Analysis 1: Slenderwall Panel Implementation

Problem Statement

Wisconsin Place is a project faced with many constraints including time, money, resources, and space. The site is extremely crowded already, and some of the concurrent projects have yet to begin. Conditions will only worsen as time wears on. Turner and all subcontractors onsite could benefit greatly by simplifying the building process in as many ways as possible.

Goals

It is my goal through this analysis to simplify the construction of the façade by limiting the number of trades that need access to it. The intent is to reduce the amount of trades working in one space and to accelerate the schedule. Potential cost savings exist in the shortened project timeline as well as the removal of the masonry hoist and scaffolding from the project scope. This analysis will also address structural design considerations, specifically reducing the exterior loads and connection to the post-tensioned slabs. Finally, thermal performance is a predominant concern whenever precast is introduced to the façade. A governing factor in the selection of a panelized system will be its resistance to the elements. Overall, superior quality, productivity and performance can result from the implementation of precast panels. It is just a matter of selecting the appropriate system for the project.

Research Steps

1. Research precast systems and determine the most relevant one for this project.
2. Calculate the load associated with prefabricated panels.
3. Design the panel to slab connection detail.
4. Create a site layout plan to allocate a holding space for the panels.
5. Modify the schedule to show time savings.
6. Modify the budget to show the cost differential.
7. Determine constructability issues associated w/ prefabrication.
8. Determine thermal load differential between the existing and proposed systems.
9. Calculate the costs associated with crane, scaffolding, and hoist usage.
10. Make recommendation of proceeding with precast system.

Tools

1. RS Means 2008 Edition
2. Smith-Midland Corporation – Slenderwall Manufacturer
3. PCI Code

4. Turner GMP Budget
5. AISC Steel Construction manual
6. Whole Building Design Guide

Expected Outcome

I think that the schedule can be greatly reduced by using precast brick panels for the exterior cladding. This could eliminate the need for a material hoist and scaffolding. In turn, it will increase the demand on the crane. I expect to see a cost increase in selecting a precast system over a stick-built one, but hope to find savings in other areas like hoist and scaffolding removal. Coordination will become a more critical issue. The panels will need to be delivered to site in the order they are to be erected, and they may need a staging area. I plan to address this by developing a site layout plan that will allocate material storage areas and delivery routes.

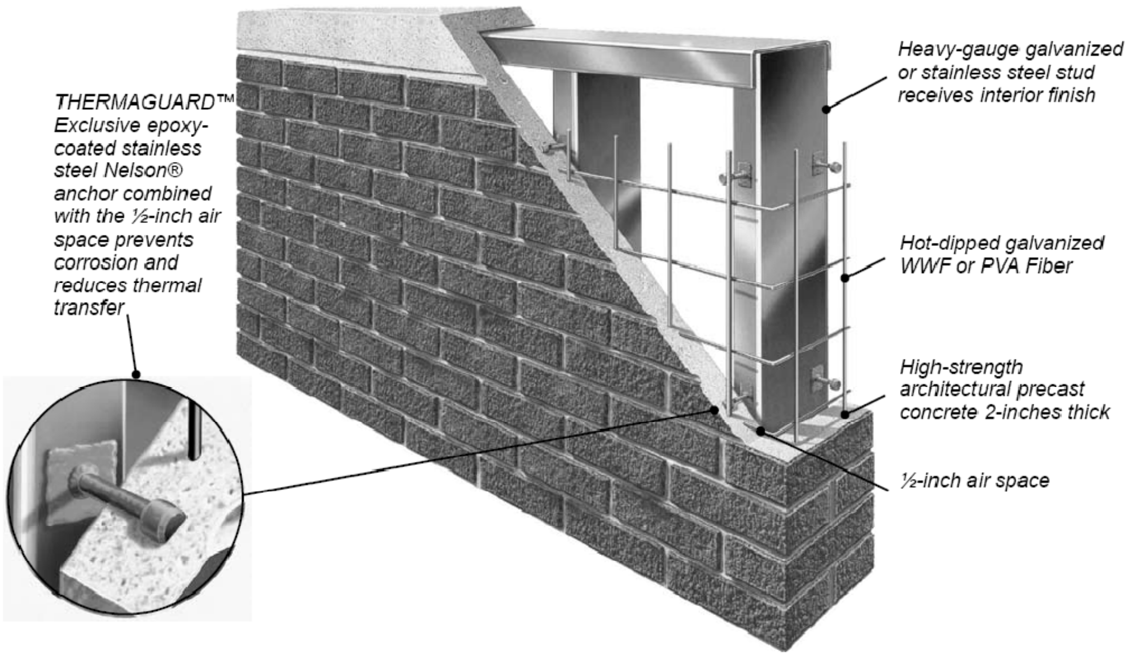
Product Information

After researching many different precast systems I have selected Smith-Midland's Slenderwall® panel system. I found this system to be very unique and even cutting edge. Their website contained extensive literature on the product, leading me to believe that it has been thoroughly tested and proven to be an effective façade system.

Slenderwall® is comprised of a 16 gauge 6 inch galvanized steel studs on 2 foot centers. The outer layers of the panel include a 2 inch concrete facing. A ½ inch air space separates the concrete and studs, reducing thermal transfer from the exterior to interior by up to 25%. These panels are self-supporting, and eliminate the need for exterior framing. In addition, they also eliminate the need for a material hoist and scaffolding, since they can be easily placed using the crane. Refer to the picture below for some of the key features.

SLENDERWALL®

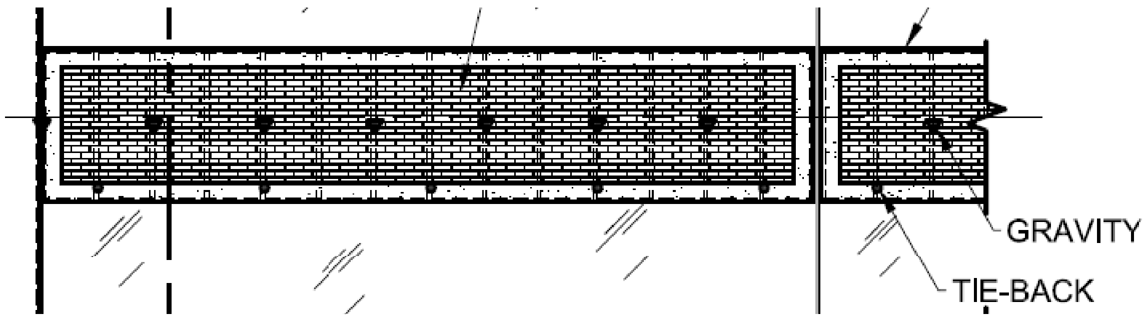
Architectural Precast Concrete/Steel Stud Building Panels



Slenderwall® uses 5,000 psi concrete with galvanized wire mesh for reinforcing. An integral concrete admixture is incorporated to reduce water penetration. Smith-Midland has successfully completed more than 50 projects in 11 different states. The average panel size is 8 feet by 30 feet. A typical size is 10 feet by 30 feet. A Slenderwall® panel weighs around 30 pounds per square foot, significantly less than a conventional precast panel weighing 85 pounds per square foot. Both Slenderwall® and conventional precast panels must rely on a backup system of insulation and waterproofing, but Slenderwall® incorporates the exterior studs into one panel. I was drawn to this system because it achieves my goal of consolidating the building envelope trades. EASI-SET Industries provides certified drawings that are reviewed and stamped by registered professional engineers.

