2014

Final Report

Wardman West Residential

The Pennsylvania State University
Department Architectural of Engineering
Construction Option

AE 481W – Fall 2013
Faculty Advisor – Ray Sowers

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4/9/2014

Wardman West

Woodley Park, NW Washington, DC

Owner: JBG Companies

GC: Clark Construction Group, LLC

Architect: Cooper Carry

Landscape Architect: Michael Vergason Landscape Architects

Civil Engineer: A. Morton Thomas & Associates

Structural Engineer: SK&A Structural Engineers, PLLC

MEP Engineer: Integral-Group

Delivery Method - Negotiated $85,000,000 GMP

Construction Dates - 6/2011 - 4/2014


West Elevation

ARCHITECTURE

- 8-Story Luxury Apartment Building with 2 subgrade parking levels
- Gross Square Foot Area - 421,000 SF
- 212 residential apartment units
- Spacious outdoor courtyard with a country club style infinity swimming pool
- Private Rooftop Terrace, fitness center, library and resident's lounge
- Brick, Cast-stone and Limestone exterior façade
- LEED Silver Rating

STRUCTURAL

- Cast - in - place concrete columns, slabs, beams and retaining walls
- Unbound two way post-tensioned slabs
- 12" concrete retaining wall supporting infinity pool


View from Rooftop Terrace looking East

CONSTRUCTION SCOPE

Phase 1

- Demolition of Existing Parking Garage/Lot
- Construction of pedestrian tunnel to Marriot Wardman Hotel

Phase 2

- Residential Construction
- 2 tower cranes used for to build superstructure
- Fraco mast climbing work platforms and swing stage scaffolding used for exterior façade construction

MEP SYSTEMS

- 2 Rooftop Mechanical Penthouses
- (2) 25,000 CFM MUAU's and (1) 2,450 GPM Cooling Tower
- WSHP's for every residential unit
- CVPC Fire Suppression Piping
- 208/120V Service Feed
- (1) 4,000A and (2) 2,500A Switchboards
- Electrical room every floor

Kevin Kroener | Construction Option
http://www.engr.psu.edu/ae/thesis/portfolios/2014/krk5133/index.html

Table of Contents

Acknowledgements

Industry Acknowledgements:

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FRACO

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Executive Summary

Over the course of 2013 and 2014 academic year the following four analyses were performed for the Wardman West Residential Project located in Northwest Washington, DC. The main theme throughout these analyses was the implementation of an architectural precast concrete wall panel system in lieu of the lagging existing brick veneer wall system construction. The intended results of this proposed change was to save the owner money and accelerate the project schedule.

Analysis 1: Prefabrication of Brick Exterior Skin

This analysis investigated the use of architectural precast concrete wall panels in lieu of the building's existing hand-laid brick veneer wall system. The ultimate goal of this analysis was offer the owner schedule and cost savings with the lower material cost and faster erection and installation time associated with architectural precast concrete panels. The erection of the precast concrete wall panels would allow the building's wall system to be completed 88 days faster and reduce the overall building enclosure schedule by over a month at 31 days. The implementation of precast concrete wall panels would also save the owner approximately $737,000 with a total cost of $3.4 million, an 18% reduction in cost from the existing brick veneer wall system's total cost of $4.1 million, and furthermore, a 4.8% reduction in the overall cost of the building's exterior enclosure.

Analysis 2: SIPS

A SIPS or Short Interval Production Schedule was developed for both for the original exterior brick work and for the erection of the proposed architectural precast concrete wall panels from the first analysis. Each scope of work will include a SIPS matrix schedule used to track the completion of construction zones and also a revised project schedule. The brick SIPS significantly improved the workflow of construction by optimizing manpower, which resulted in reducing the schedule by 12 days to 133 days, compared to the original brick work duration of 145 days. The APC Wall Panel SIPS also saved time to the project schedule by reducing the overall estimated duration for panel erection at 57 days down to 54 days.

Analysis 3: Safety Evaluation

To effectively evaluate the safety concerns associated with the erection and installation of precast concrete wall panels, an in-depth scoring comparison was performed with traditional brick masonry installation, as well as the creation of an Activity Hazardous Analysis. While, precast concrete wall panel erection resulted in a higher risk construction activity, both brick and precast wall panels have a significant amount of safety concerns when performed. With the help of this scoring comparison breakdown; the required training, inspections, PPE and concerns are identified. Also, the Activity Hazard Analysis specifically created for precast concrete wall panel erection and installation, would also benefit safety coordination on the project and ensure site safety is maintained.

Analysis 4: General Contractor Implementation Study for APC Wall Panels

The fourth analysis performed was a study investigating the implementation of architectural precast concrete wall panels as building enclosure system. The study resulted in an in-depth guide for general contractors on product selection, project team responsibilities and logistics. The practicality of the study allows it to be used as a tool for general contractors to reference when deciding on or coordinating the use of architectural precast concrete wall panels on a project. Overall, the implementations study would be beneficial to the general contractor, Clark Construction, on the Wardman West Residential Project if the building's exterior brick veneer walls were substituted with architectural precast concrete wall panels proposed in the first analysis.

Project Background

Wardman West Residential a is new construction building located in the Woodley Park neighborhood of Northwest Washington, DC, located only block from the Woodley Park-Zoo Metro station. This JBG Companies owned project is an eight-story mid-rise luxury apartment building. It features 212 high-end apartment units with 288,500 square feet of residential space and a two story below grade parking garage with 272 parking spaces. The building will also include a fitness center, clubroom lounge, library, outdoor courtyard with a country club style infinity swimming pool and landscaped rooftop terrace.
The project delivery method for Wardman is a Design-Bid-Build with a negotiated guaranteed maximum price contract. Clark Construction Group, LLC was awarded the construction of building as the general contractor for a total cost of $88 million including the over 421,000 gross square feet of work, resulting in a per square foot cost of $209. This high cost per square foot can be attributed to building's high end luxurious exterior façade and residential unit finishes.

The construction schedule for Wardman is approximately 23 months long, with construction starting June 16, 2011 and substantial completion set for March 14, 2014. The building's eight-story structure is made entirely of cast-in-place concrete and two-way post-tensioned concrete slabs. The building's exterior skin consists of hand laid brick, prefabricated Indiana limestone and cast-stone. The construction phase of exterior skin masonry is a driving force for the project's schedule and will be the main focus of this thesis proposal, specifically the exterior brick masonry. The total duration for the exterior skin construction of the building is approximately one year spanning 252 working days. The below Figure A shows a rendering of Wardman West looking at the Northeast corner of the building.

Figure A: Rendering of Wardman West Residential. Courtesy of JBG Companies.

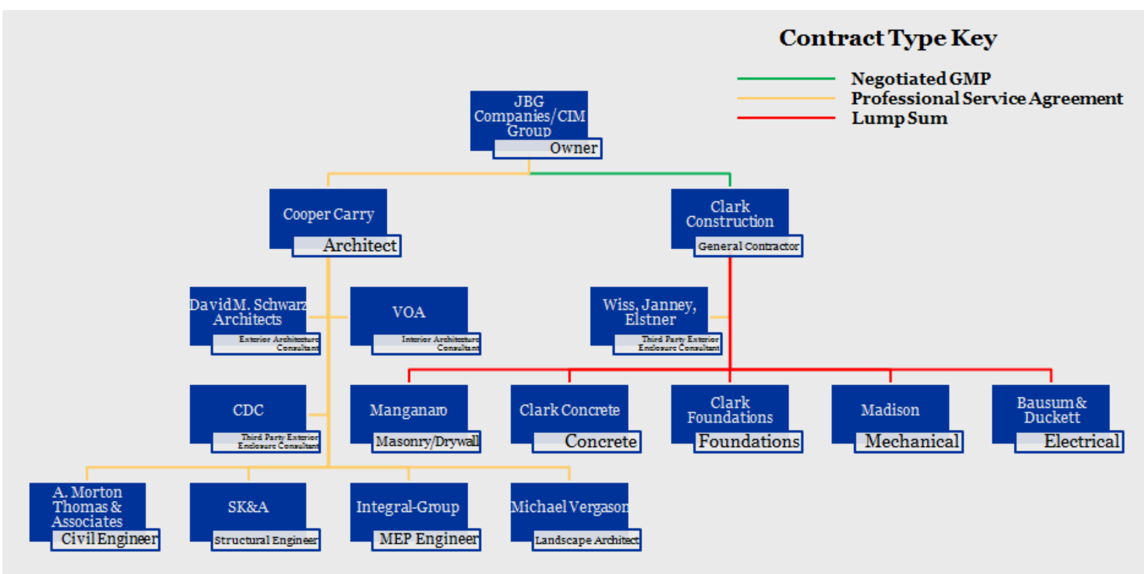
Existing Conditions

Located in the heart of Northwest Washington, DC only a block away from the Woodley Park/Zoo Metro Station, The Woodley's site is accessed by Woodley Road off of the 2700th block of Connecticut Avenue. The existing conditions result in a very compact site with a boundary converging close to the existing 10 - story Marriot Wardman Hotel. A temporary site road was built to access the site's East, North and West staging areas allowing for material deliveries and limited on-site traffic and parking. The site's only gate was located across from Woodley Road's intersection with 27th Street; this made deliveries a key scheduling and logistical challenge with large trucks and tractor trailers needing to park along Woodley Road, often interfering with pedestrian traffic feeding in and out of the existing Woodley Park Hotel Complex.

Project Delivery

The Woodley's delivery method was unique in the fact that it was a negotiated GMP bid at approximately $85 million between Clark Construction and JBG Companies. This allowed Clark to procure many repeat subcontractors helping to build relationships for future work. An interesting aspect of the project's delivery method is the use of Third Party Exterior Skin Consultants by both Clark and the architect Cooper Carry to maintain checks and balances during construction, due to JBG holding very stringent quality control requirements for the buildings very intricate and expensive façade. Figure B below illustrates the project delivery and contract system used for the construct of Wardman West.

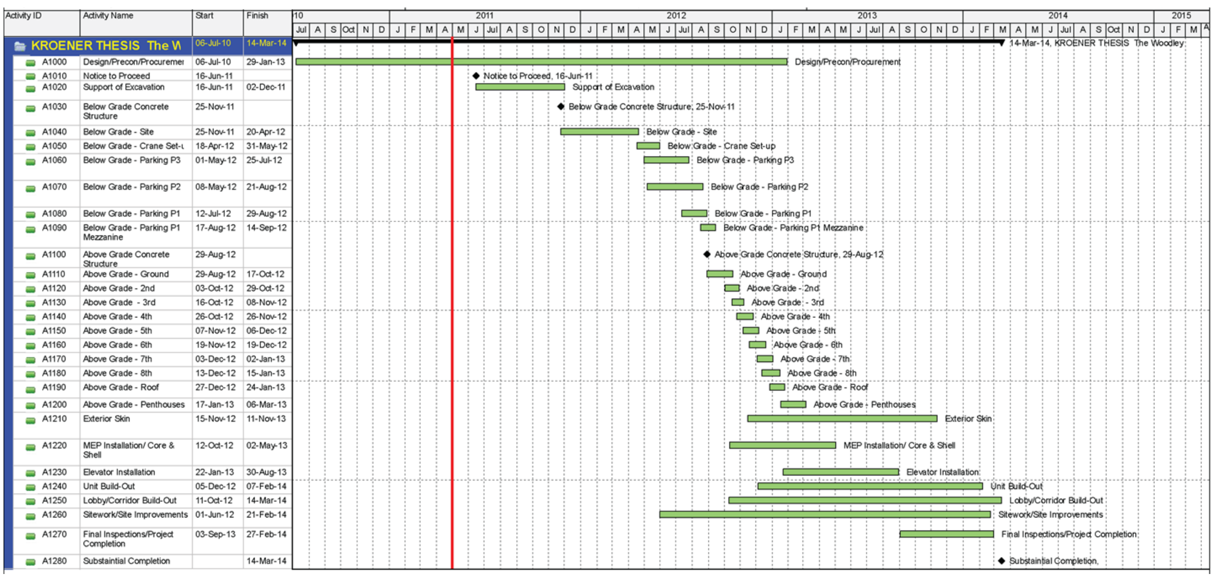
Figure B. Project Delivery and Contract System Chart



Schedule

An interesting aspect of the project schedule was that it was actually bid out in two phases. Phase 1 being the demolition of the existing parking garage and lot along with the construction of a pedestrian tunnel connecting to the existing Marriot Wardman hotel. Phase 2 was the actual construction of the residential building starting in early June of 2011 and needing with substantial completion by early March of 2014. It is worth noting that the masonry activities to construct the exterior skin of the building was a continually lagging activity that was a critical path activity due to interior finishes being dependent on the building being water and air tight. A complete project schedule for the construction of Wardman West is shown below in Figure C.

Figure C. Wardman West Residential Project Schedule



Cost

The total cost for the project was budgeted at $88,083,000 or $209.22 per square foot. This total cost includes all sitework and excavation as well as the construction of the two sub-grade parking garage levels and mezzanine fitness center. Figure D below shows the project cost breakdown.

Figure D. Wardman West Project Cost Breakdown

Project Cost Breakdown		
Item	**Cost**	**Cost/SF**
Construction Cost	**$80,916,000**	**$192.20**
Total Project Cost	**$88,083,000**	**$209.22**
Building Systems		
Structure	**$11,065,000**	**$26.28**
Mechanical	**$9,947,000**	**$23.63**
Electrical	**$6,740,000**	**$16.01**
Enclosure	**$15,297,000**	**$36.34**

Building Systems Summary

Architecture

The design of Wardman West Residential features a cast-in-place concrete structure with a brick and stone exterior facade. The structure includes eight above grade stories sized at approximately 35,000 SF with a total of 212 high-end luxury apartment residencies, as well as three below grade parking garage levels with a fitness center and 272 parking spaces. All residential units include hardwood floors, kitchen aid architect series appliances, raised panel wood carpentry and stone, stone countertops and balconies. For select units a landscaped and heavily shaded private-rooftop terrace will be accessible. The site will include an expansive outdoor courtyard with landscaped walking paths, featuring a country club style swimming pool with an infinity edge. The buildings ground floor will also include a library, residents lounge and club room. Figure E below shows a rendering of the building's rooftop terrace looking east.

Figure E. Rendering of Rooftop Terrace. Courtesy of JBG Companies

Building Enclosure

The exterior façade of the building requires extremely intricate masonry construction calling for three main veneer materials: brick, cast stone and limestone. The prefabricated cast stone and limestone pieces are anchored with engineered stone anchors adhesively attached to rigid insulation between sill joints. The brick is anchored with masonry tiebacks 16'' OC vertically and horizontally, with a 4'' pintel tying the brick veneer to the sheathing through elf drilling fastened tie back plates. Two forms of scaffolding were utilized for masonry construction of the building's exterior façade. Swing stage scaffolding was used on the south elevation due to a lack of ground staging area and the remaining North, East and West elevations using FRACO Climbing Work Platforms, allowing for a drastic reduction in scaffold installation time, in turn accelerating the already slow paced exterior masonry schedule. Excavation of the building's spread footings and two sub-grade parking levels required a soldier pile & lagging support system for its pit.

Demolition

Wardman West Residential's site required demolition of an existing multi story parking garage and the pavement of its surrounding parking lot. The sites existing conditions also called for the removal several retaining walls, elevated concrete walks, service gates and booths, vegetation and underground utility lines. Materials removed during demolition were predominantly concrete and asphalt pavement. Asbestos abatement was performed for the existing parking garage and contracted out to ACM Services, Inc. by JBG Companies.

Structure

Wardman West Residential's entire below grade and above grade structure is composed of cast-in-place concrete for all slabs, columns, foundation walls, shear walls and retaining walls. Parking levels P3 and P2 have a 5'' thick normal weight 5000 psi slab-on-grade. The upper most parking level P1 and its Mezzanine, as well as the buildings first floor, have a 8'' thick 5000 psi normal weight flat slabs with 10'x10'x5 ½'' drop panels. Floors 2 through 7 have 7 ½'' two way post-tensioned 5000 psi normal weight concrete slabs with the 8th floor calling for a thicker 10'' two way post-tensioned slab at the same type and strength to accommodate its higher floor to floor height. The roof slab is also a two way post-tensioned 5000 psi normal weight concrete slab system but at a slightly thinner thickness of 9''. The two rooftop mechanical penthouses are supported with light gauge bearing walls calling for 6'' deep 18 gauge metal studs 16'' OC. Their respected roof systems are supported by light gauge trusses spaced 4'-0'' OC. The building's shear walls enclosing all elevator pits and stairwells are all 12'' thick made of 6000 psi normal weight concrete for floors P3 through the first floor and 5000 psi normal weight concrete for the 2nd floor up to the roof.

Mechanical

Two mechanical penthouses sit atop the building's roof level servicing the buildings Cooling and Heating Water-to-Air System. The smaller north penthouse houses one of the two 25,000 CFM MUAU's which services half of the buildings water source heat pumps sized from 200 to 1500 CFM in corridors and apartment units. Located in the south penthouse is the other MUAU and a 2,450 GPM Cooling Tower, which cools all of the buildings water source heat pumps. There are also two 270 GPM gas boilers, one in each penthouse, which service the two MUAU's and WSHP's.

Electrical

The buildings main service feed comes from PEPCO by three main duct banks with 4 #750AL 4''C feeders which is stepped down into three 208/120V main switchboards, with two sized at 2500A feeing 3000A main busses and the other at 4000A feeding a 4000A main bus. From these three main busses 36 panel boards sized at either 100A or 225A feed the building's apartment units' and other spaces' panel boards.

Depth 1: Prefabrication of Brick Exterior Skin

Problem Identification

One of the major potential problems during the construction of the Woodley was the lagging brick masonry construction for the building's brick exterior façade. Brick accounts for 52% of the building's exterior skin envelope at approximately 76,225 SF of the total 147,450 SF. Windows were installed prior to exterior skin masonry, which eliminated brick from the construction schedules critical path. But brick masonry work was running behind schedule and becoming a risk to project completion. Brick masonry is typically a slow moving construction activity for any building's exterior due to the high level of craftsmanship and physical intensity of putting the material in place. Many building projects in the Washington, DC metro area, in particular residential apartment buildings and high-rises, call for brick exterior facades in their designs. Consequently, this demand for brick masonry has become a major challenge in general for project teams to maintain their construction schedules with the known problems of keeping the activity up to speed.

Analysis Goals

To effectively solve the problem of running behind schedule due to brick masonry construction this depth will analyze the use of prefabricated architectural precast concrete panels in lieu of the building's current hand-laid brick wall system. The ultimate goal of this analysis is offer the owner schedule and cost savings with the lower material cost and faster erection and installation time associated with architectural precast concrete panels. Detailed cost savings and schedule acceleration analysis will be performed to provide this benefit to the owner.

In addition to schedule acceleration and cost savings, this analysis will also aim to provide a better quality product for the building's exterior skin through the architectural precast concrete panel chosen. The product chosen should provide a more sustainable lifespan than traditional brick masonry with superior thermal energy performance characteristics, while also not deterring from the intended architectural aesthetics of the owner and architect. To achieve a suitable match for the look of the brick color used for the hand-laid brick masonry an appropriate face brick or thin brick product will be chosen to accompany the precast concrete panel product selected.

Site logistics will also be analyzed to determine if current crane sizes and locations are sufficient for the weight of panels and pick locations associated with erection and installation. Constructability will be examined as well to determine if a structural redesign is necessary through performing a structural analysis breadth. This breadth will analyze the new gravity loads placed on the building's foundation through the use of the precast concrete panels and determine if a concrete slab or foundation redesign is necessary. Constructability will also be examined by performing a mechanical breadth testing the thermal energy performance of the selected architectural precast concrete panel product in comparison to the current brick wall system of the building. This will ensure the aforementioned superior quality intended through the chosen panel product during the selection process.

Process

Preliminary Research

1. *Architectural Precast Concrete Benefits*

Aesthetics

When considering a precast concrete panelized system for a building's exterior envelope there are virtually an unlimited amount of options with unique aesthetic treatments to achieve a desired appearance. In particular, architectural inset thin-brick precast panels can create the specific appearance that an owner desires, while providing added benefits that masonry design and construction cannot. Thin-brick manufacturers often have close relationships with local precast concrete suppliers providing the advantage to owner or architect of being able to closely match an exterior brick masonry design with a thin brick color and texture. From a material cost standpoint, thin-brick is much cheaper than using a full face brick veneer and when prefabricated it provides significant economic advantages.

Using a thin-brick face significantly reduces the long scheduling needed to complete the intense labor of hand-laid brick while eliminating the cost and removal of mortar waste. Figure 1.1 shows an architectural precast concrete panel featuring a thin-brick facing. The prefabrication process of the inset thin-brick allows for a high-quality product that is evenly spaced without the associated imperfections with tradition masonry. Thin brick allows for materials to be used more efficiently, avoids problems with incorrect installation of weep holes, eliminates inconsistent labor and craftsmanship, weak mortar joints, and the effects of efflorescence. The prefabrication process also eliminates the need for on-site inspections which are taken are performed at a precast concrete plant. This ensures that a superior product arrives on site, eliminating masonry quality control and any incurred costs.

Figure 1.1. Thin-brick precast concrete panel. Courtesy of PCI.

Product Quality & Durability

As mentioned before there are advantages to the prefabrication process used when casting concrete panels in the closed environment of a plant. Factory controlled conditions offer the elimination of adverse on-site weather conditions, while providing temperature control for concrete curing, computerized factory batching and rigorous quality control that cannot be matched using on-site construction. Figure 1.2 illustrates this quality control process. Usually precast concrete plants will also be subject to semi-annual unannounced extensive quality audits by third party engineering firms as part of quality control protocol. In addition to this in-house inspection, precast concrete suppliers must also be certified based on Precast Concrete Institute (PCI) standards.

Architectural Precast concrete panels also require relatively low maintenance compared to traditional brick masonry. Panels require caulking only every 15 to 20 years to maintain the required level of performance, which is minimal upkeep in comparison with brick mortar joints. Precast concrete panels will also continue to gain strength, resulting in long-term cost savings and sustainable building value to an owner. When using panels for a building envelope there is a reduction of locations for moisture penetration, helping to prevent damage to interior finishes due to mold. Both solid and insulated sandwich (a 3”-2”-3” system where two concrete wythes enclose a layer of rid insulation) panels usually have the option of a pre-finished interior surface that can even be painted which eliminates the need for backup framing.

Figure 1.2. Precast plant quality control. Courtesy of PCI

Energy Performance

Precast Concrete panels offer the distinct advantage of having a high thermal mass which results in a high insulating value. This characteristic can also be enhanced with the use of a built in layer rigid insulation, usually between 2” and 3”, present between the two precast concrete wythes of the panel, this system is also known as a “sandwich” high performance panel. These insulated precast concrete panels often generate greater thermal gradient performance R-Values than that achievable with traditional masonry walls of equivalent thickness. On a greater scale, precast concrete panels can potentially reduce peak HVAC loads and minimize the total heating and cooling load on a building. Peak hours have been shown to shift to later hours of the day, reducing energy costs. The stated high thermal mass property of precast concrete also allows the material to absorb the heat gains produced by occupants and equipment on the inside of a building.

Cost Savings

There are many opportunities for cost savings when using precast concrete panels as far as material and construction efficiency. Precast concrete can imitate the appearance of more expensive masonry materials such as marble or limestone, resulting in significant cost savings. Veneers like the aforementioned thin brick can also be built into the exterior face of panels replacing full faced blocks of stone or brick. This lowers the cost of material while also eliminating on-site masonry labor, which consequently will accelerate a construction schedule.

As mentioned, precast concrete panels are prefabricated in closed factory-controlled environments where harsh weather conditions do not impact construction. By eliminating the effect of adverse weather during the fabrication process, panels can be erected year round and even during the cold winter months. By increasing efficiency through the erection and installation process in the field construction can fast tracked benefiting tight project schedules.

Schedule Acceleration

One of the most apparent benefits to using precast concrete panels is the speed of construction and the potential schedule acceleration that can be achieved. The design process takes less time due to the repetitive nature and lessened amount of detail required for a panelized system. PCI has standardized design for precast concrete, including wall panels, allowing quick and less complex detailing from a structural standpoint. Precast subcontractors often have experienced in-house engineering services that if brought on early during the coordination process can implement design expertise that will avoid potential problems in field that can delay construction.

The fabrication process for precast concrete panels can start long before exterior masonry construction can ever begin in the field. Production of panels can even start as early as permitting and foundation work allowing erection and installation to commence during the construction of a building's superstructure or immediately after its completion. The erection process itself is also exponentially faster than traditional masonry construction allowing a project team to meet watertight milestones for a building's exterior much more quickly. One of the unique features of the insulated sandwich panels is the option of having finished interior wall that can be "paint ready", avoiding the cost and time of furring and hanging drywall. Another schedule acceleration advantage to the finishing process for precast concrete panels is the wide variety of colors and textures of architectural veneer that can cast into the panels during fabrication at the plant.

Product Selection

1. Existing System Analysis

Figure XX. Exterior Mock-Up courtesy of Clark Construction

To effectively select an architectural precast concrete panel product the current brick wall system used for the building must be understood. Starting from the exterior the building, Glen Gery 52-DD Standard bricks (2-1/4'' by 3-5/8'' by 8'') were laid using a running bond set in a 3/8'' grapevine mortar joint (*reference Figure 1.4*) with tieback anchors 16'' on center. Flamingo Brixment Type "N" Portland Cement and Hydrated Lime blend was used for mortar. Weep holes were located at the bottom course of brick, such as, any brick ledges, relieving angles, and loose lintels. A 2'' by 10'' mortar net was also located at relieving angles and loose lintels to catch mortar droppings and to allow moisture to pass through the weep holes (*reference Figure 1.5*) and drain out through the masonry cavity. A drip edge was set directly on the L6x8x3/8 relieving angles protruding 1/4'' past the face of the brick beneath it, using Air-Bloc 31 MR compatible Henry Blueskin Thru-Wall Flashing. A 3'' Dow Styrofoam Scoreboard EPS was used for rigid insulation in front of a permeable air barrier system that separated the 5/8'' exterior gypsum sheathing. This gypsum sheathing was then fastened to 4'' x 1 5/8'' 18 Gauge Cold-Formed Metal studs at 16'' on center. An exterior mock-up of the existing wall system can be seen in Figure 1.3 above. These main components of the brick masonry wall design can be referenced in the wall section and typical relieving angle details found in Appendix A.1.

Figure 1.4. Grapevine Mortar Joint courtesy of Clark

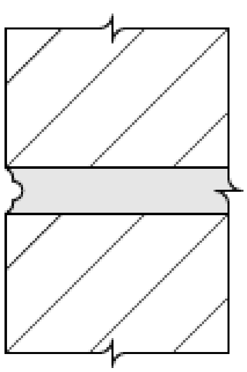
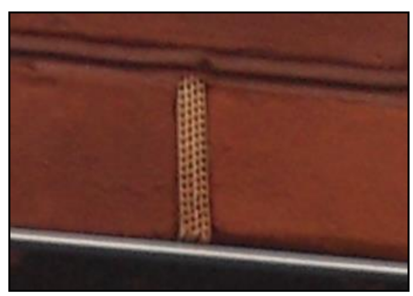


Figure 1.5. Weep Hole courtesy of Clark

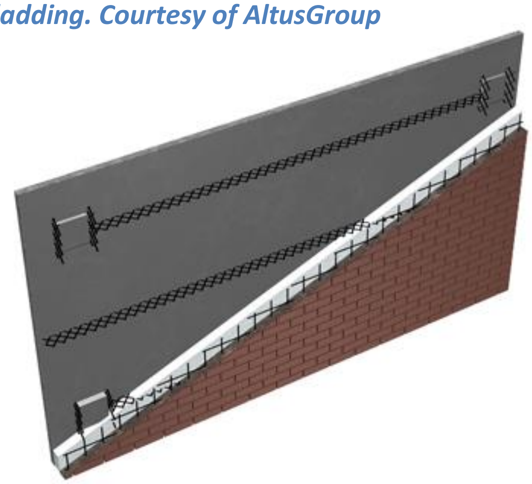


2. *Product Selection*

CarbonCast Insulated Architectural Cladding

The CarbonCast Insulated Architectural Cladding, patented by AltusGroup, was chosen as the product to be used for the precast concrete wall panel system. AltusGroup is comprised of a group of the precast concrete industries largest manufacturers and the C-GRID carbon fiber grid developer Chomarat North America. AltusGroups's focus is to develop CarbonCast technology and make it available to across North America. CarbonCast technology has allowed AltusGroup to produce a precast concrete panel that weighs 40% than that of a typical 6'' thick solid precast concrete panel.

Figure 1.6. CarbonCast Insulated Architectural Cladding. Courtesy of AltusGroup



The CarbonCast insulated architectural cladding panels consist of two concrete wythes that are thick separated by a layer of EPS, XPS or Poly Iso rigid insulation, which is similar to most insulated "sandwich" wall precast systems. However, the innovative C-GRID carbon fiber grid creates a shear connector between the two concrete wythes, which allows the panel to act as a structurally composite piece of concrete with wythes having a minimal thickness of 1 ¾''. A vertical and horizontal panel section can be referenced below in Figure 1.7 and 1.8 and other details including: miter corner connections, butt corner connections and butt joints can be found in Appendix A.2.

Figure 1.7. Vertical Section Detail. Courtesy of AltusGroup

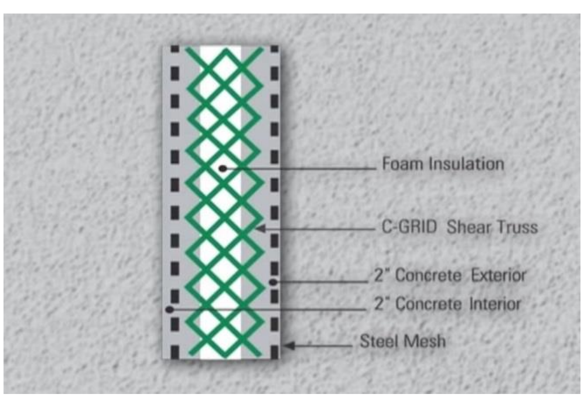
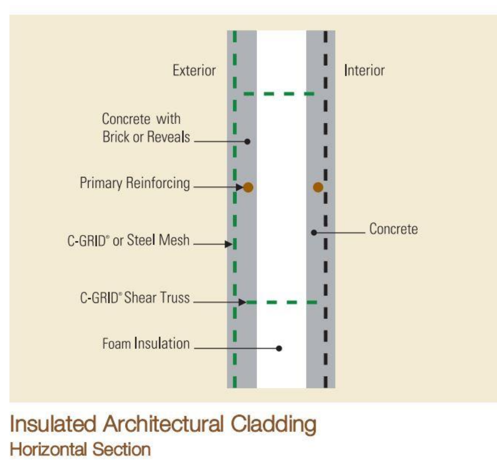


Figure 1.8. Horizontal Section Detail. Courtesy of AltusGroup



C-GRID is a non-corrosive epoxy coated composite grid made of cross-laid and superimposed carbon fiber, making its tensile strength over four times higher than steel by weight. This C-GRID technology also allows eliminates almost all thermal transfer allowing the rigid insulation to reach its full R-value of 8 or greater. Below some of the main benefits to CarbonCast technology are listed:

- Reduced load on building superstructure/foundation
- Lower transportation cost – lighter panels allow more panels to travel on one flatbed load offering better fuel consumption
- Smaller cranes can be used to pick and erect CarbonCast panels due to their lightweight design
- Lower carbon footprint
- Aesthetic Versatility
- Meets ASHRAE requirement for continuous insulation

As mentioned above CarbonCast insulated wall panels provide wide range of aesthetic options. Architectural façade elements such as window headers and sills, cornices, bullnoses and reveals can be cast into the concrete during the fabrication process of the panels. Embedded veneers such as thin brick or simulated limestone or granite can also be used instead of full blocks to reduce raw material usage. Another beneficial characteristic of CarbonCast Insulated is that it can be specified to have a prefinished interior concrete wythe that undergoes a steel trowel treatment allowing it to be smooth and durable surface ready for drywall or paint covering.

3. *Thermal Energy Performance Study (Mechanical Breadth)*

To ensure that the CarbonCast Insulated Architectural Cladding product selected had a thermal performance that meets the specifications required for the existing brick wall system a thermal energy performance study was performed. This thermal performance study consisted of calculating R-Values and a condensation analysis for the existing brick wall system and the proposed CarbonCast product.

H.A.M. (Heat, Air and Moisture Toolbox) a Quiroette Building Science Software product was used to calculate preliminary R-values and perform the condensation analysis. Figure 1.9 below illustrates the climate conditions used for the Washington, DC area and Figure 1.10 shows the H.A.M. results for the existing brick wall system, followed by Figure 1.11 showing the CarbonCast product

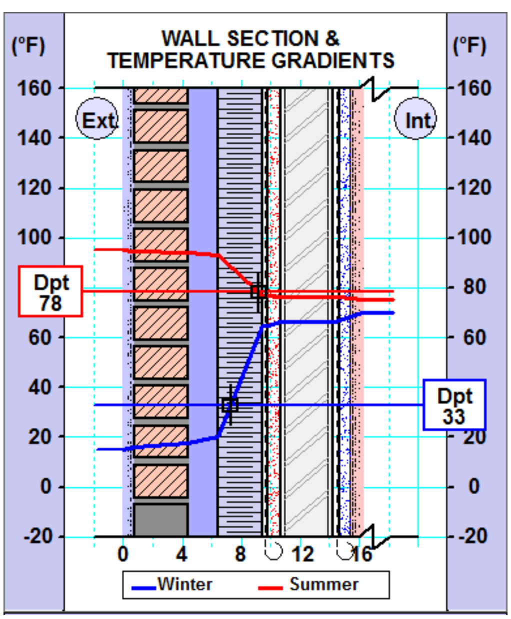
R-Value Analysis

Figure 1.9. H.A.M. Simulation Climate Conditions

CLIMATE CONDITIONS

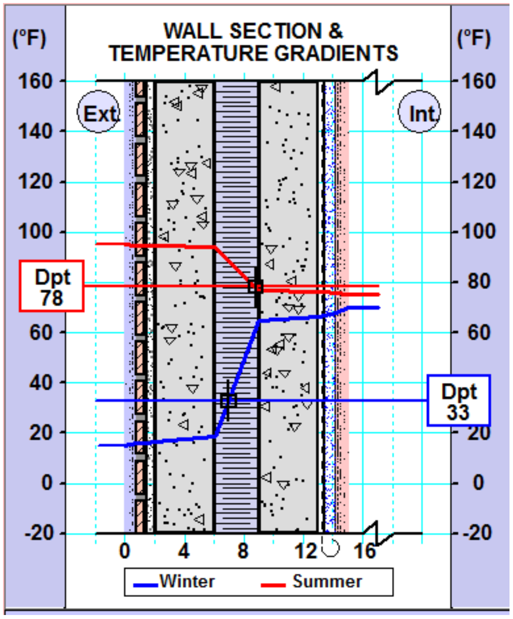
	Winter Temp(°F)	Winter RH(%)	Summer Temp(°F)	Summer RH(%)
Indoor	70	25	75	50
Outdoor	15	70	95	57
City	Washington, DC			

Figure 1.10. Existing Wall System H.A.M. R-value Simulation Results



Layer	Generic Material	Thick.	R Val.
1	air film (ext), 3/4 in.	0.75	0.17
2	brick, (vented), 4 in.	3.50	0.64
3	cavity, 2 in.	2.00	0.98
4	rigid ins.,(extru.), 3 in.	3.00	15.41
5	poly film, (4mil)	0.00	0.12
6	gypsum bd., 5/8 in., (#2)	0.63	0.46
7	steel stud, 3-1/2 in.	3.54	0.12
8	poly film, (4mil)	0.00	0.12
9	gypsum bd., 5/8 in., (#1)	0.63	0.46
10	air film (int), 3/4 in.	0.75	0.64
11			
12			
		13.30	19.11

Figure 1.11. CarbonCast H.A.M. R-value Simulation Results



Layer	Generic Material	Thick.	R Val.
1	air film (ext), 3/4 in.	0.75	0.17
2	brick, facing, 1/2 in.	0.50	0.12
3	concrete bd., 1/2 in.	0.50	0.17
4	concrete wall, 4 in.	4.00	0.58
5	rigid ins.,(extru.), 3 in.	3.00	15.41
6	concrete wall, 4 in.	4.00	0.58
7	poly film, (4mil)	0.00	0.12
8	gypsum bd., 5/8 in., (#1)	0.63	0.46
9	air film (int), 3/4 in.	0.75	0.64
10			
11			
12			
	Total or (Layer 0)	12.63	18.24

Results for the preliminary R-value comparison using H.A.M. show that the R-value for the CarbonCast product is slightly lower at 18.24 than the existing wall system's value at 19.11. This lower R-value for the CarbonCast product selected is a rough estimate for the actual R-value of the products wall section. The software has constraints where a limited amount of materials can be selected with pre-determined R-values. For instance, a minimum of 4 inch concrete wythes were available for selection, whereas, the actual product has 1.75 inch concrete wythes. Also, only a 3 inch rigid simulation material with an R-value of 15.41 could be selected when the actual CarbonCast product as a 2" XPS rigid insulation board with a 16.8 R-value. To more accurately perform this thermal gradient R-value comparison, the two wall systems' actual R-Values were hand calculated and totaled in the tables on the following page, shown in Table 1.1 and Table 1.2.

Table 1.1. Existing Wall System R-value Calculations

Material	Thickness (in.)	Density (lb./ft^3)	k (conductivity)	C (conductance or 1/k)	R-Value per Inch Thickness	R-Value
Ext. Air Film						.17
Face Brick	4	120	5.6 – 6.8		.15 - .18	.72
Air Cavity	2					1.0
EPS Rigid Insulation	3					15
Air Barrier	.002					.16
Ext. Sheathing	.625			1.78		.562
18 Ga. Metal Stud	4				.003	.12
Poly Vapor Barrier	.002					.16
Gypsum Wallboard	.625			1.78		.562
Int. Air Film						.64
Total	**14.25**					**19.094**
U-Value (1/∑R-Value)						**.052**

Table 1.2. CarbonCast R-value Calculations

Material	Thickness (in.)	Density (lb./ft^3)	k (conductivity)	C (conductance or 1/k)	R-Value per Inch Thickness	R-Value
Ext. Air Film						.17
Thin Brick Facing	.5	120	5.6 -6.8		.15 - .18	.09
Concrete Bed	.5	150	10 - 20		.08 -.14	.07
Ext. Conc. Wythe	1.75	150	10 - 20		.08 -.14	.245
XPS Rigid Insulation	2				5.6	16.8
Int. Conc. Wythe	1.75	150	10 - 20		.08 -.14	.245
Poly Film	.002					.16
Gypsum Wallboard	.625			1.78		.562
Int. Air Film						.64
Total	**8.125**					**18.982**
U-Value (1/∑R-Value)						**.057**

Based on the results from the above R-Value tables the CarbonCast product came closer to having a thermal performance R-Value that meet the existing brick wall systems approximate R-Value of 19. Although the CarbonCast product's R-Value was slightly lower than the existing system at 18.9, the architectural benefits of using a thinner wall system at approximately 8.125 feet compared to the existing system's 14.25 feet thickness, increases the overall square footage of apartment units and potentially has cost savings benefits.

Condensation Analysis

H.A.M. was also used to simulate condensation in both winter and summer climate considerations for the existing brick wall system and the proposed APC wall panel system. The simulation software created vapor pressure gradients per the two respected wall systems. Figure 1.12 and Figure 1.13 below show the winter and summer condensation simulation analysis results for both wall systems.

Figure 1.12. Existing Wall System H.A.M. Condensation Analysis

Winter Climate Conditions **Summer Climate Conditions**

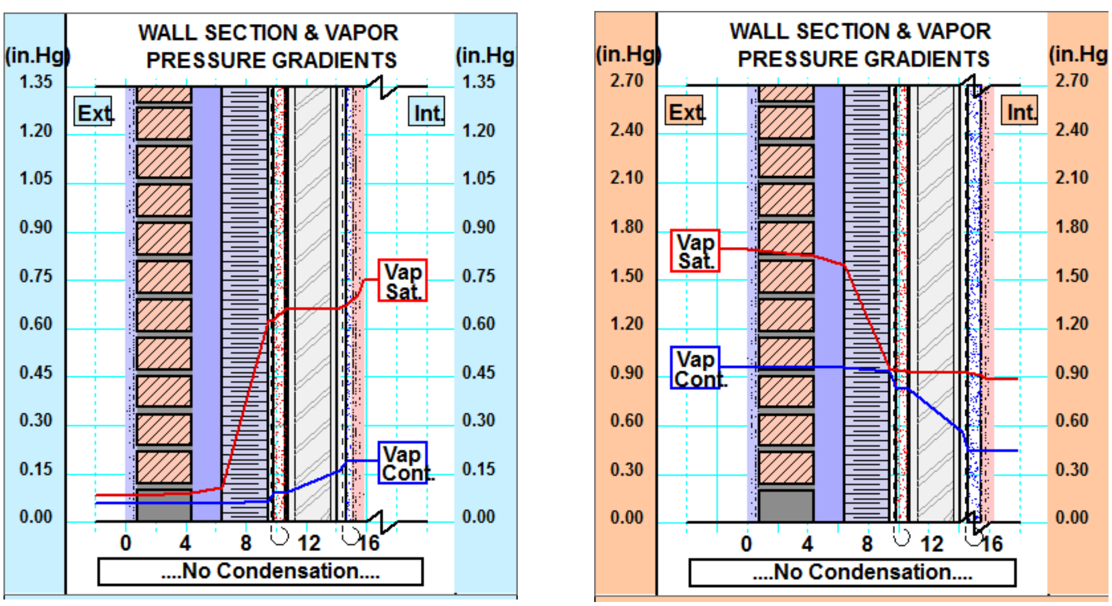
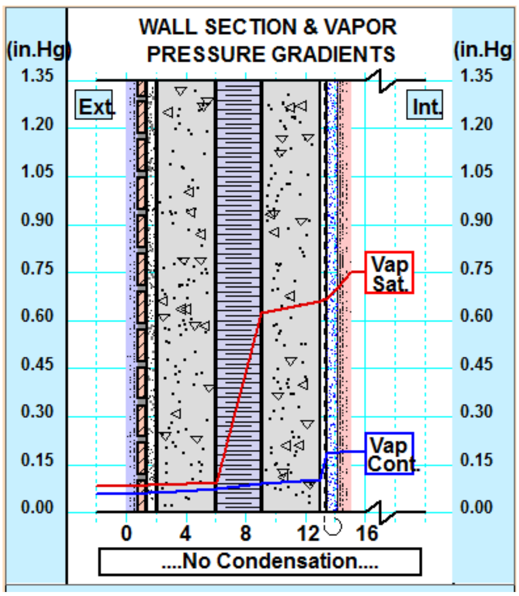
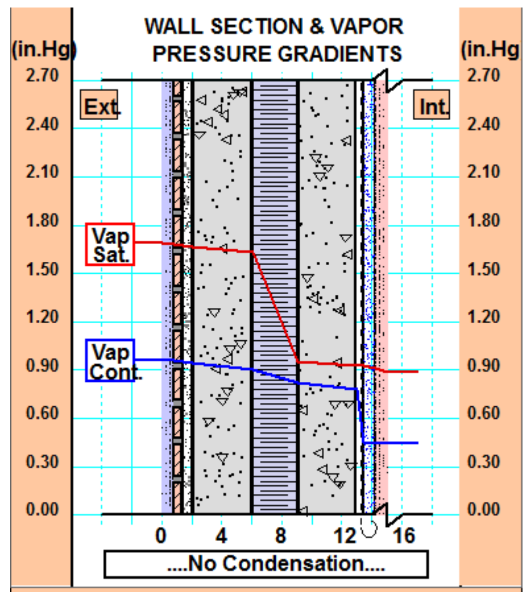


Figure 1.13. CarbonCast Product H.A.M. Condensation Analysis

Winter Climate Conditions



Summer Climate Conditions



Both wall systems performed well under the H.A.M. condensation simulation for both winter and summer weather conditions. Neither wall system resulted in a dew point or condensation point where the saturated vapor pressure gradient and the partial vapor pressure gradient meet. There is always some amount of water vapor in the atmosphere, and this amount of water vapor will typically be different on the inside of a building from that on the outside. This results in a water vapor drive across the boundary between the two locations. For these reasons it is important to design and select exterior wall systems that take into account subtle differences in atmospheric conditions, in particular the correct placement of a vapor retarder to capture for block moisture from entering into a building. Vapor retarders should strategically be placed at the anticipated dew or condensation point within in a wall or the location where the saturated and vapor pressure gradients come closest to intersecting.

Complete H.A.M. simulation results can be referenced in Appendix A.3.

