-ton hydraulic crane was used to erect all of the structure steel for the building. Column size of the structure ranges from a W12x210 at the first floor, to W12x40 at the roof level. Girder sizes range from W27x178 at the second floor, to W18x40 at the roof. The building has typical W14x26 beams which support the decking system.

The solar arrays are mounted on a steel system which was integrated into the design of the building, both structurally and electrically.

Cast-In-Place Concrete

Concrete piers and the foundation walls, as well as the composite slabs, were all poured onsite during construction. The typical composite slabs are 6.5" thick concrete with fly ash admixture, reinforced by 6x6-w2.1xw2.1 wielded wire reinforcement. Each slab was poured on 2" composite floor decking.

The foundations of the building are comprised of structural concrete walls and piers. Each 2'x2' pier is reinforced with #4 rebar, based on varying sized spread footings on grade. The concrete slab-on-grade system varies in thickness from 5"-8" depending on the structural demands of loads on the space.

Mechanical System

A 46-well, closed loop hybrid geothermal system was installed to achieve the cooling and heating loads for the building. Each well was drilled to a depth 450 feet, all located below the building, on either side of the basement space. Each floor utilizes a hot and cold water loop which transfers heat though two pumps housed in the basement. Each pump is controlled by variable frequency drives that pump the water through the geothermal field. The fully flexible water source heat pump system has a wireless thermostat system and energy recovery unit. The wireless controls on each pump communicate with an overall building temperature control system. Thesis controls also communicate with the geothermal pumps, the cooling tower, and energy recovery unit. The wireless thermostats installed assist in reducing the amount of wiring required for the system, as well as decrease field waste.

A smaller, 150 USGMP supplemental cooling tower was installed to handle the peak cooling load in the summer time. The geothermal capacity becomes less efficient on days that are 95 degrees Fahrenheit or warmer. For the Harrisburg, Pennsylvania region, these peak temperatures make up approximately 1-5% of the annual cooling degree days (CDD).

Electrical System

A 208Y/120V utility service provides the main current for the building. A 3000 amp main distribution panel provides power to the 600 amp house panel located in the mechanical room in the basement of the building. Each floor hosts two 200 amp panel per floor, where each floor is independently metered in order to easily bill tenants for power consumption. Due to the urban location of the site, transformers for the building were installed in an underground vault below the sidewalk. The vault had stringent guidelines by the utility company with regards to access, ADA compliance and dimensions for equipment.

A 47kW photovoltaic solar system was installed on the roof so assist in supplementing utility power consumption. The system hosts a 220 solar panel array which provides power to an emergency power battery backup system, eliminating the need for a generator. Six batteries, located in the basement make-up the battery backup system. The solar panels distribute power to six inverters, three located on the roof, three located in the basement. The building management system implemented in the building reports status, energy usage, and will alarm when equipment fails on the solar array. A Johnson Controls building management system was installed in the Campus Square building. This system is fully integrated into all MEP systems in order to maintain efficiency of all the systems. The management system also allows for educational uses, as the building's utility consumption, and power savings will be displayed within the building.

Building Envelope

Because of the project's intent to achieve LEED Gold classification, the exterior enclosure is designed using high performance materials in order to conserve energy, as well as being conscience about environmental impact. The main entrance is highlighted by a 4-story, painted aluminum-framed curtain wall system. The building utilizes high performance exterior masonry veneer systems, with well insulated walls, foundations, and roof. Energy Star certified operable windows and storefront systems with green tinted, Low E coated laminated glass are used throughout the exterior of the building.

Roofing consists of high performance, white TPO insulated membrane system where a photovoltaic solar system is housed. The TPO system effectively reduces heating and cooling loads on the building, as well as assisting in mitigating the heat island effect of the building's footprint.

Project Cost Evaluation

All cost information in this evaluation is approximated data obtained from Wohlsen Construction's budget for Campus Square

Actual Building Construction Cost

Total square footage of the project is 75,000 SF

Construction Cost	$8,590,000.00
CC/SF	$115.00

Construction costs do not include land costs, site work, permitting, etc.

Total Project Cost

Total Project Cost (TC)	$9,000,000.00
TC/SF	$120.00

Building Systems Costs

Structural Steel Cost (SSC)	$1,300,000.00
SSC/SF	$17.33

Cast-in-Place Concrete (CIPC)	$450,000.00
CIPC/SF	$6.00

Mechanical/Plumbing Cost (MC)	$1,300,000.00
MC/SF	$17.33

Electrical Systems Cost (EC)	$900,000.00
EC/SF	$12.00

Solar System Cost (SS)	$300,000.00
SS/SF	$4.00

Elevator Cost (ELC)	$180,000.00
ELC/SF	$2.40

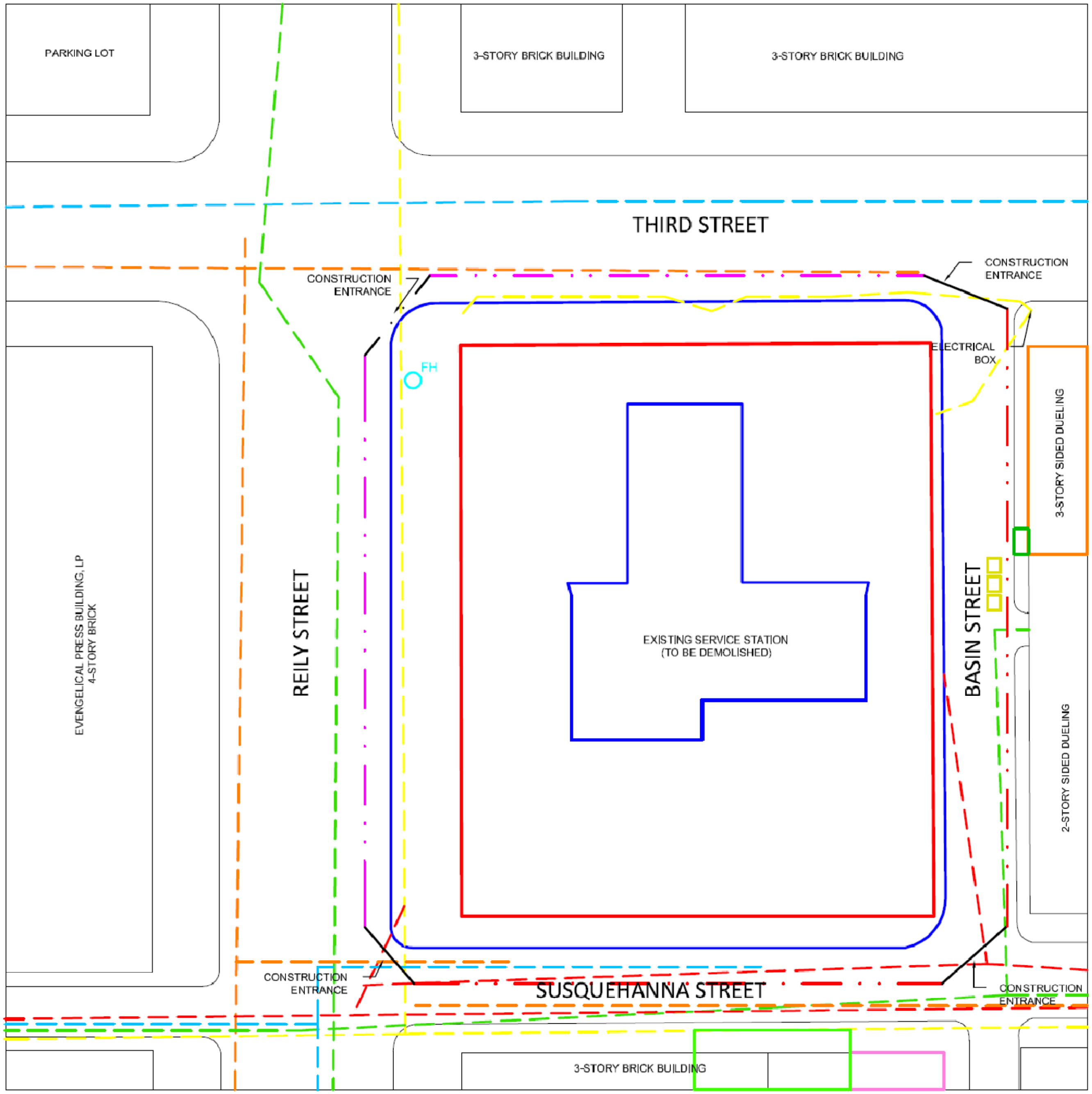
Glass and Glazing Cost (GGC)	$210,000.00
GGC/SF	$2.80

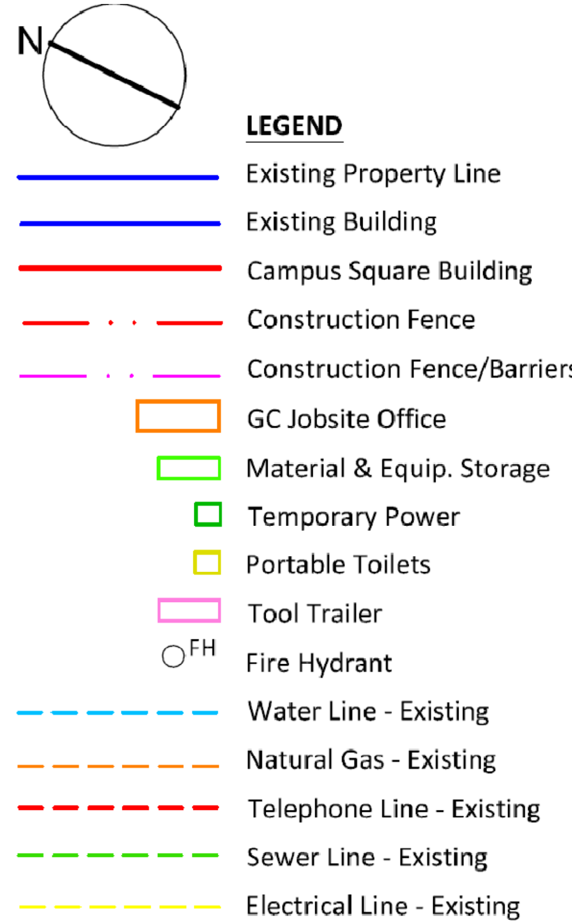
Site Plan of Existing Conditions

Located in the heart of downtown Harrisburg, Pennsylvania, Campus Square's site location resulted in many constructability limitations and logistical challenges. Overcoming these issues and developing a functioning logistical plan was critical to the projects' success. Because the footprint of the building extended to extents of the property line, there was little room for equipment, vehicles, materials, and storage. Furthermore, public pedestrian and vehicular access needed to be maintained along Reily, Susquehanna, and North 3rd Streets; creating an even more difficult problem in ensuring traffic flow, as well as public safety around an active construction zone.

GreenWorks Development, the owner of Campus Square, as well as many surrounding properties in the area, worked with Wohlsen in providing them additional space on nearby properties to be used as dumpster storage, subcontractor parking, and material storage and lay-down space. During weekly subcontractor coordination meetings, the logistical plan implemented by Wohlsen addressed where each contractor would have temporary space within the site. Similarly, equipment was provided by Wohlsen to transport materials, tools, and equipment from the off-site storage locations to the temporary areas onsite. This strategy of moving materials from off-site locations to the Campus Square site resulted in careful planning by both Wohlsen and their subcontractors in determining quantities of materials needed each day.

Please view the site plan of existing conditions on the next page.





CAMPUS SQUARE BUILDING

SITE PLAN OF EXISTING CONDITIONS

FINAL REPORT

Local Conditions

Preferred Methods of Construction

The area of downtown Harrisburg, Pennsylvania were the Campus Square building was constructed is in the Old Uptown Municipal Historic District. Therefore, certain aesthetics of the building had to coincide with the historic planning committee's regulations on new construction. The surrounding buildings from the site are older commercial and industrial buildings that have since been renovated for other uses. No particular construction method or type can be observed in this area other than the vast use of exterior brick masonry.

Availability for Construction Parking

Due to the urban location, and tight property lines, parking, staging, and movement onsite were always a logistical problem. In order to allow for movement within the site, construction fences were pushed out into the adjacent roads. However, public traffic was still able to pass through these areas. Additionally, a temporary parking lot for contractor parking was built, as well as a material staging and stockpiling area, two blocks away. Sever dumpsters were needed to coincide with the waste management plan (wood, metal, drywall, clean fill and waste); these were stored in an empty lot adjacent to the building. The off-site locations used during construction can be viewed in Figure 1 below.

Campus Square Site
Dumpster Storage
Contractor Parking Lot
Material Storage & Lay-down

Figure 1-Temporary Offsite Locations

Image provided by Google Maps

Available Recycling and Tipping Fees

A waste management program was instituted for the project, as well as being a LEED requirement for certification. In all 255 tons of waste materials were taken offsite, 76% of which were recycled. The waste management program cost was estimated at approximately $14,000.00, compared to over $21,000.00. In all, recycling efforts saved nearly $8,000.00 during construction.

Type of Soil/Subsurface Water Condition

Geotechnical reports of the site, performed by BL Companies Pennsylvania, Inc., show surficial layers of asphalt, concrete and fill materials to various depths below grade. The surficial layers were underlain by native soils that primarily consisted of brown to dark-brown clayey silt with layers of brown, black, grey, white, and tan sand and gravel. Weathered shale bedrock was encountered at depths ranging from approximately 11.7 feet below grade, to greater than 20 feet below grade. Indications of wet to saturated material representative of the water table were encountered at depths of approximately 6.5 feet to greater than 20 feet below grade. Many of boring samples concluded with levels of contamination due to gasoline leaks from the existing service station tanks. Soil remediation was required in order to decontaminate the site, as well as prevent future environmental impacts.

Client Information

The owner of the Campus Square building is GreenWorks Development, LLC. Their mission is to work to enhance the quality of life in the region by creating new communities in previously developed urban areas. They believe there is extraordinary value in the restoration of our older, blighted communities, rather than contributing to suburban sprawl by paving over our ever-shrinking open spaces. GreenWorks Development focuses on renewal projects in the 6-County Central Pennsylvania region, with activities currently underway in Harrisburg, Carlisle, and several other midstate communities and townships.

GreenWorks Development has the experience and the expertise required to manage all of the challenges of urban redevelopment. They work closely with state, county and municipal governments, building and property owners, architects and others engaged in revitalization efforts to restore our communities. "We *stimulate* investment; *integrate* the new with the old; and *create* opportunity."

Integrated Community Renewal is important not only because it creates financial value, but also because it boosts community value. GreenWorks Development is passionate about redeveloping urban core and traditional towns, as these communities are thriving with opportunity and hope.

Midtown has long been one of Central Pennsylvania's most unique neighborhoods. The area boasts a diverse racial, ethnic, and socioeconomic fabric that is unmatched elsewhere in the region. While once a thriving community of working class row houses, eclectic retail shops, and industrial activity, Midtown has suffered from years of disinvestment and urban decline. This trend has begun to change. Today, new investments bring the promise of a renewed vibrancy as a thriving retail and office corridor, academic center, and expanding residential area.

The largest project is the Midtown Corporate and Academic Center Development. The project, which began in 2006, proposes nothing short of transforming a 12 acre section of Midtown into a vibrant economic engine for the region. The project is centered at the intersection of 3rd & Reily Streets extending east to Fifth Street, West to Green Street, South to Verbeke Street, and North to Harris Street. The project is a public/private partnership between GreenWorks Development, the City of Harrisburg, and Harrisburg Area Community College (HACC). The targeted Midtown development site has been designated a Governor's Community Action Team priority location, and it is within the City's Enterprise Zone.

GreenWorks Development budgeted $15 million for the completion of Campus Square. Wohlsen Construction Company delivered the core and shell portion of the project, and will soon begin construction on a portion of the tenant fit-outs. Due to the speculative nature of the overall project, the schedule, on the owner's side, did not require any specific demands. Also, because the project was all new construction, occupancy concerns were not an issue for the core and shell portion of the project. Furthermore, once tenant fit-out begins, and the first tenants move in, continued construction will result in occupancy concerns.

As with any project, specifically projects urban in nature, there were numerous safety concerns because of the active public sidewalks and street. GreenWorks Development expressed how the Wohlsen Construction Company did an excellent job managing the site to lower any concerns regarding safety.

It was important to the owner to maintain a high level of budget and quality control; and consequently, were both achieved to satisfaction. Furthermore GreenWorks Development felt it was very important to the overall success of the project that it be awarded with, at a minimum, a LEED Silver certification. Not only was the goal met, but extra efforts contributed to the structure being awarded a LEED Gold rating.

Project Delivery System

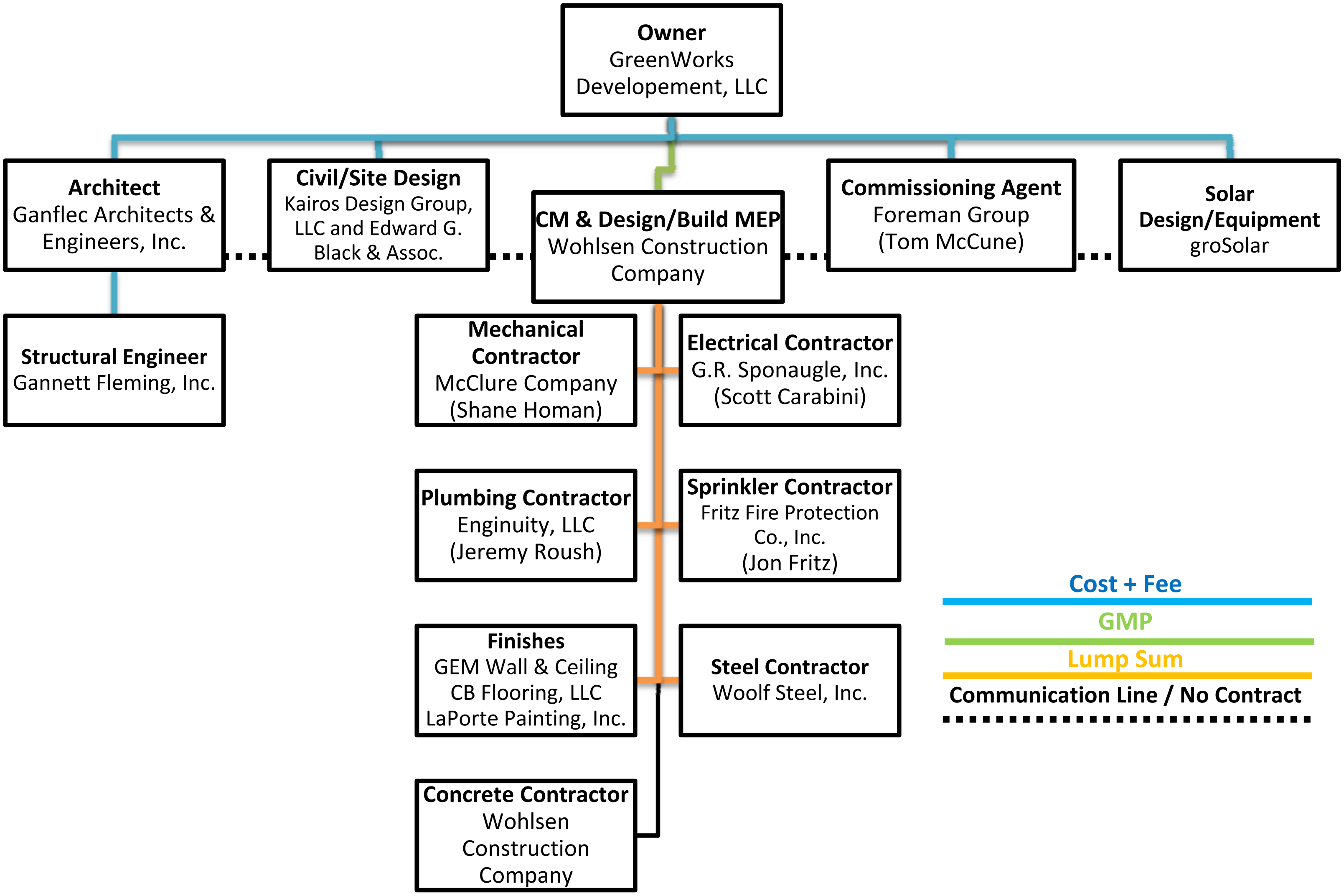


Figure 2 – Project Organization Chart

The project delivery method for the Campus Square project was design/build, with Wohlsen Construction Company as the construction manager at risk. A GMP contract was developed with GreenWorks development, and Wohlsen assisted mainly with the MEP design/build portion of the project. This contract type was chosen because of the ability to expedite the construction process, as well as maintain a higher level of cost control.

A GMP contract between GreenWorks and Wohlsen was the best solution to delivering a successful project because it allowed for a shorter design period before construction could begin. Furthermore, Wohlsen was able to start procuring subcontractors and initializing contracts while the design for later phases of the project were still being finalized. Similarly, a GMP contract also enabled Wohlsen to initiate and purchase long LEED items such as steel and transformers, which would assist in avoiding schedule growth and cost escalation.

Wohlsen awarded subcontract contracts mostly through a lowest-bidder process. However, in some instances, Wohlsen was not always confident in some of the low-bid subcontractor’s performance capabilities to perform the work to the owner’s standards and expectations. Each contract was a lump sum contract type. Payment and performance bond were required for all design/build contractors, as well as contracts over $500,000. The low-bid contracts Wohlsen had with their subcontractors assisted in keeping overall costs down, as well as helped deliver the project to the owner with the best possible value.

Critical Industry Research

Exterior Wall Systems and Building Envelope Study

Background Information

Energy efficiency in buildings has become a very important facet in the construction industry, not only as a means of sustainability, but also as an important way of reducing energy consumption and costs. With rising energy costs, it is critical to deliver a well designed and constructed building. A building's envelope is a critical aspect of energy efficiency and sustainability, as thermal losses though the exterior of a building can be very costly, and make for an uncomfortable space to work and live in. GreenWorks Development incorporated a more efficient exterior wall assembly as a means to mitigate thermal loss, as well as sustainability implications. Although the system used was more expensive than a standard masonry veneer assembly, the owner was willing to pay more upfront, with the thought of savings in operational costs attributing to a faster payback period.

Goals

The goal of this analysis is to research emerging technologies and trends associated with building envelopes, specifically exterior wall assemblies, as well as the constructability impacts associated with these technologies.

Methods

- Conduct literature reviews and professional articles associated with building envelope technologies
- Research systems which have proven to be thermally efficient
- Analyze systems which could be implemented on Campus Square
- Understand constructability constraints of different exterior wall systems
- Develop conclusions about the importance and impacts of efficient exterior wall systems

Resources

- Professional journals and articles on the topics of building envelopes
- Whole Building Design Guide (www.wbdg.org)
- ToolBase Services (www.toolbase.org)
- Wohlsen Construction

Expected Outcome

Through this analysis, I hope to become more familiar with the importance of high performance exterior wall systems, as well as emerging trends and technologies on this topic. Also, it will be important to realize constructability issues of implementing difference systems onto Campus Square. Furthermore, I hope to discover potential systems which may be applied to Campus Square in order to propose an alternative system which would make the building an even more efficient and sustainable structure.

General Considerations for Exterior Wall Systems

Perhaps the most important aspects which can affect an envelope system are the impact of air and moisture through the assembly. Understanding how material selection, design, and construction relate to the long-term durability and performance of a building enclosure is paramount. Moisture travels from high temperatures to lower temperatures, from a higher pressure to a lower pressure, and from areas of higher moisture content. However, these can be affected by interior and exterior air pressure differences, moisture loads, and material vapor pressure differences. The location, source, and prevention of air and moisture through an assembly must be realized during the design and construction process in order to properly deliver a durable building.

An effective building enclosure should also include a continuous and defined air barrier that is rigid enough to survive wind loading and air pressures across it, durable enough to remain intact throughout construction, and installed in such a way that it is continuous between building elements. In a mixed-humid climate, a wall assembly should not incorporate an air barrier material that also has vapor retarder properties. Depending on where the air barrier is placed in the assembly it has the potential to hamper drying to the interior in warmer months and to the exterior in colder months. In other climates (cold, hot-humid) it is not desirable to have the air barrier material have vapor retarder properties if it is to be placed on the cold side of the wall, since this can create a moisture problem during drying. Figure 3 below demonstrates potential air and moisture infiltration paths.

