2012

Anthony Grab

Final Report

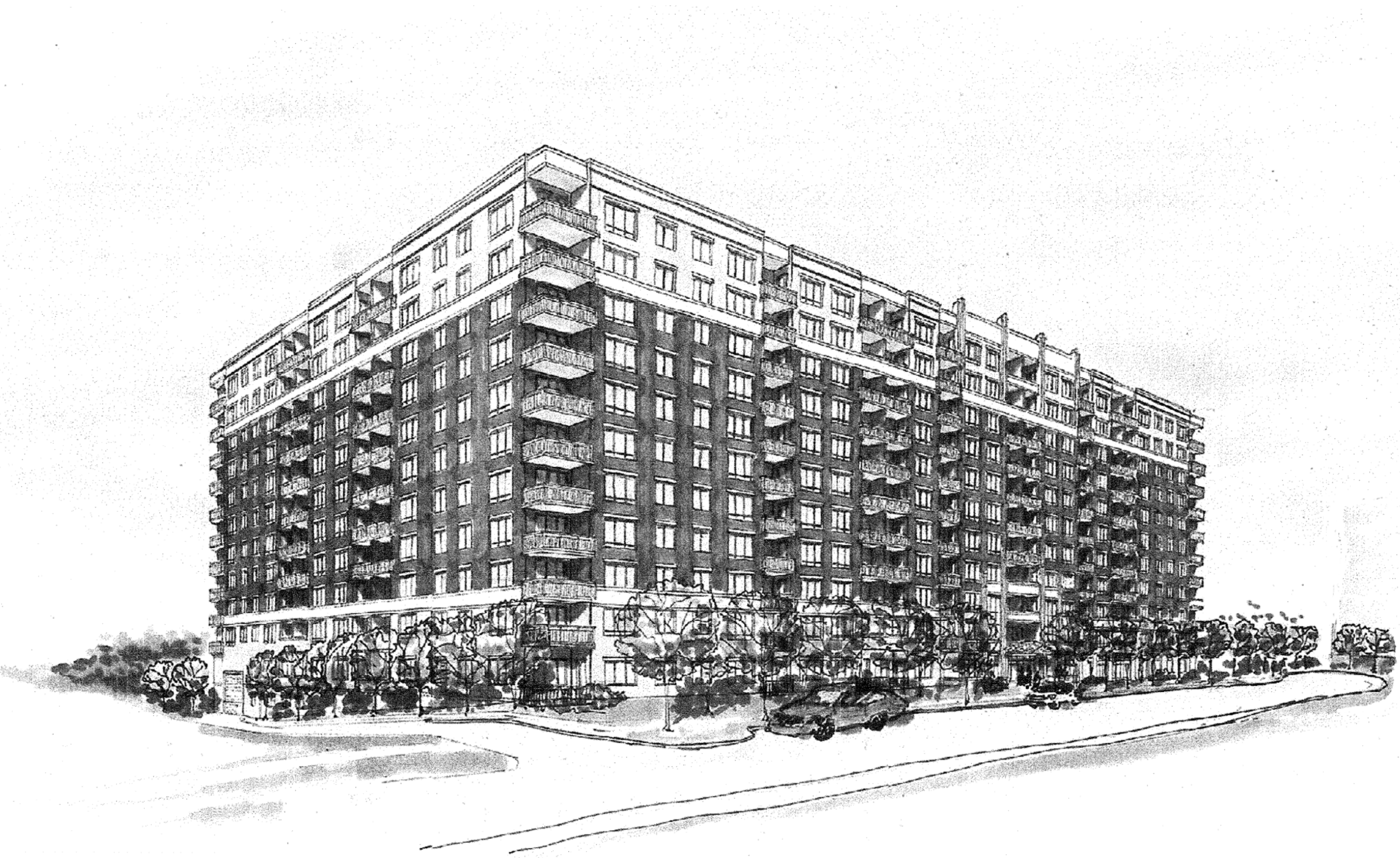


Figure 1: Sketch of Square 1400 – Courtesy of DPR

[SQUARE 1400 APARTMENTS]

Construction Management I Advisor: Raymond Sowers I Square 1400 Apartments I Fairfax, VA
11-12-2012 I Technical Assignment III

Square 1400 Apartments

Fairfax, VA l HITT Contracting

Project Information

Function	Apartment Housing
Project Cost	52 Million
Total Stories	11
Size	327,431 SF
Construction Dates	1/5/2012-10/15/2013
Delivery Method	Design-Build

Project Team

Owner	Rushmark LLC
GC	HITT Contracting
Architects	SBE & Associates Inc.
Civil	Dewberry & Davls
Structural	Meyer Consulting Engineers
Mechanical	J.B Wyble & Associates
Acoustical	Polysonics Corp.

Architecture

- The apartment building is primarily two shades of face brick on the exterior.
- The nearby precast parking structure features a precast skin with face brick to match the adjacent apartment building.
- With the site located on a corner lot, the building utilizes an L-shape to maximize the natural sun light.

Construction

- With the cast in place structure the building was constructed at a rate of 2 floor per week
- Each floor was broken into 3 pour, with a 2 foot pour strips in between to allow for expansion
- Good construction practices increased productivity, safety, and decreased the duration of the project.

Structural

- Apartment Building - composed of cast-in-place concrete frame with post tension cables
- Parking Garage - composed of precast panels

Mechanical

- Features 11 rooftop units at 5,500 CFM each, two indoor heat pumps at 675 CFM, and 850 CFM, respectively, and two outdoor heat pumps

Electrical

- Features a main electric duct bank service feeds twelve sets (4-60MCM in 4"C). A backup diesel fuel generator at 350 KW, 3 phase, 4W, 120/208V accommodated with a fuel tank of 693 gallons UL rating 142

Anthony Grab l Construction Management Option l 2012

Section 2: Executive Summary

The Thesis Final Proposal is intended to discuss the four key technical analyses that influence the execution of the Square 1400 Apartment Building located in Fairfax, VA. The building is a 327,431 SF apartment building with a neighboring three-story parking garage. Each of the analysis topics focuses on one idea that will improve the efficiency of construction. These topics include structural modification, schedule efficiency, prefabrication implantations, and energy savings systems.

Analysis 1: Change in Cast-In-Place Structure

The current structure for the Square 1400 Apartment Building is a six-inch cast-in-place structure with post-tension reinforcing. This cast-in-place structure has a large impact on construction cost, schedule, and manpower. The design of a new structural system, wood or Infinity, would result in a substantial direct and indirect cost savings with possible impact on the overall project schedule.

Analysis 2: SIPS (Short Interval Production Scheduling) + BIM (Building Information Modeling)

The project utilizes traditional scheduling techniques and minimal BIM was implemented. The use of the Short Interval Production Schedule (SIPS) method helps to break construction activities into detailed repeatable activities. This differs from the conventional way of project scheduling as it usually breaks projects into smaller operations instead of larger tasks resulting in a higher level of detail for individual tasks, which increases productivity and quality control.

Analysis 3: Increase Production Through Precast Brick Panels

Traditional Fraco Scaffolding System was used on all sides of the building to assist with the placing of exterior brick. This tied up the exterior of the building, which made it difficult for different trades to perform work on the building envelope and get materials into the building. This slowed down the production of a number of trades. The use of prefabricated brick veneer panels will substantially increase productivity, decrease site congestion, and improve trade coordination while achieving a similar building aesthetic.

Analysis 4: Critical Industry Issue: Operations and Maintenance + BIM

Today's buildings are becoming more complex and difficult to operate as there is a high demand for information rich models that will assist with the upkeep of the different building systems. In some cases, a more complex building means more energy costs. In the apartment setting, it can be challenging to monitor the energy use between each apartment unit. With the installation of an energy-savings dashboard, the hope is that the competitive nature of the residents, along with other incentives, will greatly reduce the building's overall energy intake.

Section 3: Acknowledgements

Academic Acknowledgements:

Raymond Sowers – CM Faculty Advisor

Dr. Messner

Prof. Robert Holland

Industry Acknowledgements:

Special Acknowledgments:

Randy Barrett – HITT Contracting

Tom Grab – HITT Contracting

Brain Able – Able Consulting Engineers

Friends and Family

Table of Contents

Section 4: Project Overview

Project Introduction and Client Information

About two years ago co-presidents of HITT Contracting, Brett Hitt and Jim Miller, sat down to discuss the construction of the first apartment building that would be constructed and owned by the family's brand, Rushmark LLC. The project location chosen was home to the previous HITT headquarters. After selling the first HITT headquarters property, the new owner quickly built very successful apartments. When Brett first heard of this, he decided to not sell the property; instead, he would build on it.

The total project cost for the new apartment building is about $50 million and is currently being constructed in Merrifield, VA. Within walking distance for the Dunn Loring Metro, the project is scheduled for completion in September of 2013. The new development includes a 12 story, 368,000 s.f. apartment complex with 327 units, and a 137,000 s.f. parking garage. Residents will be able to choose from 95 two bed room units or 232 one bed room units. Each floor plan will consist of 43 apartment units with dens. Residents will have the option to share a number of different amenities within the complex including a pool, yoga studio, fitness center, community room and 3,000 s.f. of commercial space.

The apartment structure is comprised of cast-in-place frame with a brick façade exterior. The nearby parking structure is utilizes a precast structure with a precast exterior skin to match the neighboring apartment building. Site work includes the demolition of the existing former HITT Contracting headquarters.

The project was designed to achieve a LEED rating of Silver for new construction. The design build team led by **HITT Contracting Inc.** includes SBE Associates as project architect; Wyble and Associates, Dewberry as Civil Engineer; MEP design; Gates Hudson and Associates as Property Manager, and developer Rushmark Properties LLC.

Figure 4.1- Square 1400 ISO View– Courtesy of HITT Contracting

LEED Evaluation

See Appendix A for the LEED Project Scorecard

Overview

Figure 2- LEED Logo – Courtesy of USGBC

The Square 1400 Apartments is currently pursing LEED Silver under the 2009 LEED-NC report rating. The 2009 system evaluates the build in a number of different categories including sustainable site, water efficiency, energy and atmosphere, and material resources. The United States Green Building Council (USGBC) set the LEED standards for all types of construction. Square 1400 falls under New Construction. HITT Contracting is working with SB Partner to develop a whole building energy simulation for the proposed apartment building. SB Partners utilizes a 3D model as a design tool specifically for the purpose of enhancing the energy performances of the facility. In doing so, this increased the LEED Energy and Atmosphere by one credit. These efforts along with HITT's in-house LEED team and the project team will ultimately save money and create a more stainable building.

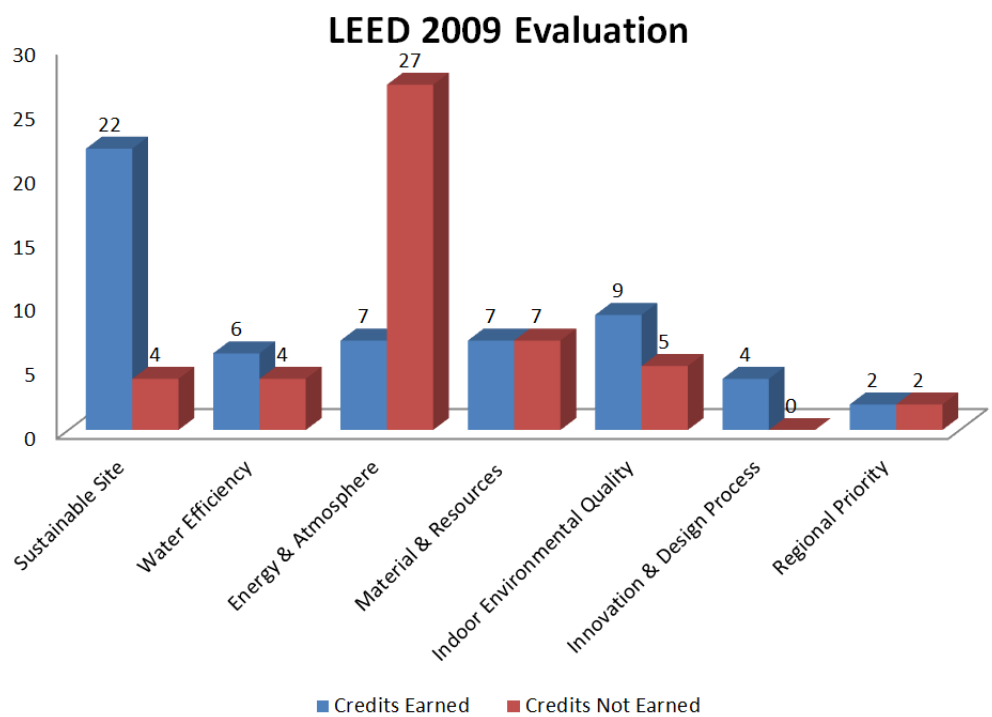


Figure 4.2- Square 1400 LEED Evaluation – Developed by Anthony Grab

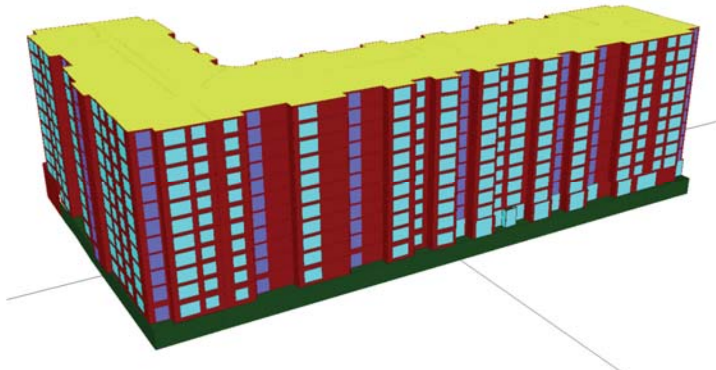


Figure 4.3- Square 1400 Energy Model – Courtesy of SB Partners

The following is a list of the energy efficiency measures that are to be implemented in the building.

- Residential: 13 SEER split system heat pumps (baseline is 9.105 EER PTHP)
- Corridors: High Efficiency Aaon units with VFD fans and Economizer
- Common Areas: High Efficiency VRF system
- High efficiency garage lighting at 0.15 W/sf max (baseline is 0.20 W/sf for covered parking and 0.15 W/sf for open parking lots an drives)
- High Efficiency Windows (apartment sliders, residential IGUs, and curtain walls)
- 1.5 gpm shower heads and faucets (assumed – no actual selections provided)
- ENERGY STAR Qualified Refrigerator (20% improvement)
- ENERGY STAR Qualified Clothes Washer (35% Improvement)
- ENERGY STAR Qualified Dish Washer (25% Improvement)
- Fixed building shading, self-shading, overhangs and porches

Local Conditions

The Square 1400 Apartment construction project incorporated construction methods common for the area. Although the project was outside the height restrictions of Washington DC, which forced a lot of buildings to be constructed of cast-in-place concrete to achieve the maximum number of floors with the lowest height, the designer still decided to follow these traditional methods. With the project being located outside the capital beltway seen in the figure below in a more urban setting, onsite parking was made available for HITT employees and subcontractor foremen.

The apartment building is trying to achieve a LEED Sliver Rating. In order to gain a few extra points, they incorporated a recycling system that allowed them to sort different material in the dumpster to be taken to a plant and reused. This was especially usefully during the demolition stage of the project. Common to the area, a shallow foundation system was used for construction. This was because the soil carried a design bearing pressure of 3,000 psf. The surface of the site was properly graded in order to enhance the drainage of surface water away from the building during the construction phase. Wherever possible, natural drainage was taken advantage of without interrupting the pattern.

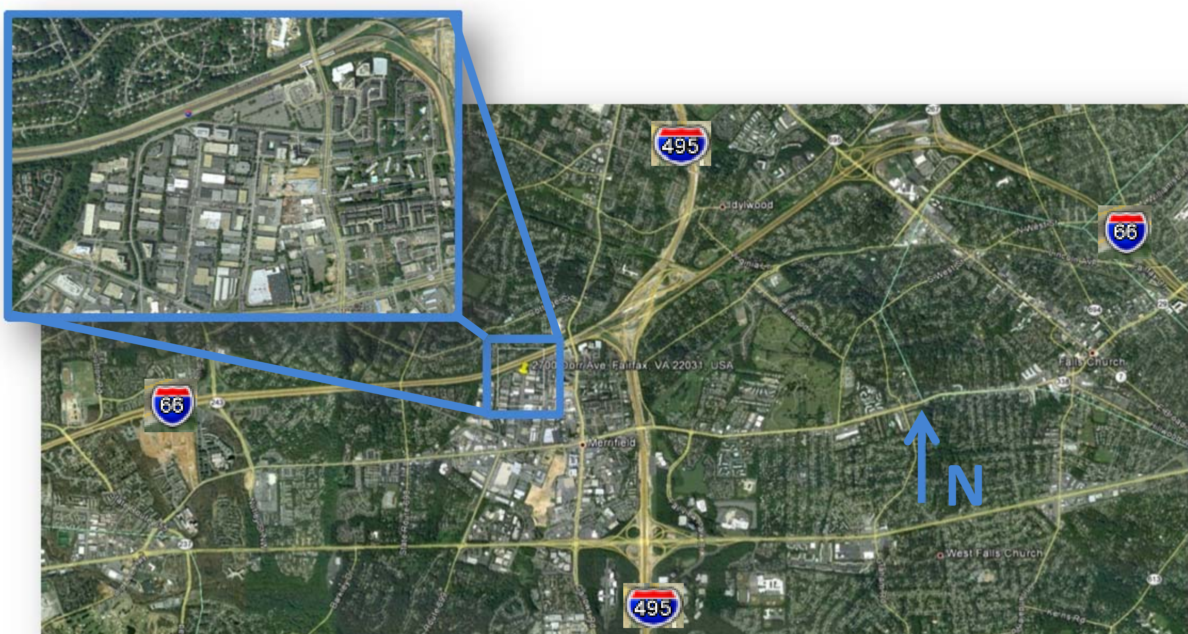


Figure 4.4: Site Location – Courtesy of Google

Existing Conditions

The location for the new apartment building is just 10 miles west of Washington, DC. The apartment building is surrounded by industrial warehouses and office buildings. Due to the location, the general contractor did not have to worry about heavy vehicular traffic or pedestrian traffic. During phase 1 of construction, Dorr Avenue will be made wider to accommodate the increased vehicular traffic flow to and from state Route 699. Along with the Dorr Avenue expansion, all existing buildings on site will be demolished as well as the existing asphalt and trees. Please see Appendix B for further detail.

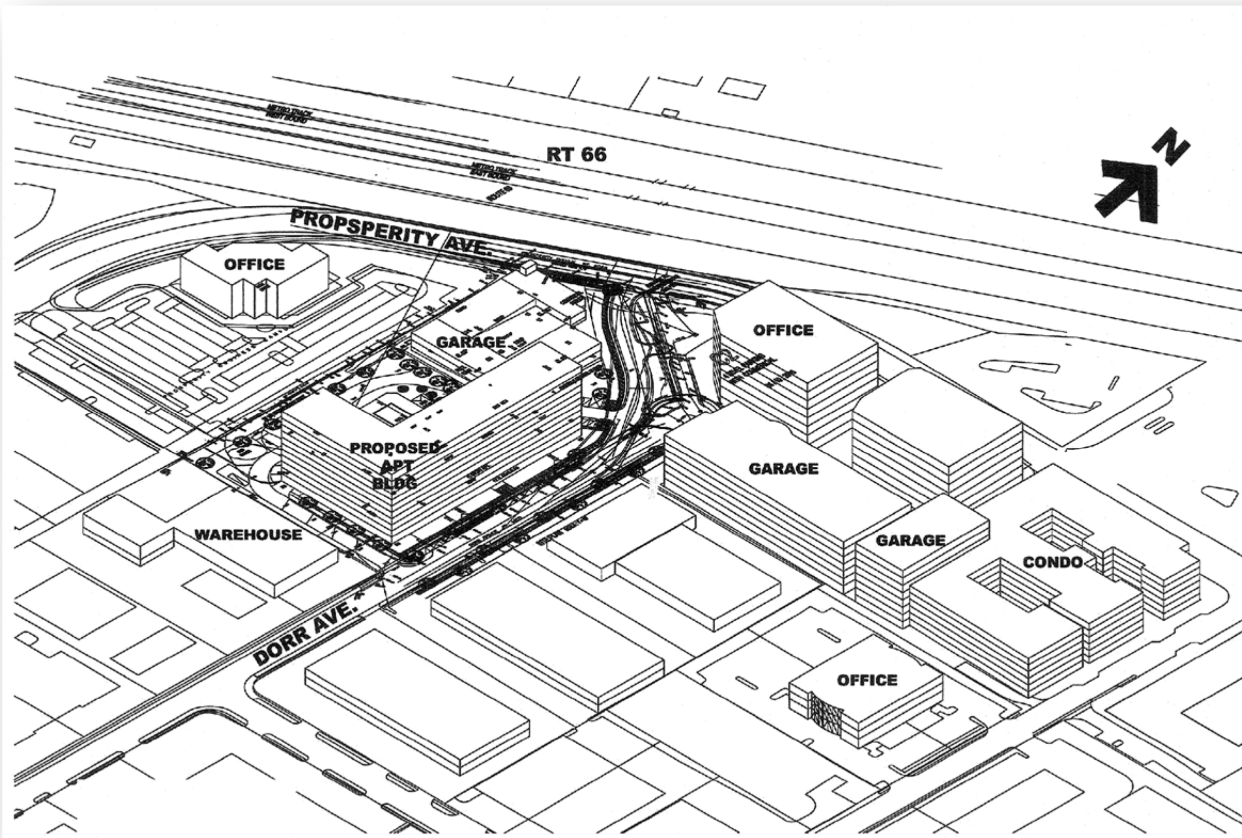


Figure 4.5: Isometric View – Courtesy of DPR

Client Information

Founded in 1937, HITT Contracting is among the top general contractors in the country, with offices up and down the east coast and about 700 employees. Their client focused teams work on anything from changing a doorknob to base building shells. This ability to adapt and take on jobs they're not accustomed to has allowed HITT to survive though the tough economy.

With the project cost and design at about $52 million, it is very important to have high expectations earlier on in the project design phase to ensure the best possible outcome. Owners Brett Hitt and Jim Miller did just that, setting high expectations for cost, quality, schedule, and most importantly safety. For cost, Brett kept a close eye on the project's financials by attending as many project meetings as possible. He understands that the sooner the project finishes, the sooner he can get tenants in his building. To ensure a quality product is being installed, the entire project team acts as a full-time quality control team, always inspecting the work through site walks. The schedule is always an important part of any construction project. Honing down on critical items early on in the project can help prevent setbacks in the future. To help keep an eye on these critical items, the project team keeps an up-to-date material tracking log with all the critical items, as well as the associated subcontractor and supplier contact information. The project team is working under a 22-month schedule for final completion, but will have first units turned out in about 17 months. Safety has always been a top priority for HITT Contracting. Just recently, the company has required all field and office personal to complete their OSHA 30-hour training. This strict safety program allows all HITT personal on site to be competent and greatly reduces the number of accident. Weekly safety inspections from the HITT safety department and weekly safety tool box talks for the subcontractor also play an important role in keeping the site safe.

Project Delivery System

The project delivery system for this project is usual in the sense that the owner of the project is Rushmark Developers, LLC which is owned by the HITT family. The delivery system chosen was design-build. The pre-construction sector at HITT Contracting worked with a local architect on the design one year prior to design. The design-build approach was chosen because HITT wanted to control the design as well as use an architect that worked on another MF builder project that the Brett Hitt wanted to mirror as much as possible. Because Brett Hitt was involved in the design at such an early stage, a large number of problems we eliminated and there was a potential savings in cost, change orders, and schedule duration.

All the contacts for the project were lump sum. This is typical for design-build projects, which is when the supplier agrees to provide a specific service for a specific price and the receiver agrees to pay upon the completion of work or in some cases to a negotiated schedule. In this case, because the developer/builder chose lump sum, it will estimate the cost of material and labor and add it to a standard amount for the desired amount of profit and overhead.

With the owner/developer being partially owned by the Hitt family, the General Contractor did not have to pull a bond, but had a requirement for all subcontractors for $250,000 and above to be bonded. HITT as the General Contractor did have to pull builders risk policy for the project. All subcontractors have to be qualified by HITT's insurance department, carry the company minimum for insurance, and have an up-to-date certificate of insurance on file. It is also a requirement that they are approved by HITTs in house approval system.

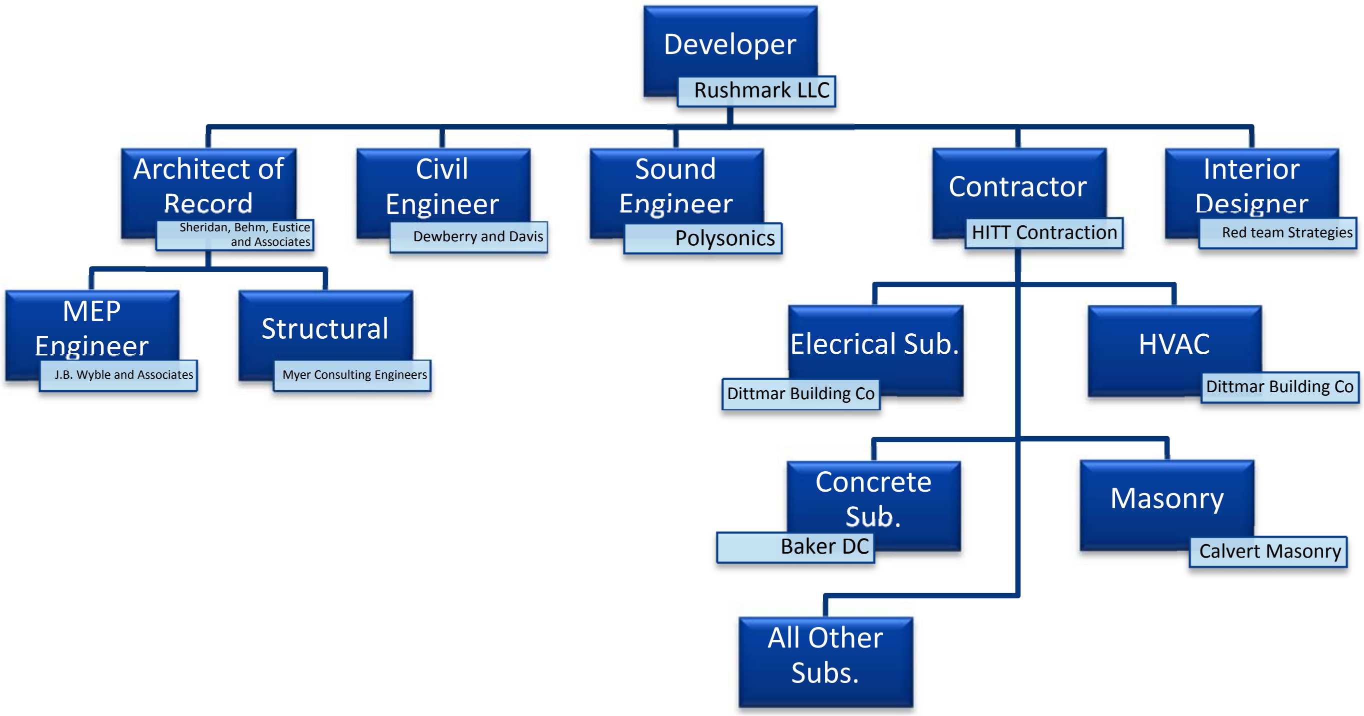


Figure 4.6: Project Delivery System – Developed by Anthony Grab

Staffing Plan

The project staffing place for HITT Contracting is illstrulated below in Figure 4.6. Unlike most projects, the president for the company does not directly get involved with the project. In this case, Brett Hitt is the owner of the project as well as the owner of HITT Contracting. Therefore he is a regular attendee at the project meetings. The rest of the project team is relatively standard with the Exctive Vice President down to the Project Manger, who splits his time at the office and the field. Both Assistant Project Managers and Project Engineers, as well as the Superintendents are on site full-time. As questions come up, they are channeled through the chain of command tree until a solution is found or the problem is resolved.

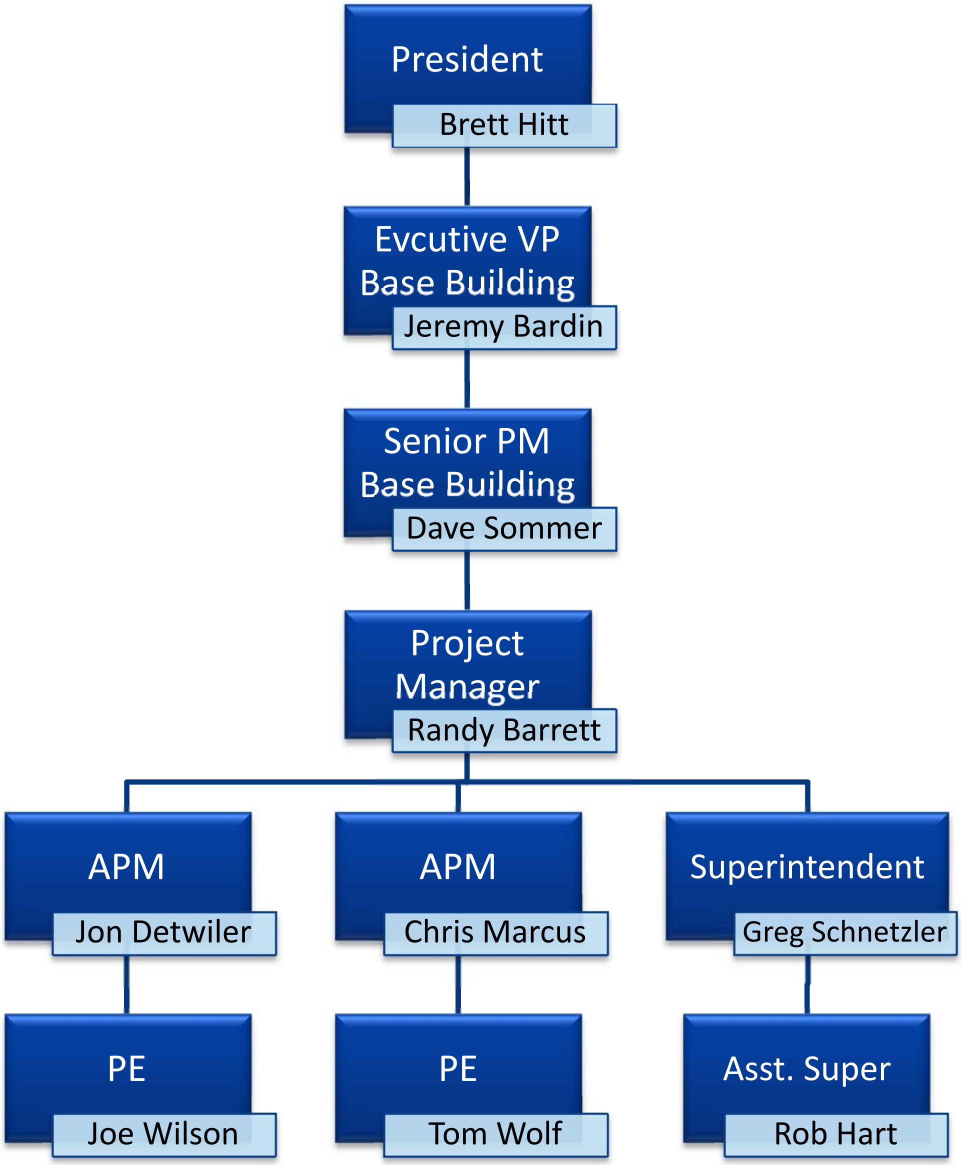


Figure 4.7: Project Staffing Plan – Developed by Anthony Grab

Building System Summary

Table 4.1: Building System Checklist – Developed by Anthony Grab

Building System Checklist		
Work Scope	**Yes**	**No**
Demolition Required	X	
Structural Steel Frame		X
Cast in Place Concrete	X	
Precast Concrete	X	
Mechanical Systems	X	
Electrical System	X	
Masonry	X	
Curtain Wall		X
Support of Excavation		X

Demolition

As mentioned earlier, the building site chosen for the project was the previous home to HITT Contracting. Therefore, demolition was required. On the north end of the site was the largest of the five buildings at about 40,204 SF. The building had an exterior façade primarily constructed of CMUs with a slab on grade, all of which had to be demolished. The remaining four smaller buildings, totaling 24,104 SF, had to be demolished as well. The last building to be demolished was the

Figure 4.8: Site Demo – Courtesy of HITT

110,860 SF asphalt parking lot.

Cast-In-Place Concrete

Common to the area, the structure is primarily cast-in-place concrete with post-tension cables with the exception of the parking structure, which used a precast structure. The cast-in-place apartment building has eleven stories all of which are about 38,480 SF. Because of this large area, the floors were broken into three pours. This

Figure 4.9: Cast –in-place – Courtesy of HITT

allowed the concrete to set up and give it room to expand and contract to prevent cracking. Pour strips were later filled in with concrete which was pumped in with a concrete pump truck. Three levels below, the pour floor had to be temporarily supported at all times. Once the slab was poured, the concrete columns followed and could be formed and poured the next day. Once the concrete reached design strength set by the structural engineer, the post tension cables could then be tightened. The building was constructed at a rate of one floor per two weeks

The nearby parking structure composed of precast concrete panels and was able to be erected in just three months. It was put together similar to a Lego set. Each piece would arrive on site on a flat bed and then be hoisted into place by a mobile crane.

Mechanical Systems

The mechanical system consisted mainly of 11 rooftop unit at 5,500 CFM each, two indoor heat pumps at 675 CFM and 850 CFM, respectively, and two outdoor heat pumps. The air distribution system utilizes series of duct risers that distribute air to each floor's corridor through branches. Each room had its own AHU that could be adjusted to the desired temperature. Because the project was striving for LEED Silver, all mechanical systems were to be protected during construction per required of section 01450, Indoor Air Quality Management.

Electrical System

The main electric duct bank service feeds twelve sets (4-60MCM in 4"C). A backup diesel fuel generator at 350 KW, 3 phase, 4W, 120/208V accommodated with a fuel tank of 693 gallons UL rating 142 and a weather proof enclosure provided emergency power.

Masonry

In trying to keep up with the quickly growing city of Merrifield, the building was skinned with a modern styling of brick veneer, which alternated from rose brick face color to a tan color. Thin masonry brick of the same color was used on the parking structure to help with the aesthetics of the cast-in-place concrete.

Figure 4.10: Ext. Mock-up – Courtesy of HITT

The masonry wall was comprised of standard brick veneer, air cavity, ridged insulation, and a vapor/air barrier, as seen in Figure 4.10. The bricks are held on the wall with brick ties that were anchored to rigid board that was attached to cold-formed steel. At every level, a galvanized steel relief angle was bolted into the concrete to support the bricks. Fraco scaffolding was used around the building to set the bricks and cast stone.

Site layout Planning

Overview

Due to the large duration, the project was broken up into three phases. This will allow the general contractor to better understand of the site logistics and other important construction processes in greater detail. The three phases are as follows: phase 1 Excavation, phase 2 building structure, and phase 3 build exterior façade.

Phase 1: Excavation

The demolition and the excavation took place on the project as phase 1. The phase consisted of the demolition of all five existing building and the removal of 71,000 SF of asphalt. Excavators were used to remove one level of soil for the apartment's foundation. The large size of the site allowed for sloped excavation and no supported excavation was required. The soil was sloped back at one to one setback seen in Appendix C. The soil was removed from the site with dump trucks that entered the site on the southeast side of the site. Once in, they could follow the delivery path around and back out the same way they entered. The same excavation process was used for the parking garage.

The construction manager was able to place their trailer on site on the west side. This was a prime location because it was far enough away from construction work, but the CM could still see a majority of the work being performed. The large construction site also allowed a limited number of parking spots to be used by the CM and subcontractor foreman. Other construction worker parked in a nearby parking lot.

Considering the challenges of building a 327,431 square foot apartment building, this stage of the project ran fairly smooth. The only disturbance to pedestrians was the closing of the sidewalk on the east side of the site, which was not an inconvenience because it led to the old demolished HITT building. Good communication between neighboring business, residents, and the project management team allowed this phase to be a success.

Figure 4.11: Site Phase 3 – Developed by Anthony Grab

Phase 2: Building Structure

The construction of the building structure came as phase 2 of the project. The cast-in-place structure required a lot of concrete, which meant concrete trucks needed to move through the site with ease. They were able to enter on the south east side of the site and follow the delivery path around and back out. With help from a 231-foot boom on a tower crane and a man/material lift, the structure was able to be constructed at a rate of 1 floor per 2 weeks.

The precast parking structures also took shape during phase 2 of construction. Similar to the concrete trucks, flatbed trucks maneuver along the delivery path carrying precast panels until it met up with the mobile crawler crane where the panels were hoisted into place.

There was a lot of planning in this phase of project and it proved to pay off. Delivery verticals could enter the site and quickly place material in the laydown area and exit. The parking garage could be constructed without interference to the apartment building, and all other processes proceeded without a hitch.

Phase 3: Building Exterior Façade

Figure4.12: Site Phase 3 – Developed by Anthony Grab

The building's exterior façade was the last major phase of construction. Once completed, it meant that the building was 100 percent water tight and the interior finishes were underway. The building envelope chosen for the apartment build was a variety of different color brick, because of the variation it was imperative that the correct brick in order and on time.

To set the bricks the construction manager chose it use fraco scaffolding. The scaffolding was place around the perimeter of the building so that every wall could be constructed at the same rate as seen in Appendix D. Bricks were carefully placed on the scaffolding with a telescoping fork lift. Once the bricks were set, the installation of the windows began. Stating on the northeast side and working their way around the building.

Overall the three main phases of construction were carried out smoothly with no major issues. This was largely because of the time spent beforehand recognizing the entire site logistic plan so that the affiliation between construction processes and deliveries could run similar to a Swiss watch.

Critical Path

The critical path schedule linked with Square 1400 Apartments shadowed a fairly traditional construction process with a variation of a few unique features. This can be observed in Figure 4.13. The site work phase consisted of mobilization, site establishment, and underground utilities. Within site establishment, many items were located such as site trailers, site fencing, material laydown, mortar mix station, and delivery routes. The next phase of construction was foundations. Within this phase, excavation as well as reinforcing, pouring spread footings, and pouring slab-on-grade were included. The timing with weather was critical during this phase as later mentioned. The Superstructure phase of construction came next in the critical path method schedule. Level 1 columns were formed, and then the post-tension-slab was formed and poured. This process was repeated up through the building. Upon completion of the buildings superstructure came the installation of the building exterior. Starting with the setting of the light gage metal framing, the enclosure was composed of masonry brick and precast panels. The windows and doors were installed after the completion of the masonry. The roof was also installed during this phase. As soon as the building was enclosed, fit-out could start for the MEP systems and interior partitions. The next phase was interior finishes. Drywall, paint, hardware, and carpet were to be installed. The final phase of the CPM schedule was the closeout phase, where HITT Contracting developed punch list items, inspections, and finally the turnover walk took place.

