Exterior Façade:

Building Façade History:

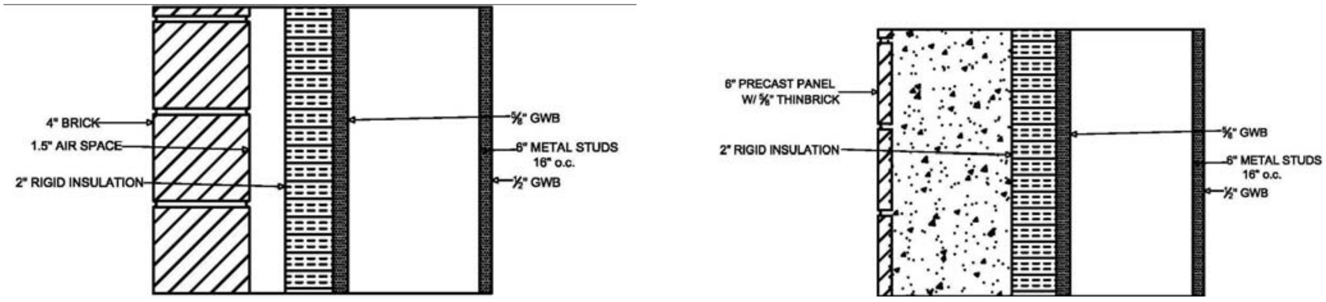
The original 1229-1231 buildings were constructed in the late 1960’s with a precast façade wrapping the entire buildings. For 40 years these buildings have served as offices for the Bureau of National Affairs. In 2007 the properties were purchased by Vornado/Charles E. Smith to be redeveloped into residential apartments. The current façade design consists of removing the old precast façade and replacing it with a combination of curtain wall on the street side of the building and a traditional brick façade for the remaining façade. The design of the brick cavity wall consists of 3-5/8” brick, 2” airspace, 2” of rigid insulation and an air/vapor barrier.

Project Problems:

The demolition work has revealed that the slab edges at varies parts of the building’s perimeter do not run in straight lines. This did not cause problems with the original precast façade, because the panels had installation tolerances that enabled to them to be adjusted to look flush. A traditional brick masonry wall lacks this benefit. Instead the slab edges must be grinded back to make the perimeter run flush. The extra work has delayed the installation of the façade and increased the demolition cost, forcing the mason to use extra crews and work overtime to get back on schedule.

Precast Solution:

Given that the original façade was precast, then a new façade design that also used precast would have negated the need for extra demolition. Discussion with Mark Taylor of Nitterhouse Concrete Products verified this fact. According to Mr. Taylor precast panels have a 1”-2” clearance between the back of the panel and the supporting structure. The purpose of this tolerance is to allow for variance, like the aforementioned, and assure the outside faces of the panels align and are visually appealing. Therefore, the proposed façade design is an architectural precast brick veneer panel system. The panels consist of 5/8” thin set brick cast in and 5-3/8” concrete. The material differences can be seen in Figure PC1 below.



Existing Façade

Proposed Facade

Figure PC1: Wall Sections

Panel Description:

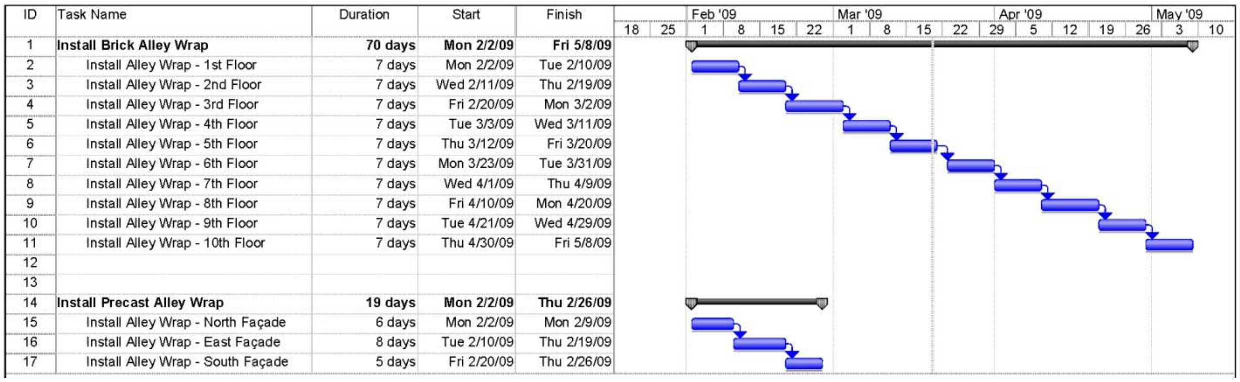
These panels are produced in a factory environment. First, the panel is formed and then the thin set bricks are arranged within a plastic set grid. Then concrete is placed, vibrated and leveled. Because of the factory environment the curing temperature is regulated resulting in higher concrete strengths. After the concrete is cured the set grid is removed revealing the joints of the brick. The joints are made to look like the panel would have been hand crafted. During installation brick tiles may chip and may require replacing.