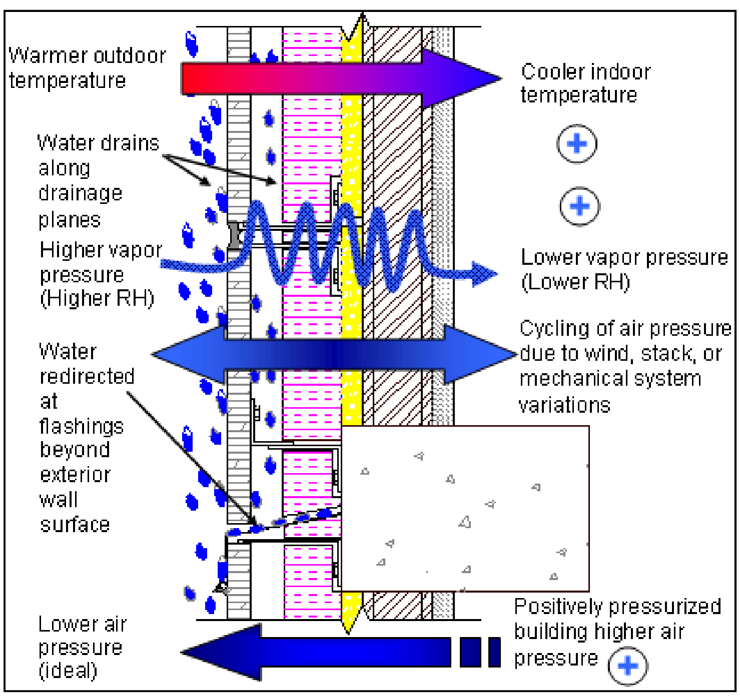


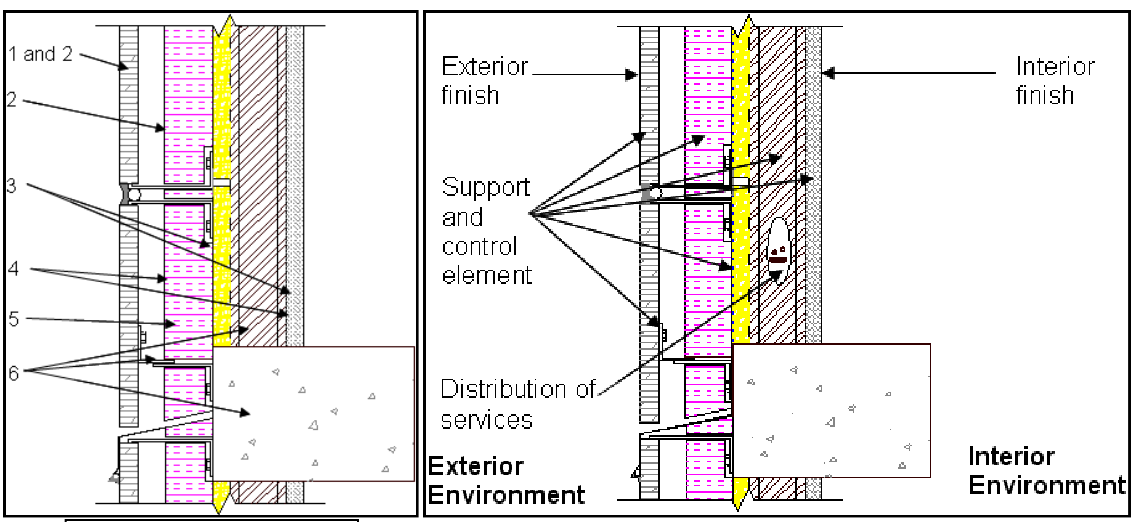
Figure 3 –Air and Moisture Transfer Diagram

Image courtesy the Whole Building Design Guide

A moisture problem generally occurs when the building element susceptible to damage (such as rot, corrosion, and microbial growth) is exposed to air, and allowed to remain "wet" at a level that is above its safe storage capacity for moisture for an extended period of time. This can occur when a building element is exposed to direct and repeated rainwater penetration, or is otherwise inhibited in some way from effectively "drying" due to improper design and/or construction. If left untreated, these materials will then create a condition inside the wall assembly that is prone to mold development and other moisture related damages. Many thermal and moisture problems can be prevented with proper installation of a wall assembly. Joints, cracks, penetrations, and other areas on the wall surface where air and moisture barriers are compromised must be properly sealed and designed for. These problematic areas commonly occur around windows, doors, panel and wall joints, flashing locations, MEP rough-in locations, and termination points.

Campus Square's Exterior Wall System

Campus Square implemented a cavity wall as the primary exterior wall system throughout all faces of the building. This common exterior wall type and method of construction is fairly popular in many regions of the United States. This is due to the redundancy of this type of wall assembly to resist rainwater infiltration, as well as its routine construction sequence. The cavity wall system used for Campus Square relies upon a concealed air space and drainage plane to effectively resist moisture penetration, as well as improve upon the thermal performance of the building enclosure where the cavity acts as an insulator. Figure 4 below demonstrates a typical cavity wall assembly.



1. Exterior Cladding
2. Drainage Plane
3. Air Barrier System
4. Vapor Retarder
5. Insulating Element
6. Structural Element

Figure 4 –Typical Cavity Wall Assembly

Image courtesy the Whole Building Design Guide

Cavity walls, such as the one used for Campus Square include an exterior cladding element; in this case a brick veneer, to act as the main defense against the majority of outside weather conditions penetrating through the wall. A drainage and air space backs the brick veneer, which is designed to collect, control and drain moisture penetration which passes through the exterior cladding. This space is passively ventilated in order to prevent moisture from traveling into "dry" sections o the wall assembly through penetrations. Furthermore, the cavity space is backed by a Tyvek® drainage plane which serves as a barrier within the wall assembly between "wet" and "dry" sections of the wall. This material prevents condensation and mold growth within the dry space of the assembly. It is important that this layer have well sealed areas where penetrations occur in order to reduce moisture penetration. Finally, the insulating layer, which is located behind the DensGlass® sheathing, protects against thermal infiltration between the inside and outside temperature gradient. Figure 5 on the following page depicts the cavity wall assembly installed on Campus Square. Exterior insulation (outside of the sheathing) was not implemented on Campus Square, and may have resulted in better thermal properties through the assembly. Instead, batting insulation was placed between the metal studs.

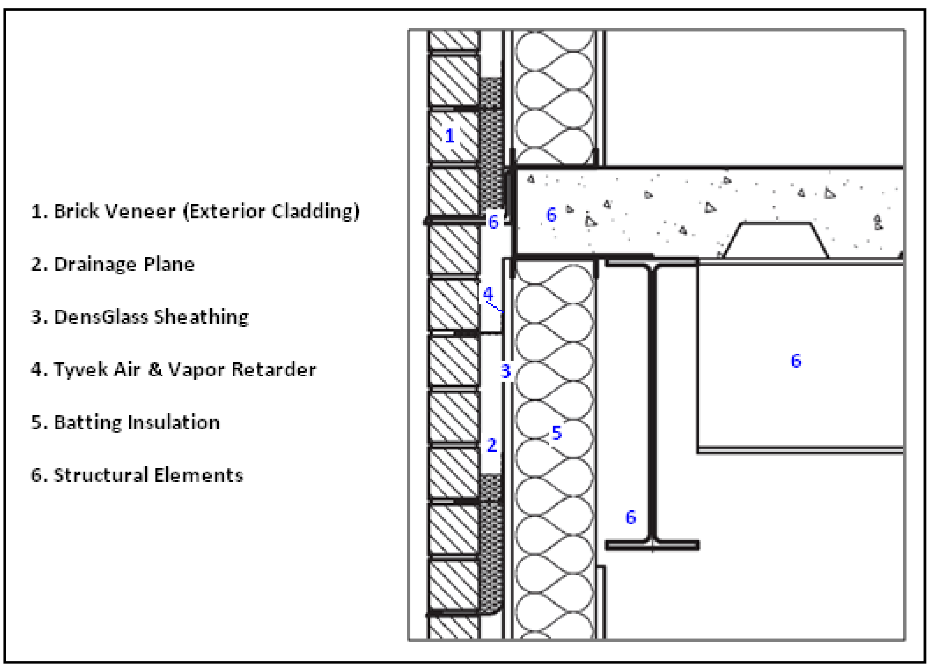


Figure 5 –Campus Square Exterior Wall Assembly

Drawing provided by Wohlsen Construction

Cavity Wall Constructability Concerns

Cavity walls offer an array of aesthetic designs, material selections, as well as versatile construction methods and tolerances for various building types. The different assembly options for cavity walls can produce effective thermal and moisture barriers; however construction methods of this wall type can severely reduce the efficiency of the system, resulting in costly deficiencies. It is also important to understand that improperly designed/ constructed cavity wall systems can be costly to properly repair after construction is complete. Throughout installation of the cavity wall system, it is important to maintain an effective envelope quality assurance program in order to ensure each wall element is properly designed for, and installed to specification standards. Similarly, it is critical that joints and penetrations along the wall face be properly sealed to prevent additional thermal and moisture leaks. Because this is true, flashing locations along the exterior wall must be installed carefully.

If moisture is able to leak into the "dry" space of the building, it can result in corrosion of steel elements, as well as mold growth, which may remain undetected before the issue become evident. Repairing these deficiencies can result in negative aesthetic impacts, as well as interfering with the use of the space. Similarly, pressure-equalized, "rain screen" cavity wall systems, place the primary drainage plane, and principal air barrier in the same plane between the wet and dry zones of the wall assembly. Rain screens diminish the forces attempting to drive moisture into the wall. There are two types of rain screens: simple rain screens and pressure-equalized rain screens (PER). Examples include brick veneer cavity walls, furred-out clapboard walls, and drainable EIFS.

However, the principal advantages of the rain screen system, which is to prevent a negative air pressure differential from occurring across the exterior wall assembly (a condition that can "draw" rainwater through the enclosure and into the building), can also be extremely difficult to effectively achieve in the field. This constructability issue can be attributed to the complicated detailing required at penetrations through the air barrier and drainage plane; including the attention to detail and workmanship needed to correctly seal the penetrations to prevent undesired inward airflow through the assembly.

Alternative Exterior Wall Systems

Barrier Wall

Another commonly used exterior wall system is the barrier wall, which implements a weather-tight outermost exterior wall surface and construction joints to resist moisture and thermal infiltration. A barrier wall system, if effectively installed, can improve upon the thermal performance of the building. Due to the reduced amount of penetrations through the air and moisture barrier, thermal bridging is mitigated. This wall type is commonly associated with precast concrete spandrel panels, certain types of composite and solid metal plate exterior cladding systems, and early generation exterior insulation and finish systems (EIFS). Barrier walls are often considered a more cost-effective and preferable alternative to cavity and mass wall assemblies. Figure 6 on the following page compares a cavity wall system with a barrier wall assembly.

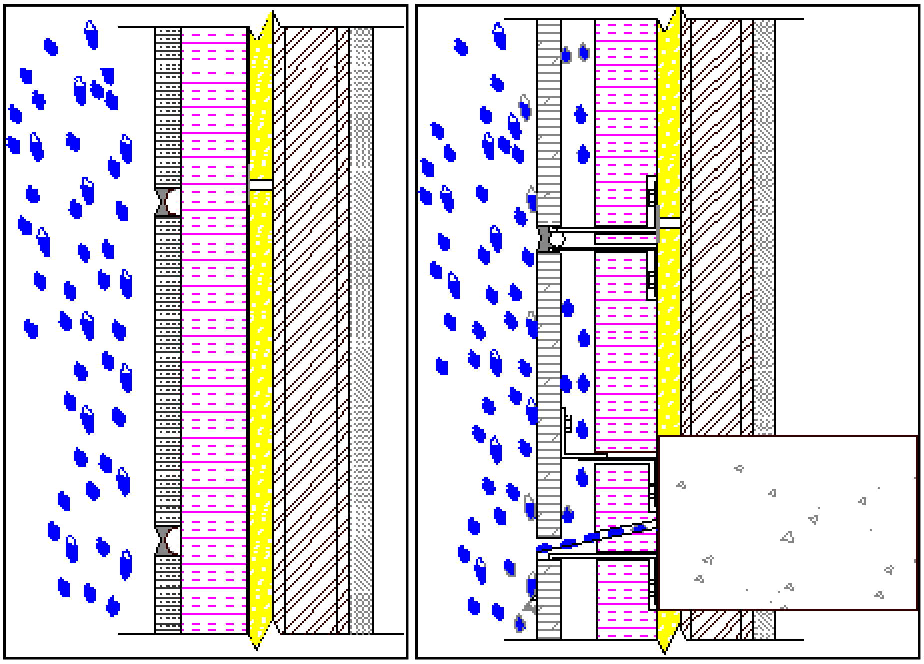


Figure 6 –Left: Barrier Wall Diagram; Right: Cavity Wall Diagram

Image courtesy the Whole Building Design Guide

Barrier Wall Constructability Concerns

Barrier wall systems only offer a single line of defense against moisture penetration due to the lack of cavity/drainage space. Also, they require more sophisticated design and constructability efforts, including workmanship in the field. Furthermore, barrier walls require a high degree of maintenance in order to keep the design performance of the assembly. Because this is true, any defect in design, installation, or workmanship can result in immediate moisture and thermal penetrations through the wall. In order to reduce the amount of field installation and construction, barrier walls offer the ability for prefabrication. The controlled environment of the prefabrication manufacturing process assists in reducing constructability issues such as moisture and thermal leaks through seam and penetrations. However, joints will still exist where each panel is connected when installed on-site; thus, close supervision and quality control is essential in ensuring construction is performed to design specifications.

Exterior Insulation and Finish Systems (EIFS)

A potential finish material which could be applied to Campus Square is EIFS. The EIFS systems can be implemented in both drainable or barrier systems, accomplishing a traditional masonry brick exterior. Because Campus Square is aesthetically confined to the historical design requirements of the area, not all wall systems will be applicable as a potential substitution. Although EIF systems can be more costly when compared to a traditional masonry façade, if installed properly, can provide improved thermal properties and efficiency.

EIFS is available in two basic types: a barrier wall system or a wall drainage system. Barrier EIFS wall systems rely primarily on the base coat portion of the exterior skin to resist water penetration. Therefore, all other components of the exterior wall must either be barrier type systems or be properly sealed and flashed to prevent water from migrating behind the EIFS and into the underlying walls or interiors. Wall drainage EIFS systems are similar to cavity walls; they are installed over a weather barrier behind the insulation that acts as a secondary drainage plane. The weather barrier must be properly flashed and coordinated with all other portions of the exterior wall to prevent water from migrating into the underlying walls or interiors.

EIFS Constructability Concerns

As with other barrier and cavity wall systems, failure to correctly install joint sealants around penetrations through the wall and wall seams can severely reduce the advantage of an EIFS system. Proper flashing at the wall/roof termination point, as well as around windows is essential during construction. Also, because EIFS is not as durable as masonry or metal cladding systems, it is more prone to damage. Because this is true, damage from ropes, cables, impact damage, etc. must be corrected immediately to prevent further thermal and moisture damage to the integrity of the assembly.

Precast Concrete Spandrel Panels

Wohlsen Construction performed nearly all the concrete work for Campus Square. This helped reduce costs in paying for installation fees from subcontractors. However, precast concrete panels may reduce construction duration, accelerating the building envelope construction time. Precast concrete wall systems allow a wide variety of colors, finishes and architectural shapes. Precast concrete can be used in environments that allow the use of conventional cast-in-place concrete, which benefits Wohlsen's self-perform concrete advantage. In addition, precast concrete may be made in a controlled environment, improving quality, and erected in an environment that would not allow site casting of concrete. Applicable precast concrete panel types for Campus Square include cladding or curtain walls, load-bearing wall units, and shear wall.

Precast cladding or curtain walls are the most common use of precast concrete for building envelopes. These types of precast concrete panels do not transfer vertical loads but simply enclose the space. They are only designed to resist wind, seismic forces generated by their own weight, and forces required to transfer the weight of the panel to the support. Common cladding units include wall panels, window wall units, spandrels, mullions, and column covers. These units can usually be removed individually if necessary.

Load-bearing wall units resist and transfer loads from other elements and cannot be removed without affecting the strength or stability of the building. Typical load-bearing wall units include solid wall panels, and window wall and spandrel panels.

Precast concrete shear wall panels are used to provide lateral load resisting system when combined with diaphragm action of the floor construction. The effectiveness of precast shear walls is largely dependent upon the panel-to-panel connections. Panel-to-panel connections, as well as construction joints, as with the previously mentioned systems, must be designed considering structural, thermal, and panel movement.

Mass Wall Systems

Different from cavity wall systems, where the wall assembly hosts a wall cavity and through-wall flashing to collect moisture to the building exterior, mass walls incorporate a combination of wall thickness, storage capacity, and bonds between masonry units and mortar to resist thermal and moisture penetration. These systems are usually more expensive, and therefore, less common in application because of material and installation costs. Furthermore, moisture penetration through mass walls systems is more difficult to track and repair due to the nature of the assembly. Evaporative drying across this type of wall assembly can result in efflorescence, deterioration of interior cement finishes, and organic growth on the interior and/or exterior wall surfaces. These problematic features not only degrade the aesthetic appeal of the wall, but also can lead to severe moisture damage if not remedied.

Rain protection of mass walls, and understanding the rate the wall will get wet, the amount of moisture it is capable of storing, and the drying rate become important design considerations, as exceeding the safe storage capacity for long periods of time may create long term moisture problems for the surrounding materials that might come in contact with the mass wall. Cavity walls operate similar to barrier walls in that they rely on the materials used to resist moisture and water penetration. However, unlike barrier systems, they tend to be more prone to infiltration due to the amount of absorption that occurs through the porous mortar and masonry units. Figure 7 below demonstrates moisture infiltration, as bulk rainwater penetrates through the mass wall assembly.

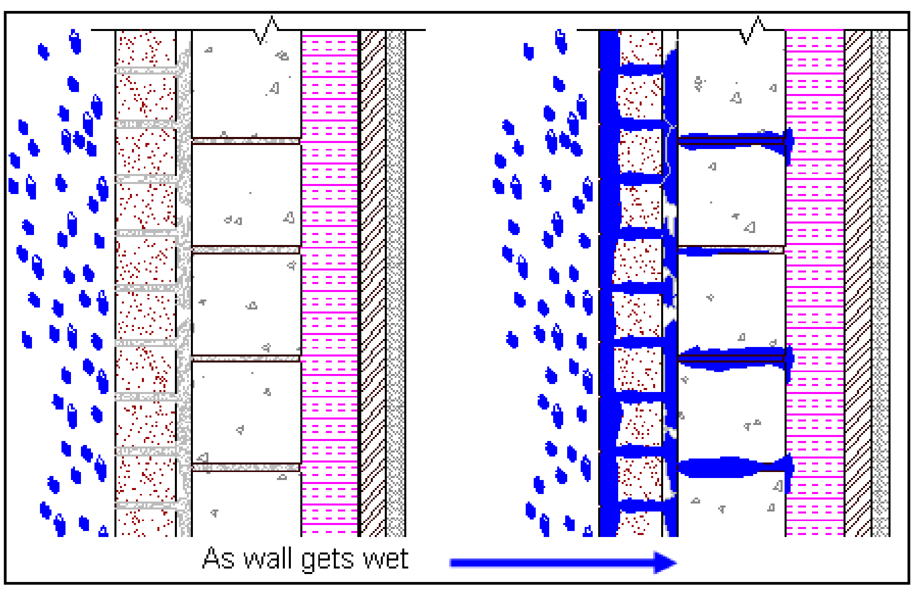


Figure 7- Mass Wall Moisture Penetration

Image courtesy the Whole Building Design Guide

Mass Wall Constructability Impacts

The installation of the brick veneer system of Campus Square consumed approximately eight weeks before it was complete. The incorporation of a mass wall system using masonry block would probably result in an even longer installation duration. Because this is true, implementing a mass wall would not be a practical substitution to the as-built assembly. Furthermore, due to the amount of on-site construction this wall takes, it can be assumed that a lesser quality of construction may occur. This degradation may result in a poorer performing envelope, resulting in higher operational costs.

Emerging Issues- Hybrid Exterior Wall Systems and Emerging Technologies

In recent years, technological advancements in the design and manufacture of building enclosure materials, components and systems, together with an increasingly refined understanding of air/moisture transfer and the behavior of wind-driven rain on the building enclosure have lead to the development of several hybrid and sustainable exterior wall systems. The following wall systems could act as possible additions to Campus Square, in an effort to further enhance the sustainable features and efficiency of the building.

Hybrid wall systems typically include design features and individual building elements that are intended to improve or enhance the long-term durability and performance of the building enclosure, and are often adapted in response to issues and concerns that are unique to a particular geographic area and/or climatic region in which a building or structure is to be designed and built. Many of these hybrid systems have varying short and long-term costs, maintenance burdens, durability, and modified performance areas of the building enclosure.

Trombe Walls

A trombe wall system is made of dark-colored masonry, stone, or concrete which have the ability to absorb and store energy from the sun. The advantage of implementing this system is to reduce mechanical heating and cooling costs throughout the year. Installed on a south facing wall, which experiences the most sun exposure of any direction, the thermal massing element is fronted with glazing which allows sunlight to pass through into the wall. Throughout the day, sun heats the south face of the wall and warms it. The heat is released back into the interior occupied space when the sun is no longer shining. Ideally, an appropriately-sized overhang is necessary to block out the high summer sun when heat gain is unwanted, yet still allow the low winter sun to penetrate through the trombe wall. As the sun heats the wall, causing heated air to rise in the air space, the heated air is directed into the building through vents at the top of the wall, passively drawing cooler air into the vents at the base of the wall to be heated in turn. At night, dampers close off the walls, preventing reverse thermo-siphoning (cold air from the cavity falling and entering the building at night), while heat stored in the mass walls is released throughout the space at this time. In summer, the walls are vented at night, allowing for passive cooling. Thermal mass has a lower initial temperature than the surrounding air and acts as a heat sink, therefore cooling the room. Figure 8 on the following page captures the basic idea and application of a trombe wall system.

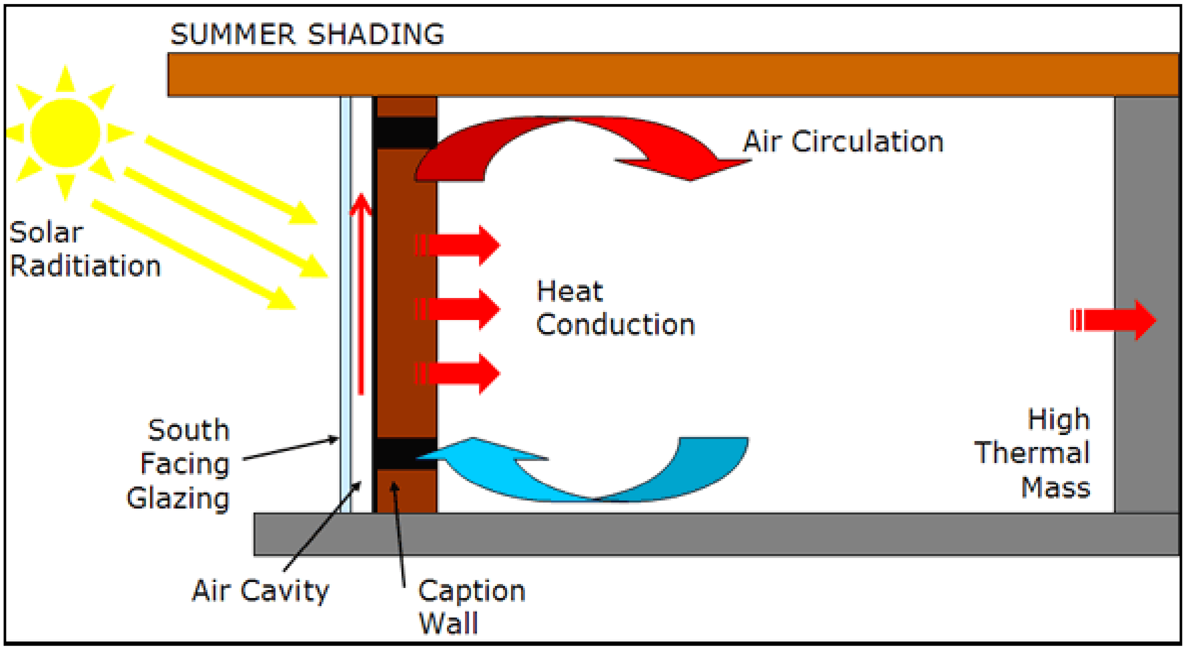


Figure 8 –Trombe Wall Heating and Cooling Diagram

Image courtesy the Druk White Lotus School

A trombe wall system could be implemented along the south face of the Campus Square building. However, due to the tight property line to adjacent buildings, the effectiveness of this system would be limited. Neighboring buildings may prevent too much shading onto Campus Square, preventing winter solar radiation to actively penetrate the wall space. Therefore, additional solar studies would need to be performed in order to justify the installation of a trombe wall system.