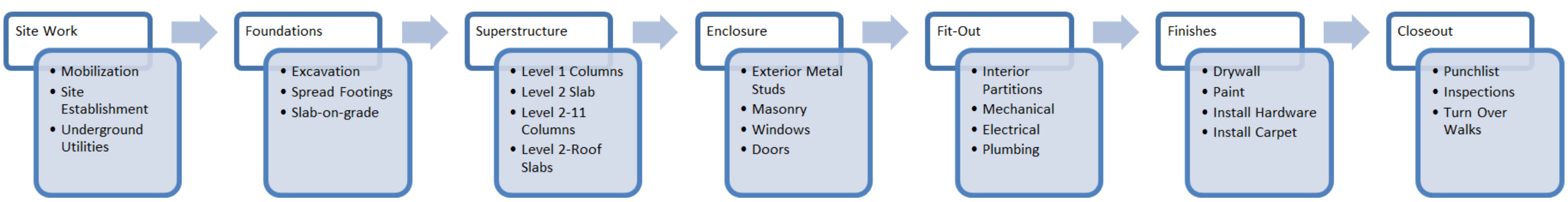


Figure 4.13- Square 1400 CPM – Developed By Anthony Grab

Project Cost Evaluation

There are a number of different cost analyses that can be done in order to come up with an accurate estimate for a construction project. A few of these include major building systems overview, assemblies estimate, and square foot estimate. The major building system overview for Square 1400 can be seen below in Table 2. The table illustrates the actual building cost for the major systems of the building. From there, the systems total cost can be evaluated based on cost per square foot. This allows the owner to look at the big picture of the project and see where the bulk of their money is being spent. Similarly, the major systems were then evaluated on their percentage of the total building cost.

Table 4.2: Major Building System Overview – Developed by Anthony Grab

Major Building System Overview			
Table 2: Major Building Systems – Developed by Anthony Grab	**Actual Cost**	**Cost/SF**	**% of Building Cost**
Asphalt Paving	$ 235,110	$ 0.72	0.45%
Cast-in-Place Concrete	$ 7,400,000	$ 22.60	14.23%
Drywall	$ 3,456,000	$ 10.55	6.65%
Earthwork	$ 1,059,000	$ 3.23	2.04%
Elevators	$ 885,000	$ 2.70	1.70%
Fire Sprinklers	$ 659,530	$ 2.01	1.27%
Glass & Glazing	$ 1,688,850	$ 5.16	3.25%
Masonry	$ 2,676,000	$ 8.17	5.15%
Mechanical/Plumbing/Electric	$ 9,584,552	$ 29.27	18.43%
Miscellaneous Metals	$ 784,000	$ 2.39	1.51%
Precast	$ 2,311,569	$ 7.06	4.45%
Residential Appliances	$ 1,131,570	$ 3.46	2.18%
Roofing and Waterproofing	$ 782,500	$ 2.39	1.50%
Site Concrete	$ 303,000	$ 0.93	0.58%

Another good estimating tool is the square foot estimate. Over the years, it has become easier to perform this test. RSMeans CostWorks online now allows the user to plug in their building's specific information, building type, number of stories, and location and the result is a quick rough estimate that can use to get a better understanding on what their projects are going to cost. After running the square foot estimate analysis for this project, the estimate resulted in a variation of only $2 million.

Table 4.3: Square Foot Estimate – Developed by Anthony Grab

RS Means CostWorks Square Foot Estimate	
Building Type	Apartment, 8-24 Stories
Construction Type	Concrete Block Back-up / R/Conc. Frame
Loacation	Fairfax, VA
Release Date	2012
Labor Type	Open Shop
Store Height (LF)	13
Stories Count	11
Area (SF)	327431
Perimeter	1056
Total Building Cost	$49,313,000.00
SF Cost	$150.61

The final test performed was the assembilies estimate. For this test, the RSMeans CostWorks was referenced to determine the valus of the mechanical, electrical, and plumbing systems in the building. Although more time consuming, this estimate is more accurate then the pervious methods. This is because it requires indvidual systems to be looked at a higher level of detail and then a value can be determind. The results show that when compared to the other two methods, the assembilies estimate for the MEP system were about the same, only variering by about half a million dollars. This proves that all the estiamtes were done with accurate information.

Table 4.4: Actual Construction Cost – Developed by Anthony Grab

Actual Construction Cost			
	Total	Cost/SF	% of Building Cost
Fire Protection	659,530.00	2.01	1.27%
MEP	9,584,552.00	29.27	18.43%
RSMean CostWorks SF Estimate			
	Total	Cost/SF	% of Building Cost
Electrical	2,235,000.00	6.83	4.30%
Fire Protection	777,500.00	2.37	1.50%
Mech./Plumbing	8,941,500.00	27.31	17.20%
RSMean Cost Works Assembilies Estimate			
	Total	Cost/SF	% of Building Cost
Electrical	2,386,967.00	7.29	4.59%
Fire Protection	2,625,996.00	8.02	5.05%
Mech./Plumbing	7,579,440.00	23.15	14.58%

After conducting the different estimate using various methods, the data was compiled on the Table 5 to compare the differences.

Table 4.5: Cost Comparison – Developed by Anthony Grab

Total Construction Cost Comparison		
	Total Cost	Cost/SF
Actual Construction Cost	$ 52,000,000.00	$ 158.81
SF Estimate Cost	$ 49,313,000.00	$ 150.61
SF Estimate Cost/MEP Asseblies Estimate	$ 47,927,864.00	$ 128.69

General Conditions Estimate

See APPENDIX G for the complete General Conditions Estimate

The table 4 below summarizes major general condition costs for Square 1400 Apartments. These values are approximate and do not reflect the contracted amount between HITT Contracting and other parties. Each line item is broken down by week and the duration is then calculated. Once the project starts, HITT used JD Edward software to track costs and manage the budget.

Table 4.6: General Conditions Take-off – Developed by Anthony Grab

General Conditions Estimate					
Line Item		Quantity	Unit Cost	Unit Cost	Amount
Project Management		95	Weeks	$ 13,048.00	$ 1,239,560.00
Supervision		95	Weeks	$ 9,832.00	$ 934,040.00
Safety		95	Weeks	$ 1,349.00	$ 128,155.00
Field Office / Staging		91	Weeks	$ 1,293.00	$ 117,663.00
Field Labor		95	Weeks	$ 2,122.00	$ 201,590.00
Field Operations		91	Weeks	$ 3,712.00	$ 337,792.00
				Total	$ 2,958,800.00

The estimate was broken down into six categories: Project Management, Supervision, Safety, Field Office/Staging, Field Labor, and Field Operations Costs. Project Management and Supervision incudes the entire project management team and support staff. Vice President, Project Managers, and Superintendent all fall under these line items. The Safety category includes the safety coordinator and first aid supplies. The Field Office/Staging line item incorporates the following: office supplies, trailer/office furniture, project meetings, record documents, and submittals, etc. For greater detail please see Appendix G. Field Labor in this line item included laborers employed by HITT Contracting, such as field labors and elevator operators. The Field Operations includes surveys, air barriers, temporary toilets, small tools and equipment, elevator protection, and temporary power.

As shown in Figure 4.14, the project management and supervision accounts for 74% of the general conditions estimate, which is fairly typical for an estimate. Overall the general conditions estimate accrues to about $3.1M.

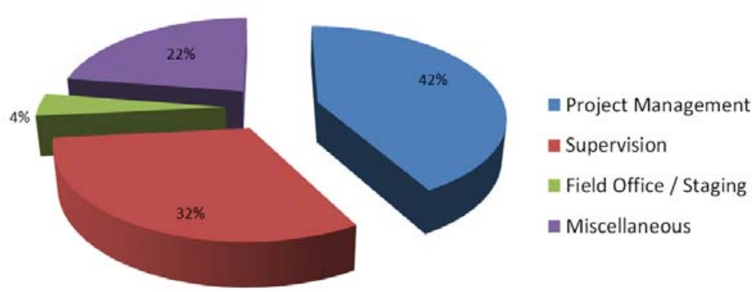


Figure 4.14: General Conditions Breakdown – Produced by Anthony Grab

Building Information Modeling (BIM) Use Evaluation

See Appendix H for the BIM use chart and Level 1 Process MAP

The project team for Square 1400 Apartments did not utilized any formal methods BIM. This is largly due to the fact the that the architect (S B E & Associates) on the project did not have adequate experence in AutoDesk Revit. Because of this, HITT Contraction developed an in-house Revit model that was then used for evalation purposes such as walk throughs and design review. The lack of experence on the architect's end forced HITT Contracting to send their Construction Documents to an outside company to have their renderings generated.

Like most construction companies, at this point, HITT Contracting is still trying to find the role of BIM. Their main focus is on the preconstruction side, not during the execution of the construction project. Below, Figure 4.15 illustrates the different phases of the project and identifies key BIM uses that can be implemented on just about an construction project.

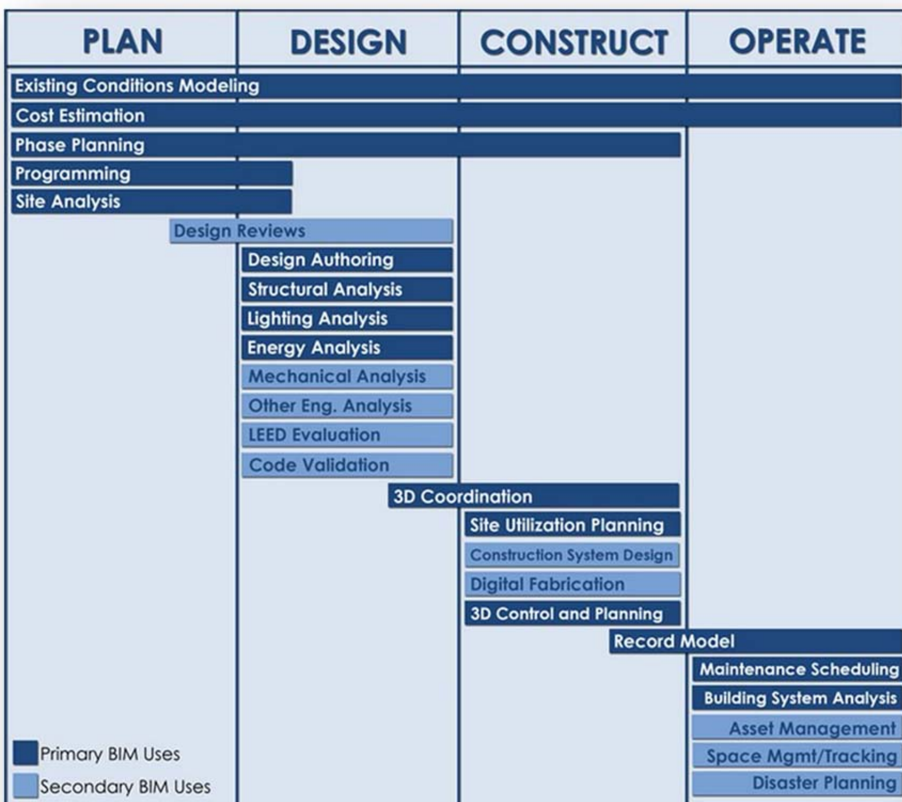


Figure 4.15- BIM Execution Phases – Courtesy of The Pennsylvania State University

Critical Industry Issues

The 21th Annual Partnership for Achieving Construction Excellence (PACE) roundtable was held at the Nittany Lion Inn on November 6, 2012. The theme of this year's round table was Improving Efficiency through Innovation. Attendees were permitted to choose from six breakout sessions, which related to a verity of critical industry issues.

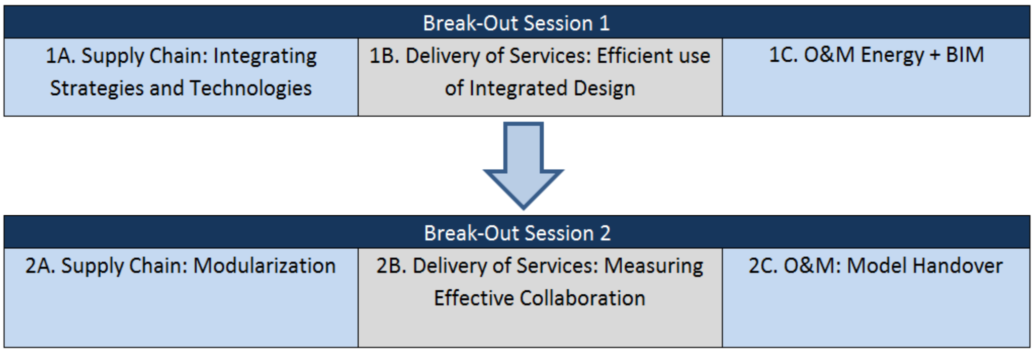


Figure 4.16 - PACE Roundtable Sessions – Developed By Anthony Grab

Session 2B. Delivery of Services: Measuring Effective Collaboration

The main topic of the session was how the industry views collaboration and how we can measure collaboration in a group meeting. When placing a project team in a room, are they really collaborating or are they just building silos?

Ray Sowers kicked off the session with how the industry looks at collaboration; it has to be cheaper, faster, better. You need to look at whether collaboration will give you the competitive edge to get the project. It is important that the project team defines what the collaborative structure looks like so we can see the problems. People need to feel that they have a sense of interaction during the meetings.

Bryan Franz, referring to the South Halls project and a number of other projects on Penn State campus, said how they have brought in a number of IPD principles such as mutual respect, trust, and other collaborative elements. Penn state is trying to use the principles on project that may not be IPD. To achieve this, Penn State sat down with the Office of Physical Plant and the project team to develop a collaboration charter that would hopefully motivate the project team to use collaborative measures. The team broke the charter into several different matrices such as cost or scheduling. These were than use to judge how effective the collaboration was. One example was a RFI turnaround time of about of three days.

Another major part of the collaboration process is having subcontractors on the project that have the ability to handle the collaboration process. Nick Umosella of Barton Malow used an example on the South Halls project of how he has six really good subcontractors and one that was a pain to work with from the start of the project. This is sometime hard to avoid because the contract type typically dictates the quality of the subcontractor. For example a lump sum contract typically awards the sub with the lowest bid and not necessarily the most qualified to perform the work.

The final major topic brought up in the info session was how do we measure trust? A lot of time this goes back to the trades. What was there number at the start of the project? It one thing to forget something in the bid package, however there are some subs that low ball their bid to guarantee the job. In some cases, previous experience can be looked at to see which subcontractors worked well.

The thing that surprised me the most about the info session was the fact that collaboration was such a big issues it the construction industry. Over the years in the classroom environment, we always talked about the best case scenario for collaboration and never what to do when a subcontractor does not perform correctly.

For the Square 1400 project, the collaboration process is somewhat different from a traditional construction project. This is due to the fact that the owner of the project is also the construction manager. Because of this, there has been excellent communication between the two. On the other hand, the collaboration between the subcontractors and the CM is very important. It would be beneficial to adopt some of the strategies outlined in the info session on the Square 1400 project. For example, a turnaround time of three days would be an excellent way to gauge the level of collaboration on the project.

Below is a list of key contacts that might be able to advise my areas of interest:

- Randy Barrett (HITT Contracting) – any general questions about Square 1400
- Ray Sowers (OPP) – questions about infinity systems
- Tom Grab (HITT Contracting) – General industry question
- Michael Barnhart (Forrester Construction) – General industry question
- Penn State AE Professors – for help with structural and MEP calculations

Sections 5: Change in Cast-In-Place Structure

Problem Identification/Background Research

The current structure for the Square 1400 Apartment Building is a six-inch cast-in-place structure with post-tension reinforcing. At twelve stories, the building is 105 feet tall with about 8.5 feet per floor-to-ceiling height. Cast-in-place concrete is the preferred structure in Washington, D.C. because it allows the end user to maximize the number of floors within local height restrictions. However, since Square 1400 is located in Fairfax, VA, it does not fall within the height-restricted area and has a potential for an alternative system. The current cast-in-place structure required has a large impact on construction cost, schedule, and manpower.

Proposed Solution

In order to reduce costs, schedule duration, and manpower, it would be beneficial to investigate other building structure systems, such as Infinity Structures, or possibly a hybrid of both Infinity Structures and cast-in-place concrete. The proposed building structure would allow for the original layout to remain relatively the same. The life of the structures would be compared to allow the owner to determine whether it fits within their needs.

Research Methods

To complete this research, an in-depth design and analysis of the Infinity Structure System must be performed. Techniques learned in AE 475, AE 308 may be utilized.

Solution Methods

- Gather information of the current structure system (dimensions, layout, code requirements)
- Design Infinity System
- Structural Analysis
- Cost and Schedule Impacts
- Life Expectancy of Infinity System vs. Cast-In-Place
- Summarize Results

Resources

- Dr. Hanagan, Dr. Boothby (Penn State structural professors)
- Raymond Sowers (Infinity System Expert)
- Infinity Subcontractors

Anticipated Results

The design of a new structural system is anticipated to result in a substantial direct and indirect cost savings with possible impact on the overall project schedule. For this analysis, only the direct cost savings will be estimated. Due to the flexibility of the infinity system, the building floor layout will remain relatively the same.

How the Infinity System works

The infinity system was first developed in 1986 and since has completed hundreds of mid-rise residential buildings. The system consists of EPICORE MSR composite floor that sits on pre-panelized load-bearing metal stud walls (Infinity Structures, Inc). Over the years, the infinity system updated, making constant improvements to be more economical, faster, trouble-free and user friendly. The system also allows for a large reduction in waste when compared to other structure systems. This is achieved with the use of a large amount of recycled materials combined with the energy efficiency of the pre-insulated exterior MSR33 WalPanel, contributes towards satisfying several of the prerequisites and credits under LEED creating a sustainable "Green" building.

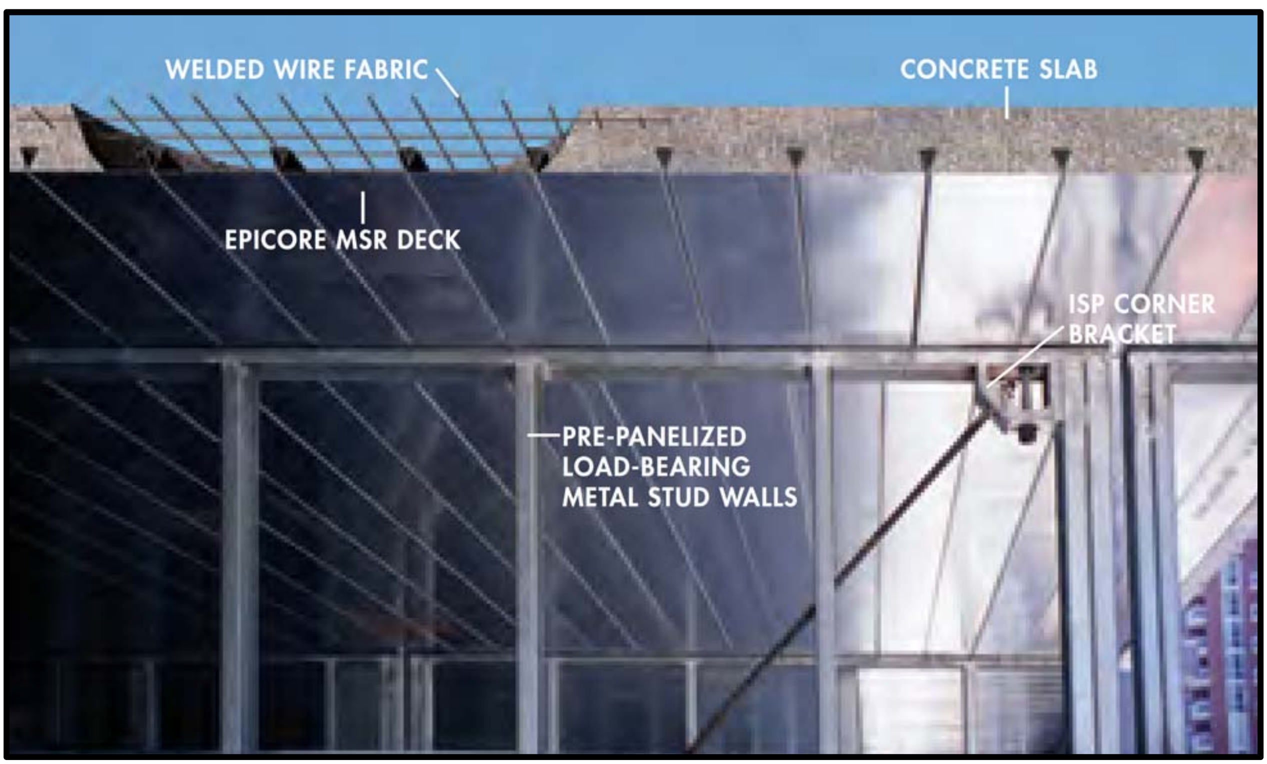


Figure 5.1- Infinity System Structure – Courtesy Infinity Structures

Manufacturing Process


Figure 5.2- Prefabricated Wall Panel – Courtesy Infinity Structures

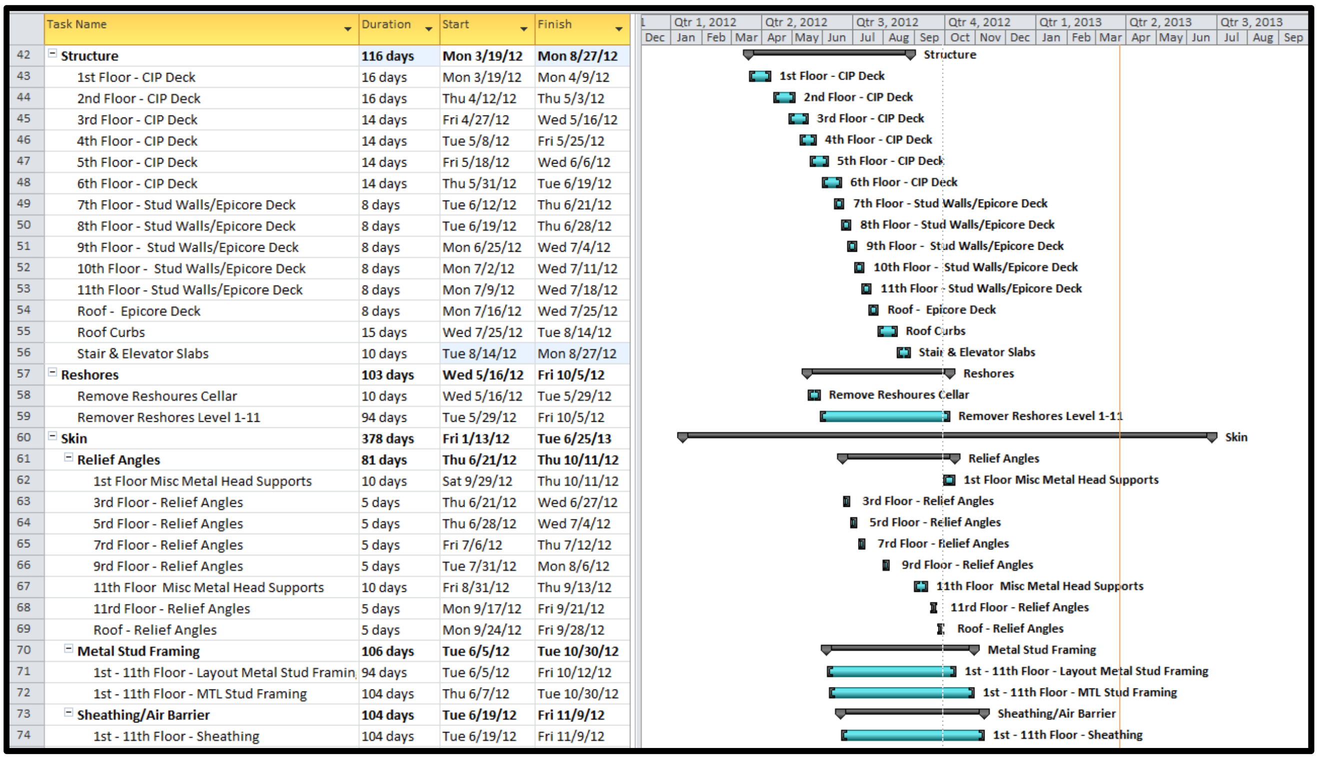

Figure 5.3- Prefabricated Wall Panel Delivery – Courtesy Infinity Structures

Similar to most construction projects, it is a good idea to bring the construction manager and structural engineer on early in the design phase of the project. This will ensure that the project will run smoothly and efficiently. Once the design is complete, shop drawings are sent out to the manufacturing facility where the load-bearing metal stud walls are constructed in a controlled environment. The panels are 3 5/8 inch or 6 inch galvanized studs spaced at 12, 16 or 24 inches on center. The gage of the studs can range from 18,16,14, or 12 gage depending on the loads. The overall size of the panels is restricted by the length of trailer used during delivery as seen in figure 5.3. All connections are welded, creating a strong-ridged panel, unlike screwed connections that can sometimes deform during delivery or even rack while being hoisted into place. The panels are then tagged, loaded on a trailer, and delivered in proper sequence to ensure fast erection. The erector unloads the panels from the truck and sets them on the slab in the location identified by the PanelCAD erection layout drawings. Epicore MSR (Multi-Story Residential) Composite Deck acts as the floor system for the structure. Epicore MSR is a 2-inch deep, high performance, long span, composite metal deck that acts as both the permanent form and the positive reinforcement. The deck


Figure 5.4 – Epicore MSR Deck – Courtesy Infinity Structures

has triangular dovetail shaped ribs at 8 inches on center. These ribs key up into the concrete, allowing for greater strength and longer span capabilities. The bottom flutes are closed and every other rib has an embossed locking lug that enhances the bond between the concrete and the deck. These key design features in the deck make it ideal for load-bearing metal studs. The Epicore system can clear spans up to 27 feet with a 4-inch to 8-inch slab thickness while using 4,000 psi regular weight concrete.

Schedule impacts



	Task Name	Duration	Start	Finish
42	**Structure**	**116 days**	**Mon 3/19/12**	**Mon 8/27/12**
43	1st Floor - CIP Deck	16 days	Mon 3/19/12	Mon 4/9/12
44	2nd Floor - CIP Deck	16 days	Thu 4/12/12	Thu 5/3/12
45	3rd Floor - CIP Deck	14 days	Fri 4/27/12	Wed 5/16/12
46	4th Floor - CIP Deck	14 days	Tue 5/8/12	Fri 5/25/12
47	5th Floor - CIP Deck	14 days	Fri 5/18/12	Wed 6/6/12
48	6th Floor - CIP Deck	14 days	Thu 5/31/12	Tue 6/19/12
49	7th Floor - Stud Walls/Epicore Deck	8 days	Tue 6/12/12	Thu 6/21/12
50	8th Floor - Stud Walls/Epicore Deck	8 days	Tue 6/19/12	Thu 6/28/12
51	9th Floor - Stud Walls/Epicore Deck	8 days	Mon 6/25/12	Wed 7/4/12
52	10th Floor - Stud Walls/Epicore Deck	8 days	Mon 7/2/12	Wed 7/11/12
53	11th Floor - Stud Walls/Epicore Deck	8 days	Mon 7/9/12	Wed 7/18/12
54	Roof - Epicore Deck	8 days	Mon 7/16/12	Wed 7/25/12
55	Roof Curbs	15 days	Wed 7/25/12	Tue 8/14/12
56	Stair & Elevator Slabs	10 days	Tue 8/14/12	Mon 8/27/12
57	**Reshores**	**103 days**	**Wed 5/16/12**	**Fri 10/5/12**
58	Remove Reshores Cellar	10 days	Wed 5/16/12	Tue 5/29/12
59	Remover Reshores Level 1-11	94 days	Tue 5/29/12	Fri 10/5/12
60	**Skin**	**378 days**	**Fri 1/13/12**	**Tue 6/25/13**
61	**Relief Angles**	**81 days**	**Thu 6/21/12**	**Thu 10/11/12**
62	1st Floor Misc Metal Head Supports	10 days	Sat 9/29/12	Thu 10/11/12
63	3rd Floor - Relief Angles	5 days	Thu 6/21/12	Wed 6/27/12
64	5rd Floor - Relief Angles	5 days	Thu 6/28/12	Wed 7/4/12
65	7rd Floor - Relief Angles	5 days	Fri 7/6/12	Thu 7/12/12
66	9rd Floor - Relief Angles	5 days	Tue 7/31/12	Mon 8/6/12
67	11th Floor Misc Metal Head Supports	10 days	Fri 8/31/12	Thu 9/13/12
68	11rd Floor - Relief Angles	5 days	Mon 9/17/12	Fri 9/21/12
69	Roof - Relief Angles	5 days	Mon 9/24/12	Fri 9/28/12
70	**Metal Stud Framing**	**106 days**	**Tue 6/5/12**	**Tue 10/30/12**
71	1st - 11th Floor - Layout Metal Stud Framin	94 days	Tue 6/5/12	Fri 10/12/12
72	1st - 11th Floor - MTL Stud Framing	104 days	Thu 6/7/12	Tue 10/30/12
73	**Sheathing/Air Barrier**	**104 days**	**Tue 6/19/12**	**Fri 11/9/12**
74	1st - 11th Floor - Sheathing	104 days	Tue 6/19/12	Fri 11/9/12

Figure 5.5 – Schedule Revision with Infinity Structure – Produced by Anthony Grab

The current schedule puts the cast-in-place structure at a little over two weeks per floor, whereas the Infinity System is projected to take just over one week per floor to construct. This speed is contributed to the 21st century technology that is used to produce the prefabricated wall panels and hoist them into place quickly and efficiently. Furthermore, the Epicore MSR Composite deck does not only act as structural reinforcement for the slab, but also is the form at which the concrete is poured on. With the cast-in-place system, workers are required to go back and remove the formwork on each level. By changing the upper five levels to use the Infinity System, the overall duration of the structure would be reduced by 42 days resulting in an earlier dry-in date and ultimately earlier tenant move-in date.

Life Expectancy of Infinity System vs. Cast-In-Place

The Infinity Structural System is ideal for mid-rise apartment projects where a higher density of units in a confined site is needed. The Infinity System is faster and less expensive than traditional concrete, pre-cast or structural steel frames. Additionally, it provides a high-quality, non-combustible, low-maintenance building with excellent STC and IIC Ratings (Infinity Structures, Inc). These key elements result in a longer building lifespan.

Another option for Infinity System is the pre-insulated exterior MSR33 WalPanel System. WalPanels consist of galvanized metal studs with rigid, fire retardant Modified Expanded Polystyrene (EPS) insulation. Similar to the bare metal stud Infinity Wall Panels, the WalPanels are shop fabricated off-site, then delivered to the jobsite, and installed by Erectors. The WalPanels combine four steps into one: the structural components, insulation, vapor barrier, and sheathing (Infinity Structures, Inc).

Layout and Design

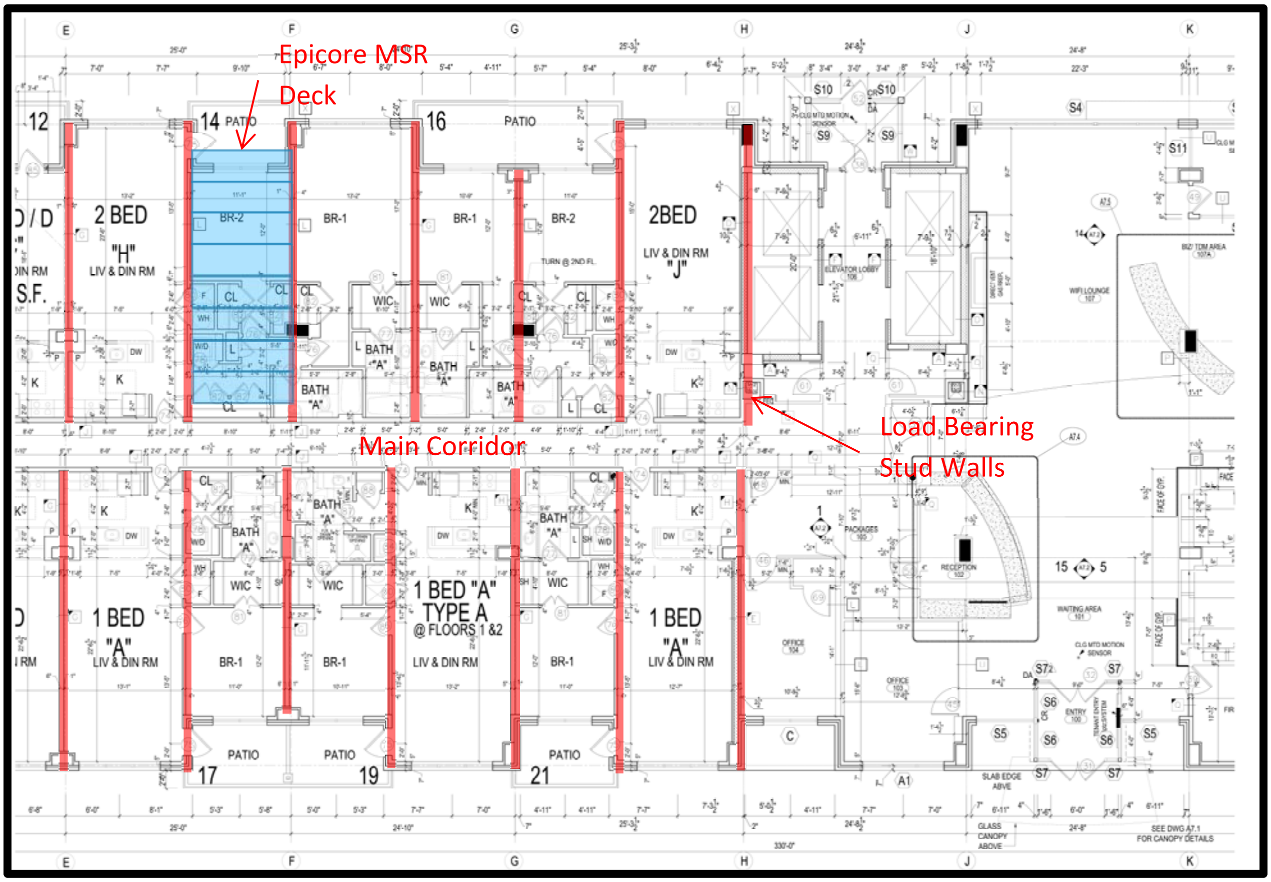


Figure 5.6 – Infinity System Layout – Produced by Anthony Grab

When designing an Infinity System, the span of the Epicore MSR deck usually dictates the direction at which the deck will be run. In apartment buildings, the deck is typically run from the exterior wall to the corridor. However, this only allows for the room size to be unobstructed at a distance of 23 feet. The apartment units at Square 1400 are about 32 feet long from the exterior wall to the corridor. Brian Able of Able Consulting suggested that the deck should span between partition walls within the apartment units as seen in figure 5.6. Structural Breadth one illustrates the load calculations for the chosen layout.

Other Advantages Infinity System (Infinity Structures, Inc)

Economical
Lower costs than traditional masonry, steel, precast or formed concrete framing.

Speed
Fast installation and "dry in" enables quick project completion under tight schedules.

Electrical Simplified
The pre-punched metal studs simplify the electrical work, enabling faster installation by smaller crews at substantially lower costs.

Uniform Load Distribution
The load distribution characteristic of EPICORE MSR simplifies the load-bearing metal stud walls and eliminates the need for expensive load-distribution headers.

Lower Maintenance
Long-term annual maintenance costs are significantly reduced and the building's lifespan is increased.

Lightweight
Compared to masonry construction, the light weight of the system significantly reduces foundation costs. Economically lower costs than traditional masonry, steel, precast or formed concrete framing.

Less Weather Sensitive
Construction proceeds smoothly with fewer delays due to severe weather.

Reduced Building Footprint
Reduced wall thicknesses allow smaller building footprints, which further reduce cost.

Mold & Mildew Resistance
Reduces potential mold and mildew problems when our pre-insulated MSR33 WalPanel System is utilized for the exterior walls.

Structural Breadth: *Contributes to Technical analysis 1*

**Please see Appendix I, Infinity Structure Calculations*
**Please see Appendix J, Engineering Tables For Epicore MSR*
**Please see Appendix K, Cold Formed Steel Framing System*

The current structure for the Square 1400 Apartment Building is a six-inch cast-in-place structure with post-tension reinforcing. This specified structure has a large impact on construction cost, schedule, and manpower. In order to reduce these factors, it would be beneficial to investigate other building structure systems such as Infinity Structures or possibly a hybrid of both an Infinity Structure and cast-in-place concrete. An in-depth design and analysis of the Infinity Structure System must be performed. With an Infinity System mainly consisting of light gage metal framing and concrete metal decking, and an average height of six stories, it is critical to perform a structural analysis in order to determine the constraints of the structure. With a height of eleven stories, it is possible to redesign Square 1400 with the lower floors to be a stronger cast-in-place concrete and the upper floors with that of the lighter Infinity System. The original floor plan layout will have little to no alterations.

The proposed hybrid structure would have a large impact on the overall cost of the building as Infinity Systems have been proven to greatly reduce the cost of the building over post-tension structures. The constructability of the Infinity Structure will also be evaluated as its can require a high level of detail to construct.

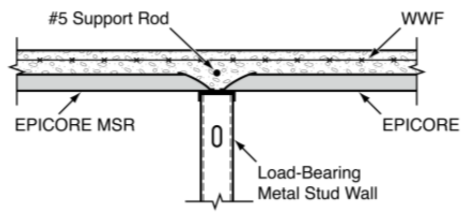
Assumptions For Design of the Infinity System

- Epicore MSR 22 Gage Composite Deck
- Simple Span Condition
- Concrete Strength 4,000 psi
- Live Load 40 psf
- Dead Load 20 psf of Epicore MSR Deck
- Concrete slab 8" thick
- Deflection is accounted for within table values (See table 5.1)
- No reinforcing is required for simple span other than Epicore MSR
- 4T10 Metal Studs to be used

Table 5.1 – Design Loads – Produced by Anthony Grab

Design Loads	
Rood Dead Loads	
Roof Dead Loads	5.0 PSF
Roofing	3.5 PSF
Sheathing/Insulation	3.5 PSF
Ceiling	4.0 PSF
Mech. & Misc.	5.0 PSF
Total	**21 PSF**
Rood Live Loads	
Total	**25 PSF**
Floor Dead Loads	
8" Concrere Concrete Slab	90 PSF
Ceiling	4.0 PSF
Mech./Electrical	3 PSF
Sprinklers	2.5 PSF
Misc.	2.5 PSF
Total	**102 PSF**
Floor Live Loads	
Total	**40 PSF**

At first glance, one can see the respective nature of the apartment units, which proved to be ideal for the design of the Infinity System. Because of this, calculations were performed at a location that was thought to be the worst case scenario loading condition. Refer to seventh floor between columns lines G and 7.