On WestEnd**25** the precast will run vertically up the building. The widths of the panels will vary because of the façade design. Figure PC2 below highlights the outlines of the precast panels.

Figure PC2: Precast Panel Typical Layout

Schedule:

Traditional brick facades are hand crafted by talented labor. Therefore, the installation is meticulous and time consuming. An advantage of precast panels over masonry brick is the speed of installation. In Figure PC3 a comparison of the time for job site installation for each system is shown.



ID	Task Name	Duration	Start	Finish
1	**Install Brick Alley Wrap**	**70 days**	**Mon 2/2/09**	**Fri 5/8/09**
2	Install Alley Wrap - 1st Floor	7 days	Mon 2/2/09	Tue 2/10/09
3	Install Alley Wrap - 2nd Floor	7 days	Wed 2/11/09	Thu 2/19/09
4	Install Alley Wrap - 3rd Floor	7 days	Fri 2/20/09	Mon 3/2/09
5	Install Alley Wrap - 4th Floor	7 days	Tue 3/3/09	Wed 3/11/09
6	Install Alley Wrap - 5th Floor	7 days	Thu 3/12/09	Fri 3/20/09
7	Install Alley Wrap - 6th Floor	7 days	Mon 3/23/09	Tue 3/31/09
8	Install Alley Wrap - 7th Floor	7 days	Wed 4/1/09	Thu 4/9/09
9	Install Alley Wrap - 8th Floor	7 days	Fri 4/10/09	Mon 4/20/09
10	Install Alley Wrap - 9th Floor	7 days	Tue 4/21/09	Wed 4/29/09
11	Install Alley Wrap - 10th Floor	7 days	Thu 4/30/09	Fri 5/8/09
12				
13				
14	**Install Precast Alley Wrap**	**19 days**	**Mon 2/2/09**	**Thu 2/26/09**
15	Install Alley Wrap - North Façade	6 days	Mon 2/2/09	Mon 2/9/09
16	Install Alley Wrap - East Façade	8 days	Tue 2/10/09	Thu 2/19/09
17	Install Alley Wrap - South Façade	5 days	Fri 2/20/09	Thu 2/26/09

Figure PC3: Schedule Comparison

As can be seen in the above schedules the precast system takes 51 less days to install. The data for the brick alley wrap installation is from the project contract schedule. The difference between the sequencing of activates is that the traditional brick will proceed by installing brick around the perimeter of the building one floor at a time moving up the building. The precast installation will complete entire facades a while moving around the building.

Cost:

The cost difference is a vital in determining the feasibility of a precast façade. The cost of the traditional brick façade includes the cost of materials, labor and hydraulic scaffolding around the building. The cost of the architectural precast panel façade is listed as a square-footage cost, which includes fabrication, delivery and installation. The cost of the precast façade also includes the benefits of a shorter schedule, discussed above, by calculating the savings in general conditions. The cost breakdown is shown in Table PC1.

Item	Quantity	Cost Basis	Total Cost
Brick Façade	23,030 sq. ft.	Budget Estimate: Labor = $48,900 Material Estimate = $416,000 Equipment = $131,250	$1,036,250
Precast Facade	23,030 sq. ft.	$35/sq.ft.	$806,050
		Difference:	$230,200
		Demolition Extra Work:	$77,000
		Total Savings:	$307,200

Table PC1: Cost Comparison

The results of the cost analysis show that there is a $230,200 cost difference in favor of the precast façade. The difference can be accounted for by the cost in equipment. The brick façade uses hydraulic scaffolding around the entire alley wrap for a long duration. The precast façade uses a crane but for a much shorter duration. The cost basis of $35/sq.ft. was gathered from Mark Taylor of Nitterhouse Precast. This cost basis is higher than the $25 square footage costs of R.S. Means, which includes material and labor. The $35/sq.ft. cost is still reasonable because it includes fabrication and delivery on top of material and labor. This cost analysis does not take general conditions into consideration because the alley wrap is not on the critical path and therefore would not shorten the schedule.

Productivity Analysis (MAE Element) :

A productivity analysis has been completed in order to implement graduate level work into this report. A similar analysis was completed for CE 533 – Construction Productivity Analysis and Performance Evaluation on the Lewis Katz building at University Park, PA. The curtain wall façade was analyzed for productivity. Weekly site visits and meetings with the subcontractor were held to build a relationship and successfully gather data. For WestEnd**25** the brick façade has been analyzed for productivity. It was unfeasible to make weekly site visits due to the location of the project. However, there is a preexisting relationship with the project team and weekly meetings were completed via phone to obtain daily installation numbers and manpower.