Dynamic Buffer Zone Systems

A Dynamic Buffer Zone (DBZ) performs the function of the air barrier in a building envelope, which protects the exterior façade from exposure to interior air moisture. The DBZ system creates conditions in an existing or purpose built air space (DBZ cavity) located within an exterior wall that effectively separates the interior and the outdoor environments. Conditions within the DBZ cavity that need to be controlled are air pressure, moisture content, and temperature.

To effectively prevent exfiltration of humid interior air through the building envelope during cold weather, the air pressure of the DBZ cavity is maintained slightly higher than the interior air pressure. Theoretically, the cavity air pressure needs only to be nominally higher than that of the interior space to prevent air leakage from the interior. During winter conditions, outdoor air will have a low moisture content which makes it an ideal air supply for the DBZ cavity. The requirement for pressurization of the DBZ cavity will ensure that interior humid air will not leak outwards into the building envelope. If any leakage of air from the cavity to the outside occurs, the low moisture content of the DBZ air will eliminate the threat of condensation within the building envelope.

There are two possible modes of operating the DBZ system. The first option is known as a "balloon" system where air is pumped into the cavity with no intentional exhaust air. That is, when the pressure inside the cavity drops below a specified lower limit, fans are activated to pressurize the cavity to the specified upper limit. The air inside the cavity will then leak out through the cracks of the exterior wall and through any imperfections in the interior wall finish until the lower prescribed pressure limit is reached, after which the process will repeat itself. The alternate mode is the exhaust system. This system entails supplying a continuous flow of air into the cavity and intentionally exhausting air from it so that the pressure within the cavity is maintained at a predetermined level. How and where the air is exhausted is dependent on a number of factors that are largely determined by the particular building involved.

The exhaust mode of operation allows for a great amount of versatility to the DBZ system. By controlling the flow rate and the initial temperature of the DBZ air, the system can act as both an air barrier and as a dynamic insulation system that can provide greater thermal efficiencies when compared to the same envelope without airflow.

Additional advantages of the exhaust DBZ system are its ability to promote drying of the masonry following rain penetration, to allow airborne contaminants to be contained in a space and controlled, and to increase the temperature of interior finishes of the exterior wall by supplying warm DBZ air. This will eliminate drafts associated with uninsulated walls and will increase thermal comfort.

In addition to walls and roofs, the DBZ system can also incorporate windows. Additional thermal comfort and condensation control can be provided by increasing the interior surface temperature of windows, allowing higher indoor humidities. This system can also eliminate the need for convection units below windows that are used to mitigate cold drafts.

Outdoor air is an ideal source for the DBZ air because of its low moisture content during winter conditions. Since winter outdoor air temperatures are much cooler in northern climates, some heat must be added to the DBZ air before it is introduced into the cavity. Although the temperature of the cavity air supplied is not important when dealing with the prevention of air exfiltration, it is important from the perspective of thermal comfort, surface condensation, and operating costs.

Buildings which are humidified and pressurized often suffer from wall or roof cavity condensation due to imperfect air sealing, higher indoor humidity and an air pressure difference. Air pressure differences may occur from stack effect, fan pressurization or wind. Efforts to upgrade the air tightness of building envelopes to prevent condensation have not been entirely successful. Furthermore, ventilation design produces ever increasing indoor building pressure conditions. For these reasons an alternate technology such as a DBZ system, which can control construction cavity condensation effectively, without the necessity of perfect design or perfect construction is gaining understanding and market acceptance for many types of buildings, including high and low-rise office buildings.

Double-Skinned Façades

A Double Skin Façade is a system consisting of two glass skins placed in such a way that air flows in the intermediate cavity. The ventilation of the cavity can be natural, fan supported or mechanical. Apart from the type of the ventilation inside the cavity, the origin and destination of the air can differ depending mostly on climatic conditions, the use, the location, the occupational hours of the building and the HVAC system implemented. The glass skins can be single or double glazing units with a distance up to 6ft. Often, for protection and heat extraction reasons during the cooling period, solar shading devices are placed inside the cavity.

The solar properties of the Double Skin Façade do not differ from the Single Skin Façade. However, due to the additional skin, a thermal buffer zone is formed which reduces the heat losses and enables passive solar gains. During the heating period, the preheated air can be introduced inside the building providing natural ventilation with retained good indoor climate. On the other hand, during the summer overheating problems were mentioned when the façade was poorly ventilated. Different configurations can result in different ways of using the façade, proving the flexibility of the system to different climates and locations.

Double Skin Façades for office buildings were developed mostly in Europe in order to arrive at increased transparency combining acceptable indoor environment with reduced energy use. The main disadvantage of this system is that in countries with high solar gains the air temperatures inside the cavity are increased during periods with warm weather, leading to overheating problems. The thermal discomfort leads to higher energy consumption for cooling, in turn, leading to lesser energy efficiencies. The Double Skin Facades are systems that highly depend on the outdoor conditions (solar radiation, outdoor temperature, etc) since they allow the outside conditions to influence the indoor climate. Thus, it is obvious that each Double Skin Façade has to be designed for a certain building location and façade orientation otherwise the performance of the system will not be beneficial.

Different panes and shading devices result in different physical properties. The interior and exterior openings can influence the type of flow and the air temperatures of the cavity. All together these parameters determine the use of the Double Skin Façade and the HVAC strategy that has to be followed in order to succeed in improving the indoor environment and reducing the energy use. It is necessary for the design approach to be overall considering the façade as an integrated part of the building and detailed enough in order to determine all the parameters that will lead to a better performance. Figure 9 on the following page demonstrates the functionality of a double-skinned façade system.

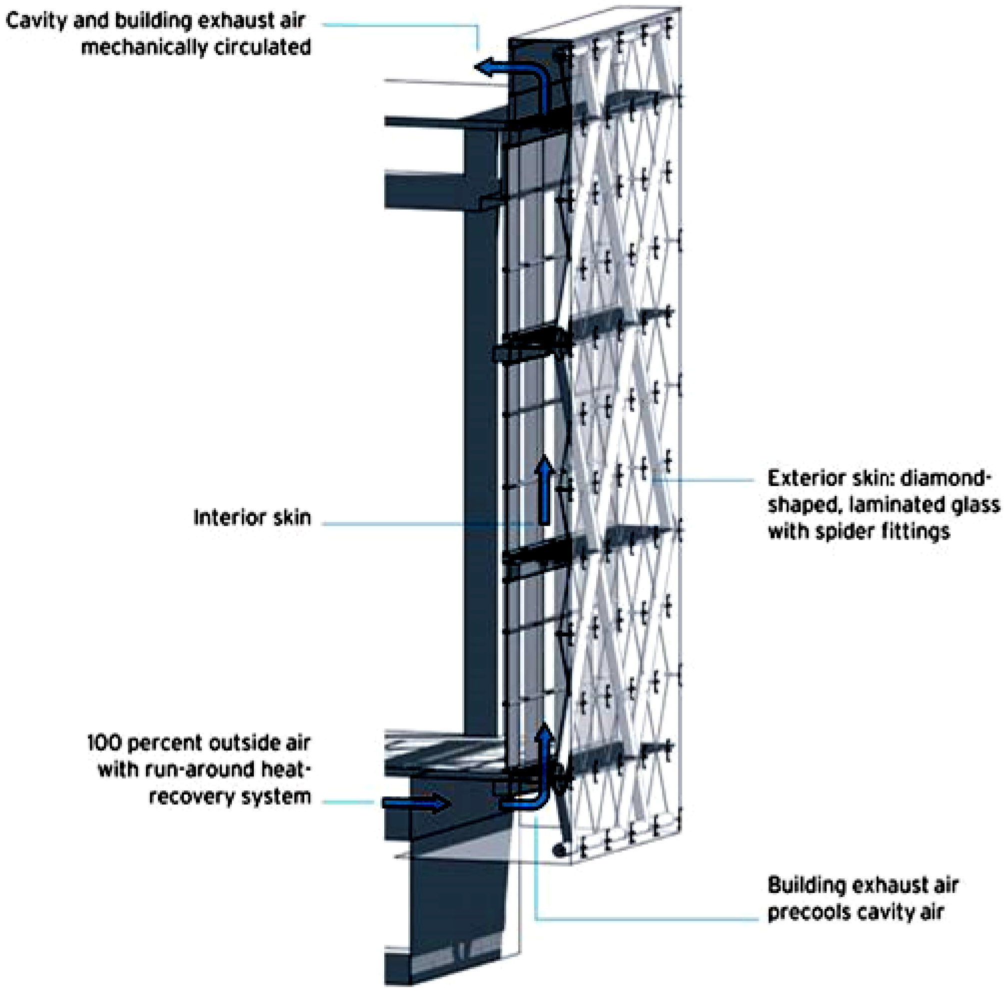


Figure 9 –Double-Skinned Façade System

Image courtesy of the Design Build Network

As mentioned in the description of this system, a double-skinned façade depends greatly on the existing conditions of the building, as well as its location. The implementation of this system on Campus Square could potentially be realized, however, further mechanical analysis, as well as solar studies would need to be performed.

Conclusions and Recommendation

The incorporation of sustainability in Campus Square is evident in GreenWorks efforts to build a LEED® Gold building. Additional sustainable systems could indeed be incorporated into Campus Square as means to advance the building to a LEED® Platinum structure. The aforementioned exterior wall types and envelope systems are a few potentially applicable methods which could be used to accomplish that feat. However, extensive analysis would need to be performed in determining the associated costs and payback periods of each system. Although these systems may prove beneficial to the structure, the limitations of the physical site location may impede upon application due to the dependence of thermal efficiencies on non obstructed solar gains. In short, perhaps under a different site location, with more exposure on the faces of the building, these systems may be more appropriate. However, the south face of Campus Square is backed with more buildings, masking much of the wall from sun exposure. The construction management depth analysis will focus more on a prefabricated wall system as a substitute for the as-built methods.

Construction Management Depth Analysis

Prefabricated Exterior Panels: Construction Sequence, Cost, and Schedule Impacts

Background Information

The exterior walls for Campus Square were constructed implementing a 4.5" masonry brick veneer with metal stud backing. The exterior walls were all constructed on-site over the course of approximately 11 weeks, including the curtain wall systems. The exterior masonry veneer took longer to complete than the original proposed duration of four weeks, which lengthened the overall duration of the project.

During preconstruction, Wohlsen Construction along with GreenWorks Development had initially proposed implementing a pre-fabricated wall system in order to accelerate the schedule. However, this idea was value engineered out early in the conceptualization of Campus Square due to the lack of tenant interest at the time, and associated costs of prefabrication.

Figure 10 –Installation of the Exterior Wall System

Image provided by Wohlsen Construction

Goal

If GreenWorks Development was able to secure tenants for Campus Square early in the preconstruction phase of the project, a prefabricated system could have been ideal in order to accelerate the schedule, and begin leasing out the building. The goal of this analysis is to determine the construction schedule and cost impacts of implementing a prefabricated exterior wall system on the Campus Square project.

Methods

- Consult with manufacturers of prefabricated wall systems to determine appropriate systems which may apply to Campus Square.

- Consult with Wohlsen Construction project manager for construction sequence considerations and cost impacts, as well as feasibility of proposed system.
- Determine cost impacts to General Conditions and building shell
- Determine construction sequence changes, and project duration changes
- Develop new construction schedule and costs analysis for the proposed prefabricated system

Resources

- TEAM Panels International
- KERR Interior Systems Ltd. & Composite Building Systems Inc.
- Manitex Crane Guide
- Wohlsen Construction
- Microsoft Project
- R.S. Means Cost Data

Expected Outcome

By implementing a prefabricated system for the façade of the building, I expect an accelerated enclosure duration once the superstructure is erected. Furthermore, the prefabricated system will allow for interior work to commence sooner due to the envelope of the building being completed sooner. However, this method will result in a higher CSF for the prefabricated wall assemblies, and will also result in a crane needed onsite to erect the panels. Overall, the wall panels will have a higher direct cost than the method implemented, however savings will occur in General Conditions costs, as well as schedule duration.

Actual Construction Sequence

Construction of the exterior façade was conducted entirely onsite. The sequence implemented, following the completion of the superstructure and cast-in-place concrete decks, was to essentially install each material used in the exterior wall assembly by wall face. Lifts were used in installing framing, sheathing and windows, which were followed with an adjustable scaffolding system during the brick veneer installation. Figure 11 below depicts the exterior façade during construction.

Figure 11-Exterior Façade Construction

Image provided by Wohlsen Construction

Scaffolding was erected, beginning with the west elevation, continuing counter-clockwise around the building. However, the east face of the building was left incomplete to allow for material access locations until enough material was stockpiled to complete the interior of the building. The brick veneer took approximately 8 weeks to complete, and the entire building shell was completed in approximately 3.5 months. A scaffolding sequence plan for the brick façade can be seen in the Figure 12 below. The curtain wall system was completed a few weeks later in order to allow for additional material access areas to the upper floors, after the east wall was completed.

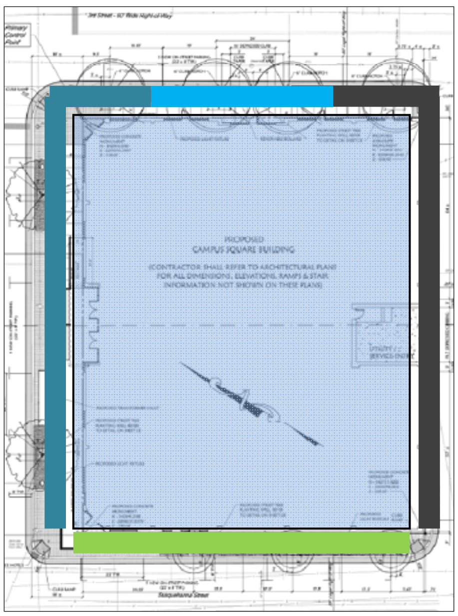


Figure 12- Scaffolding Installation Sequence

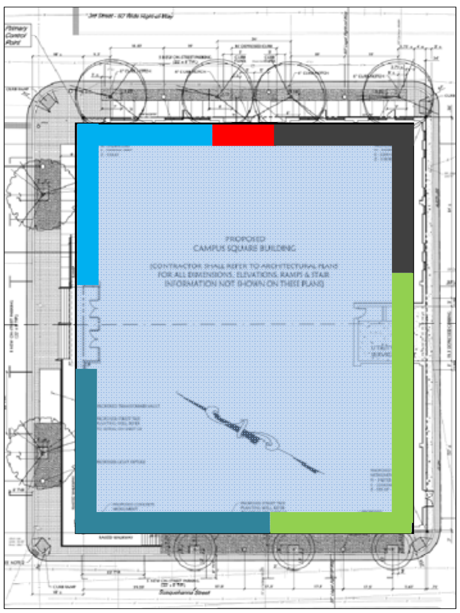
Image provided by Wohlsen Construction

Proposed Construction Sequence

For this analysis, interviews were conducted with TEAM Panels International and KERR Interior Systems Ltd. & Composite Building Systems Inc. (prefabrication manufacturers), as well as Wohlsen Construction, in order to formulate an appropriate construction sequence for the installation of the prefabricated wall panels.

The completed wall panels will be brought to the material storage and lay-down space located off of Susquehanna Street, south of the construction site. Once the superstructure is completed, and the slabs on deck are set, installation of the wall panels can begin. The panels will be loaded onto flatbed trailers at the storage locations, and then transported to the construction site in their appropriate sequence. For logistical simplicity, the 150-ton hydraulic truck crane used for steel erection will be implemented for the installation of the wall panels as well. The construction sequence used for the installation will be similar to the method used during the actual steel erection of Campus Square; where the on-site delivery rate of the panels will coincide with the daily installation rate for a crew. A crew can install approximately six wall panels per day, which includes attaching each wall panel to the superstructure of the building. Therefore, approximately four trailers will be required to make on-site deliveries of the panels per work day. Additional time will be built into the schedule in order to allow for the multiple crane deployment locations.

Installation of the panels will begin on the northwest corner of Campus Square, working counterclockwise toward the northeast corner. Each wall will begin with the installation of the first floor panels, completing each floor before moving to the next. The tight confines of the site, as well as interference from existing overhead power lines, limit the ability of crane movement around the perimeter of the site. Figures 13 and 14 depict the panel installation sequence. A small amount of the exterior brick façade will need to be completed before the panels can be installed. This is due to the slope of the site, specifically located along the north, south, and west walls. The brick façade will need to be installed up to the base of the first floor base elevation marker; this work will be complete from October 8 through November 4 (additional time is permitted due to the critical path of the project).



Panel Installation Sequence

- 1- NW Corner *(4 Days)*
- 2- SW Corner *(4 Days)*
- 3- SE Corner *(3 Days)*
- 4- NE Corner *(4 Days)*
- 5- East Wall: Construction Entrances *(1 Day)*

Figure 13-Panel Installation Sequence

Image provided by Wohlsen Construction

ID	Task Name	Duration
1	**Prefabricated Panels Installation**	**15 days**
2	Sequence 1- NW Corner	4 days
3	Crane Movement to Sequence 2	0.5 days
4	Sequence 2- SW Corner	4 days
5	Crane Movement to Sequence 3	0.5 days
6	Sequence 3- SE Corner	3 days
7	Crane Movement to Sequence 4	0.5 days
8	Sequence 4- NE Corner	4 days

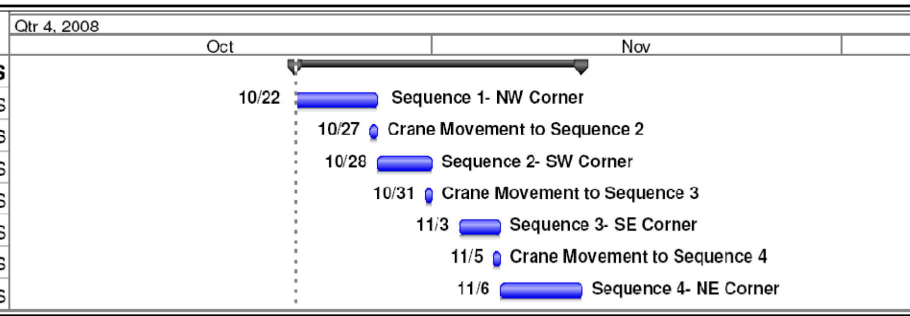


Figure 14- Panel Installation Schedule

Image provided by Wohlsen Construction

The following figures highlight each of the prefabricated panels to be installed, as well as coinciding sequence number. The red box indicates an area of Campus Square which will not be prefabricated, and will require on-site construction. This particular location, as with any red boxed area in the following figures, indicates construction entrances and/or areas of on-site construction unless otherwise noted.

The north wall will also require a unique installation sequence due to the presence of the three story curtain wall system, as well as multiple construction entrance locations. The panels will be installed in the sequence listed below in Figures 15, leaving an opening at the location of the curtain wall system on all three floors. This opening will also act as another construction material access location for the upper floors until the curtain wall system is installed after the completion of sequence 4. Once the curtain wall system is complete, the building envelope will be essentially complete besides the access areas on the east side. After sequence 4 is complete, interior work may begin.