Conclusion and Reconnections

The analysis of infinity structure system uncovered many advantages over a cast-in-place structure. One of the prime advantages was the speed at which the Infinity System could be erected. This was due to the fact that most of the system was prefabricated off site in a controlled environment and then shipped to the project site where the panels were strategically erected. This method also reduced the manpower during erection. Whereas the cast-in-place structure system involved many parts that needed to be constructed on site under the elements, which could potentially lead to minor setbacks. With the proposed infinity structure able to maintain relative the same layout of the apartment units and at the same time meet load requirements, it would be a great alternative solution to the cast-in-place structure.

Section 6: Short Interval Production Scheduling (SIPS) + Building Information Modeling (BIM)

Problem Identification/Background Research

The project team for HITT Contracting is currently using traditional scheduling techniques while implementing minimal BIM techniques. The use of the SIPS method helps to break construction activities into detailed, repetitive activities. This actually differs from the conventional way of project scheduling as it usually breaks projects into smaller operations instead of larger tasks.

Proposed Solution

With the consistent layout of the Square 1400 Apartment Building, it would be beneficial to use SIPS on one of the wings. The schedule would then be repeated throughout the entire construction of the building. The creation of a BIM model will allow the project team, owner, and subcontractors to see a much higher level of detail of individual tasks and their relationship to the overall construction of the building.

Research Methods

- Generate BIM Model
- Identify specific critical tasks and determine the durations
- Identify controls (crane speeds and capacity)
- Generate a detailed schedule for one wing
- Link schedule and BIM Model (4D Model)
- Compare traditional schedule with the SIPS schedule
- Summarize results

Resources

- Square 1400 Project Team
- Dr. Messner (BIM Expert for Penn State)
- Andrew Thoma (HITT's BIM Coordinator)
- Dr. Dubler (SIPS consulting)

Expected Outcome

The use of SIPS scheduling with the integration of BIM will have an anticipated result of reducing the schedule for the construction of the apartment building and possibly the overall schedule. The BIM model will provide a higher level of detail for individual tasks, thus increasing productivity as well as quality control. The linked BIM and SIPS schedule will allow the owner to better understand as to how their building is to be constructed. A large focus will be on the construction of the cast-in-place post tension structure.

SIPS Overview

The use of the Short Interval Production Schedule (SIPS) method helps to break construction activities into detailed repeatable activities. This actually differs from the conventional way of project scheduling, as it usually break projects into operations instead. The implementation of the short interval production schedule is still a current initiation to the construction industry, yet it does appear to bring benefits for coordination and scheduling standpoint.

SIPS provide a faster learning curve for the crew and has a much more productive work sequence. It helps to eliminate the non-productive time related to delays in construction. Using SIPS would allow the resources and materials to be ready on site. Moreover, with close supervision of the time schedule, it instills both workers' and supervisors' immediate sense of urgency to get the job done as it creates a psychological feeling of the sense of accomplishment for every task completed at every stage. The next benefit is that SIPS utilizes personal involvement and commitment of everyone contributing to the operation as it creates a detailed crew plan for specific operation. The higher level of detail to be developed in the SIPS will help to break the construction operations into detailed and repetitive activities, complementing the main schedule. Information can be expanded and used to reschedule, in detail, the daily/weekly tasks in order to meet the project team's short-term goals and objectives.

Applications

Short interval production schedule can be implemented on a number of different projects. The most effective application is for projects that have repeatable activities, such as hotels, apartments, or in some cases, schools. In most cases, these projects have a standardized wing or floor, which makes the use of SIPS favorable. The high level of detail loaded in SIPS is necessary for the day-to-day production of construction. It is important that the detailed information at the crew level is exact; this is vital to the successful completion of construction tasks. The renovation work on the Pentagon is an excellent example of how SIPS can be beneficial. This led to a completion date years ahead of what was previously anticipated using traditional schedule methods.

Subcontractor Buy-in

Different project participants that would review the SIPS schedule include the separate subcontracting companies, but also the actual workers involved in the SIPS schedule. In order to get a total buy-in approach by the project team, each individual worker should fully understand and comprehend the end goal. This includes the crane operator, grouters, and ductile frame, precast paneling & interior wall placement workers. It is important to include these members because of the site logistic implications of the crane operator and ductile frame workers as well as productivity issues across the board. In order to meet the designated schedule, productivity must remain high among all workers, especially the key crane picks.

In order to effectively get the project team to buy into the approach used within the SIPS schedule, it would be pertinent to explain why a SIPS schedule is being used. This includes time, cost, and logistics conflicts involved with traditional construction of Square 1400. An overview of the Navisworks model would also prove to be beneficial to allow the workers to visualize the construction sequence.

Project Constraints

Similar to most construction projects, staying on the critical path and meeting milestone dates is essential to completing the project on time. For example, the start of the interior finishes is dependent on the Building Dry milestone. Square 1400 is scheduled to be completed on August 19, 2013. The current Critical Path Schedule has substantial completion for the cast-in-place structure set for June 11, 2012. This allows roughly 23 weeks to complete ALL activities involved with building the Structure according to the critical path schedule. The building envelop is scheduled to start and be completed several weeks after the buildings substantial completion set for building structure.

SIPS Development

The SIPS for Square 1400 were developed by looking at each cast-in-place with PT cables. Each floor was broken up into five pours that was determined by the pour break, about 5,000 square feet per floor. The most critical tasks that made up each pour were then evaluated for duration and manpower. For example, tasks such as frame pour, install PT cables, MEP Sleeves, and pour slab were evaluated. Baker DC was contacted for assistance with determining the daily production rate and corresponding crew sizes. In most cases the crew size had to be adjusted in order to establish activity durations as close as possible to the others. Attaining optimum results with SIPS requires this tactic so that each crew can move from zone to zone without interruption or delay from the previous crew that was just there. Figure 6.1 illustrates the recommended duration from Baker DC.

Table 6.1 – SIPS Task Break Down – Produced by Anthony Grab

Task	Duration (Dyas)	Crew Size
Frame Pour	2	3
Install PT & Rebar	2	3
MEP Sleeves	1	2
Pour Slab	1	3
Concrete Cure	3	0
Stress PT	1	2
Strip & Reshore	3	3

Now that the zones have been determined and takes-offs of the respective activities, the sequencing of the entire building can be determined. In order to make the SIPS schedule be effective, the durations obtained from Baker DC needed to be adjusted to reduce the down time of the crews between tasks. After examining the project schedule and recognizing that by adjusting the crew size and combining two tasks into one, durations for specific are able to take the same amount of time. This can be seen in table 6.3. The schedule could then be laid out in a way that allows for little down time between the crews as seen in table 6.3. This method allows one day to be saved per floor.

Table 6.2 –Revised SIPS Task Break Down – Produced by Anthony Grab

Color Code	Task	Duration (Days)	Crew Size
	Frame Pour	3	3
	Install PT & Rebar/Pour Slab	3	3
	MEP Sleeves	0	2
	Concrete Cure/Stress PT	3	2
	Strip & Reshore	3	3

Table 6.3 – SIPS Schedule – Produced by Anthony Grab

	March		April											May				
AREA		28	2	5	8	12	15	18	21	24	27	30	3	6	9	12	15
Pour 1-1																	
Pour 1-2																	
Pour 1-3																	
Pour 1-4																	
Pour 1-5																	

Cost and Schedule Impacts

After taking into consideration the other areas of building that were not in the SIPS, it was determined that the critical path schedule could be reduced by approximately one and half weeks. This, of course, is a reasonable estimate due to the many other features of the building that are included in the critical path schedule. Since the SIPS does not completely encompass the entirety of building, it is difficult to estimate exactly how much time the SIPS could actually save.

Conclusions and Recommendations

By implementing a Short Interval Production Schedule into the Square 1400 structure schedule, the project team could potentially be provided with a schedule that has a total duration that is almost two weeks shorter than the critical path schedule. This acceleration is possibly due to the streamline repetitiveness of the work. This technique not only accelerates the schedule but it also provides the project team with additional float time. This can help with any unforeseen delays that may have not been accounted for. The substantial completion milestone is critical to both the Rushmark LLC and the project team as the apartment open for occupancy. In conclusion, the Short Interval Production Schedule has the potential to generate results that would be beneficial to both parties by assuring a high quality of work due repetitive tasks, and the project team could build in an amount of float to assure the project stays on schedule.

Section 7: Increase Production through Precast Brick Panels

Problem Identification/Background Research

A traditional Fraco Scaffolding System was to be used on all sides of the building to assist with the placing of the exterior brick. The plan was to have the masons start on one corner of the building and work their way up and around in a clockwise manner. This would streamline the production of the masons. However, with the exterior occupied by the mason's Fraco lift, it was unnecessary for the other trades to perform work on the building envelope and get materials into the building. This slowed down the production of a number of trades.

Proposed Solution

The proposed solution considers using precast brick panels for the exterior of the building. An analysis will need to be performed to determine whether it would feasible to install the exterior windows in the precast panels. This would allow for an increase in productivity to meet an earlier dry-in deadline.

Research Methods

- Research different types of brick panels
- Determine how they attach to the structure
- Determine the best way to set the panels
- Re-sequence schedule for the installation of the panels
- Compare traditional brick laying methods with brick panel (schedule, cost saving, and manpower)
- Summarize results

Resources

- Square 1400 Project Team
- Penn State AE Faculty
- Brick Panel Subcontractor

Anticipated Results

Through extensive design and research, the anticipated result is to significantly increase productivity, decrease site congestion, and improve trade coordination while achieving a similar building aesthetic. The potential increase in cost may be compensated by the fast installation of the brick veneer, which would result in an earlier move-in data for the tenants.

Current Building Façade

Through design, the overall construction of Square 1400 Apartments is not overly complicated. However, there are a number of building systems that directly impact the critical path of the schedule.

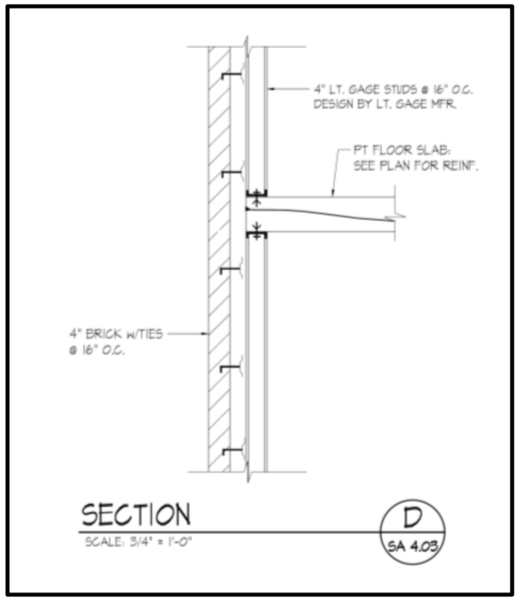


Figure 7.1 – Cast-In-Place Wall Section – Produced by HITT

The current exterior of the building consists of standard 4-inch face bricks that vary in color. Brick ties are used to secure the bricks at 16 inches on center. In most cases, the ties are fastened to light gauge metal framing. Rigid insulation 1.5 inches thick will be used on the exterior wall cavity, which gives an R-Value of 7.5. Concrete precast lintels are used at each level to provide relief for the bricks. The process of setting a large number of bricks is heavily dependent on a good crew of laborers that can provide material quickly and efficiently to the masons so that the work will not be interrupted. A traditional Fraco Scaffolding System was to be used on all sides of the building to assist with the placing of the exterior brick. The plan was to have the masons start on one corner of the building and work their way up and around in a clockwise manner; this would streamline the production of the masons. However, with the exterior occupied by the mason's Fraco lift, it was difficult for the other trades to perform work on the building envelope and get materials into the building. This slowed down the production of a number of trades.

Figure 7.2 – Square 1400 Mock-up –Taken by Anthony Grab

Research Goals

The proposed solution considers using precast brick panels or other types of exterior cladding for the building's façade. An analysis will be performed to determine whether it would be feasible to install the exterior windows in the panels, along with the transportation and installation of the panels. This would allow for an increase in productivity to meet an earlier dry-in deadline.

Choosing The Right Panel

After speaking with several precast brick panel manufactures about the installation and mounting of the panels onto a concrete structure, it has come to be known that it is not a quick and easy change. Typically precast panels are installed on steel structures where they can be mounted and secured to the steel. The decision to use the panel must be made early in the design phase of the project, therefore accounting to the added loads of the panels. One of the manufacturer's suggested using GFRC (Glass Fiber Reinforced Cladding). This would prove to be a much more feasible option for the exterior of Square 1400 Apartments.

GFRC Description

GFRC panels are typically manufactured in a factory where air temperature and humidity can be controlled. Among other benefits of the factory setting are less waste, dust control, no weather concerns, and safer environment for the workers. The panels are first layed out to the desired specification. GFRC panels are made up of a ½ inch to 1 inch thick concrete shell reinforced with glass fibers (GFRC Cladding System, LLC, 2008). The shell is fastened to an integral 16 or 18 gauge galvanized steel stud frame. The total panel thickness is normally 6 ½ inches, which includes the GFRC, airspace, and stud frame. Studs are typically 24 inches on center. The stud spacing can vary in size depending on the span. GFRC shell or skin is attached to the stud frame through "flex anchors"; these connectors range from ¼-inch to 3/8-inch diameter stainless steel rods. The entire assembly weighs from 10 to 20 lbs per square foot (GFRC Cladding System, LLC, 2008). Similar to other construction materials, they are subject to defects during delivery and may require a few replacements.

Figure 7.3 – Manufacturing Facility – Courtesy of Infinity Structures

Construction

GFRC panels are erected on site by a team of handlers and installers. The lighter weight panels are typically simpler and faster to install. In most cases, the panel installation can take place without the need for external scaffolding. If planned correctly, the GFRC panels can be manufactured while the foundations are underway and then be delivered on a just-in-time basis, allowing large areas of the structure to be quickly enclosed. This allows interior trades to have an early start.

On Square 1400, the GFRC panels will start on the east side of the building and work around the building and up in a corkscrew fashion. Due to the variation in brick color, the panels will need to be divided accordingly – see figure 7.4.

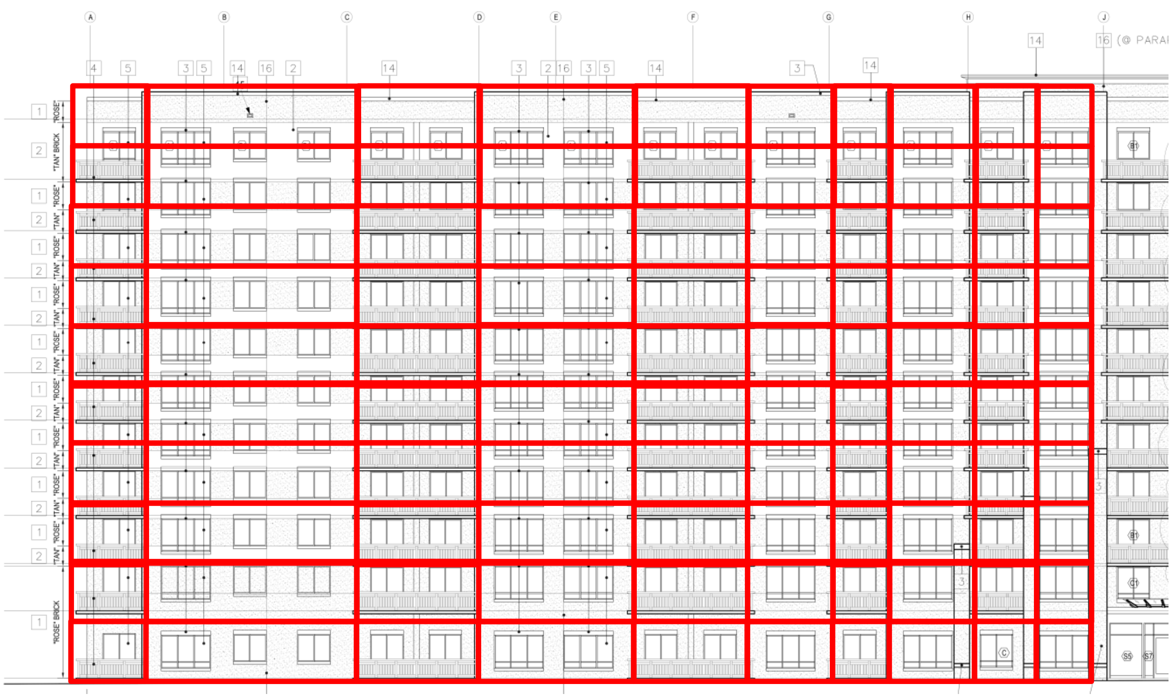


Figure 7.4 – Panel breakdown – Produced by Anthony Grab

Schedule

***Please see Appendix L, the project schedule with GFRC updates**

Traditional brick facades are handcrafted brick-by-brick, which is time consuming and labor intensive. The major advantage of GFRC panels over masonry is the speed at which they can be installed. Because the GFRC Panels, which include metal studs, are prefabricated in a factory, the duration for erecting these panels is very short. In order to receive these panels on time, there is a lead time of around 8 months. The schedule below was updated to accommodate the GFRC panels.

Table 7.1 – Façade Duration Comparison Produced by Anthony Grab

Façade Schedule Duration Comparison	
	Durations
Standard Brick System	67
GFRC System	126
Difference (Days)	**59**

For Square 1400 the time to install the GFRC was projected to take about seven days per floor, totaling about 67 days for all 11 floors. When compared to the original schedule, about 59 days were saved. This duration is very important because it dictates how quickly the building can be enclosed. This is a major milestone on the project schedule because moisture-sensitive building materials that need to be installed in a controlled environment, along with other issues, are greatly reduced once the building is enclosed. GFRC Systems allow this critical date to be met much sooner than the traditional Brick Façade System. Furthermore, if the building is enclosed earlier, it may also have an impact on the overall project completion date, resulting in a potential reduction in the overall project. In terms of schedule duration, the GFRC System is a better solution.

Cost

Table 7.2 – Façade Cost Breakdown Produced by Anthony Grab

GFRC Cost Estimate

Item	Units	Quantity	Unit Mat.	Mat. Cost	Unit Labor	Labor Cost	Unit Equip.	Equip. Cost	Total Item Cost
GFRC Panel	sf	119600	$45.00	$5,382,000	-	-	-	-	$5,382,000.00
fiberglass 3-1/2" , R15	sf	119600	0.48	$ 57,408	-	-	-	-	$ 57,408.00
								Total Cost	$5,439,408.00

Aside from choosing the GFRC panels for the speed at which they can be installed, there is a noticeable difference in initial cost when compared to a standard masonry brick system that can be seen in table 7.3. In order to have accurate cost information for the GFRC system, most of the data was obtained from various manufacturers. Although not standard with the GFRC panels, a cost for three and a half fiberglass insulations was obtained from the RSMeans Cost Works Online. The Price for the standard Brick System was obtained from Baker DC.

Table 7.3 – Façade Cost Comparison Produced by Anthony Grab

Cost Comparison of Façade Systems

Item	Cost
GFRC System	$5,382,000.00
Standard Brick System	$7,400,000.00
Difference in Cost	$2,018,000.00

Sustainability

With the panels being manufactured in a factory setting and not on-site, the GFRC panel construction produces less waste than precast panels and uses fewer natural resources. And, at the end of the long economic life of a GFRC clad building, the GFRC panels may be refurbished for re-use or crushed for recycling. Government studies have shown a significantly reduced impact with GFRC vs. precast concrete or other curtain wall and cladding options.

Site Logistic

With any construction project, the site logistics is always a major concern. It takes a lot of planning upfront to ensure everything on the site will run smoothly and not hinder the flow of construction.

The current construction site layout will be able to accommodate the delivery and installation of the GFRC panels. The panels will arrive at the east gate and then travel around to the back of the site where they will be lifted directly off the flat bed and hoisted into place by the tower crane. The flat bed will then exit the site the same way it entered. Should the project fall behind schedule, a designated area will be left open in the material laydown to store the excess panels.

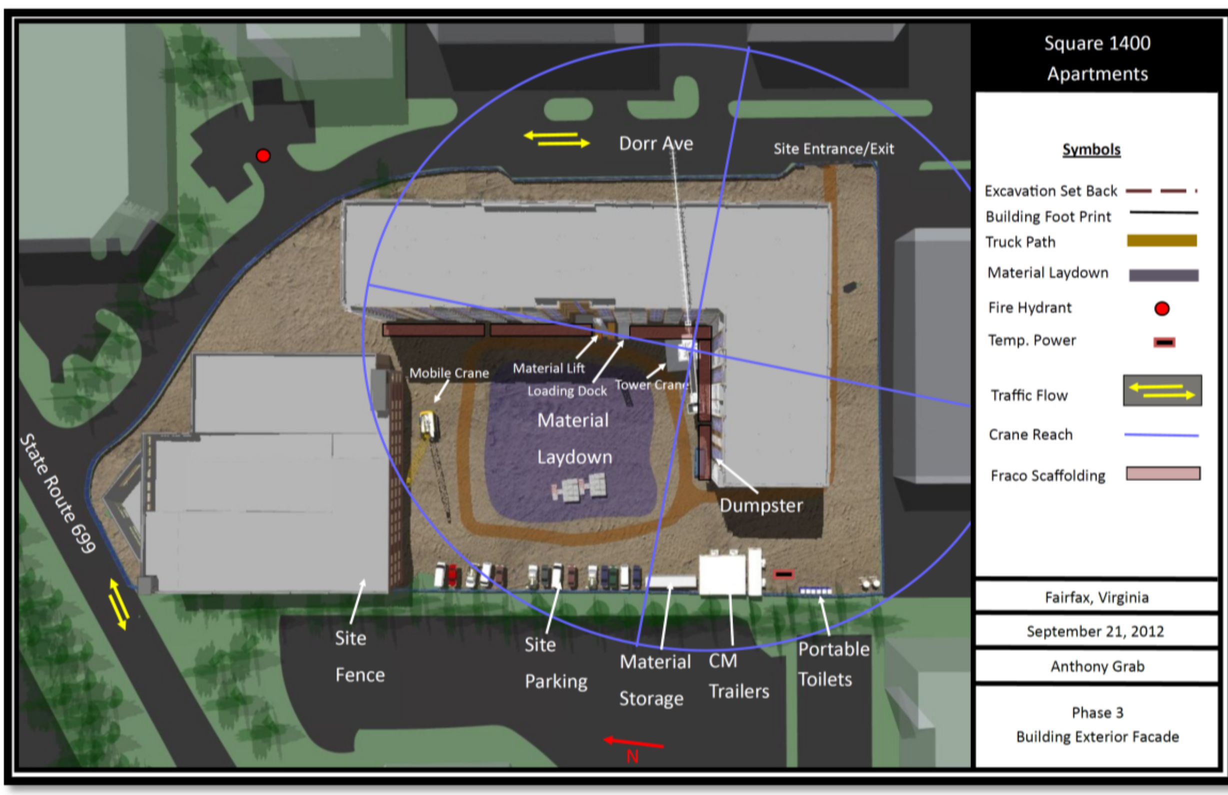


Figure 7.5 – Site Logistics for GFRC Produced by Anthony Grab

Mechanical Breadth: *Contributes to Technical Analysis 3*

****Please see Appendix M Mechanical Calculations***

Through extensive design and research, the implication of Glass Fiber Reinforced Panel would substantially increase productivity, decrease site congestion, and improve trade coordination while achieving a similar building aesthetic. With a potential increase in cost, the faster installation of the exterior façade will be compensated for by an earlier move-in date for the tenants.

The new exterior skin chosen requires a performance analysis to determine the change in the energy loads and ensure R-value requirements are met. Similarly, the upgrades to the windows will be looked at for durability and energy performance.

Thermal Quality Impact

The R-values of different materials are used to determine the thermal impact the exterior façade has on the building. The thermal quality of the façade is highly impacted on the thickness of the different materials. In most cases, thicker is better. Once determined, the R-values can then be used to calculate the U-values for the entire building. The lower the U-value, the better the exterior façade will insulate the building. The tables below show the R-values for each component within the wall system also with the thermal gradients.

Table 7.5 – R-value Brick Construction Produced by Anthony Grab

Standard Face Brick Construction

Wall U-Value		Framing	Insulating
R0	Outside	0.170	0.170
R1	4" Face Brick	0.440	0.440
R2	3/4" Air Space	1.260	1.260
R3	1.5" Rigid Insulation Board	5.000	5.000
R4	Metal Stud/3-5/8" Fiberglass batt	0.380	11.000
R5	5/8" GWB	0.560	0.560
Ri	Inside	0.680	0.680
ΣR		8.490	19.110
U		0.118	0.052
%		0.150	0.850
u		0.118	0.052
% x U		0.018	0.044
Uavg		0.062	

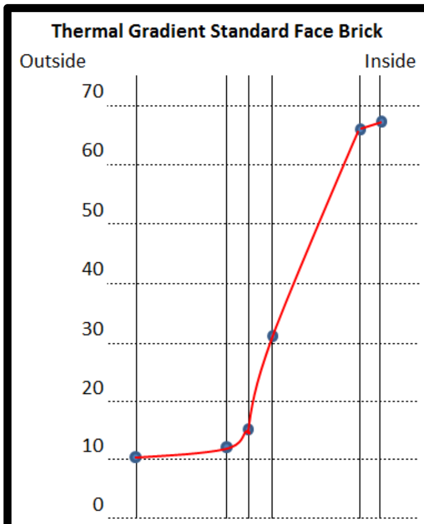
Table 7.6 – R-value GFRC Construction Produced by Anthony Grab

GFRC Panel

Wall U-Value		Framing	Insulating
R0	Outside	0.170	0.170
R1	1" Face Brick GFRC	0.070	0.070
R2	3/4" Air Space	1.260	1.260
R3	Metal Stud/3-5/8" Fiberglass batt	0.380	11.000
R4	5/8" GWB	0.560	0.560
Ri	Inside	0.680	0.680
ΣR		3.120	13.740
U		0.321	0.073
%		0.150	0.850
u		0.321	0.073
% x U		0.048	0.062
Uavg		0.110	

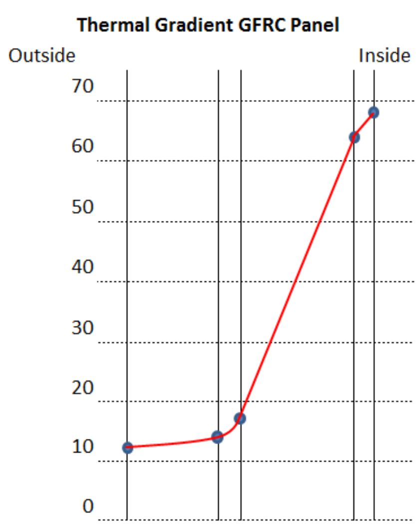
Bases on the two tables it seems the Standard Face Brick is the beter insulating system.

The two tables below illustrate the thermal gradient through the different material from the outside temperature of 10 degrees to the room temperature of 70 degrees. The sum of the R-values corresponds with the material values on the previous page. It becomes obvious that the area of the highest thermal insulating value is with the stud wall where the fiber glass insulation is located. Although the standard face brick has lower U-values because the fiber glass insulation plays such a key role, it can simply be upgraded to meet the desired overall U-value.



x	Sum of R	Tx
o-1	0.170	10.534
1-2	0.610	11.915
2-3	1.870	15.871
3-4	6.870	31.570
4-5	17.870	66.107
5-i	18.430	67.865

Figure 7.6 – Thermal Gradient Standard Brick - Produced by Anthony Grab



x	Sum of R	Tx
o-1	0.170	10.742
1-2	0.240	11.048
2-3	1.500	16.550
3-4	12.500	64.585
4-i	13.060	67.031

Table 7.7 – Thermal Gradient for GFRC - Produced by Anthony Grab

Conclusion and Recommendations

Through extensive detail analysis performed on Glass Fiber Reinforced Clad Panels and Standard Masonry Brick, both advantages and disadvantages were found. Advantages found using the Masonry Brick was a lower U-value of 0.062. This was expected because, unlike the GFRC, the masonry wall system included a one and half ridged insulation board with an R-value of five. However with a calculated U-value for GFRC at 0.110, minor upgrades could be made to the wall in order to achieve a better U-value. A cost analysis was performed on the GFRC panel system, resulting in a significantly lower overall cost when compared to the Masonry Brick. This was somewhat to be expected because of the labor intensity involved with placing the Masonry System. Furthermore, the Masonry System tends to make the site more congested and ties up the exterior of the building.

The most significant advantage of the GFRC panels mostly involved the construction process of installing the façade. The panels were able to go up much faster than the traditional masonry brick system. This was largely due to the fact that the panels were prefabricated; therefore, when they reached the site, they were ready to be installed quickly and smoothly in large sections. Unlike the masonry brick, which involved constructing many layers that were directly installed to the exterior of the building's structure and thus taking a considerable amount of time and energy? With a quicker schedule, the building is able to reach its dry in dead line much sooner than that with the traditional brick system. Typically, this critical dead line is linked with the overall timeline of the project and can result in an early move-in date by the tenants, and there might also be a potential cost saving.

Based on the advantages and disadvantages of the two systems, it was found that overall the GFRC Panels are a better system. However, the Standard Bricks system is better when it comes to durability. In most circumstances I would recommend the GFRC Panels; I believe that the speed and cost at which they can be installed makes them a better product.

Section 8: Critical Industry Issue: Operations and Maintenance + BIM

Problem Identification/Background Research

Today's buildings are becoming more complex and difficult to operate. With that in mind, there is a high demand for information-rich models that will assist with the upkeep of the different building systems. In numerous scenarios, a more complex building leads to an increase in energy costs. In the apartment setting, it can be challenging to monitor the energy use between each apartment unit. Furthermore, the average resident does not realize how much energy they are wasting. This can be contributed to a number of different reasons. For example, the residents might not understand how much can be saved by taking a few extra precautions, or they simply do not care.

Proposed Solution

To decrease the amount of energy lost, a proposed solution would be to place a live reader board in the main lobby of the building. It would illustrate a detailed breakdown of each apartment unit and its energy uses. Energy uses that would be monitored include electric, water, and gas. This is similar to hybrid cars, as in-dash display readouts communicating how much fuel was saved.

Research Methods

- Determine how gas, water, and electric will be monitored for each unit
- Develop a model that identifies the major areas for energy saving
- Locate software for the dashboard
- Survey to see how many people would cut back based on the dashboard
- Determine the payback period for the energy saving system
- Summarize Results

Resources

- Square 1400 Project team
- BIM Coordinator (HITT Contracting)
- Dr. Messner (BIM Expert for Penn State)
- Moses Ling (Mechanical Expert)
- Dr. Riley (Sustainable Building Expert)

Anticipated Results

The anticipated result is the hope that the competitive nature of the residents, along with other incentives, will greatly reduce the building's overall energy intake.

Critical Industry Issue

O&M Energy + BIM

Building information modeling (BIM) is a popular topic in the construction industry, most of which has highest focuses during the design and construction phase of the project. Lead by Dr. Messner, the first information session outlined the importance of operation and maintenance of a building with the integration of BIM along with using BIM for energy analysis.

Today's buildings are becoming more complex and difficult to operate. With that in mind, there is a high demand for information-rich models that will assist with the upkeep of the different building systems. However, there are a number of challenges that come along with achieving this goal. The first question that comes to mind is it really worth the extra time and money to develop dynamic models of the building, or is it easy and cheaper just to wait until the element fails and then the fix the problem? Another hurdle to overcome is the fact that many owners are not pushing BIM on their projects.

BIM models are becoming more popular for energy analysis study of the building. It is important to develop the model early in the design phase of the project. This will ensure all the major energy scenarios have been evaluated and will not have a high cost impact if the change is made early. However, it is also important to keep the model up-to-date as the project progresses. This will make it easier down the road to check if the building is performing the way it was intended to, typically a year later.

A lot of the existing buildings in the country are becoming outdated and are in need of updates. In the city of Philadelphia, the energy hub has set a high goal of lowering all existing buildings' energy by 2020. A good way to evaluate the energy usage of buildings is to simply look at the energy bill for the past several years. This will give a good indication as to what type of upgrades would be suitable for the building.

The thing that surprised me the most about the information session was the fact that there was not any software on the market that is able to take the BIM model created by the architect and link it to the major MEP systems in the building. In order to make this possible, manufacturers are going to have to start creating models of the systems that can then be loaded into the model for accurate data. For Square 1400 Apartments, it would be worth looking into placing vibration sensors on the mechanical equipment. When a change in vibration is indicated, an alarm would go off notifying maintenance personnel which area is in need of work. Penn State is already using similar variation sensors throughout the campus.

Background Information

HITT Contracting and Rushmark LLC are taking many steps to improve the sustainability of the operations, including promoting reuse of material, improving energy efficiency of their buildings, and encouraging alternative transit shames. The Square 1400 Apartments is currently pursing LEED Silver under the 2009 LEED-NC report rating. The 2009 system evaluates the building in a number of different categories including sustainable site, water efficiency, energy and atmosphere, and material resources. The United States Green Building Council (USGBC) set the LEED standards for all types of construction. Square 1400 falls under New Construction. HITT Contracting is working with SB Partner to develop a whole building energy simulation for the proposed apartment building. SB Partners utilizes a 3D model as a design tool specifically for the purpose of enhancing the energy performances of the facility. In doing so, this increased the LEED Energy and Atmosphere by one credit. These efforts, along with HITT's in-house LEED team and the project team, will ultimately save money and create a more sustainable building. However, an often overlooked area is a means of energy saving that provides the end user (apartment tenants) information about their energy use through a dashboard connected to the buildings information system.

An Energy Information System (EIS) is a package performance monitoring software, hardware, and communication system to collect, analyze and store the data. The "dashboard" is defined as a display and visualization tool the uses the EIS data to provide critical information to the building occupants. The hope is that the information will then lead to actions that result in an energy savings.

Product Details

Founded in 2004, Lucid is a privately held software company that develops dashboards displaying real-time information such as energy savings and water resource within in the building (Lucid). Over the past few years, Lucid has made it viable, engaging, and accessible for building occupants to visually see data and communication tools to manage and reduce their energy consumption.

Building Compatibility

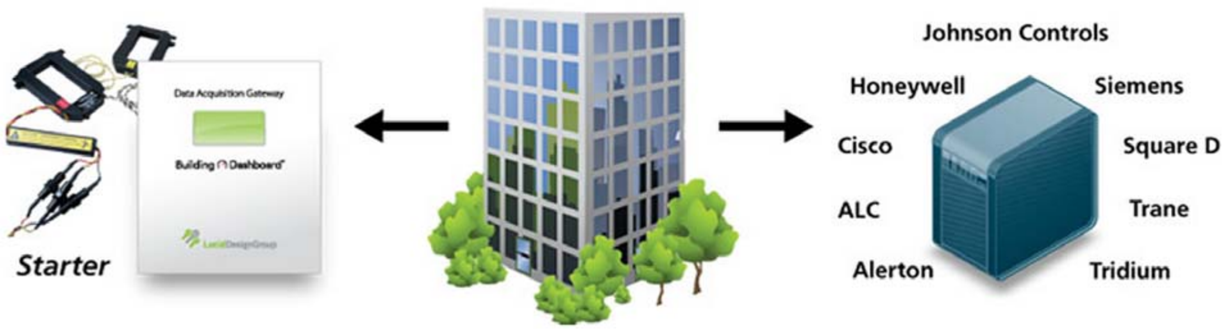


Figure 8.1 – Compatible with any building – Courtesy of Lucid

Early on, Lucid recognized no building is the same, using any number of different manufacturers to monitor and control the buildings systems. Therefore, Lucid has designed their dashboard to virtually connect with any building control system and many building meters. In some cases, buildings do not have automated metering. For these building they have designed a product called out-of-the-box data logger and metering package (Lucid). The system works by wiring the box into the building system with the provided industry-grade electric meter. The box, which is preconfigured, will bring the building online.

Figure 8.2 - ACS320 HVAC Control Panel – Courtesy of Wyble and Associates

Square 1400 Apartments uses a ACS320 HVAC Control Panel to monitor its equipment. The panel is a multifunction control panel with full graphic LCD display and multiple language capability. The control panel can be connected to and detached from the ACS320 at any time. The panel can be used to upload and copy parameters to other ACS320 drives. The panel is compatible with Lucid building control software.

What's on the Dashboard?

One of the major problems with getting people to care about saving energy is the ability to get important information to them in a way that interests them and motivates them to save energy. To help with this problem Lucid has put together a number of displays that enable occupants, visitors, and the public to view energy and water use information on touchscreen displays. Comparative graphs, glowing orbs, and other exciting visualizations make it easy to understand the performance of buildings and organizations.

One of the tactics used by Lucid to make the information displayed more interesting is with unit equivalents. The display shows electricity use in terms of dollars spent in terms of ponds of carbon dioxide emitted. It even shows water in terms of equivalent toilet flushes. By making these simple relationships, the information can be related to and understood by everyone (Lucid).

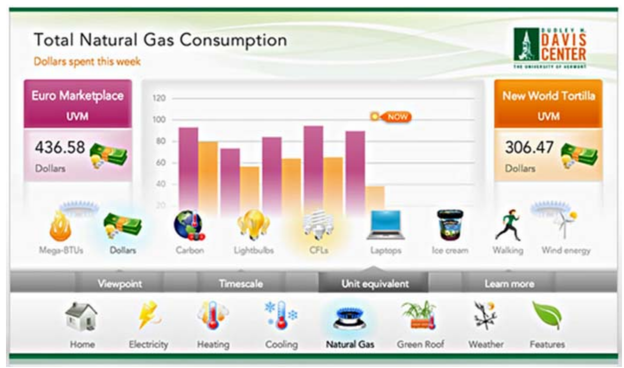


Figure 8.3 - Unit Equivalents Display – Courtesy of Lucid

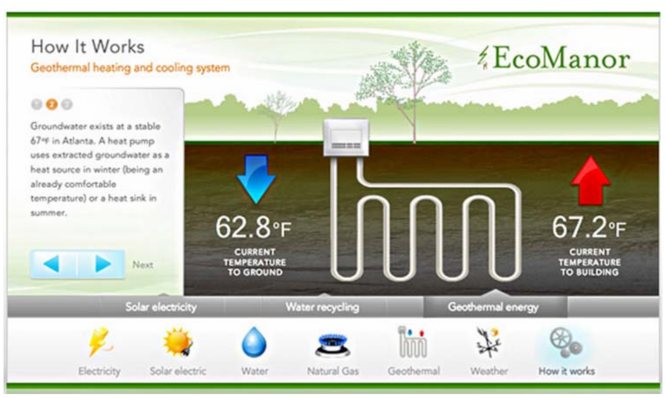


Figure 8.4 - Diagrams Display – Courtesy of Lucid

For the occupant that is more interested how the system works, diagrams and illustrations can be added to the dashboard explaining how the building's systems are performing in real time. Systems such as photovoltaic, solar thermal, rainwater catchment, and geothermal systems can be displayed (Lucid).