The flowchart in Figure PC4 shows the process used to complete this analysis. The first level of the flowchart requires that the activity of interest should be in progress while collecting data. This is important to assure accurate numbers. The next step is to obtain daily installed quantities and workhours. The best method to do this is by being on-site and physically recording the quantities and workhours in person. This was not possible for this analysis due to project location. Instead information was provided from the project team. Next, the productivity can be calculated with daily quantities and workhours. The final step of the flow chart is to evaluate the results. The evaluation should look at the baseline productivity and how much variances there is between the daily productivities vary from the baseline. Baseline productivity is calculated by taking 10% of the data dates with the highest output. A total of 5 data dates were used because 10% of the collected data dates would be too small. The baseline productivity is calculated by dividing the summed baseline workhours by the summed baseline quantity. The baseline productivity is considered the best productivity that can be expected for the construction method and design complexity. Also, during evaluation factors such as weather impact, material, and managerial impacts should be considered for peaks of poor productivity.

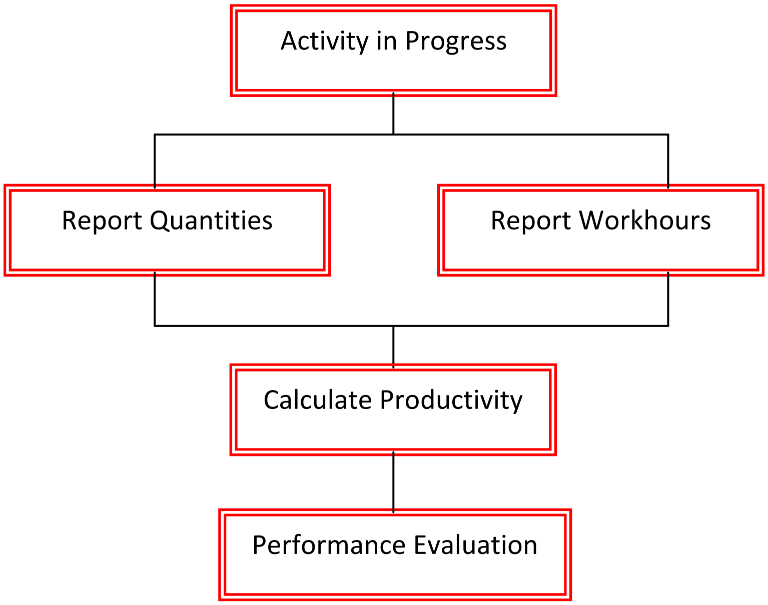
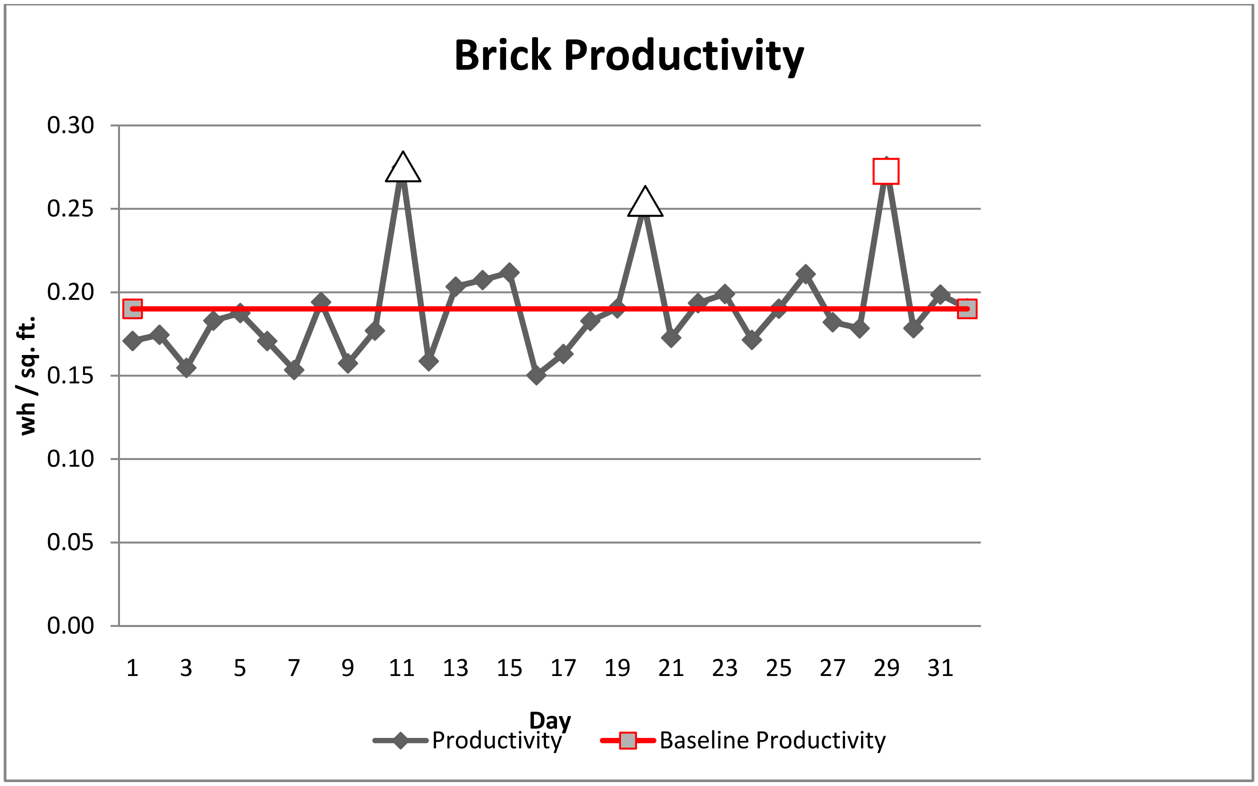