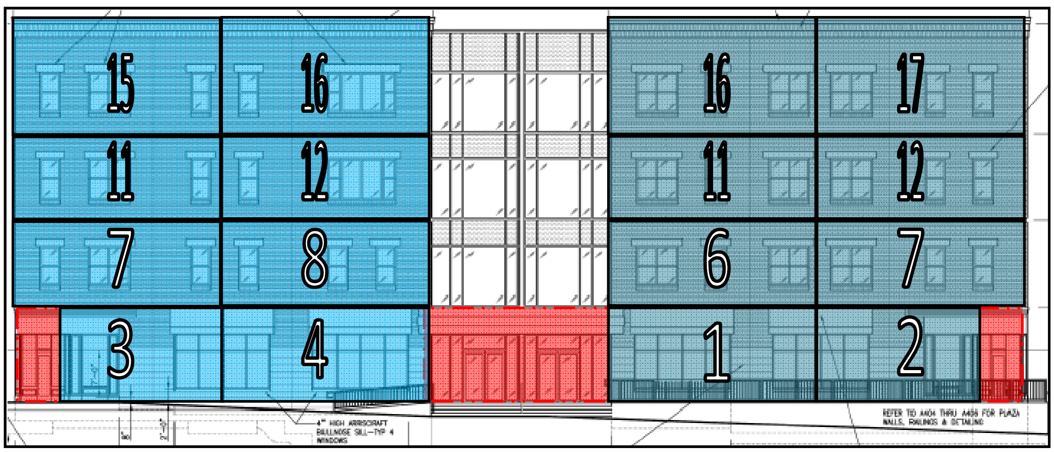


Figure 15- North Elevation: Panel Sequences 1&4

Image provided by Wohlsen Construction

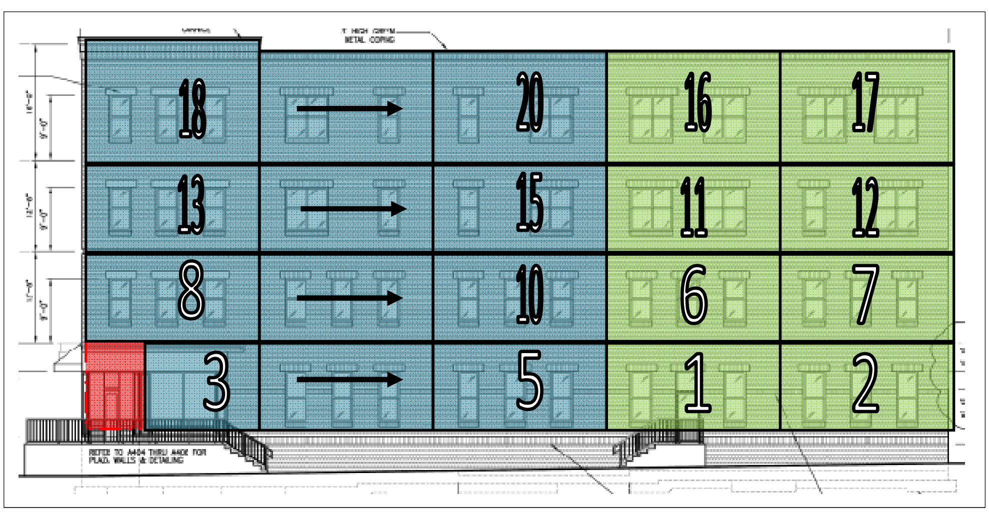


Figure 16-West Elevation: Panel Sequences 1 & 2

Image provided by Wohlsen Construction

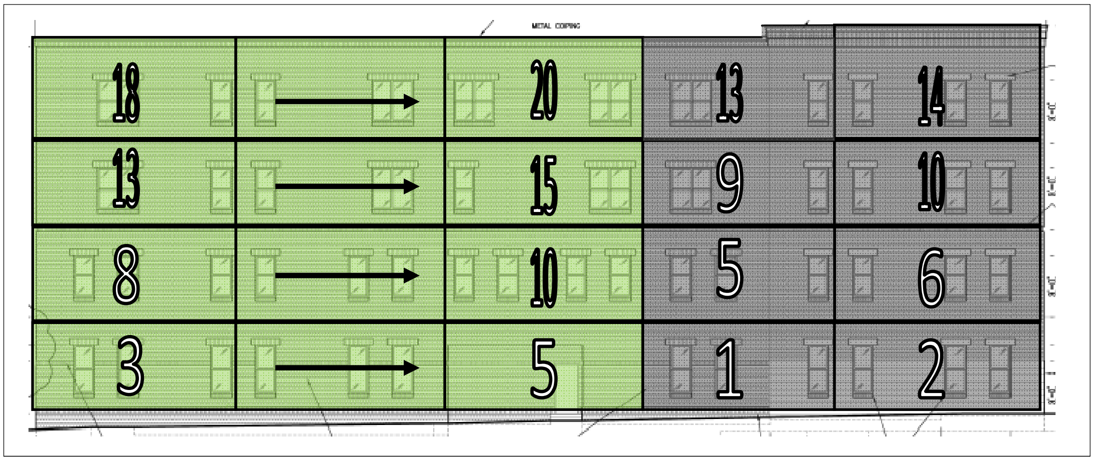


Figure 17- South Elevation: Panel Sequences 2 & 3

Image provided by Wohlsen Construction

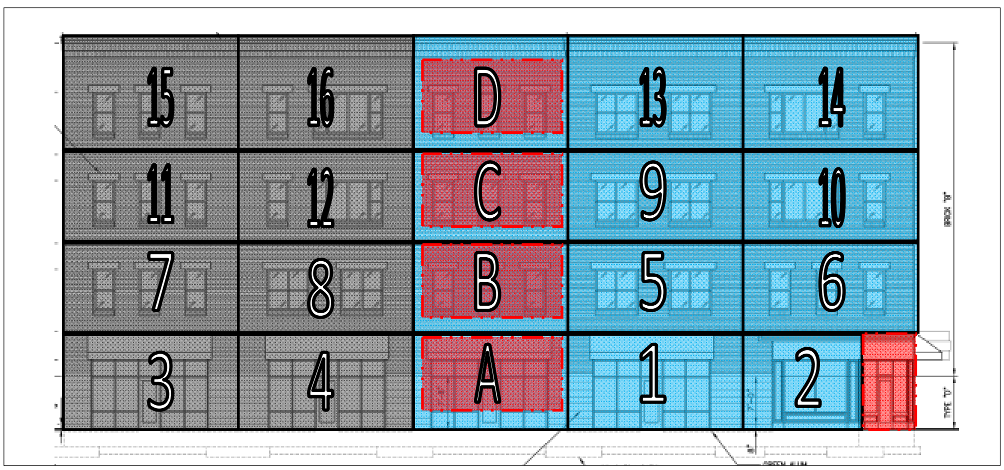


Figure 18- East Elevation: Panel Sequences 3,4,&5

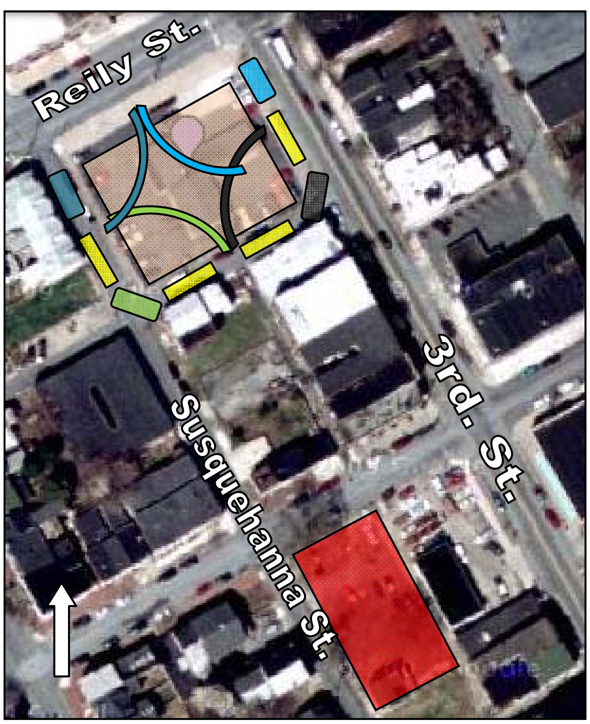
Image provided by Wohlsen Construction

Installation of the east elevation will require additional coordination during construction. This wall will have construction entrances for materials along each floor. Panels 'A' through 'D' will not be installed in the same instances as the other wall faces. Instead, these particular panels will be stored in the material storage locations, and will be installed during sequence 5, once all appropriate interior materials have been delivered within the building. The locations of these openings mimic the construction methods used for Campus Square during the exterior façade installation. This concept can be better observed in Figure 19 on the following page.

Figure 19-East Elevation Construction Entrance Locations

Image provided by Wohlsen Construction

The 150-ton truck crane will be deployed in four locations during the installation of the panels; this is due to the limited mobility the crane has within the confines of the site. The crane will be located at the four corners of Campus Square based upon which sequence is currently being executed. Figure 20 below depicts the placement of the cranes, as well as delivery points for the panels.



Crane and Trailer Locations
Campus Square Site
Trailer Storage
Crane Locations & Swing
Sequence 1
Sequence 2
Sequence 3&5
Sequence 4
On-Site Trailer Locations

Figure 20- Crane and Trailer Locations

Image provided by Google Maps

Vehicular traffic will need to be limited along streets when a panel sequence is being conducted. The most critical of the adjacent roads to Campus Square are Reily Street and 3rd Street due to their heavy traffic patterns. During Steel erection, it was possible to keep all directions of traffic active; however, with the limited mobility once steel is erected, it will be necessary to close the sections of road the crane is on. Fortunately, Reily Street will be able to remain open at all times because no crane is ever placed on that road due to the existing overhead power lines limiting the crane swing.

Schedule Impact

The construction duration of the building shell will be substantially modified in order to compensate for the prefabricated panels. Overall, the building's shell construction duration will be shortened by approximately 6 weeks. This reduction can be attributed to the lack of on-site exterior wall construction, as well as earlier start times for related activities. Furthermore, the prefabricated panels will result in an earlier start time for interior work to begin because the building envelope will be secured earlier than the original construction duration. Figure 21 below compares the building shell phases of construction for the original construction schedule with the proposed methods. Having the building secure, and envelope complete, is perhaps the most important milestone change when compared to the original schedule because it allows for interior work to begin which encompasses the majority of construction time.

ID	Task Name	Duration	Start	Finish
1	**As-Built Building Shell**	**77 days**	**Wed 10/15/08**	**Thu 1/29/09**
2	Pour Slabs on Deck	5 days	Wed 10/15/08	Tue 10/21/08
3	Exterior Wall Framing	10 days	Wed 10/22/08	Tue 11/4/08
4	Exterior MEP Rough Ins	10 days	Wed 10/22/08	Tue 11/4/08
5	CMU for stairs and elevator	10 days	Wed 10/22/08	Tue 11/4/08
6	Exterior Sheathing	10 days	Wed 11/5/08	Tue 11/18/08
7	Elevator Installation	20 days	Wed 11/5/08	Tue 12/2/08
8	Dryvit Application	5 days	Fri 11/14/08	Thu 11/20/08
9	Install Roof Sheathing/Shin	15 days	Fri 11/21/08	Thu 12/11/08
10	Exterior Brick	50 days	Fri 11/21/08	Thu 1/29/09
11	Install Windows	10 days	Mon 12/22/08	Fri 1/2/09

ID	Task Name	Duration	Start	Finish
1	**Proposed Building Shell**	**45 days**	**Fri 8/1/08**	**Thu 10/2/08**
2	Exterior MEP Rough Ins	10 days	Fri 8/1/08	Thu 8/14/08
3	Pour Slabs on Deck	5 days	Fri 8/15/08	Thu 8/21/08
4	Install Roof Sheathing/Shingles	15 days	Fri 8/22/08	Thu 9/11/08
5	Pre-Fab. Panels Instal.	15 days	Fri 8/22/08	Thu 9/11/08
6	CMU for stairs and elevator shaft	10 days	Fri 8/22/08	Thu 9/4/08
7	Elevator Instal.	20 days	Fri 9/5/08	Thu 10/2/08
8	Curtain Wall Installation	5 days	Fri 9/12/08	Thu 9/18/08

Figure 21- As-Built vs. Prefabrication Building Shell Schedule

Implementing the proposed construction sequence for the prefabricated wall panels will ideally reduce the overall construction schedule by approximately 9 weeks. The shortened schedule reflects time saved from the building shell phase, through the end of the project due to earlier activity start times when compared to the original schedule. Modifications to the schedule can also be seen with the inclusion of on-site masonry which will need to be performed before the first floor panels can begin. For the complete project schedule, see Appendix A of this report.

In comparing the reduction in preconstruction time with the original schedule, it is somewhat difficult to convey how much time will truly be reduced. Campus Square was not mobilized until nearly a year after preconstruction efforts began, mainly due to the owner's decision to delay construction due to the lack of tenant interest. Ideally, a preconstruction time of three to six months could have been achieved if anchor tenants were secured early into the building's conception and design. TEAM Panels suggested a conservative manufacturing time of approximately eight to ten panels could be constructed each day, following a design duration of a few weeks. Therefore, a reasonable preconstruction/procurement time for the 76 panels needed would be approximately seven weeks, including design.

Cost Impacts

The basis of implementation of the prefabricated wall panels would weigh entirely on an early tenant interest, which would make the high upfront costs of prefabrication more financially feasible due to an earlier payback duration.

The direct construction cost savings can be seen primarily in general conditions, specifically Wohlsen staffing costs. Overall, a general conditions savings of $154,691 will be achieved due to the reduced schedule duration. Figure 22 below compares the original general conditions with the proposed schedule duration. The complete general conditions comparison table may be found in Appendix B of this report.

General Conditions Estimate	
Description	**Cost**
Staffing	$693,730
Administrative Facilities and Supplies	$50,150
Safety	$7,000
Cleanup	$129,255
Jobsite Work Requirements	$144,450
Permitting	$66,686
Bonds and Insurance	$105,488
Total General Conditions Cost	**$1,196,759**

Proposed General Conditions Estimate	
Description	**Cost**
Staffing	$589,671
Administrative Facilities and Supplies	$43,150
Safety	$4,400
Cleanup	$106,324
Jobsite Work Requirements	$126,350
Permitting	$66,686
Bonds and Insurance	$105,488
Total General Conditions Cost	**$1,042,069**

Figure 22- As-Built vs. Prefabrication General Conditions Costs

Substituting the as-built exterior walls for the prefabricated panels will result in a direct cost increase of approximately $585,200. The increase in cost is due to high square foot costs associated with manufacturing and installing the panels, as well as the requirement of a large crane on-site during installation. Figure 23 on the following page compares the as-built exterior wall construction costs with the proposed panel system. Cost values were compiled with the assistance of Wohlsen Construction and TEAM Panels.

As-Built Costs (Includes Installation)	
Exterior Wall Assembly	$ 600,000
Pella® Windows	$ 80,000
TOTAL	**$ 680,000**
SF COSTS	**$ 25.56**

Prefabrication Costs			
	Unit Cost (SF)	Installation Cost (SF)	Cost
Prefabricated Panels	$ 37	$ 10	$ 1,250,200
	Unit Cost (WK)	Duration (WK)	Cost
Truck Crane Costs	$ 5,000	3	$ 15,000
	Panel SF (Approx.)	**TOTAL**	**$ 1,265,200.00**
	26600	**SF COST**	**$ 47.56**

Figure 23- As-Built vs. Prefabrication Construction Costs

Overall, the prefabricated exterior wall panels will result in a substantially higher square foot (SF) cost for the building shell; however, the higher upfront costs would be mitigated by the overall strategy of a faster construction schedule.

Conclusions and Recommendation

The proposed construction sequence has several distinct advantages over the actual construction sequence implemented during the construction of the building shell of Campus Square. First, reducing the project duration reduces Wohlsen Construction's risk on the project, including risk of accidents and construction delays. Furthermore, the construction method decreases the amount of craftsmen on-site during active construction which reduces safety risk, as well as eliminates the need of exterior scaffolding during the installation of the brick veneer. Second, the proposed sequence allows the building shell to be completed approximately 6 weeks earlier, securing the exterior envelope, which enables the interior work to begin earlier. Most importantly, the time saved during preconstruction, as well as the earlier completion date, allows GreenWorks Development to begin leasing the spaces in order to begin profiting from their investment.

Although the prefabrication does have many benefits in delivering a faster, more quality building, it does come with problematic logistical and financial hurdles. The proposed construction sequence does require a crane to remain on-site past the steel erection phase. Additionally, the crane must move multiple times during the panel installation, working around tight site confines, as well as overhead power lines. These added mobility limitations increase the possibility of accidents, or other construction related damages. Throughout the installation of the panels, a high degree of logistical and safety planning must be implemented in order to ensure the safety of the public, as well as the construction workers.

The most significant of the disadvantages related to the proposed methods, is the substantially higher upfront cost for the prefabricated panels. The total cost addition for the prefabricated system will be approximately $1,110,509, which is $430,509 higher than the original. This cost includes the general conditions reduction, and reflects the time savings during construction. It is important to note that the concept behind implementing the proposed methods would only occur if GreenWorks were able to secure tenants early during conceptualization/preconstruction, and required an accelerated construction schedule.

Prefabrication is an excellent strategy in order to reduce construction duration, and deliver a higher quality building due to the ability to control construction environments during manufacturing. Although the method does come with a higher price tag, as well as safety considerations due to the confines of the site, prefabrication would be a successful and profitable alternative for GreenWorks to implement in order to quickly construct and lease out Campus Square.

Mechanical Breadth Analysis

Thermal Performance of Exterior Wall Systems

Background Information

Campus Square hosts a sizable curtain wall system along North 3rd Street which spans four stories, and is about one third the square footage of that face of the building. Furthermore, the building implements a brick façade and storefront system throughout the remaining faces of the building. Furthermore, GreenWorks Development chose to install a high performance building envelope for Campus Square, including energy efficient materials such as Energy Star® rated Pella® windows, low-e glazing, a white TPO built up roof system, as well as a more quality exterior wall assembly. All of the aforementioned sustainability efforts were port forth in order to establish a more energy efficient envelope, as well as LEED® implications for the building's gold certification.

As discussed in previous analysis sections, a proposed prefabricated exterior wall system would replace the as-built wall assembly as the primary exterior wall envelope. The two wall systems differ in materials used, as well as construction methods; where the proposed prefabricated system would be constructed out of EIFS exterior insulation and simulated brick stucco, with doors and windows installed.

Early during preconstruction, GreenWorks and Wohlsen decided to eliminate on the of the curtain wall systems from the east side of the building along 3rd Street. Although glazing benefits daylighting efforts within the building space, it degrades thermal efficiency. Through this value engineering effort approximately $20/SF was reduced in the façade price, additionally, savings may occur through thermal savings in operating costs. Figure 24 below highlights the location of the eliminated curtain wall system.

Figure 24 – Additional Curtain Wall System Location

Image courtesy Wohlsen Construction Company

Overall Goals

The goal of this analysis is to research, measure, and compare the thermal efficiency and moisture infiltration of the different envelope systems, including the proposed prefabricated wall system described in the structural breadth of this report. U-values will be obtained, and heat loss will be calculated comparing the different enclosure systems. The heat loss data, ideally, will demonstrate the thermal advantages of the proposed wall assembly over the as-built condition. Furthermore, a similar comparison will be made of the choice by Wohlsen and GreenWorks to value engineer out a large curtain wall system located on the east side of the building, similar to the one installed on the north side. Conclusions obtained from the analysis will compare energy efficiencies of each assembly.

Methods

- Perform literature review of submittals related to envelope materials
- Determine thermal ratings of all materials and assemblies used in envelope systems through the use of the *Heat, Air and Moisture Building Science Toolbox* software
- Perform take-offs of measurements of materials
- Analyze thermal efficiency and heat loss of wall assemblies and glazing
- Compare systems, and determine any energy efficiency benefits of prefabricated systems versus those constructed onsite based on performance.

Resources

- *Heat, Air and Moisture Building Science Toolbox*
- *Mechanical and Electrical Equipment for Buildings (Textbook by Benjamin Stein)*
- Submittal Log for Campus Square (Division 8- Doors and Windows)
- Wohlsen Construction Company (Project Manager for Campus Square)

Expected Outcome

Although the proposed prefabricated system will result in a higher upfront cost due to manufacturing and installation as indicated in other sections of this report, the added thermal efficiency should assist in reducing operational costs in heating and cooling. Due to the controlled environment of the proposed system's construction, a higher level of quality can be achieved. However, the higher thermal efficiency will be proportional to the increased CSF. The improved exterior wall assembly will reduce thermal penetration into the space of the building, reducing the amount of heating and cooling load the building will experience throughout its lifecycle.

The high efficiency masonry assembly used on Campus Square will prove to be above standard, and the decision of the project team to VE out an additional curtain wall system along Reily Street will prove to be beneficial in thermal savings. Although the curtain wall system is aesthetically pleasing and allows for increased daylighting, the system will prove to be thermally inefficient and less sustainable.

Heat Loss Analysis

Calculation of design heat loss is an estimation of the worst likely hourly heat flow from a building to the surrounding environment. This value is used to size heating and cooling systems; the greater the design heat loss, the larger the required heating system capacity. Design heat loss is not the highest heat loss that may occur, rather it is a reasonable maximum heat loss based upon design outside air temperatures. For this analysis, heat loss data will be used to compare the above grade, exterior wall systems of Campus Square, with the proposed prefabricated panels.

In order to determine heat loss through each wall assembly, the resistance (R-Value) of each material in the assembly must be identified. Resistance indicates how effective any material is an insulator. The R-Value is measured in hours needed for 1 BTU to flow through 1 ft^2 of a given thickness of material when the temperature difference is 1^oF.

The U-Factor expresses the steady-state rate at which heat flows through architectural envelope assemblies. U-Factor is the overall coefficient of thermal transmittance expressed in terms of $BTU/hft^{2o}F$. U-Factors are calculated for a particular assembly by determining the resistance (R-Value) of each material, then adding these resistances to obtain a total resistance. However, it is important to realize that each material's U-Factor within the assembly is proportional to the overall square footage of the envelope system. Therefore, the U-Factor is the reciprocal of the sum of R-Values:

$$U=1/\Sigma R$$

Compared to other elements of the building envelope, wall U-Factors are fairly straightforward. There are minimal complications associated with computation such as ground contact, crawl spaces, or attic spaces. However, one of the largest impacts on wall analysis is incorporating thermal bridging; where framing interrupts insulation. Therefore, an averaged insulated value and uninsulated value must be obtained. This concept also applies to determining average values for wall penetrations such as windows and doors; compiling such values into an area-weighted resistance and U-Factor of the wall assembly.

The design sensible heat loss through all types of above-ground elements of the building envelope can be calculated as follows:

$$q=(U)(A)(\Delta t) \text{ for each element}$$

U= U-factor for a given envelope component
A= Surface area of the envelope component
Δt = the design temperature difference between inside and outside air

Existing Exterior Wall Assembly

Through the use of the *Heating, Air and Moisture Building Science Toolbox* software (H.A.M), a cumulative R-Value of the exterior wall assembly could be obtained. This method had to be performed twice in order to compensate for thermal bridging. Therefore, an R-Value for both insulated, and uninsulated wall sections were calculated to be 20.51 and 3.86, respectfully. A dramatic difference between the two values can be attributed to the metal studs coming in contact with metal screws and other poor insulating material which adhere the layers of the assembly together. When poor insulators come in contact, they allow the outside temperature to flow through them, creating a thermal pathway in the assembly. Figure 25 below shows the calculated R-Value of the existing wall assembly.

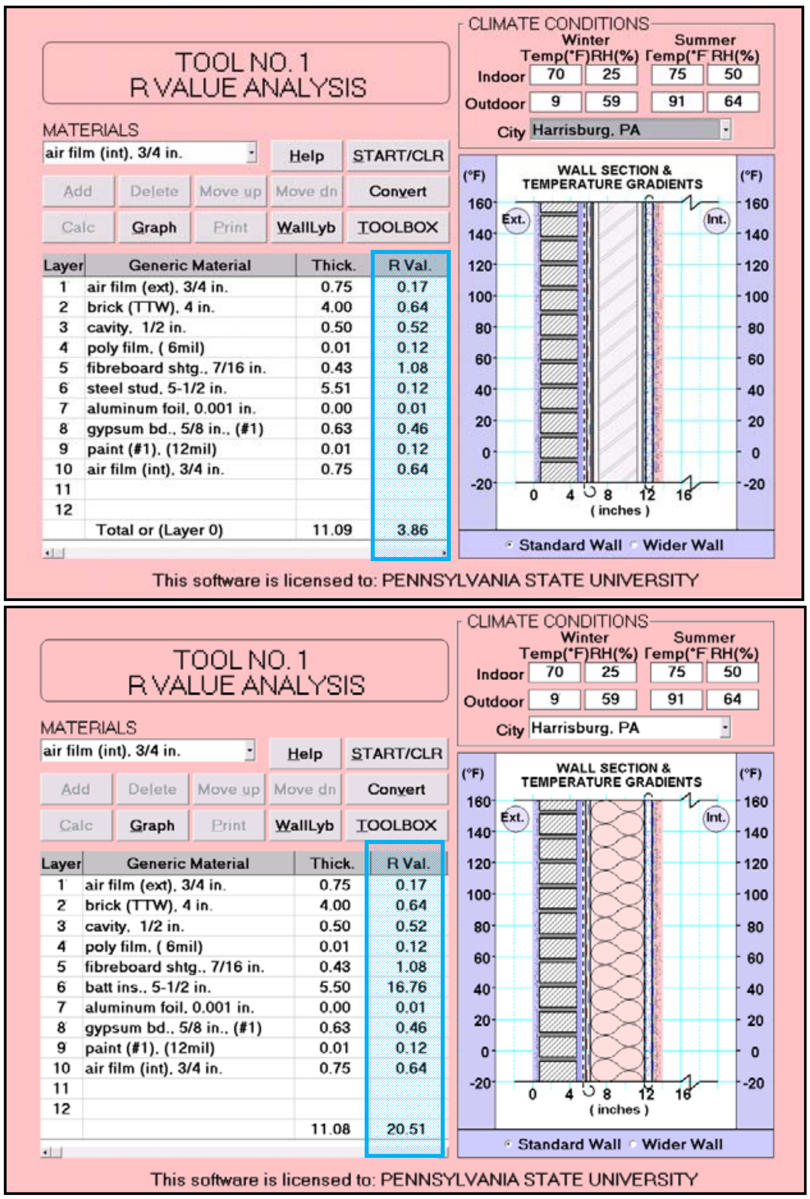


Figure 25-Existing Wall Assembly R-Value Analysis

Image produced using H.A.M. Toolbox software

Glazing and Windows Analysis

In order to correctly determine the heat loss through the exterior wall assemblies of Campus Square, a U-Value needed to be determined for the glazing used on the curtain wall system and the storefront windows and doors, as well as the Pella® windows. During the submittal process of preconstruction, performance results of the glass used were included. With these U-Values, the square footage of these materials was incorporated into the heat loss calculations in order to determine a total heat loss for all faces of the building. It was important to effectively determine these values due to the extensive heat loss through these particular materials. Figure 26 below highlights the test results obtained during the submittal process.

PPG Industries Performance Glass Calculator Calculated *Center-of-Glass* Thermal and Optical Properties Based on NFRC 100-2001 Environmental Design Conditions

Details for Double Glazing as Specified			
Outdoor Glass Lite	1/4" (6mm) Caribia		
Gas Cavity Dimension	1/2" (12mm)		
Gas Fill	Air		
Indoor Glass Lite	1/4" (6mm) Sungate 500 on Clear (Surface #3)		
Calculated Thermal and Optical Properties			
U-Values (K-Values)	Metric (Kcal/hr/m²/C)	Metric (W/m²/C)	English (BTU/hr/ft²/F)
Winter Nighttime	1.69	1.97	0.35
Summer Daytime	1.71	1.98	0.35
Shading Coefficient	0.39		
Solar Heat Gain Coefficient	0.34		
Relative Heat Gain	Metric (Kcal/hr/m²) 227	Metric (W/m²) 264	English (BTU/hr.ft²) 84

Details for Monolithic Glazing as Specified			
Glass Lite	1/4" (6mm) Clear		
Calculated Thermal and Optical Properties			
U-Values (K-Values)	Metric (Kcal/hr/m²/C)	Metric (W/m²/C)	English (BTU/hr/ft²/F)
Winter Nighttime	4.98	5.79	1.02
Summer Daytime	4.50	5.24	0.92
Shading Coefficient	0.93		
Solar Heat Gain Coefficient	0.81		
Relative Heat Gain	Metric (Kcal/hr/m²) 541	Metric (W/m²) 629	English (BTU/hr.ft²) 199

Figure 26 – Glazing Thermal Properties

Table provided by Wohlsen Construction Company

Proposed Prefabricated Wall Assembly

Similar to the as-built wall assembly, the H.A.M software was utilized in determining a cumulative R-Value of the proposed exterior wall assembly. Likewise, this method had to be performed twice in order to compensate areas of metal stud and cavity space. Therefore, an R-Value for both metal stud, and cavity wall sections were calculated to be 19.79 and 20.66, respectfully. The proposed wall assembly implements an EIFS exterior finish which acts as an exterior insulator, which thermally outperforms the material currently used. Also, the manufacturing methods used to adhere the materials together mitigate thermal bridging through the metal studs. Because this is true, the proposed assembly has an improved, more balanced U-Value over the original design. Figure 27 below shows the calculated R-Value of the proposed prefabricated wall assembly.