Smith-Midland recommends consulting with the Hilti Company or STI, Inc. to achieve a typical 2 hour fire rating between floors. A piece of light gauge break metal provided and installed by the drywall contractor bridges the gap between the floor slab and the panel since it is mounted on the exterior of the slab, adding several inches to the perimeter of the slab. Smith-Midland also recommends that a mineral-wool fireproof material be installed in the gap between the slab and the precast.

The average lead time for these Slenderwall® panels is around 12 weeks from the start of shop drawings. Slenderwall® is installed by PCI-qualified erectors or professionals who have at least 5 years of experience installing Slenderwall®. The panels are attached to the perimeter of the building by gravity and lateral connections at the floor slab. Gravity connections are suggested to be spaced at 4 feet on center with lateral tie-backs at 6 feet on center. Slenderwall® attaches easily to other wall systems using expansion joints. The caulking contractor is responsible for sealing between the panels.



Vapor barriers can be applied by the HVAC contractor. They are applied to the heated side of the panels on the northeast side of the building between the frame and concrete. The R-value of Slenderwall® when assembled with 6 inches of batt insulation and drywall is R-21. The life of Slenderwall® panels is from 50-100 years. They are warranted for one year.

A foamed-in-place insulation is available with panel installation and acts as a thermal, moisture, and air barrier. It is pressure-sprayed into the wall cavity on top of the metal studs. Because it is sprayed in a semi-liquid state, it is able to fill even the smallest cracks of the panels, making the building envelope airtight. The liquid insulation expands and hardens to seal the building skin.

Slenderwall® won the National Precast Association's Creative Use of Precast Award for above ground precast in January 2008. Below are two featured projects that implemented the Slenderwall® product.

New Jersey Institute, Newark, NJ

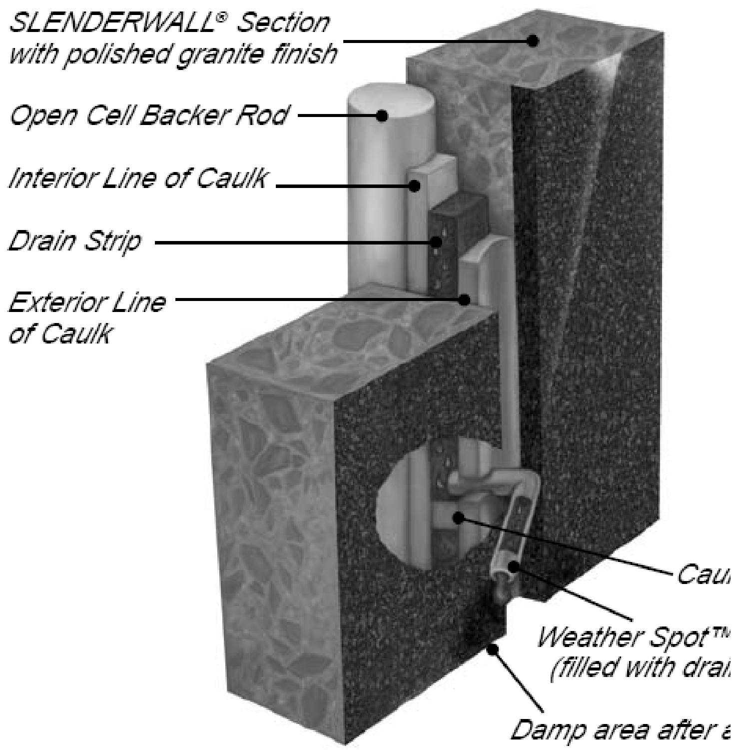
*Second Nature™ *(Architectural Precast Concrete Brick)*

Courthouse Metro Plaza, Arlington, VA

DESIGN CONSIDERATIONS

Smith-Midland carefully addresses many design issues on their website. They use a DURAFLEX 360 precast to stud frame connection that allows 360°of movement to isolate the precast skin from structural stresses like wind loads, frame movement, expansion, contraction, and seismic shock. H_2OUT™ is a secondary drainage caulk joint leak detection system. If a caulk joint fails, the water exits the building and can be located within 20 feet of the leak.

THERMAGUARD™ is Smith-Midland's patented air barrier that consists of a ½ inch air space between the concrete and stud and the use of epoxy coated stainless steel Nelson anchors. The connection prevents corrosion and reduces thermal transfer by as much as 25%.