Figure PC4: Productivity Performance Workflow

For this analysis the brick installation is the activity of interest. It is ongoing and only the first 32 days of installation data were gathered. The daily quantities and workhours used in this analysis can be found in the appendices. The graph in Figure PC5 below shows the productivity during brick installation. There are three noticeable peaks which indicate a decrease in productivity. Two of these peaks were the result of weather not allowing the installation of brick. The third peak was caused by preceding trade work not being completed. Many of the remaining data points are below the baseline productivity indicating better than expected productivity.



△ = Weather Delays

□ = Other Trade Delay

Figure PC5: Brick Productivity

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In Figure PC6 a theoretical productivity plot of the precast installation based on planned panel installation per day is shown. The planned panel installation quantities and workhours can be found in the appendices. The initial peak in the graph is caused by extra time need to maneuver equipment for installation, discussed in the preceding site logistics section. The remaining data points are mostly above the baseline but do not vary much. This indicates an expected consistent installation of panels from day to day. Weather delays are less likely during precast installation. However, precast installation is still very susceptible to delays from other trades or deliveries.

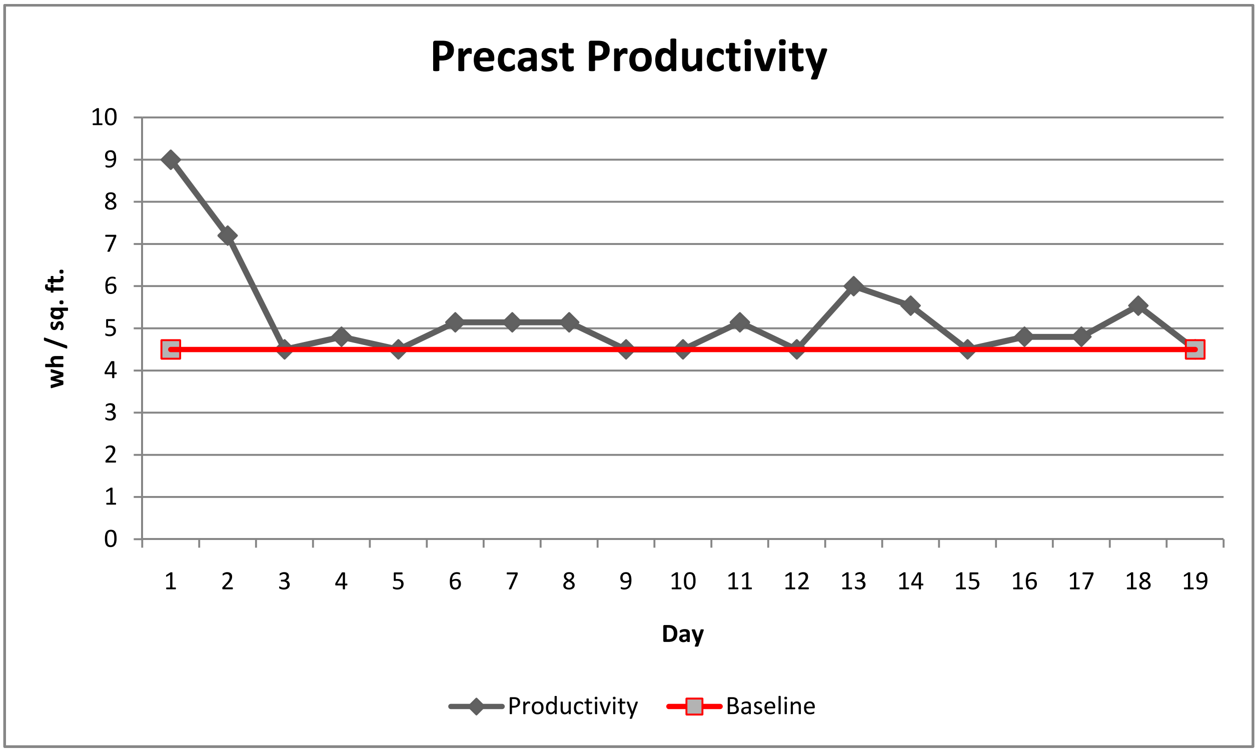


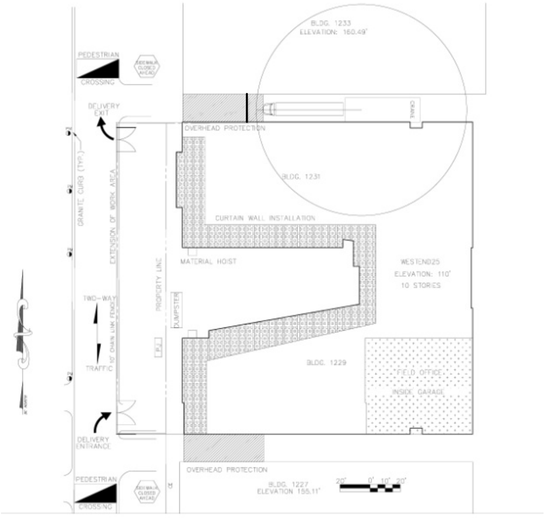
Figure PC6: Precast Productivity

Productivity Conclusion:

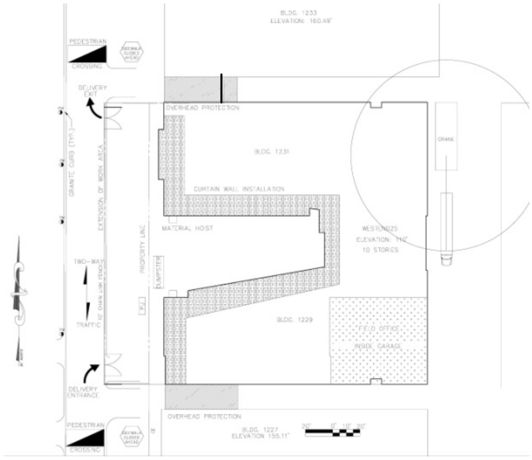
The brick installation was effected two of the 32 days of installation by weather. To make up this lost productivity extra hours will need to be worked. Delays such as this are costly on projects. With the precast productivity analysis no effects of weather were considered because precast installation is less effected by weather. The largest potential for delay comes from delivery delays from the precast fabricator. If the panels do not show on site when they are schedule the crew will have nothing to do and productivity will be greatly impacted.

Site Logistics:

Site Logistics are an important consideration to the feasibility of a precast brick façade. The precast façade panels will need to be installed with a mobile crane. The crane must be able to lift the panels the entire height of the building. It must also be able to fit and maneuver in the surrounding alley. The specifications of a Terex T790-90 ton capacity crane met the required lifting capacities for installing the precast panels with max pick weight of 19,600 pounds at a height of 110+ ft. Therefore the specifications have been used for this analysis. To best make the crane fit in the alley one