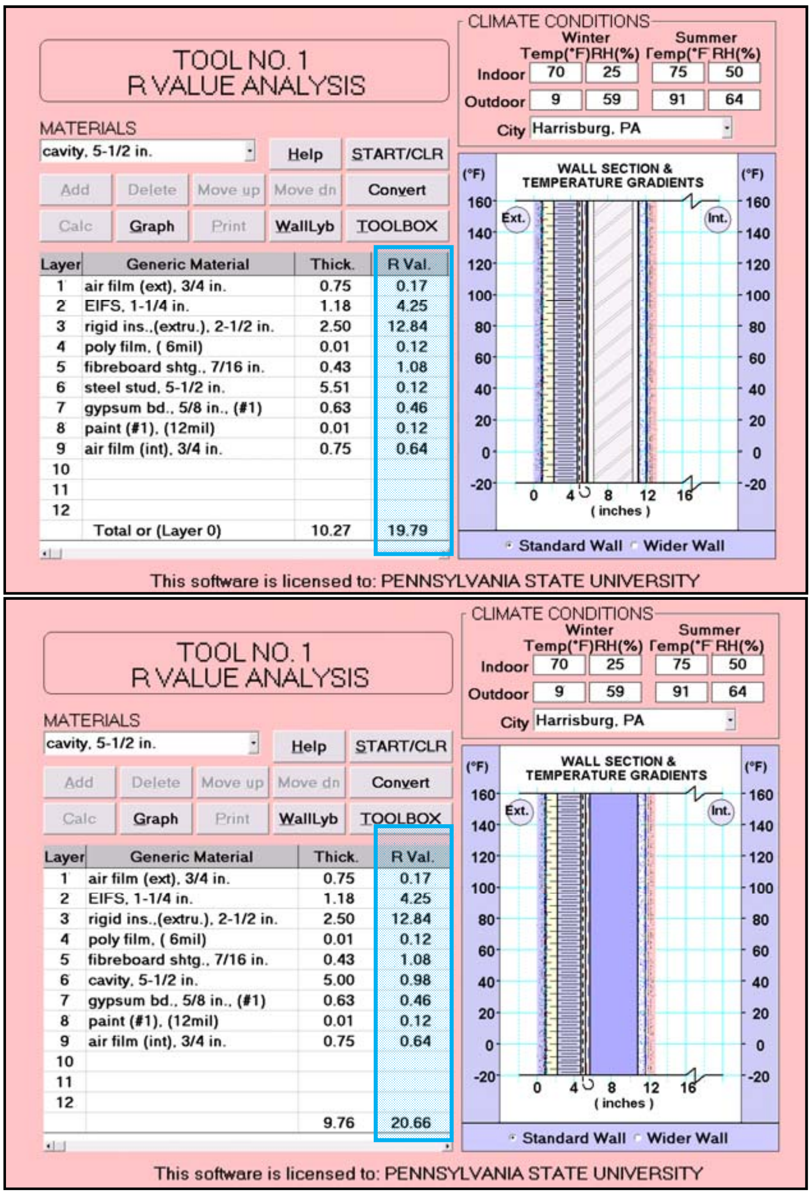


Figure 27- Proposed Wall Assembly R-Value Analysis

Image produced using H.A.M. Toolbox software

Results

Once the take-offs were tabulated, determining the square footage of each material used throughout the different exterior wall assemblies, the heat loss for Campus Square could be calculated using the heat loss equation mentioned earlier in this analysis section. As hypothesized, the prefabricated wall assembly thermally outperforms the as-built condition. This is attributed to better insulating materials, as well as a more effective wall assembly. As Figure 28 summarizes below, the prefabricated panels reduce the heat loss through the exterior wall envelope by 13.5% in the summer, and 13% in the winter. These values represent the inclusion of all exterior doors, windows, glazing, and brick/EIFS assemblies. The reduction in heat loss through the exterior walls will not only result in a more thermally efficient and sustainable building, but will also reduce operational costs in heating and cooling. The complete heat loss calculation data may be observed in Appendix D of this report.

Exterior Wall Heat Loss (Q) Comparison Table							
As-Built (Q)		Prefabricated (Q)		Difference			
Summer	Winter	Summer	Winter	Summer Δ	% Summer	Winter Δ	% Winter
90100.89	357092.64	77965.69	310827.18	**12135.20**	**13.5%**	**46265.46**	**13.0%**

Figure 28 – Heat Loss Comparison Data

Value Engineering Impact

As previously mentioned in the background information section of this analysis, GreenWorks and Wohlsen opted to eliminated a 3-story curtain wall system along the east side of the building. This was mainly done to reduce the façade square foot cost. However, savings can also be seen in the added thermal performance of the as-built assembly. Figure 29 below demonstrates the heat loss comparison of the proposed prefabricated panels with the originally proposed curtain wall system along Reily Street. A dramatic difference is observed in thermal performance if the curtain wall was added, compared to the proposed prefabricated panels. The data compares the heat loss differences between the as-built system and the prefabricated panels; as well as the difference between the prefabricated system and a curtain wall addition in the same region of the building.

East Side Heat Loss Comparison of Prefabricated System & Curtain Wall Addition					
As-Built		**Prefabricated Panels**		**Curtain Wall Addition**	
Q (Summer)	**Q (Winter)**	**Q (Summer)**	**Q (Winter)**	**Q (Summer)**	**Q (Winter)**
10719.10	40866.56	8613.93	32840.60	14602.24	61722.24
Percent Difference		**19.6%**	**19.6%**	**-69.5%**	**-87.9%**

Figure 29 – Heat Loss Comparison Data

Conclusions and Recommendations

By comparing the heat loss data of the varied envelope systems used in the exterior wall assemblies, as well as the proposed system, it is evident that a prefabricated wall system is thermally advantageous over the as-built condition. The proposed assembly will assist in reducing operation costs throughout the year, as well as assisting in a quicker payback period due to the heating and cooling savings. Perhaps the most critical advantage of the prefabricated assembly is the implantation of EIFS on the exterior of the building. EIFS acts as an insulator, as well as accomplishes the aesthetic design considerations of Campus Square. When constructing exterior wall systems, it is important to avoid excessive glazing and/or wall penetrations, as these will reduce the thermal effectiveness of the envelope system. Furthermore, the proposed assembly mitigates thermal bridging through the wall, which is one of the larger contributors to thermal loss. A more in-depth study of the thermal properties, including heat gain analysis, may further demonstrate the advantages of implementing the proposed methods.

Structural Breadth Analysis

Structural Redesign of Exterior Wall Panel Connections

Background Information

Campus Square's exterior wall assembly was constructed using a non load-bearing masonry façade system with metal stud backing, as well as a sizable curtain wall system on the north side of the building. The exterior walls were all constructed on-site, requiring scaffolding during masonry installation, as well as large numbers of craftsmen in order to complete the work. Using a prefabricated wall system will not only simplify the construction of the walls, but will also reduce the amount of workers on-site, mitigating safety risks. However, if a prefabricated wall system is implemented on exterior of the building, the structural connections which fasten the prefabricated panels to the steel structure would need to be designed. Campus Square currently supports the brick veneer with steel angles anchored in the composite deck system. Figure 30 below, illustrates the current steel angles used to support the masonry façade system. Properly designing the connections would be critical in ensuring the proposed prefabricated system is structurally anchored to the superstructure.

Figure 30 – Masonry Façade Steel Support Angles

Image courtesy Wohlsen Construction Company

Overall Goals

The goal of this analysis is to understand the connection design used for the current façade, and then redesign the connection detail in order to facilitate a prefabricated system. Furthermore, the connection locations along the wall system will need to be determined in order to efficiently design the quantity of connections needed. Proper spacing will be very important in the overall design because each connection point will require on-site craftsmen joining the walls to the structure, as well as adding to the amount of time it will take to install each panel.

Methods

- Understand current structural design of exterior masonry system
- Contact structural engineer of Campus Square about potential solutions of redesign
- Conduct literature review of prefabricated system
- Determine proposed prefabricated wall assembly and associated dead loads
- Establish schematic structural design of connections
- Analyze loads and determine proper connection spacing and connection type

Resources

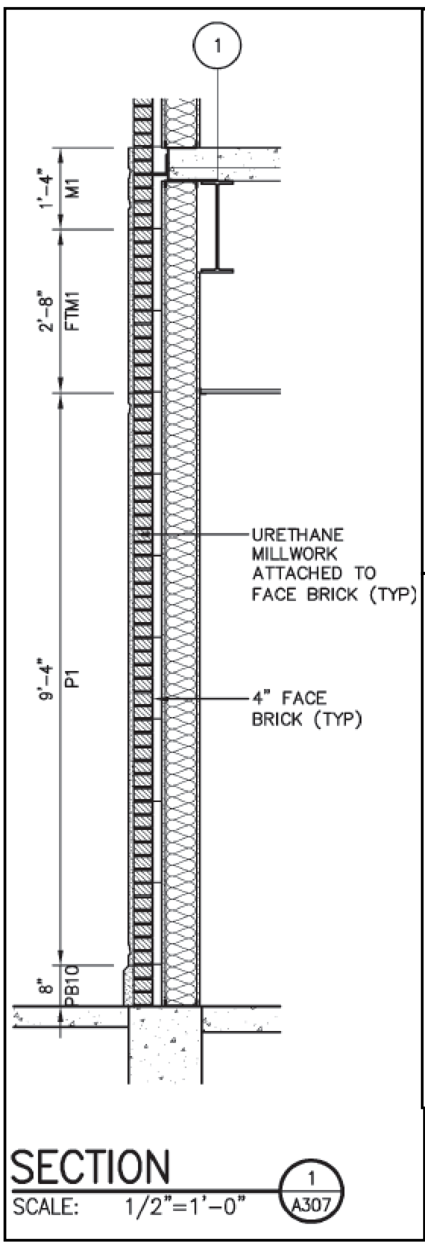
- Dietrich Metal Framing (Connection Manufacturer)
- Wohlsen Construction Company (Project Manager for Campus Square)
- Structural AE faculty
- TEAM Panels International (Prefabricated Panel Manufacturer)
- KERR Interior Systems Ltd. & Composite Building Systems Inc. (Prefabricated Panel Manufacturer)
- *Mechanical and Electrical Equipment for Buildings (Textbook by Benjamin Stein)*
- AISC Design Guide 22, Table 2-1
- ASCE 7-05, Chapter 2: Combination of Loads

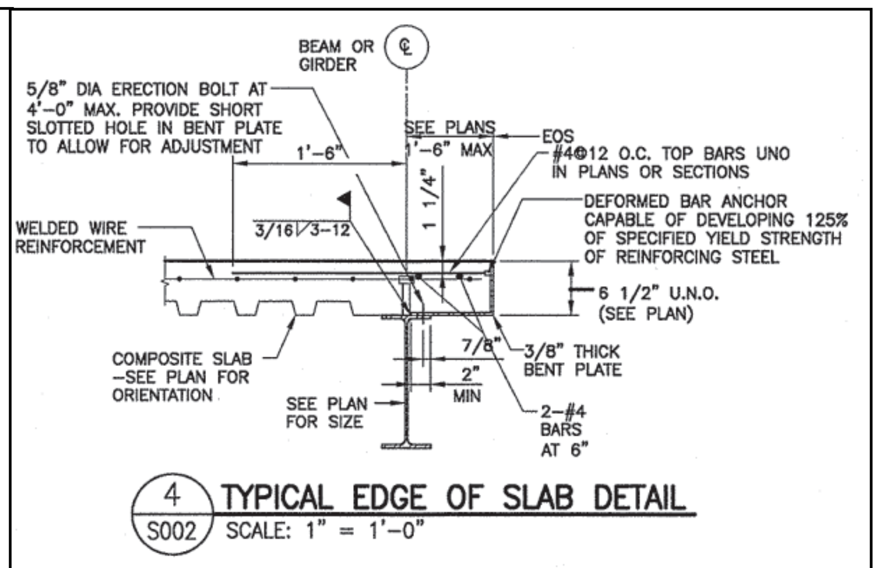
Expected Outcome
The new structural connection will be more complex than the original steel angles currently used to support the façade. The new connections will need to be stronger in order to support the added dead load of the entire wall assembly, compared to just the brick veneer. The added loads may involve additional reinforcing along the edges of the structure.

Existing Exterior Wall System
Campus Square was constructed using a high performance, brick veneer exterior wall system with galvanized steel stud backing for the exterior walls of the building. The wall assembly was implemented in order to achieve a higher thermal performance to reduce operating costs, as well as sustainability implications toward the building's LEED® Gold certification for core and shell. Supported by the foundation, as well as galvanized steel angles, the 4" brick veneer is typical throughout the façade of the building, with the exception of a small area along the entrances on the north side, which was made of an architectural stone. The 3/8" steel angles used to support the brick façade were connected to the edge of the concrete slab using a fillet weld connected to the 3/8" steel angle located along the slab edges. The angles also provide a moisture cavity between the sheathing and brick, as well as room for construction tolerances.

Each slab-on-deck is supported by the steel superstructure which acts as the main structural system for the building. The composite slab system overhangs the steel girders, requiring additional 2-way reinforcing at the slab's edge in order to resist the unsupported load. Additionally, the slabs are supported by a 3/8" bent plate attached to the steel girders.

The exterior wall assembly is rests on each slab, spanning the entire elevation for each floor, connecting once again at the bottom edge of slab of the next floor level. 14 and 16 gauge C-channel 6" metal studs are used as the primary framing material throughout the exterior of the building, coupled with 6" batting insulation with foil backing. 7/16" DensGlass® sheathing was attached to the exterior framing around the building. DensGlass® gypsum sheathing features a moisture-resistant core and enhanced fiberglass mats, instead of paper facings, to resist the effects of moisture exposure during and after construction. The drawings below, in Figure 31 depict the typical exterior wall assemblies and structural connections along the slab edges.





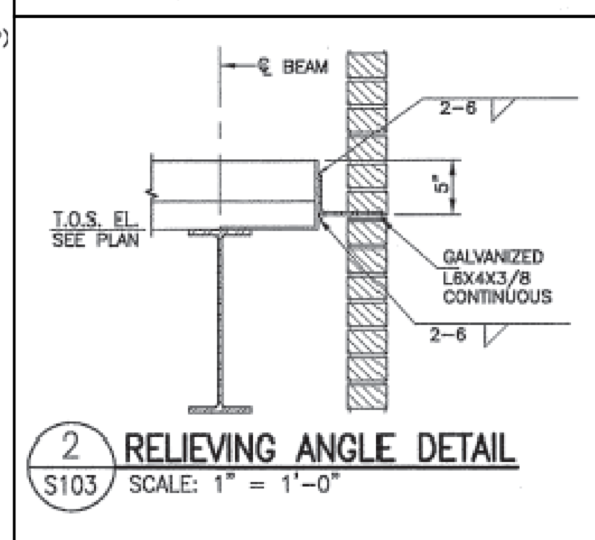


Figure 31-Typical Exterior Wall Details & Section Drawings

Drawings provided by Wohlsen Construction

Proposed Prefabricated System

After consulting with prefabricated wall manufacturers, including TEAM Panels International and KERR Interior Systems Ltd. & Composite Building Systems Inc., different wall assemblies were reviewed which could be implemented for Campus Square. It was important to identify complete panelized wall assemblies which could be manufactured in full, and installed on-site with the smallest amount of on-site installation. Furthermore, for the purposes of this report, the proposed system needed to be thermally more efficient than the as-built system, as discussed in the mechanical breadth of this report. Also, the proposed wall assembly needed to contain similar building materials as the original in order to meet aesthetic and sustainable requirements of Campus Square. By incorporating a prefabricated wall system for Campus Square, certain quality advantages may be achieved over the as-built methods due to the controlled environment of prefabrication. Such advantages include retaining aesthetic integrity and value by Eliminating problems relating to shrinkage, rotting, corrosion and cracks in the finishes; as well as pre-punched knockouts in the steel members, which decreases the time required from the other trades. Prefabrication also has LEED implications which are ideal for Campus Square and GreenWorks Development's sustainability mission. With respect to the LEED program's Materials and Resources (MR) Credits, Recycled Content, all of the cold-formed steel are produced from 90% recycled steel, comprised of 57% post-consumer recycled content and 33% post-industrial recycled content. Panel studs contain a high percentage of recycled steel comprised of both post-consumer and pre-consumer recycled content. In addition, depending upon the specific project location and manufacturer availability, opportunities may exist for credits under the Materials and Resources Credits for Regional Materials.

The wall system chosen for the proposed prefabricated system will contain 4" EIFS exterior insulation and simulated brick stucco. The simulated brick face will match that of the original design, but will provide for an improved insulating material over traditional batting insulation. The same 16" typical (unless noted otherwise on the drawings) stud spacing may also be kept the same in order to reduce the amount of framing required. Each panel is sized to span the typical bay width according to the panel's location. Utilizing this prescribed method will reduce the amount panel joints, as well as on-site time in seaming the panels together. Appendix C of this report lists the panel size and location schedule. Figure 32 on the following page shows a typical exterior wall assembly proposed for Campus Square, utilizing the EIFS system with metal stud backing.

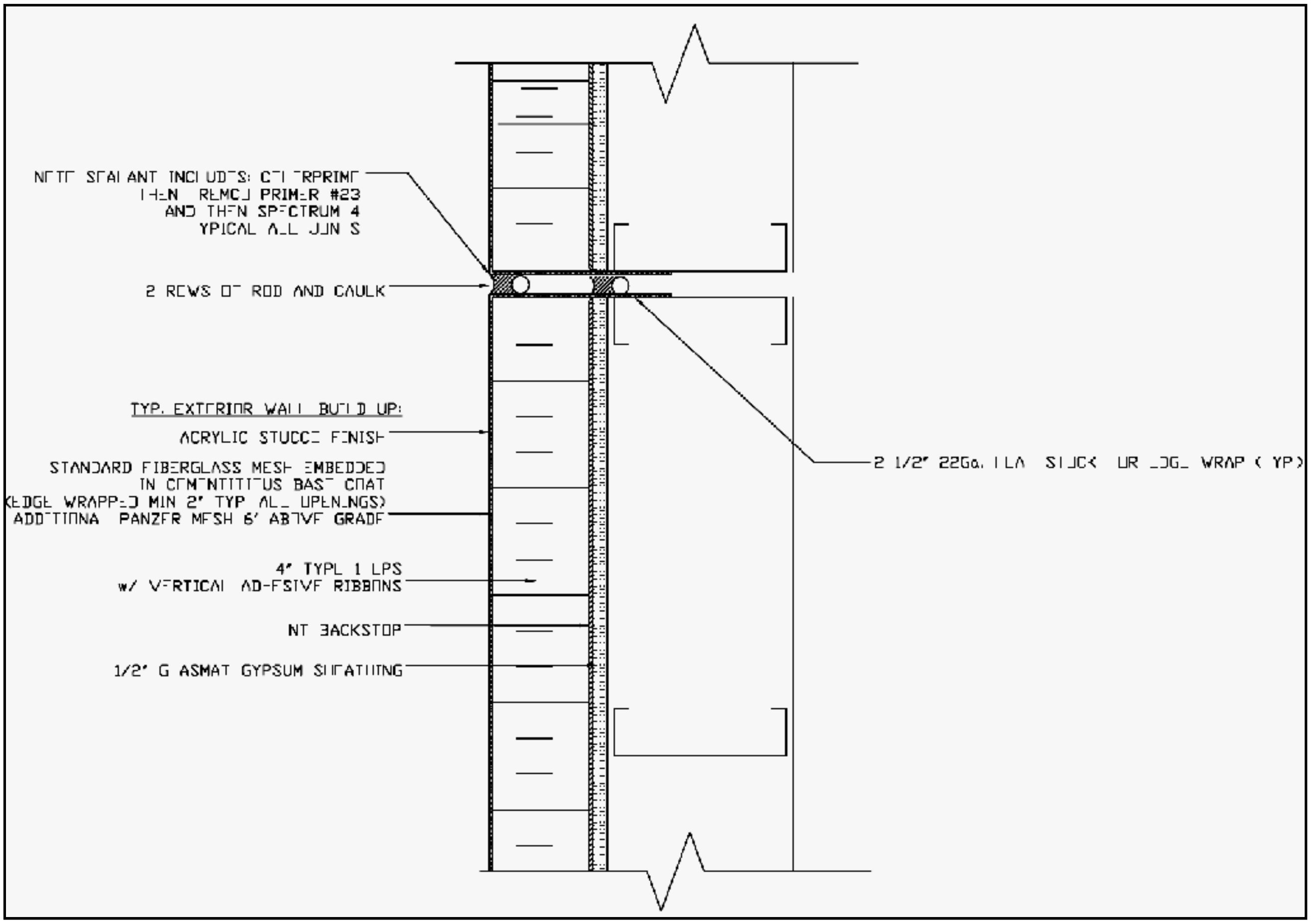


Figure 32– Typical Vertical Wall Assembly and Joint Detail

Drawing courtesy KERR Interior Systems Ltd. & Composite Building Systems Inc.

Proposed Structural Connection

For the purpose of this analysis, connections will be sized for a typical bay along the east side of Campus Square. The procedures and calculations used will mimic those which would be used to size the connections of the panels to the superstructure throughout the other elevations of the building. The bay which will be analyzed will be that of Panel #5, of erection sequence-4. This panel is located on the second floor of Campus Square, along 3rd Street. In order to determine the proper connection type to be used, gravity loads or dead loads, along with wind loads must be determined. With these values, the loadings onto the connections can be calculated, and sized appropriately. Figure 33 on the next page highlights the panel which will be analyzed.

Figure 33– Panel #5, Erection Sequence-4; Located Along 3rd Street

Drawing provided by Wohlsen Construction

The AISC Design Guide gives a common design assumption for an EIFS wall system (including gypsum sheathing, metals studs, and hardware), listing a gravity load of approximately 10 PSF. Using ASCE 7-05, an allowable load can be determined using strength design. Along with a dead load, a wind load will also need to be included into the design of the connections. Figure 34 lists the net wind uplift loads for Campus Square. Panel #5 will experience a net wind uplift of 26 PSF according to the diagram.

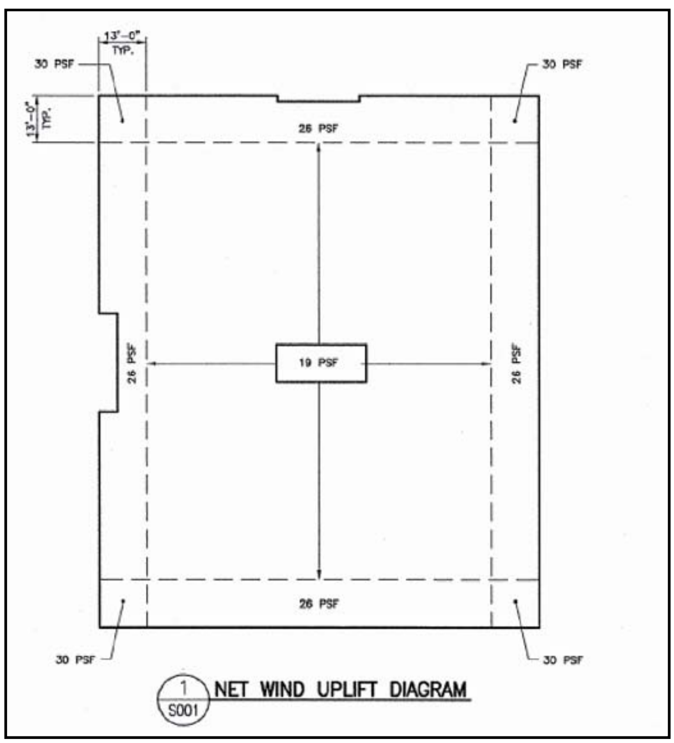


Figure 34-Net Wind Uplift Diagram

Drawings provided by Wohlsen Construction

Dietrich Metal Framing produces a series of connections used to attach curtain wall systems and wall sections to the superstructure. Using a QuickClip™ (QC-Series ™) in order to connect the proposed prefabricated wall sections to the steel and slab-on-deck of Campus Square, will provide the means to accomplish the proposed methods. The product allows for vertical building movement, restricts lateral movement, and provides up to 3" of horizontal standoff. Because the panels span each floor height, the wall sections will be attached at each 16" stud spacing at the floor and ceiling levels. Figure 35 below demonstrates how each steel stud will be attached the QuickClip™. Because the clips are installed vertically in line with another, it will negate a turning moment in design considerations.