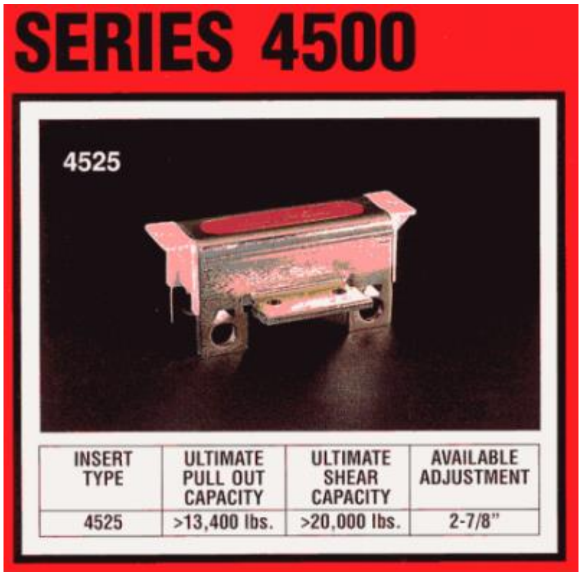
4. Design Considerations and Installation

Architectural precast concrete panels are connected to a buildings structure through either a spandrel-column system or a stacked gravity load system. A spandrel and column design or non-stacked system is a more flexible approach that allows for more shape flexibility and complexity, allowing greater story heights to be covered because panels are not stacked. However, this design system incorporates smaller panels at a greater amount which can incur a higher cost, as well as a more demanding expensive connection design. Gravity loads are also transferred to columns or slabs and not to footings, consequently if a buildings superstructure needs to be re-designed to accommodate these addition loads it can potentially add further cost fluctuation.

A stacked system does not apply gravity to a buildings structure only applying lateral pressure, wind and potential seismic loads through the panel connections to a building's slabs and columns. This technique often will offer a more typical appearance and shape of an exterior masonry building envelope. The fabrication and erection process is also usually cheaper and faster due to a more repetitive sequence. The overall gravity load applied to the building's foundation does however have to be considered when using a stacked-system to verify if a foundation re-design is required.

Figure 1.14. Series 4500 Slotted Insert. Courtesy of JVI

Figure 1.15. Series 6000 Slotted Insert. Courtesy of JVI



For both a spandrel/column or stack design system precast panels require certain lateral attachment hardware to tie into a building's superstructure. Examples of PSA slotted inserts from JVI, a manufacturer approved by AltusGroup for use with CarbonCast products, are shown on page 12 in Figure 1.14 and Figure 1.15. A full catalog for the JVI PSA Slotted Inserts can be referenced in Appendix A.4. PSA slotted insert devices are adjustable lateral tieback connection devices cast into precast concrete panels. Slotted inserts are connected at a rate of two per floor for each panel, which is illustrated in Figure 1.16 below. In locations where the next panel cannot be connected directly to a buildings slab, inserts can be used to connect the panel to panel as shown in Figure 1.17 below.

Figure 1.16. Panel-to-panel connection. Courtesy of Virginia Stone, LLC

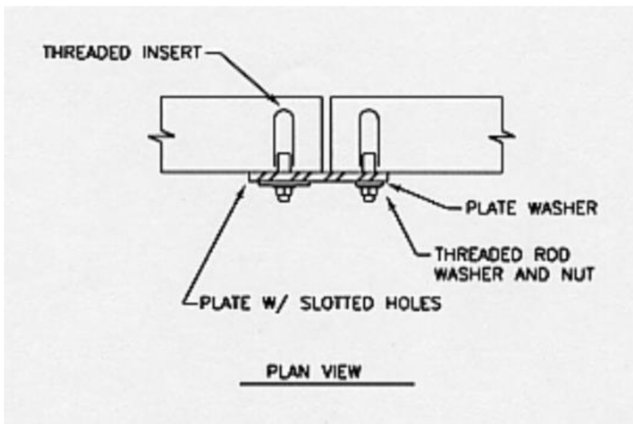
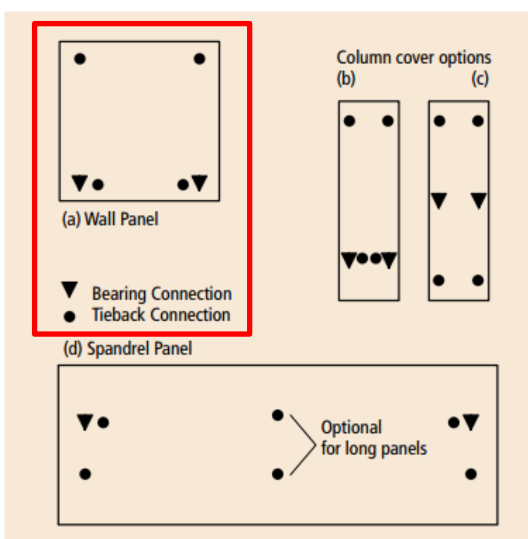


Figure 1.17. Lateral connection locations. Courtesy of PCI



Logistics & Workflow Sequence

1. Transportation Logistics

The delivery process for precast concrete panels is a very crucial aspect of transportation logistics. Precast concrete panels are shipped to a construction site on either flat bed or low deck trailers. Panels are erected right from the A-Frame of a flatbed or low deck trailer by a tower or mobile crawler crane. A low deck trailer is shown in Figure 1.18 below. Panels have built-in anchoring devices which allow this immediate pick process to happen. Before delivery to a construction site can even be considered, local transportation regulations must be taken into consideration. Most precast panels that are 12’ wide by 40’ long (which will be the maximum size used for this analysis) can be delivered without any special permits. Panels greater than 13’-6’’ wide by 50’ long usually will require tilt frame trailers, requiring special permits and escorts. One of these special tilt frame flatbed trailers is shown in Figure 1.19 below.

Figure 1.18. Low-deck trailer

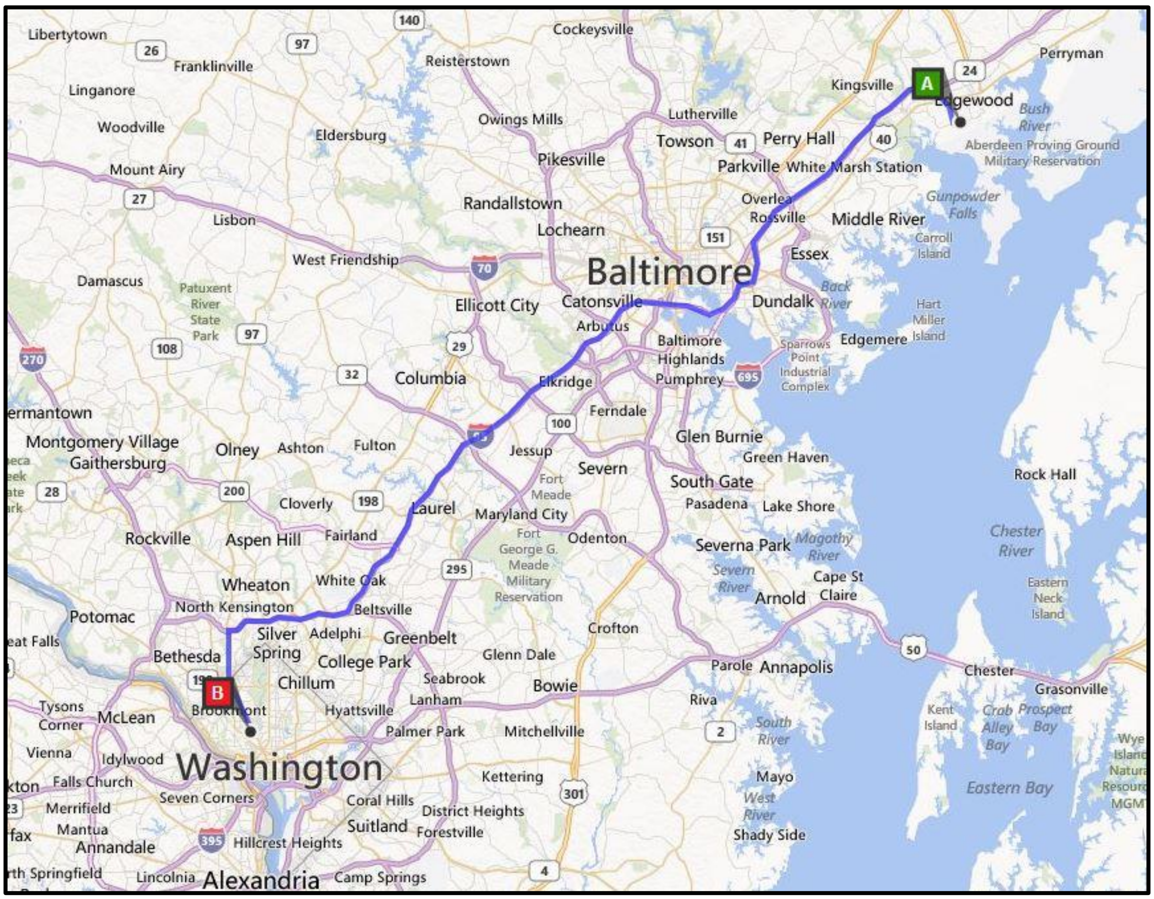
Figure 1.19. Tilt-frame flatbed trailer

Panels will not be stored on site due to the lack of space for staging and delivery present on Wardman West’s construction site. This is common practice for the typical tight constraints of residential construction projects in a metropolitan area such as Washington, DC. On-site safety and potential hazards to damaging panels also contribute in choosing not to store panels on site. When taking into account that typical erection rates for panels range from 6 to 8 pieces a day, day to day delivery and erection will provide a more efficient work flow by eliminating a buildup of un-erected panels stored on site.

One of AltusGroup’s recommended members and manufacturers is Oldcastle Precast Building Systems, who manufacture and supply the Insulated Architectural Cladding Product selected for this analysis.

Oldcastle is conveniently located in Edgewood, Maryland which is the closet location for a CarbonCast manufacturer in respect to Washington, DC. Figure 1.20 on the following page displays the shipment route from Oldcastle's plant to Wardman West's site in Northwest Washington, DC.

Figure 1.20. Panel Delivery Route

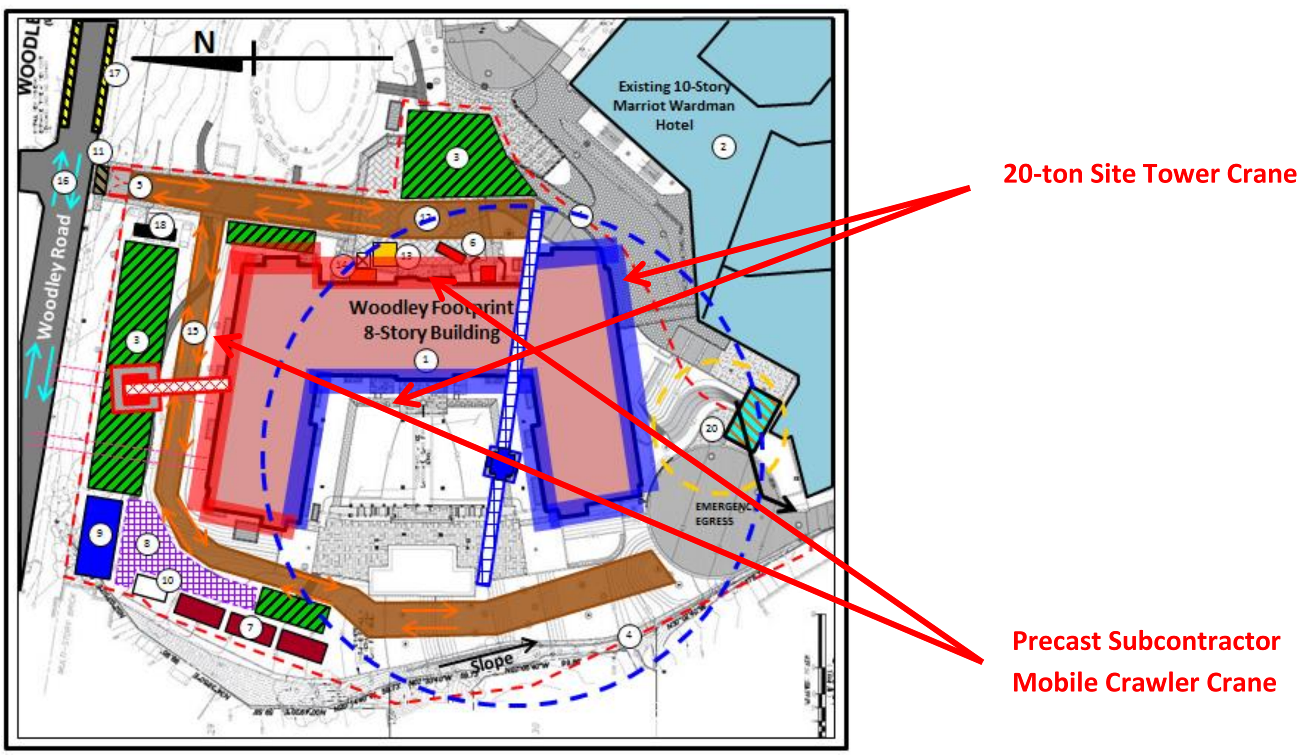


Shipping the panels from Oldcastle's plant in Edgewood, Maryland will take approximately 1 hour and 20 minutes, not including necessary stops. The travel time and location of Oldcastle's plant is fairly convenient relative to the distances to other manufacturers'' plants. Also, Wardman West is located in the Woodley Park neighborhood of Northwest Washington, DC where there are regulations that restrict construction activity to not start until 7 am. This later start to construction will give Oldcastle ample time to deliver the panels to the site on time for erection.

2. *Delivery & Crane Logistics*

On-site logistics are essential to any construction project, especially when delivering and erecting precast concrete panels. As mentioned in the Transportation Logistics section of this report, Wardman's on-site space is very limited, so the flatbeds carrying panels will enter the site through the Northeast main site gate where all deliveries enter and exit the site. Once inside the site the flatbeds will either stage along the North and East elevations where their panels will be erected by a mobile crawler crane or they will stage in below the west courtyard where their panels will be erected by a 20 ton Hammerhead Tower crane. This delivery and erection scheme is shown in Figure 1.21 below.

Figure 1.21. Erection Crane Use Sequence



The 20-ton tower crane will stay on site after it is finished being used for the building's cast-in-place concrete structure. Originally this larger of the two tower cranes was positioned within the building's footprint, but for the sake of this analysis the two tower cranes will be flip-flopped to allow the larger 20 ton tower crane to be positioned outside the building's footprint so it can be used during the building enclosure phase of construction. The original tower crane positions can be seen in Figure 1.22 below and the new positions in Figure 1.23 on the following page, showing the superstructure phase of construction.

Figure 1.22. Original Tower Crane Locations

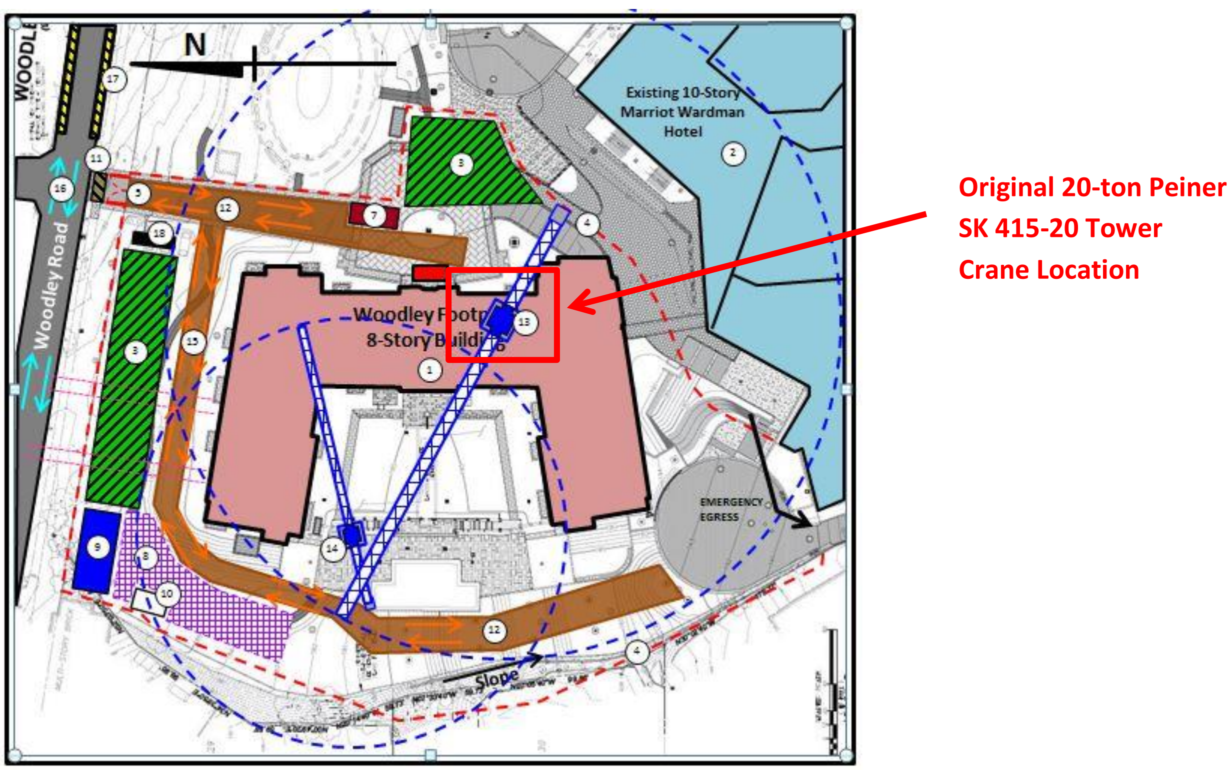
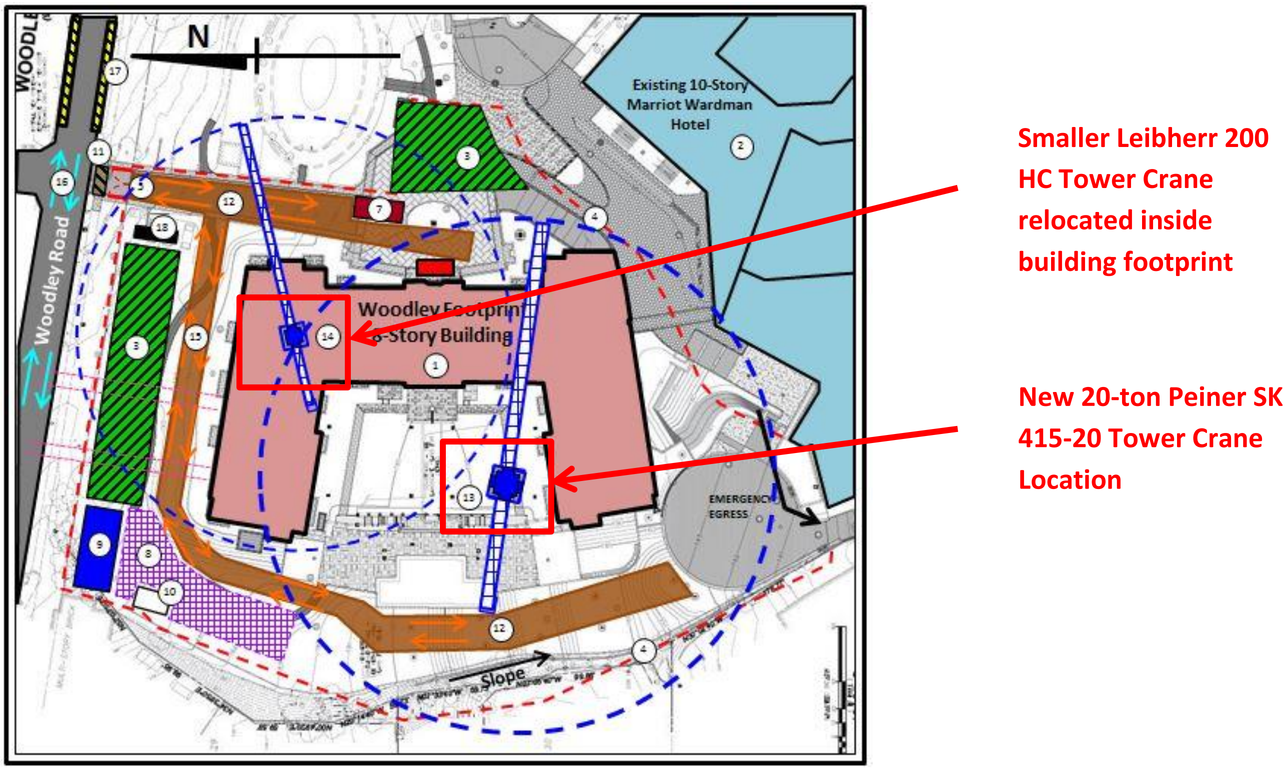


Figure 1.23. Revised Tower Crane Locations

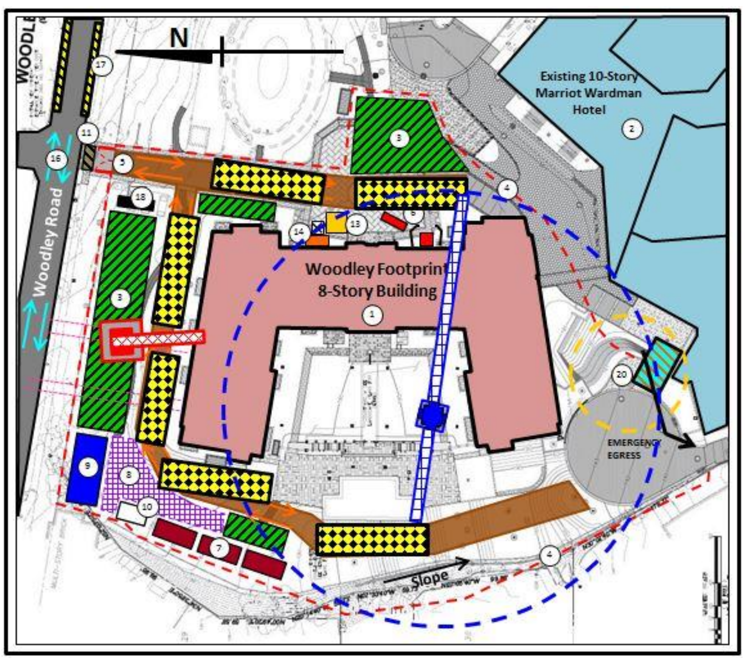


The 20 ton tower crane had to be examined further to verify if it was originally designed with a lift capacity sufficient for erecting the largest precast concrete panels brought to size. The max panel size specified by CarbonCast for their insulated Architectural Cladding is 14' wide by 30' long. However, for this analysis a max panel size of 12' wide by 30' long was used. With the panels weight ranging from 38 to 65 PSF based on thickness a lower weight of 40 PSF was used for resizing the crane. So with a max lift weight of 16,200 lbs., the original crane capacity was not sufficient at 11,680 lbs. with a 213' hook reach. To accommodate for the lack of lift capacity the crane was shortened to a 180' hook reach to increase its lift capacity to 17,200 lbs. This shortening of the hook length of the 20 ton tower crane was accounted for in its relocation outside the building's footprint. Crane design sheets and full size logistic plans used for this resizing process can be referenced in Appendix A.5.

3. Erection Logistics

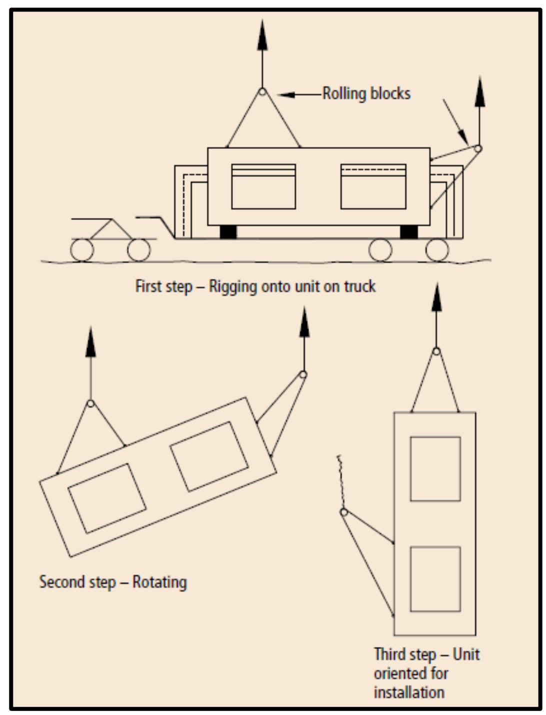
As explained earlier in the Transportation Logistics section of this analysis, once panels are delivered to a construction site the most efficient approach to the erection process is to stage the flat or low deck trailers in position and to then have panels picked and lifted directly from a trailer into place on a building's exterior. To accomplish this process adequate site space will be needed for staging the delivery trucks and the mobile crawler crane. Figure 1.24 below shows the designated staging space that would be used for erection. The East and Courtyard staging locations are ideal due to their level, stable and well-compacted soil. They are also areas built into the temporary access road which partially encircles the site.

Figure 1.24. Erection Staging Areas



Erection Staging

Figure 1.25. Rolling Block Erection Process

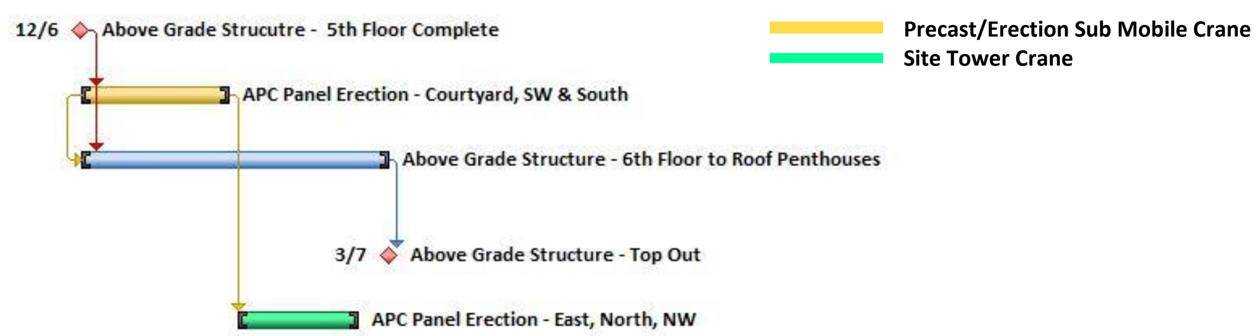


Due to panels spanning several stories at up to 30 feet in length, they cannot be simply lifted directly from a vertical position and then into place. Rather, panels will have to delivery on either an "A" or "tilt" frame on their vertical side and then rotated in the air during erection with rolling blocks. This process is shown in Figure 1.25 above.

4. Work Flow Sequence

Establishing a governing work flow sequence for an activity such as APC panel erection is absolutely necessary to ensure there are no delays in a project's schedule. Panels will be erected by elevation for Wardman West, which is typical for this method of construction. Precast and Erection Subcontractors do not favor working on different elevations simultaneously. After the 5th floor of the building finished panel erection and installation will start on December 6, 2012. In the following section the decision to start panel erection before the building's concrete superstructure is complete is explained in further detail. Knowing that the erection process will use both the site's 20 ton hammer head tower crane and the mobile crawler crane of the precast/erection subcontractor the sequencing of this crane use is crucial. The tower crane will still be needed during erection to complete the concrete structure from the 6th floor to the roof. However, erection cannot be performed with both the tower crane and the subcontractor's mobile crawler crane running at the same time. The subcontractor will expect to be erecting panels continuously with their crane is located and not agree to share erection time with the site's tower crane for the erection of a different elevation. Yet, the use of the tower crane must be a priority due to not prolong its use past the construction of the buildings concrete structure which potentially could incur additional equipment costs for the projects overall budget.

Figure 1.26. Crane Use Schedule Sequence



Knowing these constraints, erection will start on the South, Southwest and Courtyard Elevations using the site 20-ton tower crane. However, the construction of the concrete structure will not be interrupted by erection and installation of precast panels though the use of a second shift. Also, panel erection for these South, Southwest and Courtyard elevations will have to be sequenced and wrapped multiple times if necessary to not work ahead of concrete floors and columns reaching their full design strength. Once these elevations are completed using the tower crane the remaining East, North and Northeast elevations will then be erected by the precast/erection subcontractor's mobile crawler crane. Figure 1.26 above shows the sequencing used for crane use.

Schedule and Cost Analysis

1. Schedule Acceleration Analysis

The greater speed in which precast concrete panels can be erected compared to traditional exterior masonry construction is quite substantial. A comprehensive breakdown of all major activities involved in the scope of the exterior envelope had to be considered to effectively analyze the schedule acceleration obtained by using architectural precast concrete panels. This breakdown can be seen below in Table 1.3, where all exterior envelope activities and their associated durations are shown, except for the proposed architectural precast concrete panel duration. Notice that brick work for the rooftop mechanical penthouse structures was not included in the overall brick masonry duration. This brick work for the penthouses was not considered for the use of architectural precast concrete panels; therefore, it was kept separate from the original brick work when analyzing potential schedule acceleration.

Table 1.3. Existing Building Envelope Duration Breakdown

Activity	Start	Finish	Duration (Work Days)
Sheathing	13 Feb 2013	11 Jul 2013	106
Air Barrier	14 Feb 2013	12 Jul 2103	106
Windows	18 Feb 2013	15 July 13	105
Brick	8 Mar 2013	27 Sept 2013	145
Stone	9 Apr 2013	20 Sept 2013	118
Penthouse Brick	13 Aug 2013	9 Sept 2013	20
Brick Washdown & Balcony Fronts	16 Aug 2013	22 Oct 2013	67
Total Exterior Skin Duration	13 Feb 2013	22 Oct 2013	179

Table 1.4 below shows the duration and schedule acceleration for the use of architectural precast concrete panels in comparison to the original brick masonry construction. To determine the overall duration for the precast panels a productivity rate of 6 pieces erected per work day was used with an average panel square footage of 200 SF. Using a total of 69,212 SF for the area covered by panels a total duration for panel erection was calculated to be approximately 57 days, which resulted in 88 total days being accelerated, a 61% decrease in the overall duration of the original brick masonry.

Table 1.4. APC Panel Duration & Schedule Acceleration

Activity	Start	Finish	Duration (Work Days)
APC Wall Panels	13 Feb 2013	8 Jun 2013	57
Schedule Acceleration	**(compared to Brick duration)**		**88**

Although significant schedule acceleration resulted with the implementation of architectural precast concrete panels, without re-sequencing of the project schedule the new method's faster pace of construction could not be used an overall improvement to the construction of Wardman West Residential. Originally, the project's schedule installed all windows prior to installation of exterior masonry to insure the watertight milestone of July 19, 2013 was met. This was vital to ensure that interior finishes would start on schedule at the end of July. Because windows cannot be installed until after precast concrete panels are erected and installed the total duration of window installation would push the project schedule past this watertight milestone and actually delay the schedule instead of produce a reduction in overall schedule. However as long as delivery lead times are taken into consideration, the use of precast panels allows erection and installation to start before the buildings concrete superstructure is fully complete and topped out.

The buildings 5th floor slab was set to be completed on December 6, 2012, which is an adequate point at which precast panels can start to be erected. This earlier start for panel erection will allow window installation to start by February 26 2013 and end in time to meet the watertight milestone of July 19, 2013. The below Table 1.5 shows these revised start and finish dates for enclosure activities and the overall schedule acceleration for the exterior skin phase of construction. The overall duration for construction of the building's exterior envelope is longer at 207 days but by starting erection of panels during the construction of the buildings superstructure, there is an earlier finish date for the entire building envelope on September 23, 2013. This earlier finish date results in a total schedule acceleration of 14% at 28 days or approximately one month. A complete original, as well as new schedule using the precast panels and re-sequencing scheme can be referenced in Appendix A.6

Table 1.5. APC Wall Panel Revised Duration Breakdown

Activity	Start	Finish	Duration (Work Days)
APC Wall Panels	**6 Dec 2012**	**26 Feb 2013**	**57**
Windows	26 Feb 2013	19 July 13	105
Stone	12 Apr 2013	23 Sept 2013	118
Penthouse Brick	21 Aug 2013	17 Sept 2013	20
Balcony Front Brick	20 Aug 2013	20 Sept 2013	23
Revised Ext. Skin Total Duration	6 Dec 2012	23 Sept 2013	207
Schedule Acceleration w/ Earlier Finish Date			28

2. *Cost Savings Analysis*

In addition to schedule acceleration, one of the major goals of this analysis was to produce cost savings to ultimately save money for the owner and increase the amount of savings sharing possible for Clark. Table 1.6 below shows the cost breakdown for Wardman West's original brick masonry system. In this table you will notice that in addition to brick; backup, sheathing and insulation are incorporated into the overall cost for the system. With the CarbonCast insulated "sandwich" panel chosen this backup, sheathing and insulation will not be necessary if the precast panels are used; therefore, this line item must be included to show a potential reduction in cost. Limestone was also included for this reason. The limestone headers, jambs and sills present through the building's exterior skin will be cast into the APC panels using a finished concrete similar in appearance to that of the limestone.

Table 1.6. Existing System Cost Breakdown

Item	Amount
Brick	$2,676,060
Backup, Sheathing and Insulation	$55,834
Metals	$292,500
Misc.	$246,375
Limestone	$843,570
Total	**$4,114,339**

The total cost of the original brick masonry system and its additional scope was approximately $4.1 million. A per square foot cost of $40/SF was used for APC panels based on rough pricing information from Gate Precast. Table 1.7 below shows the cost breakdown for the proposed APC panels. Notice that brick for the rooftop mechanical penthouses was not part of the APC panel scope of work and was included in this cost breakdown for comparison. The total cost of new APC panel system was approximately $3.4 million resulting in a saving of 18% at $736,866. For a more detailed breakdown of the line items including square foot pricing, reference Appendix A.7.

Table 1.7. APC Wall Panel System Cost Breakdown

Item	Amount
Architectural Precast Concrete Panels (including attachment hardware)	$2,768,480
Penthouse Brick	$205,905
Metals	$292,500
Misc.	$110,588
Total	**$3,377,473**

Constructability

1. APC Panel Structural Feasibility & Redesign Study (Structural Breadth)

To ensure that architectural precast concrete panels were structurally feasible as a substitute for the existing brick wall system; applied wind loads, seismic loads and lateral attachment details were evaluated. The evaluation of the lateral forces applied by wind and seismic loading was performed to help determine suitable hardware for lateral attachment of panels to the building's concrete frame. Below the wind and seismic loads are summarized, but complete procedures, calculations and code references can be found in Appendix A.8.

Building Location – Washington, DC

Building Code – IBC 2006 / ASCE 7-05

Wind Loads

To determine the effect of wind loading, the building was considered enclosed. The building was also classified as rigid per Section 6.2 of ASCE 7-05 with a natural frequency of 1 HZ. Based on these conditions, Method 2 – Analytical Procedure as defined in Section 6.5 of ASCE 7-05 was used for developing wind loads.

Table 1.8 below shows the wind evaluation factors determined used Method 2 – Analytical Procedure (ASCE 7-05, Section 6.5.3)

Table 1.8. Method 2 – Analytical Procedure Wind Evaluation Factors

Factor	Variable	Value	Code
Basic Wind Speed (*mph*)	V	90	*Section 6.5.3, Figure 6-1*
Wind Importance	I	1.0	*Section 6.5.3, Table 6-1 and Table 1-1 for Building Occupancy Category II*
Wind Directionality	K_d	0.85	*Section 6.5.3, Table 6-4*
Velocity Pressure Exposure Coefficient	K_h	1.04	*Section 6.5.3, Table 6-3 based on Exposure Category B from Section 6.5.6.3*
Topographic	K_{zt}	1.0	*Section 6.5.7*
Internal Pressure Coefficient	GC_{pi}	+/- 0.18	*Section 6.5.11.1, Figure 6.5 for enclosed buildings*
External Pressure Coefficient (*windward*)	GC_p	+ 0.62	*Section 6.5.3, Figure 6-17 for Zone 5 wall edge zone and building height > 60 ft*
External Pressure Coefficient (*leeward*)	GC_p	-1.1	*Section 6.5.3, Figure 6-17 for Zone 5 wall edge zone and building height > 60 ft*
Velocity Pressure $q_h = 0.00256\, K_h K_{zt} K_d V^2\, (lb./ft^2)$	q_h	18.3	*Section 6.5.10*

The most extreme wind exposure condition was used for the Method 2 – Analytical Procedure, at the edge of the panel and at the top of the building. The panel's maximum dimensions for height and width were assumed to be 30 feet and 12 feet. These dimensions resulted in the entire surface area of the wall edge panel having to withstand the heightened wind pressure in the Zone 5 region. Based on Section 6.5.12.4.2 for Components and Cladding and a building height h > 60 ft., maximum wind pressures were then calculated on the edge panels.

For windward exposure:

$$\boldsymbol{P = q_h \times (+GC_p) - q_h \times (-GC_{pi})(^{lb.}/_{ft.^2})}$$

$$\boldsymbol{P = 18.3 \times (+0.62) - 18.3 \times (-0.18) = 14.64\ ^{lb.}/_{ft.^2}}$$

For leeward exposure:

$$\boldsymbol{P = q_h \times (-GC_p) - q_h \times (+GC_{pi})(^{lb.}/_{ft.^2})}$$

$$\boldsymbol{P = 18.3 \times (-1.1) - 18.3 \times (+0.18) = 23.4\ ^{lb.}/_{ft.^2}}$$

Based on the above, the maximum suction force on a leeward edge panel during an extreme wind event will be: ***23.4 lb. / ft.² x 30 ft. x 12 ft. = 8,424 lb***. and will govern the design for the hardware required for lateral attachment of the panels to the concrete frame.

Seismic Loads

To determine the effect of seismic loading on the precast wall panels, ASCE 7-05 was used for the development of seismic ground motion values for the site and methods for calculating loads on the structure of the building resulting from those ground motions. First seismic ground motion values were determined based on Mapped, Site Adjusted, and Design Spectral Acceleration Parameters. Tables 1.9 through 1.11 below summarize these seismic ground motion values and their calculations.

Table 1.9. Seismic Ground Motion Values – Mapped Acceleration Parameters

Parameter	Value	Code
S_s (*short period acceleration*)	0.154	Section 11.4.1, Figure 22-1
S_1 (*1-second acceleration*)	0.05	Section 11.4.1, Figure 22-2

Table 1.10. Seismic Ground Motion Values – Site Adjusted Acceleration Parameters

Parameter	Value	Code
F_a (Site Class C)	1.2	Section 11.4.2 and Section 11.4.3, Table 11.4 -1
F_v (Site Class C)	1.7	Section 11.4.2 and Section 11.4.3, Table 11.4 -2
S_{MS} $(S_{MS} = F_a \times S_S)$	0.185	Section 11.4.3
S_{M1} $(S_{M1} = F_y \times S_1)$	0.085	Section 11.4.3

Table 1.11. Seismic Ground Motion Values – Design Spectral Acceleration Parameters

Parameter	Value	Code
S_{DS} ($S_{DS} = {}^{2}/_{3} \times S_{MS}$)	0.123	Section 11.4.4
S_{D1} ($S_{D1} = {}^{2}/_{3} \times S_{M1}$)	0.056	Section 11.4.4

With seismic ground motion values determined the horizontal thrust force on a typical 30 ft. by 12 ft. panel was calculated. The seismic force calculation is based on Equation 13.3-1 in Section 13.3 of ASCE 7-05, which covers seismic demands on non-structural architectural components.

The horizontal seismic deign force F_P is as follows:

$$F_p = \left(\frac{0.4\, a_p\, S_{DS} W_p}{\left({}^{R_p}/_{I_p} \right)} \right) \times \left(1 + \left(2 \times {}^{z}/_{h} \right) \right)$$

Where:

a_P = 1.0; component amplification factor, Table 13.5-1 z = h, therefore z/h = 1.0

R_P = 2.5; component response modification factor, Table 13.5-1

I_P = 1.0; component importance factor, Section 13.1.3

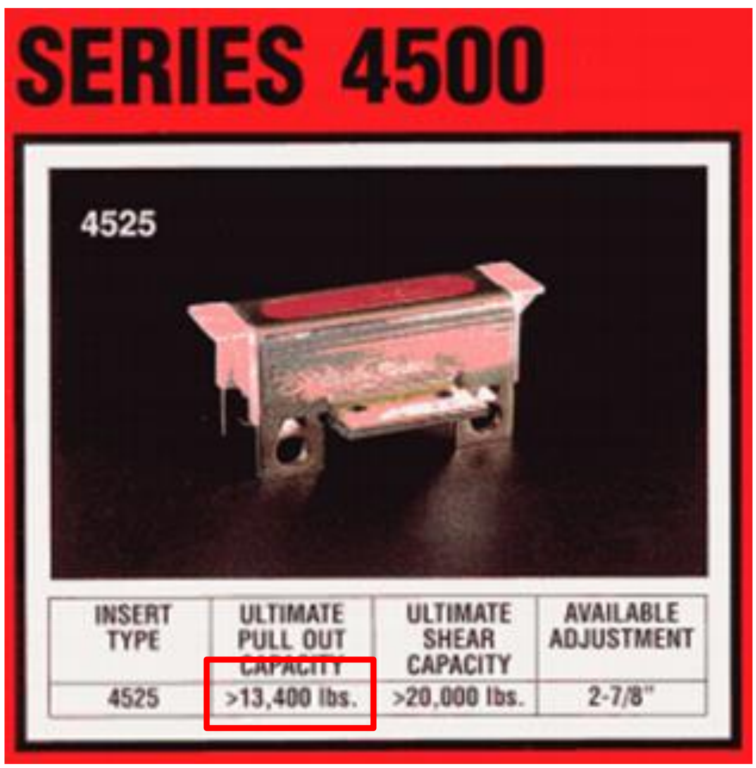
W_P = component weight – 13ft. x 12 ft. x 40 lb./ft.^{2} = 14,400 lb.

Based on working through the above equation, the horizontal seismic force exerted by a typical precast panel on its anchorage system is 850 lb. This force is only 10% of the force caused by an extreme wind event and will not govern the design of the lateral anchorage system for the precast panel.

Hardware Design

JVI is an AltusGroup approved manufacturer of slotted inserts for use as lateral attachment hardware for the CarbonCast Insulated Architectural Cladding product selected for this analysis. The below JVI PSA slotted insert was specified using the maximum suction force of 2,106 lb. per connection point (*assuming each panel will have four lateral connection points, therefore, dividing the total suction of 8,424 lb. by four*). Using the 4500 series, which feature a 2-7/8" adjustment, insert type 4525 was chosen with an ultimate pullout capacity of 13,400 lbs. To check if the insert would withstand the maximum per connection suction force the ultimate pull out capacity was divided by five resulting in a working pull out capacity of 2,680 lb. Therefore, the 4500 Series PSA Slotted Insert Type 4525 can be specified for use at lateral attachment hardware withstanding the most extreme wind loading condition reaching 2,106 lb. of maximum suction force. The JVI product is shown in Figure 1.27 below.

Figure 1.27. JVI Series 4500 Slotted Insert Type 4525



Lateral Attachment & Spandrel Beam Redesign

A comparison of self-weight was evaluated for both the existing brick veneer wall and the architectural precast concrete panels. Below the unit weights for both wall systems are listed below.

Existing Brick Veneer Wall System:

Brick Veneer (Standard Clay Brick) – 40 PSF
3" Rigid Insulation – 4.5 PSF

Total – 44.5 PSF

New APC Wall Panel System:

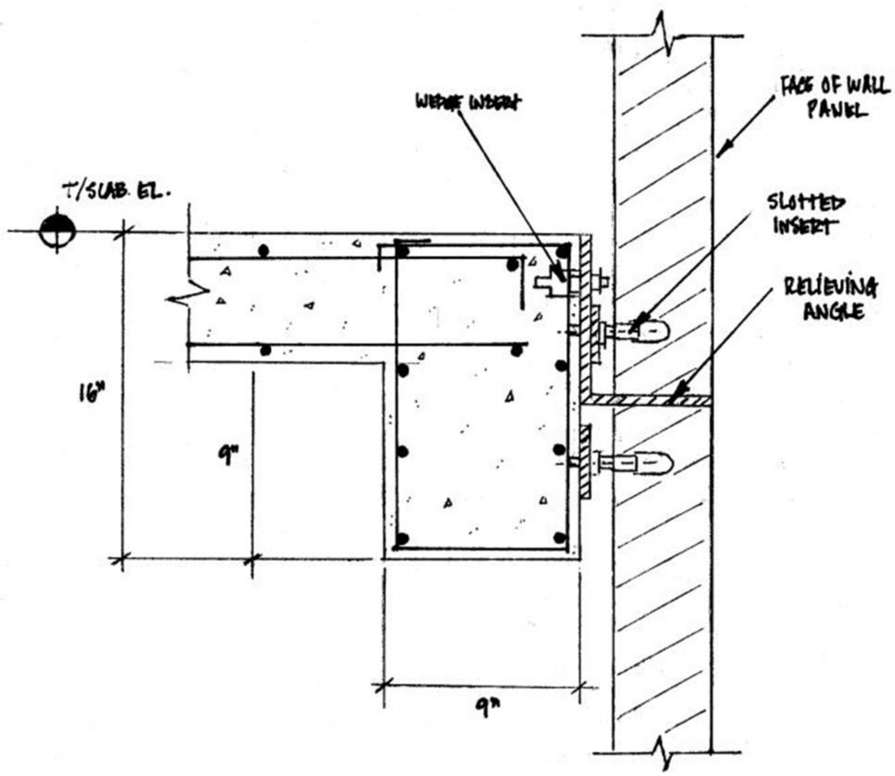
CarbonCast Insulated Architectural Cladding – 40 PSF

Based on the above self-weight comparison, the proposed CarbonCast Insulated Architectural Cladding has a lower a self-weight than the existing brick veneer wall system. Therefore, the change to a precast wall panel system will not result in a greater load on the building superstructure and foundation, eliminating the need for slab and column re-design.