set of outriggers should be set on the ground floor and the other side set in the alley. Another complication to the site logistics is a wall in the north alley near the start of the brick alley wrap. Because of this obstacle a delivery truck will need to go down the alley first followed by the crane to place the first set of panels. Then the crane will need to back out of the alley to let the truck back out of the alley and let another truck in. This process is very time consuming, but would only need to be done four times over the duration of two days. The number of panels per delivery was estimated based on the legal transportation limits. The legal weight limit is 80,000 pounds; 30,000 pounds of which are the truck allowing a maximum load of 50,000. In consultation with construction industry professional Jim Faust and professional truck driver Ronald Kreider the weight range for loads is between 44,000 pounds and 48,000 pounds. Afterwards the crane can go down the alley and essentially trail the trucks around the building. Site plans depicting this operation are below. Figure PC6 below shows the necessary crane movement during installation.



This site plan depicts the need to have the delivery truck enter the north alley. For the second delivery, both the crane and truck will need to exit to allow another delivery truck to enter.



After the first four sets of panels are installed the crane can follow the truck around the perimeter of the building.

Figure PC6: Site Logistics During Precast Installation

U Value Analysis (Breadth 1):

U-Value:

The U Value is a coefficient of heat transfer that indicates the amount of heat that will move through a material. The lower the U-Value number means a greater the ability to resist heat movement. U-Values are expressed in Btu/(hr*ft^2*^{o}F). This analysis will calculate both the existing brick cavity façade U-Value and the proposed precast façade U-Value.

Calculation Method:

The parallel material calculation method was used to calculate the U-Value. This method requires the gathering of R-Values for the materials that comprise the wall section. These R-Values come from ASHRAE standards and from manufacturer's data, based on independent test results. All the material's R-Values are summed to get a total R-Value. The reciprocal of this number is taken and is equal to the U-Value. The values can be seen in the tables below. WestEnd**25** is in Zone 4A as determined by ASHRAE Standard 90.1. As such, the wall assembly must have a U-Value under 0.064 Btu/(hr*ft^2*^{o}F) and a continuous insulation R-Value of at least 7.5 (hr*ft^2*^{o}F)/Btu , with an R-Value greater than 13 (hr*ft^2*^{o}F)/Btu for the remaining wall elements. As can be seen in the calculations below, both wall sections meet this requirement. The existing brick cavity wall has a lower U-Value and therefore better performance.