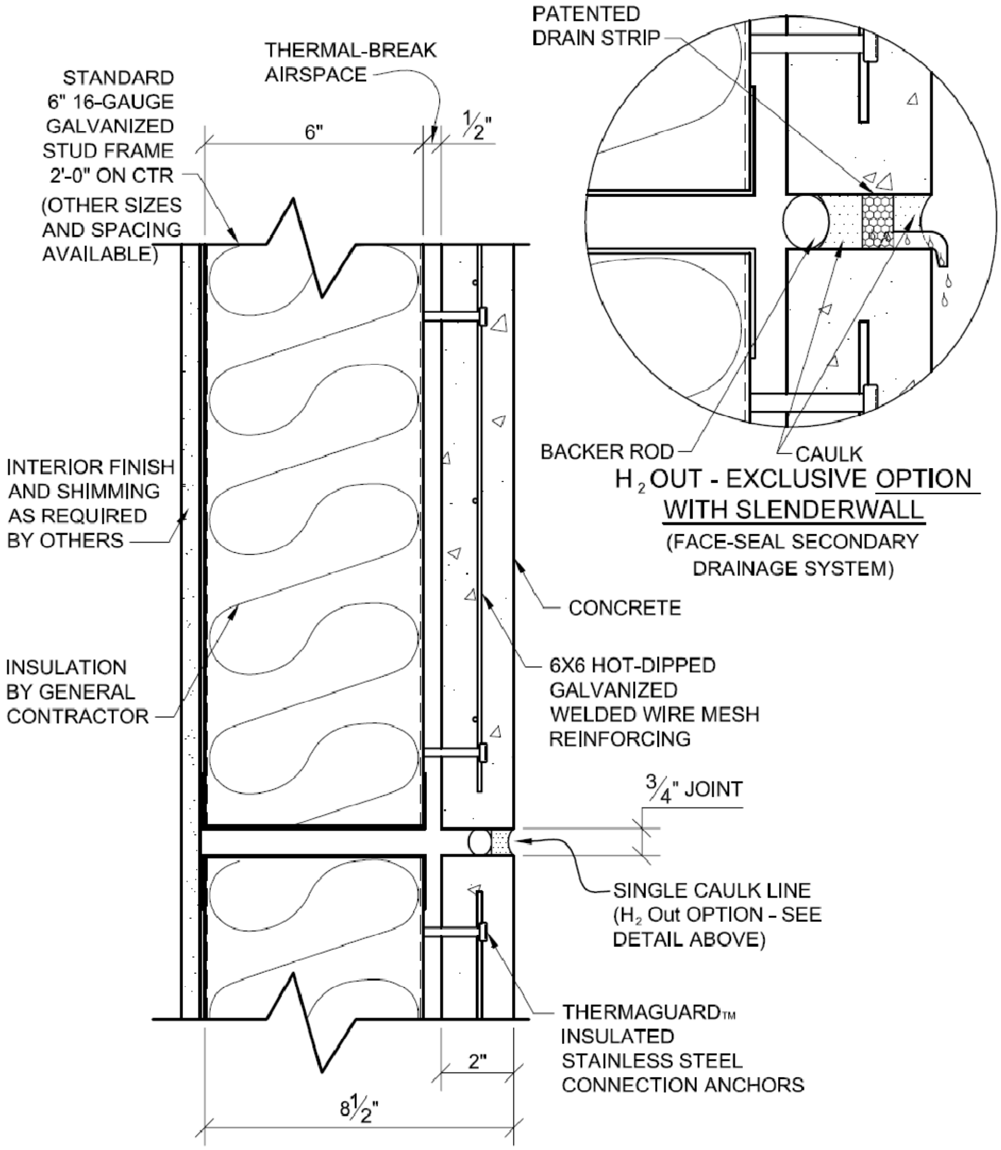


H_2Out™

DURAFLEX 360°™

Slenderwall® offers a foamed-in-place urethane continuous-insulation method that acts as an insulation, water, and air barrier. In hot and humid seasons, vapor tends to migrate from the exterior to the interior skin of a building. A closed-cell polyurethane insulation can be applied to the interior side of the concrete to remedy this issue. In cold seasons, vapor migrates in the opposite direction. To avoid this moisture problem, a layer of plastic can be installed over the light gauge steel studs on the interior before the drywall is installed.

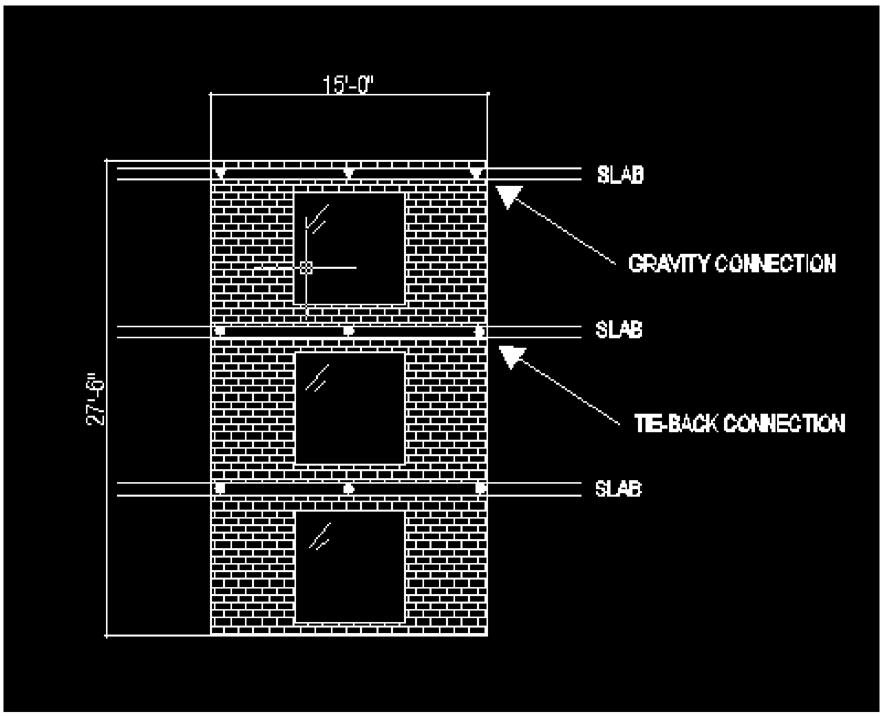
Slenderwall® panels can gain building owners LEED points due to energy savings and material selection. I was so impressed by this product because its manufacturers addressed all of the common concerns and have a solution for each. I think this stud and precast panel system will integrate well into the Wisconsin Place project, but I will save my recommendation for the end of the analysis.



TYPICAL SLENDERWALL SECTION

Structural Attachment Design

The figure below depicts the largest panel that will be used on the façade of Wisconsin Place. Note that gravity connections are only located at the topmost slab. The others are just tie-back connections to resist lateral loads like wind. The window openings will be cut out in the factory so that this is a solid piece.