Lucid System Example

Penn State University Residence Halls

Penn State University has put an energy saving program in place called "Fight the Power: East Halls Energy Competition". The program is designed to have fourteen residence halls within the East Halls Complex compete to reduce the amount of electricity used by residence halls over a three-week period. The hall that saves the most energy wins.

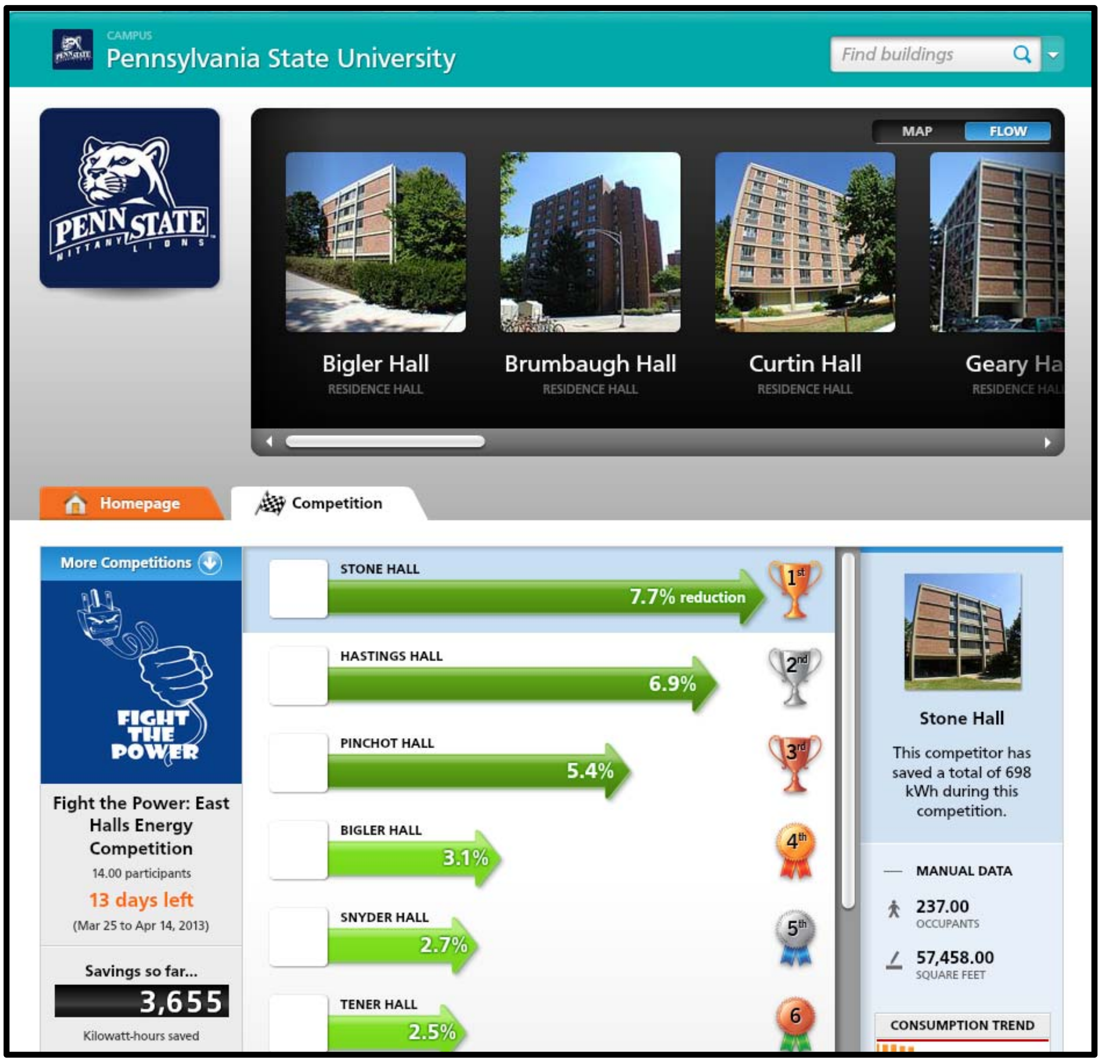


Figure 8.5 - Diagrams Display – Courtesy of Penn State University

Cost/Payback

With Square 1400 Apartments being a new construction project with currently no real energy data, it is hard to predict exactly how much energy could be saved with the implantation of an energy saving dashboard. One way to estimate the potential energy saving is through historical data collected from Lucid national competition results. It seems that over a period of about a month the building was able to save an average of 25 percent of its total energy per kilowatt hour. Similarly, it's hard to put a dollar value on the cost saving because it has not yet been occupied by tenants.

Organization	Duration	Savings	Top Reductions
Franklin & Marshall College	16 days	8,089 kWh	Top reducing residence hall: 17.3% (7 buildings participating)
St. Lawrence University	18 days	3,357 kWh	Top reducing residence hall: 20.2% (22 buildings participating)
University of Victoria	19 days	40,219 kWh	Top reducing residence hall: 56.4% (9 buildings participating)
Google NYC office	28 days	3,146 kWh	Top reducing floor: 30.4% (13 floors participating)
Agnes Scott College	7 days	8,899 kWh	Top reducing residence hall: 34.8% (5 buildings participating)
Phillips Academy at Andover v. Deerfield Academy	27 days	15,160 kWh	Top reducing residence hall: 45.4% (42 buildings participating)
Bowdoin College	30 days	16,893 kWh	Top reducing residence hall: 29.1% (21 buildings participating)
Elon University	49 days	231,454 kWh	Top reducing residence hall: 36.9% (41 buildings participating)
Bowdoin College	11 days	4,376 kWh	Top reducing residence hall: 17.2% (11 buildings participating)
St John's University	14 days	22,320 kWh	Top reducing residence hall: 15.8% (6 buildings participating)
Hamilton College	15 days	44,345 kWh	Top reducing residence hall: 40.9% (11 buildings participating)
Oberlin College	14 days	10,675 kWh	Top reducing residence hall: 42.5% (17 buildings participating)
Boston College	28 days	15,212 kWh	Top reducing residence hall: 9.1%

Figure 8.6 – Dashboard competition – Courtesy of Lucid

Conclusion and Recommendations

With energy savings dashboards being a relatively new technology, and only a few studies showing their saving potential resulting from their use, at this time it is hard to justify the implementation. These savings are determined by initial building performance, various types of monitoring, combined with the quality of EIS analysis software. As more buildings start installing these systems, a better understanding of how effective a tool they are, both for providing feedback to building operators and managers, as well as informing building end users about the energy consumed in their building. It also has to be taken into consideration whether or not the occupants will buy into good energy saving practices in order to make a difference.

Report Synopsis and Conclusion

Analysis 1: Change in Cast-In-Place Structure

The current structure for the Square 1400 Apartment Building is a six-inch cast-in-place structure with post-tension reinforcing. This cast-in-place structure has a large impact on construction cost, schedule, and manpower. The design of a new Infinity structural system resulted in a substantial reduction in the overall project schedule.

Analysis 2: SIPS (Short Interval Production Scheduling) + BIM (Building Information Modeling)

The project utilizes traditional scheduling techniques and minimal BIM was implemented. The use of the Short Interval Production Schedule (SIPS) method helped to break construction activities into detailed repeatable activities. This differs from the conventional way of project scheduling as it usually breaks projects into smaller operations instead of larger tasks resulting in a higher level of detail for individual tasks, which increases productivity and quality control. The result was a saving of one day per floor. Because the structure is on the critical path this saving could be beneficial in the long run.

Analysis 3: Increase Production Through Precast Brick Panels

Traditional Fraco Scaffolding System was used on all sides of the building to assist with the placing of exterior brick. This tied up the exterior of the building, which made it difficult for different trades to perform work on the building envelope and get materials into the building. This slowed down the production of a number of trades. The use of GFRC Panels resulted in increase productivity, decrease site congestion, and improve trade coordination while achieving a similar building aesthetic.

Analysis 4: Critical Industry Issue: Operations and Maintenance + BIM

Today's buildings are becoming more complex and difficult to operate as there is a high demand for information rich models that will assist with the upkeep of the different building systems. In some cases, a more complex building means more energy costs. In the apartment setting, it can be challenging to monitor the energy use between each apartment unit. With the installation of an energy-savings dashboard, a potential of 25 percent saving of the building's overall energy intake could be achieved.

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Appendix A

LEED Score Card

LEED-NC 2009 Project Scorecard
Square 1400
5/27/2011 11:54

Project Points
57
Silver

Targeted Rating is Silver

0-39	= No certification
40-49	= Certified
50-59	= Silver
60-79	= Gold
80-110	= Platinum

Y	?	N	Sustainable Sites		
			Prereq 1	Construction Activity Pollution Prevention	Required
1			Credit 1	Site Selection	1
5			Credit 2	Development Density & Community Connectivity	5
		1	Credit 3	Brownfield Redevelopment	1
6			Credit 4.1	Alternative Transportation, Public Transportation Access	6
1			Credit 4.2	Alternative Transportation, Bicycle Storage & Changing Rooms	1
3			Credit 4.3	Alternative Transportation, Low-Emitting Fuel Efficient Vehicles	3
2			Credit 4.4	Alternative Transportation, Parking Availability	2
		1	Credit 5.1	Site Development - Protect or Restore Habitat	1
1			Credit 5.2	Site Development - Maximize Open Space	1
1			Credit 6.1	Storm Water Management - Quantity	1
		1	Credit 6.2	Storm Water Management - Quality	1
1			Credit 7.1	Heat Island Reduction, Non-Roof Heat Island Reduction, Non-Roof	1
1			Credit 7.2	Heat-Island Reduction, Roof Heat-Island Reduction, Roof	1
		1	Credit 8	Light Pollution Reduction	1
22		4	Sustainable Sites	Possible Points	26

Y	?	N	Water Efficiency		
			Prereq 1	Water Use Reduction - 20% Reduction	Required
2		2	Credit 1	Water Efficient Landscaping; 50% potable use reduction	4
		2	Credit 2	Innovative Waste Water Technologies	2
4			Credit 3	Water Use Reduction; 30%, 35%, 40%	4
6		4	Water Efficiency	Possible Points	10

Y	?	N	Energy & Atmosphere		
			Prereq 1	Fundamental Commissioning of Building Energy Systems	Required
			Prereq 2	Minimum Energy Performance	Required
			Prereq 3	Fundamental Refrigerant Management	Required
			Prereq EA1	Achieve at least 2pts in EA Credit 1:	Required
3	1	15	Credit 1	Optimize Energy Performance (Currently 16%)	19
		7	Credit 2	Renewable Energy	7
2			Credit 2	Enhanced Commissioning	2
		2	Credit 3	Enhanced Refrigerant Management	2
		3	Credit 3	Measurement & Verification	3
2			Credit 4	Green Power	2
7	1	27	Energy & Atmosphere	Possible Points	35

Y	?	N	Materials & Resources		
			Prereq 1	Storage and Collection of Recyclables	Required
		3	Credit 1.1	Building Reuse, Maintain 55%, 75%, 95% existing walls, floors, roof	1
		1	Credit 1.2	Building Reuse, Maintain 50% Interior Non-Structural Elements	1
1			Credit 2.1	Construction Waste Management, Divert 50% From Landfill	1
1			Credit 2.2	Construction Waste Management, Divert 75% From Landfill	1
		1	Credit 3.1	Resource Reuse, 5%	1
		1	Credit 3.2	Resource Reuse, 10%	1
1			Credit 4.1	Recycled Content, 10% (post-consumer + 1/2 pre-consumer)	1
1			Credit 4.2	Recycled Content, 20% (post-consumer + 1/2 pre-consumer)	1
1			Credit 5.1	Regional Materials, 10% Extracted and Manufactured Regionally	1
1			Credit 5.2	Regional Materials, 20% Extracted and Manufactured Regionally	1
		1	Credit 6	Rapidly Renewable Materials	1
1			Credit 7	Certified Wood	1
7		7	Materials & Resources	Possible Points	14

LEED-NC 2009 Project Scorecard

Square 1400

5/27/2011 11:54

Project Points
57
Silver

Targeted Rating is Silver

0-39	= No certification
40-49	= Certified
50-59	= Silver
60-79	= Gold
80-110	= Platinum

Y	?	N	Indoor Environmental Quality		
			Prereq 1	Minimum IAQ Performance	Required
			Prereq 2	Environmental Tobacco Smoke (ETS) Control	Required
		1	Credit 1	Outside Air Delivery Monitoring	1
		1	Credit 2	Increased Ventilation	1
1			Credit 3.1	Construction IAQ Management Plan, During Construction	1
1			Credit 3.2	Construction IAQ Management Plan, Before Occupancy	1
1			Credit 4.1	Low-Emitting Materials, Adhesives and Sealants	1
1			Credit 4.2	Low-Emitting Materials, Paints and Coatings	1
1			Credit 4.3	Low-Emitting Materials, Carpet Systems	1
	1		Credit 4.4	Low-Emitting Materials, Composite Wood and Laminate Adhesives	1
		1	Credit 5	Indoor Chemical and Pollutant Source Control	1
1			Credit 6.1	Controllability of Systems, Lighting	1
1			Credit 6.2	Controllability of Systems, Temperature and Ventilation	1
1			Credit 7.1	Thermal Comfort - Compliance	1
		1	Credit 7.2	Thermal Comfort - Monitoring	1
		1	Credit 8.1	Daylight & Views - Daylight 75% of Spaces	1
1			Credit 8.2	Daylight & Views - Views for 90% of Seated Spaces	1
9	1	5	Indoor Environmental Quality	Possible Points	15

Y	?	N	Innovation & Design Process		
1			Credit 1.1	Innovation in Design - Exemplary Performance SS 5.2	1
1			Credit 1.2	Innovation in Design - Exemplary Performance SS4.1 Transportation	1
	1		Credit 1.3	Innovation in Design - Green Housekeeping	1
	1		Credit 1.4	Innovation in Design - Green Building Education	1
1			Credit 1.5	Innovation in Design - Green Power for Residents	1
1			Credit 2	LEED™ Accredited Professional	1
4	2		Innovation & Design Process	Possible Points	6

Y	?	N	Regional Priority		
1			Credit 1.1	Regional Priority - SS6.1	1
		1	Credit 1.2	Regional Priority - WE2	1
1			Credit 1.3	Regional Priority - WE3, 40%	1
		1	Credit 1.4	Regional Priority - EA 2 On Site Renewable Energy	1
			Credit 1.5	Regional Priority	1
2		2	Regional Priority	Possible Points	4

Appendix B

Site Plan – Existing Conditions

Square 1400

Symbols

Site Fence/Property

SS Lines

Domestic Water

UGG Lines

Fire Hydrant

Traffic Flow

Demo Buildings

Existing Buildings

Closed Sidewalk

Fairfax, Virginia

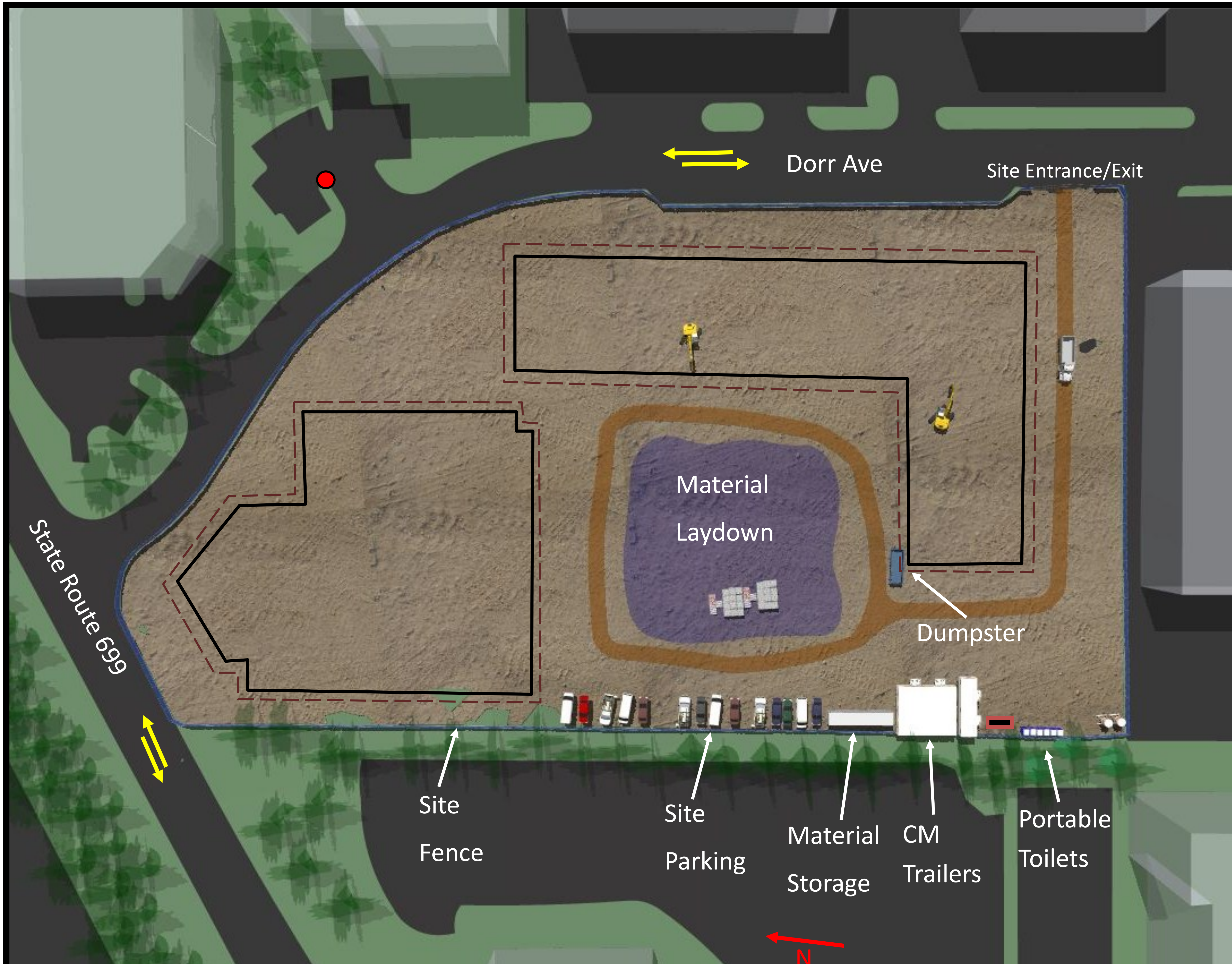
September 21, 2012

Anthony Grab

Existing Conditions

Appendix C

Phase 1 – Excavation



Square 1400 Apartments

Symbols

Excavation Set Back
Building Foot Print
Truck Path
Material Laydown
Fire Hydrant
Temp. Power
Traffic Flow

Fairfax, Virginia

September 21, 2012

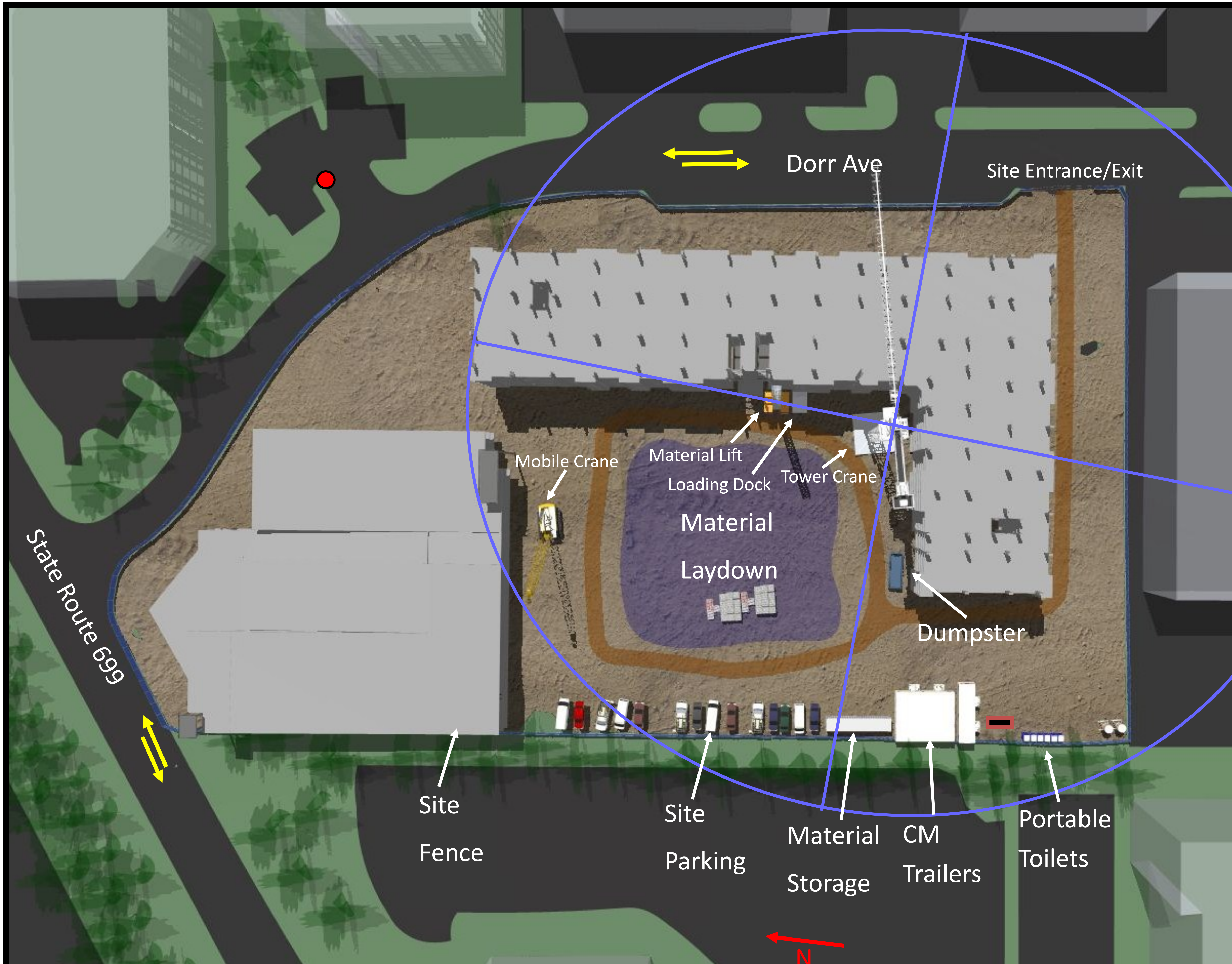
Anthony Grab

Phase 1
Excavation Site Plan

Appendix D

Phase 2 – Structure

Square 1400 Apartments



Symbols

Excavation Set Back

Building Foot Print

Truck Path

Material Laydown

Fire Hydrant

Temp. Power

Traffic Flow

Crane Reach

Fairfax, Virginia

September 21, 2012

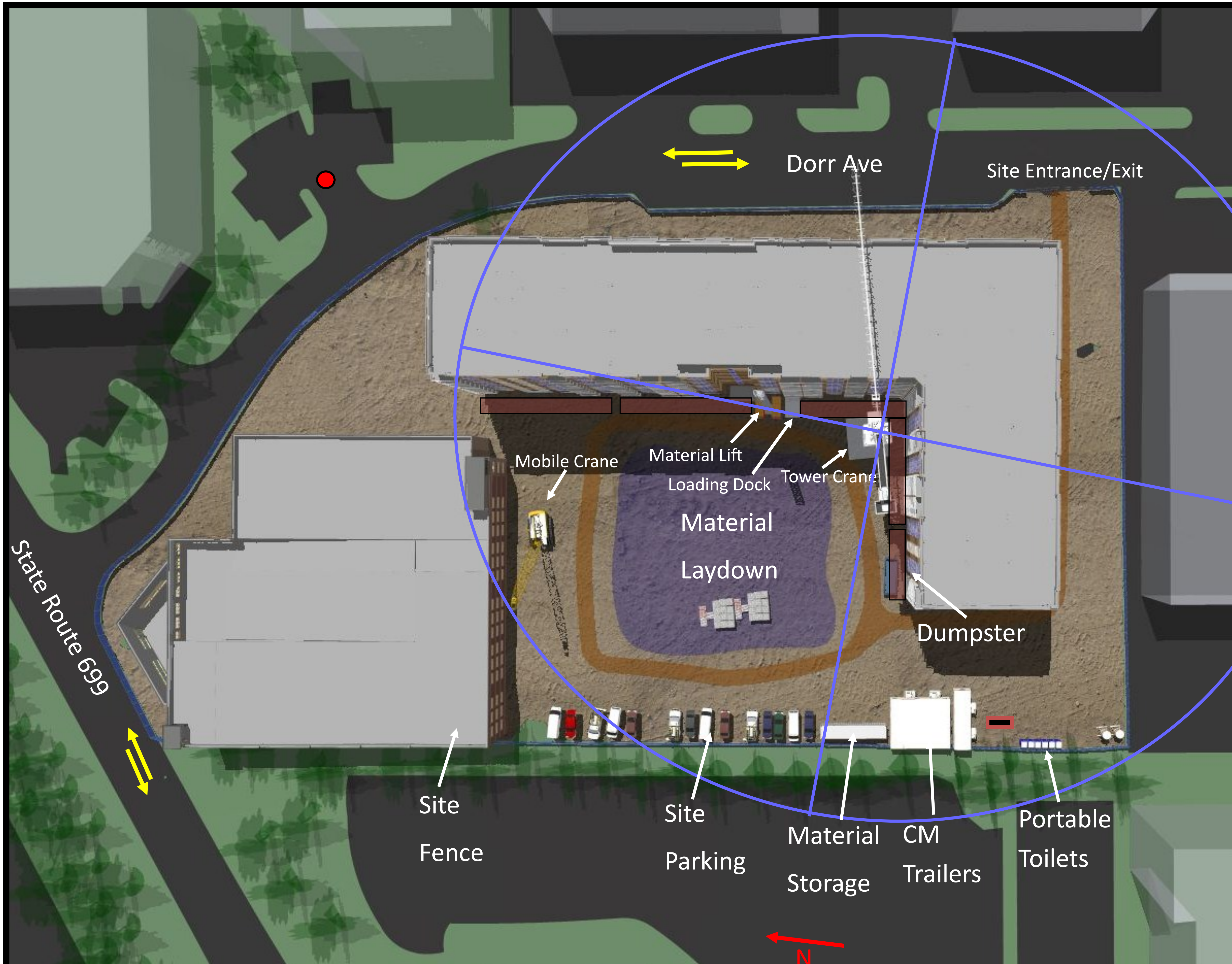
Anthony Grab

Phase 2

Building Structure

Appendix E

Phase 3 – Exterior Facade



Square 1400 Apartments

Symbols

Excavation Set Back
Building Foot Print
Truck Path
Material Laydown
Fire Hydrant
Temp. Power
Traffic Flow
Crane Reach
Fraco Scaffolding

Fairfax, Virginia

September 21, 2012

Anthony Grab

Phase 3
Building Exterior Facade

Appendix F

RSMeans CostWorks Square Foot Estimate

Square Foot Cost Estimate Report

Estimate Name:	**Square 1400**
Building Type:	**Apartment, 8-24 Story with Face Brick with Concrete Block Back-up / R/Conc. Frame**
Location:	**FAIRFAX, VA**
Story Count:	**11**
Story Height (L.F.):	**13**
Floor Area (S.F.):	**327431**
Labor Type:	**Open Shop**
Basement Included:	**Yes**
Data Release:	**Year 2012**
Cost Per Square Foot:	**$150.61**
Building Cost:	**$49,313,000**

Costs are derived from a building model with basic components.

Scope differences and market conditions can cause costs to vary significantly.

		% of Total	Cost Per S.F.	Cost
A Substructure		**12.50%**	**$16.43**	**$5,379,000**
A1010	**Standard Foundations**		**$0.55**	**$179,500**
	458 K column			
	900 K column			
A1020	**Special Foundations**		**$14.53**	**$4,758,000**
	Steel H piles, 100' long, 400K load, end bearing, 6 pile cluster			
	Steel H piles, 100' long, 800K load, end bearing, 12 pile cluster			
	Grade beam, 30' span, 52" deep, 14" wide, 12 KLF load			
A1030	**Slab on Grade**		**$0.40**	**$132,000**
	Slab on grade, 4" thick, non industrial, reinforced			
A2010	**Basement Excavation**		**$0.23**	**$75,000**
	site storage			
A2020	**Basement Walls**		**$0.72**	**$234,500**
	thick			
B Shell		**23.00%**	**$30.24**	**$9,900,000**
B1010	**Floor Construction**		**$16.51**	**$5,406,000**
	height, 253 lbs/LF, 4000PSI			
	height, 567 lbs/LF, 4000PSI			
	25'x25' bay, 40 PSF superimposed load, 129 PSF total load			
	25'x25' bay, 125 PSF superimposed load, 227 PSF total load			
	15'x15' bay, 75 PSF superimposed load, 153 PSF total load			
B1020	**Roof Construction**		**$1.12**	**$366,500**
	12" deep beam, 6" slab, 129 PSF total load			
B2010	**Exterior Walls**		**$9.02**	**$2,953,500**
	perlite core fill			
B2020	**Exterior Windows**		**$3.00**	**$983,500**
	Windows, aluminum, sliding, standard glass, 5' x 3'			
B2030	**Exterior Doors**		**$0.16**	**$51,000**
	0" opening			
	hardware, 6'-0" x 7'-0" opening			
B3010	**Roof Coverings**		**$0.43**	**$139,500**

	Insulation, rigid, roof deck, composite with 2" EPS, 1" perlite			
	Roof edges, aluminum, duranodic, .050" thick, 6" face			
	Flashing, aluminum, no backing sides, .019"			
	Gravel stop, aluminum, extruded, 4", mill finish, .050" thick			
C Interiors		**20.60%**	**$27.09**	**$8,868,500**
C1010	**Partitions**		**$7.56**	**$2,475,000**
	Concrete block (CMU) partition, light weight, hollow, 6" thick, no finish			
	gypsum board, 2-1/2" @ 24", same opposite face, no insulation			
	Furring 1 side only, steel channels, 3/4", 16" OC			
	Gypsum board, 1 face only, exterior sheathing, fire resistant, 1/2"			
	Add for the following: taping and finishing			
	1/2" fire ratedgypsum board, taped & finished, painted on metal furring			
C1020	**Interior Doors**		**$5.55**	**$1,818,000**
	Door, single leaf, wood frame, 3'-0" x 7'-0" x 1-3/8", birch, solid core			
	Door, single leaf, wood frame, 3'-0" x 7'-0" x 1-3/8", birch, hollow core			
C1030	**Fittings**		**$3.42**	**$1,120,000**
	Cabinets, residential, wall, two doors x 48" wide			
C2010	**Stair Construction**		**$1.11**	**$364,500**
	Stairs, steel, cement filled metal pan & picket rail, 12 risers, with landing			
C3010	**Wall Finishes**		**$2.11**	**$690,500**
	primer & 2 coats			
	Vinyl wall covering, fabric back, medium weight			
	Ceramic tile, thin set, 4-1/4" x 4-1/4"			
C3020	**Floor Finishes**		**$4.61**	**$1,508,000**
	Carpet tile, nylon, fusion bonded, 18" x 18" or 24" x 24", 24 oz			
	Carpet tile, nylon, fusion bonded, 18" x 18" or 24" x 24", 35 oz			
	Carpet, padding, add to above, minimum			
	Carpet, padding, add to above, maximum			
	Vinyl, composition tile, minimum			
	Vinyl, composition tile, maximum			
	Tile, ceramic natural clay			
C3030	**Ceiling Finishes**		**$2.73**	**$892,500**
	textured finish, 7/8"resilient channel furring, 24" OC support			
D Services		**43.90%**	**$57.80**	**$18,924,500**
D1010	**Elevators and Lifts**		**$12.45**	**$4,076,000**
	group, 350 FPM			
D2010	**Plumbing Fixtures**		**$13.01**	**$4,261,500**
	Kitchen sink w/trim, countertop, PE on CI, 24" x 21", single bowl			
	Laundry sink w/trim, PE on CI, black iron frame, 24" x 20", single compt			
	Service sink w/trim, PE on CI, corner floor, 28" x 28", w/rim guard			
	Bathroom, lavatory & water closet, 2 wall plumbing, stand alone			
	bathtub, stand alone			
D2020	**Domestic Water Distribution**		**$4.24**	**$1,387,500**
	Gas fired water heater, residential, 100< F rise, 30 gal tank, 32 GPH			
D2040	**Rain Water Drainage**		**$0.13**	**$42,500**
	Roof drain, DWV PVC, 4" diam, diam, 10' high			
	Roof drain, DWV PVC, 4" diam, for each additional foot add			

D3010	**Energy Supply**		$6.41	$2,098,000
	30,000 SF area,300,000 CF vol			
D3030	**Cooling Generating Systems**		$7.89	$2,582,000
	93.33 ton			
D4010	**Sprinklers**		$2.37	$777,500
	Wet pipe sprinkler systems, steel, light hazard, 1 floor, 10,000 SF			
	10,000 SF			
	Standard High Rise Accessory Package 16 story			
D4020	**Standpipes**		$0.60	$195,000
	Wet standpipe risers, class III, steel, black, sch 40, 6" diam pipe, 1 floor			
	Fire pump, electric, with controller, 5" pump, 100 HP, 1000 GPM			
	Fire pump, electric, for jockey pump system, add			
D5010	**Electrical Service/Distribution**		$0.92	$301,000
	phase, 4 wire, 120/208 V, 2000 A			
	Feeder installation 600 V, including RGS conduit and XHHW wire, 2000 A			
	Switchgear installation, incl switchboard, panels & circuit breaker, 2000 A			
D5020	**Lighting and Branch Wiring**		$6.83	$2,235,000
	with transformer			
	Wall switches, 2.5 per 1000 SF			
	Miscellaneous power, 2 watts			
	Central air conditioning power, 3 watts			
	Motor installation, three phase, 460 V, 15 HP motor size			
	V 15 HP, 575 V 20 HP			
	fixtures per 1000 SF			
D5030	**Communications and Security**		$2.75	$901,500
	detectors, includes outlets, boxes, conduit and wire			
	Fire alarm command center, addressable with voice, excl. wire & conduit			
	wire, intercom systems, 100 stations			
	wire, master TV antenna systems, 30 outlets			
	Internet wiring, 2 data/voice outlets per 1000 S.F.			
D5090	**Other Electrical Systems**		$0.20	$67,000
	gas/gasoline operated, 3 phase, 4 wire, 277/480 V, 80 kW			
	engine with fuel tank, 30 kW			
E Equipment & Furnishings		0.00%	$0.00	$0
E1090	**Other Equipment**		$0.00	$0
F Special Construction		0.00%	$0.00	$0
G Building Sitework		0.00%	$0.00	$0
SubTotal		100%	$131.55	$43,072,000
Contractor Fees (General Conditions,Overhead,Profit)		7.00%	$9.21	$3,015,000
Architectural Fees		7.00%	$9.85	$3,226,000
User Fees		0.00%	$0.00	$0
Total Building Cost			$150.61	$49,313,000