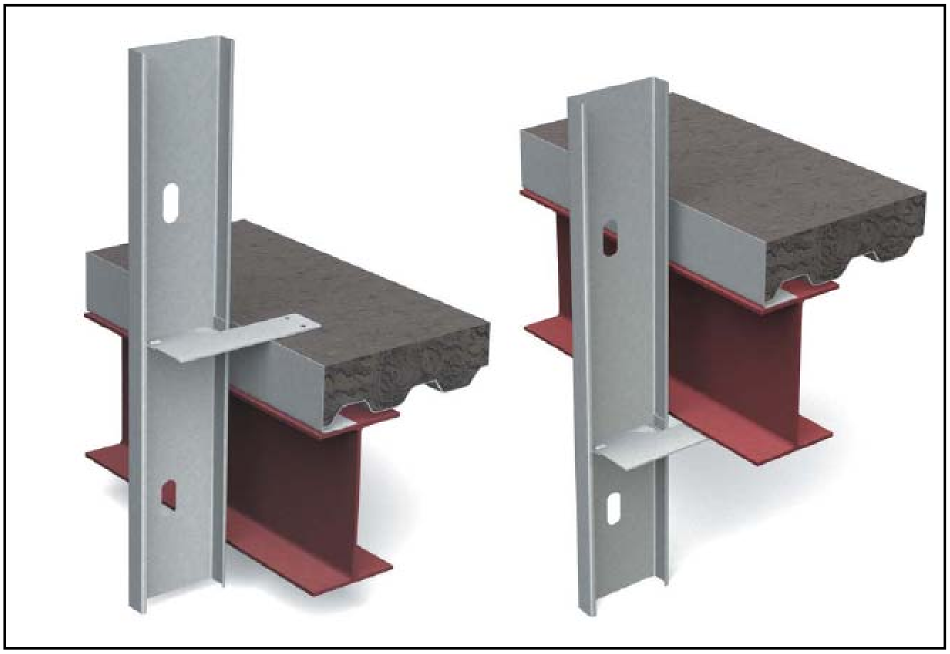


Figure 35– QuickClip™ (QC-Series™)
Left: Floor-to-Deck Connection (Typical). Right: Ceiling-to-Beam Connection (Typical).
Image courtesy Dietrich Metal Framing

Load Calculations
Chapter 2 of ASCE 7-05, Section 2.4 Combining Nominal Loading Using Allowable Stress Design, an allowable stress load can be determined using equation 5:

$$D + H + F + (W \text{ or } 0.7E)$$

Where:
D= Dead Load
H= Load due to lateral earth pressure, ground water pressure, or pressure of bulk materials
F= Load due to fluids with well-defined pressures and maximum heights
W= Wind Load
E= Earthquake Load

Equation 5 is used because this will result in the maximum design loading, ensuring worst case loading is met. The variables "H", "F", and "E" will not be needed in this calculation because those design elements do not contribute to the loading conditions of the proposed connections. Therefore:

D + W = 10PSF + 26 PSF = **36 PSF**

Each steel stud will be placed at 16" O.C., resulting in (for this specific panel) an approximate tributary area of **20.31 SF**.

Load of each stud, based on calculated tributary area:

Stud Tributary Area * Dead Load = 23.31 SF * 10 PSF = **233.10 LBS**

Based off of the above value, 16 gauge, 33 ksi steel studs will be appropriate for the prefabricated wall, as designed by the manufacturer. Also, a 10 gauge, 33 ksi QuickClip™ will be able to support the tributary area of each stud. Figure 36 below depicts allowable loads for each QuickClip™

Allowable Loads for the 10 Gauge, 33 ksi QuickClip™

Stud Type/Flange Width	Stud Gauge	Min Thickness (Inches)	Yield Strength Fy (ksi)	Allowable Load (lbs)
CSJ / 1.625"	20	0.0329	33	277
	18	0.0428	33	469
	16	0.0538	33	476
			50	722
	14	0.0677	33	754
			50	837
	12	0.0966	33	837
			50	837

Figure 36- Allowable Loads for 10 Gauge QuickClip™
Image courtesy Dietrich Metal Framing

Each QuickClip™ will need to be welded to each stud, and fastened to either the concrete deck or steel beam. The Hilti™ powder-driven fasteners will to be designed for allowable shear and tension. In order to determine these values, the wind load must be incorporated into the shear stress.

Wind Load Shear:

Tributary Area * Wind Load = Wind Load @ Center of Tributary Area
20.31 SF * 26 PSF = **528.06 LBS**
(Wind Load @ Center of Tributary Area)/2 = Shear @ Each Connection
528.06 LBS / 2 = **264.03 LBS**

The Hilit™ fasteners will need to be embedded into the 4000psi concrete deck to a depth of 1-1/2", based off of the calculated allowable shear force. Figure 37 below lists the shear and tension forces for the Hilti™ fasteners in normal weight concrete.

Allowable Hilti* Powder Driven Fastener Design Values in Normal Weight Concrete (lb)

Fastener Type	Shank Diameter	Min Embed.	2000 psi		3000 psi		4000 psi	
			Shear	Tension	Shear	Tension	Shear	Tension
X-DNI	.145"	5/8"	–	–	–	–	–	–
		3/4"	95	70	110	90	125	110
		1"	140	90	160	120	185	155
		1-1/2"	230	165	280	190	335	215
DS	.177"	1-7/16"	250	150	285	205	330	275

Figure 37- Allowable Hilti™ Fastener Design Values In Concrete

Image courtesy Dietrich Metal Framing

Shear and Tension through the steel beam also needs to be compared to the manufacturers design values to ensure the loads can be supported by the QuickClip™. Tension at the beam will be calculated because the fasteners will be installed at the bottom of the beam, directed upwards.

Tension at the steel beam:

Tributary Area * Dead Load = **233.10 LBS**

The tension value obtained does not exceed any design value listed in Figure 38 below; therefore, it will satisfy all beam types of Campus Square.

Allowable Hilti* Powder-Driven Fastener Design Values in Structural Steel (lbs)

Fastener Type	Shank Diameter	1/8" Steel		3/16" Steel		1/4" Steel		3/8" Steel	
		Shear	Tension	Shear	Tension	Shear	Tension	Shear	Tension
X-EDNI	.145"	230	110	425	455	620	800	680	810
DS	.177"	–	–	795	390	625	620	780	780

Figure 37- Allowable Hilti™ Fastener Design Values In Structural Steel

Image courtesy Dietrich Metal Framing

Lastly, the weld locations along the QuickClip™, which bonds the steel stud to the clip needs to be compared to allowable weld design values as listed by the manufacturer. As Figure 38 depicts, a 1" fillet weld connecting the clip and the 16 gauge stud will exceed the design conditions.

Allowable Weld Design Values (lbs) per inch of weld

Gauge	Fy (ksi)	Welds	
		Fillet	Flare Groove
20	33	***	***
18	33	482	405
16	33	606	510
16	50	721	510
14	33	762	641
14	50	907	641
12	33	1087	915
12	50	1294	915
10	33	1328	1118
10	50	1581	1118

Figure 38- Allowable Weld Design Values

Image courtesy Dietrich Metal Framing

Please review Appendix E of this report for the QuickClip™ product data used in this analysis.

Conclusion and Recommendation

The QuickClip™ connectors provide an excellent solution in attaching the prefabricated panels to the superstructure of Campus Square. They allow for construction tolerances in the field in their design by providing stand-off. Also, the clips can be manufactured and attached to the panels before they are delivered on-site. This will allow for less on-site welding which is costly, and allows for added risk during installation.

The redesign of the exterior wall system also eliminates the concrete slab overhang past the edge of the steel beams. This will ultimately reduce the amount of concrete needed during the pour of each floor, saving money in material costs, as well as time for installation.

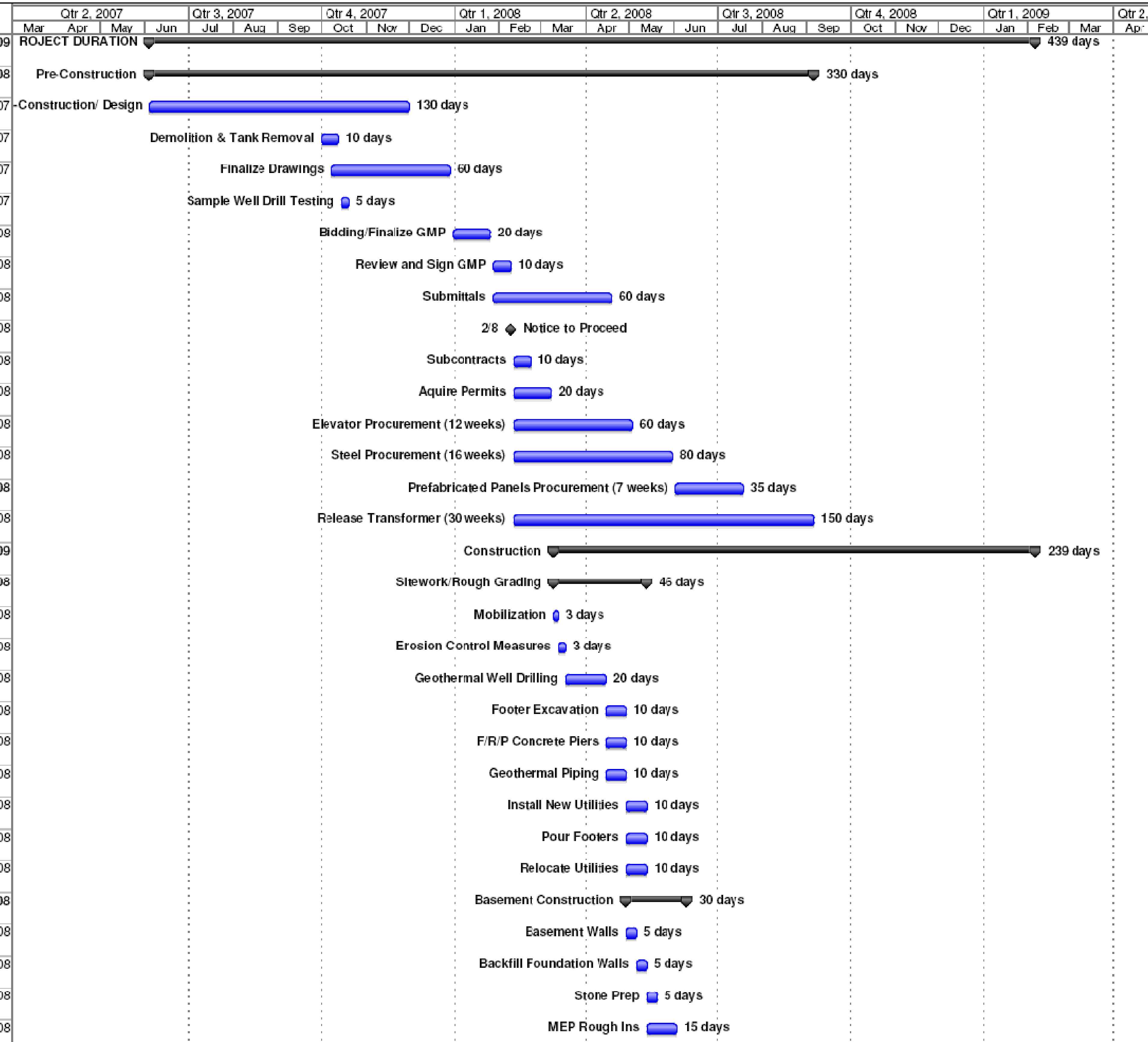
Further study could be performed in determining the deflection differences the proposed panel system will have on the steel, compared to the as-built wall system. The original wall design created a distributed load along the concrete slab edge. However, the proposed system will incorporate point loads along the beams and the concrete slab. It can be assumed that because the prefabricated system will have a lesser dead load on the structure, deflection issues may be negated.

Prefabrication of the exterior wall system will result in carefully design details, construction joints, and sizing each panel due to the importance of mitigating gaps along the panels. Defects in the design and improper installation methods will result in a lesser performing system.

Appendix A – Proposed Project Schedule

Please see next page.

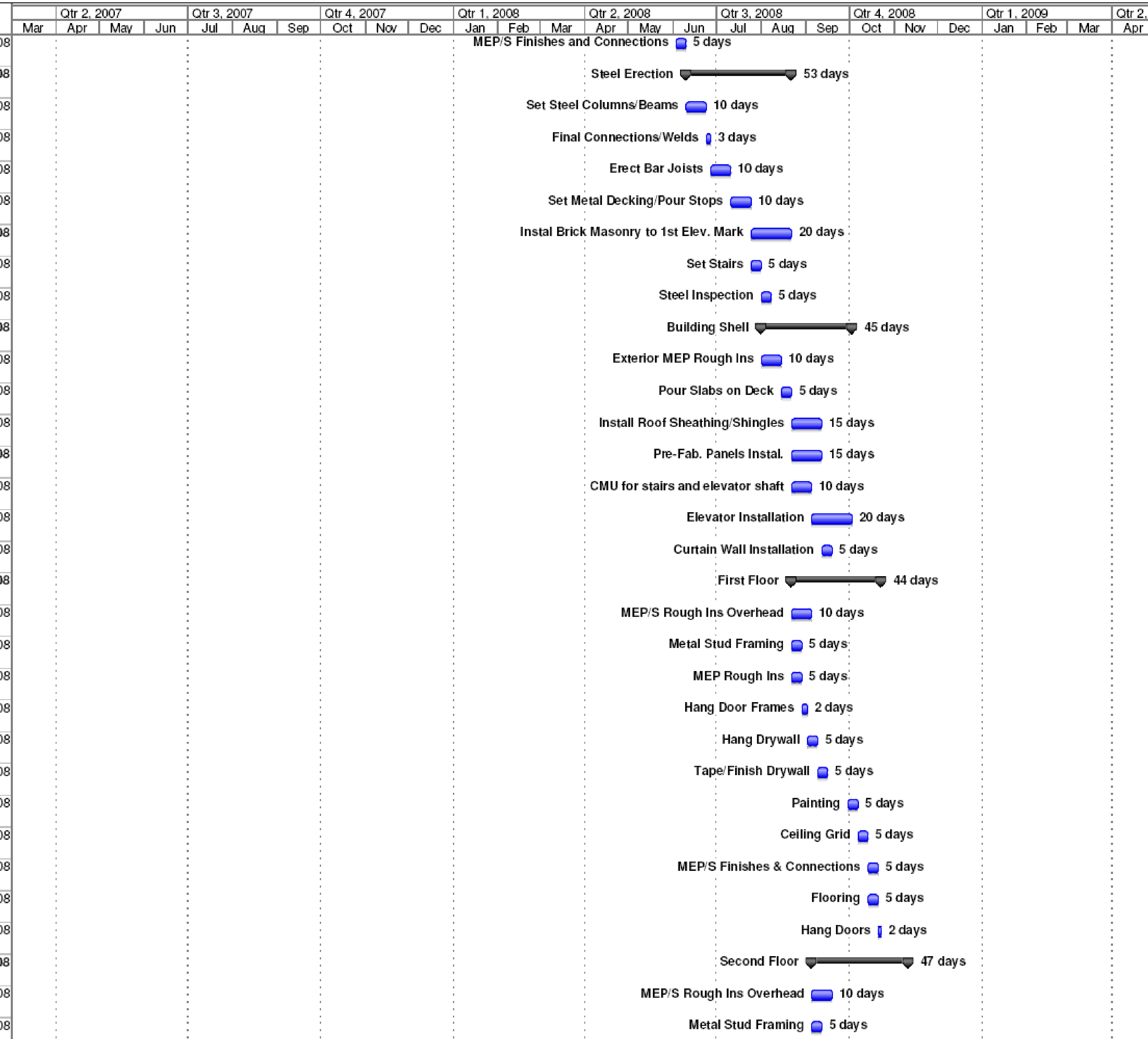
ID	Task Name	Duration	Start	Finish
1	**PROJECT DURATION**	**439 days**	**Mon 6/4/07**	**Thu 2/5/09**
2	**Pre-Construction**	**330 days**	**Mon 6/4/07**	**Fri 9/5/08**
3	Pre-Construction/ Design	130 days	Mon 6/4/07	Fri 11/30/07
4	Demolition & Tank Removal	10 days	Mon 10/1/07	Fri 10/12/07
5	Finalize Drawings	60 days	Mon 10/8/07	Fri 12/28/07
6	Sample Well Drill Testing	5 days	Mon 10/15/07	Fri 10/19/07
7	Bidding/Finalize GMP	20 days	Mon 12/31/07	Fri 1/25/08
8	Review and Sign GMP	10 days	Mon 1/28/08	Fri 2/8/08
9	Submittals	60 days	Mon 1/28/08	Fri 4/18/08
10	Notice to Proceed	0 days	Fri 2/8/08	Fri 2/8/08
11	Subcontracts	10 days	Mon 2/11/08	Fri 2/22/08
12	Aquire Permits	20 days	Mon 2/11/08	Fri 3/7/08
13	Elevator Procurement (12 weeks)	60 days	Mon 2/11/08	Fri 5/2/08
14	Steel Procurement (16 weeks)	80 days	Mon 2/11/08	Fri 5/30/08
15	**Prefabricated Panels Procurement (7 weeks)**	**35 days**	**Mon 6/2/08**	**Fri 7/18/08**
16	Release Transformer (30 weeks)	150 days	Mon 2/11/08	Fri 9/5/08
17	**Construction**	**239 days**	**Mon 3/10/08**	**Thu 2/5/09**
18	**Sitework/Rough Grading**	**46 days**	**Mon 3/10/08**	**Mon 5/12/08**
19	Mobilization	3 days	Mon 3/10/08	Wed 3/12/08
20	Erosion Control Measures	3 days	Thu 3/13/08	Mon 3/17/08
21	Geothermal Well Drilling	20 days	Tue 3/18/08	Mon 4/14/08
22	Footer Excavation	10 days	Tue 4/15/08	Mon 4/28/08
23	F/R/P Concrete Piers	10 days	Tue 4/15/08	Mon 4/28/08
24	Geothermal Piping	10 days	Tue 4/15/08	Mon 4/28/08
25	Install New Utilities	10 days	Tue 4/29/08	Mon 5/12/08
26	Pour Footers	10 days	Tue 4/29/08	Mon 5/12/08
27	Relocate Utilities	10 days	Tue 4/29/08	Mon 5/12/08
28	**Basement Construction**	**30 days**	**Tue 4/29/08**	**Mon 6/9/08**
29	Basement Walls	5 days	Tue 4/29/08	Mon 5/5/08
30	Backfil Foundation Walls	5 days	Tue 5/6/08	Mon 5/12/08
31	Stone Prep	5 days	Tue 5/13/08	Mon 5/19/08
32	MEP Rough Ins	15 days	Tue 5/13/08	Mon 6/2/08



Project: Campus Square Schedule_Pre
Date: Tue 3/16/10

Task		Milestone		Rolled Up Task		Rolled Up Progress		External Tasks		Group By Summary	
Progress		Summary		Rolled Up Milestone		Split		Project Summary		Deadline	

ID	Task Name	Duration	Start	Finish
33	MEP/S Finishes and Connections	5 days	Tue 6/3/08	Mon 6/9/08
34	**Steel Erection**	**53 days**	**Tue 6/10/08**	**Thu 8/21/08**
35	Set Steel Columns/Beams	10 days	Tue 6/10/08	Mon 6/23/08
36	Final Connections/Welds	3 days	Tue 6/24/08	Thu 6/26/08
37	Erect Bar Joists	10 days	Fri 6/27/08	Thu 7/10/08
38	Set Metal Decking/Pour Stops	10 days	Fri 7/11/08	Thu 7/24/08
39	**Instal Brick Masonry to 1st Elev. Mark**	**20 days**	**Fri 7/25/08**	**Thu 8/21/08**
40	Set Stairs	5 days	Fri 7/25/08	Thu 7/31/08
41	Steel Inspection	5 days	Fri 8/1/08	Thu 8/7/08
42	**Building Shell**	**45 days**	**Fri 8/1/08**	**Thu 10/2/08**
43	Exterior MEP Rough Ins	10 days	Fri 8/1/08	Thu 8/14/08
44	Pour Slabs on Deck	5 days	Fri 8/15/08	Thu 8/21/08
45	Install Roof Sheathing/Shingles	15 days	Fri 8/22/08	Thu 9/11/08
46	**Pre-Fab. Panels Instal.**	**15 days**	**Fri 8/22/08**	**Thu 9/11/08**
47	CMU for stairs and elevator shaft	10 days	Fri 8/22/08	Thu 9/4/08
48	Elevator Installation	20 days	Fri 9/5/08	Thu 10/2/08
49	Curtain Wall Installation	5 days	Fri 9/12/08	Thu 9/18/08
50	**First Floor**	**44 days**	**Fri 8/22/08**	**Wed 10/22/08**
51	MEP/S Rough Ins Overhead	10 days	Fri 8/22/08	Thu 9/4/08
52	Metal Stud Framing	5 days	Fri 8/22/08	Thu 8/28/08
53	MEP Rough Ins	5 days	Fri 8/22/08	Thu 8/28/08
54	Hang Door Frames	2 days	Fri 8/29/08	Mon 9/1/08
55	Hang Drywall	5 days	Tue 9/2/08	Mon 9/8/08
56	Tape/Finish Drywall	5 days	Tue 9/9/08	Mon 9/15/08
57	Painting	5 days	Tue 9/30/08	Mon 10/6/08
58	Ceiling Grid	5 days	Tue 10/7/08	Mon 10/13/08
59	MEP/S Finishes & Connections	5 days	Tue 10/14/08	Mon 10/20/08
60	Flooring	5 days	Tue 10/14/08	Mon 10/20/08
61	Hang Doors	2 days	Tue 10/21/08	Wed 10/22/08
62	**Second Floor**	**47 days**	**Fri 9/5/08**	**Mon 11/10/08**
63	MEP/S Rough Ins Overhead	10 days	Fri 9/5/08	Thu 9/18/08
64	Metal Stud Framing	5 days	Fri 9/5/08	Thu 9/11/08