Typical Panel Connection Design

15' x 27.5' vertical panel containing (3) 6' x 6' windows

Tributary Area = 10' x 27.5' = 275 SF

Gravity connections spaced at 5'

Point Load = 275 SF x 87.75 PSF = 24,131 lbs = 24.13 kips

<u>1. Angle Design</u>

Steel manual → Try L2.5" x 2.5" x 3/16"

Shear Yield = 29.2 k

Shear Rupture = 29.4 k

$A_n = 0.572 \text{ in}^2 > A_{e,min} = 0.552 \text{ in}^2$

$A_g = 0.9 \text{ in}^2 > A_{g,min} = 0.74 \text{ in}^2$

Shear Yield:

$A_g = 0.9\ in^2$

$\Phi P_n = 0.9F_yA_g = 0.9(36)(0.9) = 29.16\ k$

Shear Rupture:

$A_n = 0.572\ in^2$

Shear Lag Factor, u

X =0.687”

$U = 1 – x/L = 1 – (0.687/3) = 0.771$

$A_e = 0.771(0.572) =).441\ in^2$

$\Phi P_n = 0.75F_uA_e = 0.75(58)(0.441) = 19.18\ k$

Block Shear:

Tension: $A_{nt} = 0.762\ in^2$

$P_n = F_uA_{nt} = 58(0.762) = 44.18\ k$

Shear Yield: $A_{gv} = 1.5(3/16) = 0.281\ in^2$

$P_n = 0.6(36)(36)(0.281) = 6.07\ k$

Shear Rupture: $A_{nv} = [1.5 – 0.75(3/4 + 1/8)](3/16) = 0.158\ in^2$

$P_n = 0.6(58)(0.158) = 5.5\ k$

$\Phi R_n = 0.75(44.18 + 5.5) = 37.3\ k$ Block Shear

<u>2. Bolt Design</u>

Steel manual → 15.9 k/bolt for ¾” threaded

Shear: 24k/(15.9 k/bolt) → 2 bolts

Shear: 31.8 k

Bearing:

$L_c = 1.5 – 0.5(3/4 + 1/16) = 1.09” < 2d = 1.5”$

Tearout controls @ top bolt

$R_n = 1.2FuLct = 1.2(58)(1.09)(3/16) = 14.2\ k/bolt$

$L_c = 3 – (3/4 + 1/16) = 2.19” > 2d = 1.5”$

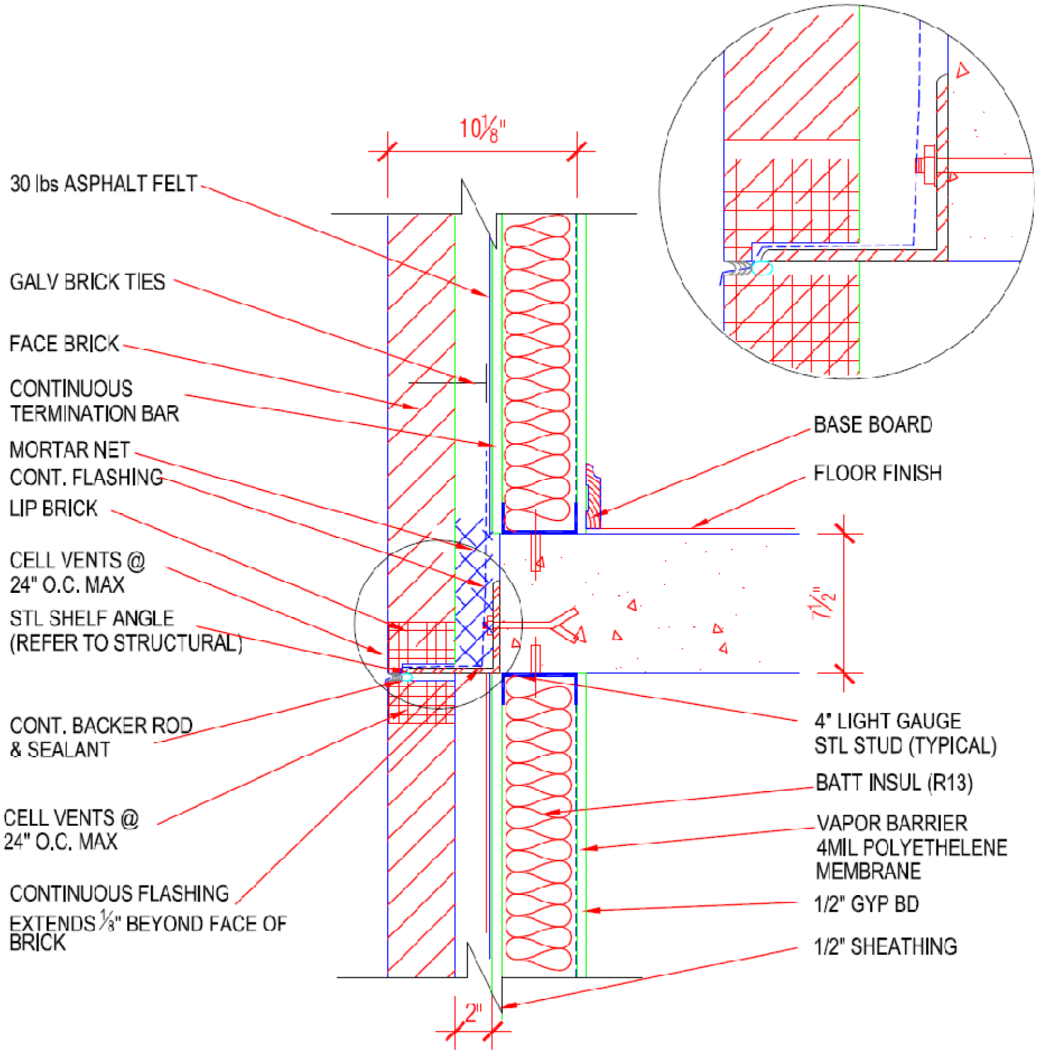
Tearout does not control at bottom bolt

$R_n = 2.4dtF_u = 2.4(3/4)(3/16)(58) = 19.6$ k/bolt

$\Phi R_n = 0.75(14.2 + 19.58) = 25.3 \text{ k} < 31.8 \text{ k}$ OK

Connection Details

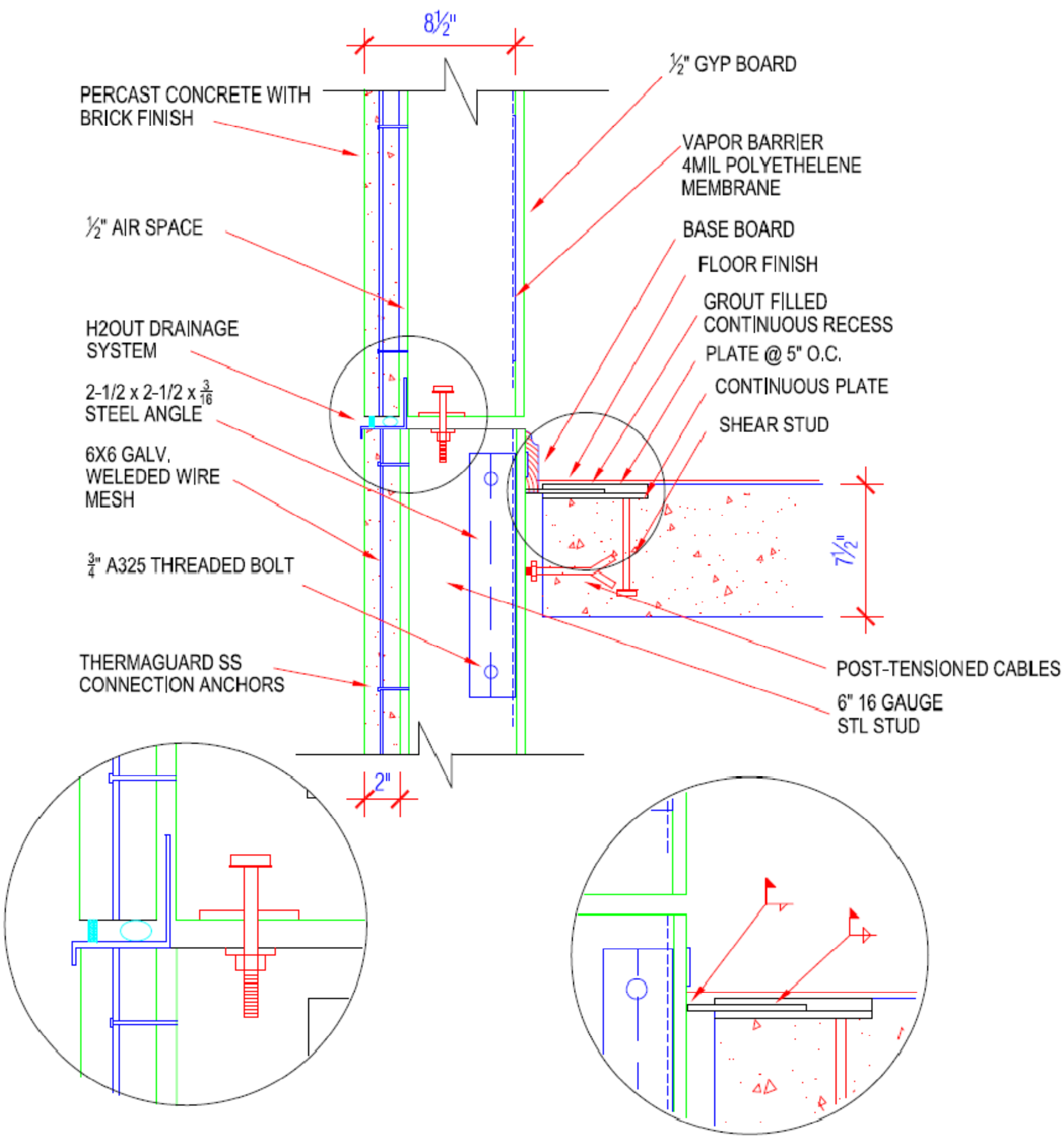
The following figures depict connection details as suggested by the manufacturer. The overall thickness of the typical brick and metal stud veneer is 10-1/8" while the Slenderwall® panel is only 8-1/2". Additional connection details can be found in Appendix B. One benefit to the Slenderwall® panels is that they are attached on the outside face of the slab, as opposed to the existing metal studs that are constructed on top of the slab. Hence, the Slenderwall® panels add approximately 6-8 inches to every apartment unit. All of the connection details can be found in Appendix B.



1

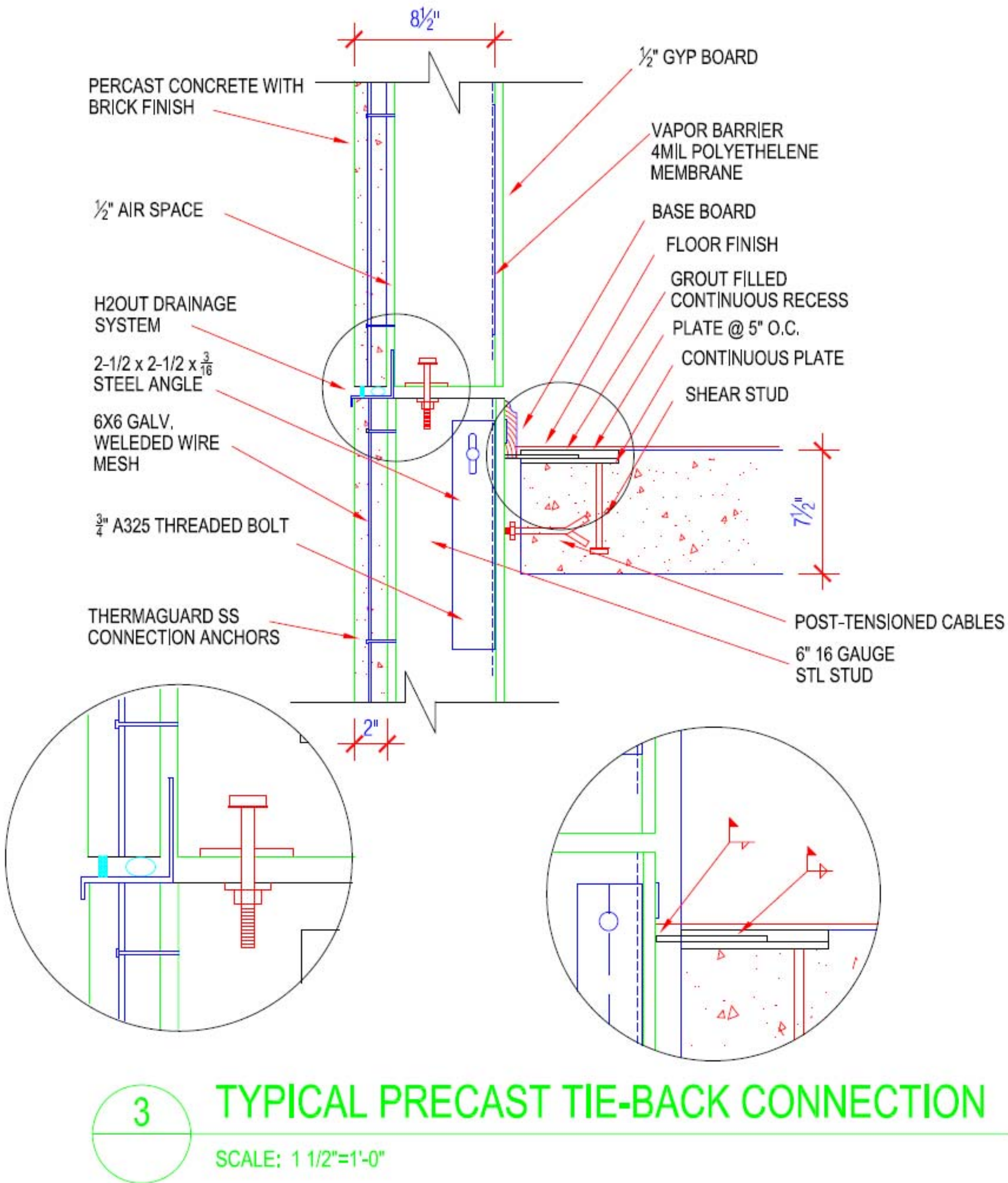
TYPICAL BRICK VENEER CONSTRUCTION

SCALE: 1 1/2"=1'-0"