Appendix G

General Conditions Estimate

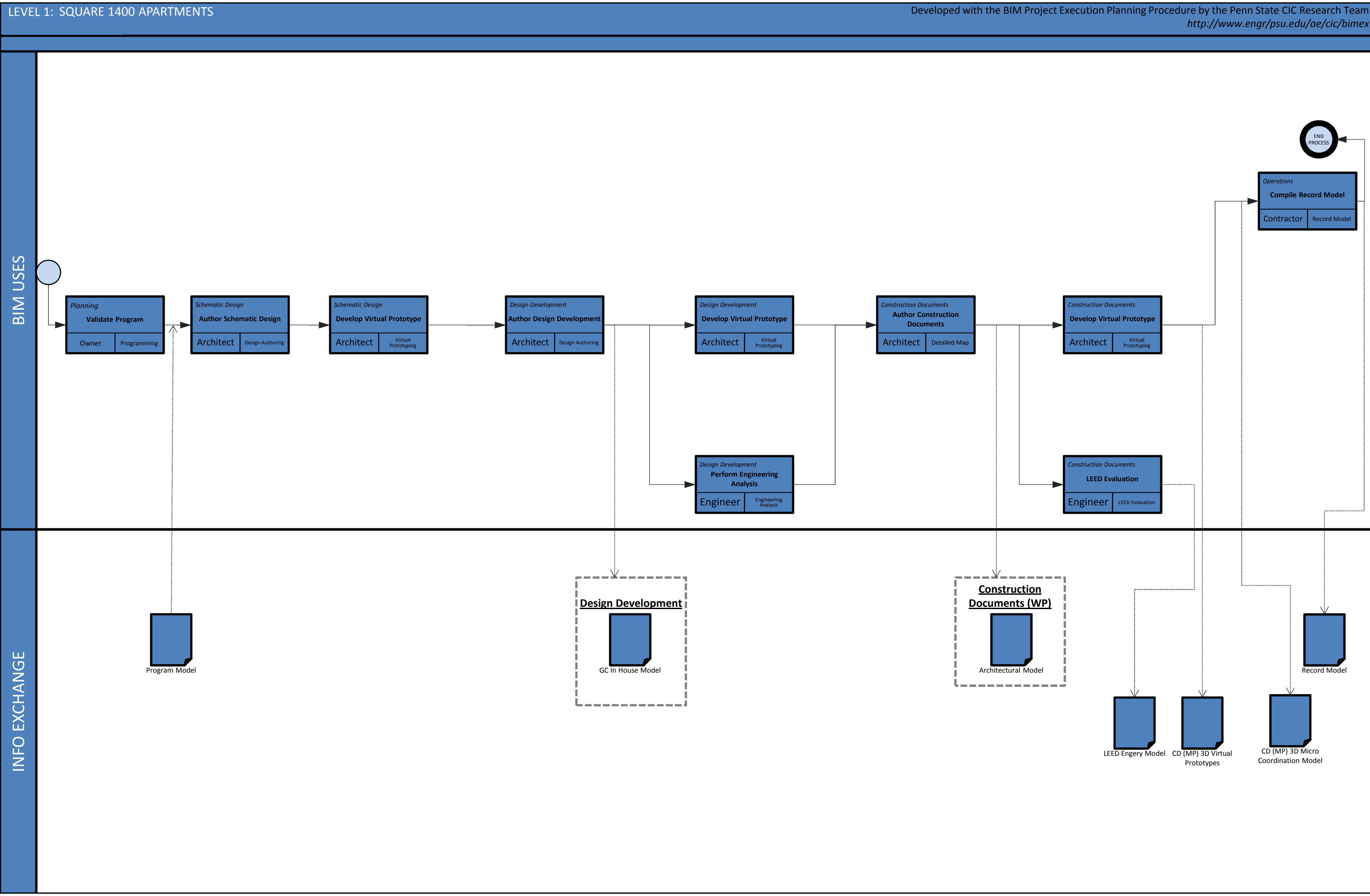
General Conditions Estimate					
Line Item		Quantity	Unit Cost	Unit Cost	Amount
Poject Management					
Executive Vice President / Base Building Director	0%	95	Week	8,500	As Needed
Sr. Project Manager	25%	84	Week	6,500	$ 136,500.00
Project Manager	100%	88	Week	5,000	$ 440,000.00
LEED Project Manager	20%	84	Week	3,500	$ 58,800.00
BIM Manager	10%	95	Week	3,500	$ 33,250.00
Assitant Project Manager	100%	88	Week	3,000	$ 264,000.00
Assitant Project Manager	100%	84	Week	3,000	$ 252,000.00
Project Accountant	25%	88	Week	2,500	$ 55,000.00
					$ 1,239,550.00
Supervision					
General Superintendent	100%	88	Week	5,000	$ 440,000.00
Superintendent - Garage / Site	100%	40	Week	3,000	$ 120,000.00
Superintendent - Building	100%	88	Week	3,000	$ 264,000.00
Project Engineer	50%	88	Week	2,500	$ 110,000.00
					$ 934,000.00
Safety					
Safety Coordinator	50%	84	Week	3,000	$ 126,000.00
First Aid		88	Week	25.00	$ 2,200.00
					$ 128,200.00
FIELD OFFICE / STAGING					
Office Supplies		21.0	Mnth	500.00	$ 10,500.00
Trailer Set Up / Office Furniture		1	LS	5,000	$ 5,000.00
Trailer / Power		21.0	Mnth	500.00	$ 10,500.00
Trailer Reintal - 2Wide		21.0	Mnth	1,000.00	$ 21,000.00
Trailer Delivery / Stairs / Deck		1	LS	5,000	$ 5,000.00
Telephone Sub - Possibly Delete with Tethered Internet		1	LS	5,000	$ 5,000.00
Telephone Monthly Costs - Possibly Delete with Tethered Internet		21.0	Mnth	500.00	$ 10,500.00
Project Meetings		84	Week	75.00	$ 6,300.00
Water / Coffee Service		21.0	Mnth	150.00	$ 3,150.00
Drawing Reprographics		1	LS	15,000	$ 15,000.00
Copier		21.0	Mnth	500.00	$ 10,500.00
Courier / Postage		21.0	Mnth	200.00	$ 4,200.00
Progress Photographs (PM Team)		1.0	LS	1,000.00	$ 1,000.00
Topping Out		1	LS	5,000	$ 5,000.00
Record Documents & Submittals		1	LS	5,000	$ 5,000.00
					$ 117,650.00
FIELD LABOR					
Field Laborer	100%	88	Week	1,200	$ 105,600.00
Field Laborer	100%	40	Week	1,200	$ 48,000.00
Elevator Operator	100%	40	Week	1,200	$ 48,000.00
					$ 201,600.00
FIELD OPERATIONS					
Survey					$ -
Project Identification / Pedestrian Signage		1	LS	10,000	$ 10,000.00
Air Barrier Consultant		1	LS	6,000	$ 6,000.00
Fair Housing / ADA Consultant		1	LS	10,000	$ 10,000.00
Temp Toilets		21.0	Mnth	750	$ 15,750.00
Temp Water		1.0	LS	40,000	$ 40,000.00
Temp Air Conditioning / Heating		1	LS	30,000	$ 30,000.00
Small Tools & Equipment		1.0	LS	25,000	$ 25,000.00
Temporary Protection		1	LS	20,000	$ 20,000.00
Equipment Rental - Sweeper/Bobcat/Lull		21.0	Mnth	1,000	$ 21,000.00
Elevator Protection		1	LS	10,000	$ 10,000.00
Sart Up Temp Power		5.0	Mnth	20,000	$ 100,000.00
Temporary Power		21.0	Mnth	5,000	$ 105,000.00
					$ 392,750.00
TESTING & INSPECTIONS					
Testing & Lab Service					In Trades
Inspection Services					In Trades
INSURANCE					
Liability Insurance					Included
P&P Bonds					Not Required
Builder's Risk Insurance		1	LS	5000	$ 5,000.00
TRASH REMOVAL					
Dumpster Pulls		325	Ea	450.00	$ 146,250.00
				Total Amount	$ 3,160,000.00

Appendix H

Building Information Modeling Use Evaluation

BIM Use*	Value to Project	Responsible Party	Value to Resp Party	Capability Rating			Additional Resources / Competencies Required to Implement	Notes	Proceed with Use
	High / Med / Low		High / Med / Low	Scale 1-3 (1 = Low)					YES / NO / MAYBE
				Resources	Competency	Experience			
Record Modeling	HIGH	Contractor	MED	2	2	2	Requires training and software		**MAYBE**
		Facility Manager	HIGH	1	2	1	Requires training and software		
		Designer	MED	3	3	3			
Cost Estimation	MED	Contractor	HIGH	2	1	1			**NO**
4D Modeling	HIGH	Contractor	HIGH	3	2	2	Need training on latest software	High value to owner due to	**NO**
							Infrastructure needs	phasing complications	
								Use for Phasing & Construction	
3D Coordination (Construction)	HIGH	Contractor	HIGH	3	3	3			**YES**
		Subcontractors	HIGH	1	3	3	conversion to Digital Fab required	Modeling learning curve possible	
		Designer	MED	2	3	3			
Engineering Analysis	HIGH	MEP Engineer	HIGH	2	2	2			**YES**
		Architect	MED	2	2	2			
		Contractor	HIGH	2	2	2	Used for LEEB Energy Model		
Design Reviews	MED	Arch	LOW	1	2	1		Reviews to be from design model	**NO**
								no additioanl detail required	
3D Coordination (Design)	HIGH	Architect	HIGH	2	2	2	Coordination software required	Contractor to facilitate Coord.	**YES**
		MEP Engineer	MED	2	2	1			
		Structural Enginee	HIGH	2	2	1			
Design Authoring	HIGH	Architect	HIGH	3	3	3			**YES**
		MEP Engineer	MED	3	3	3			
		Structural Enginee	HIGH	3	3	3			
		Civil Engineer	LOW	2	1	1	Large learning curve	Civil not required	

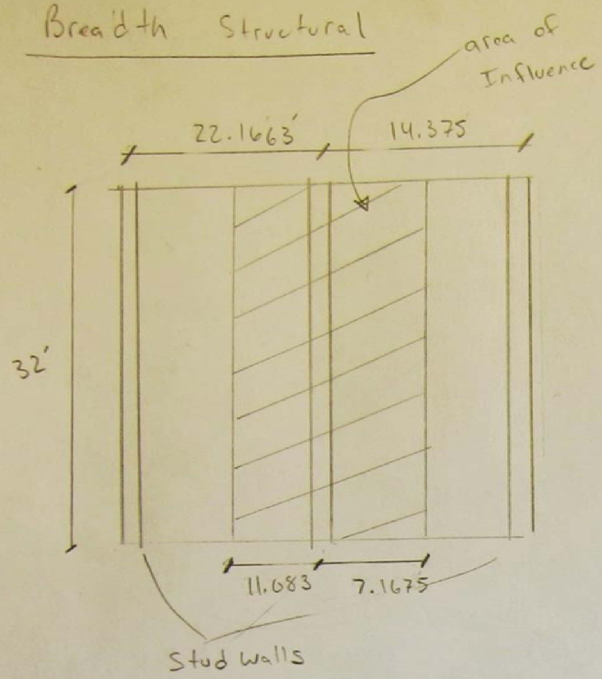
* Additional BIM Uses as well as information on each Use can be found at http://www.engr.psu.edu/ae/cic/bimex/


LEVEL 1: SQUARE 1400 APARTMENTS
Developed with the BIM Project Execution Planning Procedure by the Penn State CIC Research Team
http://www.engr/psu.edu/ae/cic/bimex
BIM USES
INFO EXCHANGE
Planning
Validate Program
Owner
Programming
Schematic Design
Author Schematic Design
Architect
Design Authoring
Schematic Design
Develop Virtual Prototype
Architect
Virtual Prototyping
Design Development
Author Design Development
Architect
Design Authoring
Design Development
Develop Virtual Prototype
Architect
Virtual Prototyping
Design Development
Perform Engineering Analysis
Engineer
Engineering Analysis
Construction Documents
Author Construction Documents
Architect
Detailed Map
Construction Documents
Develop Virtual Prototype
Architect
Virtual Prototyping
Construction Documents
LEED Evaluation
Engineer
LEED Evaluation
Operations
Compile Record Model
Contractor
Record Model
END PROCESS
Program Model
Design Development
GC In House Model
Construction Documents (WP)
Architectural Model
LEED Engery Model
CD (MP) 3D Virtual Prototypes
CD (MP) 3D Micro Coordination Model
Record Model

Appendix I

Infinity Structure Calculations

Breadth Structural



$K_{LL} A_T = (22.1663 + 14.375) \times 32'$
$= 1169.3216$

Area of Influnce = $(11.083 + 7.1675) \cdot 32'$
$= 584.656$ SF

Concrete used in Area of Inf.
584.656 SF × .667' of concrete
= 389.771 C.F.

Weight of concrete =
= 389.771 × 150 PCF
= 58465.6 lbs
= 29 Tons

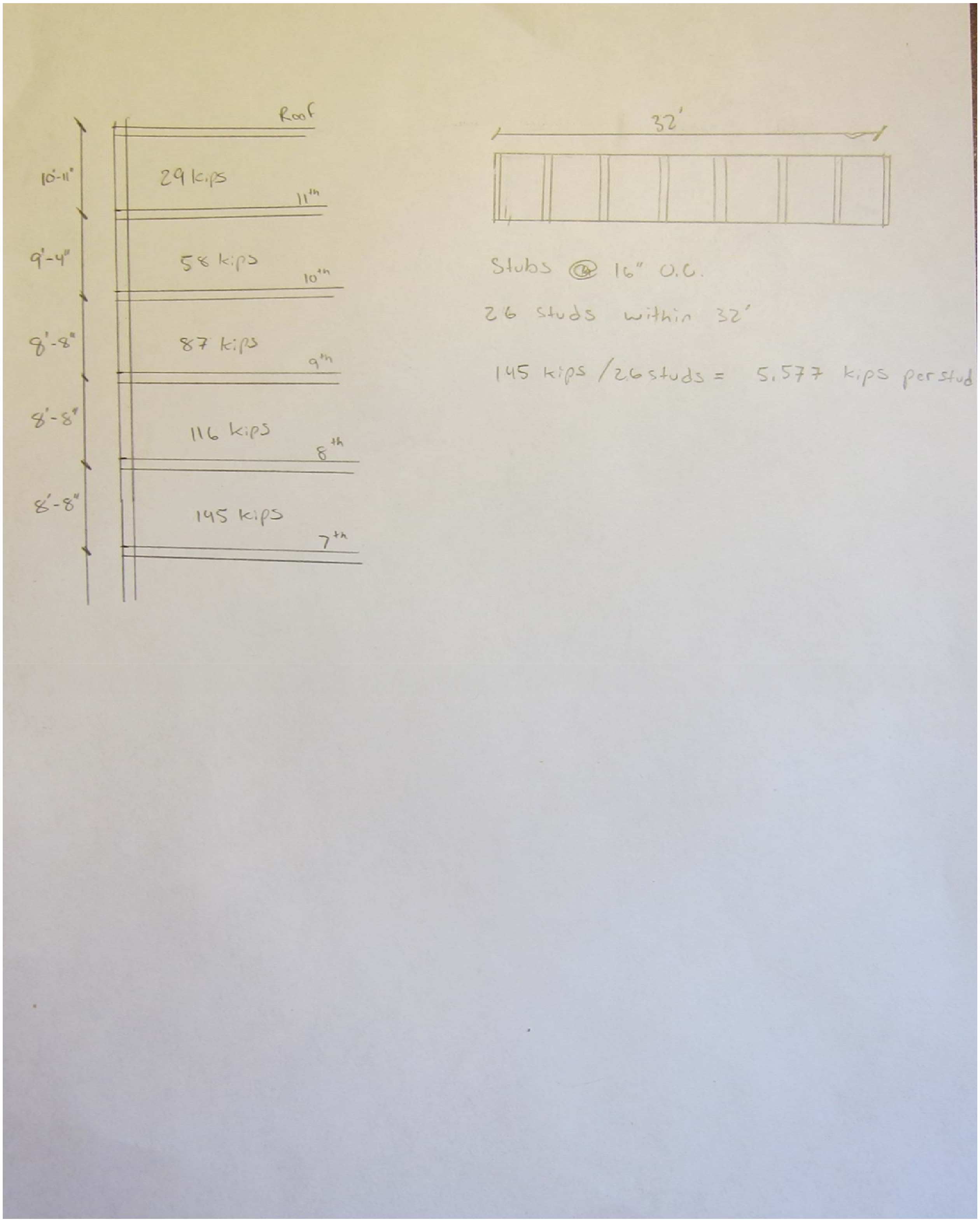
100.

90 - 100 psf
40 - LL.

ASD - DL + LL

Assumptions:

- Epicore MSR 22 Gage Composite Deck
- Simple Condition
- Concrete Strength 4,000 psi
- Live load 40 psf
- Dead load 20 psf
- 8" Concrete slab


Roof
10'-11"
29 kips
11th
9'-4"
58 kips
10th
8'-8"
87 kips
9th
8'-8"
116 kips
8th
8'-8"
145 kips
7th
32'
Studs @ 16" O.C.
26 studs within 32'
145 kips / 26 studs = 5.577 kips per stud

Appendix J

Engineering Tables for Epicore MSR

Engineering Tables For EPICORE MSR® 22 Gage Composite Deck

General Notes

All designs are based on the use of regular weight concrete (150 pcf), with a compressive strength of 4,000 psi. Reinforcing steel other than EPICORE MSR shall have a yield strength of 60,000 psi. Maximum allowable deflection under the total load (live + dead) is limited to L/360 in all cases. For lightweight and/or 3,000 psi concrete, consult Infinity Structures.

22 Gage

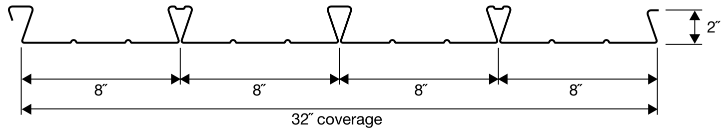


Table 1: Moment Coefficients

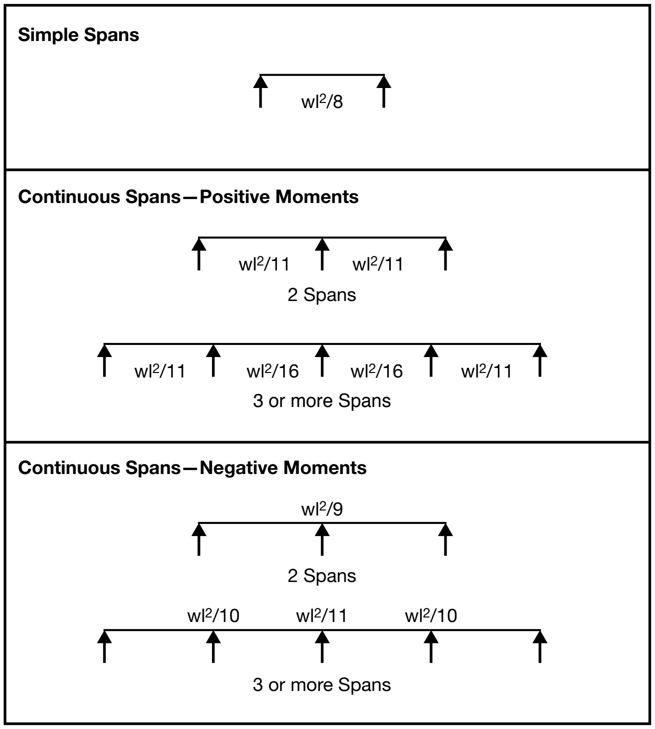


Table 2: EPICORE MSR Section Properties

Gage	22
Weight (psf)	2.0
A_s (in.^{2}/ft.)	0.577
I_s (in.^{4}/ft.)	0.272
$\bar{Y}$ (in.)	0.47
Yield (ksi)	45

NOTE: Section properties have been computed in accordance with the *A.I.S.I. Cold-Formed Steel Design Manual.*

Table 3: Shoring/Temperature Mesh Requirements

Slab Depth (in.)	Max Unshored Clear Span (ft.-in.) 22 Gage.	Temperature Mesh Required
4˝	5-0	6x6-W2.1xW2.1
4.5˝	5-0	6x6-W2.1xW2.1
5˝	5-0	6x6-W2.1xW2.1
5.5˝	5-0	6x6-W2.1xW2.1
6˝	5-0	6x6-W2.1xW2.1
6.5˝	4-6	6x6-W2.1xW2.1
7˝	4-6	6x6-W2.9xW2.9
7.5˝	4-6	6x6-W2.9xW2.9
8˝	4-6	6x6-W2.9xW2.9

NOTE: The determination of the time for removal of supporting shores may be controlled by the presence of construction loads or deflection limitation. The removal of shores may have to occur after the concrete has reached its full compressive strength f´c, and modules Ec and stiffness, particularly in those instances where the construction loads may be as high as the specified live load. If shoring is removed too early, more significant deflection may occur and may even result in permanent damage. The strength and stiffness of the concrete during the various stages of construction should be substantiated by job-constructed and job-cured test specimens (cylinders). See ACI 318 Chapter 6 for more information.

Table 4: Maximum Spans For EPICORE MSR 22 Gage (ft.-in.), f´c = 4000 psi

Total Slab Depth (in.)	SIMPLE SPANS (ft.-in.)			CONTINUOUS SPANS (ft.-in.)					
	LL = 40 psf DL = 20 psf	LL = 80 psf DL = 5 psf	LL = 100 psf DL = 5 psf	LL = 40 psf DL = 20 psf		LL = 80 psf DL = 5 psf		LL = 100 psf DL = 5 psf	
				interior span	end span	interior span	end span	interior span	end span
4˝	14-1	13-2	12-7	16-4	16-4	15-3	15-3	14-6	14-6
4.5˝	15-5	14-5	13-9	17-10	17-10	16-8	16-8	15-11	15-11
5˝	16-8	15-8	15-0	19-3	19-3	18-1	18-1	17-4	17-4
5.5˝	17-11	16-10	16-2	20-8	20-8	19-6	19-6	18-8	18-8
6˝	19-1	18-0	17-4	22-1	22-1	20-10	20-10	20-0	20-0
6.5˝	20-3	19-2	17-11	23-5	23-5	22-2	22-2	21-4	21-0
7˝	21-4	19-8	18-5	24-8	24-8	23-5	23-1	22-7	21-8
7.5˝	22-4	20-1	18-11	25-11	25-11	24-8	23-7	23-10	22-2
8˝	22-9	20-6	19-4	27-2	26-8	25-11	24-1	25-0	22-8

NOTES for Tables 4 and 5:

1. For simple spans:
   a) No reinforcing steel other than EPICORE MSR is required.
2. For continuous spans:
   a) Reinforcing steel is required over interior supports. See Table 5 for suggested rebar sizes. Table assumes 3⁄4˝ concrete cover for reinforcing steel over supports.
   b) Spans should be approximately equal with the larger of the two adjacent spans not greater than the shorter by more than 20 percent. See ACI 318.
   c) Reinforcing over supports should extend a minimum of .3 x L on both sides of the supports. See Chapter 12 (ACI 318) Development and Splices of Reinforcement.
3. Temperature and shrinkage reinforcement, consisting of welded wire fabric, shall have a minimum area of .00075 times the area of concrete above the top flange of the deck but not be less than the area of 6x6-W2.1xW2.1. See Table 3.
4. All listed spans are assumed to be measured from center to center of the supports.

Table 5: Suggested Reinforcing Steel for Continuous Span 22 Gage EPICORE MSR Slabs with 4000 psi Concrete

Slab Depth (in.)	Slab Span (ft.)	Continuous Spans														
		LL = 40, DL = 20					LL = 80, DL = 5					LL = 100, DL = 5				
		Between Supports		Over Supports			Between Supports		Over Supports			Between Supports		Over Supports		
		$\frac{WL^2}{11}$	$\frac{WL^2}{16}$	$\frac{WL^2}{9}$	$\frac{WL^2}{10}$	$\frac{WL^2}{11}$	$\frac{WL^2}{11}$	$\frac{WL^2}{16}$	$\frac{WL^2}{9}$	$\frac{WL^2}{10}$	$\frac{WL^2}{11}$	$\frac{WL^2}{11}$	$\frac{WL^2}{16}$	$\frac{WL^2}{9}$	$\frac{WL^2}{10}$	$\frac{WL^2}{11}$
4″	13	MSR	MSR	#4@10	#4@11	#4@12	MSR	MSR	#4@7	#4@8	#4@9	MSR	MSR	#5@10	#5@11	#5@12
	14	MSR	MSR	#4@9	#4@10	#4@11	MSR	MSR	#4@6	#4@7	#4@8	MSR	MSR	#5@8	#5@9	#5@10
	15	MSR	MSR	#5@11	#5@13	#4@9	MSR	MSR	#5@8	#5@9	#5@10					
	16	MSR	MSR	#5@10	#5@11	#4@8										
4.5″	13	MSR	MSR	#4@11	#4@13	#4@14	MSR	MSR	#4@8	#4@9	#4@10	MSR	MSR	#5@11	#5@12	#4@9
	14	MSR	MSR	#4@10	#4@11	#4@12	MSR	MSR	#4@7	#4@8	#4@9	MSR	MSR	#5@9	#5@11	#5@12
	15	MSR	MSR	#4@8	#4@9	#4@10	MSR	MSR	#5@10	#5@11	#4@8	MSR	MSR	#5@8	#5@9	#5@10
	16	MSR	MSR	#5@11	#5@12	#4@9	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@10	#6@11	#5@9
	17	MSR	MSR	#5@10	#5@11	#5@12										
5″	15	MSR	MSR	#4@9	#4@10	#4@11	MSR	MSR	#4@7	#4@8	#4@9	MSR	MSR	#5@9	#5@10	#5@12
	16	MSR	MSR	#5@12	#4@9	#4@10	MSR	MSR	#5@9	#4@7	#5@12	MSR	MSR	#5@8	#5@9	#5@10
	17	MSR	MSR	#5@11	#5@12	#4@9	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@10	#5@8	#5@9
	18	MSR	MSR	#5@10	#5@11	#5@12	MSR	MSR	#5@7	#5@8	#5@9					
	19	MSR	MSR	#5@8	#5@9	#5@11										
5.5″	14	MSR	MSR	#4@12	#4@13	#4@14	MSR	MSR	#4@9	#4@10	#4@11	MSR	MSR	#5@12	#5@12	#4@9
	15	MSR	MSR	#4@10	#4@11	#4@12	MSR	MSR	#4@8	#4@9	#4@9	MSR	MSR	#5@10	#5@11	#5@12
	16	MSR	MSR	#4@9	#4@10	#4@11	MSR	MSR	#4@7	#5@12	#5@8	MSR	MSR	#5@9	#5@10	#5@11
	17	MSR	MSR	#5@12	#4@8	#4@9	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#5@8	#5@9	#5@10
	18	MSR	MSR	#5@10	#5@12	#4@8	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@10	#5@8	#5@9
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	17	MSR	MSR	#4@8	#4@9	#4@10	MSR	MSR	#5@10	#5@11	#4@8	MSR	MSR	#5@9	#5@10	#5@11
	18	MSR	MSR	#5@11	#4@8	#4@9	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#6@11	#6@12	#5@9
	19	MSR	MSR	#5@10	#5@11	#4@8	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@10	#6@11	#6@12
	20	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#5@7	#5@8	#5@9	MSR	MSR	#6@8	#6@10	#6@11
	21	MSR	MSR	#5@8	#5@9	#5@10										
6.5″	17	MSR	MSR	#4@9	#4@10	#4@11	MSR	MSR	#4@7	#4@8	#4@8	MSR	MSR	#5@9	#5@10	#5@12
	18	MSR	MSR	#4@8	#4@9	#4@9	MSR	MSR	#5@9	#4@7	#5@12	MSR	MSR	#5@8	#5@9	#5@10
	19	MSR	MSR	#5@11	#4@8	#4@8	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@10	#5@8	#5@9
	20	MSR	MSR	#5@10	#5@11	#5@12	MSR	MSR	#6@11	#5@8	#5@9	MSR	MSR	#6@9	#6@10	#6@12
	21	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#6@10	#6@11	#6@12	MSR	MSR	#6@8	#6@9	#6@10
	22	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@9	#6@10	#6@11					
	23	MSR	MSR	#5@7	#5@8	#5@9										
7″	17	MSR	MSR	#4@9	#4@10	#4@11	MSR	MSR	#5@11	#4@8	#4@9	MSR	MSR	#5@10	#5@11	#5@12
	18	MSR	MSR	#5@13	#4@9	#4@10	MSR	MSR	#5@10	#5@11	#4@8	MSR	MSR	#5@9	#5@10	#5@11
	19	MSR	MSR	#5@11	#4@8	#4@9	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#5@8	#5@9	#5@10
	20	MSR	MSR	#5@10	#5@11	#4@8	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@10	#5@8	#5@9
	21	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#6@10	#5@8	#5@9	MSR	MSR	#6@9	#6@10	#5@8
	22	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@9	#6@10	#5@8					
	23	MSR	MSR	#5@7	#5@8	#5@9	MSR	MSR	#6@8	#6@9	#6@10					
	24	MSR	MSR	#6@10	#5@8	#5@8										
7.5″	19	MSR	MSR	#4@7	#4@8	#4@9	MSR	MSR	#5@9	#5@11	#5@12	MSR	MSR	#6@12	#5@9	#5@10
	20	MSR	MSR	#5@11	#5@12	#4@8	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@11	#6@12	#5@9
	21	MSR	MSR	#5@10	#5@11	#5@12	MSR	MSR	#5@8	#5@8	#5@9	MSR	MSR	#6@10	#6@11	#6@12
	22	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#6@10	#6@11	#6@12	MSR	MSR	#6@9	#6@10	#6@11
	23	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@9	#6@10	#6@11					
	24	MSR	MSR	#5@7	#5@8	#5@9										
	25	MSR	MSR	#6@9	#6@11	#5@8										
8″	21	MSR	MSR	#5@10	#4@7	#4@8	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@10	#5@8	#5@9
	22	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#6@10	#5@8	#5@9	MSR	MSR	#6@9	#6@10	#5@8
	23	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@9	#6@11	#6@12					
	24	MSR	MSR	#5@7	#5@8	#5@9	MSR	MSR	#6@9	#6@10	#6@11					
	25	MSR	MSR	#6@10	#5@8	#5@8										
	26	MSR	MSR	#6@9	#5@7	#5@8										

NOTE: See notes under Table 4 on page 22.

Engineering Tables For EPICORE MSR® 20 Gage Composite Deck

General Notes

All designs are based on the use of regular weight concrete (150 pcf), with a compressive strength of 4,000 psi. Reinforcing steel other than EPICORE MSR shall have a yield strength of 60,000 psi. Maximum allowable deflection under the total load (live + dead) is limited to L/360 in all cases. For lightweight and/or 3,000 psi concrete, consult Infinity Structures.

20 Gage

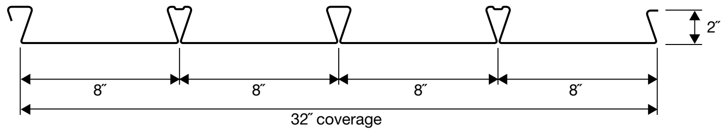


Table 6: Moment Coefficients

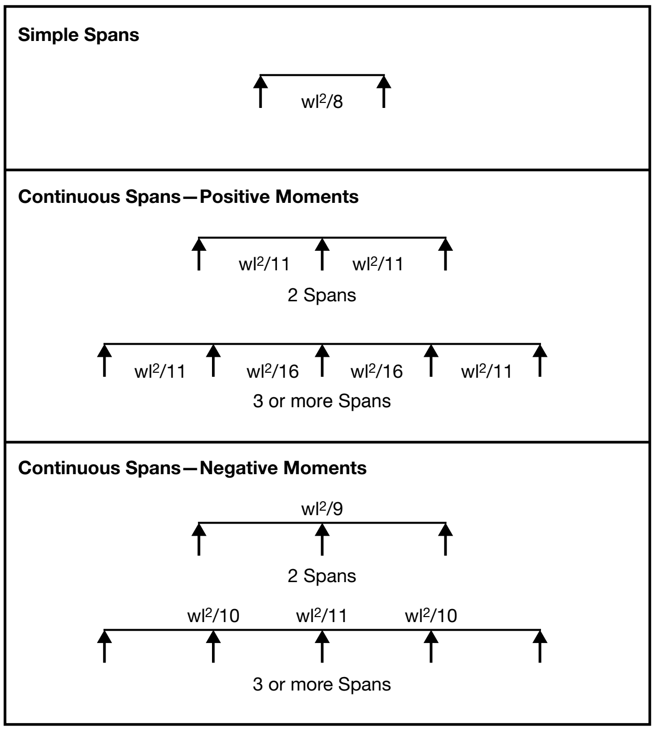


Table 7: EPICORE MSR Section Properties

Gage	20
Weight (psf)	2.5
A_s (in.²/ft.)	0.700
I_s (in.⁴/ft.)	0.330
$\bar{Y}$ (in.)	0.48
Yield (ksi)	45

NOTE: Section properties have been computed in accordance with the *A.I.S.I. Cold-Formed Steel Design Manual.*

Table 8: Shoring/Temperature Mesh Requirements

Slab Depth (in.)	Max Unshored Clear Span (ft.-in.) 20 Gage		Temperature Mesh Required
	Exposed Ceilings	Covered by Drywall	
4″	5-0	6-0	6x6-W2.1xW2.1
4.5″	5-0	6-0	6x6-W2.1xW2.1
5″	5-0	5-6	6x6-W2.1xW2.1
5.5″	4-6	5-6	6x6-W2.1xW2.1
6″	4-6	5-6	6x6-W2.1xW2.1
6.5″	4-6	5-0	6x6-W2.1xW2.1
7″	4-0	5-0	6x6-W2.9xW2.9
7.5″	4-0	5-0	6x6-W2.9xW2.9
8″	4-0	5-0	6x6-W2.9xW2.9

NOTE: The determination of the time for removal of supporting shores may be controlled by the presence of construction loads or deflection limitation. The removal of shores may have to occur after the concrete has reached its full compressive strength f´c, and modules Ec and stiffness, particularly in those instances where the construction loads may be as high as the specified live load. If shoring is removed too early, more significant deflection may occur and may even result in permanent damage. The strength and stiffness of the concrete during the various stages of construction should be substantiated by job-constructed and job-cured test specimens (cylinders). See ACI 318 Chapter 6 for more information.

Table 9: Maximum Spans For EPICORE MSR 20 Gage (ft-in) f´c = 4000 psi

Total Slab Depth (in.)	SIMPLE SPANS (ft.-in.)			CONTINUOUS SPANS (ft.-in.)					
	LL = 40 psf DL = 20 psf	LL = 80 psf DL = 5 psf	LL = 100 psf DL = 5 psf	LL = 40 psf DL = 20 psf		LL = 80 psf DL = 5 psf		LL = 100 psf DL = 5 psf	
				interior span	end span	interior span	end span	interior span	end span
4″	14-5	13-5	12-10	16-8	16-8	15-6	15-6	14-10	14-10
4.5″	15-9	14-9	14-1	18-2	18-2	17-0	17-0	16-3	16-3
5″	17-0	16-0	15-4	19-8	19-8	18-6	18-6	17-8	17-8
5.5″	18-3	17-2	16-6	21-1	21-1	19-10	19-10	19-1	19-1
6″	19-5	18-4	17-8	22-6	22-6	21-3	21-3	20-5	20-5
6.5″	20-7	19-6	18-9	23-10	23-10	22-7	22-7	21-9	21-9
7″	21-9	20-7	19-10	25-2	25-2	23-10	23-10	23-0	23-0
7.5″	22-10	21-9	20-9	26-5	26-5	25-1	25-1	24-3	24-3
8″	23-11	22-6	21-2	27-8	27-8	26-4	26-4	25-5	24-10

NOTES for Tables 9 and 10:

1. For simple spans:
   a) No reinforcing steel other than EPICORE MSR is required.
2. For continuous spans:
   a) Reinforcing steel is required over interior supports. See Table 10 for suggested rebar sizes. Table assumes 3⁄4″ concrete cover for reinforcing steel over supports.
   b) Spans should be approximately equal with the larger of the two adjacent spans not greater than the shorter by more than 20 percent. See ACI 318.
   c) Reinforcing over supports should extend a minimum of .3 x L on both sides of the supports. See Chapter 12 (ACI 318) Development and Splices of Reinforcement.
3. Temperature and shrinkage reinforcement, consisting of welded wire fabric, shall have a minimum area of .00075 times the area of concrete above the top flange of the deck but not be less than the area of 6x6-W2.1xW2.1. See Table 8.
4. All listed spans are assumed to be measured from center to center of the supports.

Table 10: Suggested Reinforcing Steel for Continuous Span 20 Gage EPICORE MSR Slabs with 4000 psi Concrete

Slab Depth (in.)	Slab Span (ft.)	Continuous Spans														
		LL = 40, DL = 20					LL = 80, DL = 5					LL = 100, DL = 5				
		Between Supports		Over Supports			Between Supports		Over Supports			Between Supports		Over Supports		
		$\frac{WL^2}{11}$	$\frac{WL^2}{16}$	$\frac{WL^2}{9}$	$\frac{WL^2}{10}$	$\frac{WL^2}{11}$	$\frac{WL^2}{11}$	$\frac{WL^2}{16}$	$\frac{WL^2}{9}$	$\frac{WL^2}{10}$	$\frac{WL^2}{11}$	$\frac{WL^2}{11}$	$\frac{WL^2}{16}$	$\frac{WL^2}{9}$	$\frac{WL^2}{10}$	$\frac{WL^2}{11}$
4″	13	MSR	MSR	#4@10	#4@11	#4@13	MSR	MSR	#5@11	#4@8	#4@9	MSR	MSR	#5@10	#5@11	#4@8
	14	MSR	MSR	#4@9	#4@10	#4@11	MSR	MSR	#5@10	#5@11	#5@12	MSR	MSR	#5@8	#5@9	#5@10
	15	MSR	MSR	#5@11	#5@13	#4@9	MSR	MSR	#5@8	#5@9	#5@10					
	16	MSR	MSR	#5@10	#5@11	#5@12										
4.5″	13	MSR	MSR	#4@11	#4@13	#4@14	MSR	MSR	#4@9	#4@10	#4@11	MSR	MSR	#4@7	#4@8	#4@9
	14	MSR	MSR	#4@10	#4@11	#4@12	MSR	MSR	#5@11	#4@8	#4@9	MSR	MSR	#5@9	#4@7	#4@8
	15	MSR	MSR	#4@8	#4@9	#4@10	MSR	MSR	#5@10	#5@11	#5@12	MSR	MSR	#5@8	#5@9	#5@10
	16	MSR	MSR	#5@11	#4@8	#4@9	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#5@7	#5@8	#5@9
	17	MSR	MSR	#5@10	#5@11	#4@8	MSR	MSR	#6@10	#6@12	#5@9					
5″	15	MSR	MSR	#4@9	#4@10	#4@11	MSR	MSR	#4@7	#4@8	#4@9	MSR	MSR	#5@9	#5@10	#5@12
	16	MSR	MSR	#4@8	#4@9	#4@10	MSR	MSR	#5@9	#5@11	#5@12	MSR	MSR	#5@8	#5@9	#5@10
	17	MSR	MSR	#5@11	#4@8	#4@9	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#5@7	#5@8	#5@9
	18	MSR	MSR	#5@10	#5@11	#4@8	MSR	MSR	#5@7	#5@8	#5@9					
	19	MSR	MSR	#5@8	#5@10	#5@11										
5.5″	14	MSR	MSR	#4@12	#4@13	#4@14	MSR	MSR	#4@9	#4@10	#4@11	MSR	MSR	#4@8	#4@9	#4@10
	15	MSR	MSR	#4@10	#4@11	#4@12	MSR	MSR	#4@8	#4@9	#4@10	MSR	MSR	#4@7	#4@7	#4@8
	16	MSR	MSR	#4@9	#4@10	#4@11	MSR	MSR	#5@10	#5@12	#4@8	MSR	MSR	#5@9	#5@10	#5@11
	17	MSR	MSR	#4@8	#4@8	#4@9	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#5@8	#5@9	#5@10
	18	MSR	MSR	#4@7	#5@12	#5@13	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#5@7	#5@8	#5@9
	19	MSR	MSR	#5@9	#5@10	#5@12	MSR	MSR	#6@10	#5@8	#5@9	MSR	MSR	#6@9	#5@7	#5@8
	20	MSR	MSR	#5@8	#5@9	#5@10										
6″	15	MSR	MSR	#4@11	#4@12	#4@13	MSR	MSR	#4@8	#4@9	#4@10	MSR	MSR	#4@7	#4@8	#4@9
	16	MSR	MSR	#4@9	#4@10	#4@12	MSR	MSR	#5@11	#4@8	#4@9	MSR	MSR	#5@10	#5@13	#4@8
	17	MSR	MSR	#4@8	#4@9	#4@10	MSR	MSR	#5@10	#5@11	#5@12	MSR	MSR	#5@9	#5@10	#5@11
	18	MSR	MSR	#5@11	#4@8	#4@9	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#5@7	#5@8	#5@9
	19	MSR	MSR	#5@10	#4@7	#4@8	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#5@7	#6@11	#5@8
	20	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#5@7	#5@8	#5@9	MSR	MSR	#6@8	#6@10	#6@11
	21	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@9	#5@7	#5@8					
	22	MSR	MSR	#5@7	#5@8	#5@9										
6.5″	17	MSR	MSR	#4@9	#4@10	#4@11	MSR	MSR	#4@7	#4@8	#4@8	MSR	MSR	#5@9	#5@10	#5@12
	18	MSR	MSR	#4@8	#4@9	#4@10	MSR	MSR	#5@9	#4@7	#5@12	MSR	MSR	#5@8	#5@9	#5@10
	19	MSR	MSR	#5@11	#4@8	#4@8	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#5@7	#6@12	#5@9
	20	MSR	MSR	#5@10	#5@11	#5@12	MSR	MSR	#6@11	#5@8	#5@9	MSR	MSR	#6@9	#6@10	#5@8
	21	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#6@10	#6@11	#5@8	MSR	MSR	#6@8	#6@9	#5@7
	22	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@9	#6@10	#6@11					
	23	MSR	MSR	#6@10	#5@8	#5@9										
7″	17	MSR	MSR	#4@9	#4@10	#4@11	MSR	MSR	#4@7	#4@8	#4@9	MSR	MSR	#5@10	#5@11	#5@12
	18	MSR	MSR	#4@8	#4@9	#4@10	MSR	MSR	#5@10	#5@11	#4@8	MSR	MSR	#5@9	#5@10	#5@11
	19	MSR	MSR	#5@11	#4@8	#4@9	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#5@8	#5@9	#5@10
	20	MSR	MSR	#5@10	#5@11	#4@8	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#5@7	#5@8	#5@9
	21	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#5@7	#5@8	#5@9	MSR	MSR	#5@6	#5@7	#5@8
	22	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@9	#6@10	#5@8	MSR	MSR	#6@8	#5@6	#5@7
	23	MSR	MSR	#6@11	#6@12	#5@9	MSR	MSR	#6@8	#6@9	#5@7	MSR	MSR	#6@7	#5@6	#5@6
	24	MSR	MSR	#6@10	#6@11	#6@12										
7.5″	20	MSR	MSR	#5@11	#4@8	#4@8	MSR	MSR	#5@8	#5@9	#4@7	MSR	MSR	#5@7	#5@8	#5@9
	21	MSR	MSR	#5@10	#4@7	#4@8	MSR	MSR	#5@8	#5@9	#5@9	MSR	MSR	#5@7	#5@7	#5@8
	22	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#5@7	#5@8	#5@9	MSR	MSR	#5@6	#5@7	#6@11
	23	MSR	MSR	#5@8	#5@9	#5@10	MSR	MSR	#6@9	#5@7	#5@8	MSR	MSR	#6@8	#6@9	#6@10
	24	MSR	MSR	#5@7	#5@8	#5@9	MSR	MSR	#6@8	#6@9	#6@10	MSR	MSR	#6@7	#6@8	#6@9
	25	MSR	MSR	#6@9	#6@11	#6@12	MSR	MSR	#6@7	#6@8	#6@9					
	26	MSR	MSR	#6@9	#6@10	#6@11										
8″	22	MSR	MSR	#5@9	#5@10	#5@11	MSR	MSR	#5@7	#5@8	#4@6	MSR	MSR	#6@9	#6@10	#6@11
	23	MSR	MSR	#6@12	#5@9	#5@10	MSR	MSR	#5@7	#5@7	#5@9	MSR	MSR	#6@8	#6@9	#6@10
	24	MSR	MSR	#6@11	#5@8	#5@9	MSR	MSR	#6@9	#5@7	#5@7	MSR	MSR	#6@8	#6@8	#6@9
	25	MSR	MSR	#6@10	#5@8	#6@12	MSR	MSR	#6@8	#6@9	#5@7		MSR	#6@7	#6@8	#6@9
	26	MSR	MSR	#6@9	#6@10	#6@11	MSR	MSR	#6@7	#6@8	#6@9					
	27	MSR	MSR	#6@8	#6@9	#6@10										

NOTE: See notes under Table 9 on page 24.