Project: Campus Square Schedule_Pre
Date: Tue 3/16/10

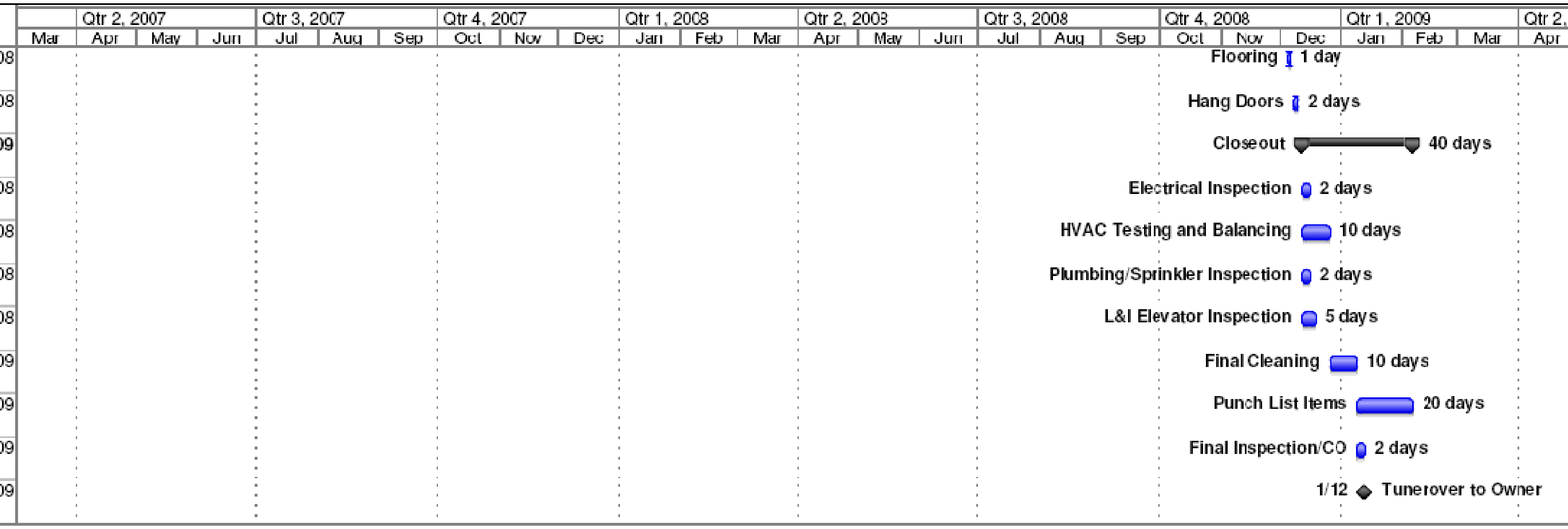
Task	Milestone ◆	Rolled Up Task	Rolled Up Progress	External Tasks	Group By Summary
Progress	Summary	Rolled Up Milestone ◇	Split	Project Summary	Deadline ⇩

ID	Task Name	Duration	Start	Finish
65	MEP Rough Ins	10 days	Fri 9/5/08	Thu 9/18/08
66	Hang Door Frames	2 days	Fri 9/12/08	Mon 9/15/08
67	Hang Drywall	5 days	Fri 9/19/08	Thu 9/25/08
68	Tape/Finish Drywall	5 days	Fri 9/26/08	Thu 10/2/08
69	Painting	5 days	Fri 10/17/08	Thu 10/23/08
70	Ceiling Grid	5 days	Fri 10/24/08	Thu 10/30/08
71	MEP/S Finishes & Connections	5 days	Fri 10/31/08	Thu 11/6/08
72	Flooring	5 days	Fri 10/31/08	Thu 11/6/08
73	Hang Doors	2 days	Fri 11/7/08	Mon 11/10/08
74	**Third Floor**	**47 days**	**Fri 9/19/08**	**Mon 11/24/08**
75	MEP/S Rough Ins Overhead	10 days	Fri 9/19/08	Thu 10/2/08
76	Metal Stud Framing	5 days	Fri 9/19/08	Thu 9/25/08
77	MEP Rough Ins	10 days	Fri 9/19/08	Thu 10/2/08
78	Hang Door Frames	2 days	Fri 9/26/08	Mon 9/29/08
79	Hang Drywall	5 days	Fri 10/3/08	Thu 10/9/08
80	Tape/Finish Drywall	5 days	Fri 10/10/08	Thu 10/16/08
81	Painting	5 days	Fri 10/31/08	Thu 11/6/08
82	Ceiling Grid	5 days	Fri 11/7/08	Thu 11/13/08
83	**Instal Panel Sequence 5: A-D**	**1 day**	**Tue 11/11/08**	**Tue 11/11/08**
84	MEP/S Finishes & Connections	5 days	Fri 11/14/08	Thu 11/20/08
85	Flooring	5 days	Fri 11/14/08	Thu 11/20/08
86	Hang Doors	2 days	Fri 11/21/08	Mon 11/24/08
87	**Fourth Floor**	**50 days**	**Fri 10/3/08**	**Thu 12/11/08**
88	MEP/S Rough Ins Overhead	10 days	Fri 10/3/08	Thu 10/16/08
89	Metal Stud Framing	5 days	Fri 10/3/08	Thu 10/9/08
90	MEP Rough Ins	10 days	Fri 10/3/08	Thu 10/16/08
91	Hang Door Frames	2 days	Fri 10/10/08	Mon 10/13/08
92	Hang Drywall	10 days	Fri 10/17/08	Thu 10/30/08
93	Tape/Finish Drywall	5 days	Fri 10/31/08	Thu 11/6/08
94	Painting	5 days	Fri 11/21/08	Thu 11/27/08
95	Ceiling Grid	5 days	Fri 11/28/08	Thu 12/4/08
96	MEP/S Finishes & Connections	5 days	Fri 12/5/08	Thu 12/11/08

Project: Campus Square Schedule_Pre
Date: Tue 3/16/10

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

ID	Task Name	Duration	Start	Finish
97	Flooring	1 day	Fri 12/5/08	Fri 12/5/08
98	Hang Doors	2 days	Mon 12/8/08	Tue 12/9/08
99	**Closeout**	**40 days**	**Fri 12/12/08**	**Thu 2/5/09**
100	Electrical Inspection	2 days	Fri 12/12/08	Mon 12/15/08
101	HVAC Testing and Balancing	10 days	Fri 12/12/08	Thu 12/25/08
102	Plumbing/Sprinkler Inspection	2 days	Fri 12/12/08	Mon 12/15/08
103	L&I Elevator Inspection	5 days	Fri 12/12/08	Thu 12/18/08
104	Final Cleaning	10 days	Fri 12/26/08	Thu 1/8/09
105	Punch List Items	20 days	Fri 1/9/09	Thu 2/5/09
106	Final Inspection/CO	2 days	Fri 1/9/09	Mon 1/12/09
107	Tunerover to Owner	0 days	Mon 1/12/09	Mon 1/12/09



Project: Campus Square Schedule_Pre
Date: Tue 3/16/10

Task		Milestone	◆	Rolled Up Task		Rolled Up Progress		External Tasks		Group By Summary	
Progress		Summary		Rolled Up Milestone ◇		Split		Project Summary		Deadline	⇩

Appendix B – General Conditions: As-Built vs. Proposed

Proposed Campus Square General Conditions Estimate				
Description	**Quantity**	**Unit**	**Unit Price**	**Total**
Supervision/Project Management				
Customer Captain/VP	17	HR	$175	$2,975
Project Executive	57.8	HR	$175	$10,115
Director of Field Operations	174.25	HR	$150	$26,138
Director of Safety	204	HR	$50	$10,200
Project Manager	1926.95	HR	$100	$192,695
Project Superintendent	2281.4	HR	$100	$228,140
Project Engineer	263.5	HR	$75	$19,763
Job Foreman	467.5	HR	$75	$35,063
Project Assistant	986	HR	$50	$49,300
Project Accountant	205.7	HR	$65	$13,371
Contract Administrator	15.3	HR	$125	$1,913
			Subtotal	**$589,671**
Administrative Facilities and Supplies				
Contractor's Office Set-Up	1	EA	$2,500	$2,500
Job Office Expenses	11	MTH	$250	$2,750
Furniture	1	EA	$1,000	$1,000
Copy Machine	11	MTH	$100	$1,100
Personal Computers	11	MTH	$100	$1,100
Local Area Network/Data	11	MTH	$100	$1,100
Telephone - Setup	1	EA	$150	$150
Monthly Telephone Bills	11	MTH	$100	$1,100
Cell Phone Bills	11	MTH	$100	$1,100
Jobsite Storage - Fence/Barriers	11	MTH	$1,200	$13,200
Drawings and Specifications	11	MTH	$200	$2,200
Photographs	11	MTH	$50	$550
Motor Vehicle Expenses (Gas/Maint.)	11	MTH	$500	$5,500
Postage and Shipping	11	MTH	$250	$2,750
Travel Expenses	11	MTH	$500	$5,500
As-Built Drawings	1	EA	$1,000	$1,000
Engineering Instruments/Supplies	11	MTH	$50	$550
			Subtotal	**$43,150**
Safety				
Job Safety Expenses	11	MTH	$200	$2,200
Safety Materials	11	MTH	$100	$1,100

Fire Protection (Extinguishers)	11	EA	$100	$1,100
			Subtotal	**$4,400**
Clean-up				
Periodic Clean-up (Laborer)	2346.4	HR	$35	$82,124
Construction Cleaning	1	LS	$11,000	$11,000
Dumpster Service	11	MTH	$1,000	$11,000
Waste management Consultant	11	MTH	$200	$2,200
			Subtotal	**$106,324**
Jobsite Work Requirements				
Fences/Barricades	10	MTH	$500	$5,000
Signage	1	LS	$5,000	$5,000
Misc. Tools & Equipment	10	MTH	$3,000	$30,000
Drinking Water	10	MTH	$100	$1,000
Protect Floors & Walls	1	LS	$8,000	$8,000
Patch FP	1	LS	$5,000	$5,000
Elevator Protection	1	LS	$1,500	$1,500
Temporary Heating/Cooling (for job office)	11	MTH	$400	$4,400
Monthly Electric Bill (for job office)	11	MTH	$100	$1,100
Fuel/Oil (misc.)	3	MTH	$200	$600
Temporary Toilets	11	MTH	$500	$5,500
Temporary Water / Electric (for construction activities)	11	MTH	$250	$2,750
Temporary Heat	3	MTH	$200	$600
Construction Site Access	1	LS	$2,500	$2,500
80' Pettibone	9	MTH	$2,200	$19,800
60' Man Lift	7	MTH	$1,800	$12,600
Contractor Parking Lot	1	LS	$11,000	$11,000
Laydown Space Preparation	1	LS	$10,000	$10,000
			Subtotal	**$126,350**
Permitting	**Cost**			
Building Permit	$65,256			
Street Cut Permit	$1,430			
Subtotal	**$66,686**			
Bonds and Insurance				
Liability Insurance	$88,456			
Mercantile Tax	$17,032			
Subtotal	**$105,488**			
Total General Conditions Cost	**$1,042,069**			

Campus Square General Conditions Estimate				
Description	**Quantity**	**Unit**	**Unit Price**	**Total**
Supervision/Project Management				
Customer Captain/VP	20	HR	$175	$3,500
Project Executive	68	HR	$175	$11,900
Director of Field Operations	205	HR	$150	$30,750
Director of Safety	240	HR	$50	$12,000
Project Manager	2267	HR	$100	$226,700
Project Superintendent	2684	HR	$100	$268,400
Project Engineer	310	HR	$75	$23,250
Job Foreman	550	HR	$75	$41,250
Project Assistant	1160	HR	$50	$58,000
Project Accountant	242	HR	$65	$15,730
Contract Administrator	18	HR	$125	$2,250
			Subtotal	**$693,730**
Administrative Facilities and Supplies				
Contractor's Office Set-Up	1	EA	$2,500	$2,500
Job Office Expenses	13	MTH	$250	$3,250
Furniture	1	EA	$1,000	$1,000
Copy Machine	13	MTH	$100	$1,300
Personal Computers	13	MTH	$100	$1,300
Local Area Network/Data	13	MTH	$100	$1,300
Telephone - Setup	1	EA	$150	$150
Monthly Telephone Bills	13	MTH	$100	$1,300
Cell Phone Bills	13	MTH	$100	$1,300
Jobsite Storage - Fence/Barriers	13	MTH	$1,200	$15,600
Drawings and Specifications	13	MTH	$200	$2,600
Photographs	13	MTH	$50	$650
Motor Vehicle Expenses (Gas/Maint.)	13	MTH	$500	$6,500
Postage and Shipping	13	MTH	$250	$3,250
Travel Expenses	13	MTH	$500	$6,500
As-Built Drawings	1	EA	$1,000	$1,000
Engineering Instruments/Supplies	13	MTH	$50	$650
			Subtotal	**$50,150**
Safety				
Job Safety Expenses	13	MTH	$200	$2,600
Safety Materials	13	MTH	$100	$1,300
Fire Protection (Extinguishers)	31	EA	$100	$3,100
			Subtotal	**$7,000**

Clean-up				
Periodic Clean-up (Laborer)	2933	HR	$35	$102,655
Construction Cleaning	1	LS	$11,000	$11,000
Dumpster Service	13	MTH	$1,000	$13,000
Waste management Consultant	13	MTH	$200	$2,600
			Subtotal	**$129,255**
Jobsite Work Requirements				
Fences/Barricades	12	MTH	$500	$6,000
Signage	1	LS	$5,000	$5,000
Misc. Tools & Equipment	12	MTH	$3,000	$36,000
Drinking Water	12	MTH	$100	$1,200
Protect Floors & Walls	1	LS	$8,000	$8,000
Patch FP	1	LS	$5,000	$5,000
Elevator Protection	1	LS	$1,500	$1,500
Temporary Heating/Cooling (for job office)	13	MTH	$400	$5,200
Monthly Electric Bill (for job office)	13	MTH	$100	$1,300
Fuel/Oil (misc.)	4	MTH	$200	$800
Temporary Toilets	13	MTH	$500	$6,500
Temporary Water / Electric (for construction activities)	13	MTH	$250	$3,250
Temporary Heat	4	MTH	$200	$800
Construction Site Access	1	LS	$2,500	$2,500
80' Pettibone	11	MTH	$2,200	$24,200
60' Man Lift	9	MTH	$1,800	$16,200
Contractor Parking Lot	1	LS	$11,000	$11,000
Laydown Space Preparation	1	LS	$10,000	$10,000
			Subtotal	**$144,450**

Permitting	**Cost**
Building Permit	$65,256
Street Cut Permit	$1,430
Subtotal	**$66,686**
Bonds and Insurance	
Liability Insurance	$88,456
Mercantile Tax	$17,032
Subtotal	**$105,488**
Total General Conditions Cost	**$1,196,759**

Appendix C – Prefabrication Panel Take-off Dimensions

Panel Sequence 1			
Panel Sequence #	Length (ft.)	Height (ft.)	SF
1	29	14	406
2	20 3/4	14	290 2/4
3	16	14	224
4	23 3/4	14	332 2/4
5	24	16	384
6,11	29	12 3/4	369 3/4
7,12	28 3/4	12 3/4	365 2/4
8,13	25	12 3/4	318 3/4
9,14	23 3/4	12 3/4	302 3/4
10,15	24	12 3/4	306
16	29	17 2/4	507 2/4
17	28 3/4	17 2/4	501 3/4
18	25	17 2/4	437 2/4
19	23 3/4	16	380
20	24	16	384

Panel Sequence 2			
Panel Sequence #	Length (ft.)	Height (ft.)	SF
1	23 3/4	14	332 2/4
2	23 2/4	14	327 3/4
3	28 3/4	14	401 1/4
4	23 3/4	14	332 2/4
5	28 3/4	14	401 1/4
6,11	23 3/4	12 3/4	302 3/4
7,12	23 2/4	12 3/4	299 3/4
8,13	28 3/4	12 3/4	366 2/4
9,14	23 3/4	12 3/4	302 3/4
10,15	28 3/4	12 3/4	366 2/4
16	23 3/4	16	380
17	23 2/4	16	376
18	28 3/4	16	460
19	23 3/4	16	380
20	28 3/4	16	460

Panel Sequence 3			
Panel Sequence #	Length (ft.)	Height (ft.)	SF
1	29	14	406
2	28 3/4	14	401 1/4
3	23 2/4	14	329
4	23 3/4	14	332 2/4
5,9	29	12 3/4	367 1/4
6,10	28 3/4	12 3/4	364 1/4
7,11	23 2/4	12 3/4	297 3/4
8,12	23 3/4	12 3/4	300 3/4
13	29	17 2/4	507 2/4
14	28 3/4	17 2/4	503 1/4
15	23 2/4	17 2/4	411 1/4
16	23 3/4	17 2/4	415 3/4

Panel Sequence 4			
Panel Sequence #	Length (ft.)	Height (ft.)	SF
1	23 3/4	14	332 2/4
2	16	14	224
3	22	14	308
4	23 3/4	14	332 2/4
5,9	23 3/4	12 3/4	302 3/4
6,10	25	12 3/4	318 3/4
7,11	28 3/4	12 3/4	365 2/4
8,12	29	12 3/4	369 3/4
13	23 3/4	17 2/4	415 3/4
14	25	17 2/4	437 2/4
15	28 3/4	17 2/4	503 1/4
16	29	17 2/4	507 2/4

Panel Sequence 5			
Panel Sequence #	Length (ft.)	Height (ft.)	SF
A	24	14	336
B,C	24	12 3/4	306
D	24	17 2/4	420

Appendix D – Heat Loss Calculations and Assembly Take-off Values

Masonry Veneer Take-off										
Wall	Type	Floor	Length	Height	SF	Windows	Doors	Storefront	Curtain Wall	Veneer SF
North	A	1	146 5/8	6 3/8	928 7/8	611	133 4/8	270 1/8	0	1038 6/8
North	D	1	146 5/8	7 5/8	1124 4/8	-	-	-		-
North	A	2	146 5/8	12 5/8	1857 6/8	288			333 4/8	1236 2/8
North	A	3	146 5/8	12 5/8	1857 6/8	312			333 4/8	1212 2/8
North	A	4	146 5/8	16	2346 5/8	312			421 3/8	1613 3/8
South	A	1	194 3/8	14	2413 7/8	252	21			2447 4/8
South	D	1	40	7 5/8	306 5/8	-	-	-	-	-
South	A	2	146 5/8	12 5/8	1857 6/8	288				1569 6/8
South	A	3	146 5/8	12 5/8	1857 6/8	270				1587 6/8
South	A	4	146 5/8	16	2346 5/8	288				2058 5/8
East	A	1	121	6 3/8	771 3/8	70 2/8	90	602 5/8		936 1/8
East	D	1	121	7 5/8	927 5/8	-	-	-	-	-
East	A	2	121	12 5/8	1532 5/8	306				1226 5/8
East	A	3	121	12 5/8	1532 5/8	336				1196 5/8
East	A	4	121	16	1936	336				1600
West	A	1	121	14	1694	301 2/8	21			1371 6/8
West	A	2	121	12 5/8	1532 5/8	270				1262 5/8
West	A	3	121	12 5/8	1532 5/8	288				1244 5/8
West	A	4	121	16	1936	306				1630
				TOTAL A	27935 2/8	4834 4/8	265 4/8	872 6/8	1088 4/8	23232 6/8
				TOTAL D	2358 6/8	Total				

Metal Studs (2" x 6") Subtracting out Curtain Wall only								
Wall	Floor	Length	Height	Stud (ft)	O.C (ft)	C Wall LF	Stud LF	Stud SF
N	1	146 5/8	14	1/8	1 3/8	26 3/8	15	210 4/8
N	2	146 5/8	12 5/8	1/8	1 3/8	26 3/8	15	190 4/8
N	3	146 5/8	12 5/8	1/8	1 3/8	26 3/8	15	190 4/8
N	4	146 5/8	16	1/8	1 3/8	26 3/8	15	240 5/8
S	1	194 3/8	14	1/8	1 3/8		24 2/8	340
S	2	146 5/8	12 5/8	1/8	1 3/8		18 3/8	232 2/8
S	3	146 5/8	12 5/8	1/8	1 3/8		18 3/8	232 2/8
S	4	146 5/8	16	1/8	1 3/8		18 3/8	293 3/8
E	1	121	14	1/8	1 3/8		15 1/8	211 6/8
E	2	121	12 5/8	1/8	1 3/8		15 1/8	191 5/8
E	3	121	12 5/8	1/8	1 3/8		15 1/8	191 5/8
E	4	121	16	1/8	1 3/8		15 1/8	242
W	1	121	14	1/8	1 3/8		15 1/8	211 6/8
W	2	121	12 5/8	1/8	1 3/8		15 1/8	191 5/8
W	3	121	12 5/8	1/8	1 3/8		15 1/8	191 5/8
W	4	121	16	1/8	1 3/8		15 1/8	242

Heat Loss Q= (Btu/h ft^2 °F)			Exterior Wall 6" batt. Insulation						
Wall	Floor	Venner SF	Batt SF	R value	U Value	Δt Summer	Δt Winter	Q (Summer)	Q (Winter)
N	1	1038.78	828.27	20.51	0.05	16.00	61.00	646.14	2463.40
N	2	1236.22	1045.76	20.51	0.05	16.00	61.00	815.81	3110.26
N	3	1212.22	1021.76	20.51	0.05	16.00	61.00	797.08	3038.88
N	4	1613.33	1372.75	20.51	0.05	16.00	61.00	1070.89	4082.78
S	1	2447.48	2107.42	20.51	0.05	16.00	61.00	1644.01	6267.80
S	2	1569.78	1337.56	20.51	0.05	16.00	61.00	1043.44	3978.10
S	3	1587.78	1355.56	20.51	0.05	16.00	61.00	1057.48	4031.64
S	4	2058.67	1765.33	20.51	0.05	16.00	61.00	1377.15	5250.38
E	1	936.10	724.35	20.51	0.05	16.00	61.00	565.07	2154.32
E	2	1226.67	1035.08	20.51	0.05	16.00	61.00	807.48	3078.50
E	3	1196.67	1005.08	20.51	0.05	16.00	61.00	784.07	2989.28
E	4	1600.00	1358.00	20.51	0.05	16.00	61.00	1059.39	4038.91
W	1	1371.72	1159.97	20.51	0.05	16.00	61.00	904.90	3449.94
W	2	1262.67	1071.08	20.51	0.05	16.00	61.00	835.56	3185.57
W	3	1244.67	1053.08	20.51	0.05	16.00	61.00	821.52	3132.04
W	4	1630.00	1388.00	20.51	0.05	16.00	61.00	1082.79	4128.13
	TOTALS	23232.74	19629.06					15312.77	58379.93

Exterior Wall Metal Stud						
Stud SF	R Value	U Value	Δt Summer	Δt Winter	Q (Summer)	Q (Winter)
210.51	3.86	0.26	16.00	61.00	872.58	3326.72
190.46	3.86	0.26	16.00	61.00	789.48	3009.89
190.46	3.86	0.26	16.00	61.00	789.48	3009.89
240.58	3.86	0.26	16.00	61.00	997.24	3801.96
340.06	3.86	0.26	16.00	61.00	1409.58	5374.01
232.22	3.86	0.26	16.00	61.00	962.58	3669.83
232.22	3.86	0.26	16.00	61.00	962.58	3669.83
293.33	3.86	0.26	16.00	61.00	1215.89	4635.58
211.75	3.86	0.26	16.00	61.00	877.72	3346.31
191.58	3.86	0.26	16.00	61.00	794.13	3027.61
191.58	3.86	0.26	16.00	61.00	794.13	3027.61
242.00	3.86	0.26	16.00	61.00	1003.11	3824.35
211.75	3.86	0.26	16.00	61.00	877.72	3346.31
191.58	3.86	0.26	16.00	61.00	794.13	3027.61
191.58	3.86	0.26	16.00	61.00	794.13	3027.61
242.00	3.86	0.26	16.00	61.00	1003.11	3824.35
3603.69					14937.57	56949.48

Pella Windows						
Area (SF)	U- Value	Δt Summer	Δt Winter	Q (Summer)	Q (Winter)	
610.94	0.35	16.00	61.00	3421.29	13043.66	
288.00	0.35	16.00	61.00	1612.80	6148.80	
312.00	0.35	16.00	61.00	1747.20	6661.20	
312.00	0.35	16.00	61.00	1747.20	6661.20	
252.00	0.35	16.00	61.00	1411.20	5380.20	
288.00	0.35	16.00	61.00	1612.80	6148.80	
270.00	0.35	16.00	61.00	1512.00	5764.50	
288.00	0.35	16.00	61.00	1612.80	6148.80	
70.28	0.35	16.00	61.00	393.56	1500.43	
306.00	0.35	16.00	61.00	1713.60	6533.10	
336.00	0.35	16.00	61.00	1881.60	7173.60	
336.00	0.35	16.00	61.00	1881.60	7173.60	
301.28	0.35	16.00	61.00	1687.16	6432.28	
270.00	0.35	16.00	61.00	1512.00	5764.50	
288.00	0.35	16.00	61.00	1612.80	6148.80	
306.00	0.35	16.00	61.00	1713.60	6533.10	
4834.50				27073.20	103216.58	TOTALS