A spandrel system was used for attaching panels to the structure of the building, instead of the common stacked system. Panels were vertically supported by relieving angle connected to the edge of the floor slab as per the typical relieving angle location used for the existing condition. It should be noted that this relieving angle will not be same product as was used for the brick veneer wall due to the greater amount of weight it was required to support from panels spanning up to 30 feet, resulting in a total panel weight of up to 14,400 lb. The relieving angle will also have a prefabricating bolt connection for the lateral attachment of the slotted insert specified on page 36.

A spandrel beam with a total depth of 16'' and width of 9'' was also added to the edge of the floor slab in each respected panel connection location. This spandrel beam provided and area for the top of each panel to be laterally connected to the structure of the building, as well as to provide further support. Bending and shear checks, as well as reinforcement sizing can referenced in Appendix A.10. Figure 1.28 on the following page shows a connection detail for the proposed welded connection that will vertically and laterally support the precast concrete wall panels, which can be referenced at a large scale in Appendix A.9

Figure 1.27. Vertical and Lateral Welded Connection Detail



Recommendations

Based on the results from this analysis, the switch to architectural precast concrete wall panels in lieu of the existing brick veneer wall system should be implemented. The erection of the precast concrete wall panels would allow the building's wall system to be completed 88 days faster and reduce the overall building enclosure schedule by over a month at 31 days. The implementation of precast concrete wall panels would also save the owner approximately $737,000 with a total cost of $3.4 million, an 18% reduction in cost from the existing brick veneer wall system's total cost of $4.1 million, and furthermore, a 4.8% reduction in the overall cost of the building's exterior enclosure.

Depth 2: SIPS

Problem Identification

The problem for this analysis is the same problem addressed in first proposed analysis where brick exterior skin masonry construction was a risk to the project meeting substantial completion due to the activity's lagging pace of production. As mentioned before brick accounts for roughly 52% of the exterior envelope's square footage and has construction schedule duration of approximately 6 months, starting in March of 2013 and ending in October 2013. Finding a way to shorten the construction schedule and increase worker productivity for this activity would be very beneficial to the success of the project.

Analysis Goals

As stated above the intent of this analysis is to provide schedule acceleration. A SIPS or short interval production schedule is used for this specific reason, as well as to increase labor productivity. A SIPS breaks down a construction activity or scope of work into a greater amount of detail than a typical project schedule. The activity or scope of work being performed is quantified and split up into multiple construction zones to develop a more specific work sequence. These construction zones should be approximately the same size and share a similar design so that a trade or team the same amount of time to complete each zone. In doing this a SIPS allows for very efficient allocation of manpower, as well as providing a simple, yet detailed schedule for trades use. This amount of detail allows tradesmen to always know what they should be performing up to the hour or even minute at any point through the work day. Once these zones are established productivity rates are found and used to calculate durations for the chosen activity or the multiple activities within a scope of work.

A SIPS is typically used for projects that are highly repetitive such as precast parking garages, residential high-rises, apartment buildings and prisons. Projects such as these with repetitive layouts or repeating scopes of work allow for application of the construction zones stated earlier. In case of Wardman West Residential, it will be an applicable project for a SIPS with the repetition present throughout design the building's exterior envelope.

A SIPS will be developed for both for the original exterior brick masonry work and for the prefabricated architectural precast concrete panels used in the first analysis. Each scope of work will include a SIPS matrix schedule used to track the completion of construction zones and also a revised project schedule. These two SIPS for brick and ACP panels will then be compared and evaluated for advantages and disadvantages to determine which scope of work benefits to most from the use of a SIPS.

Process

Analysis of Original Schedule

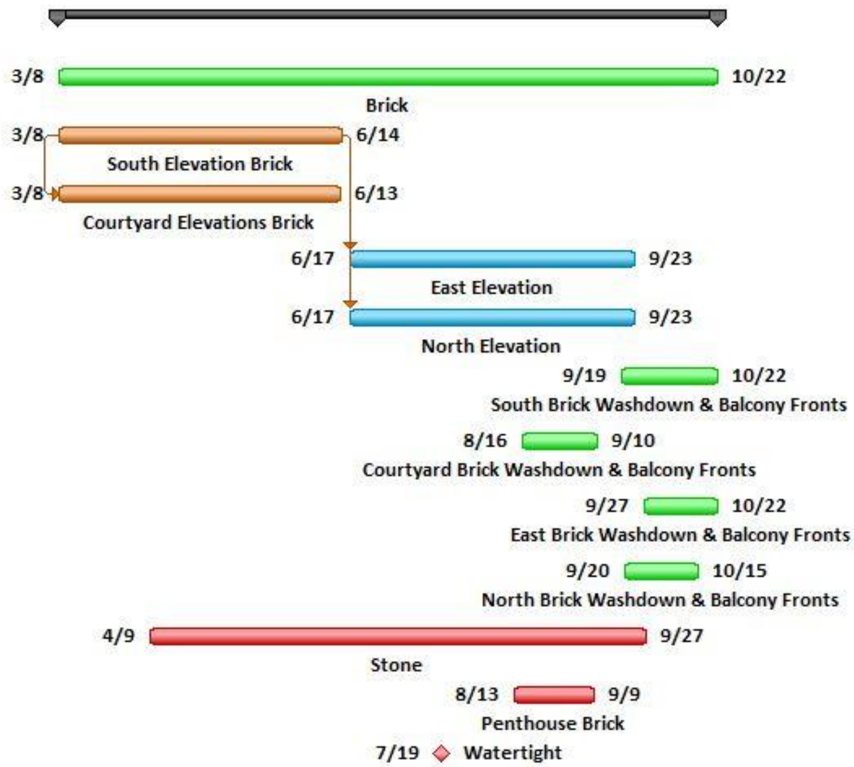
To effectively develop a SIPS schedule for both brick masonry and architectural precast concrete panels the original project schedule for the building's exterior envelope has to be examined. First, the start and end dates for brick construction each elevation was determined. Once, these dates were found the net amount of workdays between the dates was calculated to find a total number of workdays associated with the building's brick exterior skin. Table 1.12 illustrates the elevations and durations found. Note that brick washdown and balcony front brick detailing follows the main brick masonry construction for each elevation. This activity must be accounted for in the overall duration but it will not be incorporated into the overall analysis for the SIPS schedules created for brick masonry and ACP panel erection.

Table 2.1. Original Schedule Elevation Durations

Elevation	Activity	Start	Finish	Duration
South	Brick	8 Mar 2013	15 June 2013	71
	Washdown & Balcony Fronts	19 Sept 2013	22 Oct 2013	33
Court	Brick	8 Mar 2013	13 June 2013	69
	Washdown & Balcony Fronts	16 Aug 2013	10 Sept 2013	25
East	Brick	15 June 2013	20 Sept 2013	69
	Washdown & Balcony Fronts	27 Sept 2013	22 Oct 2013	25
North	Brick	15 June 2013	20 Sept 2013	69
	Washdown & Balcony Fronts	20 Sept 2013	15 Oct 2013	25
Total		8 Mar 2013	22 Oct 2013	162
Total (excluding washdown & balcony fronts)		8 Mar 2013	27 Sept 2013	145

Based on the durations calculated in the above Table 1.12, typical elevations took on average 69.5 days to complete, not including brick washdown and balcony front detailing. The south elevation durations were slightly longer due to the use of swing stage scaffolding instead of FRACO mast-climbing hydraulic platforms, which the other three elevations used to scale the building. It is also noticeable that brick masonry was performed on the south and courtyard elevations concurrently, then followed by the east and north elevations. This sequencing breakdown is illustrated on the following page in Figure 1.29 and can also be referenced in Appendix B.1

Figure 2.1. Original Schedule Brick Elevation Sequencing

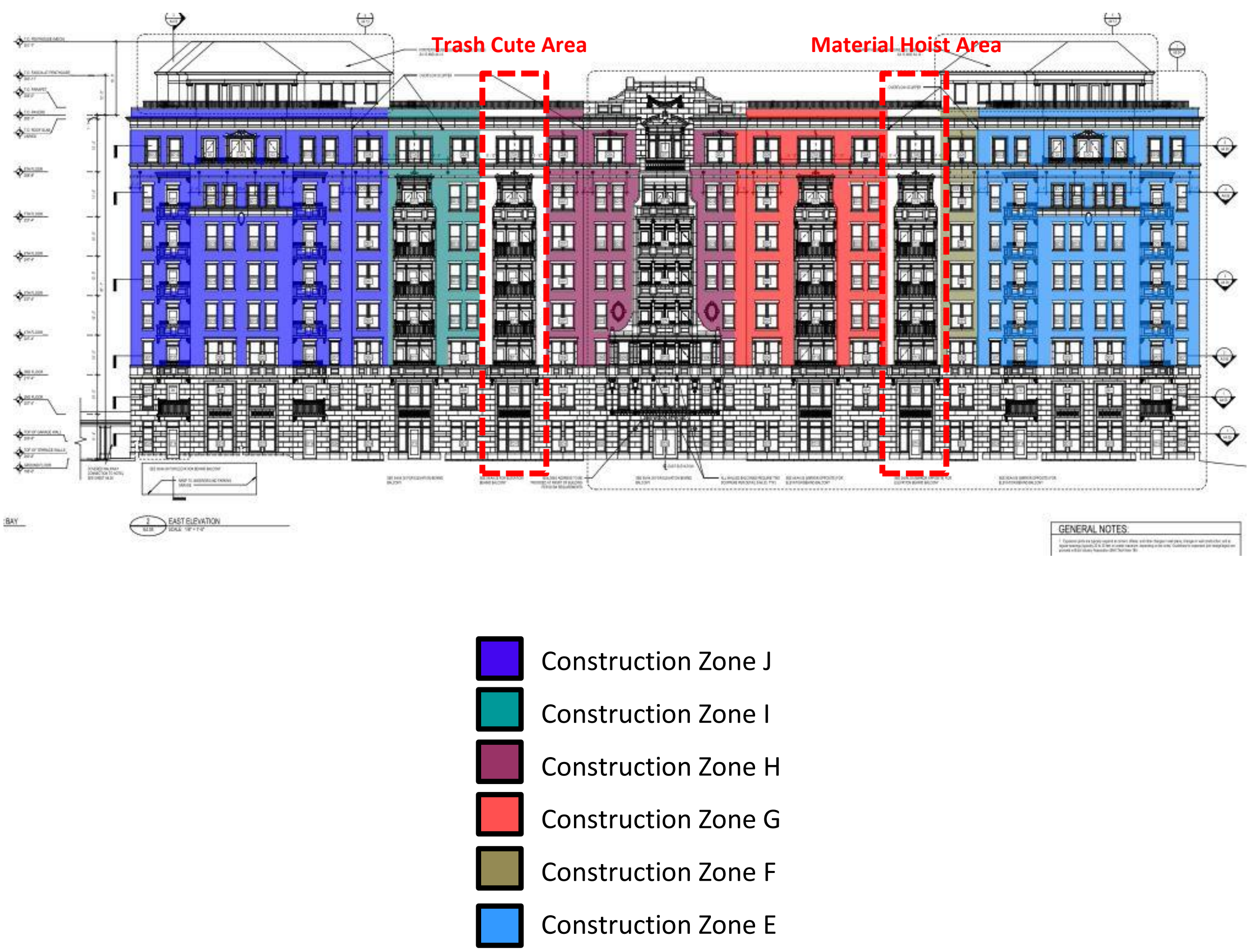


SIPS for Brick

A SIPS schedule was created for the original brick masonry work for the building's exterior skin to predetermine if the overall schedule for brick work could be shorted and productivity could be increased. Before productivity rates and durations could be calculated in developing a SIPS schedule for brick masonry construction, construction zones for the buildings elevations has to be established.

Figure 2.2 below shows the construction zone breakdown for the building's east elevation. All elevations with construction zone breakdowns can be referenced in Appendix B.2.

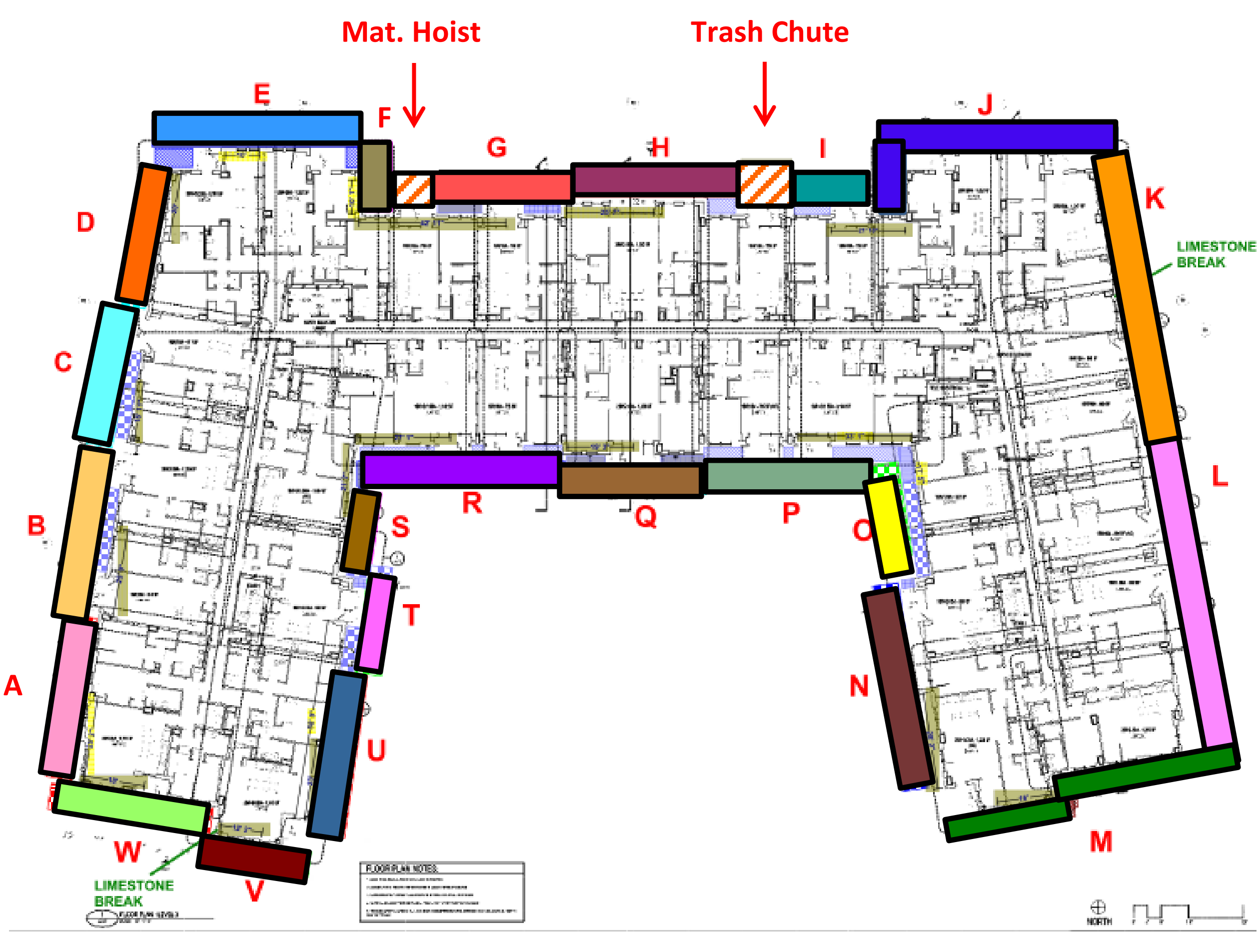
Figure 2.2. East Elevation Brick SIPS Construction Zone Breakdown



These construction zones were established based on the locations of the site's scaffolding. Exterior masonry was performed primarily on FRACO mast-climbing hydraulic platforms, with exception of the building's south elevation where swing stage scaffolding was used. The site's grade severely drops adjacent to the south elevation next to existing Marriot Wardman Hotel. Due to the ground not being flat and stable in this location swing stage scaffolding was required to perform exterior masonry work.

Below Figure 2.3 illustrates the scaffolding plan used for construction of the building's exterior skin, which is color coordinated with the construction zones used for SIPS. In Appendix B.3 a larger version of this scaffolding plan can be found, as well as another additional scaffolding plan which is color coordinated based on scaffold type and size.

Figure 2.3. Brick SIPS Construction Zone Scaffolding Plan



Once construction zones for the building's elevations were determined productivity rates and durations were calculated. The below assumptions and constraints were made and considered when calculating these duration and sequencing.

Assumptions and Constraints

- Scaffolding installation time was not included in SIPS analysis
- Wash-down and brick balcony fronts were not included in SIPS analysis
- Mortar was considered a non-critical activity that could be performed concurrently with brick laying
- Masons were assumed for work a total of 6 hours per 8 hour workday to account for unforeseen material and weather delays and a 1 hour lunch break
- A maximum of 5 masons working per FRACO Zone
- A maximum of 10 masons working per Swing Stage Zone
- A maximum of 20 masons working per day
- 6.55 bricks per SF (Standard Size brick at 2-1/4'' by 3-5/8'' by 8'')

The productivity rates used for the brick masons were not a constant rate for every level of the building. Clark Construction provided a typical rate of 200 bricks laid per day by one mason. Because the design of Wardman West's façade is more intricate than a typical brick skinned building a lower rate of 175 bricks was used. To account for the decrease in productivity as masons work at higher story-levels a decrease of 5 bricks per floor was incorporated into duration calculations starting with the 4th Floor. Table XX. Below shows this productivity rate breakdown per floor level.

Table 2.2. Floor Level Brick Productivity Rates

Floor Level	Productivity Rate (per mason)
1	175 brick/day
2	175 brick/day
3	175 brick/day
4	170 brick/day
5	165 brick/day
6	160 brick/day
7	155 brick/day
8	150 brick/day

After determining productivity rates durations were calculated for each floor level per the construction zones used for SIPS. Figure XX is a sample calculation showing how these per floor zone durations for 4th floor of Zone E of the east elevation using three masons on a FRACO.

Figure 2.4. Sample Brick SIPS Sample Calculation

4th Floor – Zone E (East Elevation)

Total Area – 375 S.F.

$$\mathbf{375\ S.F.\ \times \frac{6.55\ brick}{S.F.} = 2,457\ brick}$$

$$\mathbf{2,457 \div \left(170\ \frac{brick}{per\ mason} \times 3\ masons\right) \times 1.25\ (6\ hrs.\ of\ labor)\ = 6\ days}$$

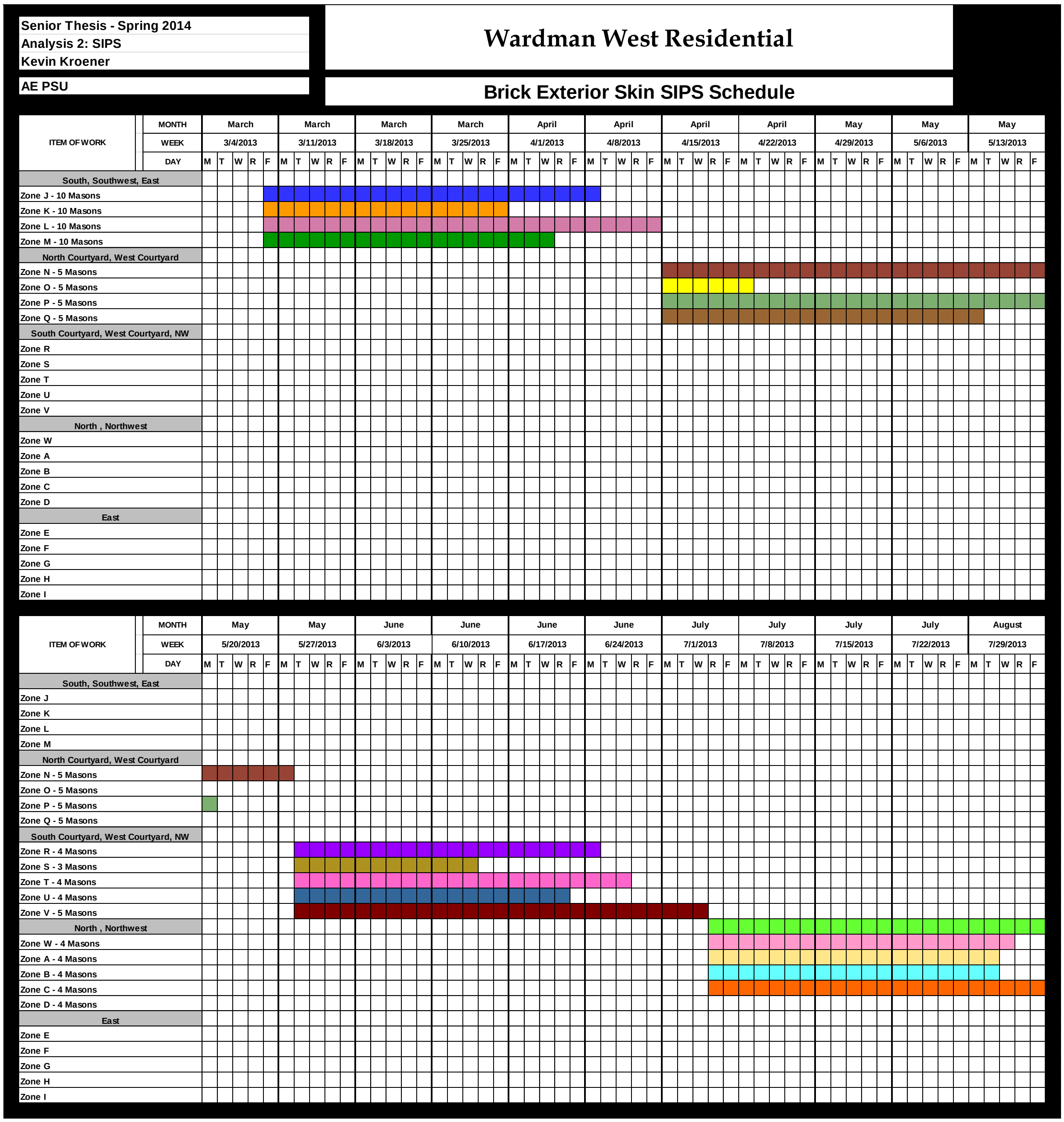
These duration calculations were performed for every floor per construction zone using 2 to 5 masons (except for the swing stage scaffolding for zones J through M) per zone to determine which manpower combination of 20 masons optimized labor and ultimately reduced the schedule most efficiently. Table 2.3 below shows the total durations found each elevation. The table also shows the sequencing for each elevation and the different phases with their associated construction zones. The Courtyard elevations were split into two phases to make full use of the 20 mason limit to accelerate durations and the project schedule. A total duration for brick construction was 133 days, a 12 day reduction from the original project schedule. A complete breakdown of these durations and the manpower allocated per construction zone can be referenced in Appendix B.4.

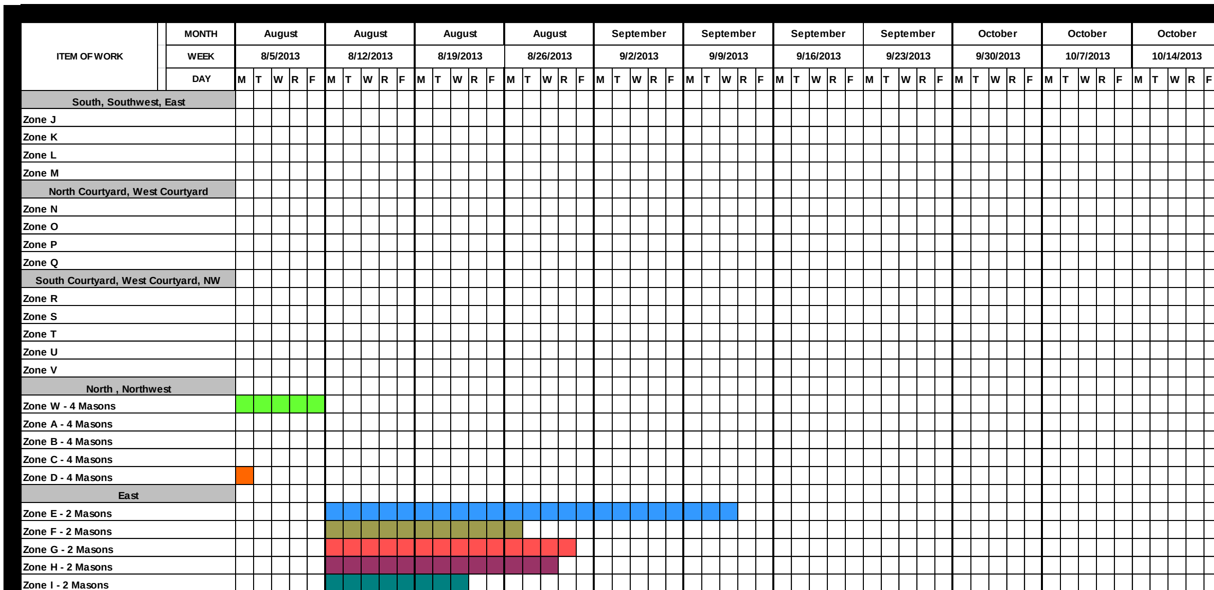
Table 2.3. Brick SIPS Elevation Durations and Phasing

Elevation	Construction Zones	Scaffold Type	Duration (Days)
Phase 1: South, Southwest, East	J – M	Swing Stage	25
Phase 2: North Courtyard, West Courtyard	N – Q	Fraco	27
Phase 3: South Courtyard, West Courtyard, Northwest	R – V	Fraco	31
Phase 4: North, Northwest	W, A – D	Fraco	27
Phase 5: East	E – I	Fraco	23
Total			**133**

Figure 2.5 below shows a portion the SIPS schedule developed for brick construction. The zone color scheme is located below the matrix schedule in this figure. The complete SIPS schedule can be referenced in Appendix B.5, as well as a revised project schedule in Appendix B.6.

Figure 2.5. Brick SIPS Matrix Schedule



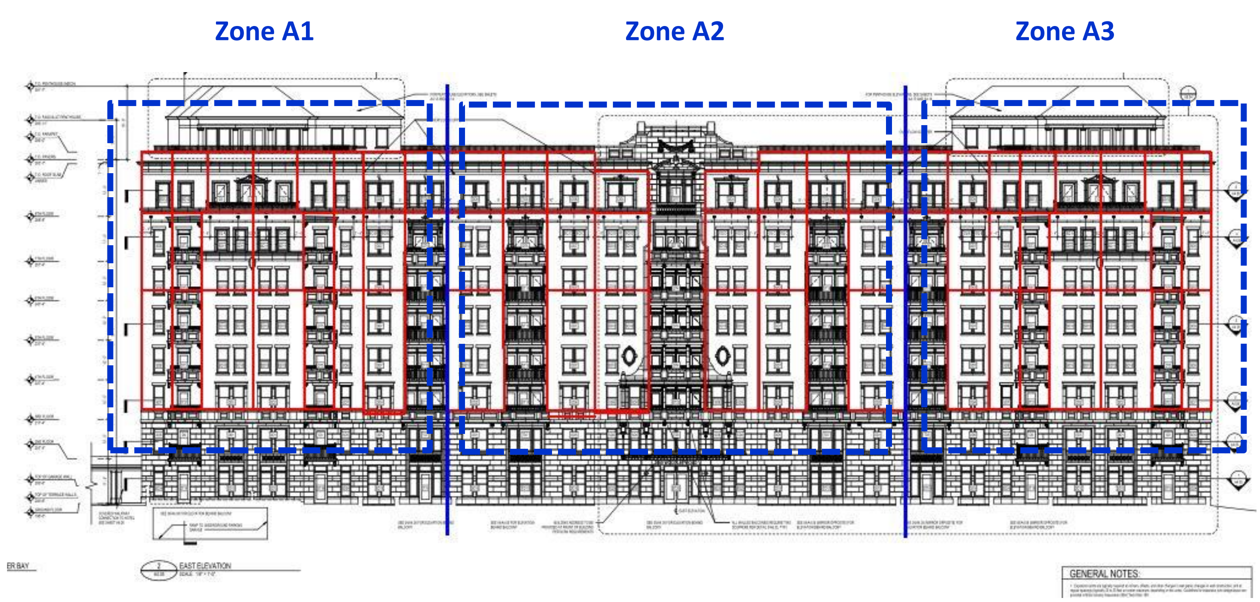


1. Zone A		14. Zone N	
2. Zone B		15. Zone O	
3. Zone C		16. Zone P	
4. Zone D		17. Zone Q	
5. Zone E		18. Zone R	
6. Zone F		19. Zone S	
7. Zone G		20. Zone T	
8. Zone H		21. Zone U	
9. Zone I		22. Zone V	
10. Zone J		23. Zone W	
11. Zone K			
12. Zone L			
13. Zone M			

SIPS for APC Panels

Like the SIPS for brick, first construction zones were established for the erection of ACP panels but a breakdown of panel sizes was first developed to determine how many panels would be erected for each of the building's elevations. Once the panel breakdown was completed the construction zones for an erection SIPS were established. Typically, because the erection of precast panels is a much simpler and faster on-site construction activity than brick, construction zones consisted of entire elevations. However, certain elevations were split into multiple zones such as the east elevation shown in Figure 2.6 below. This was done in an effort to keep the number of panels being erected per zone approximately within a close range of 21 to 38 panels, with an average of 27 per elevation. The number of panels for each construction zone is illustrated in Table XX on the following page. A detailed list of the panels sizes incorporated into each elevation and construction zone can be referenced in Appendix B.7.

Figure 2.6. East Elevation APC Panel SIPS Construction Zone Breakdown



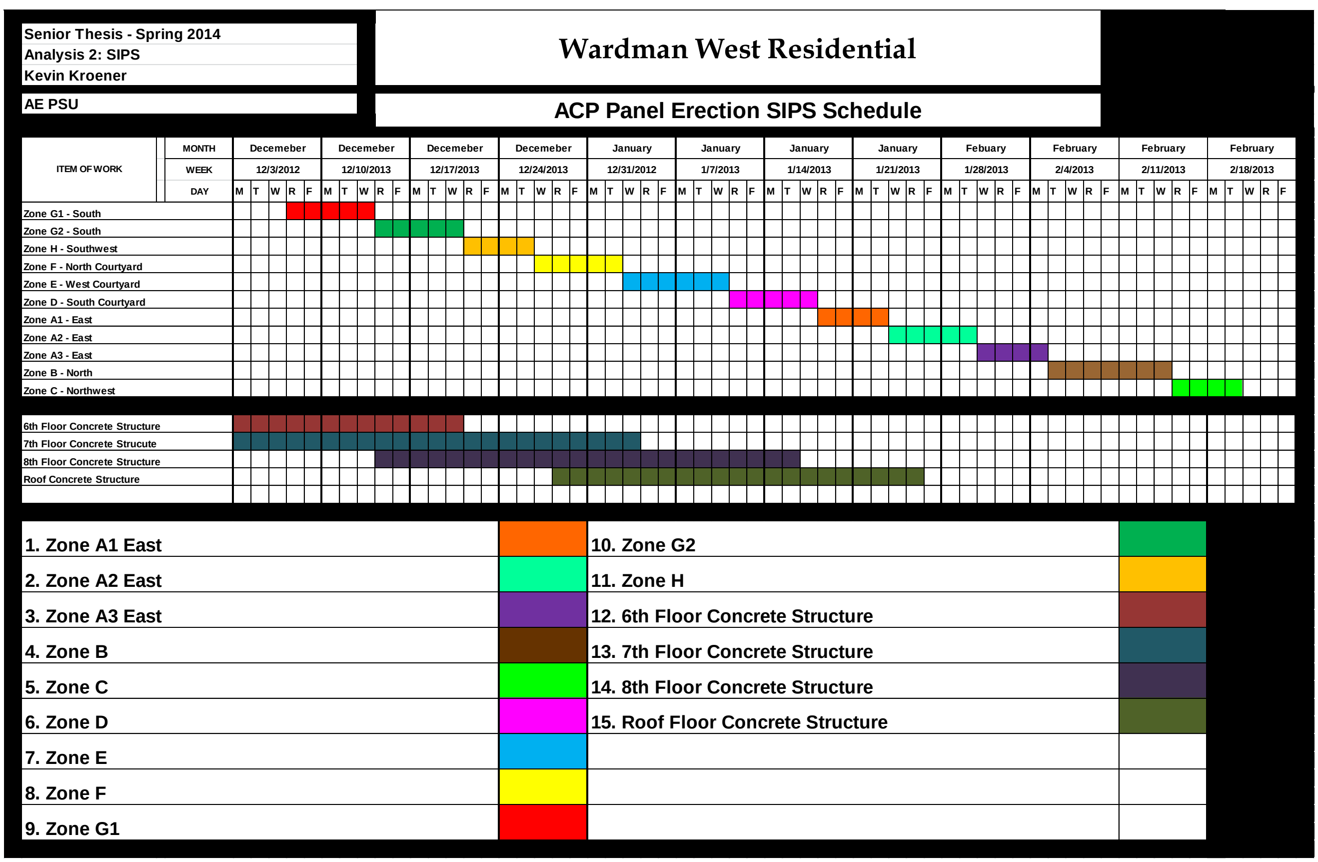
Once the construction zones were determined durations for each zone were calculated to develop the SIPS schedule. A productivity rate of 6 panels erected per workday was used to determine the duration for each construction zone used the number of panels present within their respected zones. Table 2.4 below shows these durations for each construction zone and the new total duration for erection of ACP panels using SIPS. Durations for construction zones took an average of 5 days or one work week and the new total duration of 54 days resulted in a 3 day reduction from the original 57 day schedule estimated for erection in the first analysis. The table below also shows the color scheme used for the SIPS matrix schedule which is shown on the following page. Also, the type of crane used for each zone is also illustrated in this table to verify the work sequence used for crane usage developed in the first analysis.

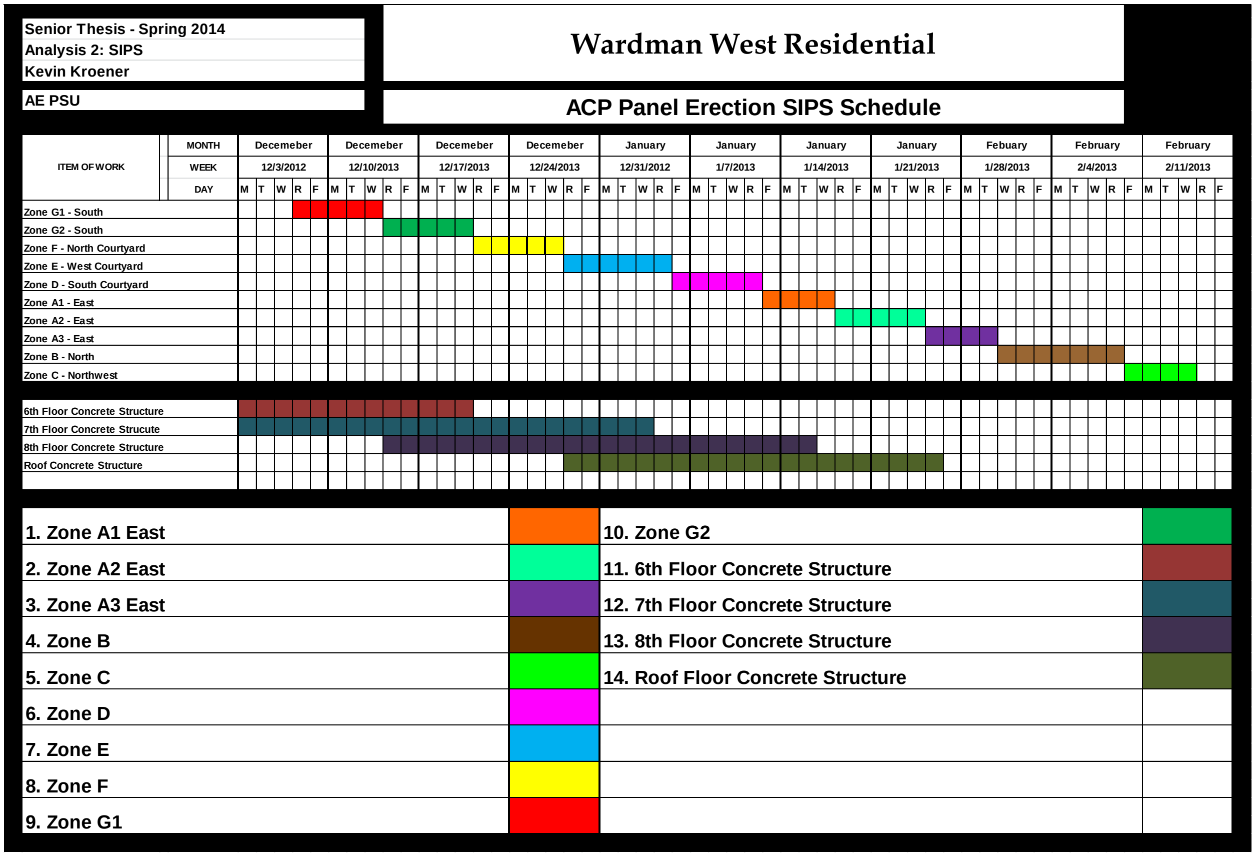
Table 2.4. APC Panel Elevation and Construction Zone Durations

Construction Zone	Matrix Color	Elevation	# of Panels	Crane	Duration (Days)
A1		East	22	Mobile	4
A2		East	26	Mobile	5
A3		East	22	Mobile	4
B		North	38	Mobile	7
C		Northwest	21	Mobile	4
D		South Courtyard	29	Tower	5
E		West Courtyard	34	Tower	6
F		North Courtyard	26	Tower	5
G1		South	26	Tower	5
G2		South	25	Tower	5
H		Southwest	21	Tower	4
Total			**290**		**54**

Below Figure 2.7 shows the ACP Panel SIPS Matrix schedule created using the duration's calculated for each construction zone. Activities for the above grade concrete structure's 6th through roof levels were also incorporated into this SIPS matrix schedule. This was done to show the sequencing process developed in the first analysis where the erection of APC panels used the site tower crane, in addition to the construction of the 6th through roof level concrete structure. Both scopes of work would be performed over the same period of time, but not concurrently, due to panels being erected during a second shift. A large full-size version of this SIPS matrix schedule can be referenced in Appendix B.8 and a revised project schedule in Appendix B.9.

Figure 2.7. APC Panel SIPS Matrix Schedule




Senior Thesis - Spring 2014
Analysis 2: SIPS
Kevin Kroener
AE PSU
Wardman West Residential
ACP Panel Erection SIPS Schedule
ITEM OF WORK
MONTH
WEEK
DAY
Decemeber
12/3/2012
Decemeber
12/10/2013
Decemeber
12/17/2013
Decemeber
12/24/2013
January
12/31/2012
January
1/7/2013
January
1/14/2013
January
1/21/2013
Febuary
1/28/2013
February
2/4/2013
February
2/11/2013
M T W R F
Zone G1 - South
Zone G2 - South
Zone F - North Courtyard
Zone E - West Courtyard
Zone D - South Courtyard
Zone A1 - East
Zone A2 - East
Zone A3 - East
Zone B - North
Zone C - Northwest
6th Floor Concrete Structure
7th Floor Concrete Strucute
8th Floor Concrete Structure
Roof Concrete Structure
1. Zone A1 East
2. Zone A2 East
3. Zone A3 East
4. Zone B
5. Zone C
6. Zone D
7. Zone E
8. Zone F
9. Zone G1
10. Zone G2
11. 6th Floor Concrete Structure
12. 7th Floor Concrete Structure
13. 8th Floor Concrete Structure
14. Roof Floor Concrete Structure

Evaluation

Along with creating a SIPS for schedule acceleration purposes for both brick and ACP panels, the other intent of this analysis was compare the two SIPS and evaluate their individual effectiveness for their respected scopes of work.

The brick SIPS significantly improved construction compared to the original schedule's sequencing by splitting up labor into construction zones that could be easily coordinated and tracked for productivity. The allocation of manpower per scaffold or construction zone would allow Clark's management and field staff to more efficiently drive the exterior brick schedule to avoid the potential delays associated with brick masonry work. Requiring the brick masonry subcontractor to follow the SIPS will eliminate the risk of relying on masonry foreman to allocate manpower and give them strict progress deadlines to meet daily. The deconstruction of brick work for the buildings elevations and the more accurate estimate of labor productivity rates also resulted in a shorter overall duration for brick work at 133 days compared to the original schedule's 145 day duration.

The ACP panel SIPS like the brick SIPS would help Clark track erection progress and aid in knowing which areas of the site would require staging for the flatbed trailers delivery panels to the site. In general the erection of ACP panels is a much simpler and faster activity than brick masonry and does not require as much schedule deconstruction as the brick SIPS. For this reason the APC panel SIPS is shorter with fewer construction zones. The APC panel SIPS also reduced the original erection duration estimated in the first analysis from 57 to 54 days.

When comparing the brick and ACP panel SIPS there are, although the brick SIPS in many benefited brick work to a greater extent the associated inconsistencies with laying brick cannot be perfectly accounted for when calculating durations. There are so many unforeseen delays such as weather, mortar and fluctuating levels of craftsmanship that can change labor productivity daily that a SIPS for brick would have to constantly be tracked and updated. Whereas, the ACP panel SIPS is a more accurate representation of actual erection durations. The more repetitive nature of panel erection better suits the use of SIPS than brick work, especially considering the high level of detail present in Wardman West brick, limestone and cast stone exterior façade design.

Recommendations

Per the results of this analysis, a SIPS (Short Interval Production Schedule) for both brick masonry and precast concrete wall panel erection should be used on this project, based on which system decided upon. The brick SIPS significantly improved the workflow of construction by optimizing manpower, which resulted in reducing the schedule by 12 days to 133 days, compared to the original brick work duration of 145 days. The APC Wall Panel SIPS also saved time to the project schedule by reducing the overall estimated duration for panel erection at 57 days down to 54 days.

Depth 3: Safety Evaluation

Problem Identification

Maintaining safety throughout the construction of any building is always of the upmost importance to any owner and builder. Ensuring a safe environment and construction sequence for a less commonly used construction method such as precast wall panel erection is especially important and an essential goal for a general contractor. In the case of the construction of Wardman West Residential, the congested and tight existing site created challenges as far as material deliveries, staging and scaffolding space. Knowing this the anticipated implementation of prefabricated brick panels for the building's exterior skin will present the general contractor with the logistical problem of ensuring safety when managing additional site traffic and equipment, as well as allocating more space for staging and erection.

Analysis Goals

To effectively evaluate the safety concerns associated with the erection and installation of precast wall panels an in-depth scoring comparison was performed with traditional brick masonry construction. This comparison through the use of a scoring system will aim to provide the general contractor with a better knowledge of the safety concerns associated will both construction activities, while also helping to determine which activity is overall a safer means of construction. This analysis will also incorporate developing an AHA or Activity Hazard Analysis for the erection and installation of precast wall panels for the use of the general contractor to communicate the safety concerns associated with performing this scope of work.

Safety Evaluation Scoring System

Generally precast wall panel erection is very dangerous due to the fact that you need a crane for erection and the pieces are very heavy increasing the risk of crush injuries occurring. On the other hand, brick installation also brings a different set of hazards along with it. It generally takes a longer period of time and usually requires the use of additional equipment, such as mast climbing platform and swing stage scaffolding. To better compare the safety issues associated with these two construction activities an in-depth safety comparison was performed through a scoring system based on these five major safety concern categories:

1. Fall Protection
2. Equipment Inspection
3. Safety Training
4. Hazardous Materials
5. Incidents/Injuries

Each of these categories will be evaluated for both precast wall panel erection and installation and brick masonry installation. The particular safety concerns for each category will first be noted and evaluated and then a final score will be given for each activity per the category being evaluated. Once each category is evaluated and scored, a final score will be totaled to compare which activity is deemed more hazardous based on the scoring breakdown illustrated in Table 3.1 below:

Table 3.1. Safety Evaluation Scoring Criteria

Scoring Value	Score Criteria
1	**Safety Category is considered fairly safe with a low level of safety concern involved.**
2	**Safety Category is considered somewhat hazardous with a moderate level of safety concern involved.**
3	**Safety Category is considered very dangerous with a high level of safety concern involved.**

The complete safety evaluation scoring comparison is shown on the following page.