EPICORE MSR® Engineering Tables

Table 11: Cantilevered Slabs, (Balconies and Corridors)

Slab Depth† (in.)	Span (ft.)	Reinforcing Steel Required Over Supports	
		80 psf Live Load*	100 psf Live Load**
4.5″	6	#4@9	#4@7
	5	#4@12	#4@10
	4	#4@12	#4@12
5″	7	#4@7	#4@6
	6	#4@9	#4@8
	5	#4@14	#4@12
	4	#4@15	#4@15
5.5″	7	#5@12	#5@10
	6	#5@16	#4@9
	5	#4@16	#4@12
	4	#4@16	#4@16
6″	8	#4@6	#6@12
	7	#4@8	#6@16
	6	#5@16	#4@10
	5	#4@16	#4@15
6.5″	9	#5@8	#5@7
	8	#6@15	#5@9
	7	#4@9	#4@8
	6	#4@12	#5@16
	5	#4@18	#4@16
7″	9	#6@12	#5@7
	8	#6@16	#6@14
	7	#5@15	#6@18
	6	#4@12	#5@16
	5	#4@18	#4@16
7.5″	10	#5@7	#6@9
	9	#4@6	#5@8
	8	#6@16	#5@10
	7	#4@10	#4@9
	6	#4@14	#4@12
	5	#4@18	#4@18

* 85 psf superimposed
** 105 psf superimposed
† at point of maximum moment

NOTE:
1. Cantilevered slabs shall be formed with ribs of EPICORE MSR parallel to span.
2. See Detail 10 on page 28 for general construction of cantilevered slabs.
3. Table assumes f′c = 4000 psi.
4. Table assumes ¾″ concrete cover for reinforcing steel over supports.
5. All listed spans are assumed to be measured from the center of the supports to the end of the cantilever.

Cantilevered Formed-in-place Balcony

Table 12: Continuous Span Slab Beams

Slab Beam Depth (in.)	Tributary Slab Span (ft.)	Slab Beam Span (ft.-in.)	Reinforcing Steel Required				
			Between Supports		Over Supports		
			$+\frac{WL^2}{11}$	$+\frac{WL^2}{16}$	$-\frac{WL^2}{9}$	$-\frac{WL^2}{10}$	$-\frac{WL^2}{11}$
5″	18	10-6	6-#6	5-#5	•	•	8-#6
		10-0	7-#5	7-#4	•	8-#6	8-#5
		9-0	6-#5	7-#4	8-#5	7-#5	7-#5
	16	11-0	5-#6	5-#5	•	•	6-#6
		10-0	4-#6	6-#4	8-#6	8-#5	7-#5
		9-0	5-#5	5-#4	7-#5	6-#5	4-#6
	14	12-0	8-#5	5-#5	•	•	8-#6
		11-0	7-#5	4-#5	•	6-#6	8-#5
		10-0	5-#5	6-#4	8-#5	7-#5	6-#5
5.5″	18	11-6	8-#5	6-#5	•	•	8-#6
		11-0	8-#5	5-#5	•	8-#6	9-#5
		10-0	6-#5	4-#5	9-#5	8-#5	7-#5
	16	12-6	6-#6	4-#6	•	•	8-#6
		12-0	8-#5	8-#4	•	8-#6	7-#6
		11-0	7-#5	7-#4	8-#6	6-#6	8-#5
	14	13-6	9-#5	4-#6	•	•	8-#6
		13-0	6-#6	4-#6	•	•	8-#6
		12-0	7-#5	5-#5	8-#6	9-#5	8-#5
6″	18	13-0	7-#6	7-#5	•	•	8-#6
		12-0	6-#6	6-#5	•	8-#6	7-#6
		11-0	7-#5	5-#5	7-#6	6-#6	8-#5
	16	13-6	7-#6	5-#6	•	•	8-#6
		13-0	6-#6	4-#6	•	8-#6	7-#6
		12-0	5-#6	5-#5	11-#5	7-#6	6-#6
	14	14-6	7-#6	7-#5	•	•	8-#6
		14-0	9-#5	4-#6	•	8-#6	11-#5
		13-0	8-#5	5-#5	8-#6	7-#6	6-#6
6.5″	20	12-6	7-#6	10-#4	•	•	12-#5
		12-0	6-#6	4-#6	•	12-#5	11-#5
		11-0	7-#5	5-#5	8-#6	7-#6	6-#6
	18	13-6	7-#6	7-#5	•	•	10-#6
		13-0	7-#6	6-#5	•	•	8-#6
		12-0	8-#5	5-#5	12-#5	11-#5	10-#5
	16	14-0	7-#6	7-#5	•	•	12-#5
		13-0	8-#5	4-#6	10-#6	8-#6	7-#6
		12-0	7-#5	7-#4	11-#5	9-#5	6-#6
7″	20	13-6	8-#6	7-#5	•	•	10-#6
		13-0	7-#6	7-#5	•	10-#6	12-#5
		12-0	8-#5	9-#4	9-#6	11-#5	10-#5
	18	14-6	11-#5	5-#6	•	•	10-#6
		14-0	7-#6	7-#5	•	10-#6	9-#6
		13-0	6-#6	4-#6	10-#6	8-#6	11-#5
	16	15-6	8-#6	8-#5	•	•	10-#6
		15-0	11-#5	7-#5	•	•	10-#6
		14-0	10-#5	6-#5	10-#6	12-#5	11-#5

• Concrete overstressed

NOTE:
1. Design of slab beam is based on superimposed load of 40 psf LL + 20 psf DL + slab weight and width of 3′-10″.
2. Spans should be approximately equal with the larger of the two adjacent spans not greater than the shorter by more than 20 percent. See ACI 318.
3. Tributary slab spans must be continuous. See Table 5 on page 23, and Table 10 on page 25.
4. Reinforcing over supports should extend a minimum of .3 x L on both sides of the supports. See Chapter 12 (ACI 318) Development and Splices of Reinforcement.
5. See Details 12 and 13 on page 29 for general construction of slab beam system.
6. All reinforcing is to be equally spaced along the 3′-10″ width.
7. Table assumes f′c = 4000 psi.
8. All listed spans are assumed to be measured from center to center of the supports.

Table 13: Simple Span Slab Beams

Slab Depth (in.)	Epicore MSR Slab Span (ft.)	Slab Beam Span (ft.)	Reinforcing Steel Required Over Supports	
			LL = 40 psf DL = 20 psf	LL = 100 psf DL = 5 psf
5″	12	5	4-#4	4-#4
		6	4-#4	5-#4
		7	4-#4	6-#4
		8	5-#4	7-#5
	14	5	4-#4	4-#4
		6	4-#4	5-#4
		7	5-#4	7-#4
		8	6-#4	8-#6
	16	5	4-#4	4-#4
		6	4-#4	6-#4
		7	6-#4	9-#4
		8	7-#5	•
	18	5	4-#4	5-#4
		6	5-#4	7-#4
		7	6-#4	8-#5
		8	9-#5	•
5.5″	14	5	4-#4	4#-4
		6	4-#4	5-#4
		7	5-#4	6-#4
		8	6-#4	9-#4
	16	5	4-#4	4-#4
		6	4-#4	5-#4
		7	5-#4	7-#4
		8	7-#4	9-#5
	18	5	4-#4	4-#4
		6	4-#4	6-#4
		7	6-#4	8-#4
		8	8-#4	8-#6
	20	5	4-#4	5-#4
		6	5-#4	7-#4
		7	6-#4	7-#5
		8	7-#5	•
6″	16	5	4-#4	4-#4
		6	4-#4	5-#4
		7	5-#4	7-#4
		8	6-#4	9-#4
	18	5	4-#4	4-#4
		6	4-#4	6-#4
		7	5-#4	8-#4
		8	7-#4	7-#5
	20	5	4-#4	4-#4
		6	4-#4	4-#4
		7	6-#4	8-#4
		8	8-#4	9-#5
	22	5	4-#4	5-#4
		6	5-#4	7-#4
		7	7-#4	9-#4
		8	6-#5	•
6.5″	16	6	4-#4	5-#4
		7	5-#4	6-#4
		8	6-#4	8-#4
		9	7-#4	8-#5
	18	6	4-#4	5-#4
		7	5-#4	7-#4
		8	7-#4	9-#4
		9	8-#4	10-#5
	20	6	4-#4	6-#4
		7	6-#4	8-#4
		8	7-#4	7-#5
		9	7-#5	•
	22	6	5-#4	6-#4
		7	6-#4	9-#4
		8	8-#4	8-#5
		9	9-#5	•

Table 13: Simple Span Slab Beams (continued)

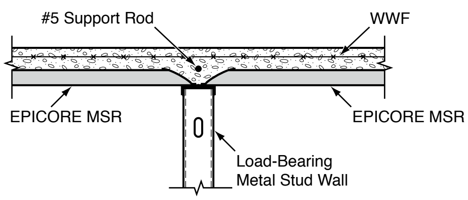
Slab Depth (in.)	Epicore MSR Slab Span (ft.)	Slab Beam Span (ft.)	Reinforcing Steel Required Over Supports	
			LL = 40 psf DL = 20 psf	LL = 100 psf DL = 5 psf
7″	18	6	4-#4	5-#4
		7	5-#4	7-#4
		8	6-#4	9-#4
		9	8-#4	7-#5
	20	6	4-#4	6-#4
		7	5-#4	7-#4
		8	7-#4	6-#5
		9	9-#4	9-#5
	22	6	4-#4	6-#4
		7	6-#4	8-#4
		8	8-#4	7-#5
		9	6-#5	•
	24	6	5-#4	7-#4
		7	6-#4	9-#4
		8	8-#4	•
		9	8-#5	•
7.5″	20	7	5-#4	7-#4
		8	7-#4	9-#4
		9	8-#4	8-#5
		10	7-#5	•
	22	7	6-#4	8-#4
		8	7-#4	7-#5
		9	9-#4	8-#5
		10	9-#5	•
	24	6	5-#4	6-#4
		7	6-#4	8-#4
		8	8-#4	7-#5
		9	7-#5	•
	26	6	5-#4	7-#4
		7	7-#4	9-#4
		8	9-#4	•
		9	7-#5	•
8″	20	8	6-#4	9-#4
		9	8-#4	7-#5
		10	7-#5	7-#6
		11	7-#6	•
	22	8	7-#4	6-#5
		9	9-#4	8-#5
		10	7-#5	•
		11	9-#6	•
	24	7	6-#4	8-#4
		8	8-#4	7-#5
		9	6-#5	•
		10	9-#5	•
	26	7	6-#4	9-#4
		8	8-#4	7-#5
		9	7-#5	•
		10	7-#6	•

• Concrete overstressed

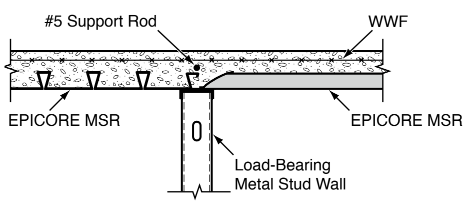
NOTE:
1. Epicore MSR Slab Span must be checked against Epicore MSR catalog to ensure that Epicore MSR slab is sufficient.
2. Epicore MSR Slab Span must be designed with negative moment resisting steel placed in the top portion of the slab and running through the Slab Beam.
3. Epicore MSR Slab Span is measured from center of support to center of slab beam (or from center of slab beam to center of slab beam if Epicore MSR slab is continuous).
4. Table assumes the use of Normal Weight Concrete (approx. 150 pcf) and f′c = 4000 psi.
5. Slab Beam width is 3′-10″. Reinforcing steel is to be equally spaced along the 3′-10″ width.
6. Placement and coverage of reinforcing steel shall be in accordance with the recommendations of the latest edition of ACI-318.
7. Vertical shear is based on uniformly end-supported slab beams. If columns and plates are used to support slab beams, punching shear must be checked and the columns and plates must be sized accordingly.

Typical Details*

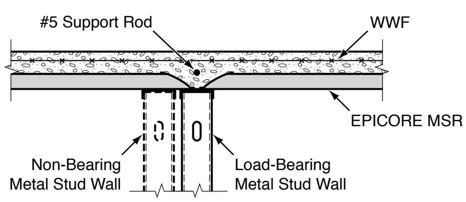
1. Interior Bearing Wall



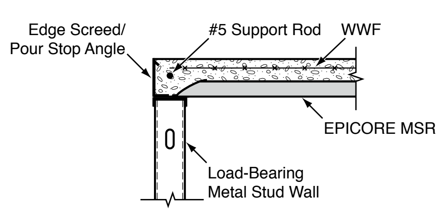
2. Interior Bearing Wall



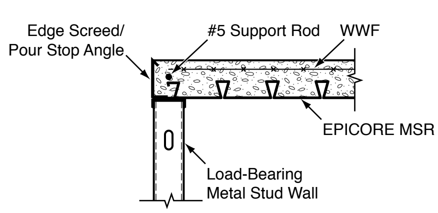
3. Double "Demising" Wall



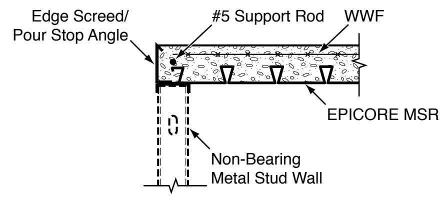
4. End Bearing Wall



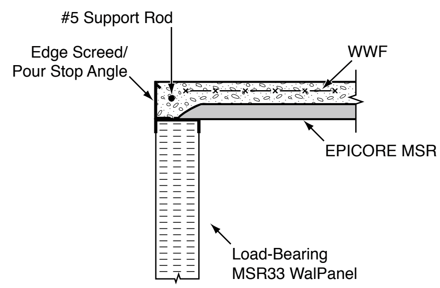
5. End Bearing Wall



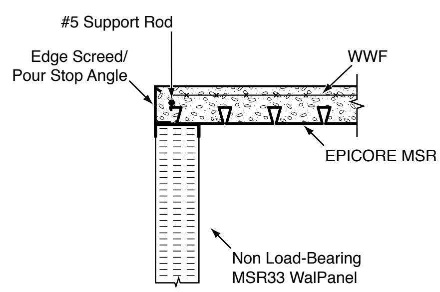
6. End Non-Bearing Wall



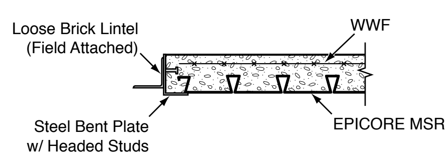
7. Exterior MSR33 WalPanel



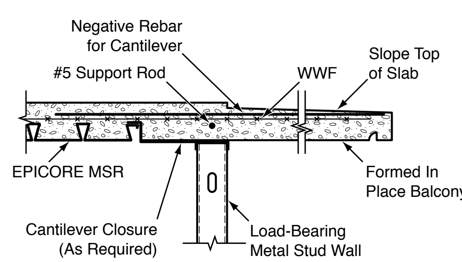
8. Exterior MSR33 WalPanel



9. Brick Relief

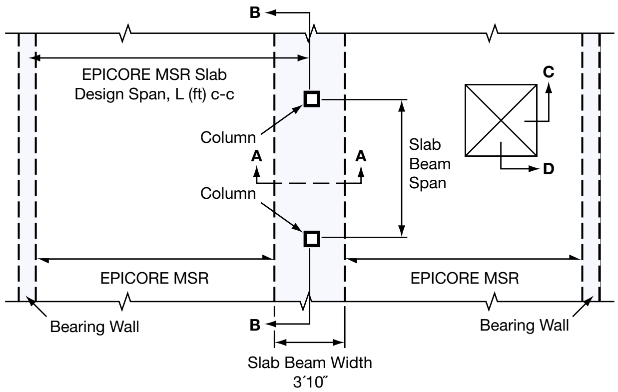


10. Cantilevered Balcony

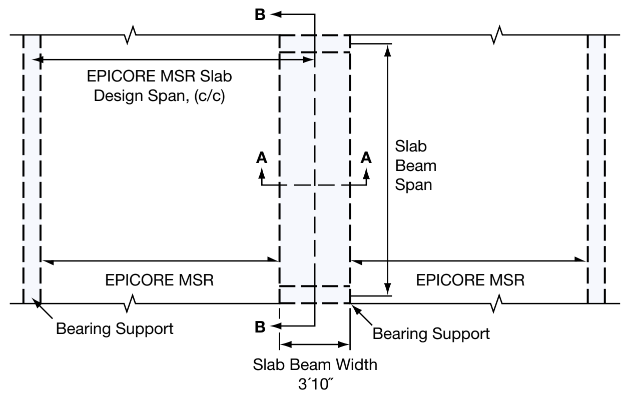


*Details shown are based on simple span design. For Continuous Span Design, negative reinforcing shall be added over bearing (See Table 5 & 10, pages 23 and 25).

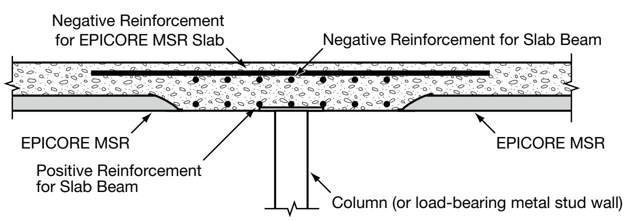
11. Continuous Span Slab-Beam



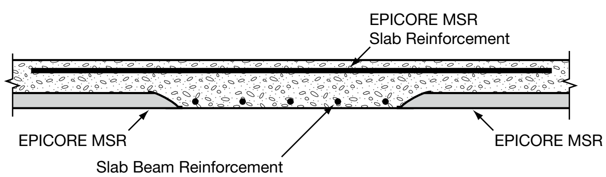
16. Simple Span Slab-Beam



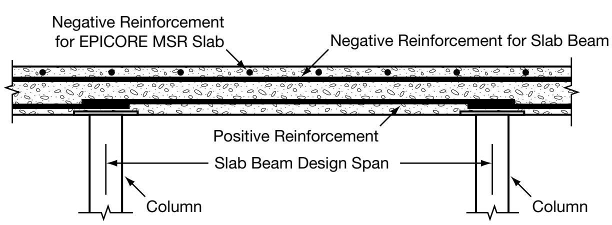
12. Continuous Slab Beam: Section A-A



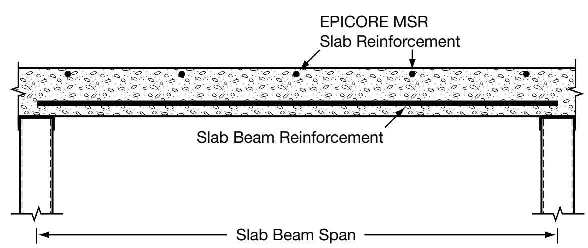
17. Simple Slab Beam: Section A-A



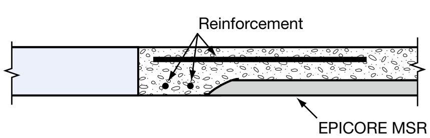
13. Continuous Slab Beam: Section B-B



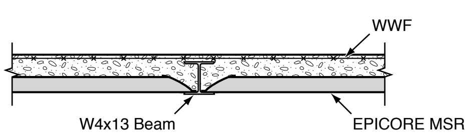
18. Simple Slab Beam: Section B-B



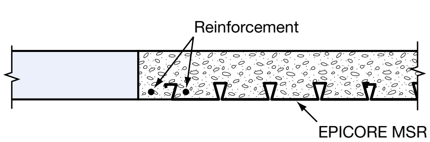
14. Opening Perpendicular to Deck Span: Section C



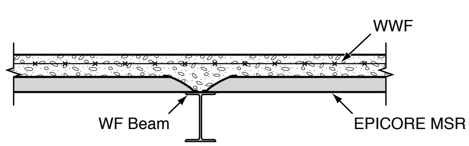
19. Embedded W4x13 Beam



15. Opening Parallel to Deck Span: Section D



20. Steel Beam



NOTE:
Temperature and shrinkage reinforcement is required for all EPICORE MSR Slabs.
See tables 3 and 8, pages 22 and 24.

Appendix K

Cold Formed Steel Framing System

QUALITY AND SERVICE COUNT

Marino\WARE® is proud to present this catalog that details our Lightweight Steel Framing Products. For over 70 years, Marino\WARE has been providing their customers with top quality steel products.

Marino\WARE is committed to customer satisfaction. This starts with quality. Marino\WARE products are manufactured from quality steel and precision formed to meet or exceed industry standards established by the ASTM, SSMA and the AISI.

Marino\WARE prides itself on providing the fastest delivery and finest service in the steel framing industry. Most steel framing manufacturers speak of lead times and deliveries in terms of weeks. Marino\WARE with its own fleet of trucks, 3 shift operation, latest technology in roll forming capabilities and commitment to service excellence, in most cases provides next day delivery. Marino\WARE stands prepared to exceed your expectations. Steel framing products, competitive prices, excellent service along with timely deliveries and technical assistance are available to you.

TECHNICAL SERVICES

Marino\WARE's Technical Services personnel are available to assist their clients in all aspects of Cold-Formed Steel Design. This includes answering technical calls regarding products and installation applications as well as providing accurate certified shop drawings.

For Technical Services, please call 866-545-1545.

SSMA CODE COMPLIANCE CERTIFICATION PROGRAM

SSMA CERTIFIED
STEEL FRAMING PRODUCT

Sponsored by: **Steel Stud Manufacturers Association**

SSMA developed its Code Compliance Certification Program as a means for member manufacturers to certify that structural stud and track cold-formed steel framing they produce complies with IBC 2006 code requirements.

Structural cold-formed steel framing certification is independently validated by Architectural Testing. The validation process includes a minimum of two unannounced manufacturing facility audits per year, as well as on-going random selection and independent testing of certified cold-formed steel framing products.

Manufacturing facilities that satisfy the requirements for certification are authorized to certify structural cold- formed steel framing members that they produce as permitted by the Program Requirements. For a complete and current list of manufacturers with certification authorization please visit the SSMA website at **www.ssma.com/certification.aspx.**

Look for the label. The SSMA Certification Label, prominently displayed on units (skids or bundles), or optionally on each framing member, certifies that the material meets or exceeds Code requirements.

BENEFITS OF COLD-FORMED STEEL FRAMING PRODUCTS

Cold-formed steel framing is a versatile structural product for use in load bearing and curtainwall construction. The popularity of corrosion resistant galvanized steel framing can be attributed to these benefits:

High Strength to Weight Ratio
In curtainwall applications, the reduced dead load may result in primary frame and foundation material savings. Exterior retrofits are less likely to require expensive reinforcement of the existing structure. In load bearing construction, a light weight steel framing system is a benefit when the site is plagued by poor soil conditions. Multi-story residences requiring unique ground level construction (parking structure, meeting or dining facilities, etc.) benefit from the reduced dead weight applied to the supporting structure.

Non-combustible Construction
The use of steel framing, protected with fire resistive materials, offers the designer numerous rated non-combustible assemblies. As an alternate to conventional wood framing, increases in floor areas and/or building heights may be attained. Non-combustible ratings may also yield long term insurance savings.

Design Versatility
Curtainwalls in various finishes and profiles are attainable. Whether used as floor joists and roof rafters or in mansard and truss framing works well independently or in combination with other structural systems. Steel framing is adaptable to numerous applications traditionally constructed with hot rolled structural steel or masonry.

Low in place and Performance Costs
Steel framing systems are conducive to prefabrication at or away from the job site. Quality is improved due to the controlled work atmosphere while its efficiency of construction may result in earlier building enclosure and ultimate occupancy.

WARRANTY & LIMITATIONS

All products presented herein are warranted to the buyer to be free from defects in material and workmanship.

The foregoing warranty is non-assignable and in lieu of and excludes all other warranties not expressly set forth herein, whether express or implied by operation of law or otherwise, including but not limited to any implied warranties of merchantability or fitness for a particular purpose. All details and specifications presented herein are intended as a general guide for the use of Marino\WARE framing systems. These products should not be used without evaluation by a qualified engineer or architect to determine their suitability for a specific use. Marino\WARE assumes no responsibility for failure resulting from use of its details or specifications, or for failure resulting from improper application or installation of these products.

GOVERNING LAW

All issues arising in connection with your order and all transactions associated with it shall be interpreted according to the laws of the State of New Jersey, and all actions or other proceedings arising out of such issues shall be brought only in Superior Court, State of New Jersey, County of Essex, or United States District Court for the District of New Jersey. No action may be brought more than one year after accrual of the cause of action therefore.

GENERAL INFORMATION

Steel Thickness:

Product		Design		Minimum		ASTM C955
Gauge	Mils	(in.)	(mm.)	(in.)	(mm.)	Color Code
20	33	.0346	0.879	.0329	0.838	White
18	43	.0451	1.1565	.0428	1.087	Yellow
16	54	.0566	1.4376	.0538	1.367	Green
14	68	.0713	1.8110	.0677	1.720	Orange
12	97	.1017	2.5832	.0966	2.454	Red
10	118	.1242	3.1547	.1180	3.000	Blue

Finish:

Galvanized in accordance with ASTM C-955. Products will be furnished with a G60 coating. G90 available upon request.

Grades of Steel:

20 and 18 gauge stud and track
Fy (min) = 33 KSI

16 gauge studs and joists
Fy (min) = 33 KSI (Applies to stud & track only. All 16ga. joists are 50 ksi)
Fy (min) = 50 KSI must be requested when ordering 16ga. stud & track

14, 12 and 10 gauge stud, track, and joists
Fy (min) = 50 KSI

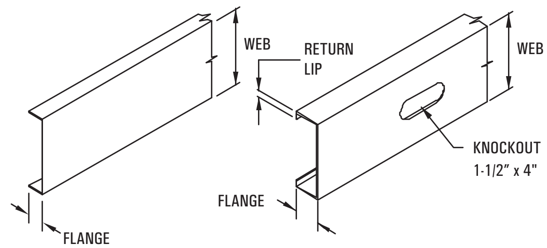
TABLE OF CONTENTS

FRAMING COMPONENTS

STUD & JOISTS (CW, SW, J, JE, JX & JXW): Studs serve as a general all purpose framing component used in a variety of applications including exterior curtainwalls, load bearing walls, headers, floor & roof joists, soffits and truss frame components.

TRACK (T & DT): Track is used as a closure to stud and joist ends as well as head and sill conditions. It is also used for blocking and bridging conditions.

KNOCKOUT SIZE & LOCATION: Knockouts are provided 12" from the indexed end and intermediate knockouts are placed at 24" o.c. intervals. Unpunched studs are available upon request.



C-STUDS (CW, SW, J, JE, JX & JXW)

M\W	GAUGES	FLANGE	WEB	RETURN LIP
CW	20 – 14	1-3/8"	2-1/2" – 8"	3/8"
SW	20 – 10	1-5/8"	2-1/2" – 16"	1/2"
J	20 – 10	2"	2-1/2" – 16"	5/8"
JE•	18 – 10	2-1/2"	3-5/8" – 16"	5/8"
JX•	16 – 10	3"	3-5/8" – 16"	1"
JXW•	16 – 10	3-1/2"	3-5/8" – 16"	1"

TRACK (T & DT)

M\W	GAUGES	FLANGE	WEB
T	20 – 10	1-1/4"	2-1/2" – 16"
DT	20 – 10	2" MIN.	2-1/2" – 16"

Notes:
1. Products shown with • symbol will be available subject to minimum order quantities.
2. 10'-0" standard length for track. Custom orders are available.

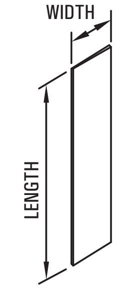
FLAT STRAP

Tension component of shear wall assembies. Component of strap & blocking for bridging applications. (See page 25 for more details.)

LENGTH: Available as required by purchaser.

WIDTH: See page 13 for standard sizes

GAUGE: 20, 18, 16, 14, 12, & 10 gauges available.



WEB STIFFENER (JS)

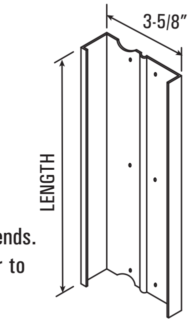
Web Stiffeners are used to provide reinforcement of joist webs to prevent crippling. Web reinforcement is often required by design to enhance the load capacity of joists.

LENGTH: 8", 9-1/4", 10", 11-1/4", 12", 14" (inside or outside)

WIDTH: 3-5/8"

INSTALLATION:

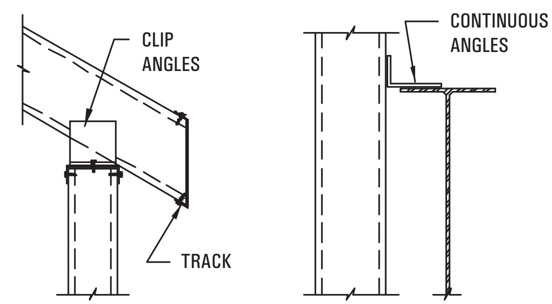
- Centered within the load or reaction bearing width.
- Installed on the inside or outside of the joist.
- Web stiffeners require full bearing along their supported ends.
- (4-6) #10 - 16 screws are required to attach the stiffener to the joist web using pre-punched holes.



BRAKE FORMED ACCESSORIES

For miscellaneous closures, continuous angles, etc.

LENGTH: 12'-0" maximum.
Dimensioned product drawing must accompany order



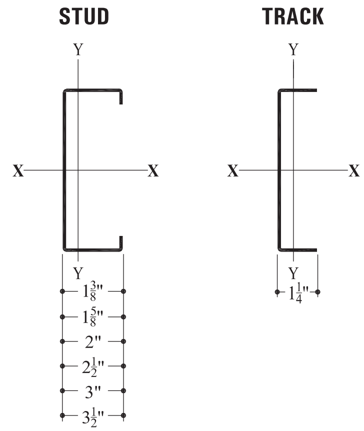
STRUCTURAL PROPERTIES

MARINO WARE®

SSMA CERTIFIED — CERTIFIED CODE COMPLIANT — STEEL FRAMING PRODUCT
Sponsored by: Steel Stud Manufacturers Association

SYMBOLS AND DEFINITIONS:

A	Gross cross sectional area of the member.
Ix,Iy	Moment of Inertia of the gross section about the principal axis.
Ix_e	Moment of Inertia of the effective section stressed at yield about the principal axis.
Rx,Ry	Radius of gyration of the gross section.
Sx	Section Modulus of the gross section.
Sx_e	Section Modulus of the effective section stressed at yield about the principal axis.
Ma	Allowable bending moment with contribution due to coldworking where applicable
Va	Allowable shear force at punched sections
Cw	Torsional warping constant of the cross section
J	St. Venant torsion constant
Ro	Polar radius of gyration of the cross section about the shear center
Beta	$1-(Xo/Ro)^2$
Xo	Distance from shear center to centroid along the principal axis.