Doors, Storefront, and Curtain Wall						
Area (SF)	U- Value Summer	U-Value Winter	Δt Summer	Δt Winter	Q (Summer)	Q (Winter)
403.61	0.92	1.02	16.00	61.00	5941.16	25112.68
333.56	0.92	1.02	16.00	61.00	4909.94	20753.83
333.56	0.92	1.02	16.00	61.00	4909.94	20753.83
421.33	0.92	1.02	16.00	61.00	6202.03	26215.36
21.00	0.92	1.02	16.00	61.00	309.12	1306.62
692.67	0.92	1.02	16.00	61.00	10196.05	43097.72
21.00	0.92	1.02	16.00	61.00	309.12	1306.62
2226.72	6.44				32777.35	138546.66

Value Engineering Analysis- East Side Curtain Wall Addition:

Addition of Curtain Wall System on East Side										
Wall	Floor	Height (ft)	Width (ft)	SF	U-Value Summer	U-Value Winter	Δt Summer	Δt Winter	Q (Summer)	Q (Winter)
E	2	12 5/8	24	304	0.92	1.02	16.00	61.00	4474.88	18914.88
E	3	12 5/8	24	304	0.92	1.02	16.00	61.00	4474.88	18914.88
E	4	16	24	384	0.92	1.02	16.00	61.00	5652.48	23892.48
			TOTALS	992					14602.24	61722.24

Proposed Prefabricated Panel Analysis:

Heat Loss Q= (Btu/h ft^2 °F)			Exterior Wall Cavity Space						
Wall	Floor	Venner SF	Batt SF	R value	U Value	Δt Summer	Δt Winter	Q (Summer)	Q (Winter)
N	1	1038.78	828.27	20.66	0.05	16.00	61.00	641.45	2445.51
N	2	1236.22	1045.76	20.66	0.05	16.00	61.00	809.88	3087.68
N	3	1212.22	1021.76	20.66	0.05	16.00	61.00	791.30	3016.81
N	4	1613.33	1372.75	20.66	0.05	16.00	61.00	1063.12	4053.13
S	1	2447.48	2107.42	20.66	0.05	16.00	61.00	1632.08	6222.30
S	2	1569.78	1337.56	20.66	0.05	16.00	61.00	1035.86	3949.22
S	3	1587.78	1355.56	20.66	0.05	16.00	61.00	1049.80	4002.37
S	4	2058.67	1765.33	20.66	0.05	16.00	61.00	1367.15	5212.26
E	1	936.10	724.35	20.66	0.05	16.00	61.00	560.97	2138.68
E	2	1226.67	1035.08	20.66	0.05	16.00	61.00	801.61	3056.15
E	3	1196.67	1005.08	20.66	0.05	16.00	61.00	778.38	2967.57
E	4	1600.00	1358.00	20.66	0.05	16.00	61.00	1051.69	4009.58
W	1	1371.72	1159.97	20.66	0.05	16.00	61.00	898.33	3424.89
W	2	1262.67	1071.08	20.66	0.05	16.00	61.00	829.49	3162.44
W	3	1244.67	1053.08	20.66	0.05	16.00	61.00	815.55	3109.30
W	4	1630.00	1388.00	20.66	0.05	16.00	61.00	1074.93	4098.16
	TOTALS	23232.74	19629.06					15201.59	57956.07

Exterior Wall Metal Stud						
Stud SF	R Value	U Value	Δt Summer	Δt Winter	Q (Summer)	Q (Winter)
210.51	19.79	0.05	16.00	61.00	170.20	648.87
190.46	19.79	0.05	16.00	61.00	153.99	587.07
190.46	19.79	0.05	16.00	61.00	153.99	587.07
240.58	19.79	0.05	16.00	61.00	194.51	741.57
340.06	19.79	0.05	16.00	61.00	274.93	1048.19
232.22	19.79	0.05	16.00	61.00	187.75	715.79
232.22	19.79	0.05	16.00	61.00	187.75	715.79
293.33	19.79	0.05	16.00	61.00	237.16	904.16
211.75	19.79	0.05	16.00	61.00	171.20	652.69
191.58	19.79	0.05	16.00	61.00	154.89	590.53
191.58	19.79	0.05	16.00	61.00	154.89	590.53
242.00	19.79	0.05	16.00	61.00	195.65	745.93
211.75	19.79	0.05	16.00	61.00	171.20	652.69
191.58	19.79	0.05	16.00	61.00	154.89	590.53
191.58	19.79	0.05	16.00	61.00	154.89	590.53
242.00	19.79	0.05	16.00	61.00	195.65	745.93
3603.69					2913.54	11107.88

Comparison Table:

As-Built Heat Loss Q= (Btu/h ft^2 °F)				Pre-Fab Heat Loss Q= (Btu/h ft^2 °F)				Difference			
Wall	Floor	Summer	Winter	Wall	Floor	Summer	Winter	Summer Δ	% Summer	Winter Δ	% Winter
N	1	10881.16	43946.47	N	1	10174.09	41250.73	707.08	6.5%	2695.73	6.1%
N	2	8128.02	33022.77	N	2	7486.61	30577.38	641.42	7.9%	2445.40	7.4%
N	3	8243.70	33463.79	N	3	7602.42	31018.91	641.28	7.8%	2444.88	7.3%
N	4	10017.36	40761.30	N	4	9206.85	37671.26	810.50	8.1%	3090.04	7.6%
S	1	4773.91	18328.63	S	1	3627.33	13957.30	1146.58	24.0%	4371.32	23.8%
S	2	3618.82	13796.74	S	2	2836.41	10813.81	782.41	21.6%	2982.92	21.6%
S	3	3532.06	13465.97	S	3	2749.55	10482.66	782.51	22.2%	2983.31	22.2%
S	4	4205.84	16034.76	S	4	3217.11	12265.22	988.73	23.5%	3769.54	23.5%
E	1	12032.40	50098.78	E	1	11321.77	47389.52	710.63	5.9%	2709.26	5.4%
E	2	3315.20	12639.21	E	2	2670.11	10179.78	645.10	19.5%	2459.43	19.5%
E	3	3459.80	13190.49	E	3	2814.87	10731.70	644.93	18.6%	2458.79	18.6%
E	4	3944.09	15036.86	E	4	3128.95	11929.12	815.15	20.7%	3107.74	20.7%
W	1	3778.90	14535.15	W	1	3065.81	11816.49	713.09	18.9%	2718.67	18.7%
W	2	3141.69	11977.68	W	2	2496.39	9517.47	645.30	20.5%	2460.21	20.5%
W	3	3228.45	12308.45	W	3	2583.25	9848.63	645.20	20.0%	2459.82	20.0%
W	4	3799.50	14485.58	W	4	2984.18	11377.19	815.32	21.5%	3108.39	21.5%
	TOTALS	90100.89	357092.64			77965.69	310827.18	12135.20	13.5%	46265.46	13.0%

Energy Consumption Comparison:

Q (kW) = Q(BTU/hr) x (1kW/3413 BTU/hr)

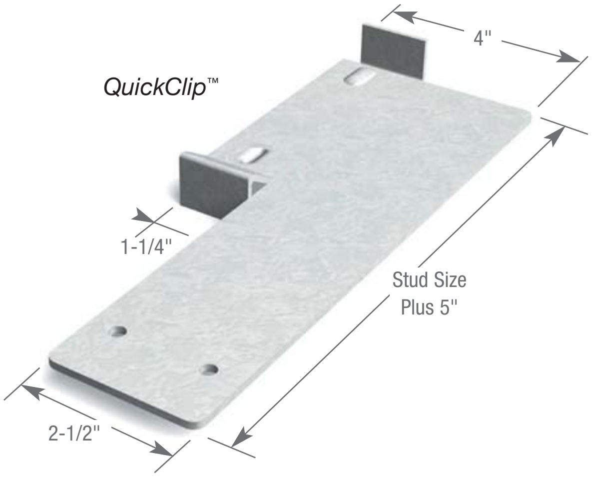
kW/hr Camparrison		As-Built		Pre-Fab		Difference			
Wall	Floor	Summer	Winter	Summer	Winter	Summer kW	%	Winter kW	%
N	1	3.2	12.9	3.0	12.1	0.2	6.5%	0.8	6.1%
N	2	2.4	9.7	2.2	9.0	0.2	7.9%	0.7	7.4%
N	3	2.4	9.8	2.2	9.1	0.2	7.8%	0.7	7.3%
N	4	2.9	11.9	2.7	11.0	0.2	8.1%	0.9	7.6%
S	1	1.4	5.4	1.1	4.1	0.3	24.0%	1.3	23.8%
S	2	1.1	4.0	0.8	3.2	0.2	21.6%	0.9	21.6%
S	3	1.0	3.9	0.8	3.1	0.2	22.2%	0.9	22.2%
S	4	1.2	4.7	0.9	3.6	0.3	23.5%	1.1	23.5%
E	1	3.5	14.7	3.3	13.9	0.2	5.9%	0.8	5.4%
E	2	1.0	3.7	0.8	3.0	0.2	19.5%	0.7	19.5%
E	3	1.0	3.9	0.8	3.1	0.2	18.6%	0.7	18.6%
E	4	1.2	4.4	0.9	3.5	0.2	20.7%	0.9	20.7%
W	1	1.1	4.3	0.9	3.5	0.2	18.9%	0.8	18.7%
W	2	0.9	3.5	0.7	2.8	0.2	20.5%	0.7	20.5%
W	3	0.9	3.6	0.8	2.9	0.2	20.0%	0.7	20.0%
W	4	1.1	4.2	0.9	3.3	0.2	21.5%	0.9	21.5%
	TOTALS	26.4	104.6	22.8	91.1	3.6	13.5%	13.6	13.0%

Appendix E – Dietrich Metal Framing QuickClip™ Product Data

Please see the following page for the Dietrich Metal Framing QuickClip™ Product Data.

QuickClip™ vertical slide clip allows for vertical building movement and provides up to 3" of horizontal standoff.

- *Quick installation–twist and fasten.*
- *Horizontal stand-off up to 3".*
- *One-piece for right- or left-handed attachment.*
- *Accommodates 1-5/8" and 2" flanges.*
- *No shims or additional framing components needed.*
- *Custom sizes available.*



U.S. Patent No. 5, 836, 133 of B&D Industries

Dietrich™ QuickClip™ vertical slide clips are used to attach exterior curtain-wall studs to the building structure and provide for vertical building movement independent of the cold-formed steel framing. A QuickClip™ slide clip provides variable standoff and eliminates the need for shims or additional framing components. The QuickClip™ slide clip simply twists into place and fastens to the floor/ceiling beam. The clips restrict lateral movement, but enables the curtainwall system to move vertically.

Alternative Products

Fast Strut™ (FS12, FS15, FS24), Slide Clip (SD), FastClip™

Product Dimensions

Length: Stud size plus 5" (127mm)
Width: 2-1/2" (63.5mm) tail, 4" (101.6mm) overall.
Flange Support Tabs: 1-1/4" (31.7mm) x 15/16" (23.8mm)

Material Specifications

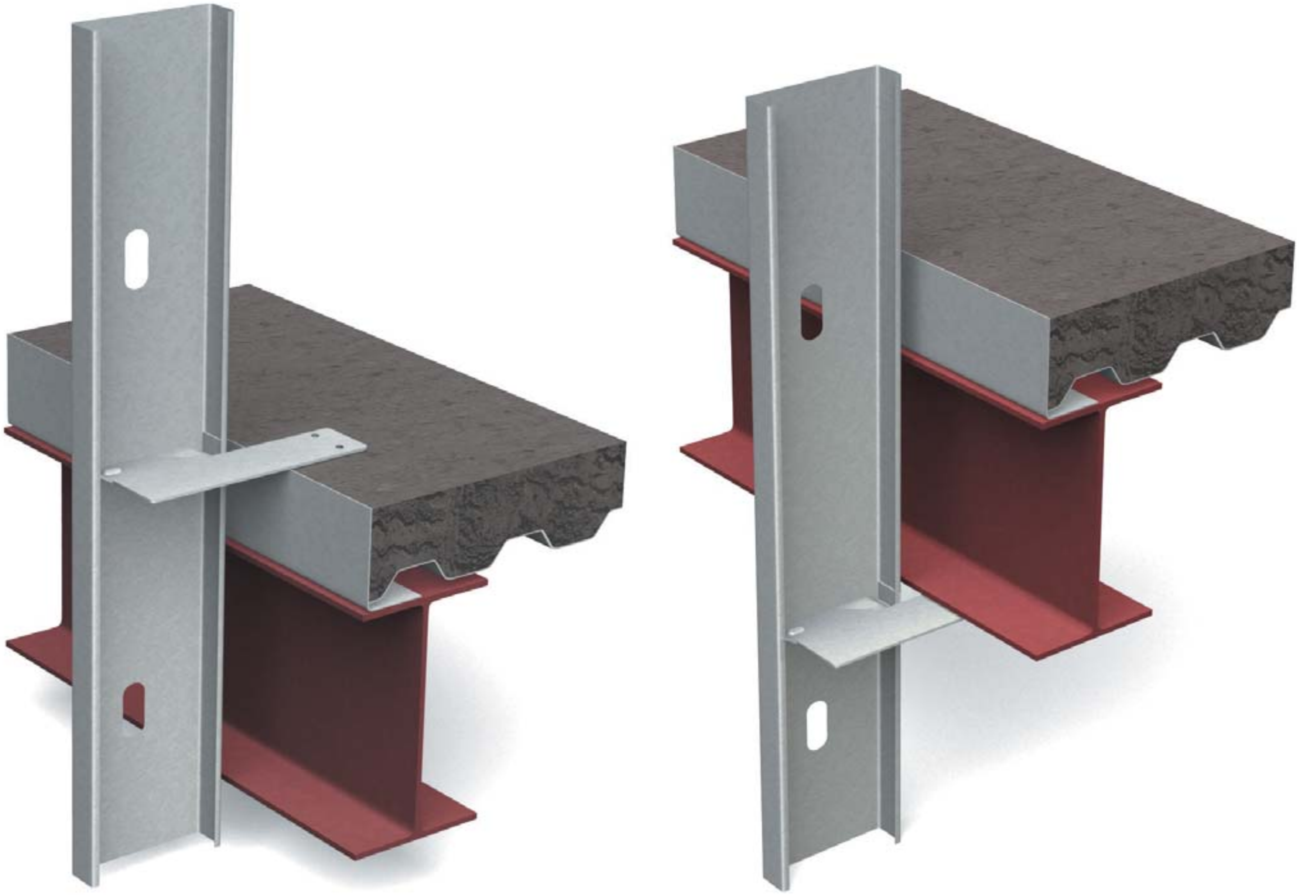
Gauge: 10 gauge (118 mils)
Design Thickness: 0.124 inches (3.155mm)
Coating: G60 (Z180) hot-dipped galvanized
Yield Strength: 33 ksi (230 MPa)
ASTM: A 653/ A 653M

Installation

Insert QuickClip™ into open end of C-stud at a diagonal and slide to horizontal support. Twist clip to horizontal position engaging tabs. Plumb/align stud and fasten clip to horizontal support as determined by others.

QuickClip™ (QC-Series™)

DMF Product Code	Thickness				Stud Width	Weight/Piece		Packaging
	Gauge	Mils	Design Thickness			lbs	kg	Pcs/ Bucket
			Inches	mm	Inches			
QC3	10	118	0.1242	3.155	3-5/8	0.940	0.426	50
QC4	10	118	0.1242	3.155	4	1.160	0.526	50
QC6	10	118	0.1242	3.155	6	1.460	0.662	50
QC8	10	118	0.1242	3.155	8	1.770	0.803	40



Allowable Loads for the 10 Gauge, 33 ksi QuickClip™

Stud Type/Flange Width	Stud Gauge	Min Thickness (Inches)	Yield Strength Fy (ksi)	Allowable Load (lbs)
CSJ / 1.625"	20	0.0329	33	277
	18	0.0428	33	469
	16	0.0538	33	476
			50	722
	14	0.0677	33	754
			50	837
	12	0.0966	33	837
			50	837
CSW / 2"	20	0.0329	33	84
	18	0.0428	33	151
	16	0.0538	33	166
			50	252
	14	0.0677	33	293
			50	444
	12	0.0966	33	702
			50	837

Typical Construction Details

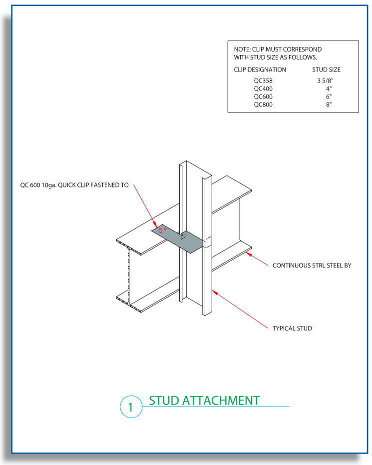


Table Notes

1) Tabulated values do not include the 1/3 stress increase.
2) The Quick-Clip is not recommended for use in areas controlled by seismic.
3) Tabulated values are based on 1" of weld on each side of the Quick-Clip as shown in the accompanying drawing. Use E60XX electrodes.
4) Allowable loads based on 2000 psi minimum concrete.
5) For technical service call Dietrich Design Group at 1-800-873-2443.

Visit our CAD Library at
dietrichmetalframing•com
to view or download construction details in .dwg, .dxf, and .pdf formats.

FASTENING OPTIONS

Connections can be made using a variety of fastening options. It is critical to specify the proper fastener to ensure the proper performance of the connections used in light-gauge (cold formed) steel construction. The most common and widely used connection methods include screw connections, welding connections and powder-driven fastener connections. Each type of connection method has various advantages and disadvantages. Therefore, we provide data for the three most common types so you can choose your preferred connection method.

Screw Connections

Self-Drilling Screws are externally threaded fasteners with the ability to drill their own hole and form, or "tap," their own internal threads without deforming their thread and without breaking during assembly. These screws are high-strength, one-piece installation fasteners and are used if the connection is multiple thicknesses of 33 mil steel or thicker. One of the more common self-drilling screws is a #10-16 x 5/8 HWH SD, which indicates a 10 diameter shaft, 16 threads per inch, 5/8 length, hex washer head self-drilling screw.

Allowable Screw Design Values (lb)

Gauge	Fy (ksi)	#8 Screws (.16" Dia)			#10 Screws (.19" Dia)			#12 Screws (.21" Dia)			1/4" Dia Screws		
		Shear	Pullover	Pullout	Shear	Pullover	Pullout	Shear	Pullover	Pullout	Shear	Pullover	Pullout
20	33	129	154	56	140	231	66	147	309	73	158	309	84
18	33	191	201	73	208	301	86	219	401	96	234	401	109
16	33	267	252	91	293	378	109	308	505	120	329	505	137
16	50	267	382	139	373	573	165	467	765	182	499	765	208
14	33	267	317	115	373	476	137	435	635	151	465	635	173
14	50	267	481	174	373	722	207	533	962	229	693	962	262
12	33	267	453	164	373	680	195	533	906	216	693	906	246
12	50	267	686	249	373	1030	296	533	1373	327	693	1373	373
10	33	267	553	201	373	830	238	533	1107	263	693	1107	301
10	50	267	838	304	373	1258	361	533	1677	399	693	1677	456

Assumed screw head diameter is 3/8".
Screw ultimate shear capacity is based on Buildex DATA as a minimum.

FastClip™ Deflection Screws — Many of the Dietrich™ deflection clips include our proprietary FastClip™ fastener that has been specifically designed to provide friction-free deflection. These fasteners eliminate drag, binding or resistance that can often occur with common fasteners.

FastClip™ Deflection Screw

Average Ultimate Shear	2400 lbs
NASPEC 2001 ASD Factor of Safety	3.0
Average Allowable Shearload	800 lbs

The load value listed is for single shear. There maybe other controlling shear failure modes specific to the application (e.g. pull-through from slot, bearing failure) which are to be considered seperately in the design of that perticular application.

Welded Connections

Fillet welds are used to make lap joints, corner joints and T-joint connections. As the illustration suggests, the fillet weld is roughly triangular in cross-section, although its shape is not always a right triangle or an isosceles triangle. Weld metal is deposited in a corner formed by the fit-up of the two members and penetrates and fuses with the base metal to form the joint.

Flare welds, including Flare Bevel and Flare V, are used to join rounded or curved pieces.

A Flare Bevel groove weld is commonly used to join a rounded or curved piece to a flat piece.

A Flare V groove weld is commonly used to join two rounded or curved parts.

NOTE: For graphical clarity, the weld illustrations do not show the penetration of the welded material. Weld penetration is critical in determining the quality of the weld.

Allowable Weld Design Values (lbs) per inch of weld

Gauge	Fy (ksi)	Welds	
		Fillet	Flare Groove
20	33	***	***
18	33	482	405
16	33	606	510
16	50	721	510
14	33	762	641
14	50	907	641
12	33	1087	915
12	50	1294	915
10	33	1328	1118
10	50	1581	1118

*Based on E60XX electrodes.

Powder-Actuated Connections

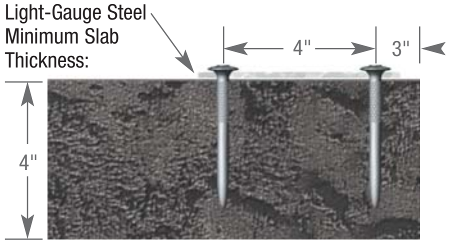
Powder-actuated or low velocity driven-fasteners are commonly used to attach cold-formed steel framing members to concrete or structural steel supports. Drive pins are used for permanent attachments and are the most common type used for cold-formed construction.

Allowable Hilti* Powder-Driven Fastener Design Values in Structural Steel (lbs)

Fastener Type	Shank Diameter	1/8" Steel		3/16" Steel		1/4" Steel		3/8" Steel		1/2" Steel		3/4" Steel	
		Shear	Tension	Shear	Tension	Shear	Tension	Shear	Tension	Shear	Tension	Shear	Tension
X-EDNI	.145"	230	110	425	455	620	800	680	810	605	850	545	500
DS	.177"	–	–	795	390	625	620	780	780	810	560	–	–

Shear values shall be checked against allowable bearing design values. The minimum value shall be used for design.
Tension values shall be checked against pullout or pullover values and the minimum value used.
Reference Hilti North America Products Technical Guide 2001 section 3.2.3.

Minimum Fastener Spacing and Edge Distances:



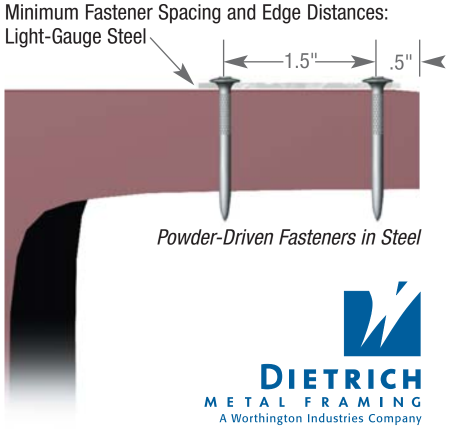
Powder Driven Fasteners in Concrete

Allowable Hilti* Powder Driven Fastener Design Values in Normal Weight Concrete (lb)

Fastener Type	Shank Diameter	Min Embed.	2000 psi		3000 psi		4000 psi		6000 psi	
			Shear	Tension	Shear	Tension	Shear	Tension	Shear	Tension
X-DNI	.145"	5/8"	–	–	–	–	–	–	60	45
		3/4"	95	70	110	90	125	110	95	75
		1"	140	90	160	120	185	155	195	130
		1-1/2"	230	165	280	190	335	215	–	–
DS	.177"	1-7/16"	250	150	285	205	330	275	–	–

Shear values shall be checked against allowable bearing design values and the minimum value used.
Tension values shall be checked against pullout or pullover values and the minimum value used.
Reference Hilti North America Products Technical Guide 2001 section 3.2.3.1

Minimum Fastener Spacing and Edge Distances:



Powder-Driven Fasteners in Steel

Allowable Hilti* Bearing Against Sheet Steel Design Values (lbs)

Pin Diameter	Gauge and Yield Strength (ksi) of Connected Part									
	20	18	16		14		12		10	
	33	33	33	50	33	50	33	50	33	50
0.145"	179	233	292	443	368	558	526	796	642	972
0.177"	218	285	357	541	450	681	642	972	783	1187

*Hilti is a registered trademark of the Hilti Aktiengeseilschaft Corporation.

DIETRICH METAL FRAMING
A Worthington Industries Company