Safety Category 1: Fall Protection

Activity	Safety Concerns	Score	Activity	Safety Concerns	Score
Precast Wall Panel Erection & Installation	• Commonly Precast Wall Panel erection requires laborers to work off of electric boom lifts, engine powered boom lifts or scissor lifts to secure panels once a crane picks the load to the desired location. • Work on these JLG's requires laborers to be tied off at all times	3	**Brick Masonry Installation**	• Exterior Enclosure brick work is performed on scaffolding. • If all required guardrails are properly in place per OSHA, masons are not required to tie off due to the protected fall exposure.	2

Safety Category 2: Equipment Inspection

Activity	Safety Concerns	Score	Activity	Safety Concerns	Score
Precast Wall Panel Erection & Installation	• To erect precast wall panels crane use is required. Inspection of the crane(s) being used is also required (*either annually and/or prior to use on site*). • If a crane leaves site and then is brought back for further use, another inspection is required. • Crane Inspection Checklist: ➢ Level/stable ground ➢ Outrigger pads ➢ Certified operator ➢ Qualified rigger ➢ Rigging equipment check ➢ Clearance for power lines ➢ Etc.	2	**Brick Masonry Installation**	• Brick masonry work requires that scaffolding is inspected daily. • Daily inspections are usually a very time consuming process, epically if there are multiple scaffolds being used at one time (*the case with the brick work performed for Wardman West*). • Inspections must be performed by a competent person. • Scaffold Inspection Checklist: ➢ Level/stable ground ➢ Tie back to building once 4 bays high ➢ Built by a competent person ➢ Tagged daily ➢ Access-ladders ➢ Stairs ➢ Guardrails ➢ Fully planked ➢ Etc.	3

Safety Category 3: Safety Training

Activity	Safety Concerns	Score	Activity	Safety Concerns	Score
Precast Wall Panel Erection & Installation	• Crane Operator Training • Qualified Rigger Training • Fall Protection Training • JLG Operator Training • Erection Foreman PCI Certification Erector Course • Hazardous Material Training • Hearing Protection Training • PPE Training (*in addition to typical PPE, some operations require face shields and hearing protection*) • Overall Precast Wall Panel Erection necessitates more required intensive training	2	**Brick Masonry Installation**	• Competent Person Training • Fall Protection Training • Scaffold Erection/Dismantling Training • Power Tools Training • Hazardous Material Training • Hearing Protection Training • PPE Training (*in addition to typical PPE, some operations require face shields and hearing protection)*	1

Safety Category 4: Hazardous Materials

Activity	Safety Concerns	Score	Activity	Safety Concerns	Score
Precast Wall Panel Erection & Installation	• Possible silica exposure from cutting concrete • Dust contains silica which becomes breathable and laborers are at risk if not protected properly (*respirators, ventilation, dust masks, etc.)*	2	**Brick Masonry Installation**	• Possible silica exposure from cutting brick • Breathable dust safety concern, as noted in safety concerns for precast erection.	2

Safety Category 5: Incidents/Injuries

Activity	Safety Concerns	Score	Activity	Safety Concerns	Score
Precast Wall Panel Erection & Installation	• Falls • Falling objects • Crush Injuries • Struck by hazard from crane superstructure • Swinging loads over other employees • Swinging or out of control load • Material handling (crush, caught in between, lifting, etc.) • Crane collapse • Faulty sling (load drop) • Rigging failure • Contact with overhead power line	3	**Brick Masonry Installation**	• Falls • Falling debris • Material handing (*crush, lifting, cuts*) • Scaffolding Collapse/Tipping/Hit by equipment • Windblown debris, contact with cement when mixing mortar • Burns and explosion when heating water and sand	2

Table 3.2. Safety Evaluation Scoring Results

Safety Category	Precast Wall Panel Erection & Installation	Brick Masonry Installation
Fall Protection	3	2
Equipment Inspection	2	3
Safety Training	2	1
Hazardous Materials	2	2
Incidents/Injuries	3	2
Total Score	12	10

The above Table 3.2 illustrates the scoring breakdown per safety category and the total scores for each activity. Results show that precast wall panel erection and installation had a slightly higher score than brick installation at 12 points to 10. Precast erection and installation outscored brick installation in 3 out of 5 safety categories including: fall protection, safety training and incidents/injuries. The erection and installation process for precast wall panels can be a very high risk activity from safety standpoint if proper training, inspections and fall protection procedures are not met. The possible incidents, and especially injuries, are more severe than exterior brick installation due to the fact that such large and heavy loads are being picked through the air and then handled by precast erectors. Although, precast erection and installation was considered a more hazardous and potentially unsafe construction activity than brick installation the total score was fairly close with only a 2 point value difference. This almost equivalence in safety concern for both activities is indicative of shear physicality and elevated working conditions of both activities. Precast wall panel erection might have a higher risk for incident and/or injury than brick installation but if proper training requirements are met and logistical concerns are accounted, the erection and installation process, as well as overall site safety, can be maintained.

APC Panel Erection AHA

To support overall safety procedures for the change to architectural precast concrete wall panels from exterior brick installation an Activity Hazard Analysis was developed. AHA's define the activities being performed and identify the work sequences, the specific anticipated hazards, site conditions, equipment, materials and the control measures to be implemented to eliminate or reduce each hazard to an acceptable level of risk. AHA's are also usually complied into a complete JHA (Job Hazard Analysis) serving as documentation for job-site and activity specific analysis of health hazards. Figure 3.1 below illustrates a section of the AHA developed for precast wall panel erection and installation. The AHA was comprised of two scopes of work: installation of precast concrete wall panels and lifting (erection) of precast concrete wall panels. A full version of the AHA can be referenced in Appendix C.1 and Appendix C.2.

Figure 3.1. APC Wall Panel Activity Hazard Analysis

ACTIVITY HAZARD ANALYSIS

ACTIVITY: LIFTING PRECAST CONCRETE WALL PANELS

Project: AE Senior Thesis
Prepared By: Kevin Kroener
Date: 4/9/2014

Scope of Work: Precast Concrete Wall Panels

PRINCIPAL STEPS	POTENTIAL HAZARDS	RECOMMENDED CONTROLS
1. Select and Inspect Rigging	1.a. Damaged or unsafe rigging 1.b. Under sized rigging or incorrect rigging	1.a. & 1.b. Inspect rigging on a daily basis for safe working conditions. Remove form service and discharge any rigging if as necessary. Competent groundman, assisted by Erection Foreman, will select appropriate rigging for each lift.
2. Lift wall panel load	2.a. Crane malfunction or failure	2.a. Operator must perform daily inspections to ensure that crane is in safe working condition. Inspections will also be documented in the a crane logbook.
	2.b. Improper crane setup leading to tipping or failure	2.b. Ensure crane is on stable and level ground per the manufacturers specifications/recommendations. Proper boom radius as specified in crane capacity chart.
	2.c. Struck by hazard from crane superstructure	2.c. Barricade tail swing of crane
	2.d. Swinging of loads other employees	2.d. Ensure swing path is clear. Groundman and Erection Foreman will control area within swing radius of crane boom with assistance from GC field supervision. Swing path perimeter will be marked or barricaded to prevent employees from walking beneath load. The CAZ (Controlled Access Zone) will be set at an appropriate distance and the Groundman and Erection Foreman will remain alert to personnel entering restricted areas to keep people out of the swing path.
	2.e. Swinging or out of control panel load	2.e. Only one person at a time will give signals and have radio communication with crane operator. Taglines will be used to control loads

EQUIPMENT TO BE USED	INSPECTION REQUIREMENTS	TRAINING REQUIREMENTS
1. Tower Crane 2. Mobile Crane 3. Rigging 4. Tag lines 5. PPE - hard hat, safety glasses, steel-toe boots, reflective vests	1. Annual crane inspection 2. Daily crane inspection 3. Crane inspection upon arrival at site 4. Posted Certificate of Compliance on Crane 5. Daily rigging inspection	1. Certified Crane Operator 2. Erection Foreman has completed PCI's Certified Erector course 3. All erectors and riggers have completed rigging training ***** GC is responsible for training of all non- precast/erector personnel to remain clear of the precast work area and to obey warning signs and barricades.***

Recommendations

Based on the results of this analysis, it is recommended that that the proposed safety evaluation be used on this project, to accompany the use of architectural precast concrete wall panels proposed in the first analysis. The safety evaluation's scoring comparison between exterior brick installation and precast concrete wall panel erection provided a detailed breakdown of the safety concerns associated with each activity. While, precast concrete wall panel erection resulted in a higher risk construction activity, both brick and precast wall panels have a significant amount of safety concerns when performed, but with the aid of this scoring comparison breakdown, the required training, inspections, PPE and concerns are identified. The Activity Hazard Analysis specifically created for precast concrete wall panel erection and installation will also benefit safety coordination on the project and ensure site safety is maintained.

Depth 4: General Contractor Implementation Study for Architectural Precast Concrete Wall Panels (Critical Industry Issue)

Problem Identification

One of the main critical research issues discussed at the PACE Roundtable event in fall of 2013 was the use of prefabrication and multi-trade modularization. Both of these topics have been proven to save money and time for project teams when implemented successfully. However, much of this success is due to careful planning, coordination and ideal project scopes. Without the right circumstances prefabrication and modularization can result in escalated costs and coordination issues between project team members and trades. Like prefabrication and modularization, the use of architectural precast panel as substitute for traditional exterior masonry can offer many benefits to a project team. But it also has the potential to result in negative ways that can outweigh its benefits, without proper early planning and coordination.

Analysis Goals

This analysis was an in-depth investigation of the planning required for implementation and project team coordination necessary to make the use of architectural precast concrete panels a success. This implementation and coordination study will be created for the use of a general contractor to determine the best decision making process when choosing a precast panel product, know their responsibilities and coordination role as part of a project team and managing the associated logistics involved. The following outline summarizes the main topics that will be discussed in this study:

1. **Production Selection**
   - Architectural Aesthetics
   - Cost
   - Quality

2. **General GC Responsibilities and Coordination**

3. **Logistics**
   - Transportation Logistics
   - Delivery, Staging and Erection
   - Crane Use

Production Selection

The selection process for an architectural precast concrete panel product is one that takes a good deal of planning and coordination. General contractor guidelines when approaching this coordination process is covered more in-depth in the next section of this analysis. However, there are several areas for a general contractor to consider when deciding on a product to submit to an architect. The major areas of consideration are architectural surface aesthetics, budgeting of design decisions and product quality.

Architectural Aesthetics

Precast concrete has many capabilities that allow very detailed and customized façade designs to be aesthetically achievable during the casting process. From a GC's point of view this flexibility in appearance options for architectural precast concrete represents a less expensive solution to detailed exterior masonry work. Precast concrete aggregates, mixtures and finishing techniques allow for almost any stone type and color to be imitated, such as the limestone headers, jambs and sills proposed in the first analysis. Much of this aesthetic matching can be done during design before a project is awarded to a GC through a pre-bid approval process where a pre-determined precaster can send pre-bid samples for approval. However, if a pre-bid approval process was not used a GC should request submittals from a precast concrete manufacturer as soon as possible, with samples being at least 12" x 12" in size. Although, 12 in. samples may provide enough information on texture and color to obtain approval often it is beneficial for GC to require a precaster to supply a on or off-site complete panel mockup to demonstrate a more accurate physical representation or an architect's initial aesthetic evaluation. Mockups are especially beneficial when evaluating major details and reveals casted to imitate the appearance of natural stone and brick materials. A sample or mockup should also be viewed at a distance of no less than 20 feet to accurately evaluate a product's appearance on a building's façade during the approval process.

Cost

When considering design economy for APC panels there are many variables that a general contractor must consider both during the manufacturing process and the erection process when selecting a product. The highly customized designs that are possible with precast concrete can be achieved within a limited budget by selecting appropriate aggregates and textures combined with repetitive units at the largest possible size and efficient erection details. Generally, panel size and repetition govern cost impacts to a project, but the below breakdown shows the other criteria to consider when budgeting:

Design	**Material**	**Construction**
Panel Size	Material & Texture Selection	Erection Details
Repetition	Uniformity of Appearance	Jobsite Access Conditions
Cross Section	Surface Geometry	Connections

When a general contractor is pricing precast concrete panels, costs are determined primarily by the size of the panels and repetition. A larger panel size on a large project is the most desirable circumstance for pricing. For instance, a large project requiring 200 panels at larger sizes usually is a less expensive approach than a 1,000 panel project using smaller panel sizes. Pricing is dependent on the number and size of panels because it is a direct reflection of the labor required by an architectural precaster and erector. If the project has more panels it directly correlates to more labor hours designing, casting, stripping, finishing, loading, delivering, erecting and installing panels. A general contractor can optimize economy by minimizing the number of panels needed for a project by using the largest possible panel sizes per a project's design, manufacturing and shipping limitations. The difference in cost of erecting a larger panel relative to a smaller one is insignificant when compared with the decrease in cost by using larger and fewer panels. Figure 4.1 below is a table from the PCI Manual for Architectural Precast Concrete Third Edition illustrating this effect of panel size on erection cost per square foot. A typical rule of thumb to follow is that a project's average panel size should be at least 100 to 150 SF and ideally larger if possible.

Figure 4.1. Erection Costs Per Sq. Ft.

Panel size, ft^2	Erection cost per piece, dollar amount per ft^2			
	$500	$1000	$1500	$2000
50	10.00	20.00	30.00	40.00
100	5.00	10.00	15.00	20.00
150	3.33	6.67	10.00	13.33
200	2.50	5.00	7.50	10.00
250	2.00	4.00	6.00	8.00
300	1.67	3.33	5.00	6.67

Quality

A general contractor can ensure that the APC product chosen during the submittal process is quality assured by requiring in a project's specifications. The requirements should include:

1. *The precaster facility be certified by the PCI Plant Certification Program;*

2. *The precaster have personnel certified in the appropriate levels of the PCI Plant Quality Personnel Certification Program; and*

3. *The precast concrete erector be certified by the PCI Field Certification Program or the precaster have a qualified person to oversee the work of the erector.*

A general contractor should make sure to verify the different categories of certification involved with these three requirements. A Plant Certification for APC requires two categories to be met within Product Group A based on PCI Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products. These two categories are: A1 for major, primary architectural panels and products; and AT for miscellaneous architectural trim elements. A Plant Quality Personnel Certification is a program that PCI has provided since 1974 and offers three levels (Level I, II, and III) of certification. The Field Certification Program also has three categories that an erector can be qualified in: A – architectural systems (non-loadbearing cladding), S1 – Simple Structural Systems (horizontal decking members, single-lift walls), S2 – Complex Structural Systems (category S1 plus all other structural products, including loadbearing architectural units).

This certification process for a precast facility will involve an independent inspection by a third party that will confirm the plant has the capability to produce a quality product and perform in-house quality control efficiently. By contractually requiring quality assurance a general contractor can better ensure that the project owner and architect are confident that materials, methods, products and the manufacturer's quality control procedures satisfy the requirements for a particular project.

General Responsibilities and Coordination

For any project to be successful, close cooperation and communication are a necessity. A project that requires architectural precast concrete is especially dependent on a high level of coordination to be successful. The owner, architect, structural engineer of record, precast manufacturer and/or erector and the general contractor must all be communicating efficiently and clearly defining responsibly based on the scope of precast work to maintain quality of work and keep a project within budget and on schedule. The following guidance will be intended for a GC as to what their responsibilities will entail and the coordination required to carry out these responsibilities efficiently.

Before guidance for a GC's responsibilities are discussed, it should be noted that the responsibilities of a CM on an architectural precast concrete project can be quite different from those of GC depending on the level of involvement they have has with the owner and architect during design. A GC has the responsibility and authority of implementing the design intent of an owner and architect per a project's contract document s. This involves furnishing materials, equipment and labor, while maintain quality of work and schedule requirements. For an architectural precast project this particularly involves the furnishing of a precast product (explained in the above Production Selection portion of this study) and the selection of equipment and providing unloading areas on site during erection, which is discussed more in-depth in the following Logistics section of this study.

A GC generally does not have direct input during the design process for an architectural precast scope of work, but can make a significant impact on the design process through their coordination role. A GC should prepare for coordinating information regarding precast erection drawings, in addition to reviewing and gaining approval through the architect for shop drawings, submittal samples, and mockups. As the central HUB for project communication, the GC should also encourage (if not require) direct communication between the precast, erector and architect to avoid miscommunication.

Shop drawings for any trade are completed and approved as a project works towards completion. In the case of precast, a GC is responsible for dimensional interfacing of architectural precast concrete with other materials and trades to ensure that structural tolerances are satisfied. The precaster/erector should be notified when as-builts of structural framing elements vary from pre-determined tolerances per the construction documents. One case in particular where this communication process with the precaster is vital is coordinating steel attachments with a projects steel fabricator. The GC is typically responsible for placing embedded items in a cast-in-place concrete structure and communicating these locations to the steel fabricator per the layout or anchor plan supplied by the precaster. The most efficient and economical approach in this circumstance is for the GC to have the steel fabricator attached the precaster's specified hardware to the concrete structure of a building. To initiate this this early coordination process a GC should awarding contracts to the precaster and steel fabricator simultaneously. Also, the GC should provide any as-builts to the precaster for these pre-installed embedded anchors prior to erection to ensure there is no missing hardware. As mentioned in the first analysis, erection of architectural precast concrete can begin before a concrete structure is entirely complete, therefore, a GC should authorize when concrete floors and columns have reached their design full strength and all formwork and shoring has been removed.

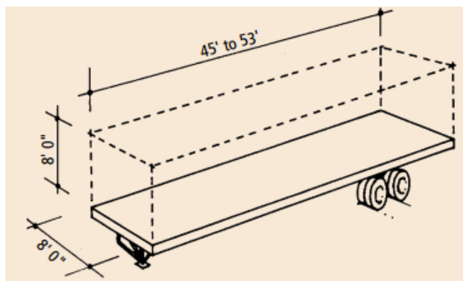
During the erection process a GC should notify the architect for inspections of installed precast concrete panels. The GC also needs to coordinate with the precaster and erector to be present during these inspections to answer any questions from the architect. A final punch list is also recommended for erected and installed panels to eliminate delays for other enclosure trades.

Logistics

Transportation

Transporting finished panels to a construction site is a major logistical issue that a GC must consider. Transportation limitations should be considered during the design process but it is important that GC is also aware of legal highway load limitations to avoid incurred costs with over-height, over-width or over-length panels during the permitting process. Federal, state and local regulations often dictate the size, weight and timing of shipping panels. Figure 4.2 below illustrates a typical trucking volume limits for shipping.

Figure 4.2. Common Trucking Load Volume Limits



A common payload in many locales is 20 ton with the panel size limits shown I n Figure XX above. If a panel can be shipped within these common trucking parameters a standard flatbed can be used without requiring the aforementioned permits. A lowboy or drop deck trailer can be used to increase allowable panel height for shipment to about 10 to 12 feet. However, a GC must consider that lowboy trailers are often not a readily available for shipping and their shorter bed length can also limit the overall length of panels being shipped. Allowable total heights (roadbed to top of panel) for shipping are usually 13 ft. 6 in. or 12 ft. depending on location. Special circumstances can require alternate routing to avoid low overpasses and overhead restrictions. Restrictions generally limit panels to be from 10 to 14 feet in width and some areas allow overall lengths of up to 70 feet, requiring only a simple permit, front and rear escorts, and travel time limited to certain times of the day. Apart from the length, height and width restrictions, load restrictions can vary widely on location. Typically, the load limit without a permit is 20 to 22 ton. In some areas payloads can be increases to 100 ton but it will require a special permit and other areas have a strict restriction at 25 ton. A GC should keep in mind that exceeding these height, width, length, and weight restrictions will require special permits that often add significant cost to a project budget and should be avoided if possible.

Delivery, Staging & Erection

A GC should commit a considerable amount of time planning the delivery of panels to a construction site and their erection once staged properly in an appropriate location. Erection costs are a significant portion of the overall cost for installing APC panels for a building's exterior envelope. The most desirable approach for GC to use during erection is have panels loaded on a A-frame trailer in the same orientation as they will be installed on a building's exterior, allowing a crane to simply pick the panel directly from the trailer into place. Yet, panels are often not shipped in a vertical orientation to allow this process and rather are horizontally loaded on a trailer, which requires rotating panels in the air using rolling blocks. Both these approaches require that trailers have an adequate staging area on-site. For a staging area to be suitable it must be easily accessible for trucks and mobile equipment and reachable if panels are to be picked by a tower crane. Staging areas must also have level, stable and well-compacted ground. A GC should plan ahead and known when these areas need to be used and clear any other construction activity being performed in the general vicinity. Knowing this, site safety is paramount during erection for both erection laborers and other trades working nearby. Safety concerns and issues will not be cover in-depth for this analysis, as they were investigated in more detail in the third analysis.

Crane Use

In most cases a precaster and/or erector will provide and use their own mobile crane during erection. However, if a site tower crane is available for use the time required for erection can be significantly accelerated as long as sequencing and logistics are properly coordinated. A GC should coordinate with the precaster the anticipated maximum panel weights and pick distances to verify when a tower crane can be used for erection. If a tower crane is lifting a panel that weighs close to its pick capacity the allowable boom length can rapidly be shortened. For this reason when using a tower crane for erection the GC should only authorize safe pick distances and unloading areas that are approved by the precaster.

Recommendations

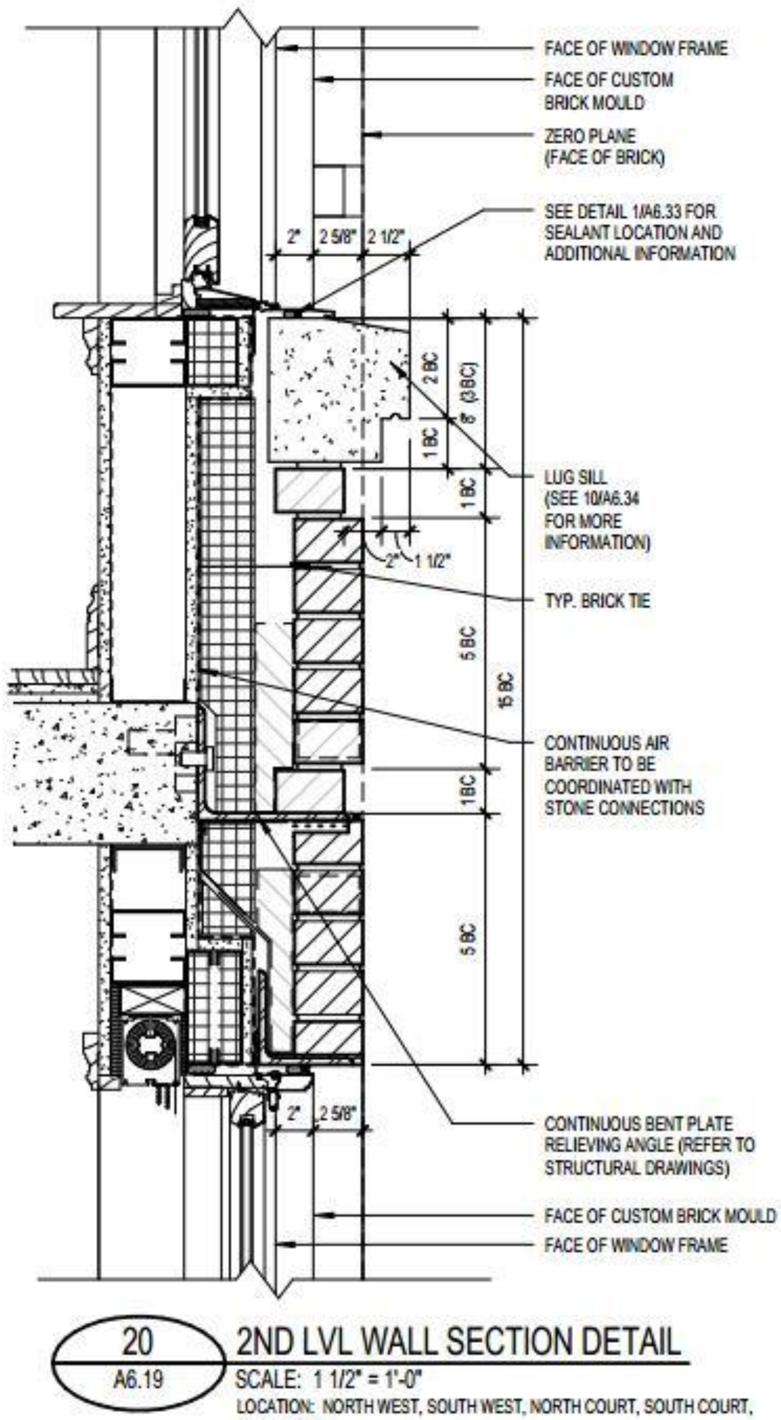
The study performed to investigate the implementation of architectural precast concrete wall panels as building enclosure system resulted in an in-depth guide for general contractors on product selection, project team responsibilities and logistics. Although, much research went into developing the implementation study, the actual final guide was kept rather concise. This was done to ensure that could be used as a practical tool that a general contractor could reference when deciding on or coordinating the use of architectural precast concrete wall panels on a project. Overall, the implementations study would be beneficial to the general contractor, Clark Construction, on the Wardman West Residential Project if the building's exterior brick veneer walls were substituted with architectural precast concrete wall panels proposed in the first analysis.

Appendix A

Appendix A.1

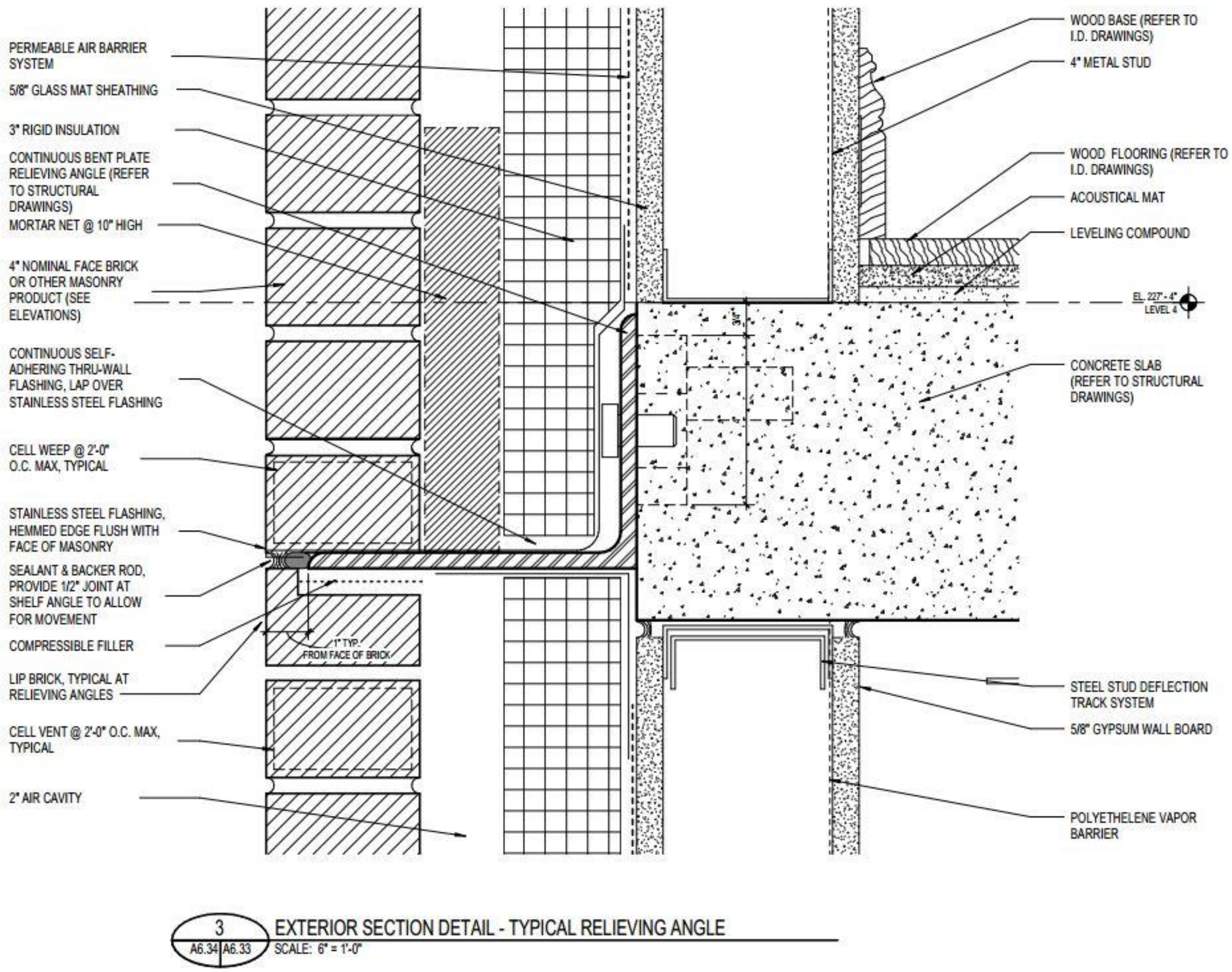
Original Wall System Details and Section

Typical Wall Section Detail



2ND LVL WALL SECTION DETAIL
SCALE: 1 1/2" = 1'-0"
LOCATION: NORTH WEST, SOUTH WEST, NORTH COURT, SOUTH COURT, WEST COURT

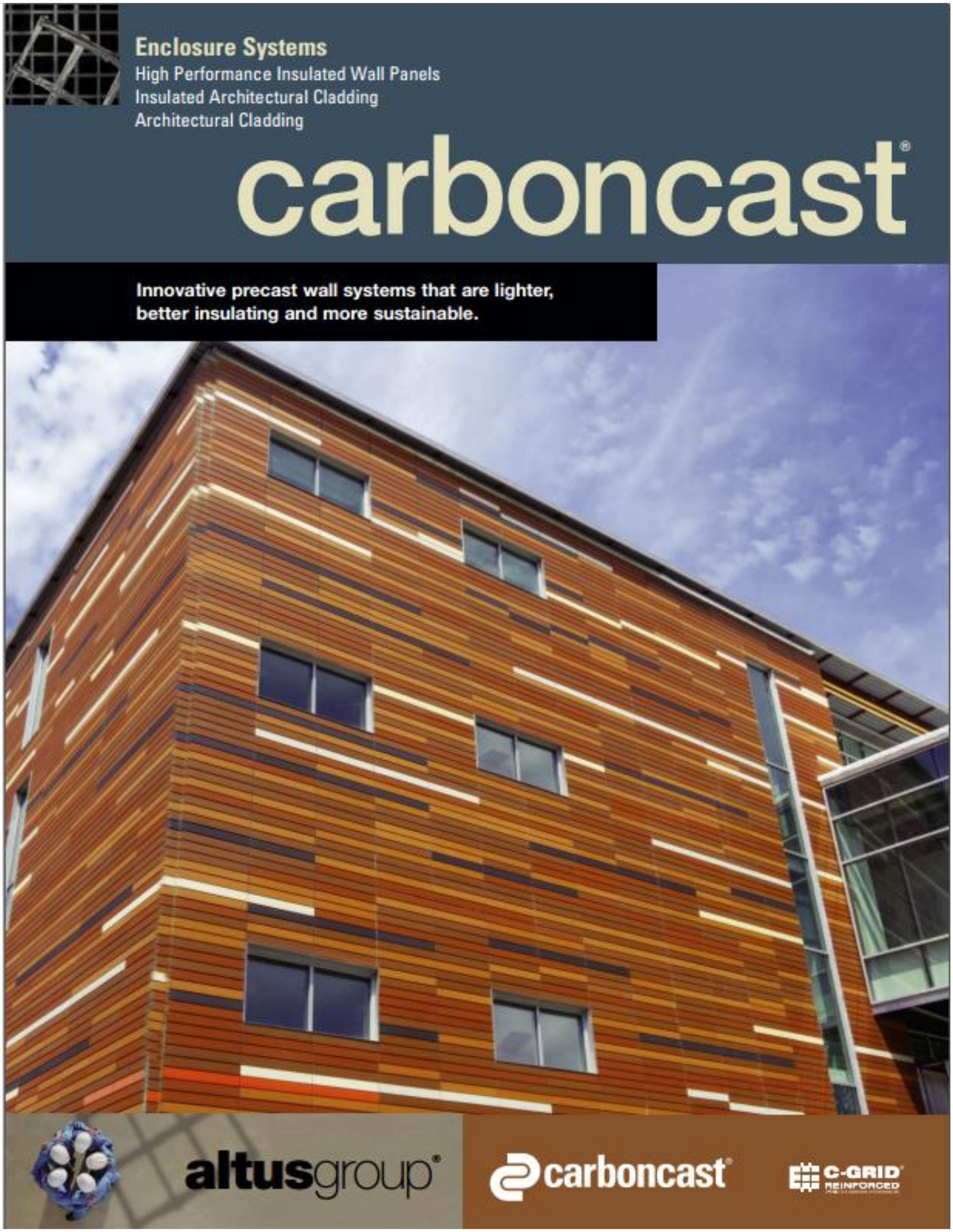
Typical Relieving Angle Detail



EXTERIOR SECTION DETAIL - TYPICAL RELIEVING ANGLE
SCALE: 6" = 1'-0"

Appendix A.2

CarbonCast Insulated Architectural Cladding Product Data


Enclosure Systems
High Performance Insulated Wall Panels
Insulated Architectural Cladding
Architectural Cladding
carboncast®
Innovative precast wall systems that are lighter, better insulating and more sustainable.
altusgroup®
carboncast®
C-GRID® REINFORCED

CarbonCast Technology: One simple change, a multitude of benefits.

High Performance Insulated Wall Panel
PAGE 4–5

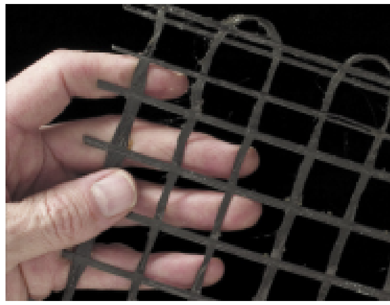
- Full composite action for load-bearing performance
- Continuous insulation to meet ASHRAE 90.1 requirements
- Aesthetic versatility

Insulated Architectural Cladding
PAGE 6–7

- Continuous insulation to meet ASHRAE requirements
- Up to 40% lighter; enables reduced super-structure and foundation
- Lower carbon footprint
- Aesthetic versatility

Architectural Cladding
PAGE 8–9

- Up to 50% lighter; enables reduced super-structure and foundation
- Integral insulation for improved R-value
- Virtually unlimited aesthetic options



Less concrete means less weight, less embodied energy and a reduced carbon footprint.

CarbonCast® Enclosure Systems use advanced technology to improve precast concrete by integrating ultra-strong, non-corrosive C-GRID® into the wall panels during fabrication. By taking the place of steel reinforcement C-GRID provides a multitude of benefits that makes factory-made precast concrete an even more intelligent choice for commercial building envelopes.

Depending on design, CarbonCast panels are priced competitively with other curtainwall systems such as brick-veneer, masonry, stud walls or concrete. And after factoring in reductions to superstructure requirements and potential HVAC system and operating savings, CarbonCast enclosure systems can help pay for themselves immediately.

Enabling superior performance.
Lightweight, non-corrosive C-GRID is the "enabling technology" that allows CarbonCast enclosure systems to be lighter, insulating, more durable and cost competitive. C-GRID has many of the same strength-weight benefits as high-performance aerospace carbon fiber, but at a significantly lower cost. The carbon fibers used to make C-GRID are over four times stronger in tensile strength than steel by weight. Each carbon fiber "tow" or strand is comprised of thousands of ultra-fine fibers that are bundled together. These tows are assembled perpendicular to each other into a grid using a continuous rotary-forming process that chemically binds them with a tough, heat-cured epoxy resin.

It takes jet fighters to Mach 2. Imagine what it does for precast.
The exceptional strength and durability of carbon fiber translate to several enhancements to the performance of precast concrete enclosure systems.

Lighter Weight. Because carbon fiber resists corrosion, CarbonCast cladding with C-GRID in the face requires less protective concrete

CarbonCast Enclosure System Selector

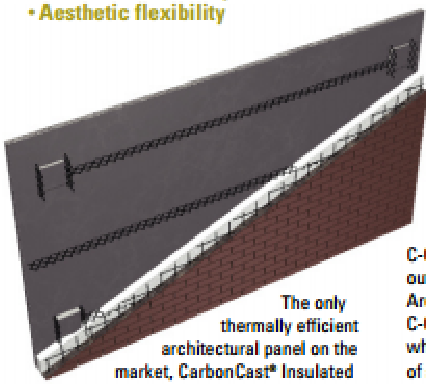
Feature	High Performance Insulated Wall Panel	Insulated Architectural Cladding	Architectural Cladding
Length	Up to 60'	Up to 30'	Up to 30'
Width	Up to 13'	Up to 14'	Up to 14'
Thickness	6"–12"	6"–9"	7"–12"
Weight PSF	> 65	38–65	37–50¹
R-Value	10–37	8–20	< 10
Continuous Insulation	Yes	Yes	No
Fire Rating	2 hrs	2 hrs	1–2 hrs²
Load-bearing	Optional	Optional	No
Paintable Interior Face	Yes	Yes	No
Window/Door Recess	1–2"	1–2"	1–10"
Applications			
Low- and Mid-Rise	■	■	■
High-Rise		■	■
Poor Soil		■	■

¹Weight can be reduced with lightweight backer mix. ²Assembly rating includes interior wall system of steel studs, batt insulation, and 5/8" type X gypsum board(s). Specifications vary by precaster.

2 1-866-GO-ALTUS

CarbonCast Insulated Architectural Cladding

- Continuous insulation to meet ASHRAE requirements
- Up to 40% lighter; enables reduced superstructure and foundation
- Lowers carbon footprint
- Aesthetic flexibility



The only thermally efficient architectural panel on the market, CarbonCast® Insulated Architectural Cladding offers weight reductions of about 40% compared to solid, 6" thick precast and is engineered to deliver insulation values of R-8 or more.

The design of this CarbonCast system is based on the extensively tested CarbonCast High Performance Insulated Wall Panel. CarbonCast Insulated Architectural Cladding is intended for horizontal and vertical placement as a non-load-bearing spandrel or column cover. The similarity in sandwich design means the CarbonCast Insulated Architectural Cladding panels are engineered to exhibit the exceptional strength and durability benefits of their brethren.

COMMERCIAL AND INSTITUTIONAL USES

- Mid- and high-rise office buildings
- Multi-unit residential
- Mixed use commercial/residential
- Healthcare facilities
- Education
- Hotels/Dormitories

Highly insulated for lower energy consumption.
CarbonCast Insulated Architectural Cladding features edge-to-edge continuous insulation (ci). The resulting thermally efficient panel provides steady-state R-values of R-8 or more as additional insulation is incorporated between the panel's inner and outer wythes. AltusGroup® precasters can use either EPS, XPS or Poly Iso foam insulation depending on design requirements. All the insulation you need can be provided by the panel. Additionally, the physical properties of precast concrete provide a beneficial thermal lag effect that can further reduce HVAC demands.

Lightweight and strong coexist beautifully.
CarbonCast Insulated Architectural Cladding features inner and outer wythes 1¾" thick and up (depending on reveal depth). The wythes sandwich a layer of insulation of usually 2" or more depending on R-value demands. The thicker you specify the insulation layer, the higher the R-value can be.

C-GRID® shear trusses connect the inner and outer wythes of concrete. CarbonCast Insulated Architectural Cladding can also incorporate C-GRID into the exterior face in deep reveals which would otherwise be limited with the use of steel mesh.

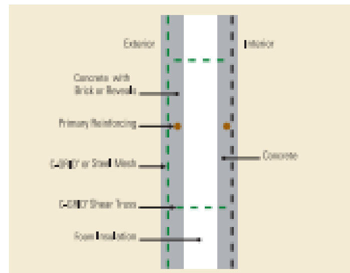
Reducing the amount of concrete lowers the panel weight. Inner and outer wythes of 1¾" result in total concrete thickness of 3½". That's 40% less concrete than a conventional 6"-thick precast panel, which decreases embodied energy. The dramatic weight reduction delivers significant benefits.

- Reduced load/superstructure: In most cases, lighter panels mean the building's superstructure and foundation can be engineered for less dead load, resulting in cost savings and a lower carbon footprint.
- Lower transportation costs: Precasters can ship more panels on each flatbed truck, lowering costly fuel consumption.
- Smaller cranes: Crane size and expense can be reduced with lower-weight panels.
- Seismic performance: Lighter panels are generally more desirable in high-seismic areas.

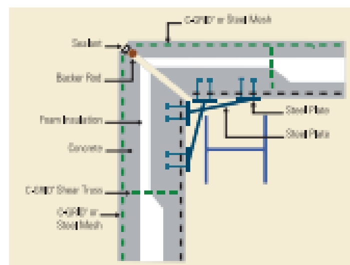
Architectural finishes abound.
AltusGroup® precasters are able to incorporate a variety of architectural finishes into CarbonCast Insulated Architectural Cladding to create a distinct, expressive facade that will meet a wide variety of design needs. An assortment of architectural elements such as cornices, bullnoses and reveals can be cast into the concrete carefully and cost-efficiently. Embedded finishes and veneers such as thin brick can also be used as well as simulated limestone or granite instead of extracted rock to further reduce raw material extraction. In addition, CarbonCast Insulated Architectural Cladding can be specified with a prefinished interior wythe. A steel-trowel treatment during manufacturing imparts a smooth, durable, surface ready for paint or wallcovering and ideal for applications like dormitories and apartments.

See page 5 for Window/Door Head and Sill detail.