NOTES:

1. *Section properties are based on the North American Specification for the Design of Cold Formed Steel Structural Members, 2001 edition.*
2. *Gross and torsional properties were based on the unreduced cross section of the shape.*
3. *Sx_e was based on the effective section stressed at yield. For further information consult AISI Section B2.*
4. *All products annotated by "*" exceed the h/t ratio of 200 and require a web stiffener at support and concentrated load locations.*
5. *Allowable bending moment, Ma was calculated according to AISI Section C3.1.1, Procedure 1, based on the initiation of yielding in the effective section.*
6. *Refer to page 3 for physical dimensions of sections.*
7. *Weights shown are based on the uncoated base metal design thickness.*
8. *Designer should check the Product Availability Matrix on page 3.*
9. *Allowable shear, Va was calculated in accordance with Section C3.2.2 at punched section.*

Physical and Structural Properties

Member Physical Properties						Gross Section Properties						Effective Section Properties								Torsional Properties				
												33ksi				50 ksi								
M\W Type	SSMA	Flange/ Leg (in.)	Lip (in.)	Design Thickness (in.)	Weight (p lf.)	Area (in.^{2})	Ix (in.^{4})	Sx (in.^{3})	Rx (in.)	Iy (in.^{4})	Ry (in.)	Ix_e (in.^{4})	Sx_e (in.^{3})	Ma (k-in)	Va (k)	Ix_e (in.^{4})	Sx_e (in.^{3})	Ma (k-in)	Va (k)	J x1000 (in.^{4})	Cw (in.^{6})	Xo (in.)	Ro (in.)	ß Beta
2-1/2" Members																								
212CW20	250S137-33	1 3/8"	3/8"	0.0346	0.671	0.197	0.203	0.163	1.015	0.052	0.515	0.195	0.144	3.123	0.203	0.195	0.129	3.874	0.262	0.079	0.075	-1.170	1.633	0.486
212CW18	250S137-43	1 3/8"	3/8"	0.0451	0.869	0.255	0.261	0.209	1.011	0.067	0.511	0.249	0.195	4.306	0.199	0.249	0.186	5.555	0.302	0.173	0.094	-1.158	1.620	0.489
212CW16	250S137-54	1 3/8"	3/8"	0.0566	1.075	0.316	0.318	0.255	1.004	0.080	0.504	0.304	0.243	5.487	0.182	0.304	0.231	7.766	0.276	0.337	0.113	-1.150	1.608	0.488
212CW14	250S137-68	1 3/8"	3/8"	0.0713	1.327	0.390	0.386	0.309	0.995	0.096	0.495	0.369	0.294	6.848	0.182	0.369	0.293	10.133	0.182	0.661	0.134	-1.141	1.593	0.48 7
212SW20	250S162-33	1 5/8"	1/2"	0.0346	0.760	0.223	0.235	0.188	1.027	0.087	0.624	0.227	0.172	3.391	0.203	0.227	0.153	4.586	0.262	0.089	0.144	-1.501	1.923	0.391
212SW18	250S162-43	1 5/8"	1/2"	0.0451	0.984	0.289	0.302	0.242	1.022	0.111	0.620	0.291	0.231	5.012	0.199	0.291	0.205	6.129	0.302	0.196	0.182	-1.489	1.909	0.392
212SW16	250S162-54	1 5/8"	1/2"	0.0566	1.219	0.358	0.370	0.296	1.016	0.135	0.614	0.356	0.284	6.301	0.182	0.356	0.271	8.969	0.276	0.383	0.219	-1.482	1.898	0.391
212SW14	250S162-68	1 5/8"	1/2"	0.0713	1.509	0.444	0.450	0.360	1.008	0.162	0.605	0.433	0.345	7.870	0.182	0.433	0.342	11.588	0.182	0.752	0.262	-1.474	1.885	0.38 9
212T20	250T125-33	1 1/4"	none	0.0346	0.588	0.173	0.192	0.145	1.054	0.027	0.397	0.166	0.103	2.033	1.024	0.157	0.096	2.875	1.260	0.069	0.033	-0.771	1.365	0.681
212T18	250T125-43	1 1/4"	none	0.0451	0.766	0.225	0.250	0.188	1.055	0.035	0.395	0.231	0.147	2.909	1.356	0.220	0.137	4.090	2.054	0.153	0.042	-0.766	1.362	0.684
212T16	250T125-54	1 1/4"	none	0.0566	0.961	0.282	0.318	0.236	1.062	0.044	0.392	0.310	0.203	4.013	1.692	0.297	0.188	5.640	2.563	0.301	0.054	-0.763	1.365	0.688
212T14	250T125-68	1 1/4"	none	0.0713	1.209	0.355	0.409	0.297	1.072	0.054	0.389	0.409	0.281	5.556	2.112	0.403	0.262	7.847	3.199	0.602	0.068	-0.758	1.370	0.694
3-5/8" Members																								
358CW20	362S137-33	1 3/8"	3/8"	0.0346	0.804	0.236	0.479	0.264	1.424	0.059	0.501	0.466	0.233	4.603	0.521	0.464	0.198	5.937	0.552	0.094	0.162	-1.026	1.826	0.684
358CW18	362S137-43	1 3/8"	3/8"	0.0451	1.041	0.306	0.616	0.340	1.419	0.076	0.497	0.605	0.321	6.346	0.676	0.602	0.293	8.760	0.832	0.207	0.204	-1.015	1.814	0.687
358CW16	362S137-54	1 3/8"	3/8"	0.0566	1.291	0.379	0.756	0.417	1.412	0.091	0.490	0.747	0.404	7.978	0.705	0.745	0.383	11.467	1.016	0.405	0.246	-1.006	1.801	0.68 8
358CW14	362S137-68	1 3/8"	3/8"	0.0713	1.600	0.470	0.923	0.509	1.401	0.109	0.481	0.913	0.500	11.656	0.662	0.913	0.496	14.845	1.004	0.797	0.294	-0.996	1.785	0.6 89
358SW20	362S162-33	1 5/8"	1/2"	0.0346	0.892	0.262	0.551	0.304	1.450	0.099	0.616	0.539	0.269	5.305	0.521	0.535	0.235	7.047	0.552	0.105	0.293	-1.334	2.065	0.582
358SW18	362S162-43	1 5/8"	1/2"	0.0451	1.156	0.340	0.710	0.392	1.446	0.127	0.611	0.699	0.373	7.365	0.676	0.696	0.322	9.651	0.832	0.230	0.371	-1.323	2.052	0.585
358SW16	362S162-54	1 5/8"	1/2"	0.0566	1.436	0.422	0.873	0.482	1.438	0.154	0.605	0.864	0.468	9.251	0.705	0.862	0.445	13.325	1.016	0.451	0.449	-1.314	2.040	0.58 5
358SW14	362S162-68	1 5/8"	1/2"	0.0713	1.782	0.524	1.069	0.590	1.429	0.186	0.596	1.060	0.581	13.244	0.662	1.060	0.577	17.259	1.004	0.887	0.540	-1.305	2.024	0.5 85
358SW12	362S162-97	1 5/8"	1/2"	0.1017	2.464	0.724	1.435	0.792	1.408	0.241	0.577	1.427	0.781	18.736	0.577	1.427	0.781	27.696	0.875	2.496	0.699	-1.285	1.992	0.5 84
358SW10	362S162-118	1 5/8"	1/2"	0.1242	2.995	0.880	1.701	0.939	1.390	0.277	0.561	1.694	0.925	23.094	0.511	1.694	0.925	33.986	0.774	4.732	0.803	-1.270	1.965	0.582
358J20	362S200-33	2"	5/8"	0.0346	1.010	0.297	0.648	0.358	1.478	0.177	0.772	0.633	0.293	5.785	0.521	0.607	0.260	7.771	0.552	0.118	0.571	-1.770	2.432	0.470
358J18	362S200-43	2"	5/8"	0.0451	1.310	0.385	0.836	0.461	1.474	0.227	0.767	0.825	0.428	8.453	0.676	0.822	0.377	11.278	0.832	0.261	0.726	-1.758	2.419	0.472
358J16	362S200-54	2"	5/8"	0.0566	1.628	0.479	1.030	0.568	1.467	0.277	0.761	1.021	0.555	10.964	0.705	1.020	0.491	14.699	1.016	0.511	0.884	-1.750	2.407	0.472
358J14	362S200-68	2"	5/8"	0.0713	2.025	0.595	1.266	0.698	1.459	0.337	0.753	1.256	0.690	15.347	0.662	1.256	0.669	20.021	1.004	1.008	1.070	-1.741	2.393	0.471
358J12	362S200-97	2"	5/8"	0.1017	2.810	0.826	1.712	0.945	1.440	0.446	0.735	1.703	0.933	21.698	0.577	1.703	0.933	32.195	0.875	2.847	1.404	-1.724	2.363	0.468
358J10	362S200-118	2"	5/8"	0.1242	3.427	1.007	2.042	1.127	1.424	0.522	0.720	2.035	1.114	26.783	0.511	2.035	1.114	39.581	0.774	5.415	1.634	-1.710	2.339	0.466
358T20	362T125-33	1 1/4"	none	0.0346	0.721	0.212	0.438	0.232	1.439	0.030	0.377	0.385	0.174	3.437	1.024	0.368	0.164	4.922	1.039	0.085	0.075	-0.667	1.630	0.833
358T18	362T125-43	1 1/4"	none	0.0451	0.939	0.276	0.572	0.302	1.439	0.039	0.375	0.531	0.245	4.839	1.739	0.508	0.230	6.892	2.141	0.187	0.097	-0.663	1.628	0.834
358T16	362T125-54	1 1/4"	none	0.0566	1.177	0.346	0.723	0.378	1.445	0.048	0.373	0.705	0.332	6.569	2.480	0.678	0.312	9.342	3.372	0.369	0.123	-0.659	1.632	0.837
358T14	362T125-68	1 1/4"	none	0.0713	1.482	0.436	0.921	0.475	1.454	0.060	0.370	0.921	0.453	8.955	3.104	0.907	0.427	12.776	4.703	0.738	0.155	-0.655	1.637	0.84 0
358T12	362T125-97	1 1/4"	none	0.1017	2.112	0.621	1.344	0.675	1.471	0.082	0.364	1.343	0.675	15.242	4.370	1.343	0.675	20.204	6.622	2.140	0.223	-0.646	1.648	0.8 46
358T10	362T125-118	1 1/4"	none	0.1242	2.635	0.774	1.708	0.839	1.485	0.100	0.359	1.707	0.839	19.508	5.398	1.707	0.839	28.945	8.178	4.163	0.281	-0.639	1.656	0.851

Physical and Structural Properties

M\W Type	SSMA	Member Physical Properties: Flange/ Leg (in.)	Lip (in.)	Design Thickness (in.)	Weight (plf.)	Gross Section Properties: Area (in.²)	Ix (in.⁴)	Sx (in.³)	Rx (in.)	Iy (in.⁴)	Ry (in.)	Effective Section Properties 33ksi: Ix_e (in.⁴)	Sx_e (in.³)	Ma (k-in)	Va (k)	50 ksi: Ix_e (in.⁴)	Sx_e (in.³)	Ma (k-in)	Va (k)	Torsional Properties: J x1000 (in.⁴)	Cw (in.⁶)	Xo (in.)	Ro (in.)	ß Beta
4" Members																								
4CW20	400S137-33	1 3/8"	3/8"	0.0346	0.848	0.249	0.603	0.302	1.556	0.061	0.496	0.584	0.260	5.133	0.595	0.580	0.221	6.607	0.595	0.099	0.200	-0.987	1.908	0.733
4CW18	400S137-43	1 3/8"	3/8"	0.0451	1.099	0.323	0.776	0.388	1.551	0.078	0.491	0.761	0.360	7.115	0.810	0.755	0.327	9.782	0.997	0.219	0.253	-0.976	1.897	0.736
4CW16	400S137-54	1 3/8"	3/8"	0.0566	1.364	0.401	0.953	0.477	1.543	0.094	0.484	0.944	0.455	8.997	0.944	0.938	0.430	12.874	1.223	0.428	0.305	-0.967	1.884	0.73 7
4CW14	400S137-68	1 3/8"	3/8"	0.0713	1.691	0.497	1.165	0.583	1.531	0.112	0.475	1.159	0.571	11.274	0.895	1.157	0.561	16.786	1.356	0.842	0.365	-0.956	1.867	0.7 38
4SW20	400S162-33	1 5/8"	1/2"	0.0346	0.936	0.275	0.692	0.346	1.586	0.103	0.611	0.674	0.300	5.923	0.595	0.669	0.262	7.849	0.595	0.110	0.358	-1.288	2.133	0.635
4SW18	400S162-43	1 5/8"	1/2"	0.0451	1.214	0.357	0.892	0.446	1.582	0.131	0.606	0.876	0.418	8.255	0.810	0.872	0.360	10.777	0.997	0.242	0.454	-1.276	2.121	0.63 8
4SW16	400S162-54	1 5/8"	1/2"	0.0566	1.508	0.443	1.098	0.549	1.574	0.159	0.600	1.088	0.527	10.423	0.944	1.082	0.499	14.947	1.223	0.473	0.550	-1.268	2.108	0.6 38
4SW14	400S162-68	1 5/8"	1/2"	0.0713	1.873	0.550	1.346	0.673	1.564	0.192	0.591	1.340	0.661	13.061	0.895	1.338	0.651	19.492	1.356	0.933	0.663	-1.258	2.092	0.6 39
4SW12	400S162-97	1 5/8"	1/2"	0.1017	2.594	0.762	1.813	0.907	1.542	0.250	0.572	1.811	0.898	21.544	0.797	1.811	0.898	31.848	1.207	2.627	0.860	-1.238	2.059	0.6 39
4SW10	400S162-118	1 5/8"	1/2"	0.1242	3.157	0.928	2.154	1.077	1.524	0.287	0.556	2.157	1.067	26.636	0.719	2.157	1.067	39.198	1.090	4.988	0.990	-1.222	2.031	0.638
4J20	400S200-33	2"	5/8"	0.0346	1.054	0.310	0.812	0.406	1.619	0.183	0.769	0.791	0.327	6.463	0.595	0.758	0.289	8.666	0.595	0.124	0.689	-1.715	2.481	0.522
4J18	400S200-43	2"	5/8"	0.0451	1.367	0.402	1.048	0.524	1.615	0.235	0.764	1.033	0.479	9.474	0.810	1.028	0.421	12.605	0.997	0.272	0.876	-1.703	2.468	0.524
4J16	400S200-54	2"	5/8"	0.0566	1.701	0.500	1.292	0.646	1.608	0.287	0.758	1.282	0.624	12.339	0.944	1.278	0.550	16.472	1.223	0.534	1.068	-1.695	2.456	0.524
4J14	400S200-68	2"	5/8"	0.0713	2.116	0.622	1.590	0.795	1.599	0.349	0.750	1.584	0.783	15.462	0.895	1.582	0.753	22.558	1.356	1.054	1.295	-1.686	2.441	0.523
4J12	400S200-97	2"	5/8"	0.1017	2.940	0.864	2.156	1.078	1.580	0.463	0.732	2.153	1.069	24.852	0.797	2.153	1.069	36.874	1.207	2.978	1.704	-1.667	2.411	0.522
4J10	400S200-118	2"	5/8"	0.1242	3.590	1.055	2.577	1.289	1.563	0.541	0.716	2.579	1.279	30.755	0.719	2.579	1.279	45.451	1.090	5.671	1.987	-1.653	2.385	0.520
4T20	400T125-33	1 1/4"	none	0.0346	0.765	0.225	0.549	0.265	1.563	0.031	0.371	0.484	0.201	3.971	0.940	0.465	0.189	5.668	0.940	0.090	0.094	-0.639	1.729	0.863
4T18	400T125-43	1 1/4"	none	0.0451	0.996	0.293	0.716	0.344	1.564	0.040	0.369	0.666	0.282	5.568	1.739	0.639	0.266	7.956	2.078	0.199	0.122	-0.635	1.727	0.865
4T16	400T125-54	1 1/4"	none	0.0566	1.250	0.367	0.904	0.431	1.569	0.049	0.367	0.883	0.381	7.528	2.739	0.849	0.359	10.739	3.372	0.392	0.153	-0.631	1.731	0.86 7
4T14	400T125-68	1 1/4"	none	0.0713	1.573	0.462	1.150	0.541	1.577	0.061	0.364	1.150	0.517	10.220	3.435	1.134	0.488	14.622	5.205	0.783	0.193	-0.627	1.736	0.8 70
4T12	400T125-97	1 1/4"	none	0.1017	2.242	0.659	1.674	0.768	1.594	0.084	0.358	1.673	0.768	17.352	4.842	1.673	0.768	23.001	7.337	2.271	0.277	-0.618	1.747	0.8 75
4T10	400T125-118	1 1/4"	none	0.1242	2.797	0.822	2.123	0.955	1.607	0.102	0.353	2.122	0.955	22.200	5.987	2.122	0.955	32.940	9.071	4.419	0.347	-0.612	1.755	0.879
6" Members																								
6CW20	600S137-33	1 3/8"	3/8"	0.0346	1.083	0.318	1.583	0.528	2.230	0.069	0.464	1.582	0.513	10.127	0.638	1.582	0.414	12.393	0.638	0.127	0.494	-0.823	2.422	0.8 85
6CW18	600S137-43	1 3/8"	3/8"	0.0451	1.406	0.413	2.042	0.681	2.224	0.087	0.459	2.042	0.670	14.801	1.240	2.042	0.648	19.394	1.240	0.280	0.625	-0.813	2.412	0.8 86
6CW16	600S137-54	1 3/8"	3/8"	0.0566	1.749	0.514	2.518	0.839	2.214	0.105	0.452	2.517	0.839	18.981	1.890	2.517	0.809	27.231	1.947	0.549	0.757	-0.804	2.398	0.8 88
6CW14	600S137-68	1 3/8"	3/8"	0.0713	2.177	0.640	3.095	1.032	2.200	0.126	0.443	3.094	1.031	24.048	2.339	3.094	1.030	35.603	2.879	1.084	0.911	-0.793	2.380	0.8 89
6SW20	600S162-33	1 5/8"	1/2"	0.0346	1.172	0.344	1.793	0.598	2.282	0.116	0.581	1.793	0.577	11.408	0.638	1.793	0.480	14.376	0.638	0.137	0.851	-1.091	2.596	0.8 23
6SW18	600S162-43	1 5/8"	1/2"	0.0451	1.521	0.447	2.316	0.772	2.277	0.148	0.576	2.316	0.767	16.679	1.240	2.316	0.706	21.121	1.240	0.303	1.082	-1.080	2.585	0.8 25
6SW16	600S162-54	1 5/8"	1/2"	0.0566	1.893	0.556	2.861	0.954	2.268	0.181	0.570	2.860	0.953	21.165	1.890	2.860	0.916	30.324	1.947	0.594	1.318	-1.071	2.572	0.8 27
6SW14	600S162-68	1 5/8"	1/2"	0.0713	2.358	0.693	3.525	1.175	2.256	0.218	0.561	3.525	1.175	26.784	2.339	3.525	1.164	39.465	2.879	1.174	1.596	-1.061	2.555	0.8 28
6SW12	600S162-97	1 5/8"	1/2"	0.1017	3.286	0.966	4.799	1.600	2.229	0.283	0.542	4.797	1.599	38.374	2.512	4.797	1.599	56.725	3.806	3.329	2.093	-1.039	2.518	0.8 30
6SW10	600S162-118	1 5/8"	1/2"	0.1242	4.022	1.182	5.756	1.919	2.207	0.326	0.525	5.754	1.918	47.864	2.376	5.754	1.918	70.438	3.600	6.354	2.434	-1.021	2.488	0.832
6J20	600S200-33	2"	5/8"	0.0346	1.289	0.379	2.076	0.692	2.341	0.209	0.743	2.059	0.618	12.218	0.638	2.016	0.521	15.598	0.638	0.151	1.577	-1.479	2.867	0.734
6J18	600S200-43	2"	5/8"	0.0451	1.674	0.492	2.683	0.894	2.335	0.268	0.739	2.683	0.873	17.243	1.240	2.683	0.805	24.102	1.240	0.334	2.012	-1.468	2.855	0.736
6J16	600S200-54	2"	5/8"	0.0566	2.086	0.613	3.320	1.107	2.327	0.329	0.732	3.319	1.106	24.073	1.890	3.319	1.015	30.394	1.947	0.655	2.461	-1.459	2.843	0.737
6J14	600S200-68	2"	5/8"	0.0713	2.601	0.764	4.101	1.367	2.317	0.400	0.723	4.100	1.367	30.416	2.339	4.100	1.317	43.707	2.879	1.295	2.997	-1.448	2.826	0.737
6J12	600S200-97	2"	5/8"	0.1017	3.632	1.067	5.613	1.871	2.293	0.530	0.705	5.612	1.871	43.494	2.512	5.612	1.871	64.535	3.806	3.679	3.981	-1.427	2.791	0.739
6J10	600S200-118	2"	5/8"	0.1242	4.454	1.309	6.766	2.255	2.274	0.622	0.689	6.764	2.255	54.236	2.376	6.764	2.255	80.151	3.600	7.036	4.680	-1.409	2.762	0.740
6JE18	600S250-43	2 1/2"	5/8"	0.0451	1.828	0.537	3.083	1.028	2.396	0.458	0.923	3.082	0.918	18.139	1.240	2.977	0.816	24.438	1.240	0.364	3.379	-1.898	3.193	0.6 47
6JE16	600S250-54	2 1/2"	5/8"	0.0566	2.279	0.670	3.820	1.273	2.389	0.562	0.917	3.819	1.159	22.896	1.890	3.766	1.069	31.999	1.947	0.715	4.146	-1.889	3.180	0.6 47
6JE14	600S250-68	2 1/2"	5/8"	0.0713	2.844	0.836	4.728	1.576	2.379	0.688	0.908	4.727	1.508	32.824	2.339	4.723	1.386	41.490	2.879	1.416	5.071	-1.878	3.164	0.6 48
6JE12	600S250-97	2 1/2"	5/8"	0.1017	3.978	1.169	6.498	2.166	2.358	0.923	0.889	6.496	2.161	48.806	2.512	6.496	2.063	69.377	3.806	4.030	6.798	-1.857	3.130	0.6 48
6JE10	600S250-118	2 1/2"	5/8"	0.1242	4.886	1.436	7.861	2.620	2.340	1.093	0.873	7.859	2.620	60.904	2.376	7.859	2.554	88.093	3.600	7.719	8.055	-1.839	3.102	0.648
6T20	600T125-33	1 1/4"	none	0.0346	1.000	0.294	1.429	0.465	2.205	0.034	0.339	1.297	0.335	6.627	0.622	1.273	0.273	8.174	0.622	0.117	0.237	-0.523	2.291	0.948
6T18	600T125-43	1 1/4"	none	0.0451	1.303	0.383	1.862	0.604	2.205	0.044	0.337	1.750	0.515	10.172	1.377	1.700	0.466	13.939	1.377	0.260	0.306	-0.519	2.290	0.9 49
6T16	600T125-54	1 1/4"	none	0.0566	1.635	0.480	2.345	0.757	2.209	0.054	0.335	2.294	0.685	13.533	2.728	2.221	0.653	19.546	2.728	0.513	0.383	-0.516	2.293	0.9 49
6T14	600T125-68	1 1/4"	none	0.0713	2.059	0.605	2.970	0.951	2.216	0.067	0.332	2.969	0.916	18.091	4.347	2.930	0.874	26.171	5.350	1.025	0.481	-0.512	2.298	0.9 50
6T12	600T125-97	1 1/4"	none	0.1017	2.934	0.862	4.282	1.348	2.229	0.092	0.327	4.281	1.347	30.426	7.359	4.281	1.347	40.330	10.885	2.973	0.681	-0.504	2.308	0.952
6T10	600T125-118	1 1/4"	none	0.1242	3.662	1.076	5.393	1.674	2.239	0.111	0.322	5.392	1.673	38.899	9.130	5.392	1.673	57.717	13.834	5.785	0.845	-0.498	2.316	0.954
8" Members																								
8SW20*	800S162-33	1 5/8"	1/2"	0.0346	1.407	0.414	3.583	0.896	2.944	0.125	0.550	3.582	0.758	14.970	0.474	3.533	0.635	18.996	0.474	0.165	1.615	-0.951	3.142	0.9 08
8SW18	800S162-43	1 5/8"	1/2"	0.0451	1.828	0.537	4.635	1.159	2.938	0.160	0.546	4.633	1.158	22.889	1.051	4.633	0.930	27.853	1.051	0.364	2.056	-0.941	3.133	0.9 10
8SW16	800S162-54	1 5/8"	1/2"	0.0566	2.279	0.670	5.737	1.434	2.927	0.194	0.539	5.736	1.434	31.830	2.091	5.736	1.397	41.837	2.091	0.715	2.509	-0.932	3.119	0.9 11
8SW14	800S162-68	1 5/8"	1/2"	0.0713	2.844	0.836	7.091	1.773	2.913	0.235	0.530	7.089	1.772	40.404	3.367	7.089	1.757	59.572	3.367	1.416	3.047	-0.921	3.101	0.9 12
8SW12	800S162-97	1 5/8"	1/2"	0.1017	3.978	1.169	9.716	2.429	2.883	0.305	0.511	9.713	2.428	58.269	4.824	9.713	2.428	86.136	5.938	4.030	4.022	-0.899	3.063	0.9 14
8SW10	800S162-118	1 5/8"	1/2"	0.1242	4.886	1.436	11.721	2.930	2.857	0.351	0.495	11.718	2.929	73.103	4.950	11.718	2.929	107.581	7.259	7.719	4.703	-0.881	3.03 1	0.916

* = Exceeds the H/T ratio of 200

See notes on page 4

MARINO WARE

STRUCTURAL PROPERTIES

SSMA CERTIFIED · CERTIFIED CODE COMPLIANT · STEEL FRAMING PRODUCT
Sponsored by: Steel Stud Manufacturers Association

Physical and Structural Properties

8" Members

M\W Type	SSMA	Flange/ Leg (in.)	Lip (in.)	Design Thickness (in.)	Weight (plf.)	Area (in.²)	Ix (in.⁴)	Sx (in.³)	Rx (in.)	Iy (in.⁴)	Ry (in.)	33ksi Ixe (in.⁴)	33ksi Sxe (in.³)	33ksi Ma (k-in)	33ksi Va (k)	50 ksi Ixe (in.⁴)	50 ksi Sxe (in.³)	50 ksi Ma (k-in)	50 ksi Va (k)	J x1000 (in.⁴)	Cw (in.⁶)	Xo (in.)	Ro (in.)	ß Beta
8J18	800S200-43	2"	5/8"	0.0451	1.981	0.582	5.303	1.326	3.018	0.292	0.708	5.302	1.294	25.570	1.051	5.302	1.063	31.831	1.051	0.395	3.763	-1.295	3.360	0.851
8J16	800S200-54	2"	5/8"	0.0566	2.471	0.726	6.574	1.644	3.009	0.357	0.701	6.572	1.643	35.749	2.091	6.572	1.501	44.938	2.091	0.775	4.612	-1.286	3.347	0.852
8J14	800S200-68	2"	5/8"	0.0713	3.086	0.907	8.142	2.036	2.996	0.435	0.692	8.140	2.035	45.286	3.367	8.140	1.964	65.207	3.367	1.537	5.631	-1.275	3.329	0.853
8J12	800S200-97	2"	5/8"	0.1017	4.324	1.271	11.206	2.801	2.970	0.576	0.674	11.203	2.801	65.120	4.824	11.203	2.801	96.622	5.938	4.381	7.524	-1.253	3.293	0.85 5
8J10	800S200-118	2"	5/8"	0.1242	5.318	1.563	13.572	3.393	2.947	0.676	0.658	13.569	3.392	81.598	4.950	13.569	3.392	120.587	7.259	8.402	8.889	-1.234	3.262	0.8 57
8JE18	800S250-43	2 1/2"	5/8"	0.0451	2.135	0.627	6.017	1.504	3.097	0.500	0.893	6.015	1.315	25.979	1.051	5.910	1.078	32.265	1.051	0.425	6.320	-1.695	3.641	0.7 84
8JE16	800S250-54	2 1/2"	5/8"	0.0566	2.664	0.783	7.467	1.867	3.089	0.614	0.886	7.465	1.712	33.821	2.091	7.377	1.527	45.721	2.091	0.836	7.769	-1.685	3.628	0.7 84
8JE14	800S250-68	2 1/2"	5/8"	0.0713	3.329	0.978	9.263	2.316	3.077	0.752	0.877	9.261	2.220	48.331	3.367	9.240	2.059	61.648	3.367	1.658	9.526	-1.674	3.611	0.7 85
8JE12	800S250-97	2 1/2"	5/8"	0.1017	4.670	1.372	12.792	3.198	3.053	1.009	0.858	12.789	3.191	72.065	4.824	12.789	3.053	102.693	5.938	4.731	12.837	-1.652	3.5 76	0.787
8JE10	800S250-118	2 1/2"	5/8"	0.1242	5.751	1.690	15.540	3.885	3.033	1.196	0.841	15.537	3.884	90.301	4.950	15.537	3.791	130.757	7.259	9.085	15.279	-1.633	3.5 46	0.788
8JX16	800S300-54	3"	1"	0.0566	3.001	0.882	8.792	2.198	3.158	1.145	1.139	8.782	2.011	39.732	2.091	8.532	1.801	53.932	2.091	0.942	15.946	-2.354	4.100	0.670
8JX14	800S300-68	3"	1"	0.0713	3.754	1.103	10.927	2.732	3.148	1.411	1.131	10.925	2.696	53.274	3.367	10.925	2.508	75.092	3.367	1.869	19.634	-2.344	4.084	0.671
8JX12	800S300-97	3"	1"	0.1017	5.276	1.550	15.154	3.789	3.127	1.922	1.114	15.151	3.788	83.846	4.824	15.151	3.675	121.429	5.938	5.345	26.700	-2.323	4.051	0.67 1
8JX10	800S300-118	3"	1"	0.1242	6.507	1.912	18.477	4.619	3.109	2.308	1.099	18.474	4.619	104.824	4.950	18.474	4.619	155.988	7.259	10.280	32.027	-2.306	4.023	0.672
8T20*	800T125-33	1 1/4"	none	0.0346	1.236	0.363	2.897	0.711	2.824	0.036	0.313	2.706	0.434	8.569	0.465	2.550	0.360	10.771	0.465	0.145	0.456	-0.443	2.876	0.97 6
8T18	800T125-43	1 1/4"	none	0.0451	1.610	0.473	3.774	0.925	2.824	0.046	0.311	3.600	0.740	14.623	1.030	3.545	0.597	17.867	1.030	0.321	0.588	-0.440	2.875	0.9 77
8T16	800T125-54	1 1/4"	none	0.0566	2.020	0.594	4.747	1.158	2.828	0.057	0.309	4.653	1.065	21.038	2.039	4.547	0.963	28.833	2.039	0.634	0.734	-0.437	2.878	0.9 77
8T14	800T125-68	1 1/4"	none	0.0713	2.544	0.748	6.000	1.455	2.833	0.070	0.307	5.998	1.409	27.844	4.087	5.925	1.355	40.578	4.087	1.267	0.919	-0.434	2.883	0.9 77
8T12	800T125-97	1 1/4"	none	0.1017	3.626	1.066	8.616	2.062	2.844	0.097	0.301	8.613	2.062	46.564	8.843	8.613	2.062	61.721	10.885	3.674	1.293	-0.427	2.891	0.978
8T10	800T125-118	1 1/4"	none	0.1242	4.526	1.330	10.817	2.562	2.852	0.117	0.297	10.813	2.561	59.536	12.274	10.813	2.561	88.338	16.975	7.150	1.595	-0.421	2.8 98	0.979

10" Members

M\W Type	SSMA	Flange/ Leg (in.)	Lip (in.)	Design Thickness (in.)	Weight (plf.)	Area (in.²)	Ix (in.⁴)	Sx (in.³)	Rx (in.)	Iy (in.⁴)	Ry (in.)	33ksi Ixe (in.⁴)	33ksi Sxe (in.³)	33ksi Ma (k-in)	33ksi Va (k)	50 ksi Ixe (in.⁴)	50 ksi Sxe (in.³)	50 ksi Ma (k-in)	50 ksi Va (k)	J x1000 (in.⁴)	Cw (in.⁶)	Xo (in.)	Ro (in.)	ß Beta
10SW18*	1000S162-43	1 5/8"	1/2"	0.0451	2.135	0.627	8.028	1.606	3.577	0.168	0.518	8.025	1.415	27.953	0.836	8.013	1.148	34.366	0.836	0.425	3.404	-0.836	3.710	0.949
10SW16	1000S162-54	1 5/8"	1/2"	0.0566	2.664	0.783	9.953	1.991	3.566	0.204	0.511	9.950	1.990	39.322	1.661	9.950	1.713	51.291	1.661	0.836	4.159	-0.827	3.696	0.950
10SW14	1000S162-68	1 5/8"	1/2"	0.0713	3.329	0.978	12.329	2.466	3.550	0.247	0.502	12.325	2.465	56.196	3.345	12.325	2.465	73.802	3.345	1.658	5.060	-0.816	3.67 7	0.951
10SW12	1000S162-97	1 5/8"	1/2"	0.1017	4.670	1.372	16.972	3.394	3.517	0.320	0.483	16.966	3.393	81.427	6.434	16.966	3.393	120.368	7.177	4.731	6.707	-0.795	3.6 38	0.952
10SW10	1000S162-118	1 5/8"	1/2"	0.1242	5.751	1.690	20.560	4.112	3.488	0.369	0.467	20.553	4.111	102.578	7.908	20.553	4.111	150.956	9.734	9.085	7.869	-0.777	3.604	0.954
10J18*	1000S200-43	2"	5/8"	0.0451	2.288	0.672	9.088	1.818	3.676	0.309	0.677	9.085	1.582	31.260	0.836	9.045	1.318	39.446	0.836	0.456	6.189	-1.162	3.915	0.912
10J16	1000S200-54	2"	5/8"	0.0566	2.856	0.839	11.281	2.256	3.666	0.378	0.671	11.278	2.256	44.570	1.661	11.278	1.835	54.943	1.661	0.896	7.595	-1.153	3.901	0.9 13
10J14	1000S200-68	2"	5/8"	0.0713	3.572	1.050	13.998	2.800	3.652	0.460	0.662	13.994	2.799	62.281	3.345	13.994	2.744	82.155	3.345	1.779	9.290	-1.142	3.883	0.9 14
10J12	1000S200-97	2"	5/8"	0.1017	5.016	1.474	19.341	3.868	3.622	0.610	0.643	19.335	3.867	89.913	6.434	19.335	3.867	133.409	7.177	5.082	12.460	-1.120	3.846	0.915
10J10	1000S200-118	2"	5/8"	0.1242	6.183	1.817	23.506	4.701	3.597	0.715	0.627	23.499	4.700	113.051	7.908	23.499	4.700	167.069	9.734	9.768	14.768	-1.101	3.81 4	0.917
10JE18*	1000S250-43	2 1/2"	5/8"	0.0451	2.442	0.718	10.205	2.041	3.772	0.531	0.861	10.202	1.618	31.973	0.836	10.141	1.341	40.147	0.836	0.486	10.404	-1.534	4.1 62	0.864
10JE16	1000S250-54	2 1/2"	5/8"	0.0566	3.049	0.896	12.680	2.536	3.762	0.653	0.854	12.677	2.279	45.039	1.661	12.659	1.881	56.318	1.661	0.957	12.805	-1.525	4.1 48	0.865
10JE14	1000S250-68	2 1/2"	5/8"	0.0713	3.814	1.121	15.755	3.151	3.749	0.799	0.844	15.751	3.028	65.929	3.345	15.738	2.771	82.961	3.345	1.899	15.726	-1.514	4.1 31	0.866
10JE12	1000S250-97	2 1/2"	5/8"	0.1017	5.362	1.576	21.832	4.366	3.722	1.073	0.825	21.826	4.356	98.401	6.434	21.826	4.181	140.621	7.177	5.432	21.268	-1.491	4. 094	0.867
10JE10	1000S250-118	2 1/2"	5/8"	0.1242	6.615	1.944	26.601	5.320	3.699	1.271	0.809	26.594	5.319	123.652	7.908	26.594	5.198	179.308	9.734	10.450	25.389	-1.47 2	4.063	0.869
10JX16	1000S300-54	3"	1"	0.0566	3.386	0.995	14.824	2.965	3.860	1.227	1.111	14.821	2.667	52.706	1.661	14.545	2.239	67.042	1.661	1.063	25.484	-2.153	4.557	0.77 7
10JX14	1000S300-68	3"	1"	0.0713	4.239	1.246	18.451	3.690	3.849	1.513	1.102	18.446	3.646	72.041	3.345	18.446	3.384	101.320	3.345	2.111	31.425	-2.142	4.540	0.7 78
10JX12	1000S300-97	3"	1"	0.1017	5.968	1.754	25.662	5.132	3.825	2.061	1.084	25.656	5.131	113.583	6.434	25.656	4.981	164.567	7.177	6.046	42.867	-2.120	4.506	0.779
10JX10	1000S300-118	3"	1"	0.1242	7.371	2.166	31.367	6.274	3.806	2.476	1.069	31.360	6.272	142.355	7.908	31.360	6.272	211.838	9.734	11.645	51.554	-2.102	4.477	0.780
10JXW16	1000S350-54	3 1/2"	1"	0.0566	3.579	1.052	16.223	3.245	3.928	1.768	1.297	15.948	2.760	54.531	1.661	15.584	2.316	69.326	1.661	1.123	36.305	-2.573	4.871	0.721
10JXW14	1000S350-68	3 1/2"	1"	0.0713	4.482	1.317	20.208	4.042	3.917	2.185	1.288	20.204	3.824	75.567	3.345	20.030	3.407	102.007	3.345	2.232	44.852	-2.562	4.85 5	0.722
10JXW12	1000S350-97	3 1/2"	1"	0.1017	6.314	1.855	28.153	5.631	3.895	2.992	1.270	28.147	5.517	120.323	6.434	28.147	5.118	153.239	7.177	6.397	61.427	-2.540	4.8 20	0.722
10JXW10	1000S350-118	3 1/2"	1"	0.1242	7.804	2.293	34.462	6.892	3.877	3.609	1.255	34.455	6.891	153.642	7.908	34.455	6.568	218.407	9.734	12.328	74.129	-2.522	4.792	0.723
10T18*	1000T125-43	1 1/4"	none	0.0451	1.917	0.563	6.633	1.306	3.431	0.047	0.290	6.432	0.893	17.645	0.822	6.340	0.735	22.003	0.822	0.382	0.973	-0.383	3.465	0.988
10T16	1000T125-54	1 1/4"	none	0.0566	2.405	0.707	8.337	1.635	3.434	0.059	0.288	8.212	1.446	28.564	1.628	8.115	1.157	34.640	1.628	0.755	1.212	-0.380	3.467	0.988
10T14	1000T125-68	1 1/4"	none	0.0713	3.029	0.890	10.526	2.054	3.439	0.073	0.286	10.521	1.998	39.478	3.261	10.414	1.900	56.888	3.261	1.508	1.514	-0.377	3.47 1	0.988
10T12	1000T125-97	1 1/4"	none	0.1017	4.319	1.269	15.083	2.913	3.448	0.100	0.281	15.076	2.912	65.765	8.843	15.076	2.912	87.173	9.507	4.375	2.121	-0.371	3.47 9	0.989
10T10	1000T125-118	1 1/4"	none	0.1242	5.391	1.584	18.902	3.620	3.455	0.121	0.277	18.894	3.618	84.111	13.790	18.894	3.618	124.802	16.975	8.516	2.609	-0.365	3.485	0.989

12" Members

M\W Type	SSMA	Flange/ Leg (in.)	Lip (in.)	Design Thickness (in.)	Weight (plf.)	Area (in.²)	Ix (in.⁴)	Sx (in.³)	Rx (in.)	Iy (in.⁴)	Ry (in.)	33ksi Ixe (in.⁴)	33ksi Sxe (in.³)	33ksi Ma (k-in)	33ksi Va (k)	50 ksi Ixe (in.⁴)	50 ksi Sxe (in.³)	50 ksi Ma (k-in)	50 ksi Va (k)	J x1000 (in.⁴)	Cw (in.⁶)	Xo (in.)	Ro (in.)	ß Beta
12SW16*	1200S162-54	1 5/8"	1/2"	0.0566	3.049	0.896	15.735	2.623	4.191	0.212	0.486	15.729	2.335	46.142	1.377	15.729	2.025	60.633	1.377	0.957	6.293	-0.744	4.28 4	0.970
12SW14	1200S162-68	1 5/8"	1/2"	0.0713	3.814	1.121	19.525	3.254	4.174	0.255	0.477	19.517	3.253	64.278	2.771	19.517	2.955	88.466	2.771	1.899	7.665	-0.734	4.26 5	0.970
12SW12	1200S162-97	1 5/8"	1/2"	0.1017	5.362	1.576	26.974	4.496	4.138	0.332	0.459	26.964	4.494	107.841	7.411	26.964	4.494	159.415	7.411	5.432	10.187	-0.713	4.224	0.972
12SW10	1200S162-118	1 5/8"	1/2"	0.1242	6.615	1.944	32.780	5.463	4.107	0.382	0.443	32.768	5.461	136.284	9.919	32.768	5.461	200.558	11.538	10.450	11.979	-0.6 95	4.189	0.972
12J16*	1200S200-54	2"	5/8"	0.0566	3.242	0.953	17.668	2.945	4.307	0.394	0.643	17.662	2.661	52.588	1.377	17.662	2.176	65.155	1.377	1.017	11.462	-1.047	4.479	0.945
12J14	1200S200-68	2"	5/8"	0.0713	4.057	1.192	21.954	3.659	4.291	0.479	0.634	21.946	3.658	81.396	2.771	21.946	3.270	97.890	2.771	2.020	14.038	-1.036	4.460	0.946
12J12	1200S200-97	2"	5/8"	0.1017	5.709	1.677	30.426	5.071	4.259	0.635	0.615	30.415	5.069	117.865	7.411	30.415	5.069	174.883	7.411	5.783	18.875	-1.014	4.421	0.947
12J10	1200S200-118	2"	5/8"	0.1242	7.047	2.071	37.076	6.179	4.231	0.744	0.600	37.063	6.177	148.587	9.919	37.063	6.177	219.585	11.538	11.133	22.421	-0.996	4. 388	0.949