To obtain the R-Values ASHRAE Standard 90.1 was primarily used. The tables below list the location the R-Value was found. The ASHRAE Handbook – Fundamentals was used to determine the R-Value for the brick and concrete. The density of the brick façade is 113 lbs/ft^3, to calculate the R-Value a more conservative density of 110 lbs/ft^3 was used from Table 25.4 to obtain a value of 0.8 (hr*ft^2*^{o}F)/Btu. To calculate the R-Value of concrete the density of 150 lbs/ft^3 was used from Table 25.4 to obtain a value of 0.6 (hr*ft^2*^{o}F)/Btu. Part of the wall assembly is also a vapor barrier and air barrier. These were left out of the analysis because according ASHRAE Handbook – Fundamentals their thermal barrier effectiveness is negligible. This is not to say their importance in the wall assembly is negligible. The air and vapor barriers play a vital role in the prevention of moisture infiltration to the dry zone of a wall assembly.

Hand Calculations:

Traditional Brick Façade:

Layer	R – Value ((hr*ft^2*^{o}F)/Btu)	Source
Exterior Air Film	0.17	Standard 90.1 – 2004 A9.4.1
4 in. Face Brick	0.80	2005 ASHRAE Handbook Table 25.4
1.5” Air Space	0.93	Standard 90.1 -2004 TableA9.4A
2” Rigid Insulation	10.00	Manufacturer’s Data
5/8” Gypsum Board	0.56	Standard 90.1 – 2004 Table A9.2D
Framing Cavity	9.0	Standard 90.1 – 2004 Table A9.2B
1/2” Gypsum Board	0.45	Standard 90.1 – 2004 Table A9.2D
Interior Air Film	0.68	Standard 90.1 – 2004 A9.4.1
Total	22.59	
U-Value	0.044	

Table U1: Brick Façade U-Value

Precast Façade:

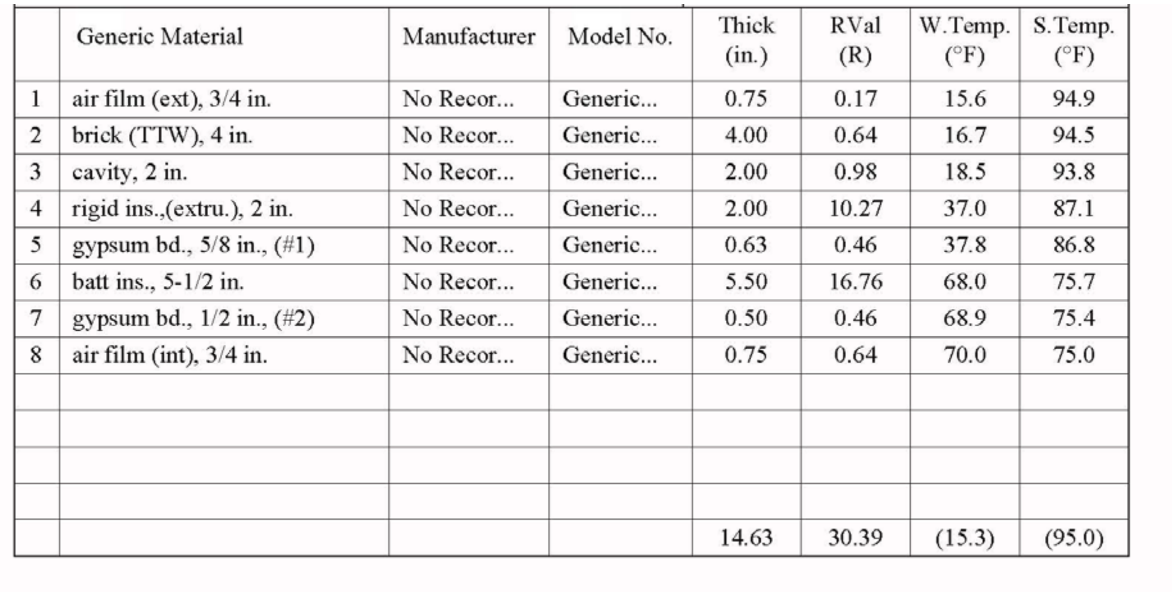
Layer	R - Value ((hr*ft^2*^{o}F)/Btu)	Source
Exterior Air Film	0.17	Standard 90.1 – 2004 A9.4.1
6” Concrete	0.60	2005 ASHRAE Handbook Table 25.4
2” Rigid Insulation	10.00	Manufacturer’s Data
5/8” Gypsum Board	0.56	Standard 90.1 – 2004 Table A9.2D
Framing Cavity	9.0	Standard 90.1 – 2004 Table A9.2B
1/2" Gypsum Board	0.45	Standard 90.1 – 2004 Table A9.2D
Interior Air Film	0.68	Standard 90.1 – 2004 A9.4.1
Total	21.46	
U-Value	0.047	

Table U2: Precast Façade U-Value

H. A. M. Analysis:

The Heat, Air, and Moisture Building Science Toolbox is a computer program that facilitates design analysis of an exterior wall system. There are several analyses that can be completed on an exterior wall. This program was used in AE 542 - Building Enclosure Science and Design to determine wall systems' R-Value. This analysis looks at the program's R-Value calculation features. The first step of this program is selecting the location of the project. The following step requires the user to build the wall section from materials in the program's database that match the materials that make up the wall system. The H.A.M. program contains stored data for the weather conditions that the wall system will be subjected to, as well as material properties for the components of the wall. The results of the analysis are shown below.