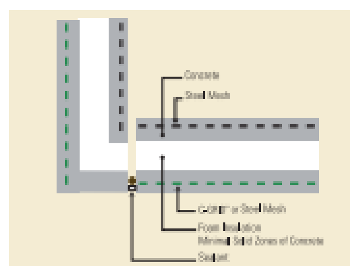
Additional technical information is available at altusprecast.com/products



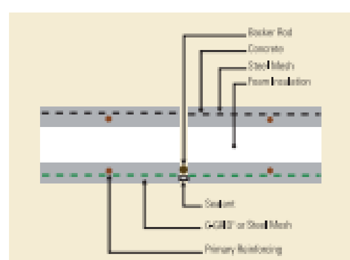
Insulated Architectural Cladding
Horizontal Section



Insulated Architectural Cladding
Thermally Efficient Miter Corner Connection Detail

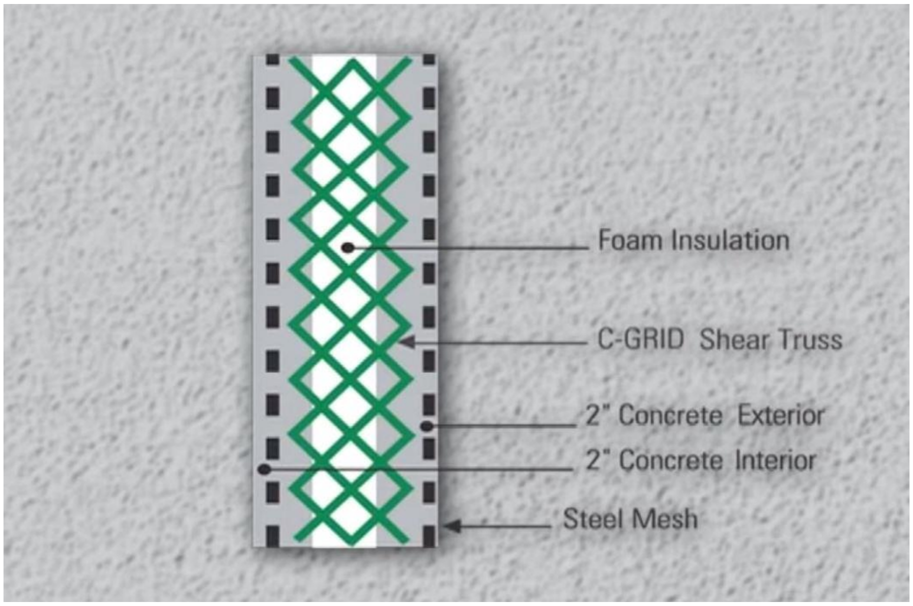


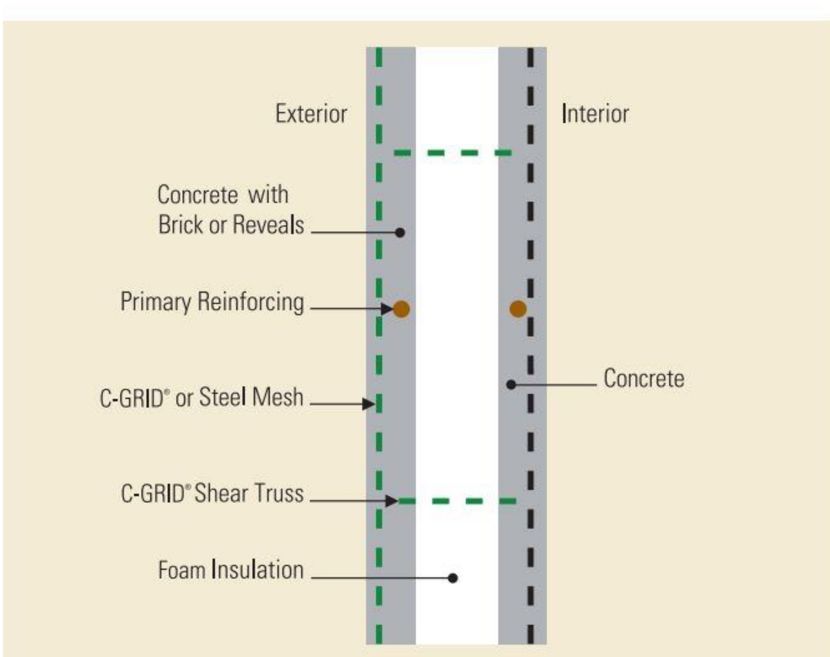
Insulated Architectural Cladding
Thermally Efficient Butt Corner Detail



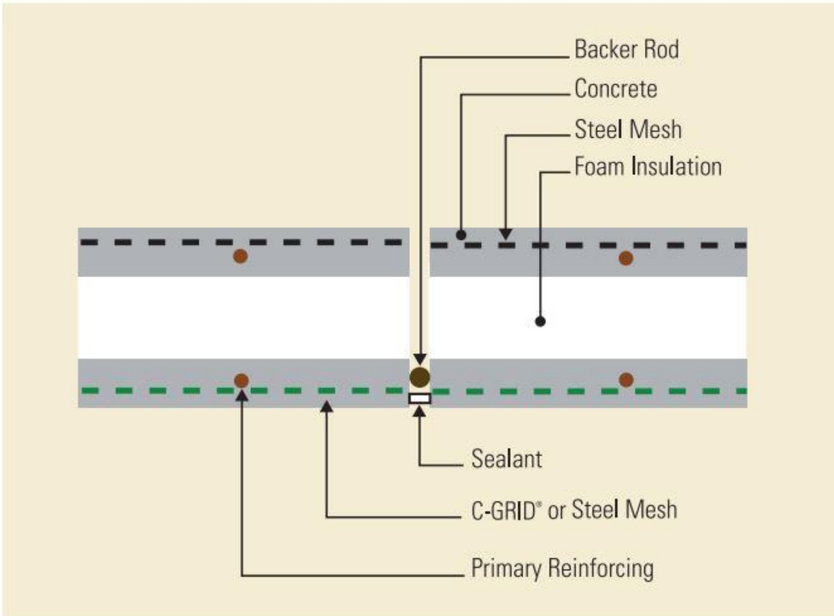
Insulated Architectural Cladding
Thermally Efficient Butt Joint

Vertical Section

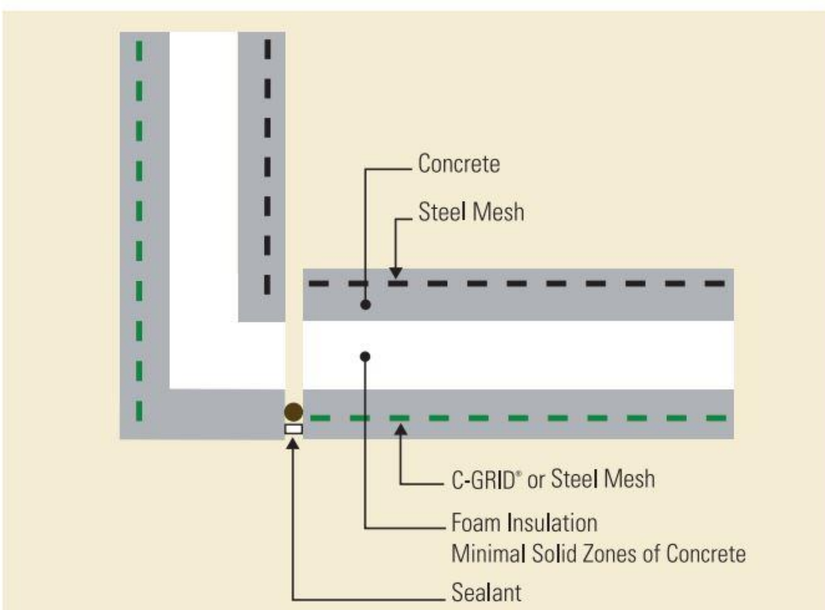




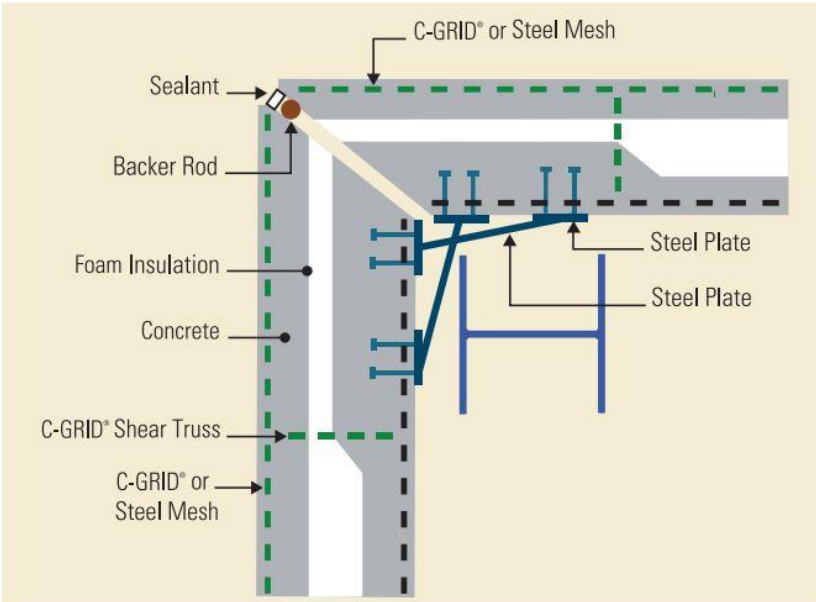
Insulated Architectural Cladding
Horizontal Section



Insulated Architectural Cladding
Thermally Efficient Butt Joint



Insulated Architectural Cladding
Thermally Efficient Butt Corner Detail

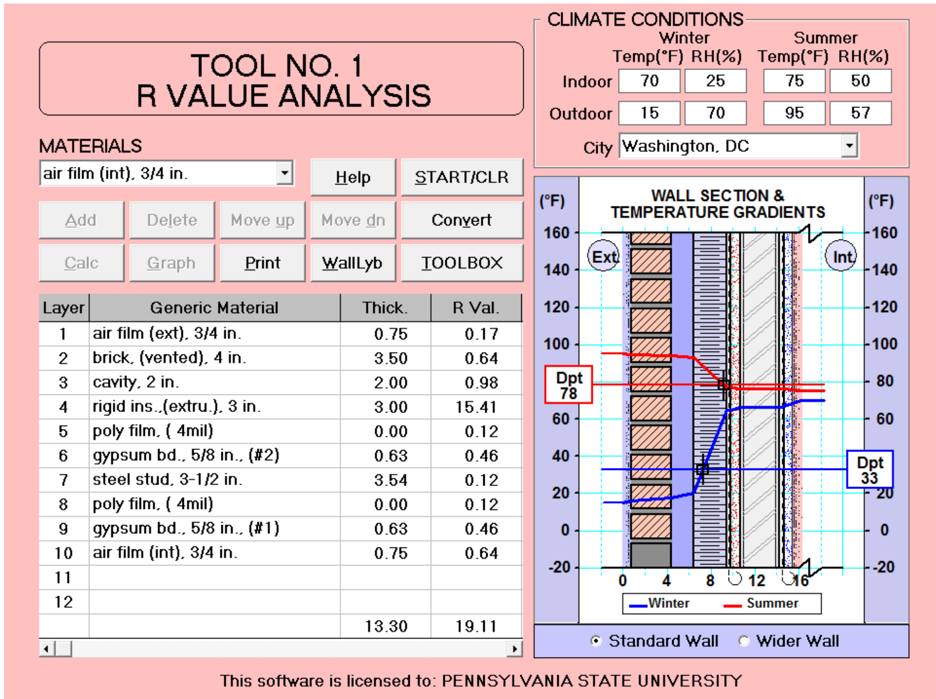


Insulated Architectural Cladding
Thermally Efficient Miter Corner Connection Detail

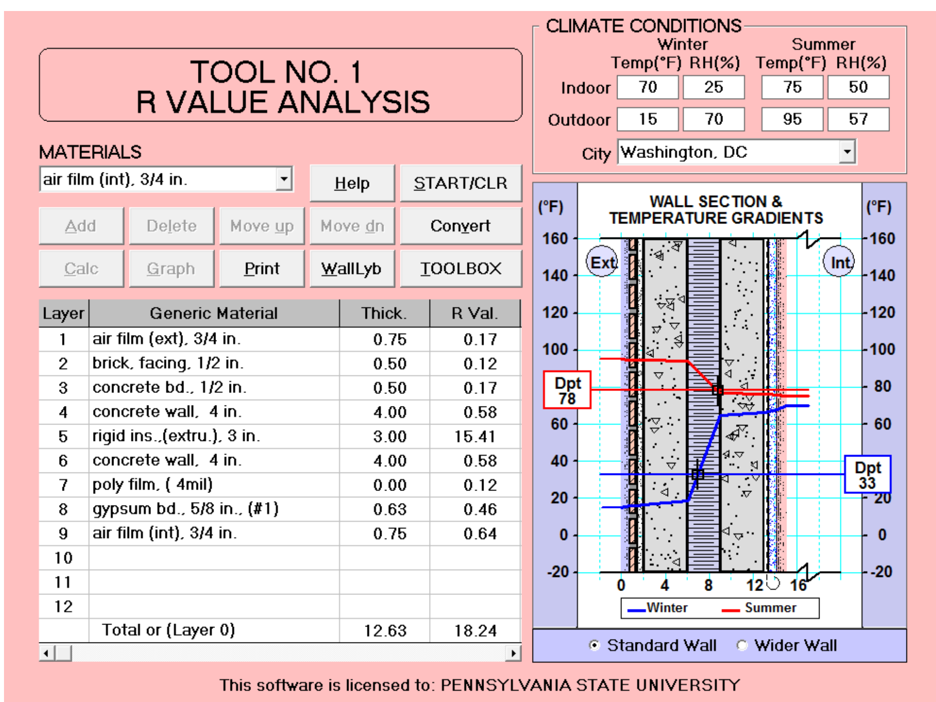
Appendix A.3

Thermal Energy Performance Study

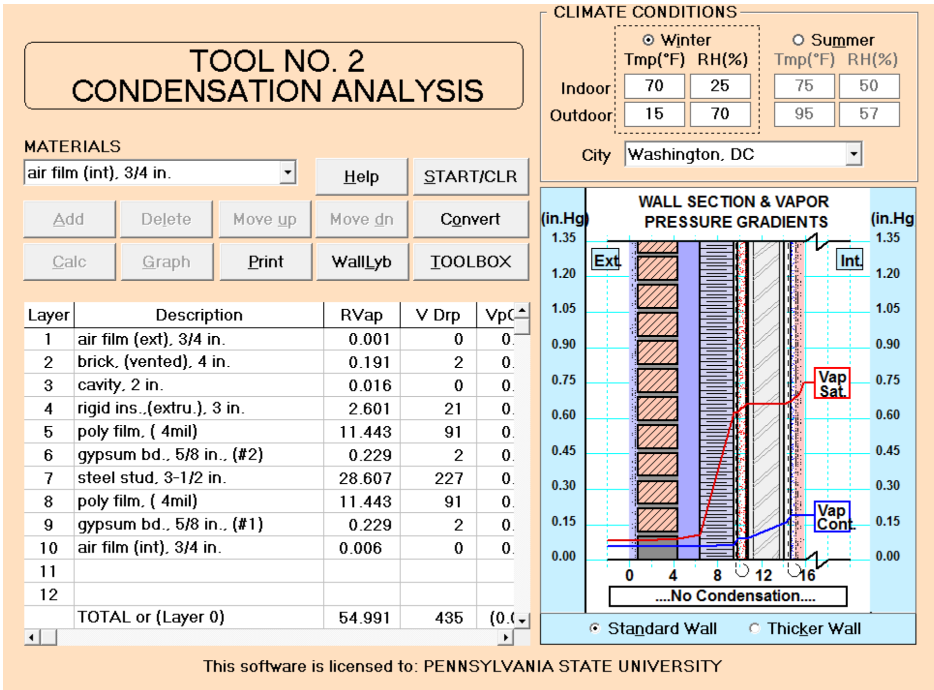
Existing Brick Veneer Wall System R-value Results



Proposed APC Wall Panel System R-value Results

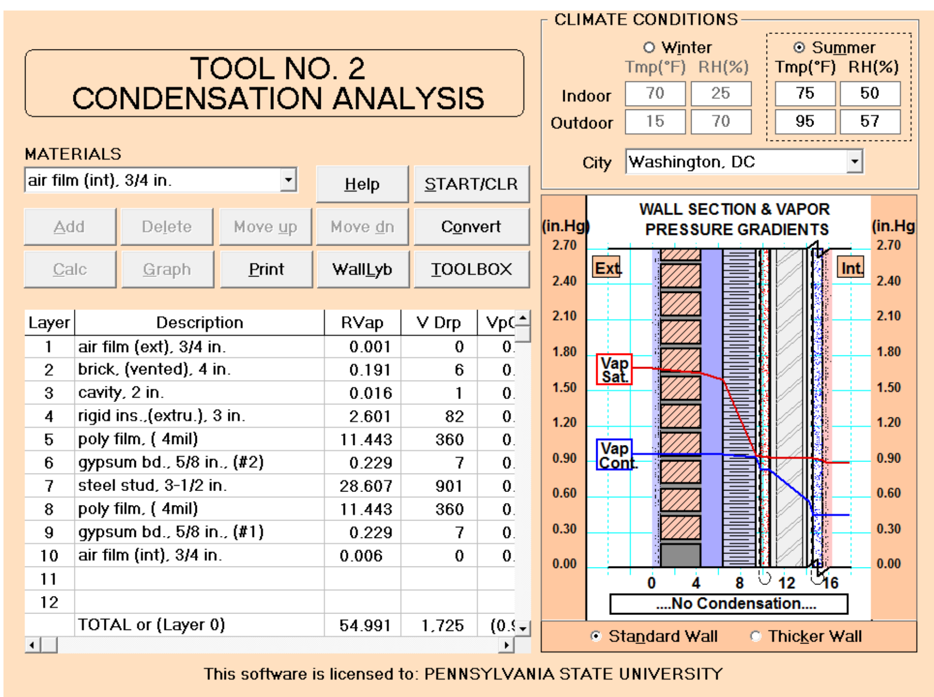


Proposed APC Wall Panel Condensation Results – Winter Conditions



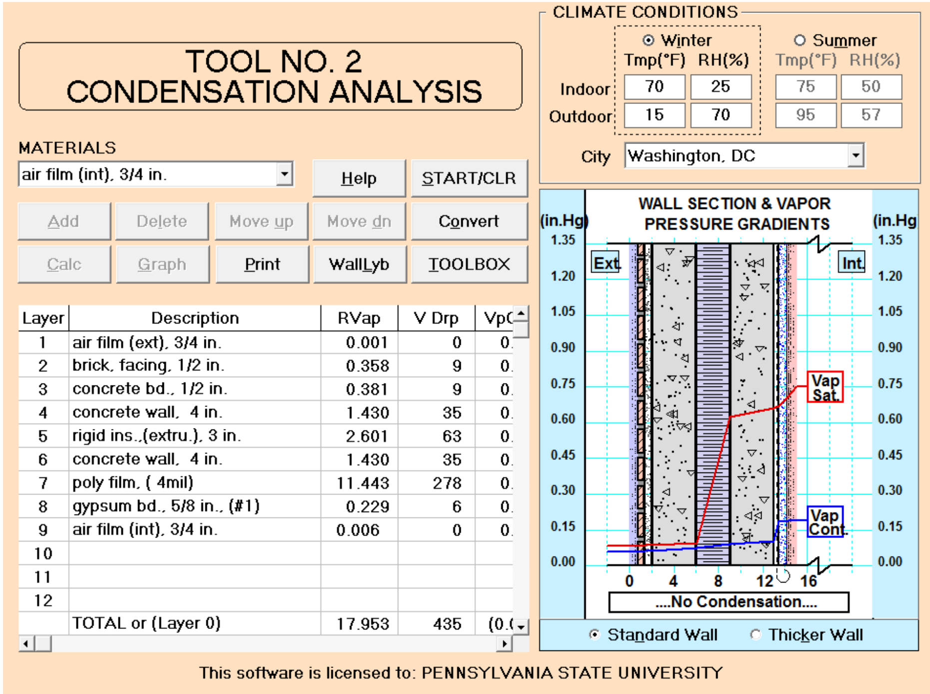
Layer	Description	RVap	V Drp	VpC
1	air film (ext), 3/4 in.	0.001	0	0.
2	brick, (vented), 4 in.	0.191	2	0.
3	cavity, 2 in.	0.016	0	0.
4	rigid ins.,(extru.), 3 in.	2.601	21	0.
5	poly film, (4mil)	11.443	91	0.
6	gypsum bd., 5/8 in., (#2)	0.229	2	0.
7	steel stud, 3-1/2 in.	28.607	227	0.
8	poly film, (4mil)	11.443	91	0.
9	gypsum bd., 5/8 in., (#1)	0.229	2	0.
10	air film (int), 3/4 in.	0.006	0	0.
11				
12				
	TOTAL or (Layer 0)	54.991	435	(0.(

Proposed APC Wall Panel Condensation Results – Summer Conditions

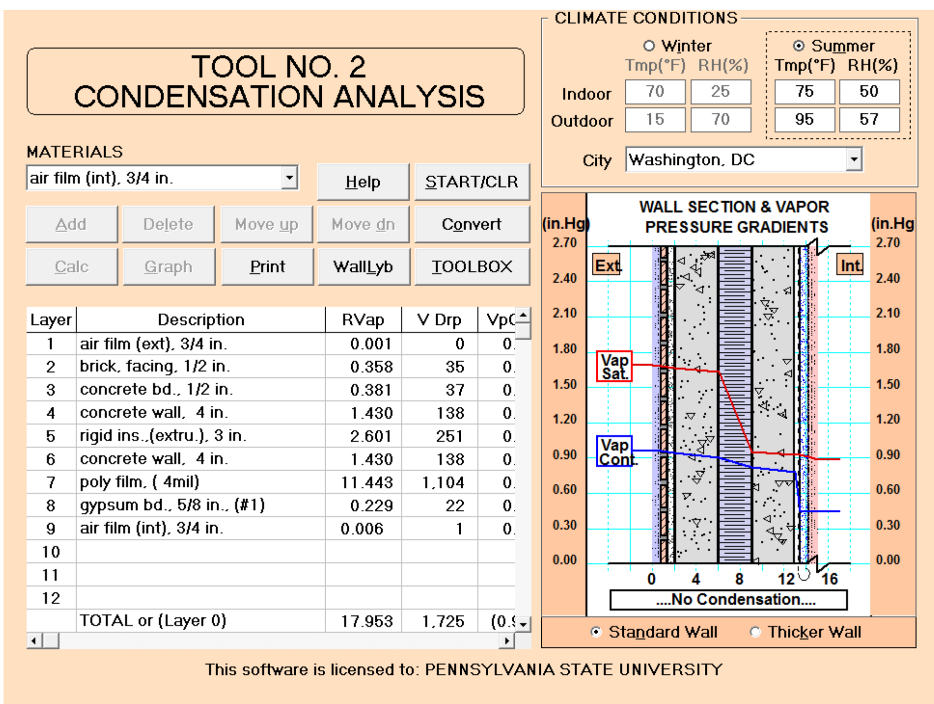


Layer	Description	RVap	V Drp	VpC
1	air film (ext), 3/4 in.	0.001	0	0.
2	brick, (vented), 4 in.	0.191	6	0.
3	cavity, 2 in.	0.016	1	0.
4	rigid ins.,(extru.), 3 in.	2.601	82	0.
5	poly film, (4mil)	11.443	360	0.
6	gypsum bd., 5/8 in., (#2)	0.229	7	0.
7	steel stud, 3-1/2 in.	28.607	901	0.
8	poly film, (4mil)	11.443	360	0.
9	gypsum bd., 5/8 in., (#1)	0.229	7	0.
10	air film (int), 3/4 in.	0.006	0	0.
11				
12				
	TOTAL or (Layer 0)	54.991	1,725	(0.(

Proposed APC Wall Panel System Condensation Results – Winter Conditions

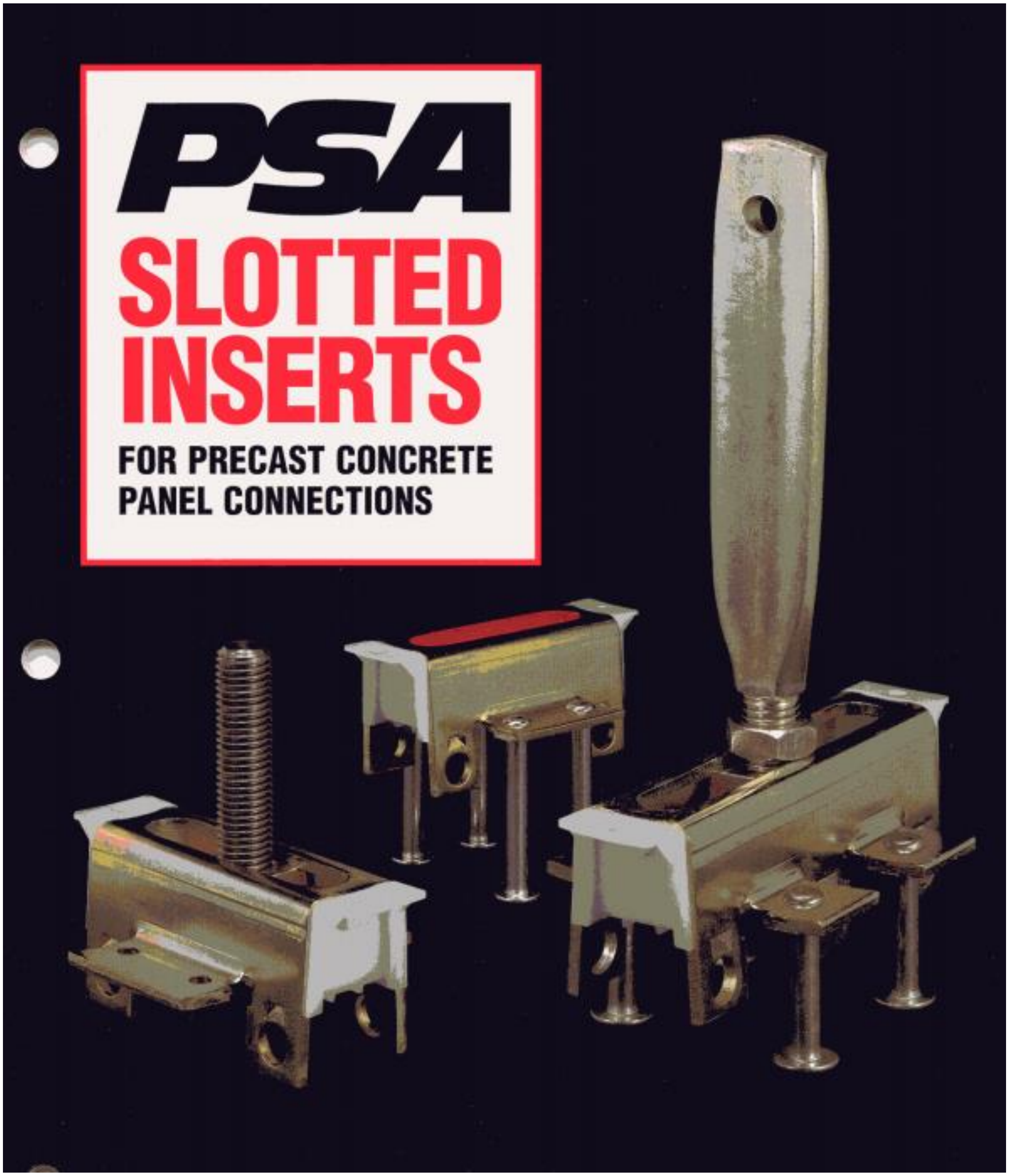


Proposed APC Wall Panel System Condensation Results – Summer Conditions



Appendix A.4

JVI Slotted Insert Product Data


PSA
SLOTTED INSERTS
FOR PRECAST CONCRETE PANEL CONNECTIONS

WHY A SLOTTED INSERT?

The early use of slotted inserts was in response to a need to move away from a myriad of complex and costly connection schemes and forward to an engineered prefabricated adjustable connection system providing the measurably consistent performance characteristics so necessary for credibility. They were – and are – an easy, safe, accurate, and economical method to locate and connect precast panels to framework while dramatically reducing erection costs.

WHY PSA SLOTTED INSERTS?

A fresh look at design concepts, manufacturing methods, and performance characteristics have resulted in numerous innovations that have pushed the evolution of the slotted insert to the next level...the PSA slotted insert!

CONSIDER THESE INNOVATIVE FEATURES:

- The modular design concept offers improved pull-out capacity of the basic insert. Higher capacities – up to 30 kips (ultimate) – are easily achieved by the addition of component parts.
- The totally automated manufacturing process offers the credibility of consistent performance levels not previously possible.
- Improved corrosion resistance is being mandated throughout the construction industry. The PSA slotted insert and strap anchor utilizes the J-finish, a remarkable new patented 3 step coating process developed by the automotive industry. Salt spray tests have rendered such superior results that traditional coatings of epoxy and hot-dipped galvanized are obsolete.
- Extensive performance reports provide the highest level of credibility and are readily available on request. Reports include:

Test #1: Pull-out capacity
Test #2: Pull-out capacity near edge
Test #3: Shear capacity
Test #4: Pull-out capacity, sandwich panels
Test #5: Pull-out capacity, end of insert
Test #6: Corrosion resistance
Test #7: 30 KIP load capacity

2-WAY ADJUSTMENT WELDED TO FRAMEWORK.

4-WAY ADJUSTMENT BOLTED TO FRAMEWORK.

2

SERIES 4500

INSERT TYPE	ULTIMATE PULL OUT CAPACITY	ULTIMATE SHEAR CAPACITY	AVAILABLE ADJUSTMENT
4525	>13,400 lbs.	>20,000 lbs.	2-7/8"

INSERT TYPE	ULTIMATE PULL OUT CAPACITY	ULTIMATE SHEAR CAPACITY	AVAILABLE ADJUSTMENT
4535	>18,800 lbs.	>20,000 lbs.	2-7/8"

INSERT TYPE	ULTIMATE PULL OUT CAPACITY	ULTIMATE SHEAR CAPACITY	AVAILABLE ADJUSTMENT
4545	>21,500 lbs.	>20,000 lbs.	2-1/8"

SERIES 6000

INSERT TYPE	ULTIMATE PULL OUT CAPACITY	ULTIMATE SHEAR CAPACITY	AVAILABLE ADJUSTMENT
6025	>13,400 lbs.	>20,000 lbs.	4-3/8"

INSERT TYPE	ULTIMATE PULL OUT CAPACITY	ULTIMATE SHEAR CAPACITY	AVAILABLE ADJUSTMENT
6035	>18,800 lbs.	>20,000 lbs.	4-3/8"

INSERT TYPE	ULTIMATE PULL OUT CAPACITY	ULTIMATE SHEAR CAPACITY	AVAILABLE ADJUSTMENT
6045	>21,500 lbs.	>20,000 lbs.	3-5/8"

3

PSA Insert (Top) J-Type Finish after 648 hrs.

PSA Strap Anchor J - Type Finish after 360 hrs.

PSA Insert (Top) Hot Dip Galv. Finish after 648 hrs.

PSA Strap Anchor Hot Dip Galv. Finish after 360 hrs.

STATE-OF-THE-ART CORROSION RESISTANCE

J-FINISH is a patented 3 step process (dip, rinse, and seal) developed by the automotive industry as a necessary improvement over the traditional inconsistent methods of hot-dipped galvanizing. It was an obvious choice for the PSA Slotted Insert and Strap Anchor. Full documentation of this advanced coating technology can be found in PSA Test Report #6 on corrosion resistance. Of special note is that the J-Finish (only .0005" thick) can be applied to the threads of strap anchors...traditionally the area most vulnerable to corrosion. Moreover, the choice of the J-Finish dramatically reduces toxic fumes generated from welding and does not contaminate a weld.

THREADED STRAP = SAFETY

SAFETY is always the highest priority in the development of new products at JVI. That is why a notched strap could not be considered. There is simply too much risk of failure. A threaded strap, conversely, provides a dramatically more positive connection method while maintaining the highest level of safety and ease of use.

+ SAFETY ISSUES +

● Tolerance Variations

If notched straps are not installed at 90° to the insert, pull-out strengths are partially compromised. A threaded strap anchor can be rotated to any angle to safely accommodate any variation or irregularity without loss of pull-out capacity.

● Eccentric Loading

Shear forces cause eccentric loading on inserts. The notched method concentrates these forces over its narrow 3/8 inch width which can result in a "can-opener" type failure of the insert lips. The threaded method - with its heavy duty nut (and optional washer) distributes these forces widely and evenly across the insert lips.

● Erection

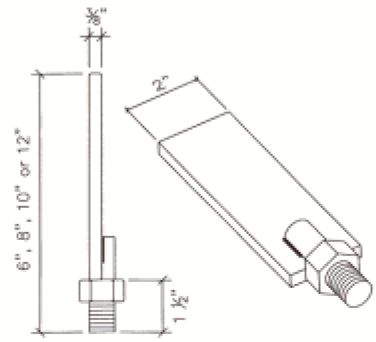
The notched strap anchor must be placed after the panel has been placed and requires at least 2" of clearance to rotate to 90° into the insert. If the insert was placed too low, tipping the panel away from the frame to clear the insert opening may put the installer (fingers, hands, etc.) in harms' way.

4

PSA STRAP ANCHORS

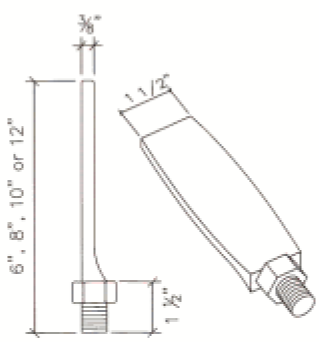
INNOVATIVE FEATURES INCLUDE:

- Flush placement of the threaded rod allows flat placement of the strap anchor thus eliminating the need for cumbersome shimming.
- The J-finish applies full protection onto the threads (traditionally the area most vulnerable to corrosion).
- A jam nut is supplied to accommodate the "push-pull" movement of wind loads.
- When vertical movement is desired, the introduction of a flat washer between the jam nut (tightened "finger tight") and the insert promotes full movement.
- Tension capacity exceeds 30 KIPS.
- A range of strap anchors provide a range of shear capacities while offering dramatic savings.



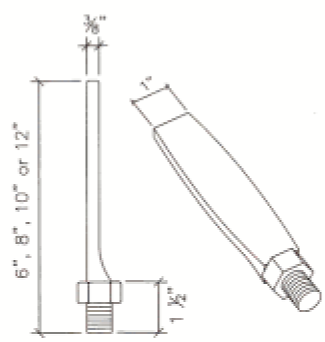
SHEAR CAPACITY - 2" WIDTH	
Eccentricity	KIPS - Avg
1"	20.2
1 1/2"	17.9
2"	14.2
2 1/2"	13.2
3"	11.3

Our standard 2" wide welded strap anchor provides the Highest shear capacity.



SHEAR CAPACITY - 1 1/2" WIDTH	
Eccentricity	KIPS - Avg
1"	17.1
1 1/2"	15.8
2"	14.9
2 1/2"	12.2
3"	11.2

Our Non-Welded Monolithic 1-1/2" wide strap anchor provides very high shear capacity at significant savings.

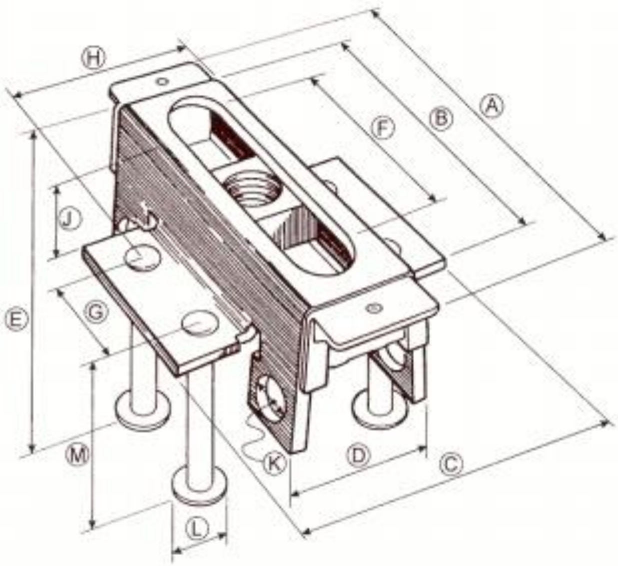


SHEAR CAPACITY - 1" WIDTH	
Eccentricity	KIPS - Avg
1"	11.1
1 1/2"	9.1
2"	8.4
2 1/2"	6.9
3"	6.4

Our Non-Welded Monolithic 1" wide strap anchor is the ideal solution for low shear applications at dramatic savings.

5

DIMENSIONAL SKETCHES



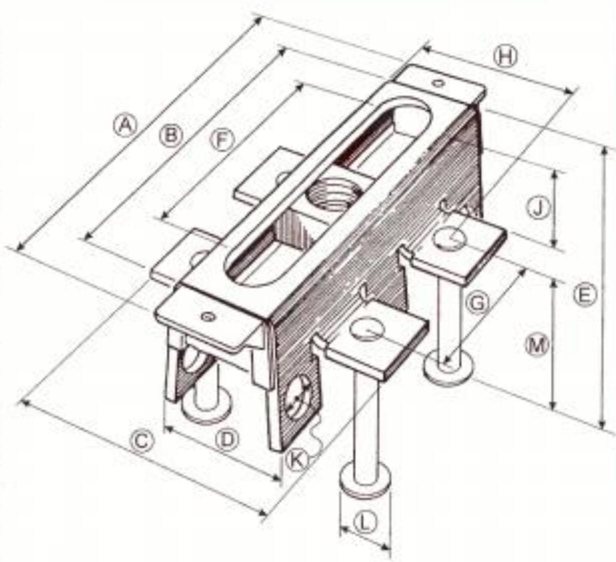
#4545 ILLUSTRATED

SERIES 4500

Ⓐ LENGTH (OVERALL)		5 3/4"
Ⓑ LENGTH (EXCLUDING PLASTIC TAB)		4 1/2"
Ⓒ WIDTH (OVERALL)		4 1/8"
Ⓓ WIDTH (AT BASE)		2"
Ⓔ DEPTH	4525 (NO STUD)	2 1/2"
	4535	3 1/2"
	4545	4 1/2"
Ⓕ ADJUSTMENT	4525	2 7/8"
	4535	2 7/8"
	4545	2 1/8"
Ⓖ CENTER TO CENTER (ON SAME SIDE)		1 1/2"
Ⓗ CENTER TO CENTER (ACROSS INSERT)		2 3/4"
Ⓙ TOP OF INSERT TO WING		1 1/4"
Ⓚ HOLE DIAMETER		9/16"
Ⓛ STUD HEAD DIAMETER		7/8"
Ⓜ STUD LENGTH	4535	2 1/4"
	4545	3 1/4"

SERIES 6000

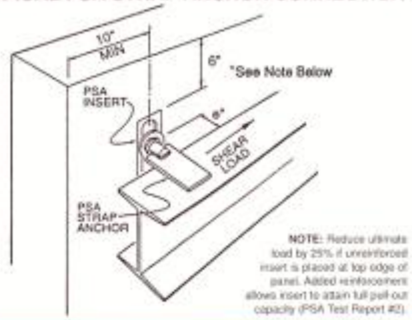
Ⓐ LENGTH (OVERALL)		7 1/4"
Ⓑ LENGTH (EXCLUDING PLASTIC TAB)		6"
Ⓒ WIDTH (OVERALL)		4 1/8"
Ⓓ WIDTH (AT BASE)		2"
Ⓔ DEPTH	6025 (NO STUD)	2 1/2"
	6035	3 1/2"
	6045	4 1/2"
Ⓕ ADJUSTMENT	6025	4 3/8"
	6035	4 3/8"
	6045	3 5/8"
Ⓖ CENTER TO CENTER (ON SAME SIDE)		2 1/2"
Ⓗ CENTER TO CENTER (ACROSS INSERT)		2 3/4"
Ⓙ TOP OF INSERT TO WING		1 1/4"
Ⓚ HOLE DIAMETER		9/16"
Ⓛ STUD HEAD DIAMETER		7/8"
Ⓜ STUD LENGTH	6035	2 1/4"
	6045	3 1/4"



#6045 ILLUSTRATED

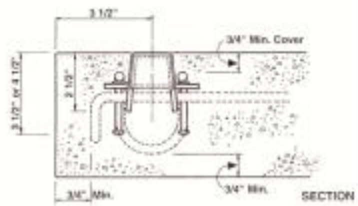
6

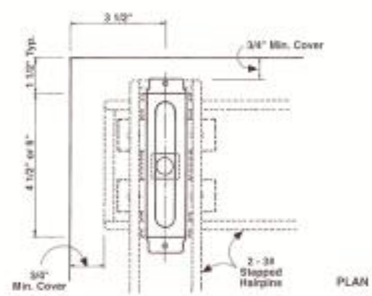
TYPICAL PSA STRAP ANCHOR CONNECTION



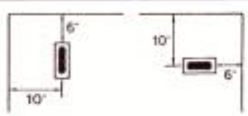
NOTE: Reduce ultimate load by 25% if unreinforced insert is placed at top edge of panel. Added reinforcement allows insert to attain full pull-out capacity (PSA Test Report #2).

STEPPED HAIR PIN REINFORCEMENTS NEAR EDGE





SUGGESTED CORNER DETAIL
(IN ADDITION TO PANEL REINFORCEMENT)



MINIMUM EDGE DISTANCE

The minimum edge distance without the use of additional reinforcing steel is 6" and 10" as shown in the illustration. The edge distance can be reduced if extra reinforcement is installed (PSA Test Report #2).

MATERIAL SPECIFICATIONS:

INSERTS	
Steel	ASTM - A607, GR 50
Square Nut	SAE GR 5, AISI 1045
H.D. Galv.	CSA G164-M92, ASTM-A123, A153
Studs	AISI 1016 (Round Head)
J-Finish	GM 4345M-8D500/96
	ASTM B633 Type II (0.0005 Thk)
	+ Dichromate Rinse + Seal Coat
(Patented)	
STRAP ANCHORS	
Steel	CSA G40, 21, GR 44W
Thd. Studs	SAE 1038
J-Finish	GM 4345 M-8D500/96
	ASTM B633 Type II (0.0005 Thk)

WEIGHT-INSERTS:

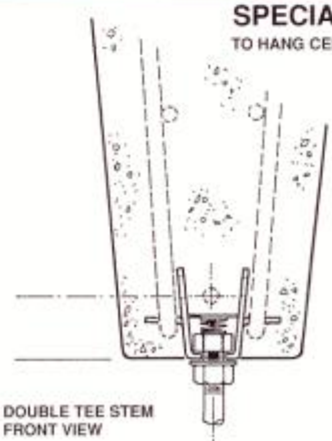
	lb.	kgf
4525	1.5	.680
4535	1.9	.862
4545	2.3	1.043
6025	2.0	.907
6035	2.3	1.043
6045	2.5	1.134

WEIGHT-STRAP ANCHORS:

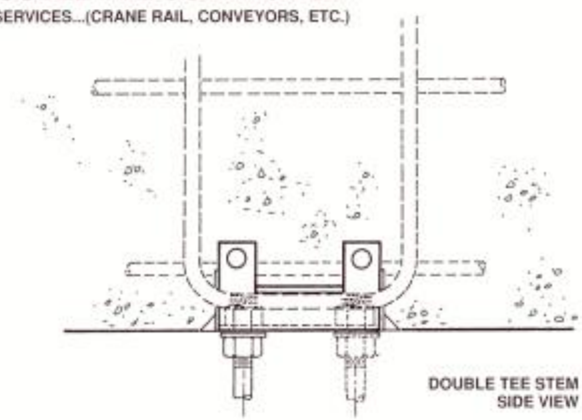
	lb.	kgf
675	1.2	.544
875	1.6	.726
1075	2.0	.907
1275	2.4	1.089

SPECIAL DOUBLE TEE CONNECTION

TO HANG CEILING SERVICES...(CRANE RAIL, CONVEYORS, ETC.)