2 TYPICAL PRECAST GRAVITY CONNECTION

SCALE: 1 1/2"=1'-0"


8½"
PERCAST CONCRETE WITH BRICK FINISH
½" GYP BOARD
VAPOR BARRIER 4MIL POLYETHELENE MEMBRANE
½" AIR SPACE
BASE BOARD
FLOOR FINISH
GROUT FILLED CONTINUOUS RECESS
H2OUT DRAINAGE SYSTEM
PLATE @ 5" O.C.
CONTINUOUS PLATE
2-1/2 x 2-1/2 x 3/16 STEEL ANGLE
SHEAR STUD
6X6 GALV. WELEDED WIRE MESH
7½"
¾" A325 THREADED BOLT
THERMAGUARD SS CONNECTION ANCHORS
POST-TENSIONED CABLES
6" 16 GAUGE STL STUD
2"
3
TYPICAL PRECAST TIE-BACK CONNECTION
SCALE: 1 1/2"=1'-0"

BUILDING LOAD ANALYSIS

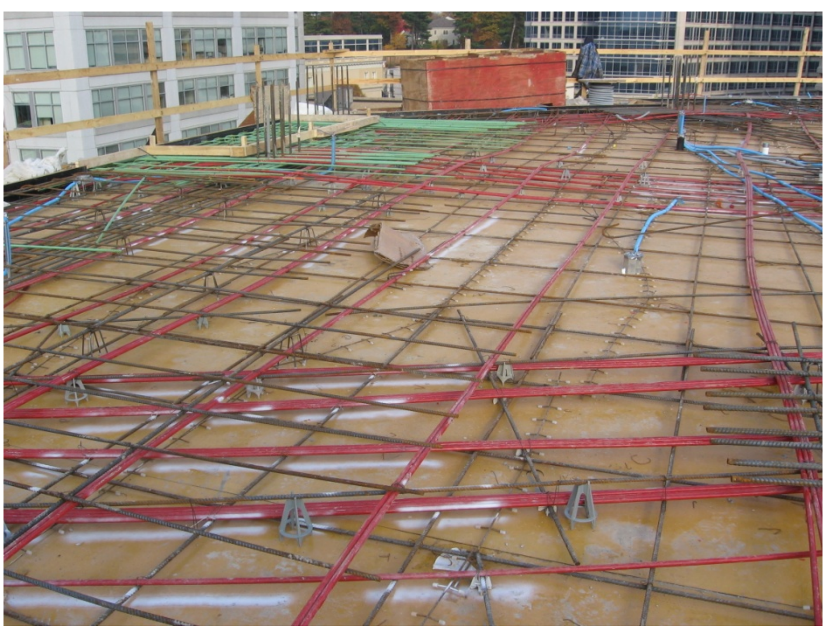
Existing System

Component	Weight (psf)
Gypsum Board	2
Steel Studs	18
Sheathing	50
Mortar	39
Brick	35
Total Weight	**144**

Proposed System

Component	Weight (psf)
Slenderwall Panel	30
Gypsum Board	2
Sheathing	50
Total Weight	**82**

Since the Slenderwall® system weighs about half of the existing brick veneer system, there will be no structural implications associated with changing to the alternate. Perhaps some structural modifications could be made. This would be an extremely difficult undertaking because the post-tensioned slab is already a slim 7-1/2" thick. If it were reduced to a smaller thickness I cannot guarantee that all of the tendons and conduits could be cast into it. Please refer to the picture below showing how many elements are embedded into the floor slab.



Schedule Review

Durations

System	Quantity	Unit	Daily Output	Days	
Brick w/ Metal Studs	79208	SF	565	140.2	
Slenderwall	79208	SF	2500	31.7	
		Difference:		108.5	Day Reduction

The Slenderwall® brochure claims that each panel can be set by the crane in 20 minutes, but this does not account for adjustments and field welding. So to be conservative I said that a typical panel takes about 2 hours to fully erect. There are roughly 250 panels to be placed on the exterior. This brought me to a duration of 31.7 days. Remember that the Slenderwall® system is replacing both the brick veneer and metal studs, so I combined the schedule time of the two to attain a duration of about 7 months, or 140 days. The overall time savings from switching to the Slenderwall® system is 22 weeks.

Constructability Review

According to the brochure, one Slenderwall® panel can be installed in 20 minutes thanks to the Lift-and-Release system. This means that the panel can be plumbed and aligned after the crane has unhooked using a turn-of-nut connection. Welds are completed after the panel is aligned. I have made the inference that the installation of one panel takes approximately 2 hours. The crane will be needed only for those first 20 minutes, however. Basing my calculations off of this piece of information and the estimated 250 panels that must be attached to the exterior, the added crane usage time due to the Slenderwall® system is:

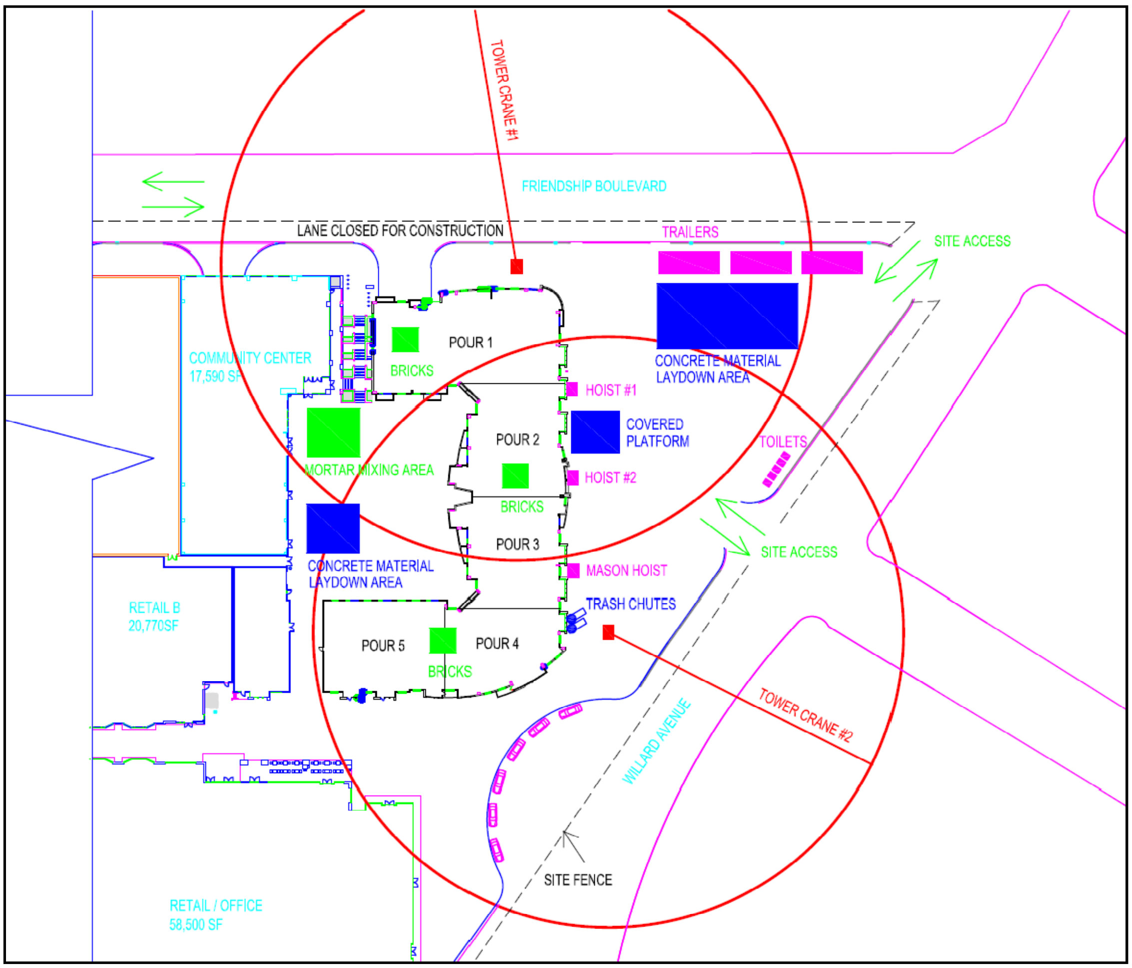
250 panels x .333 hours/panel = **83.33 hours of crane operation**

The schedule above shows that it will take roughly 32 days to place the Slenderwall® panels, not including the waterproofing, insulation, and interior drywall. The crane usage per day during this period is:

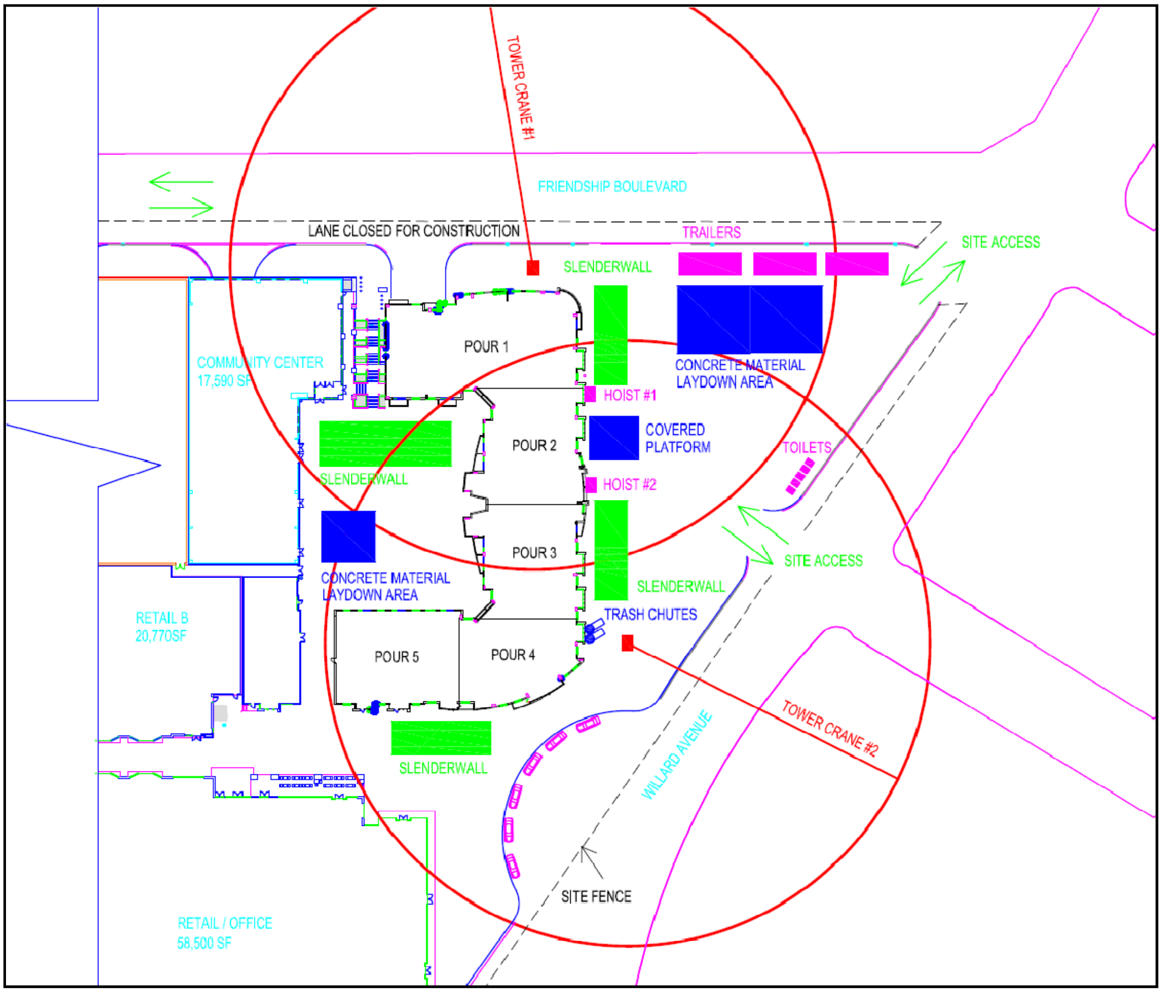
83.33 hours/32 day duration = **2.6 hours/day of crane operation**

This will be a coordination issue to discuss with the other subcontractors on site, especially since the concrete structure will be going up as the panels begin to be attached. If a crane usage schedule can be developed by Turner and the subcontractors this situation could have a favorable result. Maybe the concrete crew will spend the morning forming columns and slab and pour in the afternoon. This way the crane will be free to place panels as the pump truck places concrete.