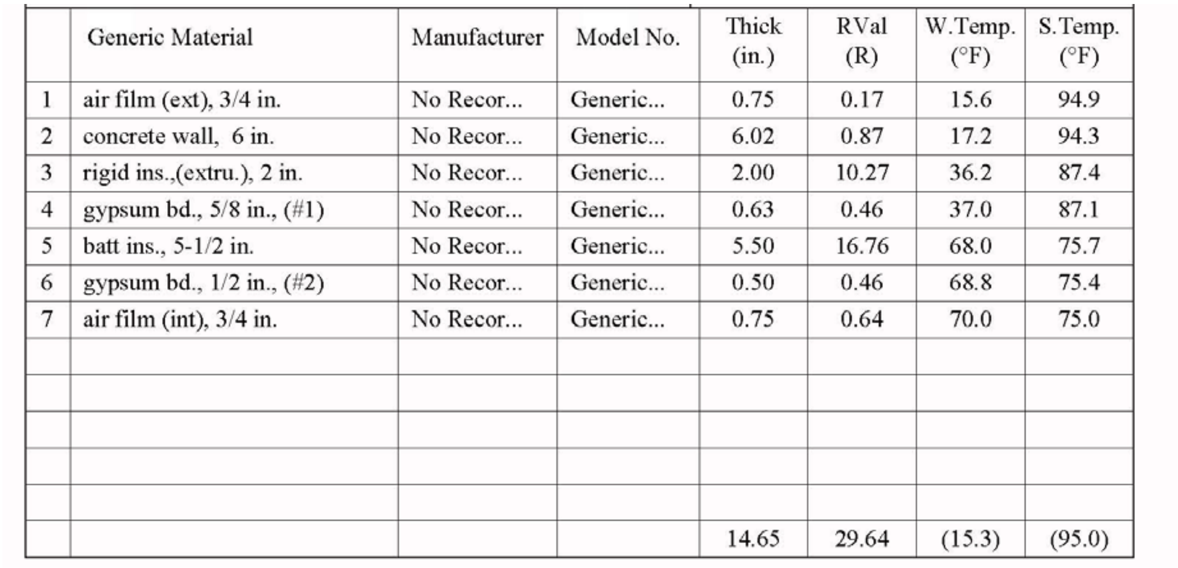
Traditional Brick Façade:



	Generic Material	Manufacturer	Model No.	Thick (in.)	RVal (R)	W.Temp. (°F)	S.Temp. (°F)
1	air film (ext), 3/4 in.	No Recor...	Generic...	0.75	0.17	15.6	94.9
2	brick (TTW), 4 in.	No Recor...	Generic...	4.00	0.64	16.7	94.5
3	cavity, 2 in.	No Recor...	Generic...	2.00	0.98	18.5	93.8
4	rigid ins.,(extru.), 2 in.	No Recor...	Generic...	2.00	10.27	37.0	87.1
5	gypsum bd., 5/8 in., (#1)	No Recor...	Generic...	0.63	0.46	37.8	86.8
6	batt ins., 5-1/2 in.	No Recor...	Generic...	5.50	16.76	68.0	75.7
7	gypsum bd., 1/2 in., (#2)	No Recor...	Generic...	0.50	0.46	68.9	75.4
8	air film (int), 3/4 in.	No Recor...	Generic...	0.75	0.64	70.0	75.0
				14.63	30.39	(15.3)	(95.0)

Table U3: H.A.M. R-Value Calculation for Brick Façade

Precast Façade:



	Generic Material	Manufacturer	Model No.	Thick (in.)	RVal (R)	W.Temp. (°F)	S.Temp. (°F)
1	air film (ext), 3/4 in.	No Recor...	Generic...	0.75	0.17	15.6	94.9
2	concrete wall, 6 in.	No Recor...	Generic...	6.02	0.87	17.2	94.3
3	rigid ins.,(extru.), 2 in.	No Recor...	Generic...	2.00	10.27	36.2	87.4
4	gypsum bd., 5/8 in., (#1)	No Recor...	Generic...	0.63	0.46	37.0	87.1
5	batt ins., 5-1/2 in.	No Recor...	Generic...	5.50	16.76	68.0	75.7
6	gypsum bd., 1/2 in., (#2)	No Recor...	Generic...	0.50	0.46	68.8	75.4
7	air film (int), 3/4 in.	No Recor...	Generic...	0.75	0.64	70.0	75.0
				14.65	29.64	(15.3)	(95.0)

Table U4: H.A.M R-Value Calculation for Precast Façade

The H.A.M. analysis resulted in a much higher wall assembly R-Value. This difference can be attributed to the program's inability to take into consideration the thermal breaks of the metal studs in the interior cavity. In the H.A.M. analysis the R-Value of the cavity is the value of the batt insulation, 16.67 (hr*ft^2*^{o}F)/Btu. In comparison the effective R-Value taking into consideration the metal framing and the batt insulation, per ASHRAE standards, is 9.0 (hr*ft^2*^{o}F)/Btu, a difference of 7.67 (hr*ft^2*^{o}F)/Btu. If this difference would be taken into account then difference between the analysis would only be 0.13 (hr*ft^2*^{o}F)/Btu, a more reasonable difference.