DOUBLE TEE STEM
FRONT VIEW



DOUBLE TEE STEM
SIDE VIEW

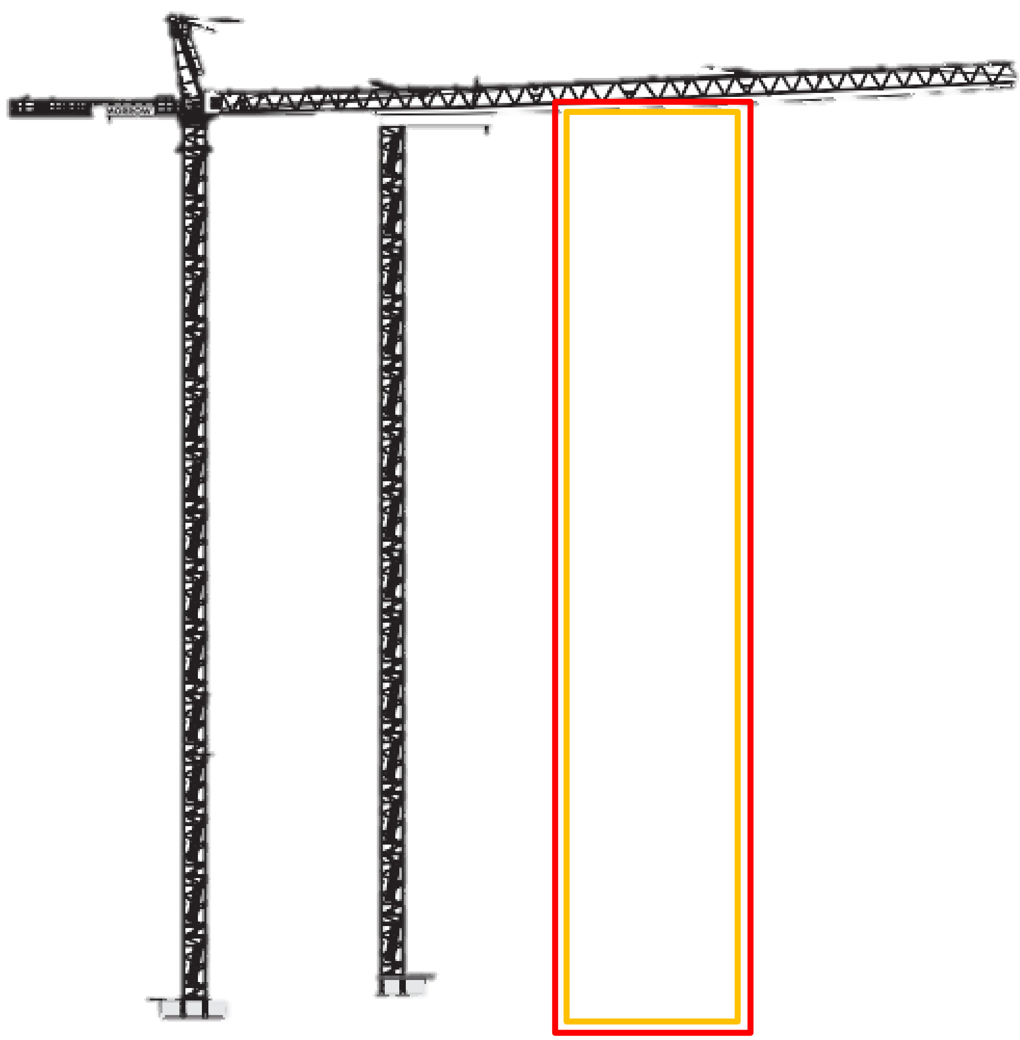
7

Appendix A.5

Crane Resizing Selection Sheets and Site Logistics Plans

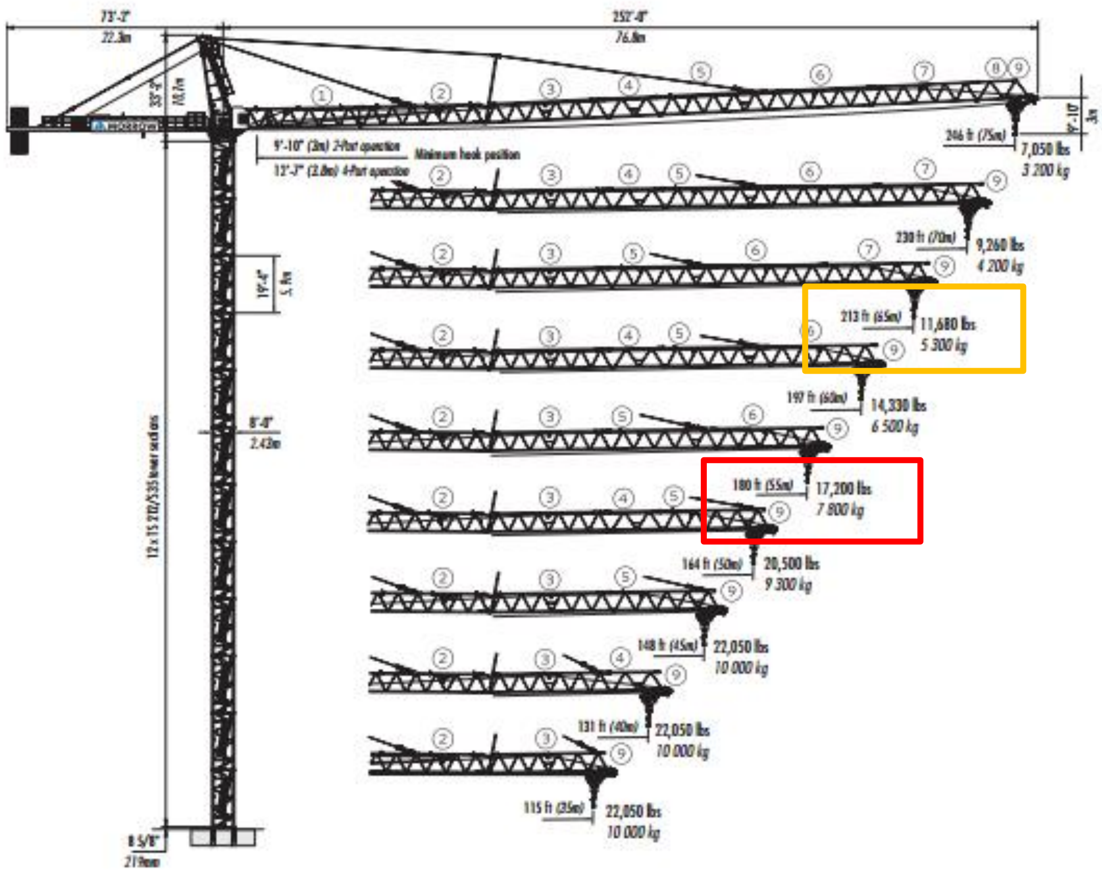
Original Sizing

New Sizing



SK 415-20

Jib Layout



Counterweights

246-ft Jib	230-ft Jib	213-ft Jib	197-ft Jib	180-ft Jib	164-ft Jib	148-ft Jib	131-ft Jib	115-ft Jib
8 A	8 A	8 A	8 A	7 A	7 A	7 A	6 A	6 A
54,675 lbs	54,675 lbs	54,675 lbs	54,675 lbs	47,840 lbs	47,840 lbs	47,840 lbs	41,000 lbs	41,000 lbs
24 800 kg	24 800 kg	24 800 kg	24 800 kg	21 700 kg	21 700 kg	21 700 kg	18 600 kg	18 600 kg

NOTE! *Counterweight information above applies to 2-part and 4-part operation. Weight of the A Block is 6,835 lbs (3 100 kg). Counterweights must be installed from rear to front, i.e. toward the tower. It is recommended that the weight of each counterweight be verified before installation. Counterweight figures displayed in the chart above are for crane with hoist unit SR WB 76 - 100/4F. If another hoist unit is installed, refer to the SK 415-20 Operation Manual or contact Morrow Equipment.*

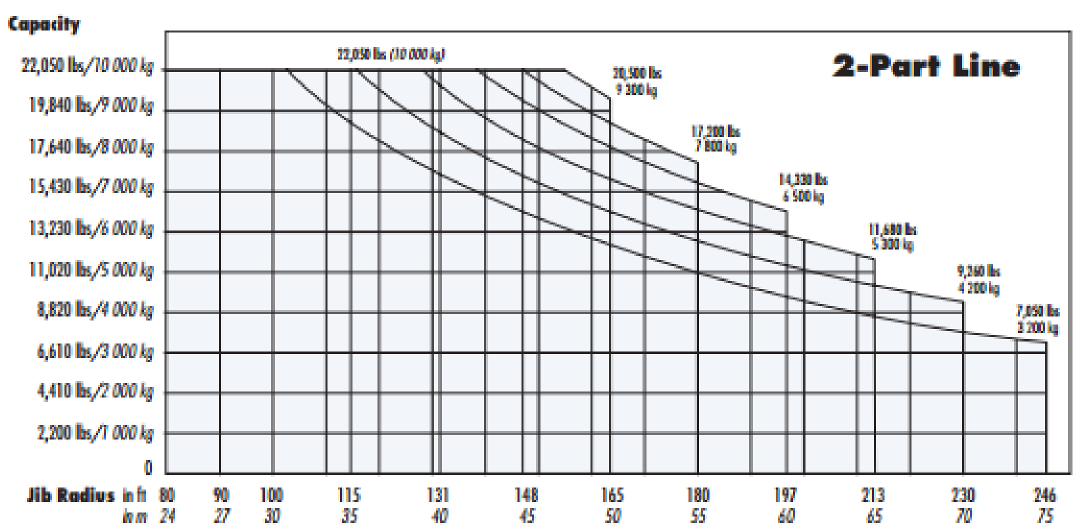
MORROW

SK 415-20

Radius and Capacities

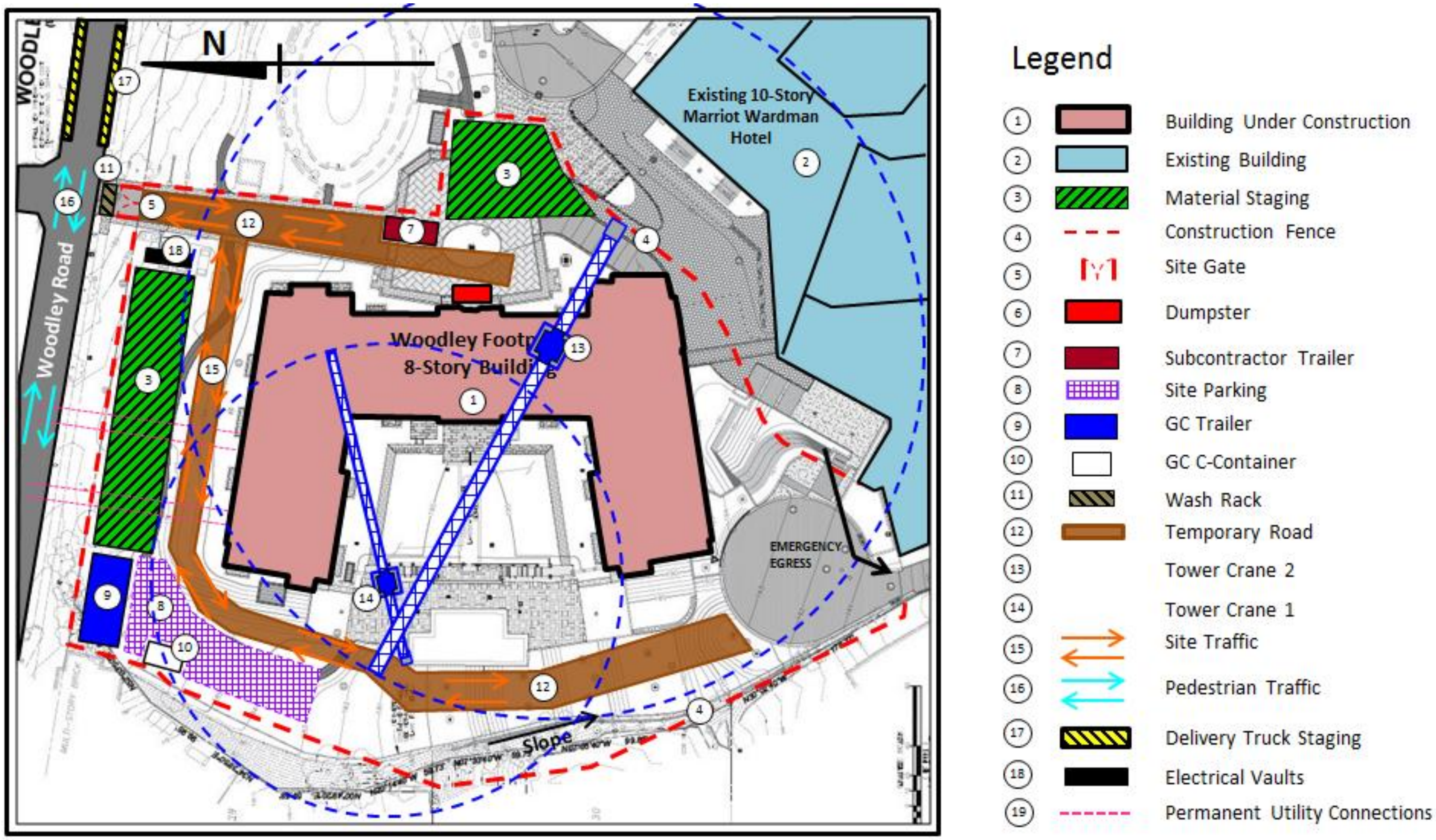
2-Part Operation

Hook Reach	Jib Tip Radius	Maximum Capacity – Radius	ft / m	33 / 10	49 / 15	66 / 20	82 / 25	98 / 30	115 / 35	131 / 40	148 / 45	164 / 50	180 / 55	197 / 60	213 / 65	230 / 70	246 / 75
246 ft / 75m	252'-0" / 76.8m	22,050 lbs – 104 ft / 10 000 kg – 31.6m	lbs / kg	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	19,670 / 8 920	16,670 / 7 560	14,370 / 6 520	12,540 / 5 690	11,050 / 5 010	9,790 / 4 440	8,730 / 3 960	7,830 / 3 550	7,050 / 3 200
230 ft / 70m	235'-7" / 71.8m	22,050 lbs – 117 ft / 10 000 kg – 35.6m	lbs / kg	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	19,180 / 8 700	16,600 / 7 530	14,530 / 6 590	12,850 / 5 830	11,460 / 5 200	10,270 / 4 660	9,260 / 4 200	
213 ft / 65m	219'-2" / 66.8m	22,050 lbs –129 ft / 10 000 kg – 39.2m	lbs / kg	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	21,500 / 9 750	18,650 / 8 460	16,380 / 7 430	14,530 / 6 590	12,990 / 5 890	11,680 / 5 300		
197 ft / 60m	202'-9" / 61.7m	22,050 lbs – 139 ft / 10 000 kg – 42.4m	lbs / kg	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	20,460 / 9 280	17,990 / 8 160	16,000 / 7 260	14,330 / 6 500			
180 ft / 55m	186'-0" / 56.7m	22,050 lbs – 148 ft / 10 000 kg – 45m	lbs / kg	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	21,910 / 9 940	19,310 / 8 760	17,200 / 7 800				
164 ft / 50m	169'-7" / 51.7m	22,050 lbs – 155 ft / 10 000 kg – 47.3m	lbs / kg	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	20,500 / 9 300					
148 ft / 45m	153'-3" / 46.7m	22,050 lbs – 148 ft / 10 000 kg – 45m	lbs / kg	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000						
131 ft / 40m	136'-10" / 41.7m	22,050 lbs – 131 ft / 10 000 kg – 40m	lbs / kg	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000							
115 ft / 35m	120'-5" / 36.7m	22,050 lbs – 115 ft / 10 000 kg – 35m	lbs / kg	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000	22,050 / 10 000								



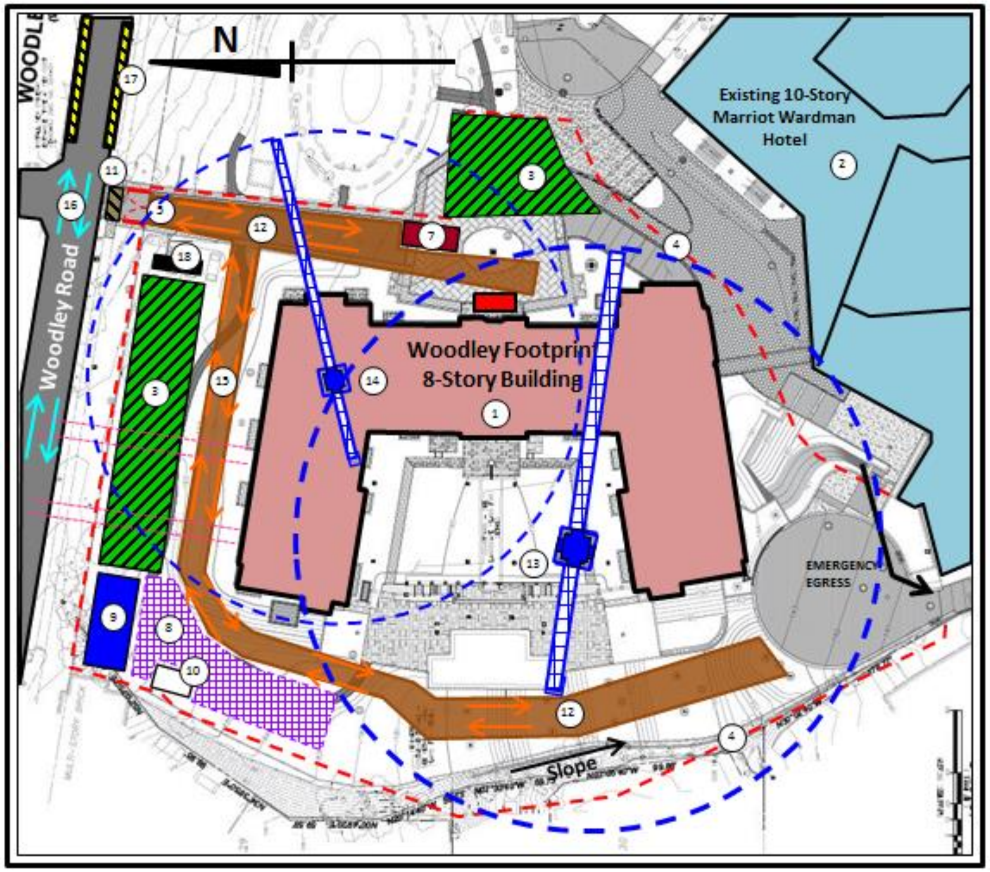
MORROW

Concrete Structure Phase – Original Tower Crane Locations and Sizing



The Woodley Woodley Park NW Washington, DC	**Site Utilization Plan** Phase 2 Residential – Structure	CLARK CONSTRUCTION The JBG Companies	Kevin Kroener Construction Option 4/9/2014

Concrete Structure Phase – Revised Tower Crane Locations and Sizing

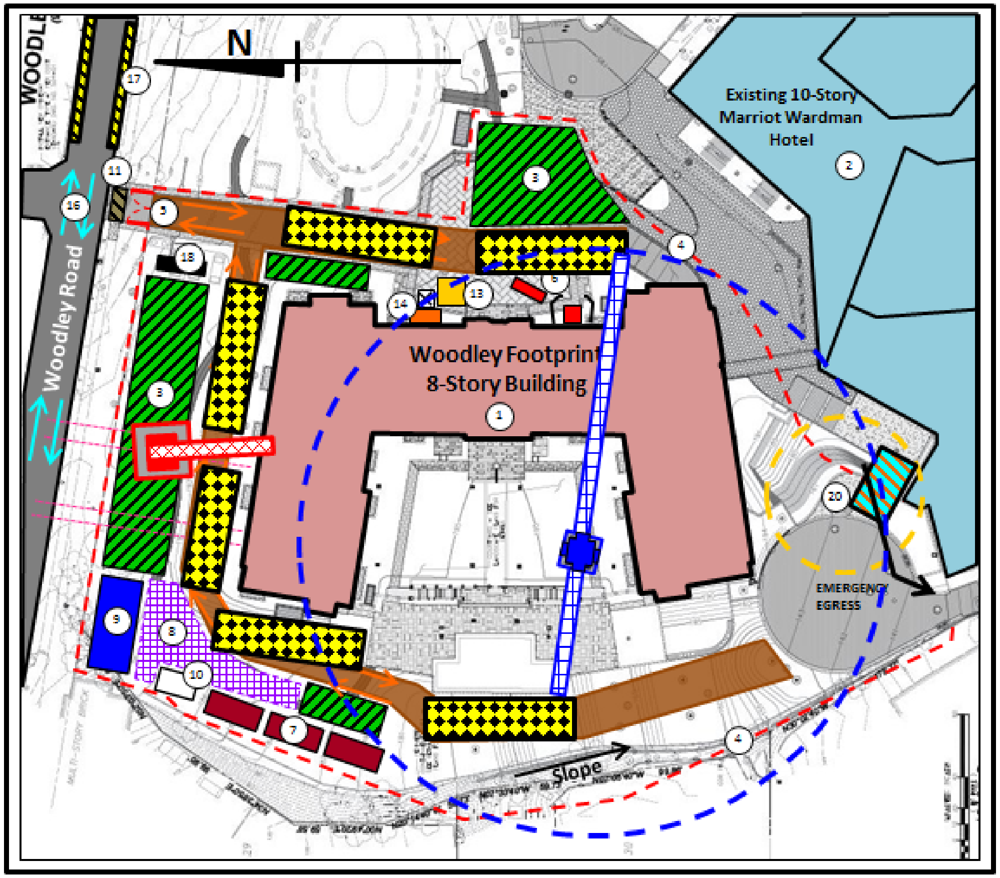


Legend

1		Building Under Construction
2		Existing Building
3		Material Staging
4		Construction Fence
5		Site Gate
6		Dumpster
7		Subcontractor Trailer
8		Site Parking
9		GC Trailer
10		GC C-Container
11		Wash Rack
12		Temporary Road
13		Tower Crane 2
14		Tower Crane 1
15		Site Traffic
16		Pedestrian Traffic
17		Delivery Truck Staging
18		Electrical Vaults
19		Permanent Utility Connections

The Woodley Woodley Park NW Washington, DC	**Site Utilization Plan** Phase 2 Residential – Structure	CLARK CONSTRUCTION THE JBG COMPANIES	Kevin Kroener Construction Option 4/9/2014

Exterior Skin Phase – Erection Staging Area Locations

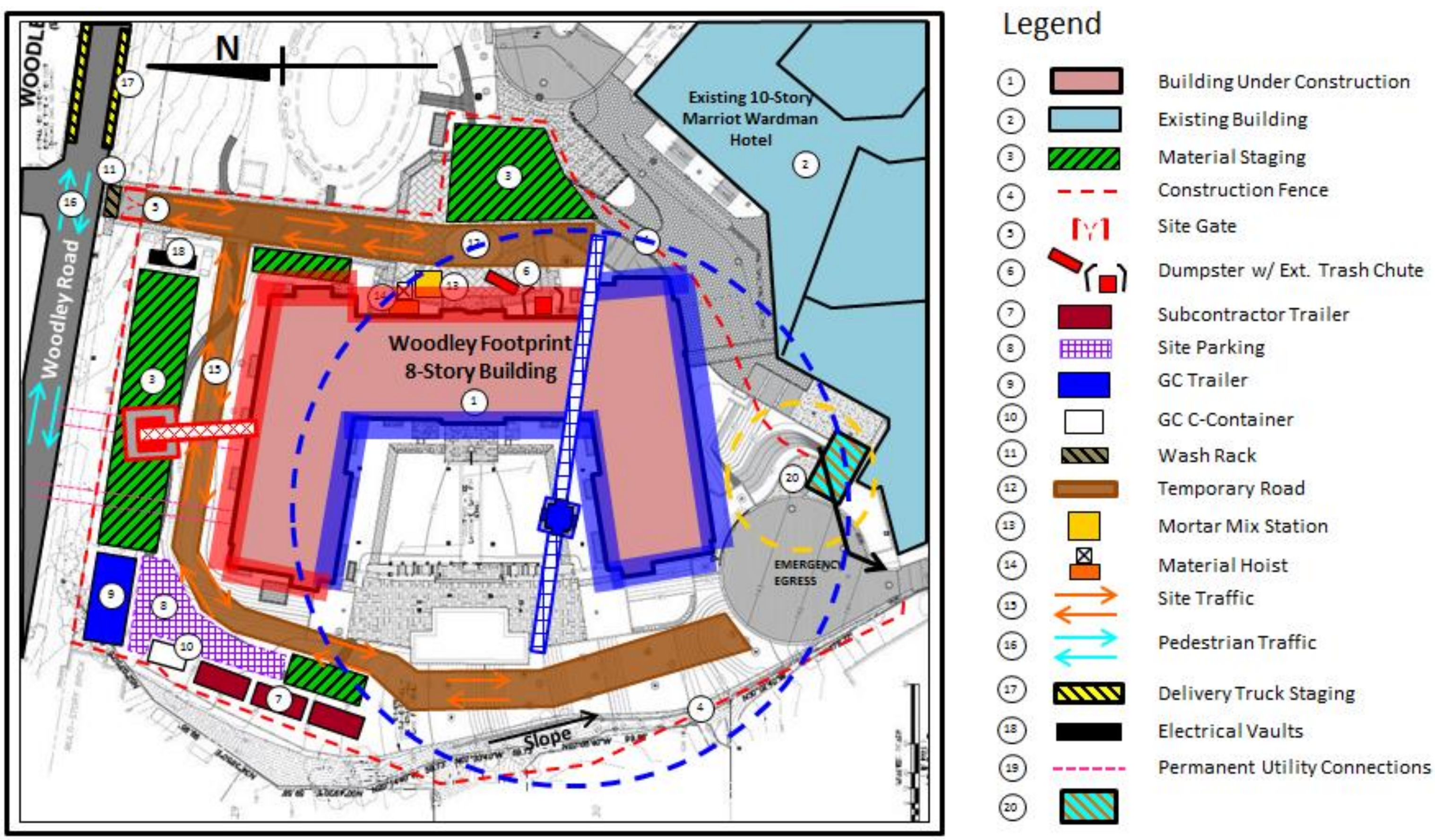


Legend

1. Building Under Construction
2. Existing Building
3. Material Staging
4. Construction Fence
5. Site Gate
6. Dumpster w/ Ext. Trash Chute
7. Subcontractor Trailer
8. Site Parking
9. GC Trailer
10. GC C-Container
11. Wash Rack
12. Temporary Road
13. Mortar Mix Station
14. Material Hoist
15. Site Traffic
16. Pedestrian Traffic
17. Delivery Truck Staging
18. Electrical Vaults
19. Permanent Utility Connections
20.

The Woodley Woodley Park NW Washington, DC	**Site Utilization Plan** Phase 2 Residential – Skin/Finishes/Site	CLARK CONSTRUCTION The JBG Companies	Kevin Kroener Construction Option 4/9/2014

Exterior Skin Phase – Erection Crane Use Sequencing



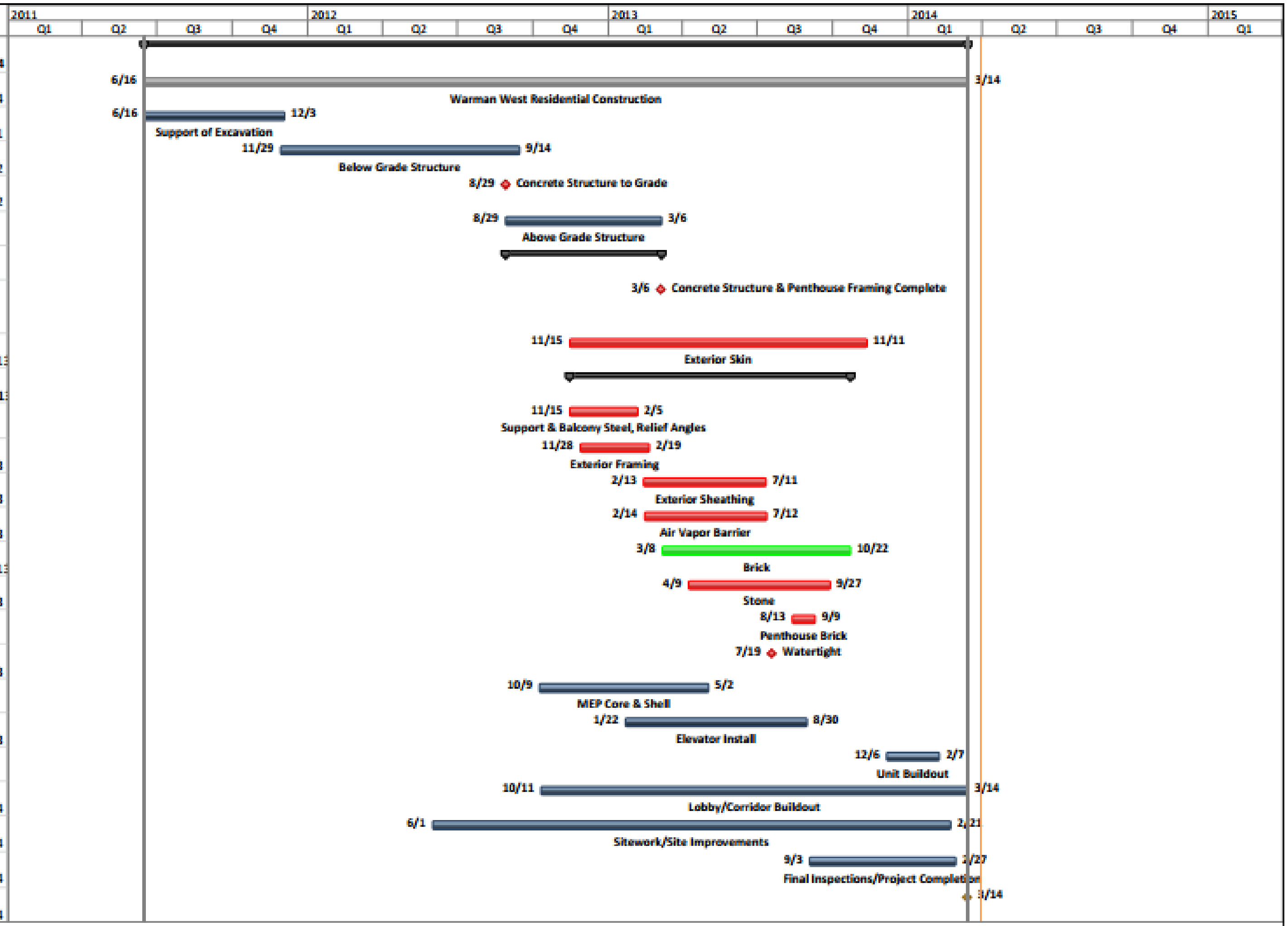
The Woodley Woodley Park NW Washington, DC	**Site Utilization Plan** Phase 2 Residential – Skin/Finishes/Site	CLARK CONSTRUCTION THE JBG COMPANIES	Kevin Kroener Construction Option 4/9/2014

Appendix A.6

Original & Revised APC Panel Project Schedules

Original Project Schedule

ID	Task Name	Duration	Start	Finish
1	Wardmn West Residenital Construction	717 days	Thu 6/16/11	Fri 3/14/14
2	Warman West Residential Construction	717 days	Thu 6/16/11	Fri 3/14/14
3	Support of Excavation	123 days	Thu 6/16/11	Sat 12/3/11
4	Below Grade Structure	209 days	Tue 11/29/1	Fri 9/14/12
5	Concrete Structure to Grade	0 days	Wed 8/29/12	Wed 8/29/12
6	Above Grade Structure	136 days	Wed 8/29/12	Wed 3/6/13
7	Above Grade Structure	136 days	Wed 8/29/12	Wed 3/6/13
18	Concrete Structure & Penthouse Framing Complete	0 days	Wed 3/6/13	Wed 3/6/13
19	Exterior Skin	258 days	Thu 11/15/1	Mon 11/11/1
20	Exterior Skin	244 days	Thu 11/15/1	Tue 10/22/1
21	Support & Balcony Steel, Relief Angles	59 days	Thu 11/15/1	Tue 2/5/13
22	Exterior Framing	60 days	Wed 11/28/1	Tue 2/19/13
23	Exterior Sheathing	107 days	Wed 2/13/13	Thu 7/11/13
24	Air Vapor Barrier	107 days	Thu 2/14/13	Fri 7/12/13
25	Brick	163 days	Fri 3/8/13	Tue 10/22/1
26	Stone	124 days	Tue 4/9/13	Fri 9/27/13
27	Penthouse Brick	20 days	Tue 8/13/13	Mon 9/9/13
28	Watertight	0 days	Fri 7/19/13	Fri 7/19/13
29	MEP Core & Shell	148 days	Tue 10/9/12	Thu 5/2/13
30	Elevator Install	159 days	Tue 1/22/13	Fri 8/30/13
31	Unit Buildout	46 days	Fri 12/6/13	Fri 2/7/14
32	Lobby/Corridor Buildout	372 days	Thu 10/11/1	Fri 3/14/14
33	Sitework/Site Improvements	451 days	Fri 6/1/12	Fri 2/21/14
34	Final Inspections/Project Completion	128 days	Tue 9/3/13	Thu 2/27/14
35	Substantial Completion	0 days	Fri 3/14/14	Fri 3/14/14



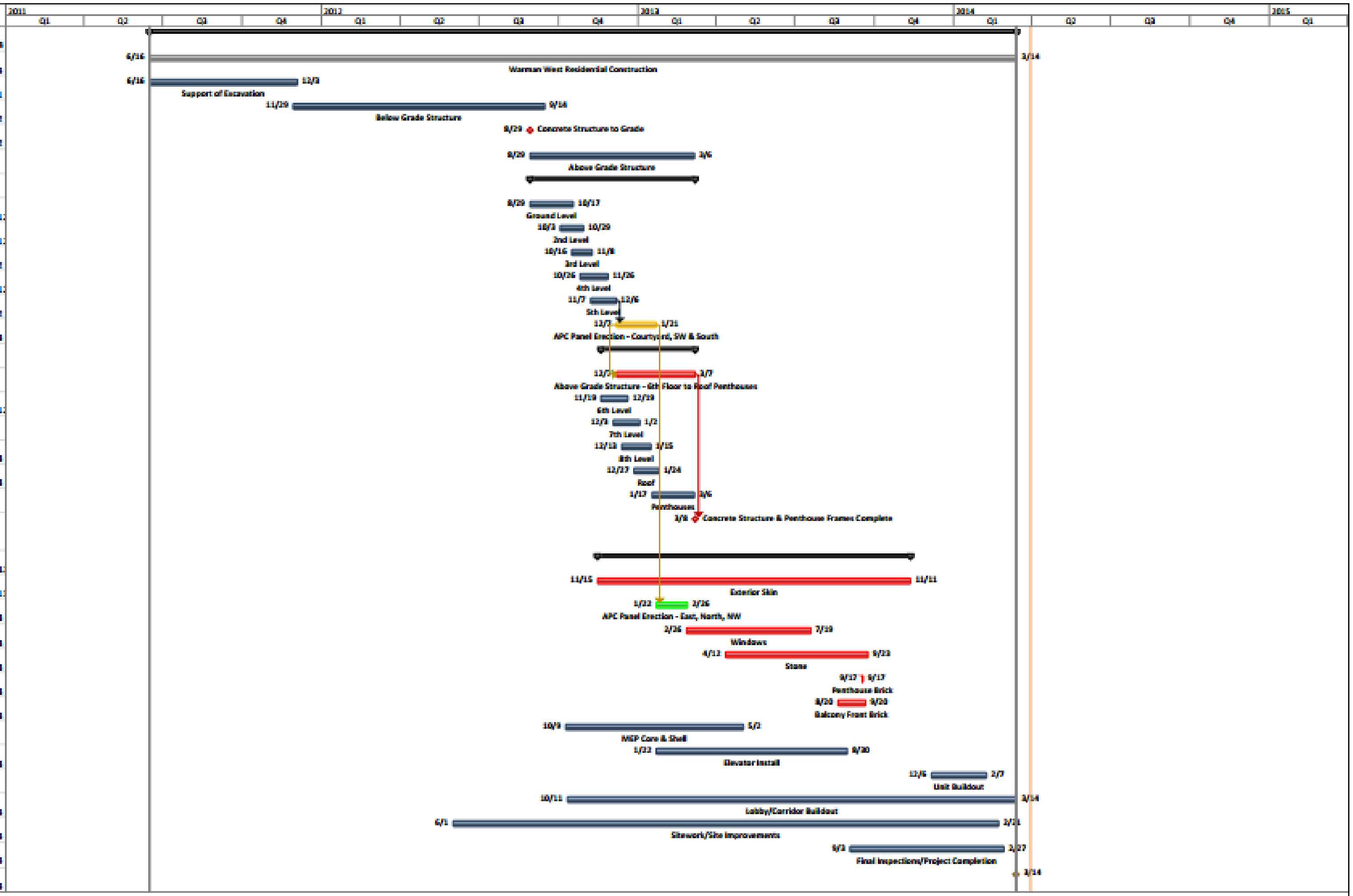
Project: Thesis_Wardman_Orignia
Date: Mon 3/31/14

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

Page 1

Revised ACP Panel Project Schedule

ID	Task Name	Duration	Start	Finish
1	Wardmn West Residential Construction	717 days	Thu 6/16/11	Fri 3/14/14
2	Warman West Residential Construction	717 days	Thu 6/16/11	Fri 3/14/14
3	Support of Excavation	123 days	Thu 6/16/11	Sat 12/3/11
4	Below Grade Structure	209 days	Tue 11/29/1	Fri 9/14/12
5	Concrete Structure to Grade	0 days	Wed 8/29/12	Wed 8/29/12
6	Above Grade Structure	136 days	Wed 8/29/12	Wed 3/6/13
7	Above Grade Structure	137 days	Wed 8/29/12	Thu 3/7/13
8	Ground Level	36 days	Wed 8/29/12	Wed 10/17/1
9	2nd Level	19 days	Wed 10/3/12	Mon 10/29/1
10	3rd Level	18 days	Tue 10/16/1	Thu 11/8/12
11	4th Level	22 days	Fri 10/26/1	Mon 11/26/1
12	5th Level	22 days	Wed 11/7/12	Thu 12/6/12
13	APC Panel Erection - Courtyard, SW & South	32 days	Fri 12/7/12	Mon 1/21/13
14	<New Summary Task>	79 days	Mon 11/19/1	Thu 3/7/13
15	Above Grade Structure - 6th Floor	65 days	Fri 12/7/12	Thu 3/7/13
16	6th Level	23 days	Mon 11/19/1	Wed 12/19/1
17	7th Level	23 days	Mon 12/3/12	Wed 1/2/13
18	8th Level	24 days	Thu 12/13/1	Tue 1/15/13
19	Roof	21 days	Thu 12/27/1	Thu 1/24/13
20	Penthouses	35 days	Thu 1/17/13	Wed 3/6/13
21	Concrete Structure & Penthouse Frames Complete	0 days	Fri 3/8/13	Fri 3/8/13
22	<New Summary Task>	258 days	Thu 11/15/1	Mon 11/11/1
23	Exterior Skin	258 days	Thu 11/15/1	Mon 11/11/1
24	APC Panel Erection - East, North, NW	26 days	Tue 1/22/13	Tue 2/26/13
25	Windows	104 days	Tue 2/26/13	Fri 7/19/13
26	Stone	117 days	Fri 4/12/13	Mon 9/23/13
27	Penthouse Brick	1 day	Tue 9/17/13	Tue 9/17/13
28	Balcony Front Brick	24 days	Tue 8/20/13	Fri 9/20/13
29	MEP Core & Shell	148 days	Tue 10/9/12	Thu 5/2/13
30	Elevator Install	159 days	Tue 1/22/13	Fri 8/30/13
31	Unit Buildout	46 days	Fri 12/6/13	Fri 2/7/14
32	Lobby/Corridor Buildout	372 days	Thu 10/11/1	Fri 3/14/14
33	Sitework/Site Improvements	451 days	Fri 6/1/12	Fri 2/21/14
34	Final Inspections/Project Completion	128 days	Tue 9/3/13	Thu 2/27/14
35	Substantial Completion	0 days	Fri 3/14/14	Fri 3/14/14



Project: Thesis_Wardman_Revised
Date: Mon 3/31/14

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

Page 1

Appendix A.7

Cost Savings Breakdown

Existing Brick Veneer Wall System

Item	Unit	Quantity	Unit Price		Amount
Brick					
Brick at Balconies	sf	1,130	$35.00	$	39,540
Birck Soldier Course	sf	821	$45.00	$	36,927
Brick Standard Size Running Bond	sf	74,274	$35.00	$	2,599,593
Subtotal				**$**	**2,676,060**
Backup, Sheathing and Insulation					
Metal Stud Backup with Sheathing	sf	111,669	$3.50	$	390,841
Gypsum Board and Batt Insulation	sf	111,669	$2.25	$	251
Rigid Insualtion	sf	111,669	$1.50	$	255
Exterior Tyvek Wrap	sf	111,669	$0.50	$	167,503
Subtotal				**$**	**55,834**
Metals					
Slab edge shelf angles	lf	11,700	$25.00	$	292,500
Subtotal				**$**	**292,500**
Misc.					
Wall Flashings	sf	147,450	$1.00	$	147,450
Caulking	sf	147,450	$0.50	$	73,725
Scaffolding	mon.	9	$ 2,800.00	$	25,200
Subtotal				**$**	**246,375**
Limestone					
Headers and Sills	lf	3915	75	$	293,625
Jambs	lf	4275	75	$	320,625
Install of Headers, Sills and Jambs	lf	8190	28	$	229,320
Subtotal				**$**	**843,570**
Total					**$4,114,339**

Proposed APC Wall Panel System

Item	Unit	Quantity	Unit Price		Amount
Architectural Precast Concrete Panels					
APC Wall Panels	sf	69,212	$40.00	$	2,768,480
*** includes attachment hardware*					
Subtotal				**$**	**2,768,480**
Metals					
Slab edge shelf angles	lf	11,700	$25.00	$	292,500
Subtotal				**$**	**292,500**
Misc.					
Caulking	sf	221,175	$0.50	$	110,588
Brick at Penthouses	sf	5,883	$35.00	$	205,905
Subtotal				**$**	**316,493**
Total					**$3,377,473**

Appendix A.8

APC Panel Structural Feasibility & Redesign Study: Wind and Seismic Load Complete Calculations

Architectural Precast Wall Panels – Applied Wind and Seismic Loads

Building Location – Washington, DC

Building Code – IBC 2006 / ASCE 7-05

Wind Loads

Basis – Provisions for wind in IBC 2006, Section 1609 are identical and/or make reference to those in Chapter 6 of ASCE 7-05. The provisions of ASCE 7-05 will be referenced for development of wind loads on the precast wall panels.

Building Structure - Building framing system is of rigid frame cast-in-place concrete construction. Floor system is also of cast-in-place concrete employing a post-tensioning system in the floor slab construction. The exterior walls are composed of an insulated brick veneer supported vertically and laterally from the concrete frame.

Wind Design Procedure – For the purpose of evaluating wind load effects, the building is considered enclosed. The building structure is also classified as rigid per Section 6.2 of ASCE 7-05 with a natural frequency greater than 1 Hz. Based on the above conditions, Method 2 – Analytical Procedure as defined in Section 6.5 of ASCE 7-05 will be used for developing wind loads.

Wind Evaluation Factors for Method 2 – Analytical Procedure (ASCE 7-05, Section 6.5.3):

1. The basic wind speed V is 90 mph as given in Figure 6-1.

2. The wind importance factor (I) is 1.0 as given in Table 6-1 and is based on an occupancy category of II for the building as defined in Table 1-1.

3. The wind directionality factor (Kd) is 0.85 for building components and cladding as given in Table 6-4

4. The exposure category is B as defined in Section 6.5.6.3. Based on exposure category B for the building, the velocity pressure exposure coefficient (Kh) is 1.04 as given in Table 6-3.

5. The topographic factor (Kzt) is 1.0 as defined in Section 6.5.7.

6. The internal pressure coefficient (GCpi) is +/- 0.18 as defined in Section 6.5.11.1 and Figure 6-5 for enclosed buildings.

7. The external pressure coefficient (GCp) is + 0.62 for windward exposure, and -1.1 for leeward exposure. These coefficients have been determined based on wall edge zone (Zone 5) exposure requirements in Figure 6-17 for Components and Cladding – Method 2; Walls and Roofs for buildings greater than 60 feet in height.

Wind Loads (cont'd)

8. The velocity pressure qh is calculated by the following equation given in Section 6.5.10:

qh = 0.00256 Kh Kzt Kd V2 I (lb/ft2);

qh = 0.00256 x 1.04 x 1.0 x 0.85 x 902 x 1.0 = 18.3 lb/ft2

The precast panels chosen for replacement of the brick veneer on the building walls will have maximum dimensions of height and width of 30 feet and 12 feet respectively. These dimensions will result in the entire surface area of a wall edge panel having to withstand the heightened wind pressures in the Zone 5 region.

Therefore, maximum wind pressures on the edge panels based on Section 6.5.12.4.2 for Components and Cladding, Buildings with h > 60 ft., are as follows:

For windward exposure:

P = qh x (+GCp) – qh x (-GCpi) (lb/ft2)

P = 18.3 x (+0.62) – 18.3 x (-0.18) = 14.64 lb/ft2

For leeward exposure:

P = qh x (-GCp) – qh x (+GCpi) lb/ft2

P = 18.3 x (-1.1) – 18.3 x (+0.18) = 23.4 lb/ft2

Based on the above, the maximum suction force on a leeward edge panel during an extreme wind event will be: 23.4 lb/ft2 x 30 ft. x 12 ft. = 8,424 lb. and will govern the design for the hardware required for lateral attachment of the panels to the concrete frame.

Seismic Loads

Basis – IBC 2006 defers to ASCE 7-05 for development of seismic ground motion values for the site and methods for calculating loads on structures resulting from those ground motions. Therefore, the provisions of ASCE 7-05 will be used for development of seismic forces on the precast wall panels.

Seismic Ground Motion Values

Mapped Acceleration Parameters from Figure 22-1 for short period acceleration (SS), and Figure 22-2 for 1-second acceleration (S1):

SS = 0.154; S1 = 0.05

Subsurface conditions warrant the designation of Site Class C for purposes of determining the factors Fa and Fv for adjusting the mapped acceleration parameters. Based on Site Class C rating and mapped acceleration factors SS = 0.154 and S1 = 0.05, the site coefficients Fa and Fv in Tables 11.4-1 and 11.4-2 are as follows:

Fa = 1.2; Fv = 1.7

The Site Adjusted Acceleration Parameters SMS and SM1 are calculated in accordance with Section 11.4.3 and are as follows:

SMS = Fa SS; SM1 = Fv S1

SMS = 1.2 x 0.154 = 0.185 SM1 = 1.7 x 0.05 = 0.085

The Design Spectral Acceleration Parameters SDS and SD1 are calculated in accordance with Section 11.4.4 and are as follows:

SDS = 2/3 SMS SD1 = 2/3 SM1

SDS = 2/3 x 0.185 = 0.123 SD1 = 2/3 x 0.085 = 0.056

Seismic Forces

The following calculates the horizontal thrust force for a typical 30 ft. x 12 ft. precast panel. The force is calculated based on Equation 13.3-1 in Section 13.3 of ASCE 7-05, which covers seismic demands on nonstructural architectural components.

The horizontal seismic deign force FP is as follows:

FP = (0.4 aP SDS WP / (RP / IP)) x (1 + (2 x z/h))

Where:

aP = 1.0; component amplification factor, Table 13.5-1 z = h, therefore z/h = 1.0

RP = 2.5; component response modification factor, Table 13.5-1

IP = 1.0; component importance factor, Section 13.1.3

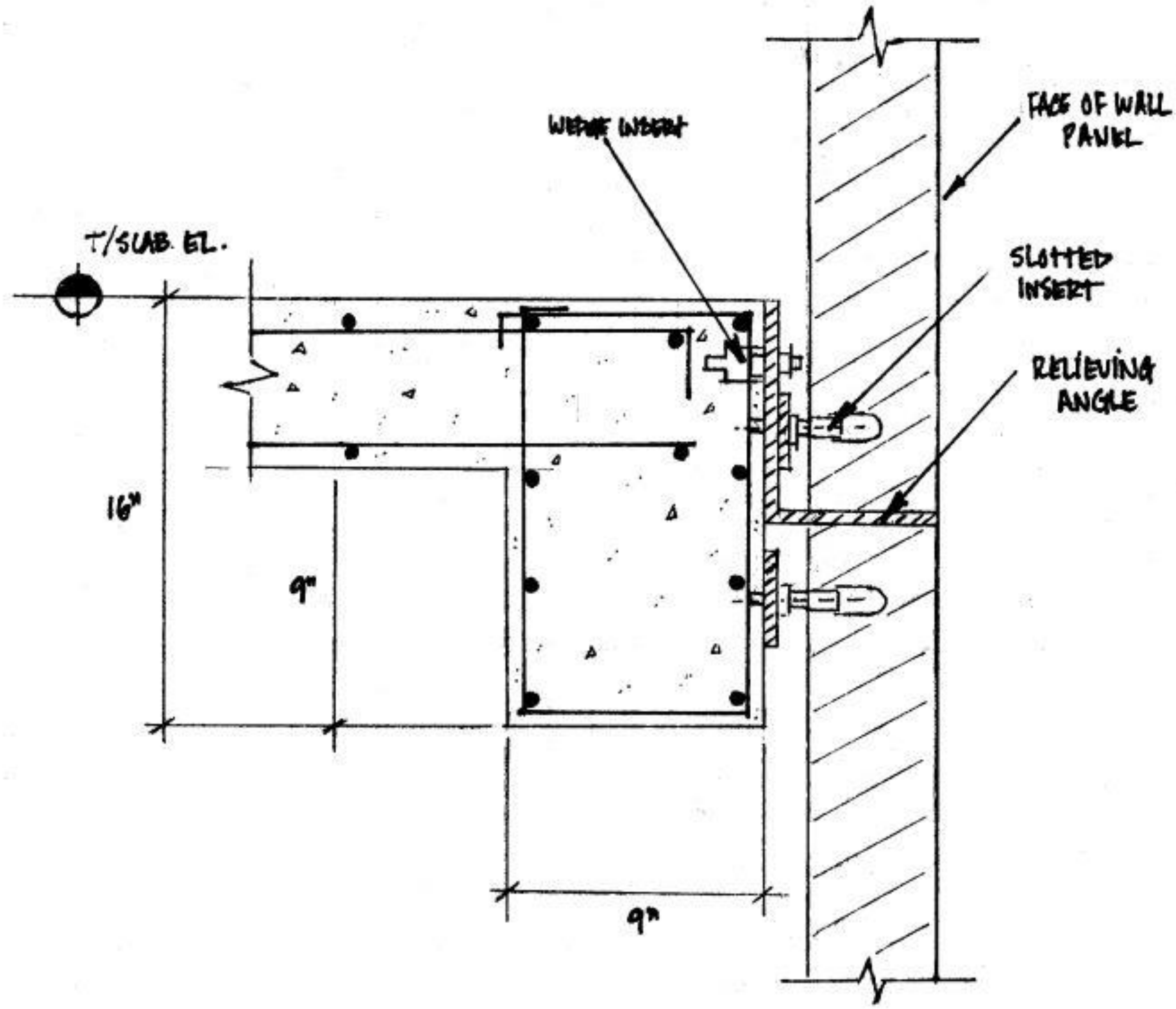
WP = component weight – 13ft. x 12 ft. x 40 lb/ft2 = 14,400 lb.