* = Exceeds the H/T ratio of 200

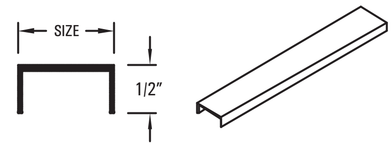
See notes on page 4

Physical and Structural Properties

M\W Type	SSMA	Member Physical Properties: Flange/Leg (in.)	Lip (in.)	Design Thickness (in.)	Weight (plf.)	Gross Section Properties: Area (in.^{2})	Ix (in.^{4})	Sx (in.^{3})	Rx (in.)	Iy (in.^{4})	Ry (in.)	Effective Section Properties 33ksi: Ix_e (in.^{4})	Sx_e (in.^{3})	Ma (k-in)	Va (k)	50 ksi: Ix_e (in.^{4})	Sx_e (in.^{3})	Ma (k-in)	Va (k)	Torsional Properties: J x1000 (in.^{4})	Cw (in.^{6})	Xo (in.)	Ro (in.)	ß Beta
12" Members																								
12JE16*	1200S250-54	2 1/2"	5/8"	0.0566	3.434	1.009	19.686	3.281	4.417	0.683	0.823	19.680	2.682	53.005	1.377	19.680	2.239	67.024	1.377	1.078	19.354	-1.395	4.704	0.912
12JE14	1200S250-68	2 1/2"	5/8"	0.0713	4.300	1.263	24.490	4.082	4.403	0.836	0.813	24.483	3.963	78.309	2.771	24.483	3.262	97.676	2.771	2.141	23.796	-1.384	4.686	0.913
12JE12	1200S250-97	2 1/2"	5/8"	0.1017	6.055	1.779	34.025	5.671	4.373	1.122	0.794	34.015	5.658	127.807	7.411	34.015	5.445	183.140	7.411	6.134	32.259	-1.361	4.649	0.914
12JE10	1200S250-118	2 1/2"	5/8"	0.1242	7.479	2.198	41.551	6.925	4.348	1.329	0.778	41.539	6.923	160.949	9.919	41.539	6.776	233.728	11.538	11.816	38.591	-1.342	4.617	0.916
12JX16*	1200S300-54	3"	1"	0.0566	3.771	1.108	22.847	3.808	4.541	1.292	1.080	22.841	3.165	62.532	1.377	22.571	2.680	80.248	1.377	1.183	37.836	-1.986	5.072	0.847
12JX14	1200S300-68	3"	1"	0.0713	4.724	1.388	28.466	4.744	4.528	1.593	1.071	28.459	4.692	92.707	2.771	28.459	4.010	120.054	2.771	2.352	46.706	-1.975	5.055	0.847
12JX12	1200S300-97	3"	1"	0.1017	6.660	1.957	39.678	6.613	4.503	2.171	1.053	39.668	6.611	146.347	7.411	39.668	6.423	212.243	7.411	6.747	63.857	-1.953	5.020	0.849
12JX10	1200S300-118	3"	1"	0.1242	8.236	2.420	48.591	8.099	4.481	2.608	1.038	48.579	8.097	183.763	9.919	48.579	8.097	273.457	11.538	13.011	76.946	-1.935	4.990	0.850
12JXW16*	1200S350-54	3 1/2"	1"	0.0566	3.964	1.165	24.866	4.144	4.620	1.866	1.266	24.616	3.283	64.881	1.377	24.096	2.776	83.114	1.377	1.244	53.909	-2.386	5.352	0.801
12JXW14	1200S350-68	3 1/2"	1"	0.0713	4.967	1.460	31.003	5.167	4.609	2.306	1.257	30.995	4.908	96.977	2.771	30.921	4.051	121.294	2.771	2.473	66.669	-2.375	5.335	0.802
12JXW12	1200S350-97	3 1/2"	1"	0.1017	7.006	2.059	43.277	7.213	4.585	3.159	1.239	43.267	7.071	154.210	7.411	43.267	6.590	197.301	7.411	7.098	91.503	-2.352	5.300	0.803
12JXW10	1200S350-118	3 1/2"	1"	0.1242	8.668	2.547	53.067	8.845	4.565	3.811	1.223	53.055	8.842	197.150	9.919	53.055	8.442	280.722	11.538	13.694	110.624	-2.334	5.270	0.804
12T16*	1200T125-54	1 1/4"	none	0.0566	2.791	0.820	13.341	2.187	4.034	0.060	0.271	13.266	1.666	32.914	1.355	13.116	1.364	40.846	1.355	0.876	1.820	-0.337	4.057	0.993
12T14	1200T125-68	1 1/4"	none	0.0713	3.515	1.033	16.833	2.748	4.037	0.074	0.268	16.825	2.682	52.992	2.713	16.799	2.180	65.271	2.713	1.750	2.271	-0.334	4.060	0.993
12T12	1200T125-97	1 1/4"	none	0.1017	5.011	1.472	24.088	3.899	4.045	0.102	0.264	24.077	3.897	88.030	7.902	24.077	3.897	116.685	7.902	5.076	3.173	-0.328	4.067	0.994
12T10	1200T125-118	1 1/4"	none	0.1242	6.255	1.838	30.157	4.847	4.051	0.124	0.260	30.143	4.844	112.623	13.790	30.143	4.844	167.108	15.438	9.881	3.894	-0.323	4.072	0.994
14" Members																								
14SW14	1400S162-68	1 5/8"	1/2"	0.0713	4.300	1.263	28.963	4.138	4.788	0.262	0.456	28.951	3.849	76.056	2.365	28.951	3.384	101.311	2.365	2.141	10.882	-0.667	4.856	0.981
14SW12	1400S162-97	1 5/8"	1/2"	0.1017	6.055	1.779	40.130	5.733	4.749	0.341	0.438	40.113	5.731	137.512	6.939	40.113	5.731	171.571	6.939	6.134	14.488	-0.647	4.813	0.982
14SW10	1400S162-118	1 5/8"	1/2"	0.1242	7.479	2.198	48.890	6.984	4.717	0.392	0.422	48.870	6.981	174.218	11.800	48.870	6.981	256.383	11.800	11.816	17.063	-0.630	4.777	0.983
14J14	1400S200-68	2"	5/8"	0.0713	4.542	1.335	32.295	4.614	4.919	0.494	0.609	32.283	4.327	85.499	2.365	32.283	3.753	112.363	2.365	2.262	19.920	-0.949	5.047	0.965
14J12	1400S200-97	2"	5/8"	0.1017	6.401	1.881	44.867	6.410	4.884	0.655	0.590	44.850	6.407	148.974	6.939	44.850	6.407	191.832	6.939	6.484	26.833	-0.927	5.006	0.966
14J10	1400S200-118	2"	5/8"	0.1242	7.912	2.325	54.789	7.827	4.855	0.767	0.575	54.768	7.824	188.201	11.800	54.768	7.824	278.128	11.800	12.499	31.925	-0.910	4.972	0.967
14JE14	1400S250-68	2 1/2"	5/8"	0.0713	4.785	1.406	35.754	5.108	5.043	0.865	0.784	35.741	4.623	91.361	2.365	35.741	3.760	112.582	2.365	2.383	33.827	-1.276	5.261	0.941
14JE12	1400S250-97	2 1/2"	5/8"	0.1017	6.747	1.983	49.778	7.111	5.011	1.161	0.765	49.762	7.096	160.281	6.939	49.762	6.886	206.162	6.939	6.835	45.940	-1.253	5.222	0.942
14JE10	1400S250-118	2 1/2"	5/8"	0.1242	8.344	2.452	60.899	8.700	4.984	1.375	0.749	60.879	8.697	202.187	11.800	60.879	8.523	294.007	11.800	13.181	55.041	-1.235	5.189	0.943
14JX14	1400S300-68	3"	1"	0.0713	5.210	1.531	41.260	5.894	5.192	1.659	1.041	41.248	5.531	109.290	2.365	41.248	4.644	139.042	2.365	2.594	65.681	-1.835	5.604	0.893
14JX12	1400S300-97	3"	1"	0.1017	7.353	2.161	57.610	8.230	5.164	2.261	1.023	57.594	8.228	182.128	6.939	57.594	8.128	243.355	6.939	7.449	89.953	-1.813	5.568	0.894
14JX10	1400S300-118	3"	1"	0.1242	9.100	2.674	70.658	10.094	5.140	2.715	1.008	70.637	10.091	229.033	11.800	70.637	10.091	340.824	11.800	14.376	108.550	-1.794	5.537	0.895
14JXW14	1400S350-68	3 1/2"	1"	0.0713	5.452	1.602	44.718	6.388	5.283	2.406	1.226	44.706	5.704	112.705	2.365	44.706	4.701	140.747	2.365	2.715	93.789	-2.216	5.859	0.857
14JXW12	1400S350-97	3 1/2"	1"	0.1017	7.699	2.262	62.522	8.932	5.257	3.296	1.207	62.505	8.761	191.077	6.939	62.505	8.192	245.281	6.939	7.799	128.936	-2.193	5.823	0.858
14JXW10	1400S350-118	3 1/2"	1"	0.1242	9.532	2.801	76.768	10.967	5.235	3.976	1.191	76.748	10.964	244.452	11.800	76.748	10.488	348.730	11.800	15.059	156.094	-2.174	5.793	0.859
14T14	1400T125-68	1 1/4"	none	0.0713	4.000	1.175	25.208	3.538	4.631	0.076	0.254	25.195	3.062	60.504	2.322	25.195	2.483	74.354	2.322	1.992	3.191	-0.299	4.648	0.996
14T12	1400T125-97	1 1/4"	none	0.1017	5.703	1.676	36.041	5.021	4.638	0.104	0.249	36.023	5.019	113.357	6.761	36.023	5.019	150.256	6.761	5.777	4.450	-0.294	4.654	0.996
14T10	1400T125-118	1 1/4"	none	0.1242	7.119	2.092	45.091	6.243	4.643	0.126	0.246	45.068	6.240	145.072	13.202	45.068	6.240	215.255	13.202	11.247	5.452	-0.289	4.658	0.996
16" Members																								
16SW14*	1600S162-68	1 5/8"	1/2"	0.0713	4.785	1.406	40.930	5.116	5.395	0.268	0.436	40.912	4.297	84.910	2.062	39.562	3.828	114.623	2.062	2.383	14.725	-0.612	5.448	0.987
16SW12	1600S162-97	1 5/8"	1/2"	0.1017	6.747	1.983	56.846	7.106	5.355	0.348	0.419	56.821	7.103	170.439	6.043	56.821	6.696	200.465	6.043	6.835	19.629	-0.592	5.404	0.988
16SW10	1600S162-118	1 5/8"	1/2"	0.1270	8.344	2.452	69.398	8.675	5.320	0.400	0.404	69.367	8.671	216.380	11.866	69.367	8.671	318.430	11.866	13.181	23.143	-0.576	5.367	0.989
16J14*	1600S200-68	2"	5/8"	0.0713	5.028	1.477	45.308	5.664	5.538	0.506	0.585	45.290	4.847	95.778	2.062	44.013	4.252	127.303	2.062	2.503	26.970	-0.876	5.637	0.976
16J12	1600S200-97	2"	5/8"	0.1017	7.093	2.084	63.072	7.884	5.501	0.671	0.567	63.047	7.881	183.238	6.043	63.047	7.476	223.841	6.043	7.186	36.380	-0.855	5.596	0.977
16J10	1600S200-118	2"	5/8"	0.1242	8.776	2.579	77.154	9.644	5.470	0.786	0.552	77.123	9.640	231.891	11.866	77.123	9.640	342.695	11.866	13.864	43.333	-0.838	5.561	0.977
16JE14*	1600S250-68	2 1/2"	5/8"	0.0713	5.270	1.549	49.830	6.229	5.673	0.889	0.758	49.812	5.193	102.624	2.062	49.812	4.270	127.829	2.062	2.624	45.889	-1.184	5.844	0.959
16JE12	1600S250-97	2 1/2"	5/8"	0.1017	7.439	2.186	69.498	8.687	5.639	1.193	0.739	69.473	8.669	195.820	6.043	69.473	7.905	236.662	6.043	7.536	62.406	-1.162	5.804	0.960
16JE10	1600S250-118	2 1/2"	5/8"	0.1242	9.208	2.706	85.153	10.644	5.610	1.412	0.723	85.123	10.640	247.366	11.866	85.123	10.440	360.139	11.866	14.547	74.854	-1.144	5.771	0.961
16JX14*	1600S300-68	3"	1"	0.0713	5.695	1.673	57.116	7.140	5.842	1.713	1.012	57.098	6.246	123.425	2.062	56.247	5.281	158.100	2.062	2.836	88.511	-1.715	6.172	0.923
16JX12	1600S300-97	3"	1"	0.1017	8.045	2.364	79.866	9.983	5.813	2.335	0.994	79.841	9.980	220.919	6.043	79.841	9.415	281.881	6.043	8.150	121.381	-1.693	6.135	0.924
16JX10	1600S300-118	3"	1"	0.1242	9.965	2.928	98.075	12.259	5.788	2.804	0.979	98.044	12.256	278.159	11.866	98.044	12.256	413.927	11.866	15.742	146.160	-1.674	6.104	0.925
16JXW14*	1600S350-68	3 1/2"	1"	0.0713	5.938	1.745	61.639	7.705	5.944	2.490	1.195	61.621	6.455	127.546	2.062	61.555	5.355	160.326	2.062	2.957	126.463	-2.079	6.409	0.895
16JXW12	1600S350-97	3 1/2"	1"	0.1017	8.391	2.466	86.292	10.787	5.916	3.410	1.176	86.267	10.588	230.916	6.043	86.267	9.220	276.045	6.043	8.500	174.076	-2.056	6.373	0.896
16JXW10	1600S350-118	3 1/2"	1"	0.1242	10.397	3.055	106.074	13.259	5.893	4.114	1.160	106.043	13.255	295.541	11.866	106.043	12.704	422.415	11.866	16.425	210.970	-2.037	6.342	0.897
16T14*	1600T125-68	1 1/4"	none	0.0713	4.485	1.318	35.934	4.423	5.222	0.077	0.241	35.915	3.399	67.164	2.030	35.915	2.805	83.977	2.030	2.233	4.278	-0.271	5.234	0.997
16T12	1600T125-97	1 1/4"	none	0.1017	6.395	1.879	51.347	6.279	5.227	0.106	0.237	51.320	6.276	141.747	5.908	51.320	5.710	170.971	5.908	6.479	5.956	-0.266	5.239	0.997
16T10	1600T125-118	1 1/4"	none	0.1242	7.984	2.346	64.211	7.809	5.232	0.128	0.233	64.177	7.805	181.457	11.532	64.177	7.805	269.243	11.532	12.613	7.287	-0.262	5.244	0.998

CR Channel

M\W Type	SSMA	Member Physical Properties: Flange/Leg (in.)	Lip (in.)	Design Thickness (in.)	Gross Section Properties: Area (in.^{2})	Ix (in.^{4})	Rx (in.)	Iy (in.^{4})	Ry (in.)	Effective Section Properties 33ksi: Ix_e (in.^{4})	Sx_e (in.^{3})	Ma (k-in)	Torsional Properties: J x1000 (in.^{4})	Cw (in.^{6})	Xo (in.)	Ro (in.)	ß Beta
3/4CR16	75U50-54	1/2"	N/A	0.0566	0.087	0.007	0.289	0.002	0.156	0.007	0.019	0.457	0.093	0.000	-0.354	0.483	0.462
112CR16	150U50-54	1/2"	N/A	0.0566	0.130	0.039	0.549	0.003	0.145	0.039	0.052	1.228	0.138	0.001	-0.266	0.627	0.820
2CR16	200U50-54	1/2"	N/A	0.0566	0.158	0.080	0.710	0.003	0.137	0.080	0.080	1.881	0.169	0.002	-0.230	0.759	0.908



* = Exceeds the H/T ratio of 200

See notes on page 4

Limiting Height Tables

Member		Wind Load & Spacing																							
M\W Type (SSMA)	Deflection	5 PSF			15 PSF			20 PSF			25 PSF			30 PSF			35 PSF			40 PSF			50 PSF		
		12"o.c.	16"o.c.	24"o.c.	12"o.c.	16"o.c.	24"o.c.	12"o.c.	16"o.c.	24"o.c.	12"o.c.	16"o.c.	24"o.c.	12"o.c.	16"o.c.	24"o.c.	12"o.c.	16"o.c.	24"o.c.	12"o.c.	16"o.c.	24"o.c.	12"o.c.	16"o.c.	24"o.c.
12" Members																									
12SW16* (1200S162-54)	L/240	59'- 0"	53'- 8"	46'- 10"	40'- 11"	37'- 2"	32'- 0"	37'- 2"	33'- 9"	27'- 8"	34'- 6"	30'- 4"	24'- 9"	32'- 0"	27'- 8"	22'- 7"	29 '- 7"	25'- 8"	20'- 11"	27'- 8"	24'- 0"	19'- 7"	24'- 9"	21'- 5"	17'- 6"
	L/360	51'- 7"	46'- 10"	40'- 11"	35'- 9"	32'- 6"	28'- 4"	32'- 6"	29'- 6"	25'- 9"	30'- 2"	27'- 5"	23'- 11"	28'- 4"	25'- 9"	22'- 6"	26 '- 11"	24'- 6"	20'- 11"	25'- 9"	23'- 5"	19'- 7"	23'- 11"	21'- 5"	17'- 6"
	L/600	43'- 6"	39'- 6"	34'- 6"	30'- 2"	27'- 5"	23'- 11"	27'- 5"	24'- 10"	21'- 9"	25'- 5"	23'- 1"	20'- 2"	23'- 11"	21'- 9"	19'- 0"	22 '- 9"	20'- 8"	18'- 0"	21'- 9"	19'- 9"	17'- 3"	20'- 2"	18'- 4"	16'- 0"
12SW14 (1200S162-68)	L/240	63'- 5"	57'- 8"	50'- 4"	44'- 0"	39'- 11"	34'- 11"	39'- 11"	36'- 4"	31'- 8"	37'- 1"	33'- 8"	29'- 3"	34'- 11"	31'- 8"	26'- 8"	33 '- 2"	30'- 1"	24'- 8"	31'- 8"	28'- 4"	23'- 1"	29'- 3"	25'- 4"	20'- 8"
	L/360	55'- 5"	50'- 4"	44'- 0"	38'- 5"	34'- 11"	30'- 6"	34'- 11"	31'- 8"	27'- 8"	32'- 5"	29'- 5"	25'- 8"	30'- 6"	27'- 8"	24'- 2"	28 '- 11"	26'- 4"	23'- 0"	27'- 8"	25'- 2"	22'- 0"	25'- 8"	23'- 4"	20'- 5"
	L/600	46'- 9"	42'- 6"	37'- 1"	32'- 5"	29'- 5"	25'- 8"	29'- 5"	26'- 9"	23'- 4"	27'- 4"	24'- 10"	21'- 8"	25'- 8"	23'- 4"	20'- 5"	24 '- 5"	22'- 2"	19'- 4"	23'- 4"	21'- 3"	18'- 6"	21'- 8"	19'- 8"	17'- 2"
12SW12 (1200S162-97)	L/240	70'- 8"	64'- 2"	56'- 1"	49'- 0"	44'- 6"	38'- 10"	44'- 6"	40'- 5"	35'- 4"	41'- 4"	37'- 6"	32'- 9"	38'- 10"	35'- 4"	30'- 10"	36 '- 11"	33'- 7"	29'- 4"	35'- 4"	32'- 1"	28'- 0"	32'- 9"	29'- 9"	26'- 0"
	L/360	61'- 9"	56'- 1"	49'- 0"	42'- 9"	38'- 10"	33'- 11"	38'- 10"	35'- 4"	30'- 10"	36'- 1"	32'- 9"	28'- 8"	33'- 11"	30'- 10"	26'- 11"	32 '- 3"	29'- 4"	25'- 7"	30'- 10"	28'- 0"	24'- 6"	28'- 8"	26'- 0"	22'- 9"
	L/600	52'- 1"	47'- 4"	41'- 4"	36'- 1"	32'- 9"	28'- 8"	32'- 9"	29'- 9"	26'- 0"	30'- 5"	27'- 8"	24'- 2"	28'- 8"	26'- 0"	22'- 9"	27 '- 2"	24'- 8"	21'- 7"	26'- 0"	23'- 8"	20'- 8"	24'- 2"	21'- 11"	19'- 2"
12SW10 (1200S162-118)	L/240	75'- 5"	68'- 6"	59'- 10"	52'- 3"	47'- 6"	41'- 6"	47'- 6"	43'- 2"	37'- 8"	44'- 1"	40'- 1"	35'- 0"	41'- 6"	37'- 8"	32'- 11"	39 '- 5"	35'- 10"	31'- 3"	37'- 8"	34'- 3"	29'- 11"	35'- 0"	31'- 9"	27'- 9"
	L/360	65'- 11"	59'- 10"	52'- 3"	45'- 8"	41'- 6"	36'- 3"	41'- 6"	37'- 8"	32'- 11"	38'- 6"	35'- 0"	30'- 7"	36'- 3"	32'- 11"	28'- 9"	34 '- 5"	31'- 3"	27'- 4"	32'- 11"	29'- 11"	26'- 1"	30'- 7"	27'- 9"	24'- 3"
	L/600	55'- 7"	50'- 6"	44'- 1"	38'- 6"	35'- 0"	30'- 7"	35'- 0"	31'- 9"	27'- 9"	32'- 6"	29'- 6"	25'- 9"	30'- 7"	27'- 9"	24'- 3"	29 '- 0"	26'- 4"	23'- 0"	27'- 9"	25'- 3"	22'- 0"	25'- 9"	23'- 5"	20'- 5"

* = Exceeds the H/T ratio of 200

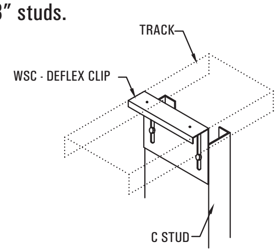
DEFLEX CLIP

The Deflex Slide Clips allow for up to 1-1/2" vertical floor or roof deflection without the use of laborious slip tracks it can be installed with or without standard leg tracks. Simple and fast to install which saves time and money. Two sizes available for 3-5/8", 4", 6" and 8" studs.

MATERIAL: 16 ga (54 mil) 50ksi.

FINISH: Galvanized – G90

- 3T1000 accommodates 3-5/8" and 4" stud widths
- 6T1000 accommodates 6" and 8" stud widths

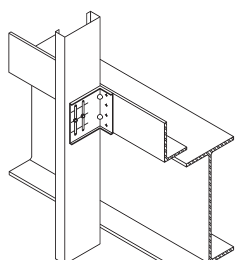


WSC SLIDE CLIP

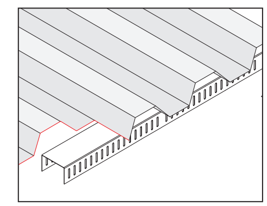
WSC Slide clips connect exterior curtainwall studs to the building structure and allow for vertical movement of the building independent of the studs. The new WSC series allows for 3" total deflection, 1-1/2" up and 1-1/2" down. WSC series 14 ga. clips come with extended leg lengths and shouldered screws are provided in each box of clips. 25 pieces per box.

MATERIAL: See Table

FINISH: Galvanized – G90



SLOTTED SLIP TRACK (SLT) CEMCO



Slotted Track manufactured by CEMCO and distributed by Marino\WARE is used at the head of wall and can absorb up to 1" of total vertical movement while providing a positive attachment for wall framing. The positive attachment allows for greater load resistance with thinner gauges of material.

MATERIAL: 20ga (33 mil-33ksi), 18ga (43 mil-33ksi), 16ga (54 mil- 50ksi), 14ga (68 mil - 50ksi)

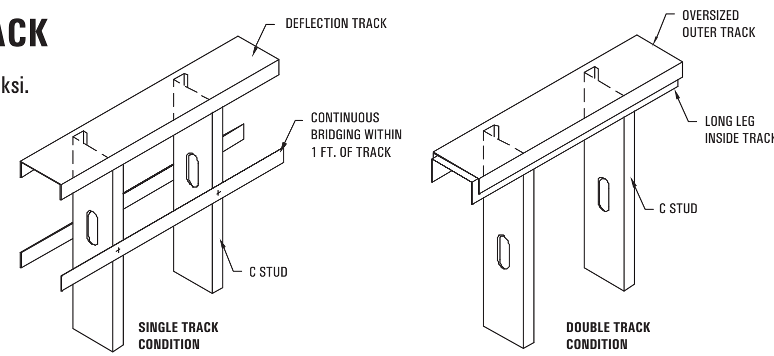
WEB SIZES: 2-1/2", 3-5/8", 4", 6", 8"

FINISH: G60-18ga & 16ga, G40-20ga

DEFLECTION TRACK

MATERIAL: 16 ga (54 mil) 50ksi.

FINISH:
Galvanized – G40 or equivalent

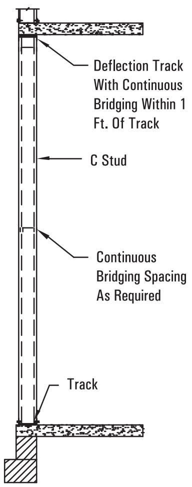


Deflection Track Notes:

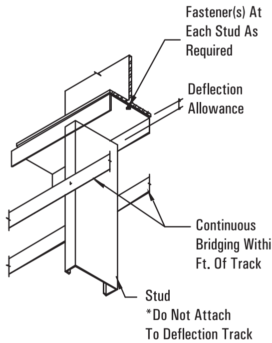
1. *Curtain wall deflection tracks may be required to accommodate the deflection of floor beams or floor decks above curtain wall or interior partitions. Deflection tracks cannot be used in axial load bearing stud conditions or above continuous windows spandrels.*
2. *Deflection track details must be designed for the specific conditions of a building to accomodate the required deflection and the end reactions of the studs. The deep leg tracks are not standard and the gauge width and leg height must be specified for each particular application. All detailing and connections should be specified by a qualified engineer or architect.*
3. *Deflection track 16ga and heavier must be 50 ksi steel.*

CURTAINWALL ILLUSTRATIONS

INFILL WALL APPLICATION

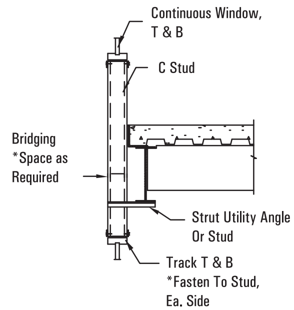


INFILL STUD

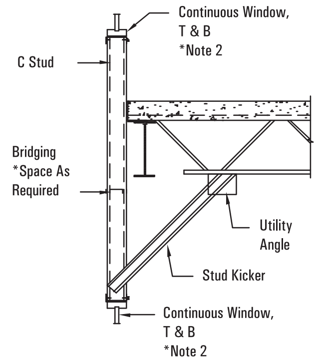


DEFLECTION TRACK

SPANDREL APPLICATION

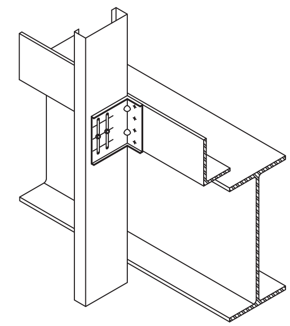


STRUT TO BEAM

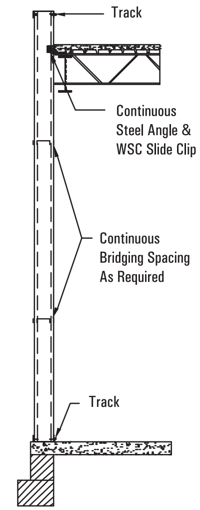


DIAGONAL KICKER

BY-PASS WALL APPLICATION

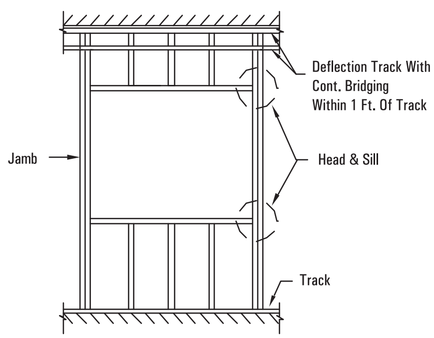


WSC-SLIDE CLIP

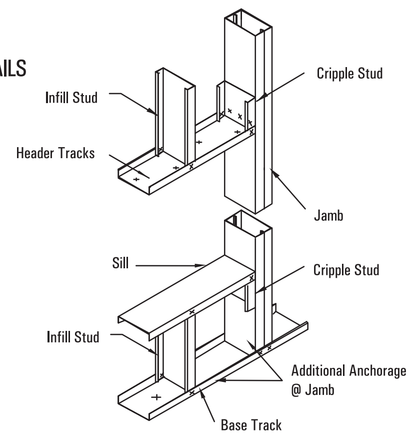


BY-PASS WALL

WINDOW OPENING DETAILS

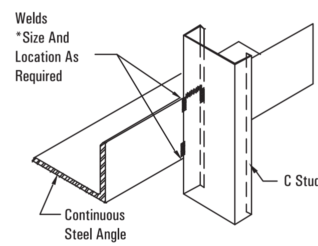


WINDOW FRAMING

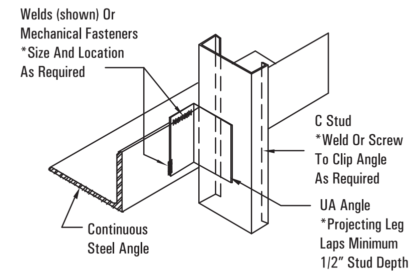


ISOMETRIC APPLICATION

GRAVITY/LATERAL ATTACHMENT ALTERNATIVES



DIRECT TO STEEL ANGLE



UA ANGLE

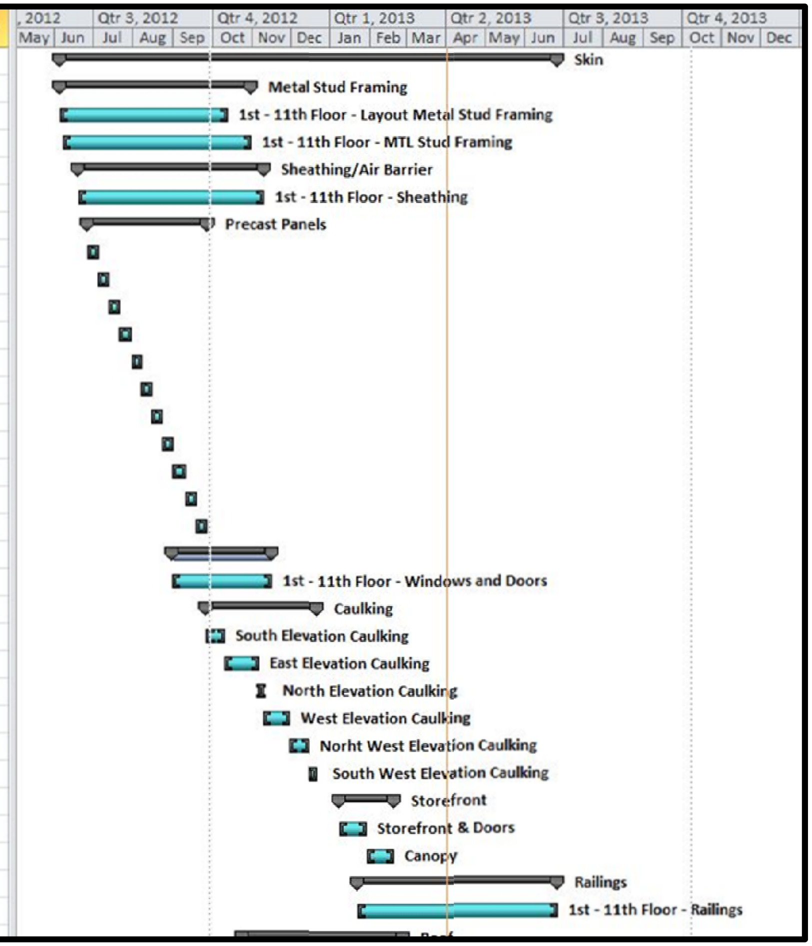
Notes:

1. *Size, spacing and anchorage of framing components shall be qualified by design.*
2. *Vertical deflection of the primary frame shall be accommodated in the window head.*

Appendix L

Project Schedule with GFRC Updates

	Task Name	Duration	Start	Finish
60	**Skin**	**276 days**	**Tue 6/5/12**	**Tue 6/25/13**
61	**Metal Stud Framing**	**106 days**	**Tue 6/5/12**	**Tue 10/30/12**
62	1st - 11th Floor - Layout Metal Stud Framin	94 days	Tue 6/5/12	Fri 10/12/12
63	1st - 11th Floor - MTL Stud Framing	104 days	Thu 6/7/12	Tue 10/30/12
64	**Sheathing/Air Barrier**	**104 days**	**Tue 6/19/12**	**Fri 11/9/12**
65	1st - 11th Floor - Sheathing	104 days	Tue 6/19/12	Fri 11/9/12
66	**Precast Panels**	**67 days**	**Tue 6/26/12**	**Wed 9/26/12**
67	Install Precast Panels 1st Floor	7 days	Tue 6/26/12	Wed 7/4/12
68	Install Precast Panels 2nd Floor	7 days	Wed 7/4/12	Thu 7/12/12
69	Install Precast Panels 3rd Floor	7 days	Thu 7/12/12	Fri 7/20/12
70	Install Precast Panels 4th Floor	7 days	Fri 7/20/12	Mon 7/30/12
71	Install Precast Panels 5th Floor	7 days	Mon 7/30/12	Tue 8/7/12
72	Install Precast Panels 6th Floor	7 days	Tue 8/7/12	Wed 8/15/12
73	Install Precast Panels 7th Floor	7 days	Wed 8/15/12	Thu 8/23/12
74	Install Precast Panels 8th Floor	7 days	Thu 8/23/12	Fri 8/31/12
75	Install Precast Panels 9th Floor	7 days	Fri 8/31/12	Mon 9/10/12
76	Install Precast Panels 10th Floor	7 days	Mon 9/10/12	Tue 9/18/12
77	Install Precast Panels 11th Floor	7 days	Tue 9/18/12	Wed 9/26/12
78	**Windows/Balcony Doors**	**55 days**	**Fri 8/31/12**	**Thu 11/15/12**
79	1st - 11th Floor - Windows and Doors	55 days	**Fri 8/31/12**	Thu 11/15/12
80	**Caulking**	**62 days**	**Wed 9/26/12**	**Thu 12/20/12**
81	South Elevation Caulking	10 days	Wed 9/26/12	Tue 10/9/12
82	East Elevation Caulking	20 days	Tue 10/9/12	Mon 11/5/12
83	North Elevation Caulking	5 days	Mon 11/5/12	Fri 11/9/12
84	West Elevation Caulking	15 days	Fri 11/9/12	Thu 11/29/12
85	Norht West Elevation Caulking	12 days	Thu 11/29/12	Fri 12/14/12
86	South West Elevation Caulking	5 days	Fri 12/14/12	Thu 12/20/12
87	**Storefront**	**30 days**	**Tue 1/8/13**	**Mon 2/18/13**
88	Storefront & Doors	15 days	Tue 1/8/13	Mon 1/28/13
89	Canopy	15 days	Tue 1/29/13	Mon 2/18/13
90	**Railings**	**111 days**	**Tue 1/22/13**	**Tue 6/25/13**
91	1st - 11th Floor - Railings	111 days	Tue 1/22/13	Tue 6/25/13



Appendix M

Mechanical Calculations

Standard Face Brick Construction

Air Space R-value	
Direction of heat flow	←
Mean temperature	0
Temperature difference	10
Thickness	3/4"
E	0.89
Find R	1.26

Standard Face Brick Construction

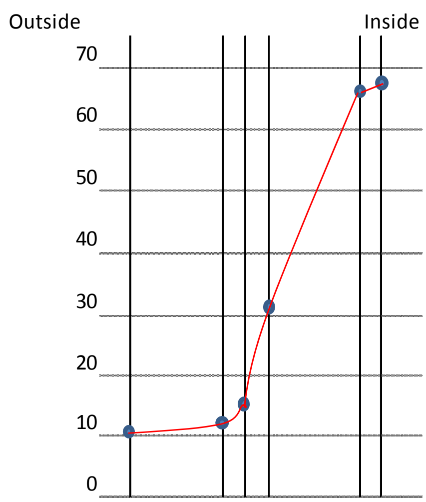
Wall U-Value		Framing	Insulating
R0	Outside	0.170	0.170
R1	4" Face Brick	0.440	0.440
R2	3/4" Air Space	1.260	1.260
R3	1.5" Rigid Insulation Board	5.000	5.000
R4	Metal Stud/3-5/8" Fiberglass batt	0.380	11.000
R5	5/8" GWB	0.560	0.560
Ri	Inside	0.680	0.680
ΣR		8.490	19.110
U		0.118	0.052
%		0.150	0.850
u		0.118	0.052
% x U		0.018	0.044
Uavg		0.062	

Ti	70d F
To	10d F
Ti - To	60d F

Tdb	70d F
% RH	50% RH
Tdp	51d F

ΣR0-i	19.110

Thermal Gradient Standard Face Brick



x	Sum of R	Tx
o-1	0.170	10.534
1-2	0.610	11.915
2-3	1.870	15.871
3-4	6.870	31.570
4-5	17.870	66.107
5-i	18.430	67.865

Standard Face Brick Construction

Air Space R-value	
Direction of heat flow	←
Mean temperature	0
Temperature difference	10
Thickness	3/4"
E	0.89
Find R	1.26

GFRC Panel

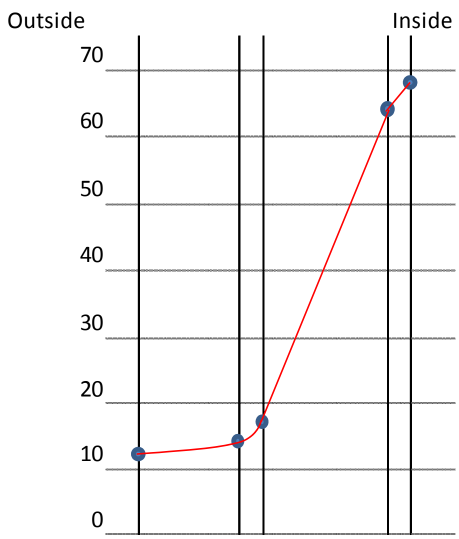
Wall U-Value		Framing	Insulating
R0	Outside	0.170	0.170
R1	1" Face Brick GFRC	0.070	0.070
R2	3/4" Air Space	1.260	1.260
R3	Metal Stud/3-5/8" Fiberglass batt	0.380	11.000
R4	5/8" GWB	0.560	0.560
Ri	Inside	0.680	0.680
ΣR		3.120	13.740
U		0.321	0.073
%		0.150	0.850
u		0.321	0.073
% x U		0.048	0.062
Uavg		0.110	

Ti	70d F
To	10d F
Ti - To	60d F

Tdb	70d F
% RH	50% RH
Tdp	51d F

ΣR0-i	13.740

Thermal Gradient GFRC Panel



x	Sum of R	Tx
o-1	0.170	10.742
1-2	0.240	11.048
2-3	1.500	16.550
3-4	12.500	64.585
4-i	13.060	67.031