U-Value Conclusion:

Both the precast and the brick facades meet the required U-Value requirements. Their closeness stems from their similarities of materials and their properties. The concrete and the brick do not provide a significant thermal barrier. The thermal strength of the wall comes from the rigid insulation. The higher precast U-Value implies that there will be a greater rate of heat flow across the wall assembly, requiring more energy to be consumed conditioning the interior spaces. Nevertheless, the precast system is a feasible option.

Structural Analysis (Breadth 2):

Structural Implications:

The use of precast panels will approximately add an additional 40 lbs/ft^3. to the structural system of WestEnd**25**. It is important to assure that the existing structure will be able to support this added load without significant extra reinforcing. The following analysis uses a computer program to determine if the carrying capacity of the existing structure is high enough to support the added precast loads.

pcaColumn:

A computer program called pcaColumn was used to determine the ability of the existing structure to carry the added loads to the building from the weight of the precast panels. pcaColumn is software designed for investigation of reinforced concrete column strengths. The program takes the load values and the existing structure column properties, both entered by the user, to run through calculations and determine the capabilities of the structure with the given loads. The load values that were entered can be found in Table ST1.

Load	Calculation	Total
Panel	150lbs/ft^3(.5ft)(1ft)(10.6ft)=795lbs/ftwidth 795lbs/ftwidth(12ftwidth)	9,540 lbs
Concrete	(0.625ft)(150lb/ft^3)=93.75lbs/ft^2 93.57lb/ft^2(200ft^2)+(22.5ft^3)(150lbs/ft^3)	22,089 lbs
Wind	43psf(1ft)(10.6)=455.8lbs/ftwidth 455.8lbs/ftwidth(12ftwidth)	5,469.6 lbs
Floor	40psf + 20psf =60psf 60psf(200 ft^2)	12,000lbs

Table ST1: Calculations for Entered Load Values

In order to run this analysis there were several assumptions made to simplify the data set. The loads used in this calculation were run assuming no windows and that the loads acted across the entire tributary area of the column. This is a conservative assumption because in fact windows break the tributary area and would lessen the dead loads applied to the column. This analysis was completed looking at a one story column located on the ground floor. This was done to simplify calculations. Loads were magnified by a factor of ten to factor all stories of the building.

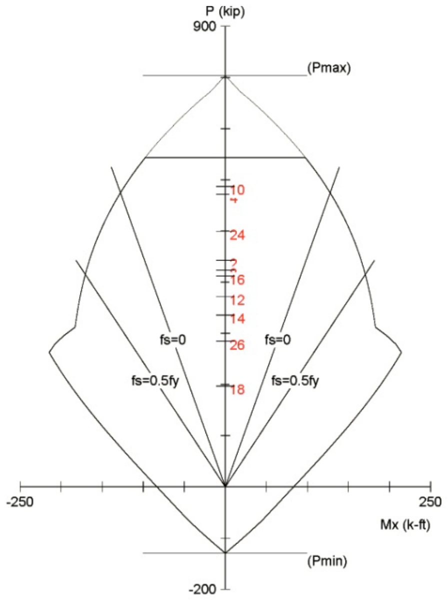


Figure ST1: Moment Interaction Diagram

Figure ST1, is a moment interaction diagram that is typically used to illustrate a columns ability to support axial and eccentric loads. This analysis was completed with the assumption of no lateral forces and no eccentric loads. The diagram indicates that all loads are within the compressive carrying capacity of the existing structure and below the critical load 640 kips and therefore the column is adequate for precast panels.

Structural Conclusion:

The precast panels add an additional weight to the building's structure. By using a computer software program it has been determined that the structure will be adequate enough to support the added loads. Therefore, from a structural standpoint the precast panels are feasible.

Façade Conclusion:

Both the R-Value analysis and the structural analysis prove that a precast exterior façade is feasible. But, because of the complex issues involved with precast in an urban environment on a mid rise building there can be considerable amount of hesitation to implement, even with the cost savings of $307,200. The risk involved is high and only a team with several years of experience would be able to determine their capabilities of maneuvering through the urban alley ways and not causing any damage. From the many issues that arose in analyzing the site plan one can determine a more practical use of precast would be on a low rise facility with large open areas around the perimeter of the building.