Based on working through the above equation, the horizontal seismic force exerted by a typical precast panel on its anchorage system is 850 lb. This force is only 10% of the force caused by an extreme wind event and will not govern the design of the lateral anchorage system for the precast panel.

Appendix A.9

APC Panel Structural Feasibility & Redesign Study: Vertical and Lateral Attachment Detail

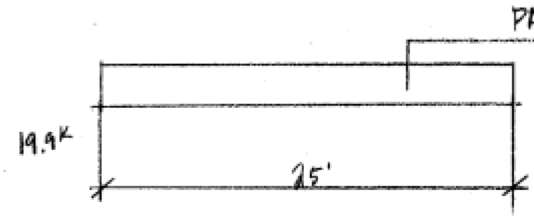
Vertical and Lateral Attachment Welded Connection Detail



Appendix A.10

APC Panel Structural Feasibility & Redesign Study: Spandrel Beam Design Check

SPANDREL BEAM DESIGN CHECK



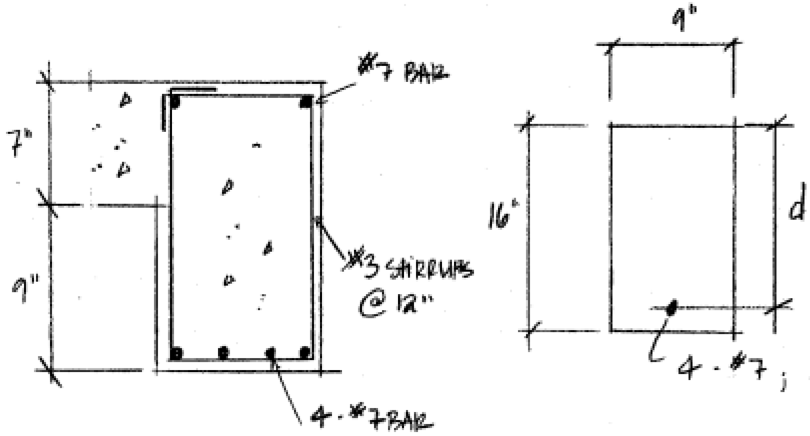
$\frac{144}{12} \times 1.2 = 1.44\ k/l$

$.15\ k/l$ – BEAM

$1.59\ k/l$

$$M_u = \frac{1.59 \times 25^2}{8} = 124^{\,l\text{-}k}$$

$$V_u = 1.59 \times 12.5 = 19^k$$



$d = 16" - .75 - .375 - .44$
$= 14.43"$

BENDING:

$$a = \frac{2.4 \times 60}{.85 \times 4 \times 9} = 4.7"$$

$$\phi M_n = .9 \times \frac{2.4 \times 60}{12}\left(14.43 - 4.7/2\right) = 132.6^{\,l\text{-}k}$$

SHEAR:

$$V_c = \frac{2\sqrt{4000} \times 9 \times 14.43}{1000} = 16.21k$$

$V_c/2 = 9.1^k < 19.9k$; Stirrup REQ'D

$$V_s = \frac{2 \times .11 \times 60 \times 14.43}{12} = 15.9k$$

$\phi V_n = .75\,(16.21 + 15.9) = 25.5k$

$25.5 > 19.9k$

– USE #3 STIRRUPS @ 12"

Appendix B

Appendix B.1

Original Brick Elevation Schedule

ID	Task Name	Duration	Start	Finish
1	Wardmn West Residential Construction	717 days	Thu 6/16/11	Fri 3/14/14
2	Warman West Residential Construction	717 days	Thu 6/16/11	Fri 3/14/14
3	Support of Excavation	123 days	Thu 6/16/11	Sat 12/3/11
4	Below Grade Structure	209 days	Tue 11/29/11	Fri 9/14/12
5	Concrete Structure to Grade	0 days	Wed 8/29/12	Wed 8/29/12
6	Above Grade Structure	136 days	Wed 8/29/12	Wed 3/6/13
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18	Concrete Structure & Penthouse Framing Complete	0 days	Wed 3/6/13	Wed 3/6/13
19	Exterior Skin	258 days	Thu 11/15/1	Mon 11/11/1
20	Exterior Skin	244 days	Thu 11/15/1	Tue 10/22/1
21	Support & Balcony Steel, Relief Angles	59 days	Thu 11/15/1	Tue 2/5/13
22	Exterior Framing	60 days	Wed 11/28/1	Tue 2/19/13
23	Exterior Sheathing	107 days	Wed 2/13/13	Thu 7/11/13
24	Air Vapor Barrier	107 days	Thu 2/14/13	Fri 7/12/13
25	<New Summary Task>	163 days	Fri 3/8/13	Tue 10/22/1
26	Brick	163 days	Fri 3/8/13	Tue 10/22/1
27	South Elevation Brick	71 days	Fri 3/8/13	Fri 6/14/13
28	Courtyard Elevations Brick	70 days	Fri 3/8/13	Thu 6/13/13
29	East Elevation	71 days	Mon 6/17/13	Mon 9/23/13
30	North Elevation	71 days	Mon 6/17/13	Mon 9/23/13
31	South Brick Washdown & Balcony	24 days	Thu 9/19/13	Tue 10/22/1
32	Courtyard Brick Washdown & Balcony	18 days	Fri 8/16/13	Tue 9/10/13
33	East Brick Washdown & Balcony Fronts	18 days	Fri 9/27/13	Tue 10/22/1
34	North Brick Washdown & Balcony	18 days	Fri 9/20/13	Tue 10/15/1
35	Stone	124 days	Tue 4/9/13	Fri 9/27/13
36	Penthouse Brick	20 days	Tue 8/13/13	Mon 9/9/13
37	Watertight	0 days	Fri 7/19/13	Fri 7/19/13
38	MEP Core & Shell	148 days	Tue 10/9/12	Thu 5/2/13
39	Elevator Install	159 days	Tue 1/22/13	Fri 8/30/13
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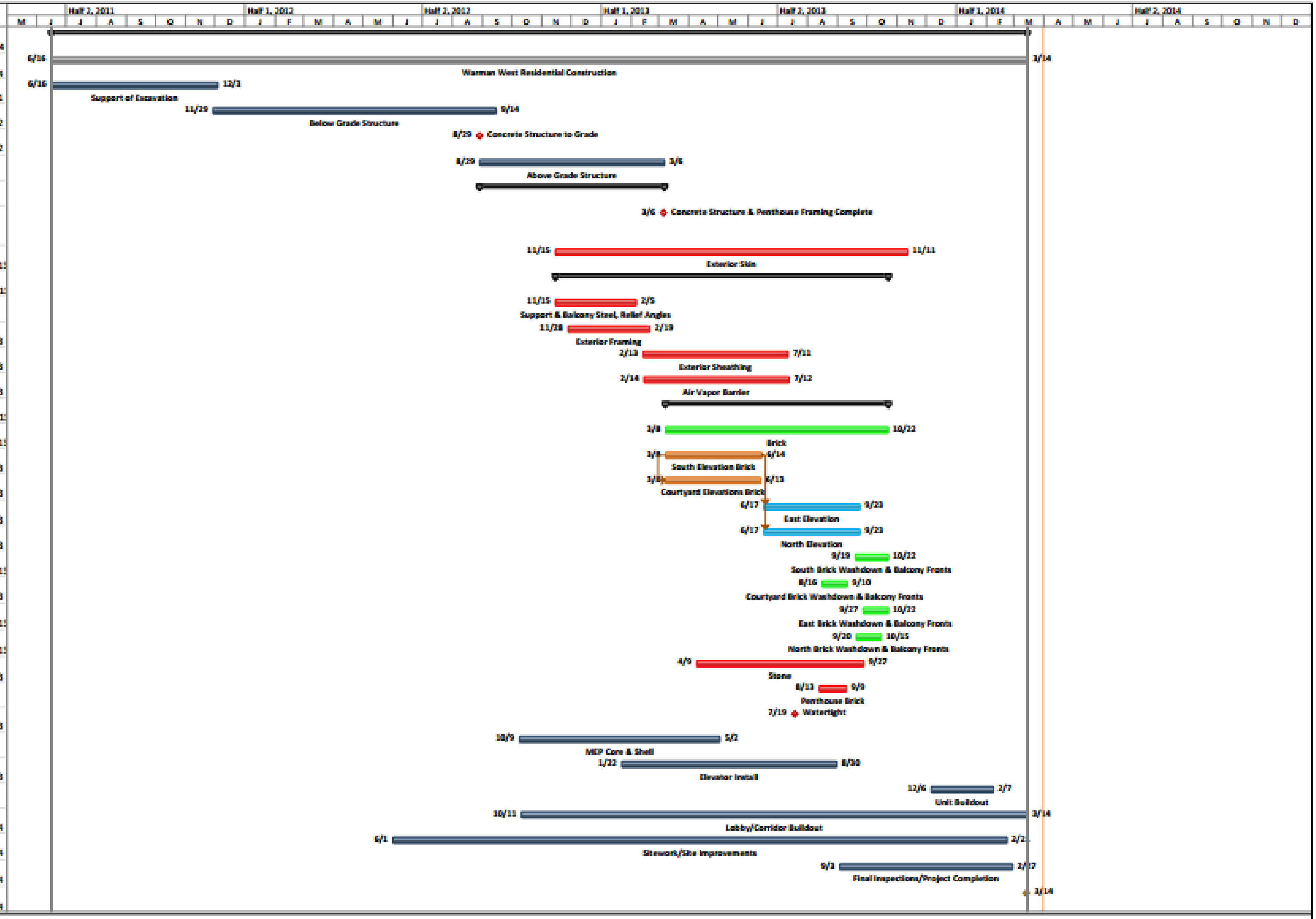
44	Substantial Completion	0 days	Fri 3/14/14	Fri 3/14/14



Project: Thesis_Wardman_Orignia
Date: Mon 3/31/14

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

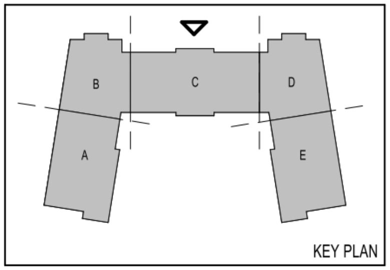
Finish-only
Deadline
Progress

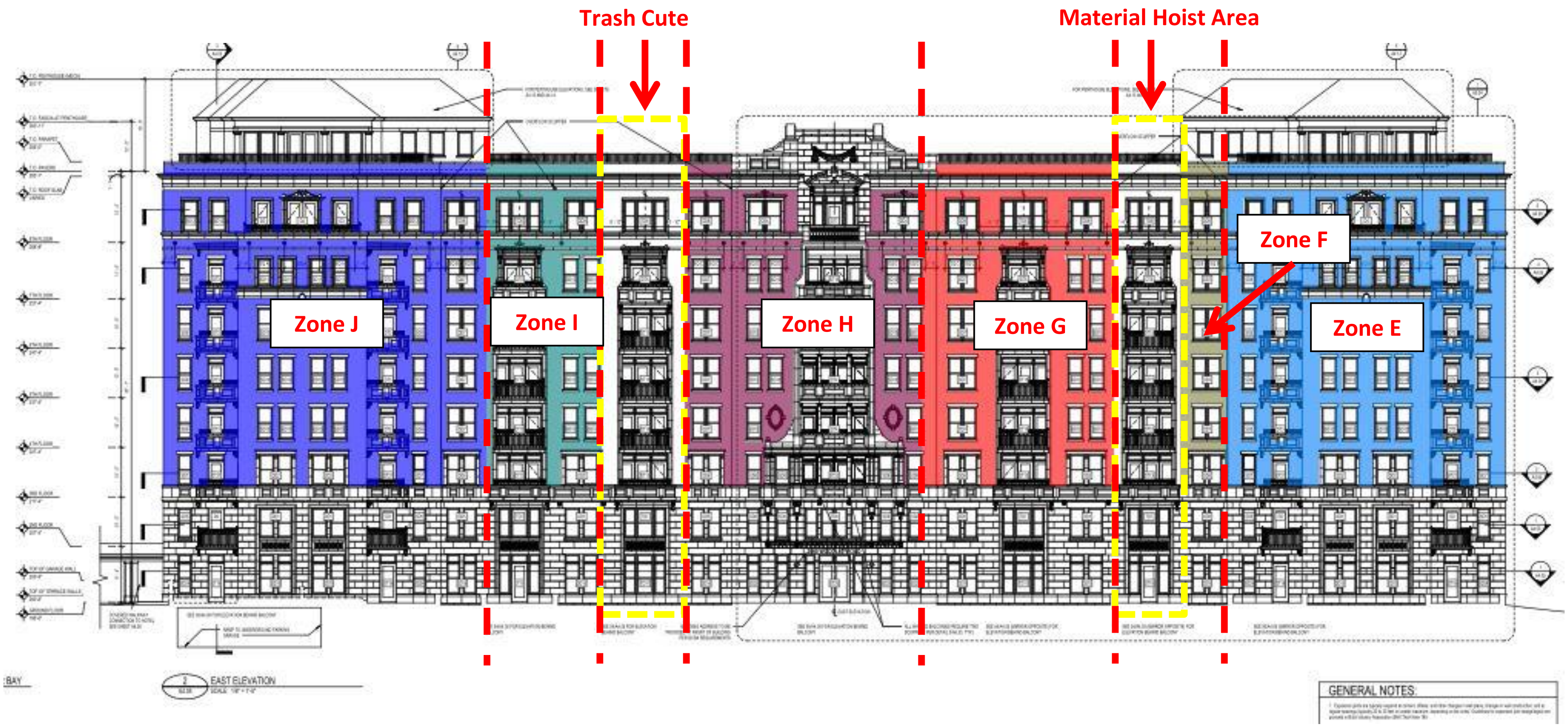
Page 1

Appendix B.2

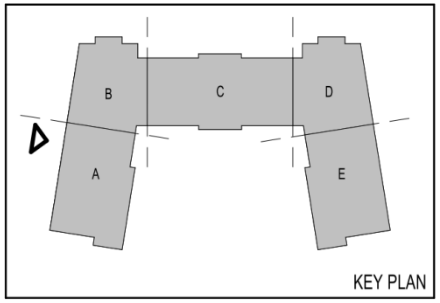
Brick SIPS Construction Zones

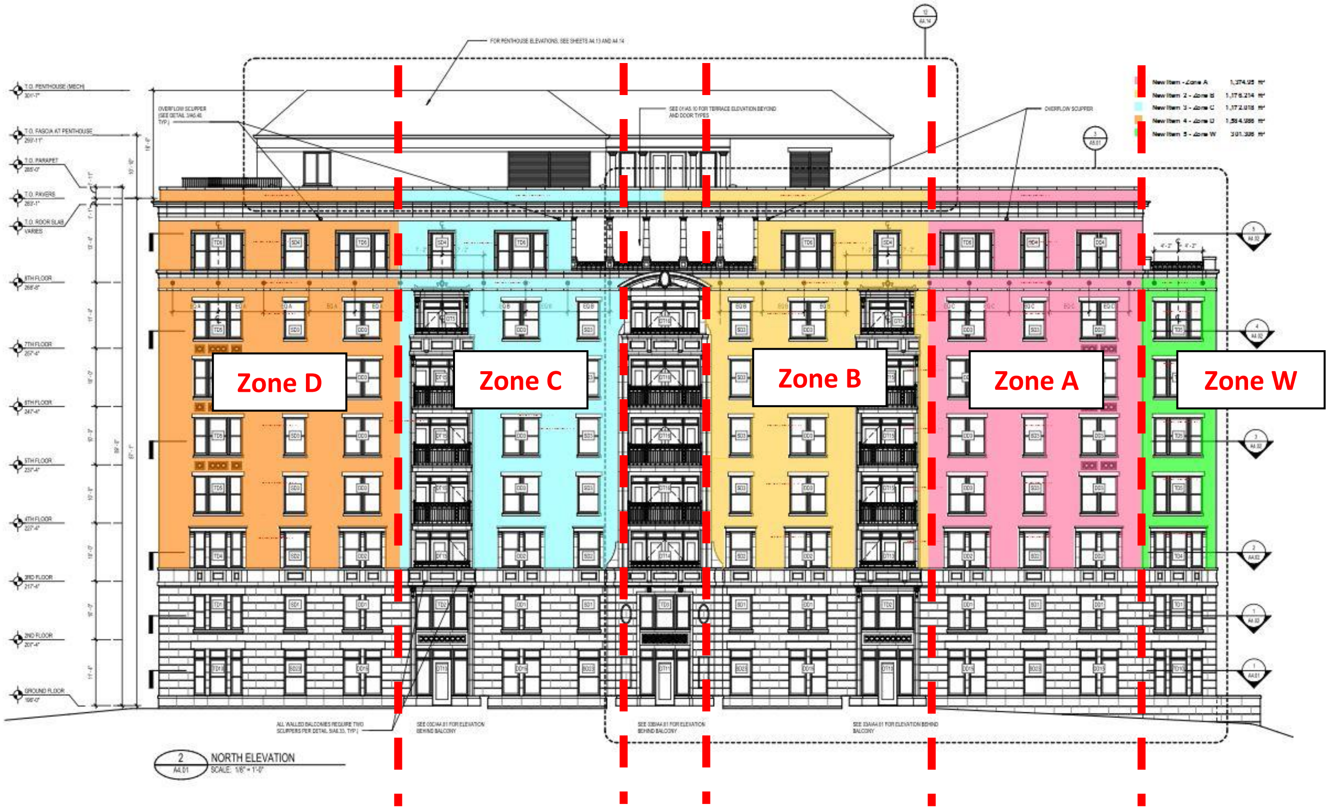
East Elevation



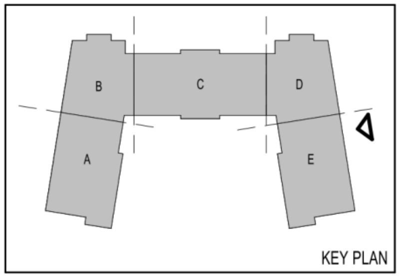


North Elevation

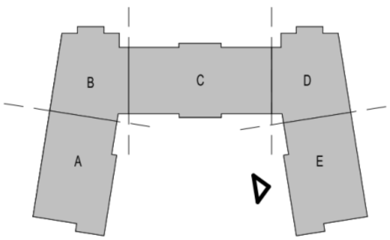




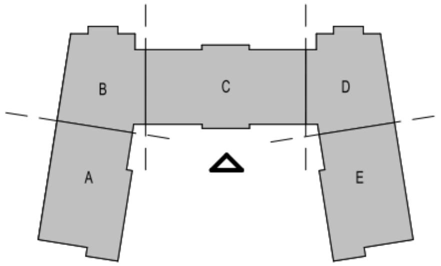
South Elevation

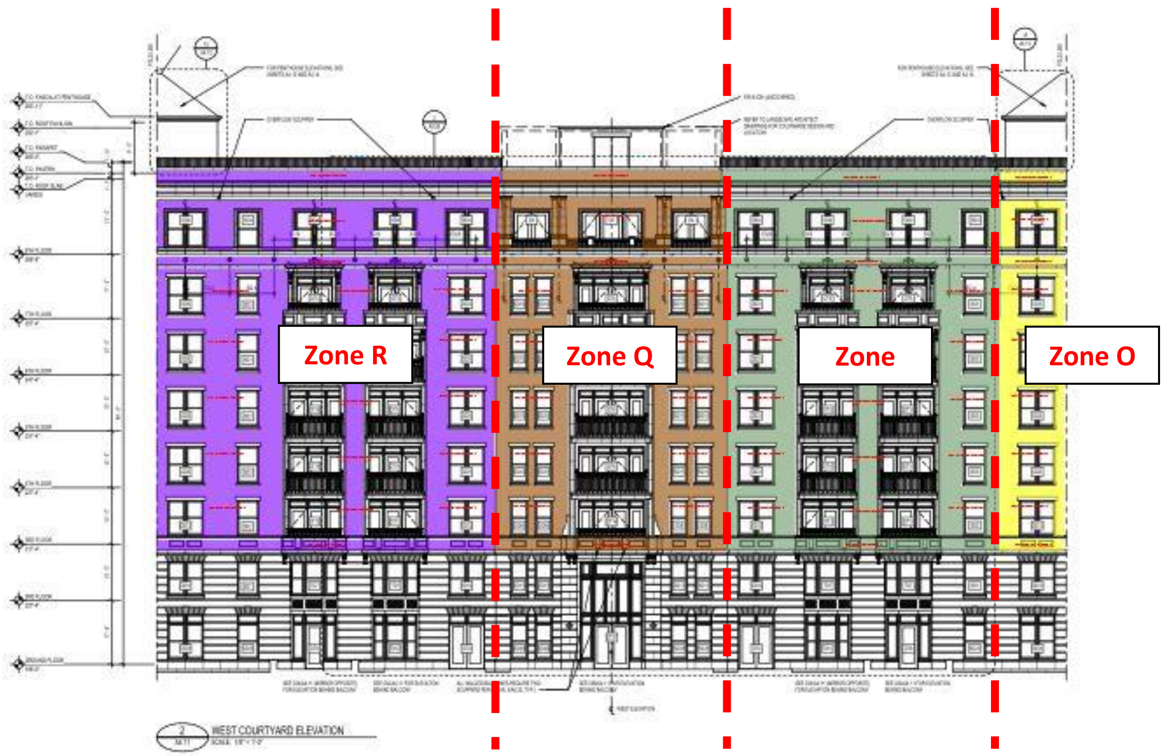


North Courtyard Elevation

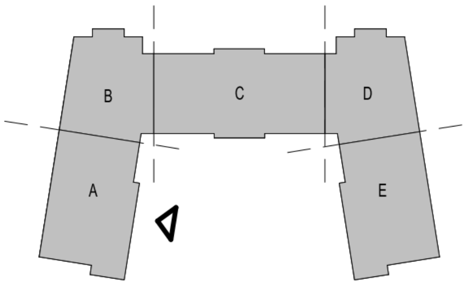


West Courtyard Elevation

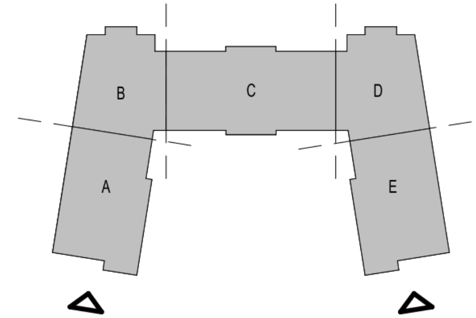




South Courtyard Elevation



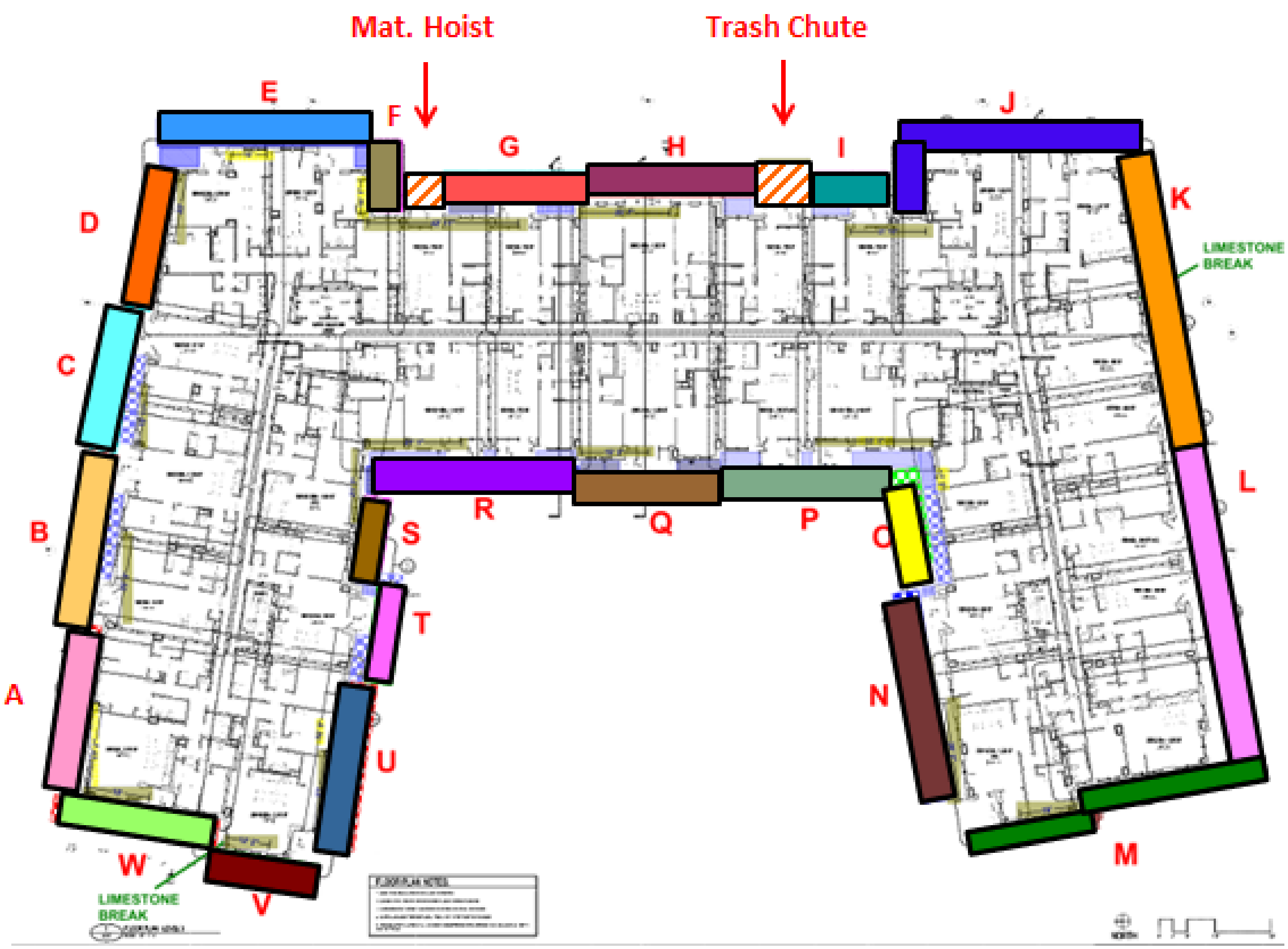
Northwest & Southwest Elevations



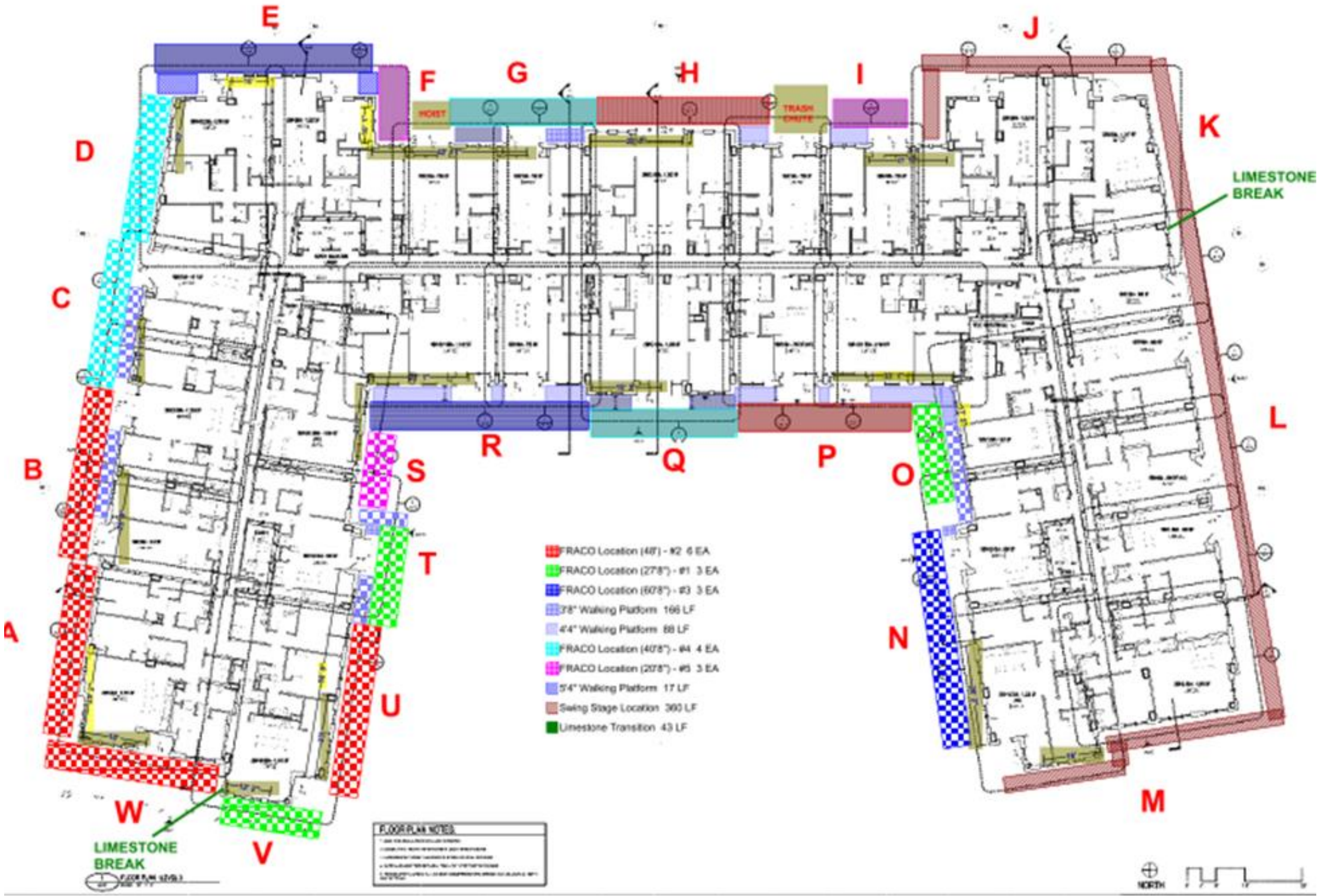
Appendix B.3

Scaffold Plans

Brick SIPS Construction Zone Scaffolding Plan



Brick SIPS Scaffolding Type & Size Plan



Appendix B.4

Brick SIPS Manpower & Duration Breakdown

	Construction Zone	Manpower	Floor Level Durations								Total Duration
North Elevation		**# of Masons**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	W	4			4	4	4	4	5	6	**27**
	A	4			2	3	3	4	4	4	**20**
	B	4			2	3	3	3	4	4	**19**
	C	4			2	3	3	3	4	4	**19**
	D	4			3	4	4	4	4	4	**23**
South Elevation		**# of Masons**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	M	10			3	3	3	3	3	3	**18**
	L	10	4	3	2	3	3	3	4	3	**25**
	K	10	2	2	2	3	3	3	4	3	**22**
	J	10			2	2	3	2	3	3	**15**
Courtyard		**# of Masons**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	N	5			5	5	5	5	6	5	**31**
	O	5			1	1	1	1	1	1	**6**
	P	5			4	4	4	4	5	5	**26**
	Q	5			4	3	3	3	4	4	**21**
	R	4			4	3	3	3	4	4	**21**
	S	3			2	2	2	2	2	2	**12**
	T	4			4	3	3	3	4	5	**22**
	U	4			3	2	3	3	3	4	**18**
	V	5			4	4	4	4	5	6	**27**
East Elevation		**# of Masons**	1	2	3	4	5	6	7	8	
	E	2			3	4	4	4	4	4	**23**
	F	2			1	2	2	2	2	2	**11**
	G	2			2	2	2	2	3	3	**14**
	H	2			1	3	2	2	3	2	**13**
	I	2			1	1	1	1	2	2	**8**

Appendix B.5

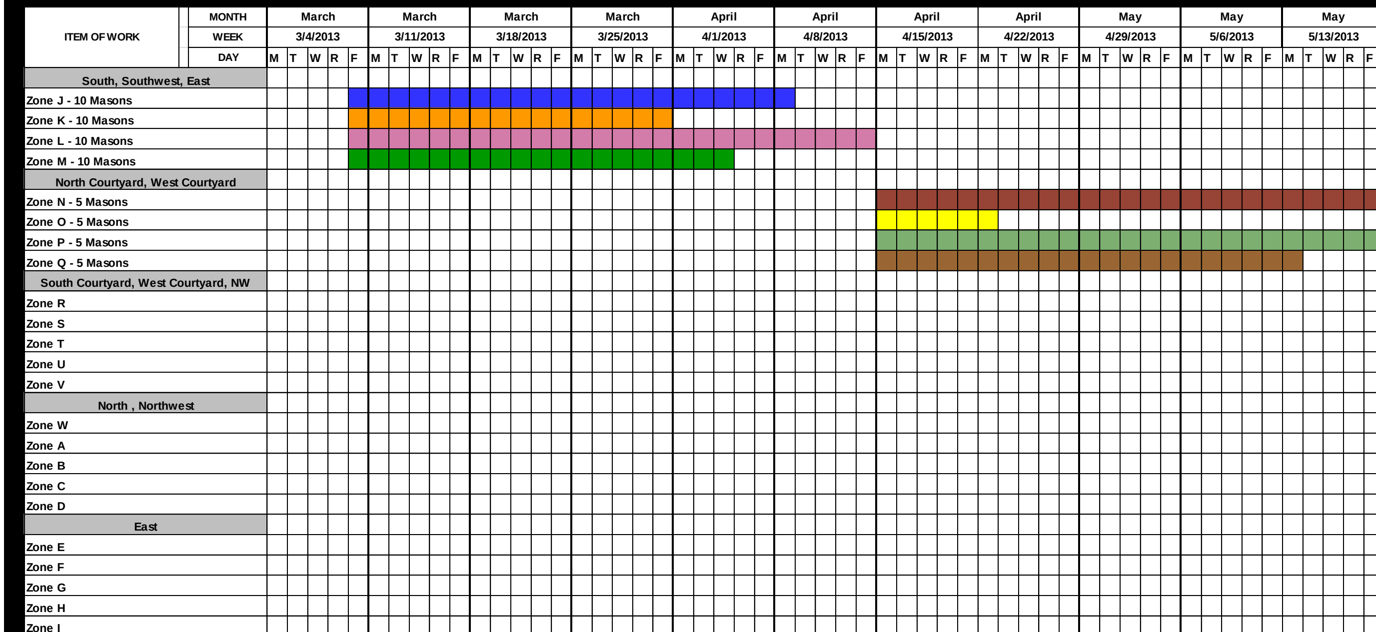
Brick SIPS Matrix Schedule

Senior Thesis - Spring 2014
Analysis 2: SIPS
Kevin Kroener

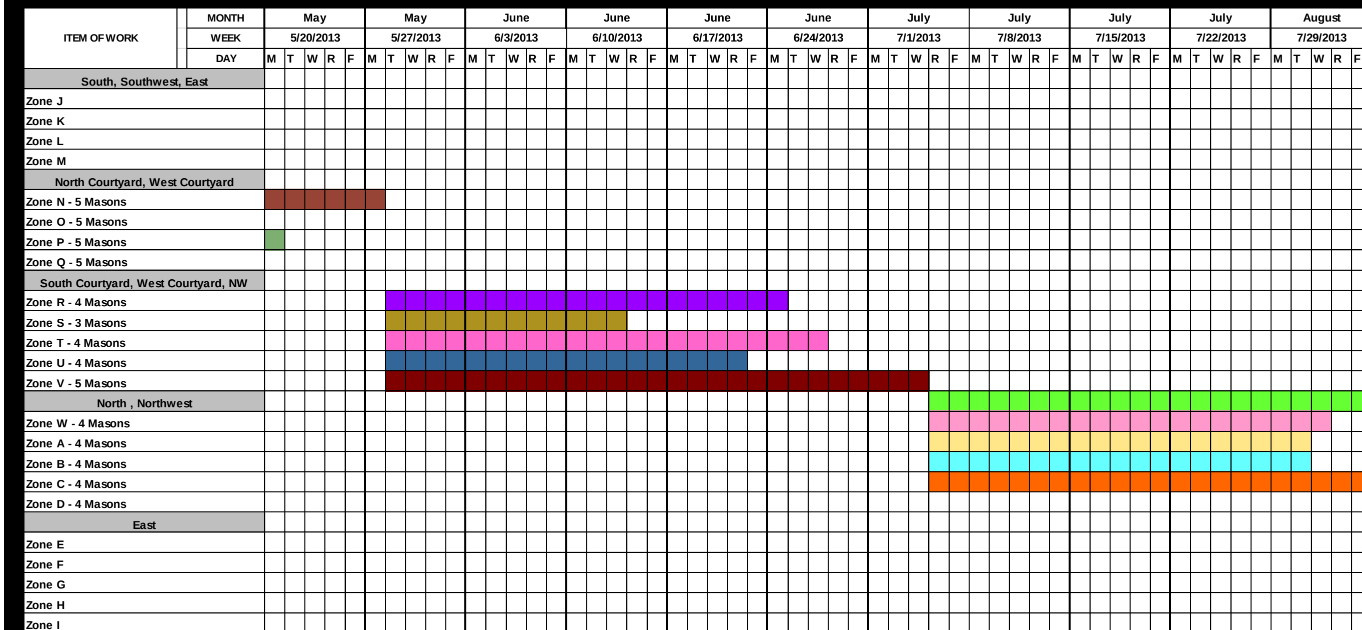
AE PSU

Wardman West Residential

Brick Exterior Skin SIPS Schedule



1. Zone A	14. Zone N
2. Zone B	15. Zone O
3. Zone C	16. Zone P
4. Zone D	17. Zone Q
5. Zone E	18. Zone R
6. Zone F	19. Zone S
7. Zone G	20. Zone T
8. Zone H	21. Zone U
9. Zone I	22. Zone V
10. Zone J	23. Zone W
11. Zone K	
12. Zone L	
13. Zone M	



1. Zone A		14. Zone N	
2. Zone B		15. Zone O	
3. Zone C		16. Zone P	
4. Zone D		17. Zone Q	
5. Zone E		18. Zone R	
6. Zone F		19. Zone S	
7. Zone G		20. Zone T	
8. Zone H		21. Zone U	
9. Zone I		22. Zone V	
10. Zone J		23. Zone W	
11. Zone K			
12. Zone L			
13. Zone M			

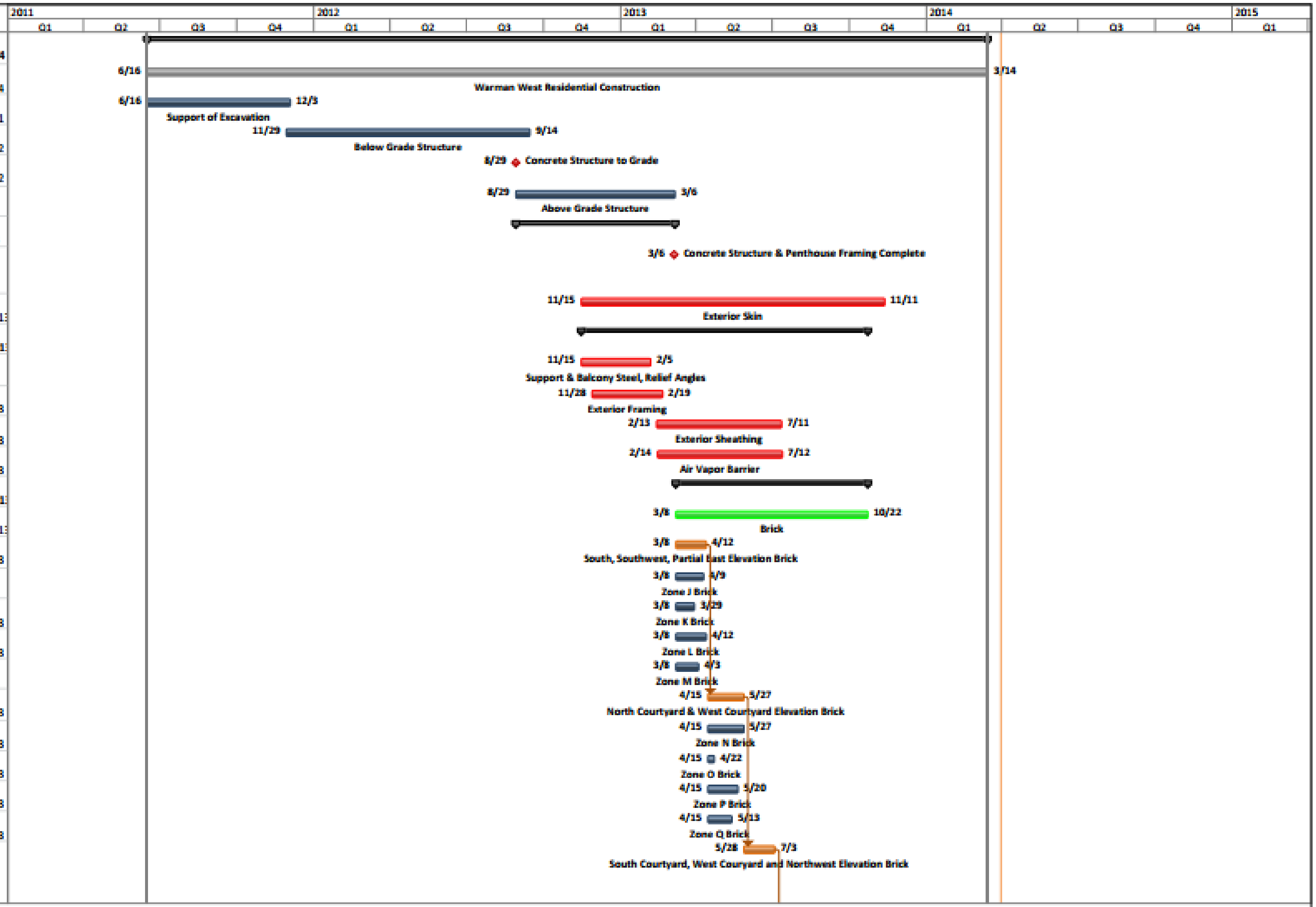
ITEM OF WORK	MONTH	August	August	August	August	September	September	September	September	October	October	October
	WEEK	8/5/2013	8/12/2013	8/19/2013	8/26/2013	9/2/2013	9/9/2013	9/16/2013	9/23/2013	9/30/2013	10/7/2013	10/14/2013
	DAY	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F
South, Southwest, East												
Zone J												
Zone K												
Zone L												
Zone M												
North Courtyard, West Courtyard												
Zone N												
Zone O												
Zone P												
Zone Q												
South Courtyard, West Courtyard, NW												
Zone R												
Zone S												
Zone T												
Zone U												
Zone V												
North , Northwest												
Zone W - 4 Masons												
Zone A - 4 Masons												
Zone B - 4 Masons												
Zone C - 4 Masons												
Zone D - 4 Masons												
East												
Zone E - 2 Masons												
Zone F - 2 Masons												
Zone G - 2 Masons												
Zone H - 2 Masons												
Zone I - 2 Masons												

1. Zone A		14. Zone N	
2. Zone B		15. Zone O	
3. Zone C		16. Zone P	
4. Zone D		17. Zone Q	
5. Zone E		18. Zone R	
6. Zone F		19. Zone S	
7. Zone G		20. Zone T	
8. Zone H		21. Zone U	
9. Zone I		22. Zone V	
10. Zone J		23. Zone W	
11. Zone K			
12. Zone L			
13. Zone M			