The two figures below show a comparison between the existing superstructure layout plan and the proposed superstructure layout plan. It is worth noting that standard bricks must be either pre-loaded onto the building floors or kept on a covered elevated platform outdoors to shield them from moisture. If wet bricks are placed in mortar the excess water prevents it from curing properly, a detrimental effect on the assembly's overall strength. The Slenderwall® panels can be stored outside as long as they are protected from physical injury. They connect via plates and angles that are bolted and welded. The Slenderwall® panels will require more laydown area, but they are a pick and place material that will go quickly. Also note that there is no longer a need for the masonry hoist.



Existing Superstructure Layout Plan



Proposed Superstructure Layout Plan

Thermal Analysis

Another deciding factor in the recommendation of a cladding system is the thermal performance of the Slenderwall® panels compared to the existing stick-built brick veneer. I initially thought the hand-laid brick system would be more sound because there are not joints in the façade. After reviewing Slenderwall® literature and all of the additional insulating products they offer, my thinking changed. The following charts calculate the R-values for the existing and proposed systems. Remember that a higher R-value means greater resistance to heat transfer, whether from the inside to outside in winter or the outside to inside in summer.

Existing System

Component	Thickness (inches)	Unit R-Value	Unit	Total R-Value
Inside air layer	N/A	0.68	ea	0.68
Gypsum board	0.5	0.45	ea	0.45
R-13 insulation	4	13	ea	13
Sheathing	0.5	1.09	ea	1.09
Asphalt felt	N/A	0.12	ea	0.12
Air gap	2	1.68	inch	3.36
Standard 4" brick	4	0.44	ea	0.44
Outside air layer	N/A	0.17	ea	0.17
Total Thickness	**11**	**R-Value**	hr-sf-F/BTU	**19.31**
		U-Value	BTU/hr-sf-F	**0.0518**

Proposed System

Component	Thickness (inches)	Unit R-Value	Unit	Total R-Value
Inside air layer	N/A	0.68	ea	0.68
Gypsum board	0.5	0.45	ea	0.45
Vapor barrier	N/A	0.12	ea	0.12
R-13 insulation	6	13	ea	13
Air gap	0.5	1.68	inch	0.84
Foamed-in-place insulation	0.5	6.25	inch	3.125
Concrete w/ admixtures	2	2.615	ea	2.615
Outside air layer	N/A	0.17	ea	0.17
Total Thickness	**9.5**	**R-Value**	hr-sf-F/BTU	**21**
		U-Value	BTU/hr-sf-F	**0.0476**

Using the U-values calculated above, the overall heat gain and loss can be computed for Wisconsin Place.

Summer Heating Loads: To = 90F, Ti = 75F

ΔT = 15F

Summer Heat Gain

System	Area (SF)	U-Value	ΔT (°F)	Heat Gain (BTU/hr)	
Standard Brick	79208	0.0518	15	61544.616	
Slenderwall Panels	79208	0.0476	15	56554.512	
			Difference	**4990.104**	
				8.11%	**Reduction of Heat Gain**

Winter Cooling Loads: To = 15F, Ti = 70F

ΔT = 55F

Winter Heat Loss

System	Area (SF)	U-Value	ΔT (°F)	Heat Loss (BTU/hr)	
Standard Brick	79208	0.0518	55	225663.592	
Slenderwall Panels	79208	0.0476	55	207366.544	
			Difference	**18297.048**	
				8.11%	**Reduction of Heat Loss**

In the category of thermal resistance, Slenderwall® appears to be a winning choice. Even a small difference in heat transfer can mean big savings in electric bills and possible reduction of the size of mechanical equipment.

Budget Review

Wall System Cost Comparison

System	Quantity	Unit	Cost/SF	Total Cost	
Brick w/ Metal Studs	79208	SF	$35	$2,772,280	
Slenderwall	79208	SF	$50	$3,960,400	
		Difference		**$1,188,120**	
				42.86%	**Increase in Cost**

At first glance, the Slenderwall® panels cost about $1 million more than the standard brick, but they have many benefits. Since the exterior studs are incorporated into the panels, that eliminates the need for an exterior framing subcontractor altogether, further simplifying the building enclosure. So, when figuring out the schedule savings, I also accounted for the exterior framing timeline as well, bringing the existing system of brick with metal studs to 7 month duration. The crane will need to be rented for two months to place these panels because they charge on a monthly basis and it takes a little over 1 month to erect all of the panels.

Scaffolding Cost

Cost	Unit	Surface Area	Total Cost
$252	SFCA	2700	$680,400

Tower Crane Cost

Cost	Unit	Rental Period	Total Cost
$35,200	month	10	$352,000
			x 2 cranes
		Total Rental Cost:	**$704,000**

Masonry Hoist Cost

Cost	Unit	Rental Period	Total Cost
$4,775	month	10	$47,750

Taking all of these factors into consideration, I developed the following chart that details all of the costs and savings that go along with the Slenderwall® panel implementation. The Slenderwall® cost differential is the added cost of changing to a new system. The 2 month crane rental is another cost that is incurred from the change. Some savings include the elimination of scaffolding, the masonry hoist, and the exterior framing contract. In total, this replacement looks like it will turn out to be an economical choice after all.

Costs	
Slenderwall Cost Differential	$1,188,120
Crane Usage (2 months)	$70,400
Total Cost	**$1,258,520**
Savings	
Scaffolding Removal	$680,400
Hoist Removal	$47,750
Cancel Ext. Framing Contract	$1,940,000
Total Savings	**$2,668,150**

The **net amount of money saved** by implementing the Slenderwall® system is:

$2,668,150 - $1,258,520 = **$1,409,630**

Conclusion & Recommendation

I would strongly recommend switching from a hand-laid brick façade to a precast Slenderwall® panel enclosure based upon the fact that it saves $1,409,630 (all things considered), significantly accelerates the schedule by 22 weeks, is lightweight and easy to handle, and reduces the heating and cooling loads on the building. Wisconsin Place could greatly benefit by switching to this precast cladding system.