Appendix B.6

Brick SIPS Revised Project Schedule

ID	Task Name	Duration	Start	Finish
1	**Wardmn West Residenital Construction**	717 days	Thu 6/16/11	Fri 3/14/14
2	Warman West Residential Construction	717 days	Thu 6/16/11	Fri 3/14/14
3	Support of Excavation	123 days	Thu 6/16/11	Sat 12/3/11
4	Below Grade Structure	209 days	Tue 11/29/1	Fri 9/14/12
5	Concrete Structure to Grade	0 days	Wed 8/29/12	Wed 8/29/12
6	Above Grade Structure	136 days	Wed 8/29/12	Wed 3/6/13
7	**Above Grade Structure**	136 days	Wed 8/29/12	Wed 3/6/13
18	Concrete Structure & Penthouse Framing Complete	0 days	Wed 3/6/13	Wed 3/6/13
19	Exterior Skin	258 days	Thu 11/15/1	Mon 11/11/1
20	**Exterior Skin**	244 days	Thu 11/15/1	Tue 10/22/1
21	Support & Balcony Steel, Relief Angles	59 days	Thu 11/15/1	Tue 2/5/13
22	Exterior Framing	60 days	Wed 11/28/1	Tue 2/19/13
23	Exterior Sheathing	107 days	Wed 2/13/13	Thu 7/11/13
24	Air Vapor Barrier	107 days	Thu 2/14/13	Fri 7/12/13
25	**<New Summary Task>**	163 days	Fri 3/8/13	Tue 10/22/1
26	Brick	163 days	Fri 3/8/13	Tue 10/22/1
27	South, Southwest, Partial East Elevation	26 days	Fri 3/8/13	Fri 4/12/13
28	Zone J Brick	23 days	Fri 3/8/13	Tue 4/9/13
29	Zone K Brick	16 days	Fri 3/8/13	Fri 3/29/13
30	Zone L Brick	26 days	Fri 3/8/13	Fri 4/12/13
31	Zone M Brick	19 days	Fri 3/8/13	Wed 4/3/13
32	North Courtyard & West Courtyard	31 days	Mon 4/15/13	Mon 5/27/13
33	Zone N Brick	31 days	Mon 4/15/13	Mon 5/27/13
34	Zone O Brick	6 days	Mon 4/15/13	Mon 4/22/13
35	Zone P Brick	26 days	Mon 4/15/13	Mon 5/20/13
36	Zone Q Brick	21 days	Mon 4/15/13	Mon 5/13/13
37	South Courtyard, West Couryard and Northwest Elevation Brick	27 days	Tue 5/28/13	Wed 7/3/13

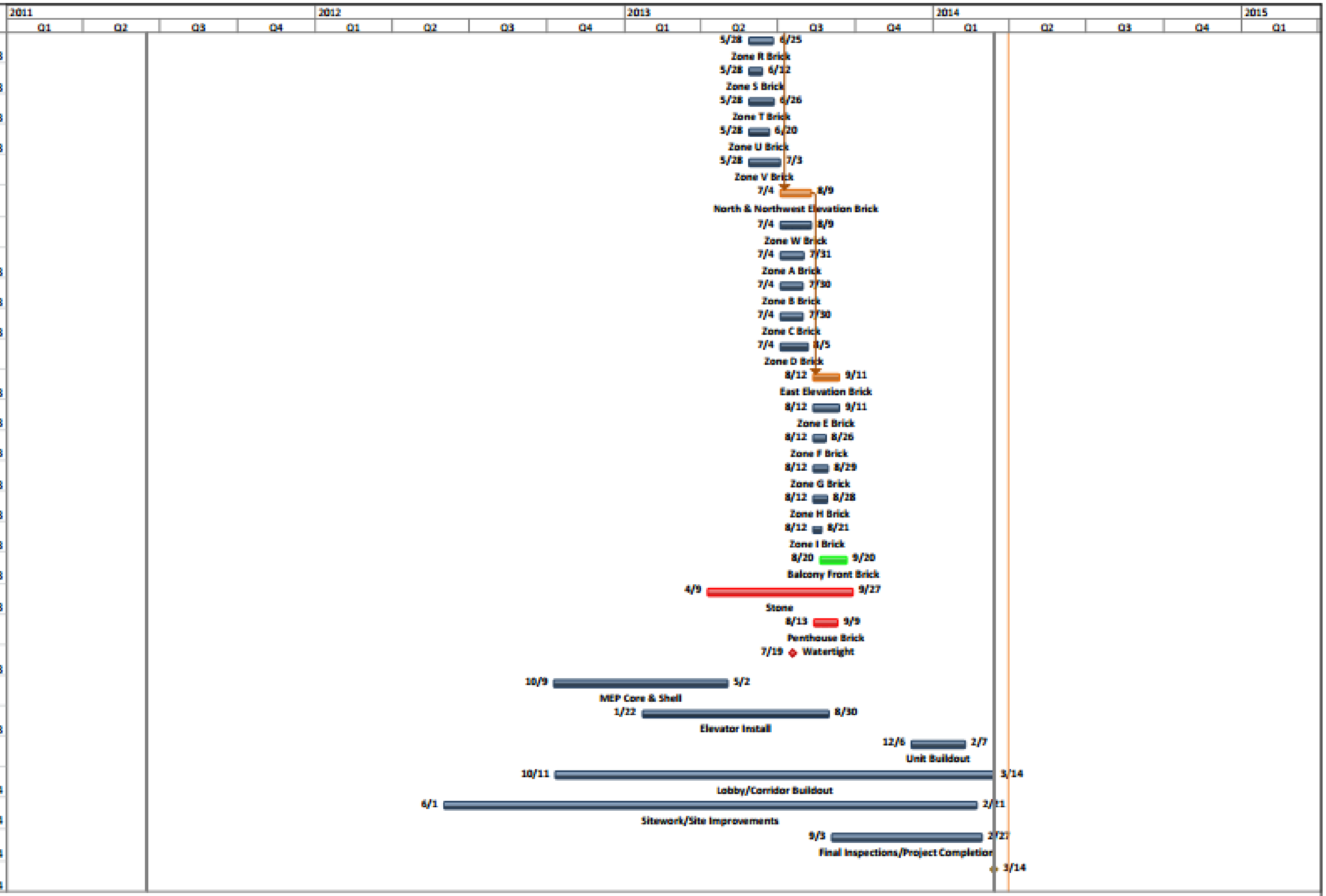


Project: Thesis_Wardman_Revised
Date: Mon 3/31/14

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

Page 1

ID	Task Name	Duration	Start	Finish
38	Zone R Brick	21 days	Tue 5/28/13	Tue 6/25/13
39	Zone S Brick	12 days	Tue 5/28/13	Wed 6/12/13
40	Zone T Brick	22 days	Tue 5/28/13	Wed 6/26/13
41	Zone U Brick	18 days	Tue 5/28/13	Thu 6/20/13
42	Zone V Brick	27 days	Tue 5/28/13	Wed 7/3/13
43	North & Northwest Elevation Brick	27 days	Thu 7/4/13	Fri 8/9/13
44	Zone W Brick	27 days	Thu 7/4/13	Fri 8/9/13
45	Zone A Brick	20 days	Thu 7/4/13	Wed 7/31/13
46	Zone B Brick	19 days	Thu 7/4/13	Tue 7/30/13
47	Zone C Brick	19 days	Thu 7/4/13	Tue 7/30/13
48	Zone D Brick	23 days	Thu 7/4/13	Mon 8/5/13
49	East Elevation Brick	23 days	Mon 8/12/13	Wed 9/11/13
50	Zone E Brick	23 days	Mon 8/12/13	Wed 9/11/13
51	Zone F Brick	11 days	Mon 8/12/13	Mon 8/26/13
52	Zone G Brick	14 days	Mon 8/12/13	Thu 8/29/13
53	Zone H Brick	13 days	Mon 8/12/13	Wed 8/28/13
54	Zone I Brick	8 days	Mon 8/12/13	Wed 8/21/13
55	Balcony Front Brick	24 days	Tue 8/20/13	Fri 9/20/13
56	Stone	124 days	Tue 4/9/13	Fri 9/27/13
57	Penthouse Brick	20 days	Tue 8/13/13	Mon 9/9/13
58	Watertight	0 days	Fri 7/19/13	Fri 7/19/13
59	MEP Core & Shell	148 days	Tue 10/9/12	Thu 5/2/13
60	Elevator Install	159 days	Tue 1/22/13	Fri 8/30/13
61	Unit Buildout	46 days	Fri 12/6/13	Fri 2/7/14
62	Lobby/Corridor Buildout	372 days	Thu 10/11/1:	Fri 3/14/14
63	Sitework/Site Improvements	451 days	Fri 6/1/12	Fri 2/21/14
64	Final Inspections/Project Completion	128 days	Tue 9/3/13	Thu 2/27/14
65	Substantial Completion	0 days	Fri 3/14/14	Fri 3/14/14



Project: Thesis_Wardman_Revised
Date: Mon 3/31/14

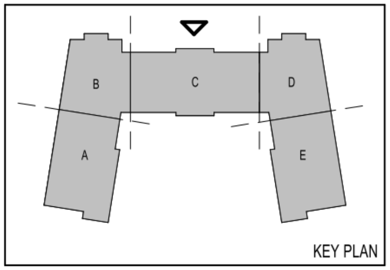
Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Deadline | Progress

Page 2

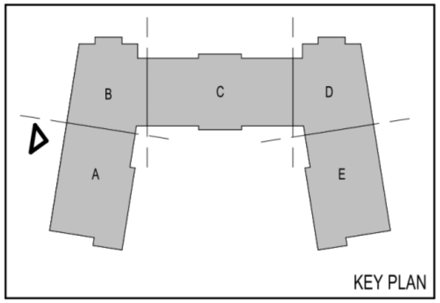
Appendix B.7

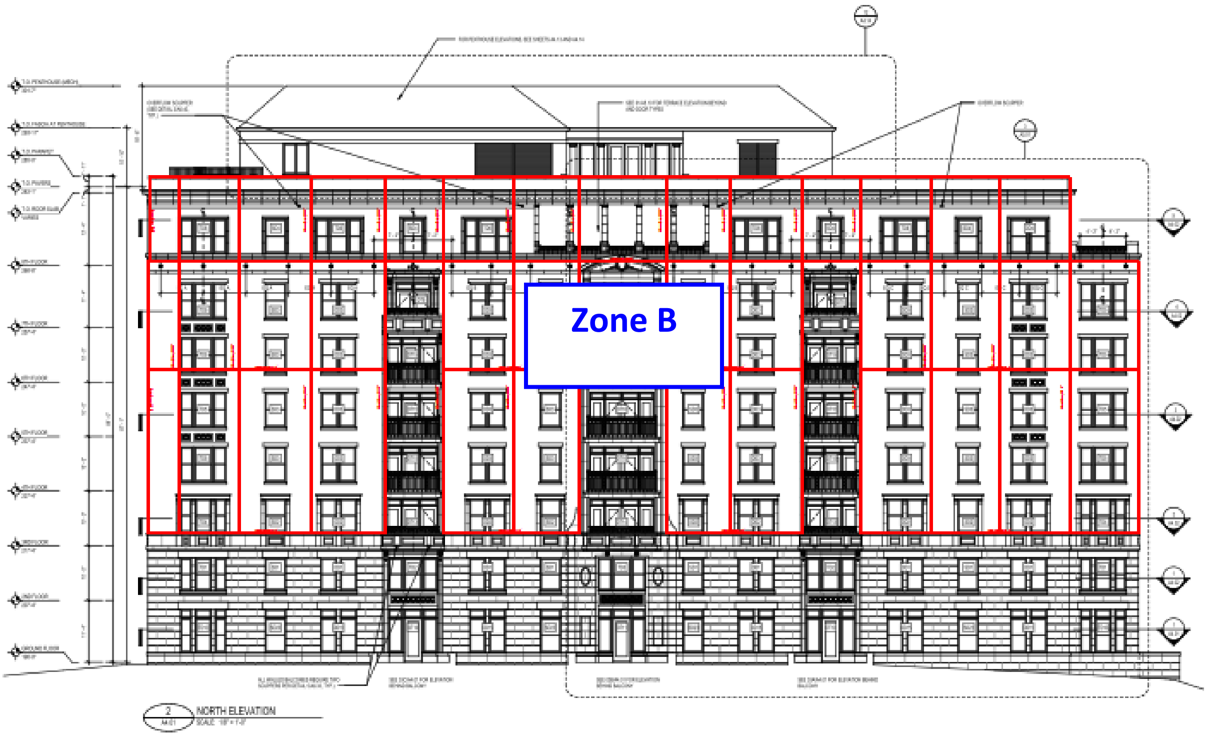
APC Panel SIPS Construction Zones

East Elevation

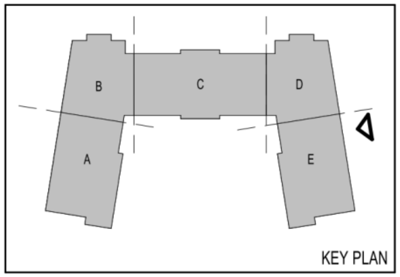


North Elevation

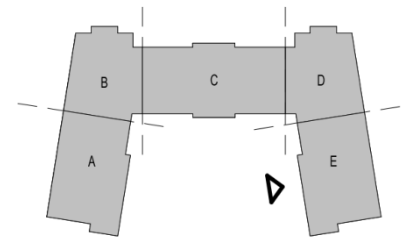


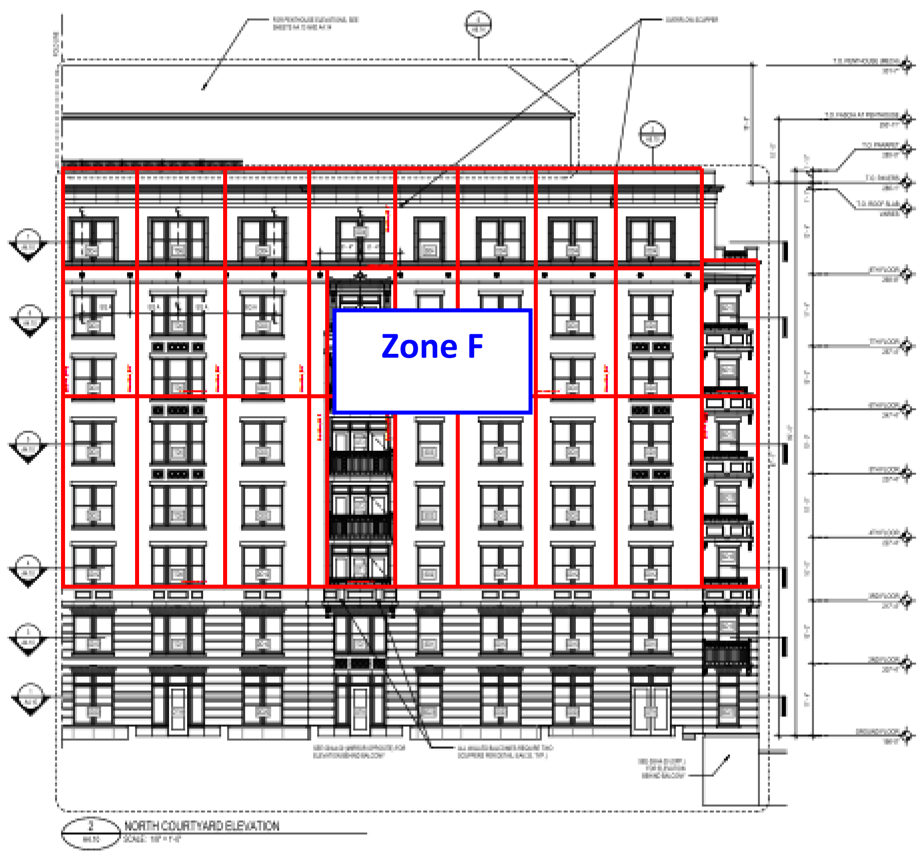


South Elevation

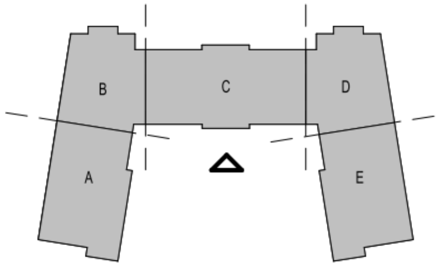


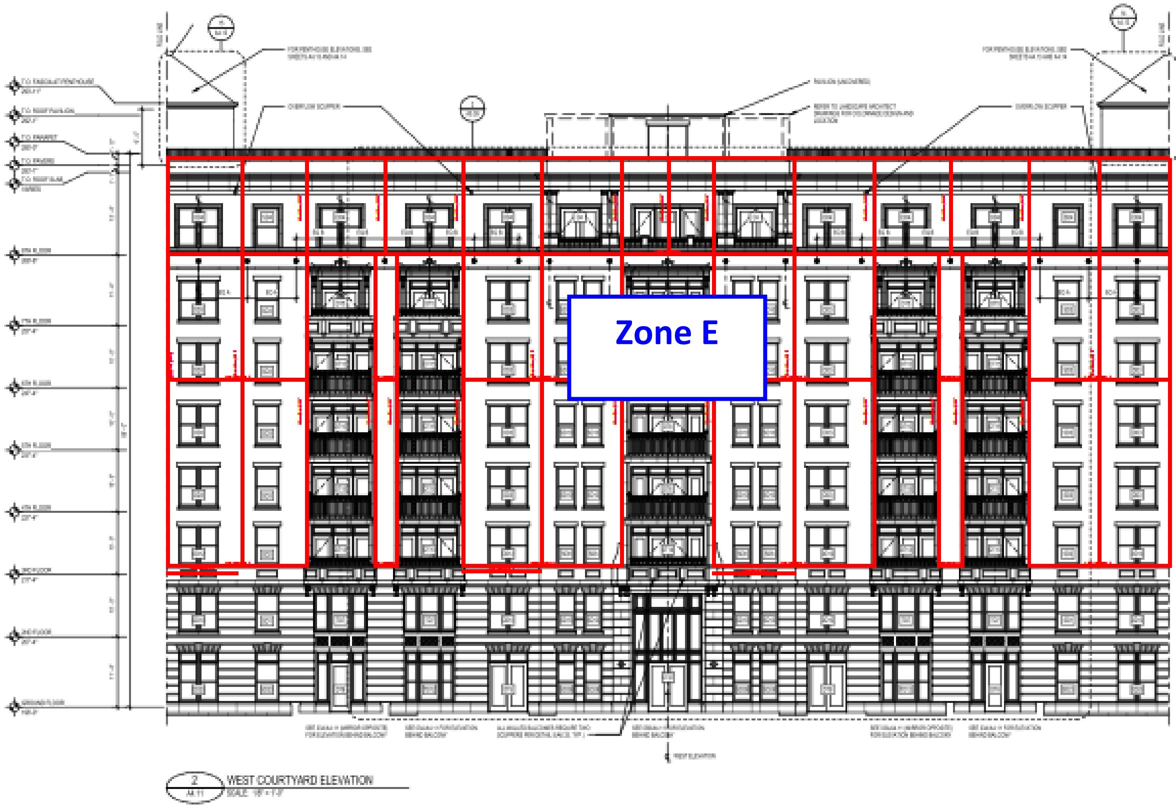
North Courtyard Elevation



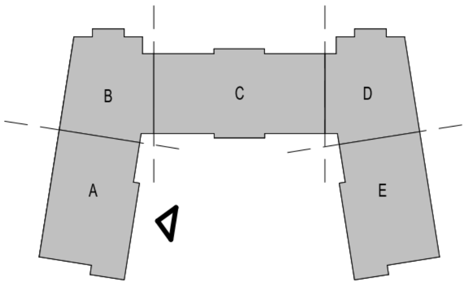


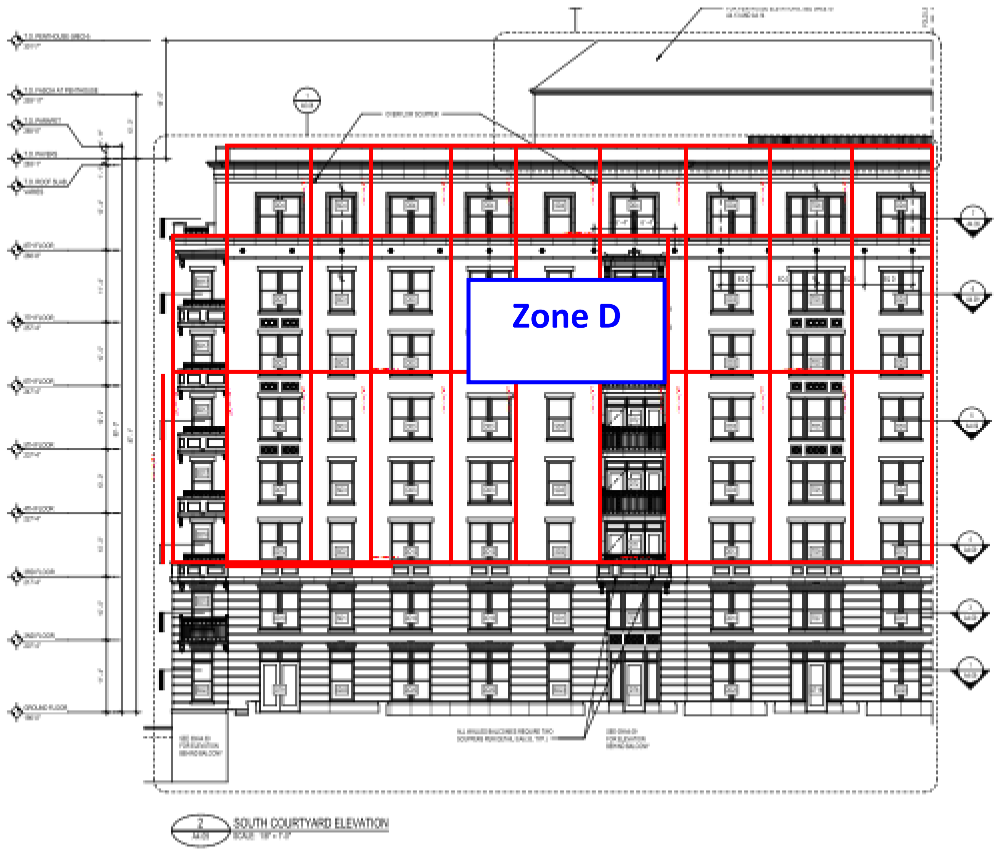
West Courtyard Elevation



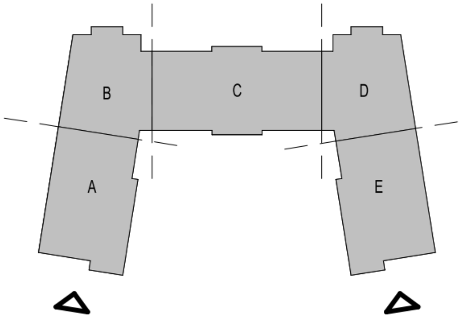


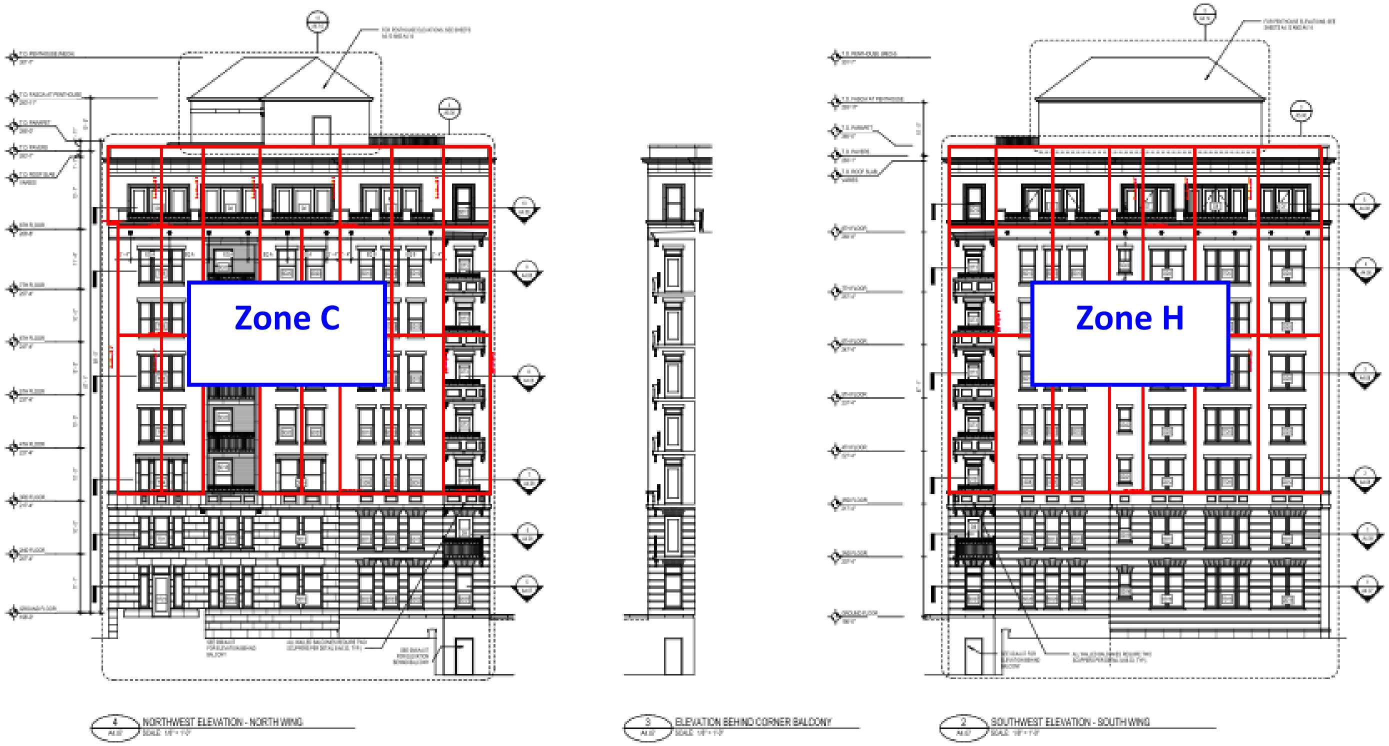
South Courtyard Elevation





Northwest & Southwest Elevations





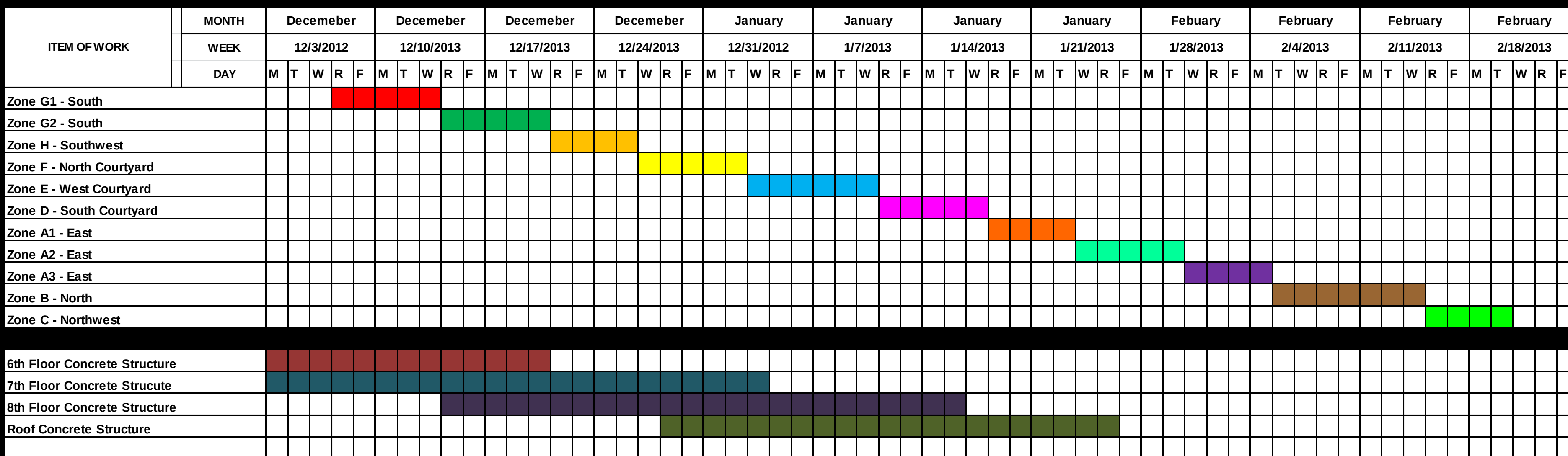
Appendix B.8

APC Panel SIPS Matrix Schedule

Senior Thesis - Spring 2014	
Analysis 2: SIPS	
Kevin Kroener	
AE PSU	

Wardman West Residential

ACP Panel Erection SIPS Schedule

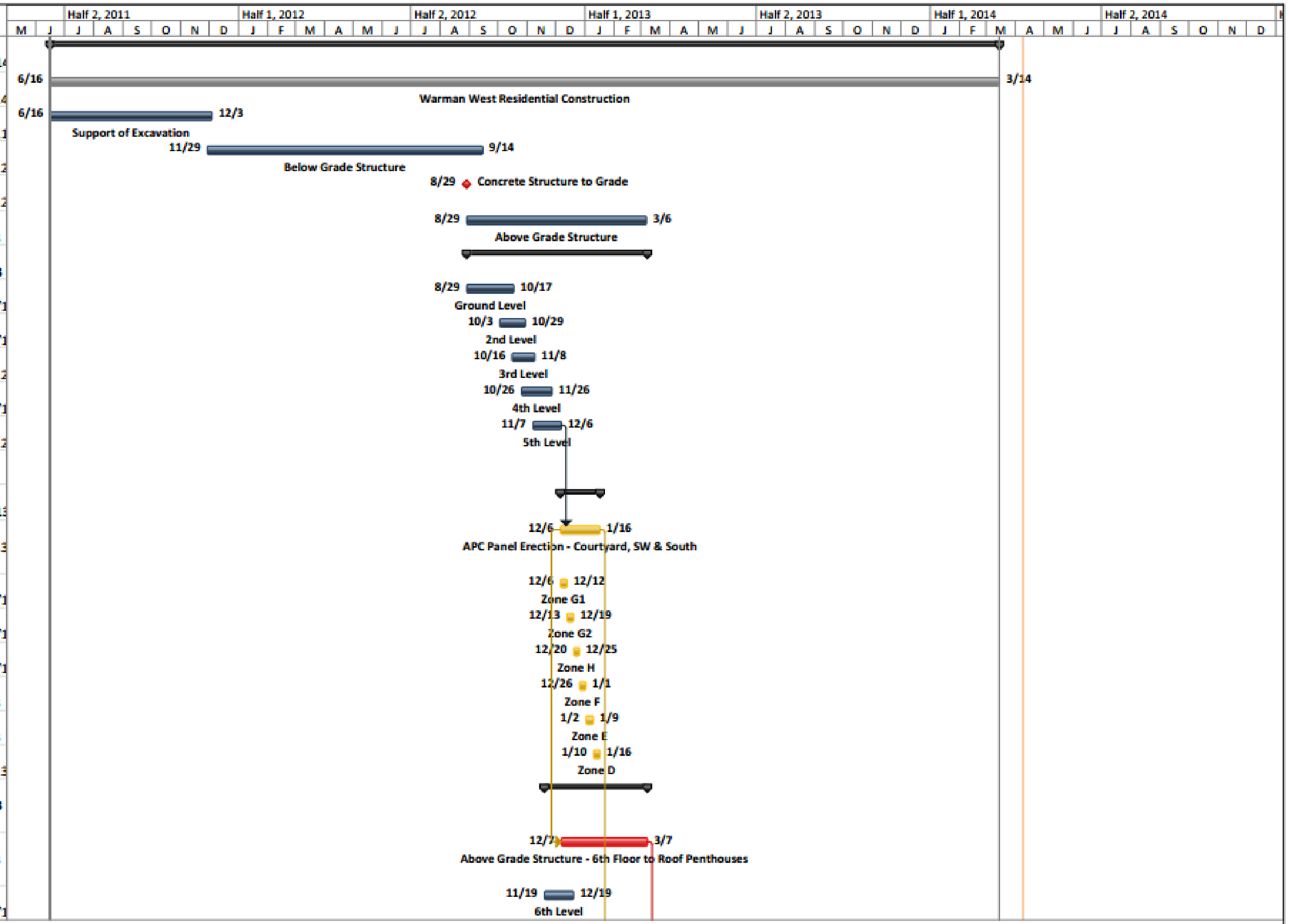


1. Zone A1 East	10. Zone G2
2. Zone A2 East	11. Zone H
3. Zone A3 East	12. 6th Floor Concrete Structure
4. Zone B	13. 7th Floor Concrete Structure
5. Zone C	14. 8th Floor Concrete Structure
6. Zone D	15. Roof Floor Concrete Structure
7. Zone E	
8. Zone F	
9. Zone G1	

Appendix B.9

APC Panel SIPS Revised Project Schedule

ID	Task Name	Duration	Start	Finish
1	**Wardmn West Residenital Construction**	**717 days?**	**Thu 6/16/11**	**Fri 3/14/14**
2	Warman West Residential Construction	717 days	Thu 6/16/11	Fri 3/14/14
3	Support of Excavation	123 days	Thu 6/16/11	Sat 12/3/11
4	Below Grade Structure	209 days	Tue 11/29/1	Fri 9/14/12
5	Concrete Structure to Grade	0 days	Wed 8/29/12	Wed 8/29/12
6	Above Grade Structure	136 days	Wed 8/29/12	Wed 3/6/13
7	**Above Grade Structure**	**137 days?**	**Wed 8/29/12**	**Thu 3/7/13**
8	Ground Level	36 days	Wed 8/29/12	Wed 10/17/1
9	2nd Level	19 days	Wed 10/3/12	Mon 10/29/1
10	3rd Level	18 days	Tue 10/16/1	Thu 11/8/12
11	4th Level	22 days	Fri 10/26/1	Mon 11/26/1
12	5th Level	22 days	Wed 11/7/12	Thu 12/6/12
13	<New Task>			
14	**APC Panel Erection - Courtyard, SW & South**	**30 days**	**Thu 12/6/12**	**Wed 1/16/13**
15	APC Panel Erection - Courtyard, SW & South	30 days	Thu 12/6/12	Wed 1/16/13
16	Zone G1	5 days	Thu 12/6/12	Wed 12/12/1
17	Zone G2	5 days	Thu 12/13/1	Wed 12/19/1
18	Zone H	4 days	Thu 12/20/1	Tue 12/25/1
19	Zone F	5 days	Wed 12/26/1	Tue 1/1/13
20	Zone E	6 days	Wed 1/2/13	Wed 1/9/13
21	Zone D	5 days	Thu 1/10/13	Wed 1/16/13
22	**Above Grade Structure - 6th Floor to Roof Penthouses**	**79 days**	**Mon 11/19/1**	**Thu 3/7/13**
23	Above Grade Structure - 6th Floor to Roof Penthouses	65 days	Fri 12/7/12	Thu 3/7/13
24	6th Level	23 days	Mon 11/19/1	Wed 12/19/1

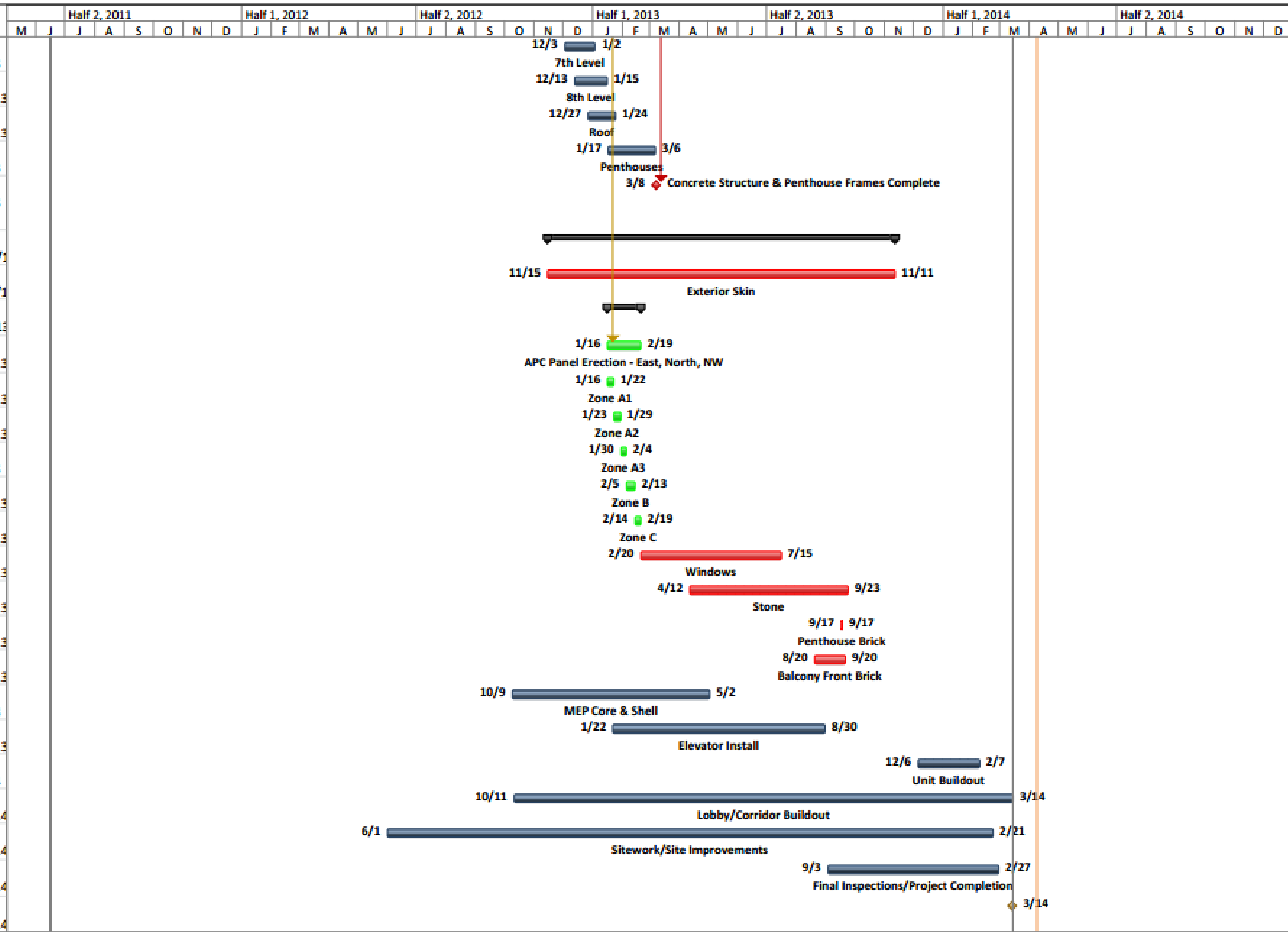


Project: Thesis_Wardman_Revised
Date: Wed 4/9/14

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

Page 1

ID	Task Name	Duration	Start	Finish
25	7th Level	23 days	Mon 12/3/12	Wed 1/2/13
26	8th Level	24 days	Thu 12/13/1	Tue 1/15/13
27	Roof	21 days	Thu 12/27/1	Thu 1/24/13
28	Penthouses	35 days	Thu 1/17/13	Wed 3/6/13
29	Concrete Structure & Penthouse Frames Complete	0 days	Fri 3/8/13	Fri 3/8/13
30	**Exterior Skin**	**258 days**	**Thu 11/15/1**	**Mon 11/11/1**
31	Exterior Skin	258 days	Thu 11/15/1	Mon 11/11/1
32	**APC Panel Erection - East, North, NW**	**25 days**	**Wed 1/16/13**	**Tue 2/19/13**
33	APC Panel Erection - East, North, NW	25 days	Wed 1/16/13	Tue 2/19/13
34	Zone A1	5 days	Wed 1/16/13	Tue 1/22/13
35	Zone A2	5 days	Wed 1/23/13	Tue 1/29/13
36	Zone A3	4 days	Wed 1/30/13	Mon 2/4/13
37	Zone B	7 days	Tue 2/5/13	Wed 2/13/13
38	Zone C	4 days	Thu 2/14/13	Tue 2/19/13
39	Windows	104 days	Wed 2/20/13	Mon 7/15/13
40	Stone	117 days	Fri 4/12/13	Mon 9/23/13
41	Penthouse Brick	1 day	Tue 9/17/13	Tue 9/17/13
42	Balcony Front Brick	24 days	Tue 8/20/13	Fri 9/20/13
43	MEP Core & Shell	148 days	Tue 10/9/12	Thu 5/2/13
44	Elevator Install	159 days	Tue 1/22/13	Fri 8/30/13
45	Unit Buildout	46 days	Fri 12/6/13	Fri 2/7/14
46	Lobby/Corridor Buildout	372 days	Thu 10/11/1	Fri 3/14/14
47	Sitework/Site Improvements	451 days	Fri 6/1/12	Fri 2/21/14
48	Final Inspections/Project Completion	128 days	Tue 9/3/13	Thu 2/27/14
49	Substantial Completion	0 days	Fri 3/14/14	Fri 3/14/14



Project: Thesis_Wardman_Revised
Date: Wed 4/9/14

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

Page 2

Appendix C

Appendix C.1

APC Wall Panel Activity Hazard Analysis: Erection

ACTIVITY HAZARD ANALYSIS

ACTIVITY: LIFTING PRECAST CONCRETE WALL PANELS

Project: AE Senior Thesis
Prepared By: Kevin Kroener
Date: 4/9/2014

Scope of Work: Precast Concrete Wall Panels

PRINCIPAL STEPS	POTENTIAL HAZARDS	RECOMMENDED CONTROLS
1. Select and Inspect Rigging	1.a. Damaged or unsafe rigging 1.b. Under sized rigging or incorrect rigging	1.a. & 1.b. Inspect rigging on a daily basis for safe working conditions. Remove form service and discharge any rigging if as necessary. Competent groundman, assisted by Erection Foreman, will select appropriate rigging for each lift.
2. Lift wall panel load	2.a. Crane malfunction or failure	2.a. Operator must perform daily inspections to ensure that crane is in safe working condition. Inspections will also be documented in the a crane logbook.
	2.b. Improper crane setup leading to tipping or failure	2.b. Ensure crane is on stable and level ground per the manufacturers specifications/recommendations. Proper boom radius as specified in crane capacity chart.
	2.c. Struck by hazard from crane superstructure	2.c. Barricade tail swing of crane
	2.d. Swinging of loads other employees	2.d. Ensure swing path is clear. Groundman and Erection Foreman will control area within swing radius of crane boom with assistance from GC field supervision. Swing path perimeter will be marked or barricaded to prevent employees from walking beneath load. The CAZ (Controlled Access Zone) will be set at an appropriate distance and the Groundman and Erection Foreman will remain alert to personnel entering restricted areas to keep people out of the swing path.
	2.e. Swinging or out of control panel load	2.e. Only one person at a time will give signals and have radio communication with crane operator. Taglines will be used to control loads
EQUIPMENT TO BE USED	**INSPECTION REQUIREMENTS**	**TRAINING REQUIREMENTS**
1. Tower Crane 2. Mobile Crane 3. Rigging 4. Tag lines 5. PPE - hard hat, safety glasses, steel-toe boots, reflective vests	1. Annual crane inspection 2. Daily crane inspection 3. Crane inspection upon arrival at site 4. Posted Certificate of Compliance on Crane 5. Daily rigging inspection	1. Certified Crane Operator 2. Erection Foreman has completed PCI's Certified Erector course 3. All erectors and riggers have completed rigging training ***** GC is responsible for training of all non- precast/erector personnel to remain clear of the precast work area and to obey warning signs and barricades.***

Appendix C.2

APC Wall Panel Activity Hazard Analysis: Installation

ACTIVITY HAZARD ANALYSIS

ACTIVITY: INSTALLING PRECAST CONCRETE WALL PANELS

Project: AE Senior Thesis
Prepared By: Kevin Kroener
Date: 4/9/2014

Scope of Work: Precast Concrete Wall Panels

PRINCIPAL STEPS	POTENTIAL HAZARDS	RECOMMENDED CONTROLS
1. Lift wall panel	1.a. Crane tipping, load shift, rigging failure	1.a. Operator must perform daily inspections to ensure that crane is in safe working condition. Inspections will also be documented in the a crane logbook.
	1.b. Load shift, rigging failure	1.b. Inspect rigging on a daily basis for safe working conditions. Remove form service and discharge any rigging if as necessary. Competent groundman, assisted by Erection Foreman, will select appropriate rigging for each lift.
2. Set wall panel in position	2. Swinging panel load, overhead load	2. Only one person at a time will give signals and have radio communication with crane operator. Taglines will be used to control loads
3. Secure wall panel	3. Unstable wall panel tipping over	3. Crane hoist lines will still be attached to wall panel as erectors secure anchor points at top and bottom of panel. Walls will be braced as needed.
4. Unhook rigging	4.a. Falling from height > 6 feet	4.a. After panel is braced and/or connected to the building structure, erector will use a ladder or JLG to disconnect the rigging at the top of the panel.
	4.b. Falling Objects	4.b. Employees will remain clear of controlled access zones and other restricted areas below load pick at all times.

EQUIPMENT TO BE USED	INSPECTION REQUIREMENTS	TRAINING REQUIREMENTS
1. JLG 2. Ladder 3. Steel prying bars 4. Wrenches 5. PPE - hard hat, safety glasses, steel-toe boots, reflective vests	1. Annual crane inspection 2. Daily crane inspection 3. Crane inspection upon arrival at site 4. Posted Certificate of Compliance on Crane 5. Daily rigging inspection 6. Daily ladder inspection 7. Daily JLG inspection	1. Certified Crane Operator 2. Erection Foreman has completed PCI's Certified Erector course 3. Tool Box Talks and/or Foreman Meeting to cover JLG, ladder, small tool and PPE use